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BEFORE THE
ARIZONA NAVIGABLE STREAM ADJUDICATION COMMISSION

IN THE MATTER OF THE NAVIGABILITY OF THE SALT RIVER [From Granite Reef Dam to the Gila River Confluence]	ADMIN. DOCKET NO. 94-1 EXHIBITS SUBMITTED BY ARIZONA CENTER FOR LAW IN THE PUBLIC INTEREST

January 13, 1994

96-002-011

SALT RIVER

ORIGINAL

RECEIVED 8-30-96
PER # 96-002-009-01

Rec'd 1-14 19 94
By:
ARIZONA NAVIGABLE STREAM ADJUDICATION COMMISSION

Maricopa County, Lower Salt River
03-005-NAV
4/7/03
Evidence Item No. 011

Exhibit List

No.	Description
1.	Affidavit of James Slingluff, from court file in Arizona Center for Law v. Hassell, No. 87-20506 (Maricopa County Superior Court, filed July 28, 1987).
2.	Cooperative Instream Flow Service Group, U.S. Fish and Wildlife Service, Methods of Assessing Instream Flows for Recreation (1978)(excerpts).
3.	Deposition of James Slingluff, November 23, 1987, in Arizona Center for Law v. Hassell and Maricopa County v. State, No. C 569870 (excerpts).
4.	Arizona Republic, July 10, 1977, Arizona magazine section at 58, article: "Agua Caliente Isn't a Hot Spot."
5.	Bartlett, John R., Personal Narrative - Explorations and Incidents (1854)(excerpts).
6.	Arizona Gazette, June 3, 5, 6 & 8, 1885 (excerpts).
7.	Governor's Task Force on Recreation on Federal Lands, Arizonans' Recreation Needs on Federal Lands (1986)(excerpts).
8.	Camp Dresser & McKee, Inc. & W.R. Mills & Associates, Riverbed Recharge Project - Executive Summary (1986).
9.	Arizona Weekly Miner, June 21, 1873 (excerpt).
10.	The Citizen, Feb. 28, 1874 (excerpt).
11.	Tombstone Daily Prospector, Jan. 24, 1889 (excerpt).
12.	Affidavit of Janet E. Cantley and copies of photos of Salt river from court files in Arizona Center for Law v. Hassell (original photos are in the collection of Tempe Historical Museum)
13.	R. Ohmart & B. Anderson, "Riparian Habitat."
14.	R. Ohmart & B. Anderson, "North American Desert Riparian Ecosystems."
15.	USDA Forest Service, Importance, Preservation and Management of Riparian Habitat - A Symposium (1977)(excerpts)
16.	Arizona State Parks Dept., Arizona Statewide Comprehensive Outdoor Recreation Plan (1989)(excerpts).

17. Arizona State Parks Dept., Arizona Rivers, Streams & Wetlands Study (1989)(excerpts).

18. R. Ohmart, Riparian Habitat Analysis - Tonto National Forest (1981).

19. Arizona State Parks Dept., Arizona Wetlands Priority Plan (1988)(excerpts).

20. Arizona Academy of Science, Salt River Between 91st and 115th Avenues, Report No. 7 (1973).

21. Arizona-Sonora Desert Museum, Sonorensis, Summer 1988.

22. D. Hendrickson & W.L. Minckley, "Cienegas-Vanishing Climax Communities of the American Southwest," in Desert Plants, vol 6, no. 3, 1984.

23. Letter of June 1, 1984, from Arizona Game & Fish Department to David Baron, with attachments.

24. Arizona Republic, Feb. 2, 1992 at C3.

25. Water Resources Research Center, Univ. of Arizona, Arroyo, vol. 5, No.2, June 1991.

26. Carr, Lynch Associates, et al, Rio Salado Master Plan (1985)(excerpts).

Note: We also may refer to and/or offer items listed in the CH2MHill report prepared for the Commission: Arizona Stream Navigability Study for the Salt River (Draft, Oct. 1993) ("References Cited" beginning on p.106, and "General Bibliography" beginning on p. 174).

1

AFFIDAVIT

STATE OF ARIZONA)
) ss
County of Pima)

My name is James Anthony Slingluff. I have twenty-two years of canoeing experience. I have canoed extensively in Arizona since 1984.

I have canoed each of the following sections of Arizona rivers on multiple occasions (exceptions noted) and believe each to be very suitable for river travel in the seasons indicated at the boating skill level noted.

1. Salt River:

A. Highway 60 bridge to Horseshoe Bend; all seasons; intermediate boating skills.

B. Horseshoe Bend to Highway 288 bridge; all seasons; beginning boating skills.

C. Stewart Mountain Dam to Granite Reef Dam; subject to dam releases (ordinarily in summer); beginning boating skills.

2. Verde River:

A. Perkinsville to TAPCO power plant (Clarkdale); all seasons; beginning boating skills (except for two particular rapids).

B. Dead Horse Park to Thousand Trails Campground; Fall/Winter/Spring; beginning boating skills.

C. Beasely Flat to Childs; Fall/Winter/Spring; intermediate boating skills.

D. Childs to Horseshoe Lake; Fall/Winter/Spring; beginning boating skills.

3. Little Colorado River, Grand Falls to Black Falls; snowmelt, monsoons; beginning boating skills.

4. Wet Beaver Creek:

A. Ranger Station to Montezuma Castle, one trip; snowmelt, monsoons; advanced boating skills.

B. Montezuma Castle to confluence with Verde; snowmelt, monsoons; beginning boating skills.

5. Dry Beaver Creek, Highway 179 to Interstate 17, one trip; snowmelt, monsoons; intermediate boating skills.

6. Oak Creek:

A. YMCA Camp to Page Spring, one trip; snowmelt, monsoons; intermediate boating skills.

B. Page Spring to Cornville; Fall/Winter/Spring; beginning boating skills.

C. Cornville to confluence with Verde; all seasons; beginning boating skills.

I have encountered other recreationists (boaters, hikers, and/or fishermen) on all the aforementioned sections of the Salt, Verde, Little Colorado, Wet Beaver, Dry Beaver and Oak Creek.

Further affiant saith not.

Dated this 15 day of July, 1987.

James Anthony Slingluff

James Anthony Slingluff

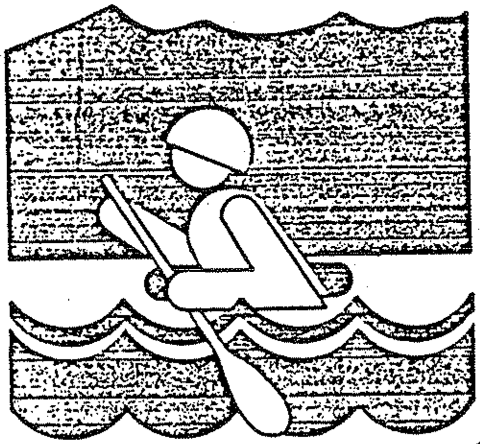
Subscribed and sworn to before me this 15th day of July, 1987.

Leta R. Chapman

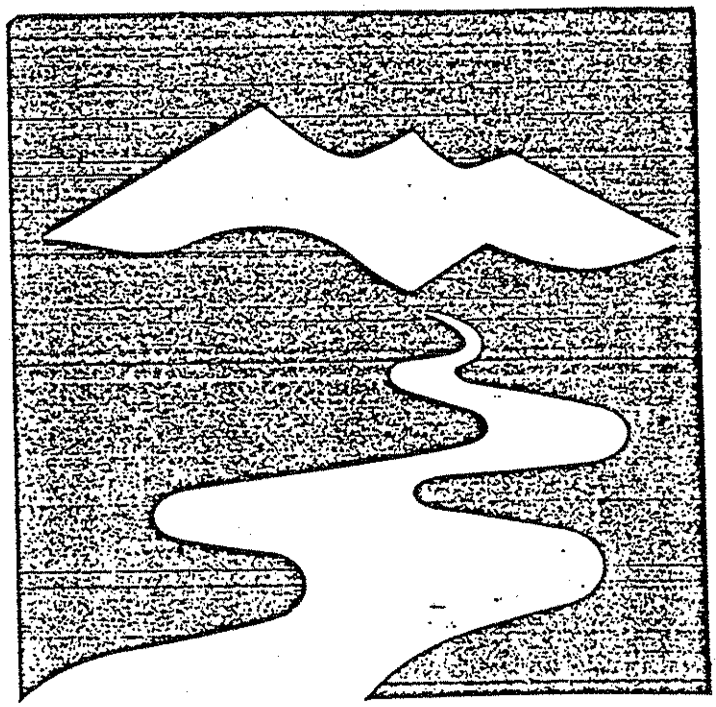
Notary Public

My commission expires: My Commission Expires February 5, 1989

2



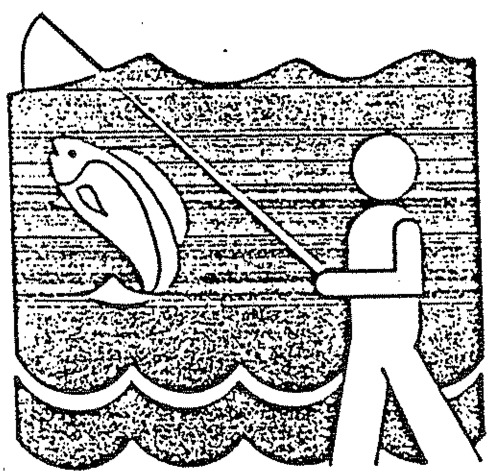
Methods of Assessing Instream Flows for Recreation



COOPERATIVE
INSTREAM FLOW
SERVICE GROUP

INSTREAM FLOW INFORMATION PAPER: NO. 6

FWS/OBS-78/34
JUNE 1978



Cooperating Agencies:

Fish and Wildlife Service
Environmental Protection Agency
Heritage Conservation and Recreation Service
Bureau of Reclamation

A. # 4

FWS/OBS-78/34
June 1978

METHODS OF ASSESSING INSTREAM FLOWS FOR RECREATION

Instream Flow Information Paper No. 6

by

Ronald Hyra[1]
Cooperative Instream Flow Service Group
Creekside Building
2625 Redwing Road
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This study was financed in
part through the Water
Resources Council under
provisions of the Federal Non-Nuclear
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Cooperative Instream Flow Service Group
Western Energy and Land Use Team
Office of Biological Services
Fish and Wildlife Service
U.S. Department of the Interior

[1]Detailed to the Cooperative Instream Flow Service Group from the Heritage Conservation and Recreation Service.

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ABSTRACT

The Instream Flow Group (IFG) has conducted research into methods of quantifying instream flow needs for fish, wildlife, and recreation. This paper describes two techniques developed by IFG for performing recreational instream flow studies. The single cross section method is relatively simple and provides a base flow figure which will provide for the boating activities which make use of the of river. The incremental method is more sophisticated and may be used to develop recommendations regarding streamflows required for various types of recreation, or to provide a recreation analysis of any streamflow. Streamflow suitability criteria for recreation are presented for both methods.

INTRODUCTION

It has been long recognized that there are many competing demands for the use of stream water. Diverting stream water for irrigation, water supply, and energy developments can deplete streamflows to the point where opportunities for recreation and the associated environmental values of the stream are seriously impaired. Numerous water planning studies, both basin-wide and project oriented, have emphasized the need to quantify the amount of water required to support recreation, fish and wildlife resources, and to maintain aesthetic conditions.

The tools and techniques for estimating streamflows required for recreation and aesthetics, and for insuring reasonable consideration of recreation and aesthetics in the allocation of stream water, are currently undergoing study. Instream flow requirements and values for recreation, in the past, have often been based only upon the amount required to maintain a fishery. However, several studies have indicated that recreation and aesthetic requirements, at times, may not be the same as for a fishery.

This paper presents the techniques of assessing instream flows for recreation. These techniques were developed by the Cooperative Instream Flow Service Group and closely parallel techniques used to assess instream flows for fisheries. The data collection procedures, the physical and hydraulic simulation of the stream, and the computer models which analyze the data are the same for both fisheries and recreation. The major difference between the two techniques is the response of the individual fish or recreationist to various physical parameters of stream flow. These responses to stream flow by different user groups are the criteria which are basic to the methods introduced here..

The first method is called the single cross section approach. This method is useful primarily for identifying flows below which a recreation activity is not feasible and results in a so called "minimum" flow recommendation.

The second method is called the incremental method. With this method the recreation planner is able to analyze various flows and determine the recreation potential of a stream at different flows.

This paper is being distributed with four objectives in mind. These are:

1. To bring the problem of preserving instream flows to the attention of recreation agencies and the research community in order to encourage more research in this vital and neglected area.

2. To discuss the development of the recreation probability-of-use curves and of recreation criteria in general, which are necessary for quantifying instream water requirements for recreation.

3. To obtain review and comment on the recreation criteria and probability-of-use curves, and to request data which may be used to test or improve the criteria or curves.

4. To describe the two approaches for assessing stream flows and discuss how various recreation planning processes can be served by their application.

Both methods of instream flow analysis discussed in this paper utilize computer modeling techniques. Both approaches also require that streamflow data be collected. The single cross section approach, as its name implies, requires that information be collected at only one location on the stream. The incremental method requires that data be collected at multiple locations on the stream. In addition to cross sectional data, data relating the streamflow parameters to recreation potential are necessary. These data are termed recreation criteria.

Recreation criteria for instream flow methodologies are the recreation activity information bases necessary to describe a relationship between the quantity of water flowing in a stream, and the quantity and quality of a particular recreation activity which takes place in the stream.

SINGLE CROSS SECTION METHOD

This method requires that only a single cross sectional measurement be taken across a stream. The product of such an approach is a determination of the lowest flow acceptable for recreation. The approach is based on the assumption that a single cross section, properly located, can define a minimum flow requirement. Such a cross section is located at an area displaying the least depth across the entire stream. When this area provides minimum depths for boat passage, the flow at this level may be defined as a minimum acceptable flow. It is assumed that when sufficient water to support boating is available in these critical areas, other areas will have sufficient water to support most of the other instream recreation activities. This approach is best applied to those streams in which flows are expected to be higher than the minimum most of the time.

Criteria for this approach are set forth in Table 1. Criteria have been developed for boating activities only, but for various types of boating craft. Only minimum criteria are presented because this approach provides information on "minimum flows." Criteria are measured in terms of stream depth and width. Velocity is not considered because a minimum velocity is not considered necessary for this approach.

Table 1. Required stream width and depth for various recreation craft as determined by single cross section method.

Recreation Craft	Required depth (ft)	Required width (ft)
Canoe-kayak	0.5	4
Drift boat, row boat-raft	1.0	6
Tube	1.0	4
Power boat	3.0	6
Sail boat	3.0	25

The criteria of Table 1 are minimal and would not provide a satisfactory experience if the entire river was at this level. However, the cross section measured for this method is the shallowest in the stream reach. Therefore, these minimum conditions will only be encountered for a short time during a boating trip, and the remainder of the trip will be over water of greater depths and widths. An important assumption is that all water greater than the minimum is equally useful for the activity (i.e., more is better until bank-full stage).

A computer program (IFG-1) has been developed which predicts width and depth across the transect of any stage (water surface elevation). The output shows discharge and the width with depth equal to or greater than a specific depth. Different water surface elevations may be put into the computer model which are translated into flow in cubic feet per second. When a flow provides the minimum width and depth necessary for an activity, discharge may be considered minimum. Such a minimum indicates that significant losses, if not elimination of this activity, will occur if minimum flow is not equaled or exceeded.

THE INCREMENTAL METHOD

This method, more sophisticated than the single cross section method, describes a relationship between the amount of water in a reach of stream and the associated recreation potential. The incremental method can describe the potential for any recreation activity at any streamflow. A major difference between the methods is that the single cross section method can only be used to identify low flow and cannot be used to assess the recreation potential at any other flow; the incremental method can be used to assess the potential at other flows or to calculate the change in receation potential caused by a change in stream flow.

The incremental method involves a modeling procedure whereby the surface area of a stretch of stream is calculated. In addition to the total surface area of the reach of stream, the area which has certain depths and velocities is calculated. The usable surface area for each activity is then calculated by use of depth and velocity requirements.

It is necessary to make three assumptions regarding the relationship between the quantity of water and the recreation uses of the water: (1) water depth and water velocity are the two streamflow components which are most important in determining whether or not a certain recreation activity may be safely and pleasurably engaged in[1]; (2) there are

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[1]Other parameters such as water quality and temperature are also very important in determining the amount of instream recreation use but in many cases are not significantly influenced by flow. Width is also important but is considered outside of the computer model (i.e., width is not a part of the calculation of usable surface area).

IN THE SUPERIOR COURT OF THE STATE OF ARIZONA

IN AND FOR THE COUNTY OF MARICOPA

MARICOPA COUNTY, et al. and ARIZONA CENTER FOR LAW IN THE PUBLIC INTEREST, et al., and CALMAT CO. OF ARIZONA, et al.,

Plaintiffs-Intervenors,

vs.

NO. C 569870

STATE OF ARIZONA, ARIZONA STATE LAND DEPARTMENT, M. JEAN HASSEL, and MILO J. HASSELL, et al.,

Defendants.

DEPOSITION OF JIM SLINGLUFF

NOVEMBER 23, 1987

TUCSON, ARIZONA

BOULEY, SCHLESINGER, DI CURTI & SCHIPPERS
Registered Professional Reporters
601 Pioneer Plaza
100 North Stone Avenue
Tucson, Arizona 85701
(602) 623-7573

A. # 5

eleven miles below Route 60 bridge of the Salt River Canyon. Two outfitters are running below 300 cfs, and George will run them as low as 200 cfs.

Q Mr. Van Gasse is one of the outfitters?

A Yes.

Q And is there another one?

A Allen Fowler.

Q What's his organization called? Does he have an organization that has a name?

A I believe he does. I'm not sure that I have it.

Q What city did he operate from?

A Excuse me. Saguaro Whitewater. It's here in Tucson.

Q Do you know or have you heard that Mr. Marsick has prepared an affidavit in this lawsuit?

A I have heard.

Q How did you become aware of that?

A Mr. Baron told me.

Q Have you seen the affidavit?

A No.

Q Have you had any discussions with Mr. Baron about that affidavit?

A No.

Q Have you talked to Mr. Marsick since July

Q Mr. Slingluff, to get back to your canoeing experience in Arizona, am I correct that that is canoeing with either moderate or heavy whitewater canoes almost exclusively?

A Yes. In what I would say is moderate design to heavy design whitewater canoes.

Q With respect to the moderate design whitewater canoe, is there a particular minimum depth that you have to have to use that boat on a river?

A Yes. In my particular boat, the Kennebec, okay, I require, if I am by myself I require about two inches minimum depth.

Q What about your newer boat?

A That requires maybe three inches minimum depth, same conditions me, by myself.

Q Why does the heavy whitewater canoe require a little bit more minimum depth?

A The more you get into a whitewater design, the boat is given what you would call rocker, just like rocker on a rocking chair. And that is what makes a boat difficult to turn in heavy water, is the end being in the water.

So what you are doing is taking the end out of the water by getting it lower, but then you are supporting the same amount of weight basically, because in the water, as you can imagine looking -- imagine a rocker-shaped thing being submersed in water. A totally flat bottomed or totally -- a boat, a boat with no rocker would maybe only require an inch and a quarter or an inch and a half of depth.

Q Let me make sure I understand what you are referring to in your affidavit when you talk about canoeing experience. Are you referring to any boating using anything other than the two canoes that we have talked about?

A No. When I wrote this affidavit, the rough of this affidavit, I only had in mind my canoeing experience.

Q And maybe you said, but if you did I don't remember. This, does this also include the inflatable raft canoe?

A No.

Q How many trips have you taken on the inflatable raft canoe?

A Two.

Q Is there a boat that you own, by the way?

A No.

Q Where did you talk those trips?

A One was on Beaver Creek, the B trip on my affidavit; and the other was Oak Creek, the B trip on my from bridge-to-bridge, from the Route 60 bridge to 288 bridge that you would consider not traveling if the flow was too high?

A Yes.

Q Is there any particular stretch that you are concerned about?

A Yes. The, the most difficult whitewater occurs from Gleason Flats down to Horseshoe Bend.

Q Have you ever had to cancel a trip that you had planned because the water flow was too high?

A No.

Q What's the --

MR. BARON: I didn't hear the answer.

THE WITNESS: No.

Q (By Mr. White) What's the minimum flow in terms of cfs that you would consider before you would schedule to undertake a trip on the Salt River between the two bridges?

A I have got to break the answer a little bit. If the water flow was below 200 cfs, I would not put on at the Route 60 bridge. I would still put on at Gleason Flats. Okay.

So you have got about, about ten miles of river there that I would not do if this were below 100 cfs at the Route 60 bridge. Now, the numbers don't match. Ten miles does not take you all the way to Gleason Flats. But there is no access between those, the separation of those ten miles and Gleason Flats, because there's a section of river in there that there would be enough water for you but there is no way to get to it.

Q Maybe I misunderstood your statement. what is the minimum at the Route 60 bridge, 200 or 100?

A For me it's 100 cfs.

Q Does that 100 cfs translate to a particular water depth?

A Well, here's where it gets difficult. It does and it does not. You recall these are deep. The problem comes at rock bars. So at 100 cfs you are talking numerous places on the rock bars where the flow is under two inches at its deepest point.

Q Where did you get the measurement of the cfs to decide whether to put in at the Route 60 bridge?

A The Salt River Project.

Q What gauge are you relying on?

A They have a gauge at the Salt River Canyon.

Q I'm sorry, that's at the Route 60 bridge?

A Correct.

Q And what's the next point of reference that you look for for a cfs measurement?

A Into Roosevelt, into Lake Roosevelt.

Q You indicated that at the low level you would not, at the low cfs level you would not put in at Route 66 bridge, neither would you at Gleason Flats; is that correct?

A Either Gleason Flats or Horseshoe Bend is correct.

Q And what is the minimum that you would have to have for Gleason Flats or Horseshoe Bend?

A I have never encountered that.

Q Is there a particular minimum in your mind that you would have to have in terms of cfs to put in at Gleason Flats or Horseshoe Bend?

A Well, yes, I have one in mind, but I don't have the experience to know whether or not it's real. The second is, I would no longer rely on the Route 60 bridge if I was putting in at either Gleason Flats or Horseshoe Bend. I would call the, I would listen for the gauge into Horseshoe -- excuse me, into Lake Roosevelt.

Q What level would you be looking for when you listened to the recording for the flow into Roosevelt Lake?

A I would be hesitant at anything under 200 cfs.

4

arizona

THE ARIZONA REPUBLIC

JULY 10, 1977 ■ SUNDAY

Chris Evert
and the summer Racquets

A. #17

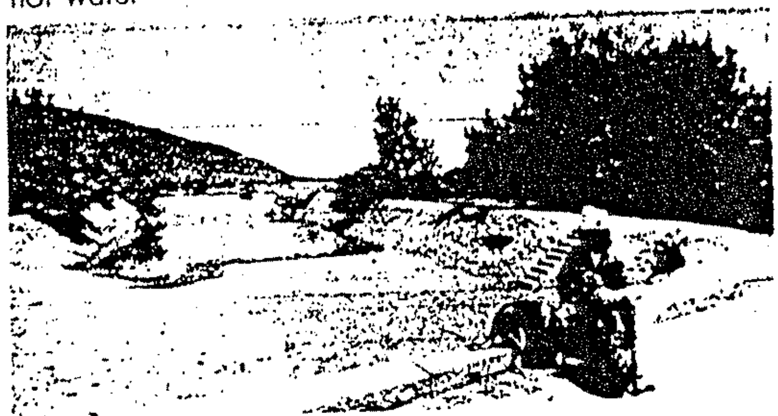
Conde has several head of cattle in his yard.

room at the resort when I was in grade school."

The Gila was a flowing stream then. It hadn't been dammed.

Conde said people came to the resort from Phoenix on a road which followed the north bank of the Gila. the springs were a stopping point on the Yuma to Tucson stage route in the 1870s, before there was construction at the site.

In its best days the resort featured twelve springs with bath houses on them, Conde said. "Each had a big spring bubbling inside, and a table with a heavy blanket so you could sweat like hell," he said. "If you had rheumatism you had to take twenty-one baths before it did you any good. But some would come in wheelchairs,



Kenneth Beloat is now the only permanent resident of Agua Caliente.

'The gamblers here played everything— cards, dice, faro'

stay six months, and walk away. People from back east, from San Diego, everywhere, rich and poor people came there."

He said the railroad went through Hyder in 1926, so that Agua Caliente was only three miles, instead of twelve miles, from a train station. That also meant people didn't have to ford the river to get to the resort. Conde's wife, Delores, said she worked as a waitress and chambermaid at the resort for a dollar a day plus tips. One of the hotel guests she remembers was Arizona's first governor, George W. P. Hunt.

A 1972 newspaper article quoted Jim O'Neal, who came to the area in the 1920s. "It cost nine dollars a week for your bedding, food and firewood," he said. "Mexicans delivered the wood to you every day.

"If you soaked your legs in the hot mud for twenty-one days straight, it cured you. That mud healed me. They dug out little baths and ran hot water to them. You could sit there all day and night if you wanted to. Some people did, but I never did.

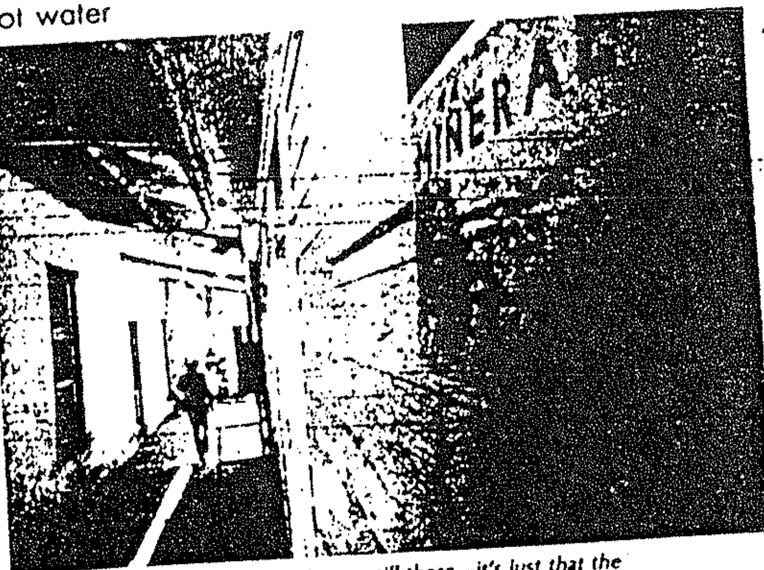
"The gamblers here played everything — cards, dice, faro, anything you could think of. It was big business."

Joe "Pee Wee" Amavisca, a rancher, remembers going to Agua Caliente for hot baths when he was a boy. "It used to be like a regular metropolitan area," he said. "It was real green, and there were ducks on the lake. It was beautiful.

"My dad used to Indian farm around there. He'd scratch with an old Ford tractor, use the water from the river, and he'd grow watermelon and squash and everything. That's how the people used to live in this area. They'd barter back and forth depending on what one raised and what he needed.

"I think they could do something with it. It won't be the same as it was when the springs used to come up natural, but the water's there, the same water. Ken tells me the lawyers are thinking about drilling and pulling out water into a basin or something where people can swim or whatever."

Beloat said there is a well close enough to the old swimming pool to bring water to it for a nominal cost,



The mineral baths are still there—it's just that the minerals aren't suspended in water anymore.

'they took a boat across the river to ferry the passengers'

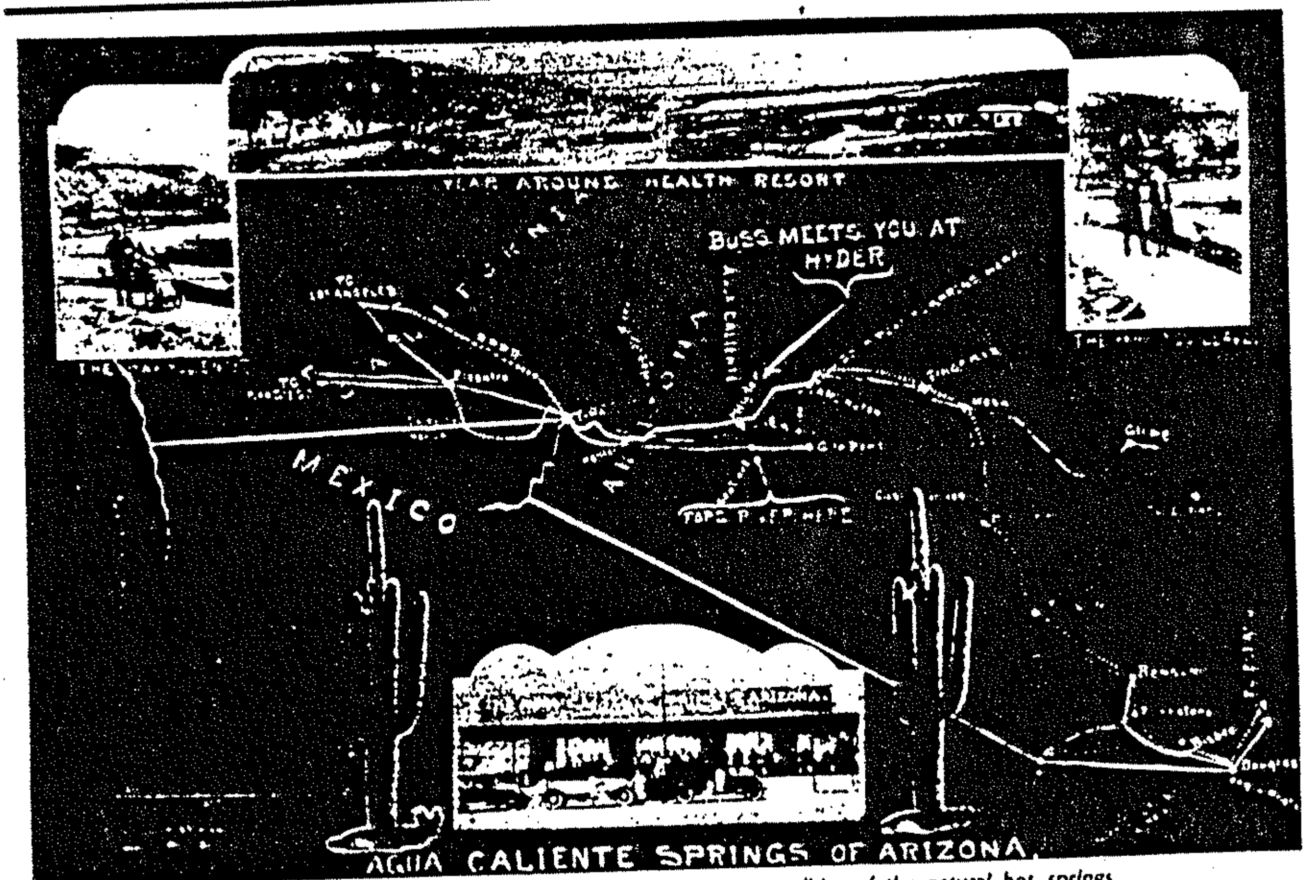
mountain one by one to build the pool.

"You see our sprinkler running out there? We're trying to get this place back to life. Our oleanders came back. We were watering to keep the dust down, and things just started popping up. The palm trees are just sucking up water. They were all dead, or they looked like they were."

Jim and Judy Lake were staying with Beloat for a few days. They are photographers who live on the road, staying wherever they have decided to work. Lake said he thinks the hotel will be fixed up by somebody. "Let's face it," he said, "General Patton ain't around building any more swimming pools and Teddy Roosevelt isn't sleeping at any more places. He found his last one."

The hotel began taking ghosts for tenants in the middle 1950s when the hot springs began to give out. Farmers were moving in and cultivating the area surrounding Agua Caliente, and at least one of them drilled into the water stratum that contained the water feeding the springs. In 1956 Phinoclad Modesti advertised nine hot mineral baths, room and board for seven dollars per day per person. The following season the baths went dry, according to Lote Conde, who lives just over the hill from the hotel.

Conde came to Agua Caliente in 1910, and because he was only six months old, was accompanied by his parents. "Old man Modesti was running it, and they had a big grocery store and all," he said. "All the passengers came from Sentinel in those days. Every day they took a boat across the river to ferry the passengers and the freight. My dad was a farmer here, and I washed dishes and worked in the engine by Dan Lee



Advertisements for Agua Caliente stressed the curative qualities of the natural hot springs.

Wars. The men didn't want to be drafted. Two attorneys, John and Colt Hughes, acquired the hotel and large chunks of surrounding agricultural land a few years ago.

The Hughes brothers hired a Buckeye farmer, Kenneth Beloat, to oversee their holdings. He lives in a mobile home across from the hotel, with a CB radio, a pickup truck and three dogs. He starts making sun tea as soon as the weather gets warm and he and his friends who drop by drink it out of quart-size glasses.

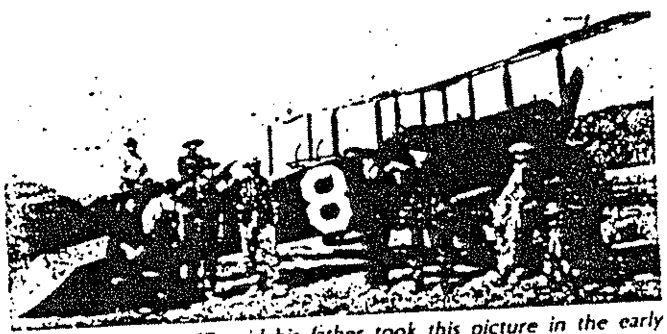
"There's a fault runs through here and traps the water," Beloat said. "We've got eight hundred acres here we're going to farm. The first well we drilled pumped seven thousand gallons a minute, and the water was so hot we had to drill another one and mix the water before we could irrigate with it."

Beloat had been at Agua Caliente only a month, and was still being filled in on its history by locals. "I understand General (George) Patton built the pool," he said. "He trained troops here to fight (German field marshal) Rommel. The guys who were screwoffs had to haul rocks off the

AGUA CALIENTE ISN'T A HOT SPOT

'Let's face it, General Patton ain't around building any more swimming pools and Teddy Roosevelt isn't sleeping at any more places'

Agua Caliente's resort hotel died when the springs stopped flowing in 1957.



Lote Conde, now 67, said his father took this picture in the early 1920s. Conde is second from left, front.

In its heyday the hotel and hot springs attracted such notables as Teddy Roosevelt.

There aren't any signs around Agua Caliente announcing, "Teddy Roosevelt Slept Here." He did. But Slim Nordahl doesn't care. He sleeps there pretty often, in an old bunk bed about two inches higher than the tops of his boots, and he eats things out of cans and listens to the floor rot. He's being paid by a couple of Phoenix lawyers to run a bulldozer, clearing land for agriculture.

The area where the hotel was built at the turn of the century is desolate. Dust blows in sheets where there isn't any irrigation. Water comes out of the ground from shallow wells and sometimes is hot, sometimes medium, sometimes cold. It depends on where the hole is drilled. At the turnoff to the hotel, on a paved county road twelve miles north of Sentinel, a sign reads, "Do not cross when flooded." On the back of it somebody has handwritten, "Paradise, God." It could be a last statement from somebody crossing the Gila during a flood.

The hotel was built at the site of a natural hot spring that used to bubble out of the ground at 118 degrees and cure things doctors are still just poking at. The Modesti family pioneered development of the area after they left Corsica during the Napoleanic but he said the pool needs a lot of work. "I think a nice fiberglass one set on the inside would be nice," he said.

"I was talking to an old well driller the other day, and he said, 'Well, we could make the springs run again, but it would take about six or eight days of drilling with a rock drill and about a truckload of powder to blow it. But we could blow the old springs back open, blow a hole down to the water where it'd come bubbling out of the ground again.' "

He said the water is so close to the ground in the area that getting water is no problem. But renovating the hotel and making it look good would be a detailed and expensive project. And water pumped to the surface doesn't have the same appeal as natural hot springs. □

in next week's

arizona

THE FUTURE IS US

an interview with Robert Theobald

by Assistant Editor James E. Cook

5

PERSONAL NARRATIVE

OF

EXPLORATIONS AND INCIDENTS...)

IN

TEXAS, NEW MEXICO, CALIFORNIA, SONORA,
AND CHIHUAHUA,

CONNECTED WITH

THE UNITED STATES AND MEXICAN BOUNDARY COMMISSION,

DURING THE YEARS 1850, '51, '52, AND '53.

BY

JOHN RUSSELL BARTLETT,
UNITED STATES COMMISSIONER DURING THAT PERIOD.

IN TWO VOLUMES, WITH MAP AND ILLUSTRATIONS.

NEW YORK:
D. APPLETON & COMPANY, 346 & 348 BROADWAY,
AND 16 LITTLE BRITAIN, LONDON.
M.DCCC.LIV.
1854

refused to accede to it, and told them that Francisco and one other would answer my purpose, as first proposed.

At six o'clock this morning we set off, the party consisting of Dr. Webb, Messrs. Thurber, Pratt, Seaton, Force, Leroux, and myself, with attendants. Lieutenant Paige, with six soldiers, also accompanied us, that officer wishing to examine the opposite bank of the Gila, as well as the lands contiguous to the Salinas, with a view of establishing a military post in the vicinity of the Pimo villages. After crossing the bed of the Gila we pursued a westerly course about eight miles to the point of a range of mountains, near which we struck the bottom-lands. We now inclined more to the north, and in about eight miles struck the Salinas, about twelve miles from its mouth, where we stopped to let the animals rest and feed. The bottom, which we crossed diagonally, is from three to four miles wide. The river we found to be from eighty t one hundred and twenty feet wide, from two to thre feet deep, and both rapid and clear. In these respect it is totally different from the Gila, which, for the tw hundred miles we had traversed its banks, was slu gish and muddy, a character which I think it assum after passing the mountainous region and entering o with alluvial banks. The water is perfectly swe and neither brackish nor salt, as would be infer from the name. We saw from the banks many fish its clear waters, and caught several of the same spec as those taken in the Gila. The margin of the riv on both sides, for a width of three hundred feet, consi of sand and gravel, brought down by freshets wh ing east from where we were, the whole prospect was shut in by mountains rising one above the other. I was informed by Leroux, that such was the character of the country all the way to New Mexico; and that there were no more broad desert plains or luxuriant valleys like those of the Salinas and Gila rivers for the entire distance. He came here from Albuquerque, on the Rio Grande, by the valley of the Rio Verde, in fourteen days.

We found the river clear and rapid, as at the first camp, with many trout, whose silvery sides glittered in the translucent stream. The quantity of water passing down the Salinas is more than double that of the Gila, which only becomes a respectable river after it receives the waters of the former. Yet there are seasons when the whole is evaporated, or absorbed by the sandy bed through which it passes, before reaching the Colorado. When at Hermosillo, in Sonora, I met an American who had passed over the same route, and he found the bed dry in many places.

At five in the afternoon, the heat being less, I crept from beneath my shelter of willows, where I had spent several hours, and, accompanied by Dr. Webb, mounted my mule, and left for the plateau in advance of the party. A ride of a mile brought us to the table-land, when we made for a large mound or heap which arose from the plain. In crossing the bottom we passed many irrigating canals; and along the base of the plateau was one from twenty to twenty-five feet wide, and from four to five feet deep, formed by cutting down the bank—a very easy mode of construction, and which produced a canal much more substan-

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We carry the largest line of hardware, iron, steel, coal, carpenter and builders' tools and Shelf hardware in the territory.
GUSS ELLIS & CO.

The New Orleans *Times-Democrat* of May 28th, has a column of space devoted to the Arizona exhibit at the world's fair, and much praise is bestowed upon our territory.

We carry a large and fine assortment of American and imported wines and liquors, and are sole agents for the celebrated Pilsner, Falk Milwaukee beer.
GUSS ELLIS & CO.

Simms' swimming baths are daily growing in popularity. Certain hours are set aside for the use of ladies, and other rules adopted to meet the desires of the public.

A comprehensive sewerage system should be established for Phoenix as soon as the same is practicable. If such steps are neglected, in a few years we will see the consequences in sickness and death.

C. J. Dyer completed, a day or two since, a handsome sketch of the fair grounds of the Arizona industrial exposition association, and the same now decorates the wall of E. H. Hiller, secretary of the association.

Five applicants for teachers' certificates have been undergoing examination since Monday morning last. The board of examiners is to-day reviewing the papers prepared by the applicants in answer to the questions submitted, and passing upon the same.

The GAZETTE's report of the bids for street carting, published yesterday, were set full, and by the printer were made to read dollars and cents where they should have read dollars. Ed Carabo was awarded the contract for $195 per quarter, and to-day executed his bonds for the faithful performance of the work.

Yesterday, Tuesday, June 2, was the day announced for the wedding of General M. H. Sherman, of this city and Mrs. Pierce, of San Francisco, in the latter place. We trust that the alliance was happily consummated and that a life of peace, pleasure and prosperity may be the lot of the happy couple.

At 11 o'clock last night a shrill and prolonged whistle of the Phœnix flouring mill startled our citizens, who feared that it was another alarm of fire. We since learned that the rope was accidentally struck by Engineer Mosher, while hurriedly moving to perform certain work.

R. C. Powers and party of surveyors arrived in Phœnix yesterday from northern Arizona, having just completed the survey of a large section of government land in the vicinity of Flagstaff. The governor tells the reporter that the weather in that section is delightful now, and that the settlers have just begun putting in their early gardens—lettuce, potatoes, etc.

The price already offered for wheat and barley is $1.25 per hundred, an advance of about fifty per cent. over the quotations a year ago. For foreign shipment the price of wheat will depend largely upon quality, and for this purpose the inferior grades will really be valueless. It is the policy of our dealers to pay the farmer the highest possible price for his grain, in order that he may free himself from debt the present season, and that the merchants may return at once to a cash system of business. [illegible] unquestionably a wise plan.

of accomplishing the passage of the canon without any mishaps. The object of the trip is to ascertain if logs could be floated through the canon. If practical, Mr. Burch intends erecting a saw mill at the foot of the Sierra Anchas and floating the logs down the river to Phœnix.—*Silver Belt.*

Wheat for England.

Rosenthal & Kutner have just effected the sale of 1,000,000 pounds of Salt river valley wheat, to San Francisco exporters, the same to be delivered on the cars at Maricopa, and to be shipped thence to England, via New Orleans. This fully demonstrates that the shipment of Salt river grain to foreign markets, so successfully inaugurated by Messrs. Rosenthal & Kutner a few months since, has become a permanent business, and carries with it much promise to the producer. Mr. Rosenthal informs us that he will commence the shipment of this new lot of wheat just as soon as the present crop is harvested.

The Chief Engineer.

In the *Herald's* account of the construction and completion of the Arizona canal, much praise is given to the engineering skill displayed in the same. Yet the name of A. Barry is not mentioned therein. Mr. Barry was the locating engineer and continued with the work of construction until a few months before its completion, and the plans adopted by him were carried out almost to the letter. A person acquainted with these facts has called the reporter's attention to the same, and believing that credit should be given where credit is due, we take pleasure in publishing them.

Notice.

A full attendance of members of Phœnix lodge No. 5, A. O. U. W. is requested at the meeting of said lodge this evening at 8 P. M. Business of importance will be transacted and officers for the ensuing term will be nominated.
JOSEPH CAMPBELL, Recorder.

A. J. Halbert, A. J. Port and John Mahan have been appointed by Probate Judge Campbell as commissioners of the town of Tempe. Last week the entry of that townsite was properly made in the Tucson land office, and the selection of the gentlemen above named as commissioners is sufficient assurance that the interests of the town will not be neglected.

Among the letters received at the GAZETTE office to-day were three making special inquiries as to the opportunities afforded by Arizona, and soliciting copies of this paper. One was from Pueblo, Colorado, one from Berryville, Arkansas, and the third from St. Charles, Missouri.

George Hamlin has purchased Tom Sherman's saloon, and will hereafter conduct that resort. George is an old Hassayamper and if he is not able to meet the demands of the public then there is no use of others trying to do so.

R. L. Osborne, M. D., to-day moved into the residence formerly occupied by R. Ruben, on south Center street, where he may be found at all hours of the day and night.

LOST—Gold globe from watch charm, containing two photographs. Liberal reward by returning to this office.

Just received a nice lot of Mexican [illegible]

That You can get the Finest Shave in Phœnix at Shumaker's.

That You have to wait the Least Length of Time.

That You can have Your Hair Cut and Dressed in the Most Approved Style.

That You can Secure the Finest Baths in the Territory.

That the Shop is between Plum's and Asher's.
H. SHUMAKER.

ROBERT STEINEGGER
ASSAYER
Vulture, Arizona.

TERMS REASONABLE.
ASSAYS RELIABLE

Assayer for Elmore & Co., formerly Central Arizona Mining Co.

NOTICE FOR PUBLICATION.
Pre-emption No. 1131.

LAND OFFICE AT TUCSON, ARIZ., May 19, 1885.
NOTICE IS HEREBY GIVEN THAT the following named settler has filed notice of his intention to make final proof in support of his claim, and that said proof will be made before the register and receiver at Tucson, Arizona, on June 22, 1885, viz: Charles Freidgast, of Phœnix, Arizona, for the N. W. ¼ of sec. 2?, tp 2 N., R. 3 E. He names the following witnesses to prove his continuous residence upon, and cultivation of, said land, viz: J. P. Holcomb, Joseph Reid, [illegible], and John Kolgendling, all of Phœnix, Arizona.
R. M. THOMAS, Register.
First publication, May 22, 1885.

SUMMONS.

IN THE DISTRICT COURT OF THE second judicial district, of the territory of Arizona, in and for the county of Maricopa. Wm. H. Thomas, plaintiff, vs. James M. Seymore, defendant.

Action brought in the district court of the second judicial district of the territory of Arizona, in and for the county of Maricopa, in the office of the clerk of said district court. The territory of Arizona sends greeting to James M. Seymore, defendant. You are hereby summoned and required to appear in an action brought against you by the above named plaintiff, in the district court of the second judicial district of the territory of Arizona, in and for the county of Maricopa, and answer the complaint filed with the clerk of this court, at Phœnix, in said county, (a copy of which complaint accompanies this summons, within twenty days (exclusive of the day of service) after the service upon you of this summons, if served in this county; but, if served out of the county and within this district, then within thirty days; in all other cases forty days—or judgment by default will be taken against you according to the prayer of said complaint. The said action is brought to obtain a judgment of this court for the sum of $[illegible] due from defendant to plaintiff for a [illegible] in making an examination of, and [illegible] and reporting on the mine known as the [illegible] quartz lode, situated in the [illegible] creek mining district, Maricopa county, Arizona territory, and for acting as agent for defendant in caring for and defending the interest of said defendant in said mine. All of which will fully appear from the complaint on file herein to which reference is here made. And you are hereby notified that if you fail to appear and answer the said complaint, as above required, the plaintiff will take judgment against you for the sum of four thousand, nine hundred ($4,900) dollars, and costs and disbursements in this behalf expended.

Given under my hand and the seal of the district court of the second judicial district of the territory of Arizona, in and for the county of Maricopa, this [illegible] day of May, A. D., 1885.
[SEAL.]
C. H. KNAPP, Clerk.
May 2?, 1885.

Todd's Garden City Drug Store
&

We are just in receipt of a fresh stock of

PURE DRUGS AND CHEMICALS,

Patent Medicines, Perfumeries, Toilet Articles, Etc.

ALSO, A LARGE AND COMPLETE LINE OF BLANK BOOKS, STATIONERY, CUTLERY, INKS, PENS, PENCILS, ETC.

Pure Wines and Liquors for Medicinal Purposes. Eastern Cigars.

ROBT B. TODD, Proprietor. C. L. FSCHMAN, Manager.

The Arizona Canal Co.

Respectfully announces the completion of its canal, and gives notice that it is now ready to furnish water for irrigating purposes. For further information apply to
CLARK CHURCHILL,
President.
Phœnix, June 1, 1885.

JIM LEE RESTAURANT.
MONTEZUMA STREET,
West Side Plaza. Phœnix, Arizona.

THE BEST MEALS IN ARIZONA.

Meals	25 cents
Meals	35 cents
Meals	50 cents

Everything is New, Neat and Clean.

If you want a good square meal give us a call

FASHION SALOON
Washington Street,
Between Center and Montezuma Sts. Phœnix, Arizona
WILLIAM JENSEN, Proprietor.

We Keep None but the Best Wines, Liquors and Cigars.

A FINE BILLIARD TABLE
Can be found at this place.

ESTRAY MULES.

ONE BLACK MARE MULE, BRANDED G M D on left shoulder. One light bay mule, branded A on left side of neck. Both mules are about 14 hands high. The above described animals strayed from the camp of the drop on the Arizona canal, on Friday, May 8, 1885. A liberal reward will be paid for their return, or for information that will lead to their recovery. Leave information at the Valley bank, Phœnix.
J. A. NORTON.
Phœnix, May [illegible]

SPECIAL NOTICE.

Having decided to handle and raise only Horses and Cattle, the entire herd of pure bred Berkshire pigs at the

The Valley Stock Farm

are offered for sale at greatly REDUCED PRICES.

A rare chance for persons wishing to grade up their hogs or start a herd of thoroughbred Berkshires. Also over 300 stock hogs, one-fourth of which are half-breed Berkshires. Also six first-class Short-Horn bulls from one to three years old.
J. T. SIMMS.

PHŒNIX COFFEE STAND
AND
ICE CREAM SALOON.

Wright & Walbridge Building, Washington St. Phœnix, Ariz.

MRS. JULIA THOMAS, Prop's.

Ice Cream, Iced Tea, Iced Milk, Coffee and Chocolate with Cake, Roll and Pie.

Ice Cream made to order for Parties, Balls etc.

All are invited to give me a call.
MRS. JULIA THOMAS.

C. H. BURY,
Contractor & Builder
Furniture Made and Repaired

Turning and Scroll Saw Work Done to Order. All Kinds of Jobbing Promptly Attended to.

SHOP
REAR OF GREGORY'S LUMBER YARD
PHŒNIX ARIZONA.

ket at figures which no competitors can approach without

DANGER OF ABSOLUTE RUINATION!

We ourselves may never again be able to repeat such advantageous offers.

This is a Bona Fide Clearance Sale

We propose dispensing with no lines of our stock, we are not closing out our business, we are not reducing its extent, we have no shopworn, shoddy, faded and unfashionable dry goods which we wish to get rid of. All lines will be kept up in the future as in the past, but we have a superflous stock and this

MUST BE SOLD!

It is a business proposition which the public will appreciate in these dull times. It is a rare opportunity which the provident will take advantage of. Our articles are first-class, warranted, but we can and will sell them at such figures as have never before been approached by the vendors of worthless, time-worn, and remnant stocks from retail houses of the Pacific Coast. A complete price list would fill the columns of our newspapers and its compilation would require more time than we have to spare but the following figures will illustrate to the public that we are sincere in our announcement

READ! PONDER! WONDER!

PRICE LIST.

American Prints, 25 yards for	$1.00
Lansdale Muslin	10 cts.
White Rock Muslin	10 cts.
Ginghams in all shades and colors	10 cts.
Brown Muslin from 4 to	10 cts.
Sheetings, 5-4	16 cts.
Sheetings, 6-4	20 cts.
Sheetings, 8-4	22 cts.
Sheetings, 9-4	25 cts.
Sheetings, 10-4	27 cts.
Dress Goods, solid color 15 cts worth	35.
Assortment of all shades	35 to cts 75.

In fact ten thousand of other articles at the same reductions. Next week we will be able to give you more of a price list. We will commence to sell our stock at these reduced prices from Friday, February 27th.

GUSS. ELLIS & CO.

IN OUR BRICK STORE,

Cor. Washington & Montezuma Streets, Phœnix

Arizona Gazette.

All the (*) Locals are 10 cents per line for first insertion, and 5 cents per line for each subsequent insertion. Subject to No Discount.

PHŒNIX, FRIDAY, JUNE 6.

LOCAL BREVITIES.

Drink boca beer.

The street-tax is now collectable.

Baths, Etc. Ferdinand's barber shop.

The Knights of Pythias meet this evening.

Poor whiskey and bad cigars at Geo. Hamlin's.

The farmers are now all busy with their crops.

Mellowed double-stamped whisky, at the Germania.

Save money and buy for cost at Dillon & Kennedy's.

You can get a very poor cocktail at Hamlin's saloon.

An interesting article on mining in the next column.

House of four rooms for rent. Enquire at this office.

Fine hammocks at $2.60 each, at the Garden City drug store.

Just received a nice lot of Mexican cigars at the Capitol Cigar Store.

Arctic Soda water with fine fruit syrups at Garden City drug store.

The Salt river carries a much larger body of water than is usual at this time of the year.

The finest 5ct cigar in the city at the Garden City drug store.

The following passengers arrived from Maricopa to-day noon: H. Moses, L. Pyeso and A. Warbach.

For a good Mexican cigar call at the Capitol Cigar Store.

It is reported that the Gillett mill will shortly be purchased and moved down on West Humbug.

Prescriptions carefully compounded at the Garden City drug store.

Persons holding city warrants must not neglect to register the same with the treasurer, as they are now paid in the order of registration.

For cash you can get bee-hives at Ryder's lumber yard for $2.75 each.

We were visited by a heavy sand storm yesterday afternoon, and its purifying effects are appreciated in the atmosphere of to-day.

We have the sole agency for the Butterick patterns. Geo. Ellis & Co.

Thomas & Shower are now negotiating with S. F. Mack, of the Golden Fleece mill, for the reduction of 1,000 tons of ore from their mine in the Winauford district.

For druggists' sundries, toilet articles, perfumery, etc., go to the Garden City drug store.

One of the mules in a large team was to-day killed by falling in the deep ditch dividing the city from Neahr's addition on Washington street.

First mon[illegible] [illegible]pment of ladies' [illegible] and [illegible] store opened to-

MINES AND MINING.

Tip Top, Castle Creek and Humbug Districts.

Mining matters in the vicinity of the old Tiptop camp are looking brighter every day and in Mineral Basin and on West Humbug, fully 250 men find employment, either in chloriding or in working for others. A citizen of Phœnix who recently visited that rich mineral district returns highly pleased with what he saw on the trip and greatly surprised at the extent and value of the operations which are now being prosecuted. He tells us that John Smithline, of the well known Silver Museum, has 11 men constantly at work in his mine, and is paying them four dollars a day. He has a tunnel 250 feet in length, all in ore, with a lift of 70 feet to which to slope. The ledge averages about six inches in width and the ore is high grade, none that has heretofore been shipped yielding less than 500 ounces of silver to the ton. Mr. Smithline has now on the dump some thirteen tons of ore which will work $300 and two tons which samples at $1,800. A shipment of the same will be shortly made to Pueblo, Colorado.

Wager Bros., who have heretofore been heavy shippers, have leased their mine to California parties of experience and capital, who are developing the same with very promising indications. They are sinking a new working shaft and expect to send out a large quantity of high grade ore this fall.

O. Urfer, of Prescott, owner of the 76 mine, which is near the old Tiptop, has a number of men at work on the property.

The Tiptop mine is itself being operated by Dan Wright, Gus Bauer and Anthony Burchan, who re-located the same the first of the present year. This famous property, which yielded so largely until the deep workings and small vein caused its abandonment has not "petered" out by any manner of means. The new owners have already taken out $15,000 in cold cash the present year, which considering the fact that their muscle and mining experience was the sum total of their original capital is a pretty good showing. They ship their ore to Pueblo, Colorado and Socorro, New Mexico.

All the parties mentioned above commenced their mining enterprises without any capital whatever, and with what little credit they could secure from Phœnix merchants. All of them, and a much larger number whose names we have not mentioned, are now making regular shipments of ore, and a majority have good bank accounts at present. It is estimated that the Tiptop country puts out $1000 worth of ore daily, under the disadvantages which lack of capital necessarily places the operators.

Pans are being placed in the 10-stamp mill of the St. Louis-Yavapai mining company on West Humbug, by which it is expected to save the several valuable metals contained in the ore of that section. Heretofore the mill has only been supplied with appliances for saving

cheerfully paid their subscriptions. The number of visitors who have used the rooms from the beginning has been quite large. Especially when there is taken into consideration the very unpretentious character of the rooms and furniture.

There has been an average attendance of two hundred and ten visitors a month for the entire year.

The receipts for the year are as follows.

From subscriptions	$ 564 45
Donations from Phœnix Temperance society and Good Templars	59 80
Total	$ 624 25

Disbursements.

For rent for the year	$ 349 75
Janitor services	115
Literature	80
Lights	40
Ice	44 50
Furnishing and Incidentals	25 00
Total	$ 624 25

The furniture and other effects have been scheduled and carefully stored away for future use of this or some similar public organization that may be started in our city.

MRS. E. A. INGALLS, M. D.
MRS. H. P. HINE,
MRS. M. MAURE,
MRS. BELLE WRIGHT,
MRS. M. MILLAY.

SUMMONS.

IN THE DISTRICT COURT OF THE second judicial district of the territory of [illegible]

We have the sole agency for the [illegible] patterns. Guss Ellis & Co.

Thomas & Showe are now negotiating with S. F. Mack, of the Golden Fleece mill, for the reduction of 1,000 tons of ore from their mine in the Winnsford district.

For druggists' sundries, toilet articles, perfumery, etc., go to the Garden City drug store. †

One of the mules in a large team was to-day killed by falling in the deep ditch dividing the city from Neahr's addition on Washington street.

First monthly shipment of ladies' gents' and children's shoes opened to-day at Dillon & Kenealy's

A man and a boy were to-day caught stealing fruit in Ganz' orchard, and were arrested by citizens. They were released, however, on a promise to sin no more.

None but first quality of chemicals, drugs and patent medicines at the Garden City drug store. †

We are the sole agents in Phœnix for the celebrated Giant & Judson powder, 3-tape fuse and caps. G. Ellis & Co.

Ira Stroud re-opened his saloon to-day, and is the first one of our citizens, who suffered in the late fire, to resume business. We trust that he will meet with success.

For all kinds of stationery, blank books, writing paper, pencils, pens, etc. go to the Garden City drug store. †

Tom Sherman, Tom Greenhaw, and Charles Hall have secured all rights to the Red Rover mine, Magazine district, and have relocated it as the "Dirty River." We hope they may be able to secure good returns from the same.

We carry the largest line of hardware, iron, steel, coal, carpenter and builders' tools and Shelf hardware in the territory. Guss Ellis & Co.

We carry a large and fine assortment of American and imported wines and liquors, and are sole agents for the celebrated Pilsner, Falk Milwaukee beer. Guss Ellis & Co.

In our issue of last Wednesday we published an extract from the *Silver Belt* relative to the exploration of the Salt river cañon, a section of the river which waters this valley, and which heretofore has never been entered much less passed through. Yesterday James Logan, Wm. Burch, John Meaders and Wm. Robinson, composing the party of daring adventurers arrived in this city, having landed their craft at Tempe and coming into this city in six days after launching their boat. They report having enjoyed a most exciting and interesting trip. Through the box cañon of the Salt river the banks frequently towered above them over 1,000 feet, and on one occasion they were wrecked, losing provisions, fire arms, etc. The object of the trip was to determine whether saw logs could be rafted to the lower Salt river, and the undisputed conclusion is that such work can be successfully carried on. In fact Mr. Burch, who is a saw-mill man on the upper Salt river has partially contracted for the delivery at Tempe of over one thousand railroad ties. If experience should demonstrate that saw logs can be successfully floated from the timber regions to this portion of the Salt river, then the benefits derived from this exploration cannot be over-estimated.

[illegible] from Phœnix merchants. All of them, and a much larger number whose names we have not mentioned, are now making regular shipments of ore, and a majority have good bank accounts at present. It is estimated that the Tiptop country puts out $1000 worth of ore daily, under the disadvantages which lack of capital necessarily places the operators.

Pans are being placed in the 10-stamp mill of the St. Louis-Yavapai mining company on West Humbug, by which it is expected to save the several valuable metals contained in the ore of that section. Heretofore the mill has only been supplied with appliances for saving the gold, and concentrators were used on the silver and lead ore, which was afterward shipped to Benson, or Colorado. As soon as the proposed improvements are effected, the company purposes buying ore from the dumps, which will be a blessing to a large number of prospectors and poor miners, who may, by this arrangement continue the development of their properties to a valuable stage. Jacob S. Merrill, of St. Louis, vice president of the company is making a complete and careful tour of the section, including Castle creek, and is quite pleased therewith. He states that his company will spare neither time nor expense in developing the mines of that section to a point where their worth will command recognition.

Bob Groome's gold mine on Castle creek is creating much attention. It is of recent discovery and such developments as have been made lead to the conclusion that it is a veritable bonanza. Samples taken from the entire width of the ledge, and assayed by J. H. Trotter, the other day, assayed $600 to the ton on an average.

The mill of the Right Bower mine, on Squaw creek, will start up next week. It was intended to commence operations sooner, but the engine broke down and occasioned the delay. An engineer went out from this city to work in the mill a day or two since. The Right Bower is an immense ledge, the ore being free gold. Mr. Fuller, a San Francisco gentleman, is in charge of the same, and has several thousand tons of ore ready for reduction. The mining enterprises we have mentioned in this summary are all contiguous to Phœnix, a fact that will be surprising to many of our own citizens. They consume largely of our products and do all their trading with Phœnix merchants. How much greater would be the benefits accruing to our city if we had a well-managed smelter in operation in this valley, the readers may judge for themselves.

Annual Report of Phœnix Reading Room.

To the Patrons of the Phœnix Reading Rooms:

The undersigned, managers of the reading rooms, respectfully submit the following report for the year ending June 1st, 1885:

It is with feelings of regret that, owing to the scarcity of money and the inconvenience of collecting the subscriptions, the managers feel compelled to close the reading rooms at least for the summer. There are a few citizens who have seemed to feel it a privilege to contribute to the support of the rooms ever since the enterprise was inaugurated, and who have always promptly and

SUMMONS.

In the District Court of the second judicial district, of the territory of Arizona, in and for the county of Maricopa. Wm. H. Thomas, plaintiff, vs. James M. Seymore, defendant.

Action brought in the district court of the second judicial district of the territory of Arizona, in and for the county of Maricopa, in the office of the clerk of said district court. The territory of Arizona sends greeting to James M. Seymore, defendant. You are hereby summoned and required to appear in an action brought against you by the above named plaintiff, in the district court of the second judicial district of the territory of Arizona, in and for the county of Maricopa, and answer the complaint filed with the clerk of this court, at Phœnix, in said county, (a copy of which complaint accompanies this summons), within twenty days (exclusive of the day of service) after the service upon you of this summons—if served in this county; but, if served out of the county and within this district, then within thirty days; in all other cases forty days—or judgment by default will be taken against you according to the prayer of said complaint. The said action is brought to obtain a judgment of this court for the sum of $4,000.00 due from defendant to plaintiff for services in making an examination, of sampling and reporting on the mine known as the Phœnix Quartz Ledge, situated in Cave creek mining district Maricopa county, Arizona territory, and for acting as agent for defendant in regard to and defending the interest of said defendant in said mine. All of which will fully appear from the complaint on file herein to which reference is here made. And you are hereby notified that if you fail to appear and answer the said complaint, as above required, the plaintiff will take judgment against you for the sum of four thousand dollars ($4,000) dollars, and costs and disbursements in this behalf expended.

Given under my hand and the seal of the district court of the second judicial district of the territory of Arizona, in and for the county of Maricopa, this 23d day of May, A. D., 1885.

[SEAL.] C. H. KNAPP, Clerk.

May 27, 1885.

ESTRAY MULES.

One black mare mule branded O G M D on left shoulder. One light bay mule, branded A on left side of neck, both mules are about 14 hands high. The above described animals strayed from the range at the drop on the Arizona canal, on Friday, May 8, 1885. A liberal reward will be paid for their return, or for information that will lead to their recovery. Leave information at the Valley bank, Phœnix. J. R. NORTON.

Phœnix, May 16, 1885.

NOTICE.

Office of H. Goldberg, at Buckeye & [illegible]

All persons having claims against the firm of H. Goldberg will please present the same at the office, and all owing bills will please come forward and pay the same, as we must have money.

H. GOLDBERG.

The Arizona Canal Co.

Respectfully announces the completion of its canal, and gives notice that it is now ready to furnish water for irrigating purposes. For further information apply to

CLARK CHURCHILL, President.

Phœnix, June 1, 1885.

FOR SALE.

A good frame dwelling House of Three Rooms, together with Splendid Lot, at the corner of Pima and Adams street. Price low; terms reasonable. Apply at this office.

SPECIAL NOTICE.

Having decided to handle and raise only Horses and Cattle, the entire herd of pure bred Berkshire pigs at the

The Valley Stock Farm

are offered for sale at greatly REDUCED PRICES.

A rare chance for persons wishing to grade up their hogs or start a herd of thoroughbred Berkshires. Also over 800 stock hogs, one-fourth of which are half-breed Berkshires Also six first-class Short-Horn bulls from one to three years old J. T. SIMMS.

DANGER OF ABSOLUTE RUINATION!

We ourselves may never again be able to repeat such advantageous offers.

This is a Bona Fide Clearance Sale

We propose dispensing with no lines of our stock, we are not closing out our business, we are not reducing its extent, we have no shop-worn, shoddy, faded and unfashionable dry goods which we wish to get rid of. All lines will be kept up in the future as in the past, but we have a superflous stock and this

MUST BE SOLD!

It is a business proposition which the public will appreciate in these dull times. It is a rare opportunity which the provident will take advantage of. Our articles are first-class, warranted, but we can and will sell them at such figures as have never before been approached by the vendors of worthless, time-worn, and remnant stocks from retail houses of the Pacific Coast. A complete price list would fill the columns of our newspapers and its compilation would require more time than we have to spare but the following figures will illustrate to the public that we are sincere in our announcement

READ! PONDER! WONDER!

PRICE LIST.

American Prints, 25 yards for	$1.00
Lansdale Muslin	10 cts.
White Rock Muslin	10 cts.
Ginghams in all shades and colors	10 cts.
Brown Muslin from 4 to	10 cts.
Sheetings, 5-4	16 cts.
Sheetings, 6-4	20 cts.
Sheetings, 8-4	22 cts.
Sheetings, 9-4	25 cts.
Sheetings, 10-4	27 cts.
Dress Goods, solid color 15 cts worth	35.
Assortment of all shades	35 to cts 75.

In fact ten thousand of other articles at the same reductions. Next week we will be able to give you more of a price list. We will commence to sell our stock at these reduced prices from Friday, February 27th.

GUSS. ELLIS & CO.

IN OUR BRICK STORE,

Cor, Washington & Montezuma Streets, Phœnix

Arizona Gazette.

All Per (?) Locals are 10 cents per line for first insertion and 5 cents per line for each subsequent insertion. Subject to No Discount.

PHOENIX, SATURDAY, JUNE 6.

LOCAL BREVITIES.

Drink Roca beer.

No. 172 is Handin's saloon.

Odd Fellows meet to-night.

Baths 25c. Ferdinand's barber shop.

No religious services to-morrow except in the Center street church.

Mellowed double-stamped whisky, at the Demands.

Save money and buy for cash at Dillon & Keealy's.

Dr. Thibodo is erecting a nice awning in front of his drug store on Washington street.

House of four rooms for rent. Enquire at this office.

Fine hammocks at $2.50 each, at the Garden City drug store.

The nights are still quite cool, and so far central Arizona has enjoyed but one touch of summer.

Just received a nice lot of Mexican cigars at the Capitol Cigar Store.

Dyer's picture of Phoenix will be a beauty, and an appropriate present to friends in the eastern states.

The finest bit cigar in the city at the Garden City drug store.

For a good Mexican cigar call at the Capitol Cigar Store.

The numerous friends of Frank B. Moss are now congratulating that young gentleman upon his recent marriage.

Prescriptions carefully compounded at the Garden City drug store.

It is proposed to fill in Washington street with the debris from the burnt buildings. No better plan could be adopted.

For cash you can get bee-hives at Ryder's lumber yard for $2.75 each.

We have the sole agency for the Butterick patterns. Goss Ellis & Co.

D. Rales returned to Phoenix to-day from Tucson, where he has been making arrangements for shipping fruit to that market.

For druggists' sundries, toilet articles, perfumery, etc., go to the Garden City drug store.

The whistle of the thresher engine can be heard in this city. The harvest is now well under way and the farmers are busy and happy.

First monthly shipment of ladies' gents' and children's shoes opened to-day at Dillon & Keealy's

Sore throat seems to be epidemic with the younger people of this city and a number of children are reported as quite sick through its effects.

Three young men were noticed on the streets at a late hour last night minus their hats. What occasioned the loss of this portion of their apparel we were unable to learn.

We have [illegible] bathing baths in Phoenix, but Prescott [illegible] a "natatorium." The higher [illegible] up in the mountain

VALUABLE DISCOVERIES

Resulting from the Exploration of the Box Canyon.

An Unlimited Timber Supply and an Unequalled Point for Constructing a Reservoir.

Last evening the GAZETTE reporter interviewed J[illegible] Meaders, one of the members of [illegible] daring party which recently passed through the Box cañon of Salt river in a small boat. The party had a most interesting and exciting trip, being five days in making the voyage, which from Armer's place, about 4 miles above the point where Tonto creek debouches into the Salt river, to the dam of the Grand canal where the boat was tied up, includes a distance of about 100 miles calculating upon the sinuosities of the stream. The box cañon pierces the foot hills of the Four Peak range, which is to the north of the stream, while lower down Superstitious mountain forms the south bank. The cañon proper is about 60 miles in length, and begins at the mouth of Tonto creek. For a distance of about eight miles the explorers passed down the river where precipitous banks arose varying from 200 to 1000 feet, then came a rolling country for a few miles and the boat entered the main box which continued for a distance of perhaps 20 miles. Before entering the second cañon the bed of the stream narrows to only 11 feet. This discovery is perhaps the most important made, simply through the fact that a dam may be placed across the river at that point, and at comparatively small expense, which could form a reservoir or lake of fully 20 miles in length. The walls at this point are precipitous only for a hight of 15 feet, but a granite mountain rises on one side, while rolling hills come down to the other bank. A dam of 11 feet at the bottom, and rising to a hight of 300 feet would not be over 600 feet in width at the top, and would form a reservoir sufficient to irrigate millions of acres of farming lands. The water is not particularly swift at this point and Mr. Meaders thinks that engineering skill could easily devise a way for constructing a reservoir.

Mr. Meaders tells the reporter that the character of the rock forming the cañon is a dark syenite, in which several iron dikes were seen.

At one point they passed through a mineral belt, the appearance of which was very good, but owing to lack of time it was not prospected. Timber exists in the Four Peak range in large quantities. Game and fish are most plentiful, the party having killed one mountain sheep and several deer, while they caught large quantities of Salt river trout—called by some white salmon. These fish closely resemble the lake trout of California but are not so game. Several of these fish, weighing eight and ten pounds, were caught by the explorers, but in previous instances fish of this species weighing forty pounds have been caught. The boat on one occasion shot under a cave, but a few feet high, and where its inmates commenced to fear that the end had come; here the fish were so thick that the boat

The Ore Belle Mine.

Edwin McGourn is now working the Ore Belle mine on the southern slope of the Bradshaw mountains, and about a mile from the Tiger. He has a furnace and roaster in operation and several arrastras. Eleven men are working in and around the mine and the returns have been quite satisfactory thus far. Mr. McGourn exhibited in the GAZETTE office the other day a nice gold button of the value of about $40 which was the product of 1000 pounds of ore worked by him, and this he claims is not a fair test, owing to the fact that the clean-up was an imperfect one. The Ore Belle mine draws on Phoenix for her supplies which have to be packed on mules a portion of the distance.

A Collision.

Clarence Aldridge, a boy 12 or 13 years of age had a narrow escape this morning. He was on horseback and was driving a loose horse up Washington street, which turned in on Center. A buckboard and a team of two mules were standing alongside of Goldman's and in turning the corner, Clarence's animal struck the pole of the buckboard, breaking the same and throwing himself and rider. The boy got up and began looking for his hat, after recovering which he mounted his horse and rode rapidly down street. The owner of the buckboard is the only loser.

Religious Services To-morrow.

The union religious services for the summer commences to-morrow night. Owing to its being the woman's missionary meeting it will be held to-morrow evening at the South Methodist church. After that it will be held on the plaza. No services at any other churches to-morrow.

Arctic Soda water with fine fruit syrups at Garden City drug store.

MARRIED.

MOSS—HARRIMAN—At Moss City on Sunday, May 31st, 188-, by H. W. Brisner, J. P., Frank B. Moss and Miss Ida Harriman, both of this city.

petomery, etc., go to the Garden City drug store. ✝

The whistle of the thresher engine can be heard in this city. The harvest is now well under way and the farmers are busy and happy.

First monthly shipment of ladies' gents and children's shoes opened to-day at Dillon & Kenealy's •

Sore throat seems to be epidemic with the younger people of this city and a number of children are reported as quite sick through its effects.

Three young men were noticed on the streets at a late hour last night minus their hats. What occasioned the loss of this portion of their apparel we were unable to learn.

We have swimming baths in Phœnix, but Prescott is to have a "natatorium." The higher you get up in the mountains, the higher comes the English language.

None but first quality of chemicals, drugs and patent medicines at the Garden City drug store. ✝

The Prescott rifles were unable to take the field against the Chiricahuas, owing to the fact that a promenade concert was to be given at their home the present week.

We are the sole agents in Phœnix for the celebrated Giant & Judson powder, Stape fuse and caps. G. Ellis & Co.

W. F. Everhart leaves to-morrow for San Francisco and will make arrangements for replacing his stock recently destroyed by fire, as soon as a store is erected for his use.

For all kinds of stationery, blank books, writing paper, pencils, pens, etc. go to the Garden City drug store. ✝

Billy Pimm is having the ceiling of his saloon papered in immitation of fresco and will put in an elegant new bar. His customers cannot complain of any lack of enterprise.

The friends of Rev. Calfee tendered that able and zealous worker in the cause of christianity, a pound social last evening. There was a large attendance and the affair proved quite pleasant.

We carry the largest line of hardware, iron, steel, coal, carpenter and builders' tools and Shelf hardware in the territory. Guss Ellis & Co

The city property belonging to the Savoy estate was to-day sold at public auction by the public administrator, bringing as good prices as could be secured at private sale. Lot 9 in block 26 was purchased by Frank Luke for the sum of $180; lots 2, 4, 6 in block 23 were bid in by Dr. Lightburne for $470; P. P. Trott bought lot 12 in block 35 for $135; while P. D. Wells secured lot 9 in block 37 for the consideration of $120.

We carry a large and fine assortment of American and imported wines and liquors, and are sole agents for the celebrated Pilsner, Falk Milwaukee beer. Guss Ellis & Co.

There has been placed on deposit in the bank of Arizona to the credit of Hon. C. W. Beach, by Thomas Bulbeck and other capitalists of New York city, funds with which to commence work on the proposed railroad between this place and the line of the Atlantic & Pacific. Owing to Mr. Beach's absence in Texas, however, the board of directors are unable to use the money without first obtaining authority from him to do so—which authority will be obtained as soon as Mr. [illegible] can be reached by telegraph.

... iron dikes were seen.

At one point they passed through a mineral belt, the appearance of which was very good, but owing to lack of time it was not prospected. Timber exists in the Four Peak range in large quantities. Game and fish are most plentiful, the party having killed one mountain sheep and several deer, while they caught large quantities of Salt river trout—called by some white salmon. These fish closely resemble the lake trout of California but are not so game. Several of these fish, weighing eight and ten pounds, were caught by the explorers, but in previous instances fish of this specie weighing forty pounds have been caught. The boat on one occasion shot under a cave, but a few feet high, and where its inmates commenced to fear that the end had come; here the fish were so thick that the boat floated on their backs.

Besides the two cañons we have referred to there are a succession of others of various lengths, aggregating a distance of about thirty miles. They are all of the same character, however. The water flows very swiftly through most portions of the cañon, and its depth varies from six to twenty feet, the stream being held in very narrow limits. No drift wood or any other debris exists in the cañon, the force of the water moving everything before it. As was stated in the GAZETTE report of yesterday, the object of the exploration was to ascertain the practicability of floating logs down the river to this city, and the absence of drift and the general character of the cañon demonstrates most fully that such a project may be successfully undertaken. This in itself is an important discovery, for the reason that it will open to this valley the timber belt of the Sierra Anche, which is undoubtedly the best and most extensive in the territory.

Of course the voyage of Messrs. Burch, Robinson, Legin and Meaders was not without its excitement and pleasures as well as dangers. They were exploring a section man never before penetrated. Dashing along in a frail craft in some instances at a rate of twenty miles an hour, and the banks of the stream rising above them on either side to a hight of 1,000 feet, is of course sufficiently exciting to satisfy the most adventurous. They expected every minute to strike a waterfall and have their boat dashed to pieces, as they [illegible] when they shot the cave. On one occasion their boat upset and much of their supplies were lost. In case of losing their vessel in the cañon but one recourse would be left, that of swimming down the stream to a break in one bank or another and that might not be encountered for a distance of twenty miles. The description of the scenery as given by Mr. Meaders, is grandly beautiful and awe inspiring, and if an artist could reproduce it, a fortune would award his genius. It was a desperate undertaking, successfully accomplished, but cannot be considered a fool-hardy attempt, for the reason that it was made for a laudable purpose.

A business man of Phœnix received a postal card this morning signed "Dynamite." The purport of the matter thereon, although senseless, was threatening, and the scribe must take care that his identity is concealed, otherwise the law is not likely to deal gently with his communistic expressions. Here we a genuine dynamitard in our ...

That You can get the Finest Shave in Phœnix at Shumaker's.

That You have to wait the Least Length of Time.

That You can have Your Hair Cut and Dressed in the Most Approved Style.

That You can Secure the Finest Baths in the Territory.

That the Shop is between Pimm's and Asher's.

H. SHUMAKER.

SUMMONS.

IN THE DISTRICT COURT OF THE second judicial district, of the territory of Arizona, in and for the county of Maricopa. Wm. H. Thomas, plaintiff, vs. James M. Seymore, defendant.

Action brought in the district court of the second judicial district of the territory of Arizona, in and for the county of Maricopa, in the office of the clerk of said district court. The territory of Arizona sends greeting to James M. Seymore, defendant. You are hereby summoned and required to appear in an action brought against you by the above named plaintiff, in the district court of the second judicial district of the territory of Arizona, in and for the county of Maricopa, and answer the complaint filed with the clerk of this court, at Phœnix, in said county, (a copy of which complaint accompanies this summons), within twenty days (exclusive of the day of service) after the service upon you of this summons—if served in this county; but, if served out of the county and within this district, then within thirty days; in all other cases forty days—or judgment by default will be taken against you according to the prayer of said complaint. The said action is brought to obtain a judgment of this court for the sum of $4,900.00 due from defendant to plaintiff for services in making an examination of, sampling and reporting on the mine known as the Phœnix Quartz Ledge, situate in Cave creek mining district Maricopa county, Arizona territory, and for acting as agent for defendant in caring for and defending the interest of said defendant in said mine. All of which will fully appear from the complaint on file herein to which reference is here made. And you are hereby notified that if you fail to appear and answer the said complaint, as above required, the plaintiff will take judgment against you for the sum of four thousand, nine hundred ($4,900) dollars, and costs and disbursements in this behalf expended.

Given under my hand and the seal of the district court of the second judicial district of the territory of Arizona, in and for the county of Maricopa, this 23d day of May, A. D., 1885.

[seal.] C. H. KNAPP, Clerk.

May 27, 1885.

ESTRAY MULES.

ONE BLACK MARE MULE BRANDED G M D on left shoulder. One light bay mule, branded A on left side of neck. Both mules are about 13 hands high. The above described animals strayed from the camp at the drop on the Arizona canal, on Friday, May 8, 1885. A liberal reward will be paid for their return, or for information that will lead to their recovery. Leave information at the Valley bank, Phœnix. J. E. MORTON.

Phœnix, May 16, 1885.

PHŒNIX HOTEL,

Chas. Ralari, Proprietor.

Coolest, Quietest and Most Commodious of Rooms. Good Reading and Dining Rooms Connected.

Best of Attention Bestowed on Guests.

BAKER & HAMILTON,

SAN FRANCISCO, CAL.

Hardware and Agricultural Implement

MANUFACTORY.

BENICIA AGRICULTURAL WORKS.

SOLE AGENTS FOR

Genuine Buffalo Pitts Separators, Ames' Engines, with Laufenburg's Patent Boiler, Arcea' Engines, with Hall's Patent Straw Burning Attachment, Baxter Engines, Benicia Header, Baldwin Hay Cutters, Mohne Plows, Eureka Gang Plows, Gem Seed Sower, Baudal Pulverising Harrows, Wood Bar Harrows, Etc

The Arizona Canal Co.

Respectfully announces the completion of its canal, and gives notice that it is now ready to furnish water for irrigating purposes. For further information apply to

CLARK CHURCHILL, President.

Phœnix, June 1, 1885.

FOR SALE.

A good frame dwelling House of Three Rooms, together with Splendid Lot, at the corner of Pima and Adams street. Price low; terms reasonable. Apply at this office.

TO THE FRONT AGAIN!

TUCK HING'S EATING HOUSE

RE-OPENED.

A GOOD SQUARE MEAL FOR 25 CENTS.

MEALS TO ORDER AT ALL HOURS.

WASHINGTON STREET, PHŒNIX.

HERRICK & CO.

General Blacksmiths, Wagon Makers and Horseshoers.

Foot of English's [illegible] PHŒNIX, ARIZONA.

SPECIAL NOTICE.

Having decided to handle and raise only Horses and Cattle, the entire herd of pure bred Berkshire pigs at the

The Valley Stock Farm

are offered for sale at greatly REDUCED PRICES.

A rare chance for persons wishing to grade up their hogs or start a herd of thorough-bred Berkshires. Also over 300 stock hogs, one-fourth of which are half-breed Berkshires. Also six first-class Short-Horn bulls from one to three years old. J. T. SIMMS.

PHŒNIX COFFEE STAND

AND

ICE CREAM SALOON.

Wright & Walbridge Building, Washington St. Phœnix, Ariz.

MRS. JULIA THOMAS, Prop's.

Ice Cream, Iced Tea, Iced Milk, Coffee and Chocolate with Cake, Roll and Pie.

Ice Cream made to order for Parties, Balls etc.

All are invited to give me a call. MRS. JULIA THOMAS.

C. H. BURY,

Contractor & Builder

Furniture Made and Repaired

Turning and Scroll Saw Work Done to Order. All Kinds of Jobbing Promptly Attended to.

SHOP

REAR OF GREGORY'S LUMBER YARD

Phœnix, Arizona.

ket at figures which no competitors can approach without

DANGER OF ABSOLUTE RUINATION!

We ourselves may never again be able to repeat such advantageous offers.

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In fact ten thousand of other articles at the same reductions. Next week we will be able to give you more of a price list. We will commence to sell our stock at these reduced prices from Friday, February 27th.

GUSS. ELLIS & CO.

IN OUR BRICK STORE,

Cor. Washington & Montezuma Streets, Phœnix

Arizona Gazette.

All local Locals are 10 cents per line for first insertion, and 5 cents per line for each subsequent insertion. Subject to No Discount.

PHŒNIX, MONDAY, JUNE 8.

LOCAL BREVITIES.

Drink fuce beer.

No 122 — Hamlin's saloon.

Good Templars meet to-night.

By January 1886 our railroad will be built.

Mellwood double-stamped whisky, at the Germania.

Tombstone is to celebrate the fourth of July.

Save money and buy for cost at Dillon & Kenealy's.

Hamlin's saloon is in on the corner of Washington and Center streets.

The brickmakers will now reap a harvest.

House of four rooms for rent. Enquire at this office.

There are eight prisoners in the county jail.

The new crop of grain is coming in quite lively.

The board of supervisors is in session this afternoon.

Just received a nice lot of Mexican cigars at the Capitol Cigar Store.

We understand the Yuma *Republican* is about to change hands.

Fine hammocks at $2.50 each, at the Garden City drug store.

Stated convocation of Phœnix chapter No, 1, R. A. M., this evening.

For druggists' sundries, toilet articles, perfumery, etc., go to the Garden City drugstore.

Lon Barbee, census marshal of school district No. 1—this city—will complete his duties by Thursday next.

For all kinds of stationery, blank books, writing paper, pencils, pens, etc. go to the Garden City drug store.

The Yuma *Republican* of June 4th announces that it has not yet heard of any reduction of railroad fares, as was promised in Arizona a few weeks ago.

Tuesdays and Fridays from 3 till 7 o'clock P. M. will be reserved at Simms' swimming baths for the exclusive use of ladies.

We carry the largest line of hardware, iron, steel, coal, carpenter and builders' tools and Shelf hardware in the territory. Gus Ellis & Co.

Several business men are mentioned in connection with the election of councilmen in the second ward, to fill the vacancy occasioned by the resignation of Ira Strond.

We carry a large and fine assortment of American and imported wines and liquors, and are sole agents for the celebrated Pilsner, Falk Milwaukee beer. Gus Ellis & Co.

A magnolia tree is in blossom on Mayor Ganz' place in the northeastern part of the city. It is a beauty and is the first one that ever blossomed in this city.

Tombstone wants to sell Phœnix a Button hand [illegible] ine, which originally cost $2,5[illegible] the sum of $1,000. It throws three [illegible] ams and for a dis-

OUR RAILROAD.

The Survey to be Completed in Two Weeks

And the Work of Construction Inaugurated September Next.

The reporter this morning enjoyed the pleasure of a conversation with L. B. Harris jr., the engineer who has charge of the location of the proposed Phœnix and Maricopa railroad. Mr. Harris' corps is now engaged in cross-sectioning between the Gila river and Tempe and in another fortnight will have completed its work for the present. Mr. Harris says that he has two sites for the construction of a bridge at Tempe and at present is undetermined which location to adopt. Both are this side of Hayden's butte and it is hard to determine which will be the less costly, as one takes more material than the other but will require a smaller expenditure of labor in building. Mr. Harris has also run two lines into Phœnix, one coming down the section line which forms the north boundary of this city and the other terminating a half mile further north. He will run still another line which will come down the south side of town. Any of the three are practicable, and the directors of the company will determine as to which shall be followed. The most important information vouchsafed by Mr. Harris is that the company will commence the construction of the road about the 1st or 15th day of September next, and push it through as rapidly as is possible. Work will begin with the connection with the line of the Southern Pacific, a short distance below the Sweetwater tanks. Monroe Salisbury leaves at an early day for the east in the furtherance of the enterprise, while Mr. Harris will go to San Francisco immediately upon the completion of the present work, to perfect in detail his plans and specifications for bridges and other work, returning in a few months, as chief engineer of the construction of the road. This is good news to our people, and they will be gratified to learn that the company so emphatically means business. The railroad will give the Salt river valley and Phœnix a boom that will surprise all, and will be lasting in its effects. It is particularly provident that railroad facilities are so closely to follow the completion of the great Arizona canal, as they will give us immigration sufficient to occupy and cultivate every acre of land which can be brought under irrigation, which will result in profit to the large amount of capital invested in each instance. Phœnix should prepare herself for the coming day of life, bustle and business importance.

The Box Canyon.

In our account of the recent exploration of the Box cañon of the Salt river, we stated that the passage through the gorge by Messrs. Robinson, Burch, Logan and Meaders was the first ever made. It now turns out that we were premature in this statement. Postmaster Mowry related to the reporter this morning his recollections of the description of the cañon and a trip made through the same by Frank Middleton, now of Flagstaff, and his brother-in-law George Shute, now residing on the upper Salt river. This was eight or ten

A contract has been let by Mr. and Mrs. Fry for the erection of a double building 50x80 feet on their lot at the corner of Washington and Montezuma street. The building will be of brick, one story high and each room 25 feet wide. The building is to be completed in thirty days after the delivery of the material on the ground. Messrs. Patton & Creighton have the contract, which is for $7,500. The foundation and walls are to be such that another story may easily be added. H. Goldberg will also build a brick store.

Mae Fitzpatrick started on a visit to relations in Texas this morning. She will probably be gone most of the summer.

A load of ripe watermelons was brought into town yesterday and being the first of the season met with ready sale.

First monthly shipment of ladies' gents' and children's shoes opened today at Dillon & Kenealy's

Harry Yarnell brought us in a basket of nice apricots this morning, for which he has our thanks.

None but first quality of chemicals, drugs and patent medicines at the Garden City drug store.

We are the sole agents in Phœnix for the celebrate Giant & Judson powder, 3-tape fuse and caps. G. Ellis & Co.

Arctic Soda water with fine fruit syrups at Garden City drug store.

Baths, 25c. Ferdinand's barber shop.

of ladies.

We carry the largest line of hardware, iron, steel, coal, carpenter and builders' tools and Shelf hardware in the territory. Gras Ellis & Co.

Several business men are mentioned in connection with the election of councilmen in the second ward, to fill the vacancy occasioned by the resignation of Ira Stroud.

We carry a large and fine assortment of American and imported wines and liquors, and are sole agents for the celebrated Pilsner, Falk Milwaukee beer. Gras Ellis & Co.

A magnolia tree is in blossom on Mayor Ganz' place in the northeastern part of the city. It is a beauty and is the first one that ever blossomed in this city.

Tombstone wants to sell Phœnix a Button hand fire engine, which originally cost $2,500, for the sum of $1,000. It throws three streams and for a distance of 200 feet.

The chain gang and the city cartman have been engaged to-day in tearing down the adobe walls in the burnt district and filling in Washington street with this material.

A gentleman in this city who recently returned from Sonora, tells the reporter that in the recent fight with the Yaquis it is understood that 400 of the Mexican troops were killed. This doesn't tally with the telegraphic reports.

Deputy Sheriff Moffett returned from Tonto basin, yesterday, where he has been subpoenaing witnesses. He tells us that that section enjoyed a splendid rain last week, which was highly valued by stockmen.

A house, hay stack and horse shed belonging to a Chinese gardener on the ranch of W. W. Jones was destroyed by fire last night. The flames were seen from this city, and several parties went out to the point, but too late to do any good. The total loss will amount to $400 or $500.

Ganz, Mrs. Fry, Peeples, Steinegger and others intend building at an early day on their lots in the burnt district. None of them have, however, decided exactly as to what kind of buildings they will erect, but the indications are that two story bricks will replace the greater portion of the burnt block.

About the last of May one Mercedes Beratez was arrested and lodged in the county jail, charged with horse stealing, on a dispatch from the sheriff of Pinal. Yesterday Deputy Sheriff Drew, of the latter county, arrived in Phœnix and took the prisoner to Florence, to be tried at the next term of district court.

Sheriff Broadway returned from Prescott to-day with two prisoners—Patrick and Michael Hassett. These are the men who, some months ago, stole three head of horses from Simms' pasture near this city. They were held in Yavapai county to await the charge of burglarly before the grand jury, but the bill being ignored, the criminals were turned over to the authorities of this county.

Mr. B. Heyman, of the firm of Schoenfeld & Heyman, furniture dealers, will leave for the east next Monday, 15th instant, to purchase the largest stock of furniture, carpets, crockery, glassware, wall-paper and novelties in their line, ever brought to Arizona. You can buy for cash at your own price this week yet. All [illegible] indebted to us please [illegible]

[illegible] the completion of the great Arizona canal, as they will give us immigration sufficient to occupy and cultivate every acre of land which can be brought under irrigation, which will result in profit to the large amount of capital invested in each instance. Phœnix should prepare herself for the coming day of life, bustle and business importance.

The Box Canyon.

In our account of the recent exploration of the Box cañon of the Salt river, we stated that the passage through the gorge by Messrs. Robinson, Burch, Logan and Meaders was the first ever made. It now turns out that we were premature in this statement. Postmaster Mowry related to the reporter this morning his recollections of the description of the cañon and a trip made through the same by Frank Middleton, now of Flagstaff, and his brother-in-law George Shute, now residing on the upper Salt river. This was eight or ten years ago. The two men started out to make the descent of the cañon on foot, carrying their rifles, blankets and food. There was much less water in the stream than at present, but nevertheless the adventurers had a very severe struggle, and came very nearly perishing before they got through. They lost their guns, and exhausted or lost their provisions when out a few days. Nevertheless they succeeded in making the trip and came on to Phœnix, where they carefully related their experience to Mr. Mowry.

It may not be known to some housewives that if flour is kept in a closet with onions or cabbage it will absorb unpleasant odors from them; you may not notice this until the flour is cooked, but then will. A large chocolate and cocoanut cake was prepared for a tea party not long since. It was not tasted until passed at tea time, when the mistress observed a strong onion flavor, which, though an excellent one in its proper place, was here a thing of evil. It was discovered afterward that a basket containing onions had been left for two days in the store-room with the flour and everything, even the bread baked from this flour, had the onion flavor.

A block of ice was brought in this morning from the Maricopa ice and packing company's works, in which were frozen peaches, pears, figs, plums, grapes and other fruits, so arranged as to be quite beautiful.

Wm. Liggett, nightwatchman for Washington street, between Center and Cortez, has been granted, by the common council, the authority to make arrests.

The finest bit cigar in the city at the Garden City drug store.

Won't Phœnix celebrate the 4th this year?

For a good Mexican cigar call at the Capitol Cigar Store.

Judge Lemon leaves to-day on a trip to Globe.

Prescriptions carefully compounded at the Garden City drug store.

Mrs. O. A. Tweed left yesterday on a visit to her home in Ohio.

For cash you can get bee-hives at Ryder's lumber yard for $2.75 each.

Fred Pollock left to-day for Nogales, and expects to remain there.

We have the sole agency for the Butterick patterns. Gras Ellis & Co.

ESTRAY MULES.

ONE BLACK MARE MULE BRANDED G M D on left shoulder. One light bay mule, branded A on left side of neck, both mules are about 15 hands high. The above described animals strayed from the camp at the drop on the Arizona canal, on Friday, May 8, 1885. A liberal reward will be paid for their return, or for information that will lead to their recovery. Leave information at the Valley bank, Phœnix.

J. H. NORTON.

Phœnix, May 18, 1886.

$300.00 REWARD.

Territory of Arizona, Executive Department, Office of the Governor.

WHEREAS, I HAVE BEEN INFORMed that on the night of April 17, A. D., 1885, some person or persons to me unknown, robbed the Vulture stage, between Vulture and Phœnix, Arizona, and took therefrom a bar of bullion, valued at $3,000, and other articles of value, and that said person or persons are still at large, not having been apprehended for said crime.

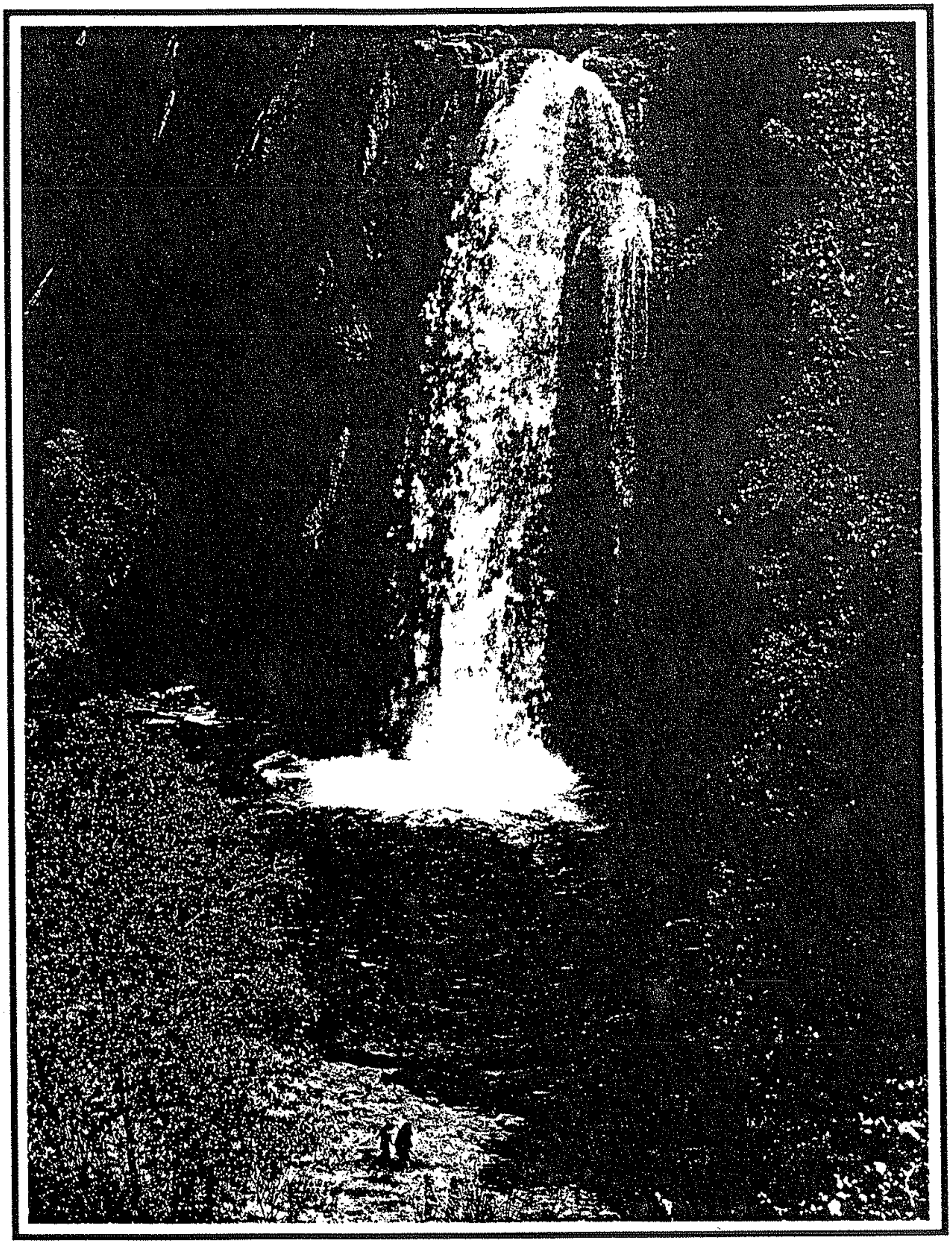
Now, therefore, I, F. A. Tritle, governor of the territory of Arizona, by virtue of the authority vested in me do hereby offer a reward in the sum of three hundred dollars for the arrest and conviction of such person, or if there be more than one, for each of such persons as committed the said robbery.

[SEAL] In witness whereof I have hereunto set my hand and caused the great seal of the territory to be hereto affixed.

Done at Prescott this 18th day of May A. D., 1885. F. A. TRITLE, Governor.

[Attest.] H. M. VAN ARMAN, Secretary of Territory.

7



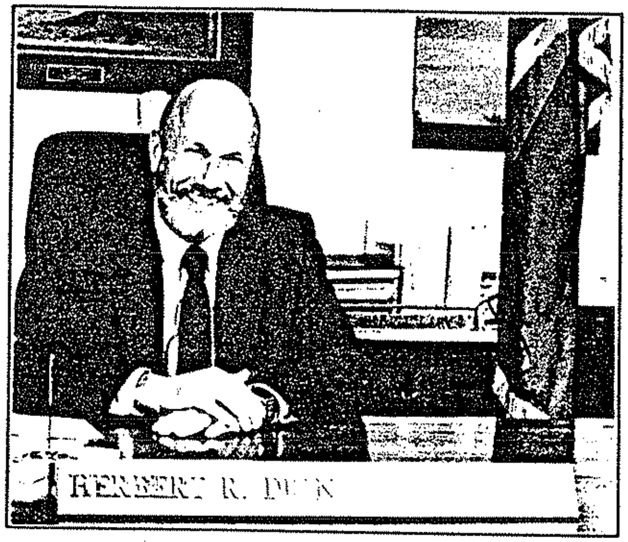
ARIZONANS' RECREATION NEEDS ON FEDERAL LANDS

The Governor's Task Force on Recreation on Federal Lands

Governor Bruce Babbitt

A. #38

Office of the Mayor
(602)994-2433



June 23, 1986

The Honorable Bruce Babbitt
Governor of the State of Arizona
1700 West Washington
Phoenix, Arizona 85007

Dear Governor Babbitt:

Your Task Force on Recreation on Federal Lands has completed its study of recreation management issues in Arizona and has prepared a final report. We had very spirited conversations with good public participation.

In the report we discuss a variety of recreation management issues and propose recommendations for action by state and federal government officials. Arizona is changing from a rural to an urban state with the third fastest growing population in the country. Changing population results in different uses and priorities for natural resources in the state. Recreation has become the single most important use of our federal lands in Arizona.

Providing quality outdoor recreation for Arizona residents and visitors requires major efforts by all the responsible agencies -- both state and federal. Financial and management commitments by responsible agencies are required to meet the growing recreation demand. Recreation lands must be managed to efficiently provide recreation opportunities while protecting the natural environment. Federal agency land planning processes allow the state and public to participate in determining management of federal lands. It is important that we take advantage of these opportunities to influence federal agency land management.

The Task Force members and I enjoyed discussing this critical and fun topic and appreciate your efforts to meet Arizonans' needs while protecting our natural resources.

Governor Babbitt, the members of this Task Force are without a doubt the finest and most competent people that I have ever worked with. It was an honor to serve as chair for you and to work with these wonderful Arizona citizens.

Sincerely,

Mayor Herb Drinkwater
Chairman

3939 CIVIC CENTER PLAZA ■ SCOTTSDALE, ARIZONA 85251

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EXECUTIVE SUMMARY

The news media today call Arizona a mecca for urban growth. Films and poetry romanticize this state as a last sanctuary for cowboys and cactus. Only now is a picture emerging of the true 20th century Arizona: a diverse, complex and in many respects fragile natural environment punctuated by sprawling metropolises, small towns and rural communities. As the 1986 State of the State report to the Legislature puts it, Arizona is a land "enriched...both with natural beauty and individual opportunity."

With Arizona's huge population growth during the last two decades, demand for recreational opportunities on public lands has exploded. But where this increasingly urban-based public can go to spend its leisure time is not so clear. State government actually owns barely one-tenth of Arizona's land. Much of the remainder is in trust to Native Americans or administered outright by the federal government. And there are as many definitions and restrictions on "public" access as there are agencies managing land in Arizona -- from the Defense Department to the U.S. Forest Service.

Six months ago, the Governor's Task Force on Recreation on Federal Lands undertook a comprehensive study of this state-federal relationship. Our objectives were to evaluate the administration of Arizona's lands by federal agencies and make practical recommendations to the Governor for improving the recreational uses of federal lands. For a number of reasons delineated in the report, the Task Force believes that the federal government has fallen short of fulfilling its responsibilities as a landlord.

Arizona has more people and more demand on outdoor resources, but not enough federal attention or money to adapt to these changes. In this time of depleted budgets, we do not ask for higher agency allocations. Rather, the Task Force is calling for new priorities, better tailored to the people and places of this state. Arizona has entered a new era in its history, an era which demands better management of and attention to natural resources.

Here, briefly, are some of the issues and recommendations contained in more detail in the Task Force report:

Declining Federal Role

**"It is clear that the federal government's attention to recreation has not kept pace with increasing demands for recreation...This shortsightedness is a principal reason for why the management of federal lands is increasingly enmeshed in controversy and why there is growing dissatisfaction in Arizona with federal recreation policy." (page 10).

Reallocating Funds From Other Sources

**"The Task Force believes that federal allocations for land management in Arizona are inappropriately biased towards traditional 'commodity' uses of the federal lands, such as timber, mining and grazing." (page 10) "Strict adherence to conventional cost-benefit analysis in setting budget priorities inevitably shortchanges the benefits of recreation, and allowing near-term revenue outputs to guide budgetary decisions is shortsighted, discriminates against recreation, and is ultimately harmful to the national interest."

(page 15) Recommendation: "The federal land managment agencies in Arizona should reexamine their budgetary priorities to better take into account state population trends and the rising demand for recreation." (page 15)

A Trust Fund for Recreational Investments

**"A policy that uses limited, nonrenewable federal assets solely to cover immediate disparities between federal revenues and expenditures is short-sighted, and will leave future generations poorer, both economically and spiritually." (page 15) Recommendation: A federal trust fund should be established using revenues collected from developing nonrenewable natural resources; the fund should further the goals of the Land and Water Conservation Fund.

User Fees

**User fees collected at recreation sites are an alternative to providing more money for recreation. However, the Task Force believes those fees must remain at the site they were collected rather than going into the U.S. Treasury. Recommendation: All resource users should be charged equitable fees for the amount of resource damage their activity causes.

A State Trail System

**"Trails for non-motorized uses are one of the most economical means of providing outdoor recreation. They serve a wide constitutency of users at relatively small unit costs." (page 25) Recommendation: The State should designate and develop a state trails system and urge federal agencies to construct and maintain additional trails on their lands.

Recreational Facilities on Lakes

**The Governor is specifically concerned about the lack of recreation facilities at Lake Roosevelt, a major lake near the Phoenix metropolitan area with very few developed recreation sites. Recommendation: "The Governor should vigorously urge the Forest Service to provide the necessary recreation budget to operate and maintain all the planned recreation facilities at Lake Roosevelt. If Cliff Dam is built, similar budget priority should be given to the needed maintenance funds." (page 31)

State Parks as Gateways for Federal Recreation Areas

**In addition to the federal agencies, the State needs to take responsibility for meeting the growing recreation demand. Recommendation: The Task Force recommends that the State Parks Board direct some of its parks development efforts to locating new parks adjacent to federal lands in order to enhance the access and use of the area.

National Recreation Areas

**"Special designation for recreational and related uses ... give ... more visibility in the planning and budgetary process, as well as in the eye of the general public." (page 42) Several Forest Service areas in the State could qualify for National Recreation Area (NRA) designation which would take management priority over other resource uses. Recommendation: The

Governor should establish a process involving interested parties to develop legislative recommendations for NRA status for those areas qualifying in Arizona.

Wild and Scenic Rivers

**Only one 40-mile segment of river has been designated a Wild and Scenic River under the Wild and Scenic River Act of 1968. Recommendation: "The Governor should press vigorously for congressional designation of all additional qualifying Arizona rivers into the National Wild and Scenic River System and propose legislation to create a state wild and scenic river system." (page 46)

Wilderness

**Wilderness designation issues are near resolution for the Forest Service, but are unresolved for the National Park Service, Bureau of Land Management, and the Fish and Wildlife Service. Recommendation: The Governor should vigorously support prompt congressional designation as wilderness areas of National Wildlife Refuges, National Parks, Bureau of Land Management lands and the remaining areas of Forest Service suitable lands.

Protecting Water for Recreation Uses - Instream Flow Water Rights

**"As competition for water supplies has grown more intense, identification and establishment of water rights has become necessary to provide certainty and stability. It is essential for federal land recreation that those waters supporting significant recreation use be protected." (page 50) Recommendation: "The Governor should order the relevant state agencies, working closely with federal agencies, to thoroughly review all stream systems in the state, to identify and take the necessary steps to provide legal protection for instream flows on water bodies in Arizona that have significant recreational use and potential." (page 51)

Controlling Off-Road Uses of Motorized Vehicles

**"Uncontrolled use of vehicles off established roads on federal lands results in numerous management problems. Motorized and non-motorized use of the same areas are generally incompatible." (page 55) Recommendation: The Task Force recommends that hiking, bicycling and equestrian trails should be restricted from any motorized use, land management agencies should designate areas where off-road use is allowed and close all the remaining lands. Strong enforcement of the designations is needed.

State Input Into the Federal Lands Planning Processes

**All federal agencies with recreational management responsibilities have some obligation to consult with the state government and are required to conduct public management planning processes. The general pattern of Arizona State Government has been to respond to proposals for specific action rather than to seek to exert influence earlier, when plans are being formulated. Recommendation: "The Governor should, by executive order, create a small coordinating office to guide state participation in the federal planning process. An attorney employed by the State should be assigned the responsibility of reviewing legal requirements that the federal agencies must meet and should monitor federal agency compliance with those requirements." (page 65) nowhere near the commitments of government attention or money to adopt to these shifts. The Task Force has studied federal-state land issues from as many angles as members and public respondents could suggest. The following pages contain the Task Force's assessment of important issues along with 68 recommendations for change.

Arizona's People

To appreciate the changes in recreation demand in Arizona, we must grasp the magnitude of our population growth. Arizona is the third fastest growing state in population in the United States. Our population increased 53 percent from 1970 to 1980. All counties experienced population increases in the 1970's, with the increase in the rural counties ranging from 10 to 116 percent.

Maricopa County, with 1.5 million people, and Pima County, with over 500,000 people, increased at 51 and 55 percent, respectively, creating concentrated demand for recreation. (See Figure 3.) Seventy-five percent of Arizona's 1980 population of 2.7 million was located in Maricopa and Pima counties, which contain, respectively, the Phoenix and Tucson metropolitan areas. The remaining 25 percent of the 1980 population was in the rural counties of the state.

Since 1980, Arizona's population has continued its dramatic growth. Between 1980 and 1985 the state added an average of 88,755 people a year, for a total increase in the state's population of 16.7 percent in the five year period. Arizona currently has an estimated 3.3 million residents.

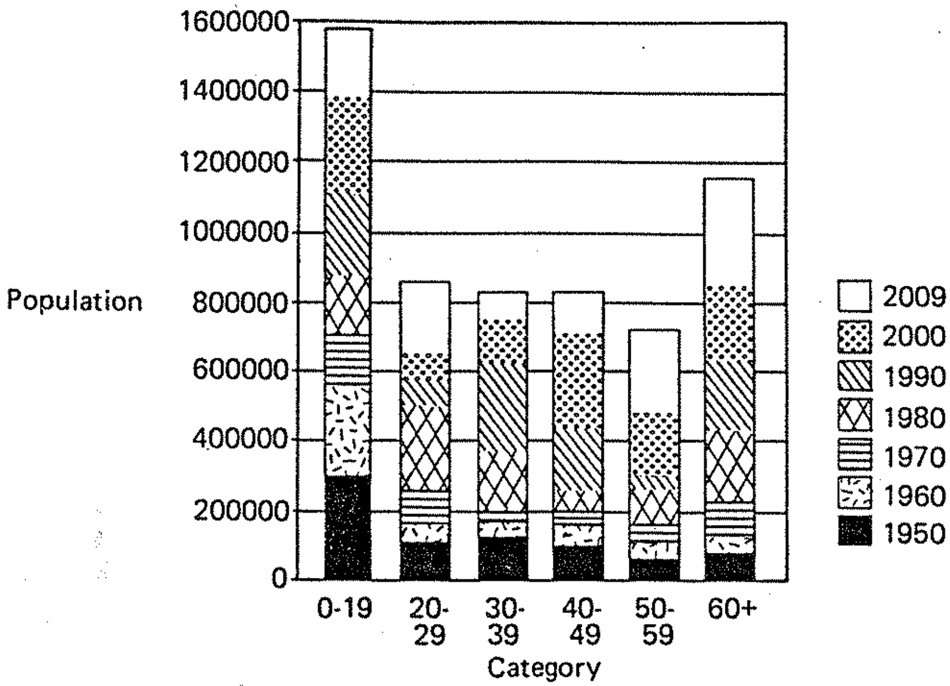
Contrary to widespread impression, Arizona's population is relatively young. The median age was 29.2 years in 1980, somewhat under the national median of 30.0 years. (See Figure 4.)

Recreation on Federal Lands

In addition to its 3.1 million residents, Arizona is visited by about 16.1 million people each year. Together, residents and visitors spent almost 20 million visitor-days participating in recreation activities on National Forests, National Wildlife Refuges, and Bureau of Land Management land. More than 8.8 million people visited Arizona's National Park Service land and state parks in 1984, the latest year for which statistics are available. For 1983 and 1984, the Tonto National Forest northeast of Phoenix had the highest recreation use of any national forest in the country. Two other Arizona national forests, the Coconino and the Coronado, ranked in the top 35 national forests for recreation use.

The Forest Service and National Park Service support most of the recreation use on federal agency lands. However, the agencies use different measures of recreation use, making direct comparison meaningless. The Forest Service had over 16.38 million visitor-days (a 12-hour period equals one visitor-day) in 1984, while the National Park Service counted 6.79 million visitors (staying on site for no specific time period) in 1985. The Bureau of Land Management, Bureau of Reclamation, and U.S. Fish and Wildlife Service have considerably less recreation use than the Forest Service and National Park Service. (See Figure 5.)

FIGURE 4. ARIZONA POPULATION DISTRIBUTION BY AGE



Source: Arizona Department of Economic Security, Population Statistical Unit.

Our public lands support a wide range of recreation activities, from mountain climbing to viewing scenery, snowmobiling to waterskiing, from big game hunting to bird watching. According to surveys conducted in the past decade by the Arizona Outdoor Recreation Coordinating Commission (AORCC) and the State Department of Tourism, almost 20 percent of the state's residents hike or backpack, as do 14 percent of non-resident visitors. Almost 40 percent of Arizona residents own hiking or backpacking equipment. Ninety-six percent of these hikers and backpackers use public facilities, and 94 percent hike in rural areas. Further, almost 10 percent of residents and visitors go horseback riding, comprising an estimated 1.5 million user days annually. Thirty-one percent of Arizona residents and visitors go bicycle riding in the state.

Camping is the most popular recreation activity in Arizona. Day use activities, including picnicking and viewing interpretive sites, is the second most popular activity. Some agencies have higher use in some activities depending on the characteristics of their land. For example, the national forests, with more land at higher elevations, supports far more winter sports activities than the Bureau of Land Management. (See Figure 6.)

<u>Recreation and the Arizona Economy</u>

As Governor Babbitt put it in his 1986 State of the State address: "Our economy is passing from the Old West of copper, cattle and cotton into a New West of technology, trade and tourism - the three T's of modern Arizona."

Recreation and tourism have become inextricably linked in today's Arizona economy. This is not to suggest that the sole or even the most important reason to promote recreational use on federal lands is economic. The Task Force believes recreational opportunities should be protected and enhanced primarily to promote the health and well-being of the state's citizens and its visitors. Nevertheless, the importance of tourism to the economy demonstrates that there are substantial economic benefits to be gained as well.

In 1975 out-of-state visitors spent $1.9 billion in Arizona; state residents brought the total tourist spending to $2.2 billion. This contribution accounted for 15.64 percent of the Gross State Product, and was greater than the mining and agriculture contributions combined. Only trade and government accounted for a larger percentage of the Gross State Product than tourism.

FIGURE 5. TOTAL RECREATION USE ON PUBLIC LANDS IN ARIZONA

Agency	1970	1980	1984
(in thousands of visitor-days)			
Forest Service	7,938	17,753*	16,382+
Bureau of Land Management	1,600	2,800	3,100
U.S. Fish & Wildlife Service	485 (1973)	NA	478
(in thousands of visitors)			
National Park Service	6,538 (1971)	7,135	6,793 (1985)
Arizona State Parks	1,195	1,843	2,021 (1985)

Source: Each managing agency

*Apache-Sitgreaves National Forest not available.
+Decrease due to U.S.F.S. altered method of counting visitor-days.

FIGURE 6. RECREATON USE BY ACTIVITY ON PUBLIC LANDS IN ARIZONA IN 1984

(In Thousands of Visitor-Days)

Activity	Agency U.S.F.S.	B.L.M.	State Parks (in Thousands of Visitors)
Camping	3,776	909	256
Hiking	928	47	NA
O.R.V.'s	352	90	NA
Hunting	592	218	NA
Fishing	581	9	NA
Boating	615	11	NA
Winter Sports	154	1	NA
Miscellaneous Day Use	2,003	161	NA
Other			304

Source:
Each managing agency

Wild and Scenic Rivers

The Wild and Scenic Rivers Act of 1968 protects designated river segments from overdevelopment and emphasizes recreation and related uses. Federal agencies have been directed to study rivers under their jurisdiction for possible protection under wild, scenic or recreational designations by Congress. Designated rivers can act as a magnet for recreation use as well as improve agency authority to manage for recreational values.

The only component of the federal Wild and Scenic River System in Arizona is a 39.5 mile segment of the Verde River between Camp Verde and Horseshoe Dam, designated in 1984. Many other stretches of streams in Arizona qualify under the Act, including portions of the Upper Verde and the East Verde, the San Francisco, portions of the Gila River, including a spectacular segment through the Gila Box, and a 22 mile segment of the upper Salt River in the Tonto National Forest. (See Figure 16.)

Generally, federal agencies and the Administration have been slow to formulate recommendations for additions to the system, although the Forest Service has recommended the upper Salt for inclusion.

The Wild and Scenic Rivers Act also allows states to designate and protect rivers as wild, scenic or recreational under state law. If state law supplies such protection, the Governor may petition the Secretary of the Interior to incorporate the state rivers in the federal system, without the need for congressional action. Arizona has no state wild and scenic river system to date.

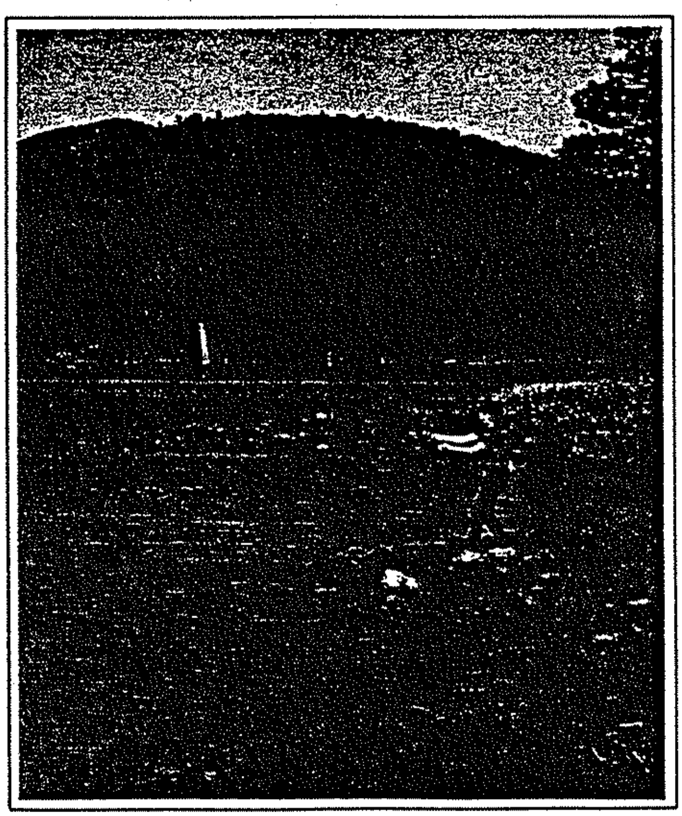
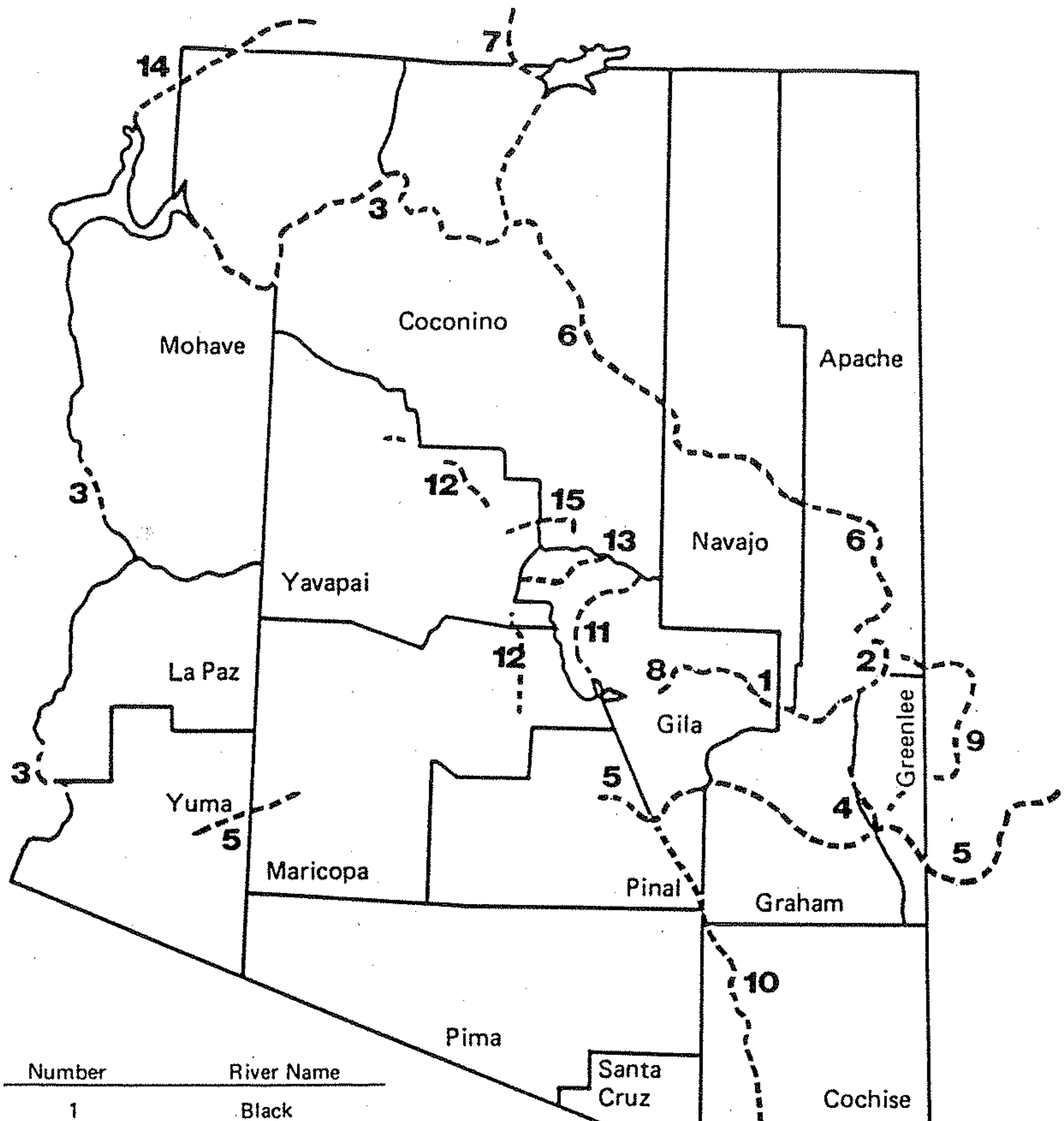


FIGURE 16. INVENTORY OF POTENTIAL WILD AND SCENIC RIVERS



Number	River Name
1	Black
2	East Fork Black
3	Colorado
4	Eagle Creek
5	Gila
6	Little Colorado
7	Paria
8	Salt
9	San Francisco
10	San Pedro
11	Tonto Creek
12	Verde
13	East Verde
14	Virgin
15	West Clear Creek

Source: U.S.D.I. Heritage Conservation and Recreation Service, Nationwide Rivers Inventory Phase I, 1980

(35) The Governor should vigorously pursue his own wilderness proposal for the Bureau of Land Management lands in Arizona. The state should also oppose any actions in these candidate areas that would impair their wilderness suitability until Congress acts.

(36) The Governor should vigorously support wilderness designation for all qualifying areas within Lake Mead National Recreation Area and Grand Canyon National Park.

(37) The Governor should vigorously support wilderness designation for the three wilderness study areas on the Coronado National Forest (Mount Graham, Whitmire Canyon and Bunk Robinson), the Blue Range Primitive Area and contiguous qualifying lands. The proposed telescope site on Mount Graham should be considered for wilderness designation.

Areas of Critical Environmental Concern

The Bureau of Land Management has authority to designate (and indeed is directed by statute to give priority to) Areas of Critical Environmental Concern (ACECs). These are areas that should receive special management attention to protect and prevent irreparable damage to important historic, cultural, or scenic values, fish or wildlife resources. To date, there are no designated ACECs in Arizona.

Recommendation:

(38) The Governor should establish a committee of concerned citizens and state agency personnel to study and identify areas that qualify for ACECs. The Governor should then vigorously pursue designation of these areas by the Bureau of Land Management.

Natural Riparian Areas -- A Fragile and Threatened Recreational Resource

Riparian areas were of course never abundant in Arizona. Since the first permanent non-Indian settlements, however, the number and quality of these areas have been reduced by an estimated 85 percent by urban and agricultural development, water diversions, channelization, pumping of groundwater connected to surface streams, pollution, and the like. Today, riparian areas and associated wetlands are among Arizona's rarest and most threatened natural systems.

Besides their many recreational uses, riparian areas also have important roles to play in easing the effects of floods and facilitating groundwater recharge. Riparian areas are always special ecological and recreational treasures, but nowhere more than in an arid state like Arizona.

Protecting Water for Recreational Uses -- Instream Flow Water Rights

Protection of stream and lake waters for recreational use may be achieved under both federal law as it applies to federal land management, and state law which has traditionally governed water allocations for most uses.

As competition for water supplies has grown more intense, identification and establishment of water rights has become necessary to provide certainty and stability. As a consequence, the state is in the early stage of a massive undertaking to adjudicate all rights to the waters of most major stream systems in the state. It is essential for federal land recreation that those waters supporting significant recreation use, which may include springs, waterholes, lakes and streams, be protected as part of this process. The most important, and generally most controversial, will be securing so-called "instream flow" rights in streams -- to gain legal protection for water in a free-flowing condition in areas of significant water-related recreation use.

Arizona state water law explicitly allows the establishment of water rights for recreational, fish and wildlife uses. Federal law also provides a basis, with respect to at least some federal land categories, for recognizing such water rights.

other state agencies should vigorously oppose any legislation that would seriously weaken protection in existing state law for recreational stream flows.

Protecting Surface Streams From Depletion by Groundwater Pumping

Groundwater pumping remains essentially unregulated in many rural areas of the state, i.e. those outside the so-called "active management areas" designated by the Groundwater Management Act of 1980. In some instances this pumping threatens to dry up surface streams, with attendant adverse effects on riparian recreational uses. Both state and federal law provide some tools to protect surface flows from such groundwater pumping. But very little has been done in law or in practice to recognize the hydrologic connection that often exists between groundwater pumping and surface water.

Recommendations:

(40) The Governor and the relevant state agencies, including Departments of Water Resources and Game and Fish, should take all steps necessary, including working closely with relevant federal agencies, to document connections between the extraction of groundwater and surface water uses.

(41) Where recreational uses are threatened, all agencies, state and federal, should use existing legal authorities (or, if necessary, seek additional authority) to ensure that surface water important to recreation is not depleted by unregulated or poorly regulated pumping of hydrologically related groundwater.

Streambed Ownership and Recreation

Ownership of the beds of waterbodies like streams and lakes (referred to here simply as streams) is becoming a subject of considerable controversy in Arizona. Under federal law, title to the beds of streams that were navigable when Arizona became a state in 1912 automatically passed to the state of Arizona as sovereign lands unless they had been previously reserved by the federal government or conveyed out of federal ownership. But no streams in Arizona other than the Colorado River have ever been subject to a legal determination of whether they were navigable at statehood.

Navigability has been defined quite expansively under federal law; e.g., the fact that a stream had intermittent flows or was not actually used as a highway for commerce does not by itself prove a stream was not navigable. Moreover, this test must be applied as of the date of statehood; current conditions on these streams do not take precedence. Finally, the courts have generally held that in order to defeat state claims to the beds of rivers shown to have been navigable at statehood, the federal government must prove a specific intention to have reserved or conveyed the beds of such streams; a general reservation or conveyance of the land surrounding the stream is usually not enough.

The upshot of this and other legal doctrines in this complicated interplay is that the state of Arizona has a credible claim of title to the beds of several streams in the state, including some in areas that have significant recreational use or potential.

The State Land Department manages river bottom lands that are determined to belong to the state. Under state law, such lands might be conveyed to other public agencies for park and recreation use at no cost. Several key riparian sites along the Colorado River are in the State's inventory.

Recommendations:

(42) When title to stream beds with significant recreational use or benefit is at stake, the state ought to vigorously press to have its ownership interest established, and should waive its ownership claims or convey its legal interest in the beds only under circumstances that assure full protection for recreational use of the streams. This protection should include guaranteeing access to the streams; securing needed water rights; and regulating uses of the stream beds, such as mining, that may conflict with recreational uses.

(43) State parks should be considered for creation on the state's sovereign land in the Colorado River corridor, using land transferred by the State Land Department.

The Public Trust Doctrine

Courts in several states, including California, Idaho and Montana, have enforced this doctrine in connection with state natural resource management programs. The doctrine has ancient roots, and sprang from the concept of "common heritage" resources, that certain governmental property interests -- such as the beds of navigable waterbodies, or beach fronts -- are so important that they cannot be alienated from public ownership and control except under extreme circumstances where the benefit to the public clearly outweighs continued government supervision. California courts, for example, have vigorously applied this doctrine to ensure public access to beaches and to restrict uses of property with high public recreational benefits in order to safeguard recreation. The Arizona courts have not yet finally determined whether this doctrine will be applied here, although the Attorney General, citing the California experience, recently expressed his opinion that the doctrine does constrain land management in Arizona.

A closely related legal doctrine enables states to protect recreational interests in streams and other waterbodies through application of a state law concept of navigability. That is, even if a stream was not navigable at statehood under federal law (and thus the federal government retained title) the state may still apply its own, more liberal definition of navigability, and protect recreational interests in those streams. The courts in California, Montana, and numerous other states have adopted a liberal test of navigability under state law and have used it to protect streams and other waterbodies. In Arizona the matter has not been decided by the courts.

Experience in these other states has shown that the public trust doctrine and the use of the navigability doctrine under state law are useful tools to protect recreational access to, and use of, waterbodies. Because of the importance and heavy recreational use of waterbodies in the arid state of Arizona, such doctrines are particularly appropriate to apply in this state.

Recommendation:

(44) The State of Arizona, by its officers and agencies having responsibility in this area, should take all necessary steps to apply the public trust and state navigability doctrines in appropriate cases, and should urge the State courts to enforce these doctrines to promote and protect recreational uses of waterbodies.

Protecting Recreational Opportunities Through Regulation

A complicated web of federal environmental laws and regulations is now in place that aims to control air and water pollution. A parallel set of existing laws and regulations provide ample legal authority for protecting recreation on federal lands against undue or unnecessary interference by other uses of these lands. In some cases the federal agencies have not done a satisfactory job in enforcing these regulations, or have otherwise failed to take sufficient account of recreation in regulatory decisionmaking. This section identifies important shortcomings in this area.

Controlling Off-Road Uses of Motorized Vehicles

Uncontrolled use of vehicles off established roads results in numerous management problems. Environmental damage caused by off-road driving on the arid terrain and in other fragile zones has been well-documented and is often permanent. Wildlife is disrupted, vegetation destroyed, erosion increases, and air quality suffers. All these impacts have adverse effects on other people outdoors.

Moreover, safety and liability issues plague land managing agencies. Unlicensed use and increased popularity of three-wheeled all-terrain motor vehicles has resulted in substantial increase in accidents. Injuries include broken necks and limbs. Lawsuits have sought to assign responsibility for such injuries to government agencies on the theory that they have opened their lands to such use without adequate supervision, control, or warnings of danger.

Motorized and non-motorized use of the same areas are generally incompatible. Vehicles used off the road may disrupt the quiet that is important to many hikers or horseback riders. In addition, the safety of both groups is endangered when motorized and non-motorized users are on the same trails.

The Task Force recognizes that many off-road vehicle (ORV) users are sincerely interested in protecting the resources they use, that they generally obey what restrictions exist, and that they are usually conscientious about trying to avoid interference with other uses. The

II. Water Supply in the TAMA

Present Supplies

Groundwater satisfies nearly one hundred percent of the water demand in the Tucson Active Management Area. In 1980 approximately 313,000 acre-feet were depleted by users in the basin while natural recharge to the groundwater reservoir totalled about 75,000 acre-feet. Consequently, about 238,000 acre-feet were removed or "mined" from the groundwater reservoir. The occurrence of such "mining" over the past 40 years has produced groundwater level declines of over 180 feet in several parts of the basin.

Surface water from streamflow in the basin is highly variable and the major streams are dry more than 300 days a year. Annual flows leaving the basin via the Santa Cruz River channel average 17,000 acre-feet.[1] In 1965 the outflow was measured at only 907 acre-feet, while in 1979 it was over 77,000 acre-feet. The infrequent and erratic nature of flows has precluded the development of a surface supply. With the exception of stock ponds and some small lakes for recreation or wildlife purposes, no surface water supplies have been established.

Projected Supplies

Central Arizona Project and Natural Recharge

	1990	2000	2010	2020	2025
CAP	113,000	134,000	163,000	196,000	215,000
Natural Recharge	75,000	75,000	75,000	75,000	75,000
TOTAL	188,000	209,000	238,000	271,000	290,000

Upon completion of the delivery system to Pima County, the Central Arizona Project will provide a major dependable water supply for the Tucson Active Management Area. In conjunction with the renewable supply from natural recharge, Tucson Active Management Area projections for dependable supplies are summarized in the preceding chart. The projections represent the quantity of water allocated to municipal and industrial users and the Papago Tribe for 1985 through 2034. A further discussion of CAP allocations and dependability is presented in Section IV.

Although natural recharge is shown as a constant of 75,000 acre-feet per year, it is in reality a dynamic component of the water budget. The primary areas of recharge are along the mountain fronts and in the stream channels. Streamflow is considered the major source in the Tucson Active Management Area. Actual recharge may range from less than forty to as much as ninety percent of the flood flows in the stream channels, depending upon the magnitude, duration, and intensity of the flow events. Other factors which affect the volume of natural recharge are land use, vegetative cover, alteration of stream channels, surface water diversions, and aquifer storage capacity.

[1] United States Geological Survey, Water Supply Paper 1930-E, 1973.

8

Feasibility Study Report

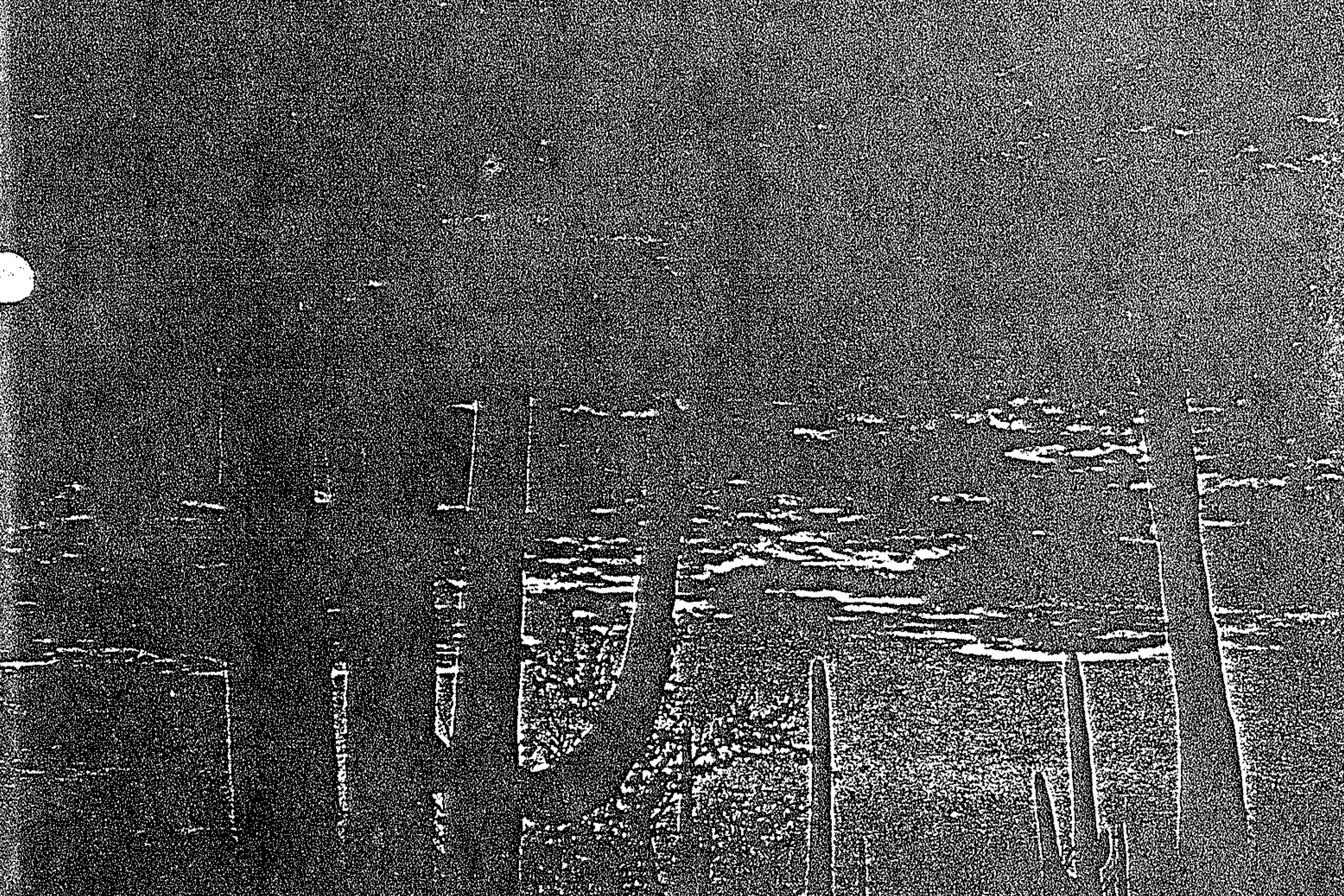
RIVERBED RECHARGE PROJECT

EXECUTIVE SUMMARY

Prepared for

ARIZONA MUNICIPAL WATER USERS ASSOCIATION

Chandler	Glendale	Mesa	Phoenix
Scottsdale	Tempe	Peoria	Goodyear



CAMP DRESSER & McKEE, INC.

AND

W.R. MILLS & ASSOCIATES

August 1986

A. #40

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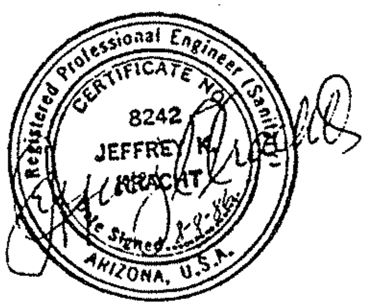
Feasibility Study Report

RIVERBED RECHARGE PROJECT



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INTRODUCTION

Artificial recharge involves releasing water over the ground surface and allowing it to infiltrate into the ground and percolate to the subsurface aquifers. Spreading methods include flooding, ditch and furrow, irrigation, natural channel, shallow spreading basins, and deep basin or pit techniques. In addition, artificial recharge may also be accomplished by using injection wells or shallow basins augmented by shafts or recharge wells. Currently, the most commonly used methods for artificial recharge are shallow spreading basins and deep basins or pits.

The purpose of this feasibility study report was to determine possible sites to be developed for artificial recharge activities of Central Arizona Project Water (CAP) into the Salt River Basin regional aquifer. The review identified a total of thirteen riverbed areas in which CAP water could potentially be recharged. The thirteen potential sites were screened to ten sites which were evaluated in depth during the investigation. Preliminary designs were then developed for two sites.

BACKGROUND

Beginning in 1986, Colorado River water will be transported via the Central Arizona Project (CAP) to CAP subcontractors in Maricopa County. At the present time, the CAP delivery capacity exceeds the water demands which may be placed on the system by CAP water users, particularly in the early years of CAP operation. Because surplus water is available, early delivery and storage of water will enhance future conjunctive management of present and future water supplies. In the Phoenix Active Management Area (AMA), significant amounts of water can be stored for later use by recharging the alluvial groundwater basins that underlie the greater Phoenix Metropolitan area.

Siting constraints established for the riverbed recharge study narrowed potential sites to river channel areas within the 100-year floodplain. In addition, recharge methods are required which will quickly transmit and store large quantities of water in the underground. The specific areas considered included the river channel areas downstream of the CAP Granite Reef/Salt-Gila Aqueducts consisting of the: 1) Agua Fria River to Grand Avenue, 2) New River to the Agua Fria River, 3) Skunk Creek to the New River, 4) Cave Creek to the Arizona Canal, 5) Indian Bend Wash to the Salt River, 6) Salt River from the Granite Reef Dam to Tempe Buttes, and 7) Queen Creek to the Roosevelt Canal. The location of each river system in the study area is shown on Figure 1. The objective of the AMWUA Riverbed Recharge Study was to identify and evaluate the recharge and storage capabilities for each of the river segments which are adjacent to, and downstream of, the Granite Reef or Salt-Gila Aqueducts.

RECHARGE SITE IDENTIFICATION AND EVALUATION

Recent aerial photographs (1985) of drainage courses were reviewed to locate undeveloped lands within the study areas and near the Central Arizona Project or other major water conveyance facilities which are connected to the CAP, such as the Arizona Canal. The review identified a total of thirteen riverbed areas in which CAP water could potentially be recharged. The thirteen potential sites were later screened to the ten sites which were evaluated in-depth during the investigation.

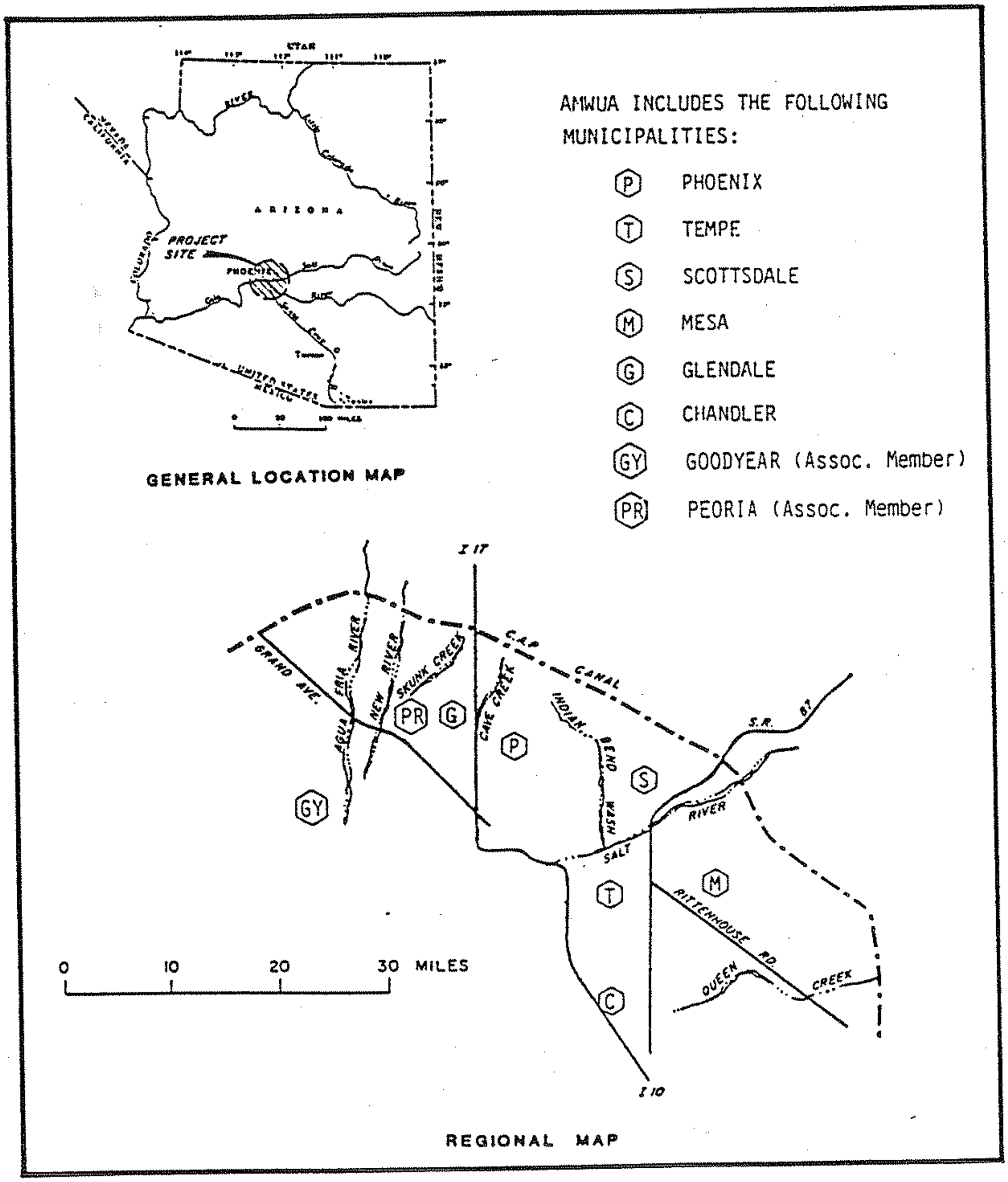
Each of the ten potential recharge sites were evaluated with regard to the following criteria, based upon existing data:

- Infiltration rates
- Mounding potential
- Available storage capacity
- Groundwater quality
- Perched water table conditions
- Proximity to residential neighborhoods
- Proximity to landfills and waste disposal sites
- Environmental factors
- Land Ownership

FIGURE 1

LOCATION OF AMWUA RIVERBED RECHARGE PROJECT

Feasibility Study Report -- AMWUA Riverbed Recharge Project



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A qualitative rating system, using the above criteria, was used to select suitable alternative recharge sites. To complete the ranking process, conceptual designs were developed for each of the ten sites so that site development costs could be factored into the rankings. The conceptual designs were prepared with considerations for public land availability, recharge water availability, and the recharge characteristics of each site. The location and relative technical merits of each site area are summarized in the following paragraphs. A summary of physical characteristics for the potential recharge sites is presented in Table 1.

Agua Fria River

Of the river systems investigated, the Agua Fria River area is one of the most suitable areas for artificial recharge from a technical standpoint. The floodplain is wide with substantial amounts of publicly-owned, undeveloped land. CAP water can be supplied to the recharge areas either directly from the Granite Reef Aqueduct or through the Beardsley Canal. The best section of the Agua Fria River area for recharge lies between Jomax Road and Grand Avenue. However, because the recharge potential in this reach of the river is so much greater than the amount of CAP water potentially available (estimated to range from 50,000 to 400,000 acre-feet per year [ac-ft/yr] in the near term), it will fully percolate by the time it gets to Deer Valley Road, located about three miles south of Jomax Road. Up to 400,000 ac-ft/yr could be available through 1992, with half of this amount being available for the West Salt River Valley and half for the East Salt River Valley.

Based on the selection criteria, groundwater mounding may be a problem. Groundwater mounding occurs when the groundwater table beneath the recharge operation rises to the ground surface, thus reducing the recharge rate. The potential for mounding can be verified with exploratory drilling in the area under consideration. However, mounding can be controlled operationally by rotating recharge operations from one area of the facility to another, thus allowing the groundwater mound time to dissipate.

The conceptual design for the Agua Fria River recharge facilities consists

TABLE 1

SUMMARY OF PHYSICAL CHARACTERISTICS FOR POTENTIAL RECHARGE AREAS IN THE AMWUA RIVERBED RECHARGE STUDY

Feasibility Study Report - AMWUA Riverbed Recharge Project

LOCATION	DEPTH TO WATER (a) (feet)		INFILTRATION RATE (ft/day)		TRANSMISSIVITY (kgpd/ft)		SPECIFIC YIELD		STORAGE CAPACITY (af/ac) (b)	AREA FOR POTENTIAL RECHARGE (ac)	PRESENCE OF PERCHING ZONE	WATER QUALITY PROBLEMS
	RANGE /	MEAN (c)	RANGE /	MEAN (c)	RANGE /	MEAN (c)	RANGE /	MEAN (c)				
Agua Fria	100-350	280	2.1-3.8	3.2	5-80	35	.05-.10	.09	25.2	2,150	2 mi. southwest & downgradient	F elevated 4 mi. SW TCE 3 mi. S
New River	250-500	450	1.2-3.2	2.5	25-200	60	.07-.12	.09	40.0	495	possible	DBCF in southern portion
Skunk Creek	480-530	500	0.2-0.3	0.3	10-75	64	.10-.15	.10	50.0	520	possible	High NO3 1 mi. upgradient
Upper Cave Creek	270-300	275	0.1-2.1	1.8	10-30	14	.07-.10	.10	27.5	240	possible	Data deficiences
Lower Cave Creek	400	400	1.8-3.0	2.3	10	10	.05-.10	.07	28.0	400	possible	TCE .5-1.0 mi. S.
Upper Indian Bend Wash	300-440	430	0.3	0.3	5-15	11	.05-.10	.09	38.7	1,430	possible	Elevated Cr does not exceed standards
Lower Indian Bend Wash	340-400	340	.25	.25	20-100	40	.03-.05	.05	17.0	90	yes	High Cr 1 mi. east
Upper Salt River	310	310	1.9	1.9	70-110	81	.07-.10	.08	24.8	810	possible	TCE, DBCP, F & Cl .5-1.0 mi. downgradient
Lower Salt River	160-320	315	1.9-2.5	2.5	20-100	56	.05-.10	.09	28.4	2,550	yes	TCE, DBCP, high Cl downgradient
Queen Creek	430-480	460	2.1-3.2	2.7	60-150	111	.03-.12	.10	46.0	755	possible	Elevated NO3, Cl

a Based on 50% wet-dry application cycle.
b Groundwater stored above the water table.
c Area weighted; considered representative for recharge site.

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of about 610 acres of in-channel "T" levee basins and about 515 acres of off-channel shallow basins. CAP water would be delivered at the Granite Reef Aqueduct turnout into the Beardsley Canal, and then released into spreading facilities near Jomax Road from the Beardsley Canal. This system would have a recharge capacity of about 415,000 ac-ft/yr. The Beardsley Canal is owned and operated by the Maricopa Water District, and it would be necessary to negotiate an agreement to use the canal for a recharge project.

New River

The area under investigation along the New River is located about 1.5 miles south of the Granite Reef Aqueduct, just below the Upper New River Dam. To avoid percolating water into a small, hydraulically isolated groundwater basin located adjacent to the aqueduct, water diverted from the CAP would have to be transported in a lined canal to the recharge area.

Using the selection criteria, several items were identified which are potential drawbacks to establishing a recharge facility on the New River. These include the need to build an expensive conveyance system between the aqueduct and the recharge basins; the existence of poor quality groundwater beneath, and downstream of, the site; the proximity of residential development; and, the presence of privately-owned, undeveloped land which would have to be purchased or leased to build the recharge facilities.

The conceptual design for the New River recharge facilities consists of about 515 acres of in-channel "T" levees which derive their water from the Granite Reef Aqueduct via a new trapezoidal, concrete-lined channel. This facility would have a recharge capacity of about 225,000 ac-ft/yr.

Skunk Creek

The area best suited for recharge facilities along Skunk Creek is behind Skunk Creek Dam, located near Deer Valley Road and 35th Avenue, approximately 3.5 miles south of the Granite Reef Aqueduct. Because the facility would be located behind a flood control structure, the 520 acres of recharge basins would be subject to periodic inundation by flood waters.

The selected site has several drawbacks related to its development as a recharge facility. Because of its distance from the aqueduct and the presence of a landfill upstream of the proposed facility, a lined conveyance channel would have to be constructed to deliver CAP water to the recharge basins. Over half of the site area is privately owned and residential development is located within one-half mile of the site. Also, environmentally sensitive areas exist near the site. Finally, quality of groundwater beneath the site may be a problem because of the extensive agricultural activity that historically surrounded the site area. However, one of the major advantages of the site is the fact that it is located in an area of considerable historic groundwater overdraft, therefore, recharging this particular area would have very positive water management implications.

The conceptual design for the Skunk Creek recharge facilities calls for 30 to 40 permanent, off-stream shallow basins, each approximately one acre in size. Water would be delivered to the basins via a 19,000-foot concrete-lined trapezoidal channel. The system would have a recharge capacity of about 40,000 ac-ft/yr.

Cave Creek

Two sites close to one another are located along Cave Creek. The first is located between Deer Valley Road and Union Hills Drive, while the second site is located between Bell Road and Greenway. These sites are located about 1.5 miles south of the Granite Reef Aqueduct.

The sites have some fundamental problems as recharge sites. First, a conveyance facility will be needed to carry water around a landfill located between the aqueduct and the recharge basins. Groundwater quality may be a problem downstream of the basins because of elevated concentrations of nitrates and volatile organic chemicals. Finally, residential zoning and other privately owned land is present.

The conceptual design for the Cave Creek recharge facilities consists of a combination of in-channel and off-channel basins, covering an area of 140 and 495 acres, respectively. Water would be delivered from the aqueduct by way of a 10,000-foot concrete-lined, trapezoidal channel. The recharge capacity of the combined facilities would be about 250,000 ac-ft/yr.

Indian Bend Wash

Most of the lands along Indian Bend Wash are already developed. However, two areas were identified for evaluation. The first site is located adjacent to the Granite Reef Aqueduct. The second potential site is located in the stream channel between Indian Bend Road and McDonald Drive, just south of the Arizona Canal. At the upper (or northern) site, CAP water would be diverted directly into the recharge basins. At the lower (or southern) site, CAP water would have to be delivered via the Arizona Canal.

The upper site is not well-suited for development of recharge facilities. Drawbacks include low infiltration rates, privately owned land and residential zoning, and possible groundwater quality problems. The lower site is not particularly suited to large-scale recharge activities. It is relatively small, underlying groundwater quality in the area is poor, and the site is very close to residential development.

The conceptual design for the upper site calls for about 40 shallow basins, each having an area of 30 to 40 acres. This facility could recharge about 105,000 ac-ft/yr.

The conceptual design for the lower site, Indian Bend Wash, calls for an in-stream "T" levee system covering an area of about 90 acres. CAP water would be diverted into the Arizona Canal at the Granite Reef Dam and conveyed to the site. The facility could recharge about 5,000 ac-ft/yr.

Salt River

The Salt River area appears to have excellent potential as a major recharge site for CAP water. Two major areas were identified along the Salt River for investigation. These two areas are adjacent to each other, and would be developed in a similar manner. For this reason, the two sites were combined to make one large site. CAP water would be delivered to the site from a turnout at the Granite Reef Dam, or out of the Southern Canal, west of Granite Reef Dam. Like the Agua Fria River recharge facilities, more land is available on the Salt River than is needed to recharge the estimated available 200,000 ac-ft/yr of recharge water, therefore, facilities can be expanded to accept additional available recharge water.

Overall, the Salt River is highly feasible for recharging CAP water. The site is near the CAP, it is a very large area, required land is publicly owned, and recharge characteristics are good. The only potential drawback for this area is the presence of poor quality groundwater downgradient of the facilities.

The conceptual design for the Salt River recharge facilities calls for both in-stream and off-stream basins, covering an area of about 1,170 acres. These basins would have a total recharge capacity of about 430,000 ac-ft/yr.

Queen Creek

The Queen Creek recharge facilities would be located immediately west of the Salt-Gila Aqueduct, covering an area of about 755 acres. The site appears to be excellent because it covers a large area with high recharge potential, is free from residential and environmental problems, and is near the CAP. Two significant problems with the site are that the land is almost entirely privately owned, and there is a potential for perched water conditions beneath the site.

The conceptual design for the Queen Creek facility consists of in-stream "T" levees. The recharge capacity of the facility would be about 385,000 ac-ft/yr.

LAND COSTS

AMWUA has investigated the cost to purchase privately owned, undeveloped for investigation. These two areas are adjacent to each other, and would be developed in a similar manner. For this reason, the two sites were combined to make one large site. CAP water would be delivered to the site from a turnout at the Granite Reef Dam, or out of the Southern Canal, west of Granite Reef Dam. Like the Agua Fria River recharge facilities, more land is available on the Salt River than is needed to recharge the estimated available 200,000 ac-ft/yr of recharge water, therefore, facilities can be expanded to accept additional available recharge water.

Overall, the Salt River is highly feasible for recharging CAP water. The site is near the CAP, it is a very large area, required land is publicly owned, and recharge characteristics are good. The only potential drawback for this area is the presence of poor quality groundwater downgradient of the facilities.

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The conceptual design for the Queen Creek facility consists of in-stream "T" levees. The recharge capacity of the facility would be about 385,000 ac-ft/yr.

LAND COSTS

AMWUA has investigated the cost to purchase privately owned, undeveloped land for use as recharge sites. The estimated land costs for the river systems ranged between $1,000 per acre along Queen Creek and $30,000 per acre along Indian Bend Wash. Because surface spreading operations are land-intensive, use of privately owned land purchased at these prices would constitute a major capital expense. For example, land for the Upper Indian Bend Wash facility, which covers about 1,430 acres would cost over $40 million, which is over ten times the estimated cost of actual recharge facilities.

SITE COMPARISONS AND RANKING

The physical characteristics for each of the ten potential recharge sites is summarized in Table 1. The physical characteristics for each site was evalauted relative to the other sites. From the evaluation, the sites were ranked on a technical basis relative to one another. Table 2 presents the relative technical ranking of the sites and indicates that the Agua Fria River, Salt River, and Queen Creek sites are most feasible, based on technical merit.

Table 3 summarizes the adjusted recharge rate used for the conceptual design, as well as the annualized capital and operation and maintenance (O&M) costs for each site. O&M costs are assumed to be constant, based on the O&M costs incurred by similar facilities in southern California. The total annualized costs shown in the last column of Table 3 provides a unit cost comparison of the recharge sites. From a unit cost standpoint, the Agua Fria River, Salt River, and Queen Creek sites are the most feasible, with annualized capital costs of less than 30 cents per acre-foot of recharge capacity for in-stream facilities.

FINAL SITE SELECTION

All ten sites evaluated during the screening process can be used to recharge CAP water. None of the sites appeared to have a technical "fatal flaw." With the exception of the Skunk Creek facilities, the difference in cost for constructing, operating, and maintaining any site was insufficient justification to eliminate that site. At the Skunk Creek site, low infiltration rates (thus the cost per acre-foot of water recharged) make the development of recharge facilities relatively expensive.

Although development of each of the sites evaluated is feasible, some sites were better than others. Considering that one of the primary objectives of the program is to recharge large quantities of water, in a short period of time, in the near future, in-channel facilities would be best for rapid development, provided that the sites are located on public

TABLE 2

RECHARGE SITE RANKING

Feasibility Study Report -- AMWUA Riverbed Recharge Project

	ADVANTAGES				DISADVANTAGES					
	Large Facility	Near Supply Source	Public Lands Available	Receiving Water Quality Good	Private Lands Required	Conveyance Facility Needed	Known Perched Water Conditions	Small Facility	Receiving Water Quality Problems	Comments
MOST FEASIBLE										
1. Aqua Fria (Middle)	●	●	●	●						
2. Salt River (Upper)	●	●	●						●	DBCP
3. Salt River (Lower)	●	●	●				◐		●	DBCP
4. Queen Creek	●	●		◐	●				◐	NO_3
FEASIBLE WITH MAJOR DRAWBACKS										
5. Skunk Creek	●				◐	●			◐	NO_3 and landfill
6. New River (Lower)	●				●	●			●	DBCP
7. Cave Creek (Upper)	●				●	●			●	VOC
8. Cave Creek (Lower)	●				●	●			◐	landfill
LEAST FEASIBLE										
9. Upper Indian Bend	●	●			●				●	Cr^{+6}
10. Lower Indian Bend		●			●		●	●		

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LEGEND

● Applies

◐ Partially Applies

land and that conveyance facilities are not required. The Agua Fria and Salt River sites best meet this criterion. Together, the in-stream recharge facilities on the Agua Fria and Salt Rivers have a maximum potential recharge capacity of 54,000 ac-tf/yr. Based on the evaluation and final screening presented, preliminary designs were prepared for in-channel facilities on the Aqua Fria and Salt River sites.

TABLE 3

ANNUALIZED CAPITAL AND O&M COSTS FOR CONCEPTUAL DESIGNS

Feasibility Study Report -- AMWUA Riverbed Recharge Project

RECHARGE SITE	RECHARGE RATE (kaf/yr)	CAPITAL COST ($ x 1000)		ANNUAL COST ($/AF)		
		TOTAL	ANNUALIZED	CAPITAL	O & M	TOTAL
AGUA FRIA RIVER						
In-Stream Facilities	225	561	53	0.23	4.00	4.23
Off-Stream Facilities	190	1,795	168	0.89	4.00	4.89
NEW RIVER						
In-Stream Facilities	225	4,921	461	2.05	4.00	6.05
SKUNK CREEK						
Off-Stream Facilities	40	6,781	635	15.88	4.00	19.88
UPPER CAVE CREEK						
In-Stream Facilities	15	756	71	4.73	4.00	8.73
Off-Stream Facilities	60	2,588	242	4.04	4.00	8.04
LOWER CAVE CREEK						
In-Stream Facilities	40	888	83	2.08	4.00	6.08
Off-Stream Facilities	135	2,950	276	2.05	4.00	6.05
UPPER INDIAN BEND WASH						
Off-Stream Facilities	105	2,999	281	2.68	4.00	6.68
LOWER INDIAN BEND WASH						
In-Stream Facilities	5	118	11	2.21	4.00	6.21
UPPER SALT RIVER						
In-Stream Facilities	110	343	32	0.29	4.00	4.29
LOWER SALT RIVER						
In-Stream Facilities	205	461	43	0.21	4.00	4.21
Off-Stream Facilities	115	1,008	94	0.82	4.00	4.82
QUEEN CREEK						
In-Stream Facilities	385	906	85	0.22	4.00	4.22

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NOTES: 1. Capital costs are exclusive of land acquisition costs.
2. Capital costs amortized at 8% over 25 years.
3. The O&M costs are exclusive of the purchase of CAP water.

PRELIMINARY DESIGNS

General Design Considerations

As the recharge site evaluation progressed from the conceptual to preliminary design phase, the focus of the study changed from a general overview, to a more detailed consideration of the selected sites. The conceptual designs for ten recharge systems were formulated as described earlier. The sites were configured to make reasonable use of available vacant lands within each study area, without regard to land ownership. The recharge area for each system was, in general, limited to vacant lands within the floodplain. However, once the Agua Fria and Salt River areas were screened, and selected as the most feasible sites, a more in-depth investigation was undertaken to develop preliminary designs.

Prior to initiating the preliminary design process, the project team and AMWUA staff considered and decided on several issues that greatly affected the preliminary designs, as follows. Based on preliminary data on the availability of surplus CAP water for artificial recharge, the recharge area for preliminary designs should be sufficient to recharge about 200,000 ac-ft/yr at each site. Because the estimated sustained infiltration rate at both sites had been previously estimated at one foot per day, the corresponding area needed to recharge 200,000 ac-ft/yr is about 550 acres. Although actual infiltration rates have not been verified in either the Agua Fria or Salt River areas, sufficient area is available at both sites to allow for expansion or contraction of facilities to accommodate actual recharge rates and available water.

The Salt River recharge facility was located convenient to a future turnout location on the Southern Canal, and a proposed CAP/SRP Inter-Connection Facility downstream of Granite Reef Dam. Potential turnout locations were investigated in the field. For the Southern Canal turnout, the most favorable location, an existing drainage channel to the Salt River was identified. The 550-acre Salt River recharge facility was then laid out downstream of the tributary drainage channel.

The use of public lands was considered as an important factor for implementation of a recharge project. Recharge facilities could be constructed more cheaply by avoiding the cost of purchase and/or lease of privately owned lands. The amount of publicly owned lands appeared sufficient at both sites, therefore preliminary designs exclude privately owned lands. Preliminary designs were prepared only for in-channel "T" levee spreading facilities which can be easily constructed at a relatively low cost, and provide the desired recharge capability. Specific details for the proposed Agua Fria and Salt River recharge facilities are outlined in the following paragraphs.

Agua Fria River

It is proposed that CAP water for the Agua Fria River recharge facility be discharged into the Beardsley Canal via the Maricopa Water District (MWD) CAP turnout. The CAP water would be conveyed approximately three miles in the Beardsley Canal to a proposed turnout at a dry wash immediately tributary to the Agua Fria River. Based on discussions with MWD, the Beardsley Canal could be utilized to convey about 180,000 ac-ft/yr to the recharge site, and canal capacity could be increased by raising and strengthening several levee segments. The in-channel average length of "T" basins is 1,300 feet. The total length of the Agua Fria recharge facility was configured at about 16,000 feet (refer to Figure 2).

Salt River

CAP water can be conveyed to the Salt River recharge facility either by discharging it directly into the river from a proposed CAP/SRP Inter-Connection Facility at Granite Reef Dam or via the SRP's Southern Canal to a proposed turnout structure to be constructed closer to the recharge facilities.

The actual vacant capacity available in the Southern Canal is presently under review by SRP. However, because the capacity of the Southern Canal is much greater in comparison to the proposed recharge flow rate of 400 cfs, adequate delivery capacity was assumed to exist within the Southern Canal to convey recharge water.

9

WEEKLY MINER.
Volume I. - - No. 25. Established 1864.
25 CTS. A COPY.] PRESCOTT, ARIZONA, SATURDAY MORNING, JUNE 21, 1873. [$7 A YEAR.

THE HAYDEN PARTY,

About which there was so much uneasiness, is all right. S. D. Bugert, one of the company, gave me the following particulars: On leaving McDowell they followed up Salt river as closely as possible for nearly 200 miles, and discovered nothing in the channel of the river to interfere with the floating of logs down it. On the route they passed through many small fertile valleys still containing the remains of old ditches and the ruins of old houses, but now overgrown with timber. They found game very scarce, walnut and

many small fertile valleys still containing the remains of old ditches and the ruins of old houses, but now overgrown with timber. They found game very scarce, walnut and
cherry trees very large, and Indians very numerous, but friendly. The latter had a habit of rushing out from some thicket which the party had just passed, whooping and hooting like demons, which action often made their hair stand on end, and, at least, was anything but agreeable. Some of these Indians had passes and others were tagged and labeled like so much merchandise. Having found a good location where pines were plenty and good they made a canoe out of a tree and putting some logs into the river, left six of the party to drive them down while Hayden and Bugert returned home by Camp Apache, San Carlos and old Camp Grant.

Mr. Bugert describes affairs at San Carlos as deplorable. Many of the Indians were in the mountains while those on the reservation were drunken and insubordinate, having distilled liquor from corn, drawn as rations.

A. #59

10

THE CITIZEN.
SATURDAY, February 28, 1874.

SALT RIVER VALLEY.

PHENIX, February 25.—C. T. Hayden arrived in town to-day from Tempe.—He reports numerous Indians in that vicinity: A band of seven camped over night at the foot of the hills near the town. They have stolen four animals from C. Leach's ranch and nine more are reported missing by various parties. A company of six or eight men was formed to go after them, but concluded in view of the number of Indians the attempt would be useless. The Indians were followed and tracked as far as the Pinal mountains, after which pursuit was given up.

A new ferry-boat has been built at Hayden's crossing on Salt river so that in future the rise of the river will not cause delay to passengers or mails.

The weather is clear and cold; mountains around the valley are covered with snow.

11

Boating in Arizona.

It does one so much good to read of boating in Arizona that we produce the following account of a wreck on the Gila from the Arizonan:

On the 9th inst. the large ferry boat which had been used for years on the Salt River at the Maricopa crossing was floated down the river with the purpose of taking her to the Gila Bend crossing. Five men were manning her and everything was going on smooth until they reached a point about forty miles below Phenix, when the boat came in contact with a willow snag just in the middle of the river. The current of the river being about at the rate of fifteen miles per hour the five men lost control of her and she struck the snag. She was cut in two parts as if she had come across a buzz saw. She is a total loss. Her owners, Messrs. Vol Gentry and W. Cox, valued her at about $1,000.

12

AFFIDAVIT

STATE OF ARIZONA)
) ss.
County of Maricopa)

Janet E. Cantley, being first duly sworn on her oath, states:

1. I currently reside at 335 W. Pebble Beach, Tempe, Arizona 85282.

2. I am Curator of Photographs at the Tempe Historical Museum at 3500 S. Rural Road, Tempe, Arizona 85282.

3. Duties of the Curator of Photographs include maintenance, conservation, and reproduction of the historical photographs of the collection.

4. According to museum records, the photograph labelled "Photo #1" was reproduced from the negative of an original photograph loaned by the Tempe Daily News. The photograph depicts the Tempe State Bridge in 1914. A copy of this photograph is attached to this affidavit as "Photo #1."

5. According to museum records, the photograph labelled "Photo #2" was reproduced from the negative of an original photograph loaned by the Salt River Project. The photograph depicts the Hayden's Ferry c. 1887. A copy of this photograph is attached to this affidavit as "Photo #2."

Law School Clinic
Arizona State University
Tempe, AZ 85287
(602) 965-6968

6. According to museum records, the photograph labelled "Photo #3" was reproduced from the negative of an original photograph loaned by Helen Harter. The photograph depicts a Salt River Swimming Hole in 1923. A copy of this photograph is attached to this affidavit as "Photo #3."

7. Photographs labelled "Photo #1", "Photo #2", and "Photo #3" are reproduced from negatives maintained in the photograph collection of the Tempe Historical Museum.

Janet E. Cantley
Janet E. Cantley

SUBSCRIBED AND SWORN to this 2nd day of May, 1988.

Bonita A. Cotter
Notary Public

My commission expires:
My Commission Expires Sept. 21, 1991

Law School Clinic
Arizona State University
Tempe, AZ 85287
(602) 965-6968

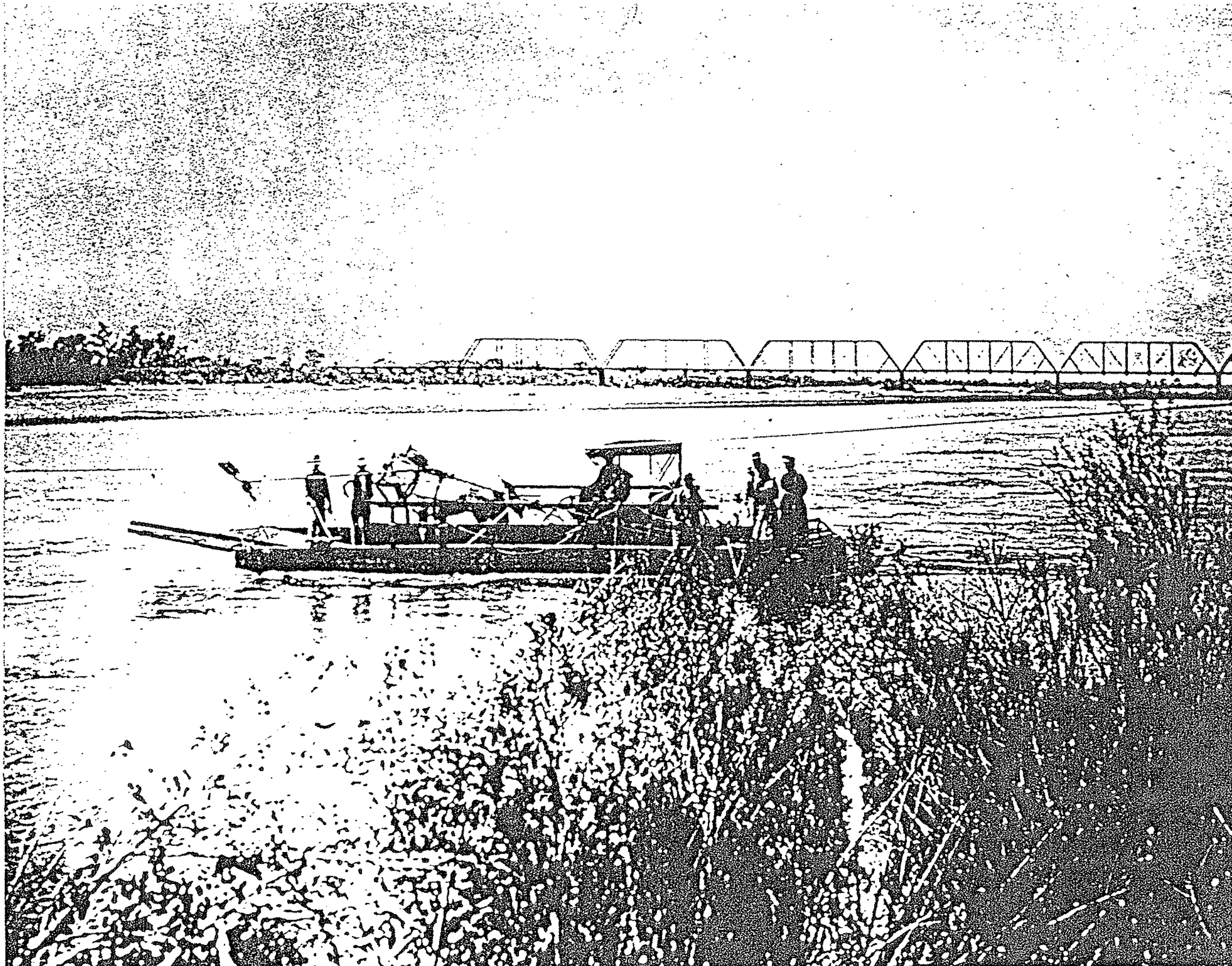

PHOTO #2

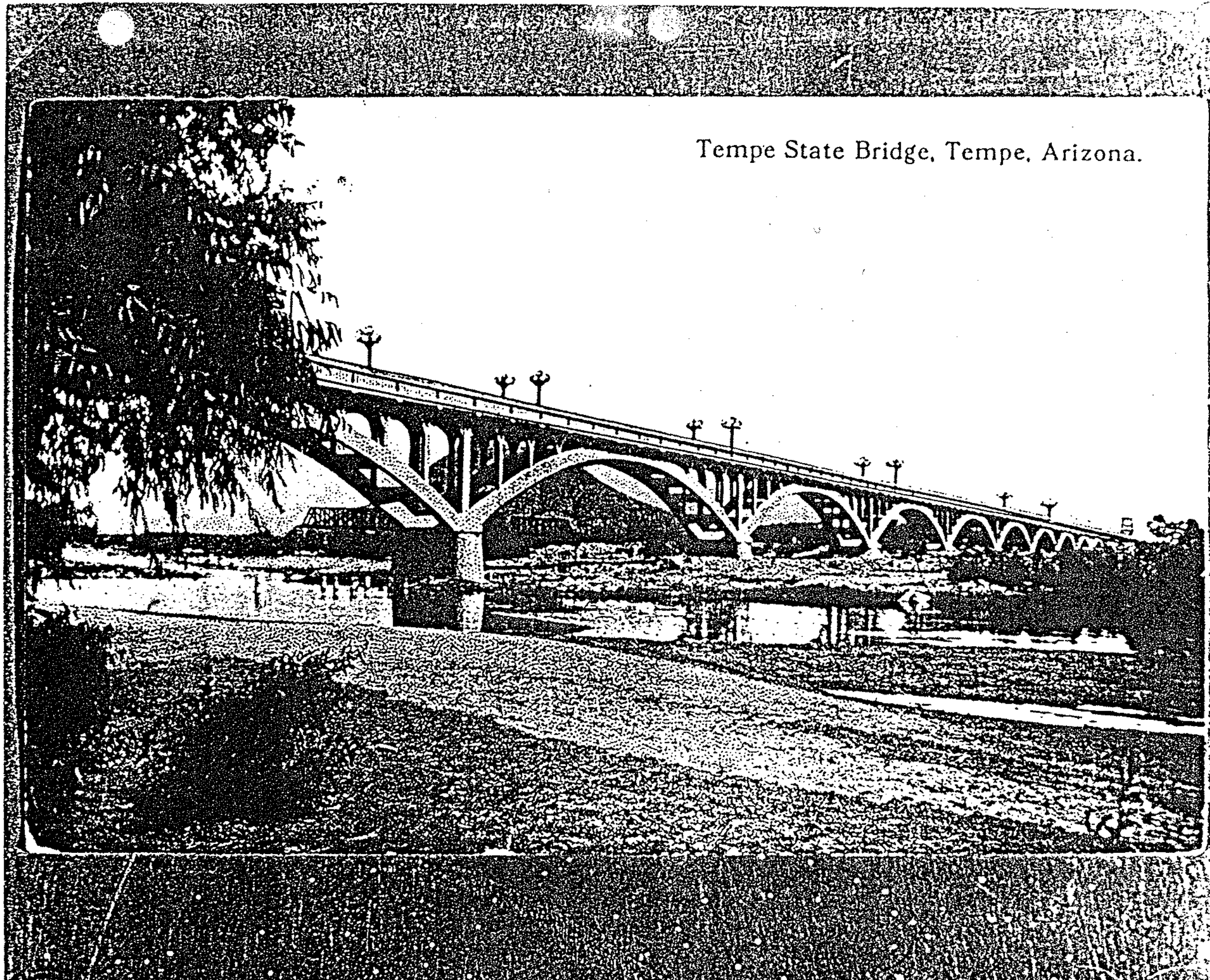

PHOTO #1

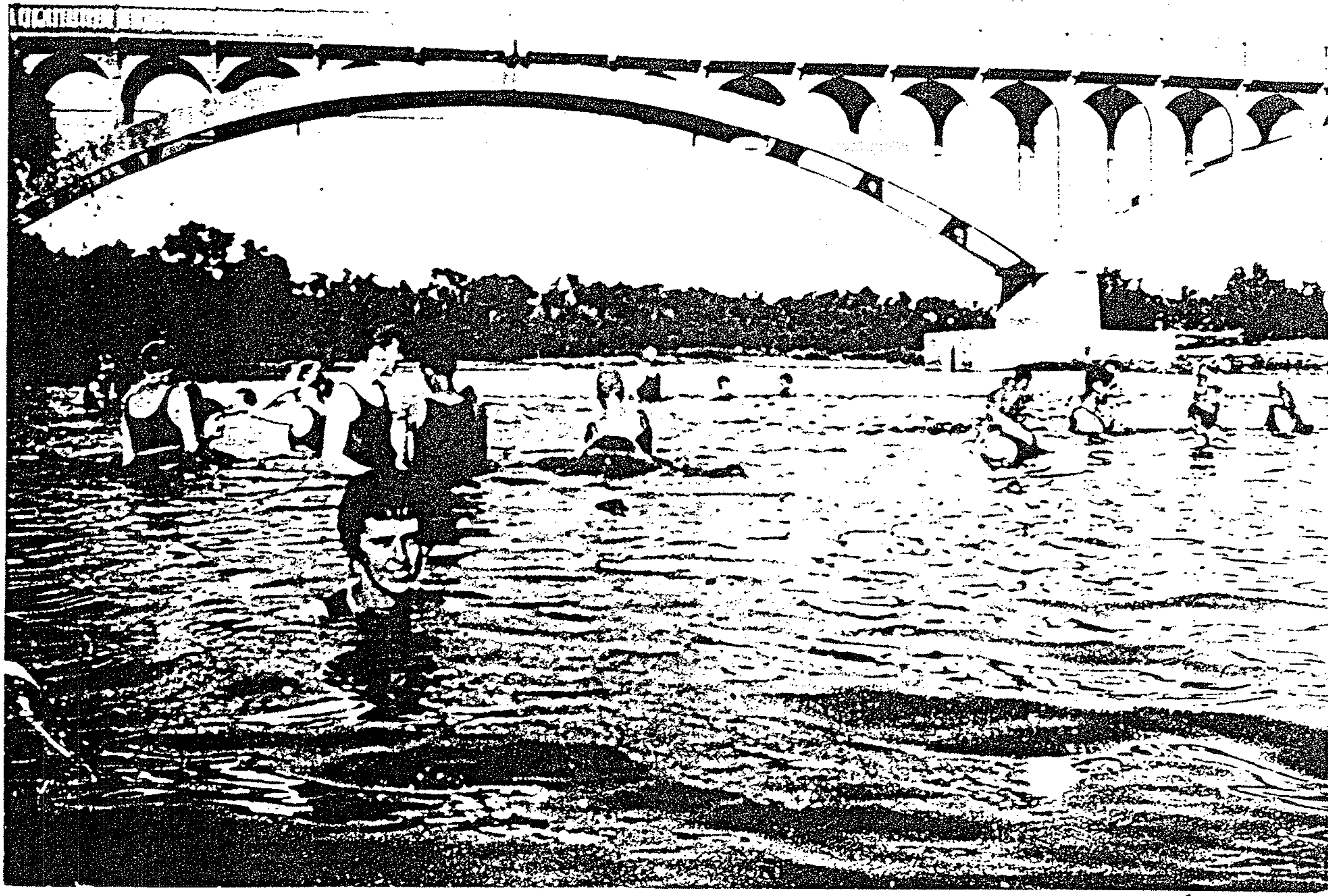

PHOTO #3

Terms for the Loan of an Object from the Tempe Historical Society, 3500 S. Rural Road, Tempe, Arizona 85282.

The Borrower agrees to credit the Tempe Historical Society and the Tempe Historical Museum for the loan of the object(s) in all publicity and exhibitions, handouts, and publications; to return the object(s) in the condition in which they were loaned; to return them to the Museum on or before the expiration date of this agreement, to reimburse the Museum for any loss or damage incurred to the loaned object(s). The borrower is responsible for being familiar with the Museum's policies and procedures as they relate to loans.

The Borrower may not photograph, make a replica of, repair or otherwise alter the loaned object(s) unless permission is herein expressly given: ____________

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9

RIPARIAN HABITAT

Robert D. Ohmart and Bertin W. Anderson

Center for Environmental Studies
Arizona State University
Phoenix, AZ 85281

Editor's Note: This chapter is the first of two on wetland habitats. These habitats are extremely important, not only because of their high inherent wildlife value, but also because of their effects on the adjacent upland and aquatic areas and their associated biota. This chapter covers wetland areas associated with running water, while the following chapter on marshes covers areas of standing water. These are not universally accepted definitions but provide a convenient breakdown for this book. The length of this chapter reflects the high importance of and current interest in riparian areas. However, much still needs to be learned about these areas, and a critical need exists for better management of them. Inventorying and monitoring riparian habitats will be a central part of such efforts.

INTRODUCTION

One of the most important assignments in the career of a wildlife biologist is to monitor or inventory riparian ecosystems. Only a decade ago few people, including wildlife biologists, had any appreciation or knowledge of these very limited and highly valuable wildlife habitats. Even today, books on wildlife habitats or plant communities seldom separate riparian ecosystems from adjacent upland plant communities. Before undertaking an assignment, we recommend obtaining copies of four riparian symposiums (Johnson and Jones [1977]; Johnson and McCormick [1978]; Warner and Hendrix [1984]; and Johnson et al. [1985]) to use as references.

Riparian as an adjective is defined as "relating to or living or located on the bank of a natural watercourse (as a river) or sometimes of a lake or a tidewater" (Webster's New Collegiate Dictionary 1979:991). To many, riparian is synonymous with wetland, but wetland is often defined as consisting primarily of emergent or marsh communities, which are not discussed in this chapter. (See Chapters 10, 11, and 12 for treatment of marshes, streams, and lakes, respectively.) For this chapter, which addresses only terrestrial riparian ecosystems, we will adhere to the following definition: "A riparian association of any kind [excluding marshes] is one which is in or adjacent to drainageways and/or their floodplains and which is further characterized by species and/or life-forms different than that of the immediately surrounding non-riparian climax" (Lowe 1964:62). This definition includes plant communities along permanently flowing or intermittent drainages. Some of these drainages may not flow for many years or even in our lifetime, but they are riparian communities if the plant species along these drainages are different from those of the adjacent upland.

Obligate or riparian-dependent species such as cottonwoods (*Populus* sp.) and willows (*Salix* sp.)

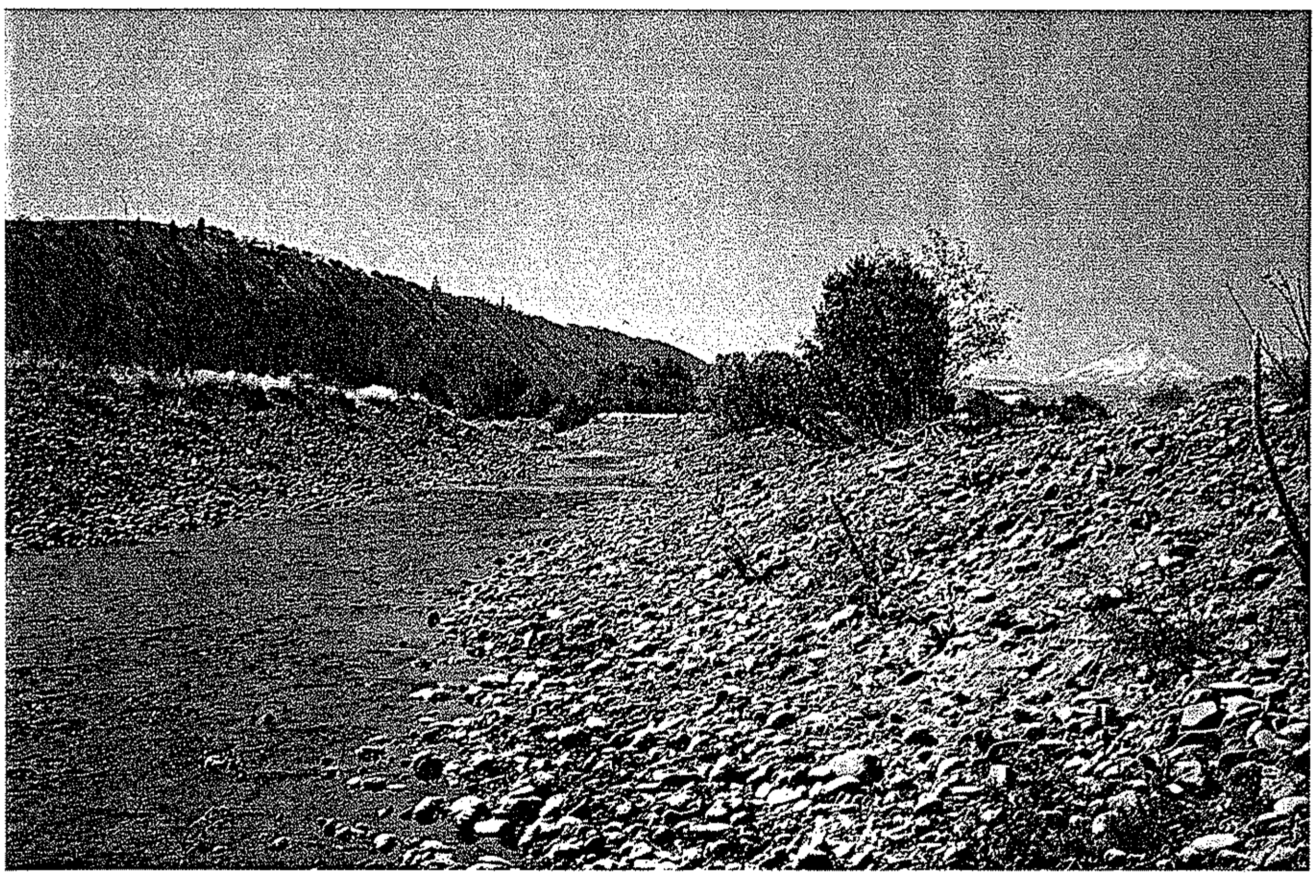
are frequently referred to in the literature as phreatophytes, referring to vegetation species having their roots in perennial ground water or in the capillary fringe above a water table. Most of these species transpire large quantities of water, and water managers believe that if the streamside vegetation is removed, this water will be saved or remain in the aquifer.

In past water management practices, thousands of acres of riparian vegetation have been removed to prevent this wicking of water into the atmosphere. For example, between 1967 and 1971, about 21,600 ha (54,000 a.) of riparian vegetation was removed along the Pecos River in New Mexico to save water. Although about 18,800 ha (47,000 a.) of the originally cleared area has remained cleared since 1971 (U.S. Department of Interior, Bureau of Reclamation 1979), preliminary results indicate that the amount of water saved is probably insignificant. Riparian ecosystems do not stand alone; they are fed by watersheds, which when destroyed, also destroy the riparian ecosystem.

Nutrients, water, and detrital materials are transported into the riparian system from its watershed. A healthy watershed generally indicates a healthy riparian system. Degraded watersheds produce high surface runoff carrying valuable soil into the stream, which reduces productivity of both the aquatic and terrestrial portions of the system. As any competent hydrologist knows, to reduce the volume and severity of floods, one must start with the point source—the watersheds; other efforts are "treating symptoms and not the disease."

The importance of western riparian habitats to humans has long been recognized, as indicated by the early settlement patterns of native North Americans and Europeans. During drought periods, settlements that were not near permanent water sources were forced to relocate; many died in the process. Riparian habitats provided and still provide water, rich fertile soils for agriculture, lush forage for domestic livestock, recreation, and home sites. Their importance is amplified in the arid western states, but is also obvious in the East where riparian areas are termed bottomland hardwood habitats.

Riparian habitats in the West are very limited when compared to the amount of acreage they constitute versus upland habitats. Riparian ecosystems

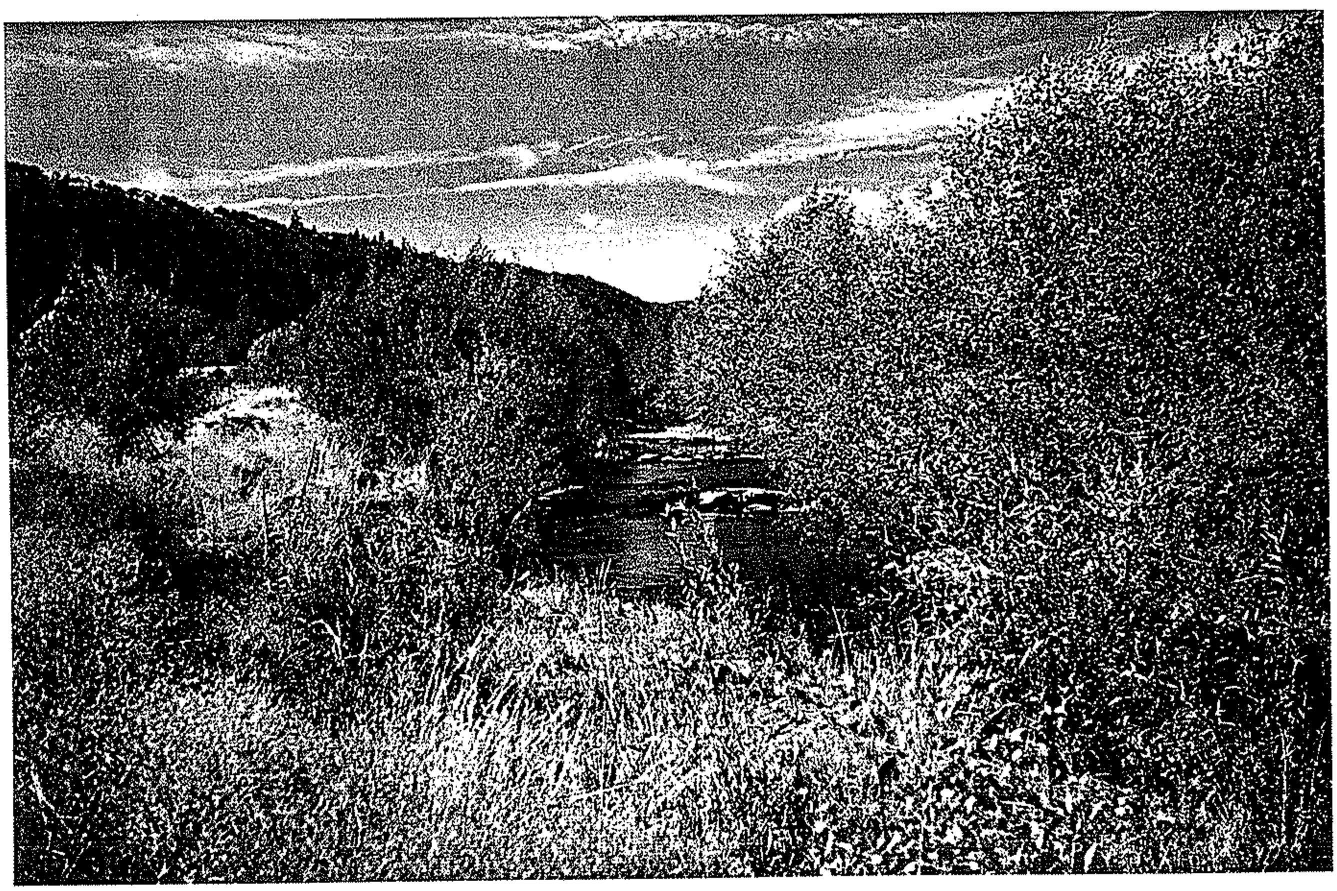


Degraded riparian area.

when compared with upland habitats may total up to 0.5% of the landscape or < 0.1%. Because of the small and finite nature of riparian habitats, their vitalness to human survival in arid environments, their recreational values, and their high fishery and wildlife values, they should receive critical concern in all land-planning and management efforts. For example, Johnson (1978) reported that 64 wildlife species presently listed as endangered, and 47 more species being considered for listing, are dependent on riparian habitats. In the past, riparian habitats have been treated as sewage transport systems and refuse landfill sites and have been subjected to numerous other types of habitat degradation.

The treatment of riparian habitats in the past and their current condition is alarming, which amplifies the need to pay special management concern to these ecosystems. For example, estimates are that 70-90% of the natural riparian ecosystems in the U.S. have been lost to human activities (U.S. Council on Environmental Quality 1978; Warner 1979a). Regional losses in these ecosystems have been estimated to exceed 98% in the Sacramento Valley in California (Smith 1977) and 95% in Arizona (Warner 1979b). Johnson and Carothers (1981) estimated that in the Rocky Mountains/Great Plains region, 90-95% of the cottonwood-willow riparian ecosystems of the plains and lower foothills have been lost. Possibly as much as 80% of the remaining riparian ecosystems in the U.S. (both privately and publicly owned) are in unsatisfactory condition and are dominated by human activities (Almand and Krohn 1978; Warner 1979b). In the West, these ecosystems support a disproportionately greater number of wildlife species than their upland counterparts.

Public support for wildlife and its habitat needs must be interpreted with caution. Kellert (1980), reporting on a nationwide opinion poll that focused on land-use allocations for wildlife, showed that many Americans were willing to make economic sacrifices in commodity resource production for endangered nongame species and certain featured big game species. Sixty percent agreed that livestock grazing on public lands should be limited if it destroyed vegetation used by wildlife, even if it resulted in higher meat prices; 34% disagreed. Over 75% believed that logging should be done in a manner to enhance wildlife even if lumber and paper prices rose. Conversely, almost 50% believed that natural resources must be developed, even if it



Same riparian area, 10-years later.

meant less wilderness and lowered wildlife populations. These results indicate public awareness for the needs of wildlife and management changes that need to be enacted on public lands to maximize natural resource values. The public at large generally supports the concept of multiple-use management on public lands, but interest groups strongly disagree on specific issues.

Sports enthusiasts in eastern Oregon favorably responded to improved grazing management practices (Megank and Gibbs 1979). Almost 70% of anglers surveyed stated that their recreation experiences would be reduced by management practices that further degraded riparian systems. Their reaction to fences was positive in that it represented better livestock control. Hunters thought that management that improved forage production for livestock would also help deer and elk.

Many values of riparian habitats to our society, seldom considered by terrestrial wildlife biologists, should be factored in as sound arguments toward managing these systems in their natural state. The riparian vegetation adjacent to streams or even large rivers is extremely important as an energy source to the aquatic organisms (see Streams, Chapter 11). In small headwater streams, 99% of the energy for heterotrophic organisms comes from the vegetation along the stream, whereas only 1% comes from photosynthesizing autotrophs (Cummins 1974). In large river systems, such as the Missouri River, as much as 54% of the organic matter consumed by fish is of terrestrial origin (Benner *in* Kennedy 1977). A factor that has not, to our knowledge, been seriously considered by fishery biologists is the quality of the organic input or species composition of the streamside vegetation. Trees may be desirable as shade to prevent large fluctuations in water temperature, but some tree species will ultimately prove more important as energy input sources than others, e.g., cottonwood and willow leaves and other tree parts are probably of more value to aquatic detritivores than leaves and other parts of the exotic salt cedar (*Tamarix chinensis*). The former would certainly impose less change on total dissolved solids and water chemistry than the latter. Biologists must manage for healthy streamside vegetation and, as knowledge progresses, some efforts should be directed toward encouraging establishment of tree species that have higher nutrient input value to the aquatic fauna. This approach toward managing terrestrial vertebrates is already underway along large river systems.

Streamside vegetation is very important in determining the structure and function of stream ecosystems (Knight and Bottorff 1984). Mahoney and Erman (1984) found that riparian vegetation is an important source of food to stream organisms, provides shade over small-order streams, and serves to stabilize banks in preventing excessive sedimentation and intercepting pollutants. Asmussen et al. (1977) reported that vegetation buffer strips were very effective in reducing pollution from agricultural chemicals. Karr and Schlosser (1977, 1978) reported that proper management of streamside vegetation and the channel may substantially improve water quality in agricultural watersheds. Corbett and Lynch (1985) stressed the importance of streamside zones in water-quality management for municipal water supplies. Haupt (1959) presented guidelines for buffer strip widths in road-building projects, and Benoit (1978) similarly presented guidelines for timber harvest operations in Oregon. Treating water to bring it to potable standards is expensive; stopping pollution at its source and managing for productive riparian vegetation will significantly reduce these costs. Finally, riparian vegetation can be important in flood-control efforts (Chaimson 1984) by reducing water velocity and its erosive energy during flood stage (Li and Shen 1973). The vegetation may also reduce streambank damage from ice, log debris, and animal trampling (Platts 1979; Swanson et al. 1982); armor levees; and prevent channel changes during high flows.

Importance of riparian systems to wildlife has not been quantified or demonstrated to any convincing extent until the past 15 years. The efforts of Carothers et al. (1974) to quantify avian densities in cottonwood habitats along the Verde River in central Arizona and those of Ohmart and Anderson (1974) along the lower Colorado River were beginnings. A riparian symposium (Johnson and Jones 1977; Hehnke and Stone 1978; Thomas et al. 1979) along with others were fruitful in focusing attention on these ecosystems. These studies and subsequent ones indicated that some of the highest densities of breeding birds in North America were found in riparian habitats, and more than 60% of the vertebrates in the arid Southwest were obligate to this ecosystem (see Ohmart and Anderson 1982 for a review). Another 10-20% of the vertebrates were facultative users (present for a portion of the annual cycle but not fully dependent on riparian habitats) of streamside vegetation. Mosconi and Hutto (1982) reported that in western Montana, 59% of the species of land birds use riparian habitats for breeding, and 36% breed only in riparian habitats. Similarly, of the 363 species of land vertebrates in the Great Basin of southeast Oregon, 299 either directly depend on riparian habitats or utilize them more than any other habitat types (Thomas et al. 1979). Therefore, if these ecosystems were totally lost or continued to be reduced to vestiges of their original state, conceivably 60-80% of our native wildlife species could be lost in the western U.S. The Colorado River is a classic example of this, in that at least four species of birds have recently been extirpated and unless some dramatic management changes are made, another six species could be lost in the next 20 years (Hunter et al. unpubl. data).

RIPARIAN HABITAT CLASSIFICATION

Small riparian ecosystems occurring in watersheds at higher elevations eventually connect to form major drainage systems. These major drainages, such as the Green River in Wyoming, connect into larger systems, such as the Colorado River. To aid in understanding these western riparian ecosystems at different elevations, we recommend using the Life Zone concept developed by Merriam (1890), which is widely used in the West for its utilitarian value.

The Brown et al. (1979) concept for naming riparian ecosystems in Merriam's Life Zones is also widely accepted in the West because its hierarchical system for North American biomes has an evolutionary and genetically based approach. It is also digitized, which makes it computer-compatible. Importantly, it is concordant with the Life Zone concept.

Succession

In highly modified or managed rivers, such as the lower Colorado, Pecos, and Rio Grande, there is little evidence of classical succession. If an area is burned or cleared, it tends to return as trees or shrubs and remains in that state. Succession is poorly studied and understood, and it may be that riparian floodplains are so rich in nutrients and water that classical plant succession does not occur. Brady et al. (1985) presented the developmental continuum of a riparian gallery forest ranging from a nursery bar to a mature forest. Bock and Bock (1985) presented data on patterns of reproduction in a species of sycamore (*Platanus wrightii*) in southeastern Arizona.

Communities

Naming individual plant communities varies depending on the biologist mapping and sampling the communities, but is generally based on one or more dominant species (either by density or stature). For example, a cottonwood-willow community may only have 1 cottonwood for every 10 willows in a stand, but because of the size and presence of cottonwoods, it may be called a cottonwood-willow community. In another example, a community may be called honey mesquite (*Prosopis glandulosa*) although it contains mostly shrubs. What a community is called is unimportant as long as the community names and accompanying written descriptions can be interpreted by others. Laurenzi et al. (1983) presented a habitat classification system for mixed broadleaf riparian forests in the Upper Sonoran Life Zone.

Structural Types

Some riparian ecosystems may be extremely dynamic through time whereas others are relatively stable. Recognizing and classifying structural stages (young through mature stages) allows a quick assessment of the riparian ecosystem's health. If no young plant communities develop to replace the old, decadent communities of similar species composition, then animal species dependent on those communities may be lost to the fauna. Also, young plant communities may support a fauna much different from that found in a mature plant community. These structural differences (in plant community age classes and foliage layers) are very important in managing for maximum riparian productivity and vertebrate species richness.

The concept of structural classification of riparian communities is an important one and not difficult to understand if an area is envisioned as going from bare soil to supporting a mature cottonwood-willow forest; all the structural types would then be present over this continuum. Figure 1 shows the structural types in lower elevational systems; Type VI is the young or beginning community, and as it grows it passes to a V, IV, etc., until it becomes a Type I which is a mature cottonwood-willow community. In Type VI, most of the foliage volume is in the grass and shrub layers; as the community matures, a good overstory (Type II) shades out much of the understory. Type I contains overstory, midstory, and understory as some trees die opening the overstory for ingression of shorter trees, shrubs, and annuals. By dividing a continuous process into stages or types, both plant communities and structural types can be assessed together in demonstrating user-oriented impacts. However, structural complexity and mean canopy height are generally reduced where riparian systems are under heavy water management, livestock grazing, pollution, and recreational activities.

In the following example of structural types, a cottonwood-willow community was used to demonstrate Types VI (young) through I (mature). At higher elevations this community could consist of sycamores, narrow-leaf cottonwoods (*Populus angustifolia*), quaking aspen (*P. tremuloides*), or other tree species that have similar vertical and foliage density attributes as cottonwood-willow. Not all tree species form communities that have the same growth pattern as those discussed above, but their community development shows some of the same structural stages. For example, salt cedar communities generally reach maturity as structural Type II,

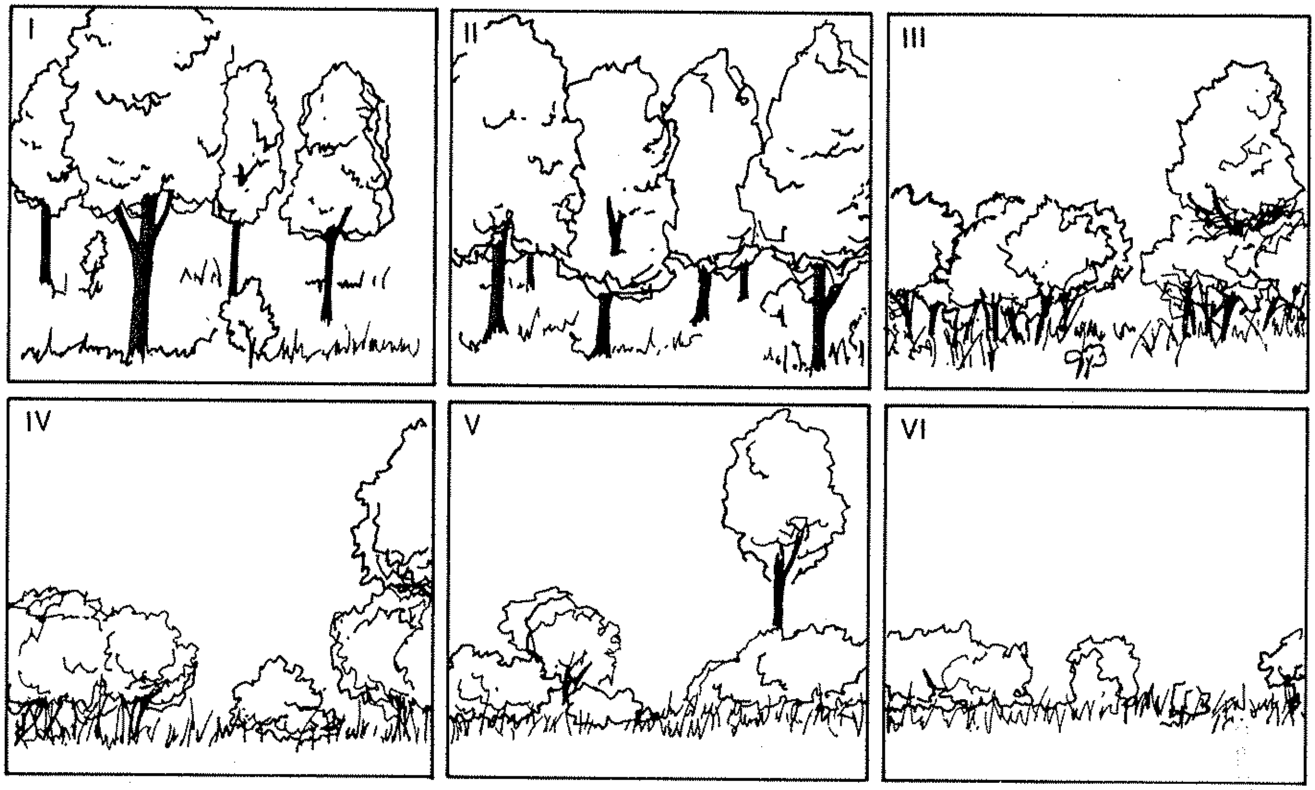


Figure 1. Vegetation structural types found in lower elevations.

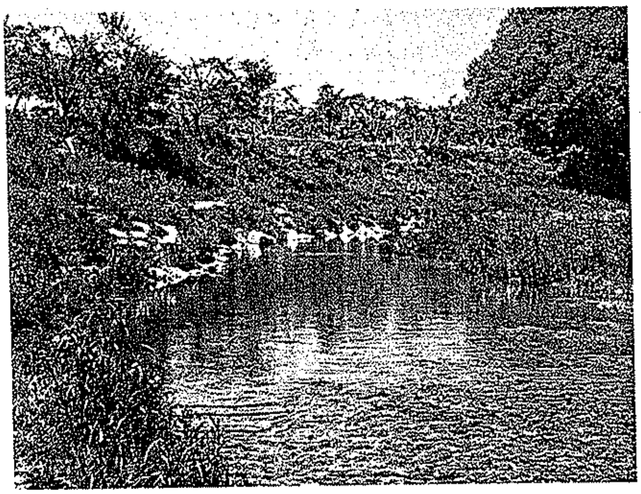
honey mesquite as Type III, and arrowweed (*Tessaria sericea*) and other shrub communities are always Type VI. Managers may find this classification system less confusing than trying to establish a more complex and, hence, more complicated approach to recognizing structural types. Most importantly, the structural types are real to wildlife and its use of the vegetation.

In habitat discussions today of the Colorado River, managers have wanted to know the community and structural type under consideration. They can easily visualize the community and structural types, and we have provided a document that gives species richness, densities, and other wildlife use values seasonally for 3 to 5 years along with mean values. These data are available for only a few riparian ecosystems, and our approach in this chapter is to help managers initiate development in their resource management areas. The system can always be expanded and improved toward better managing these invaluable wildlife habitats.

IMPORTANT HABITAT ATTRIBUTES TO WILDLIFE

Discerning habitat attributes that are most important to wildlife is not an easy task, and reliable identification of those habitat components only comes from long-term, in-depth studies. Seasonal and annual variances of wildlife numbers are generally very high, and until a number of seasons and years have been studied, the habitat components that are truly important to wildlife may not be discernible or fully understood.

Four habitat components, not discussed in depth in this section but important to wildlife, are plant community size (number of acres), continuity of riparian habitat along the streambed, edge or ecotone, and water. The streambed has been widely discussed in island biogeography theory and in terms of habitat fracturing. The more extensive stands of a riparian forest are reduced, the less wildlife value they have for some species. As the tract gets smaller, its wildlife values diminish to the point that the forest contributes little, if any, to overall wildlife values. It probably reaches its zenith of importance in riparian habitats at lower elevations where expansive alluvial floodplains support extensive stands of continuous wildlife habitat. T.E. Martin (Arizona State University, unpubl. ms) identified area size as the primary factor accounting for variation in number of breeding pairs of birds in five of seven of his ecological groups in high-elevation, riparian habitats in central Arizona. As knowledge expands and understanding of the needs of wildlife increases, we observe that continuous areas of some particular riparian community are more than twice the value of that same community in 0.8- to 4-ha (2- to 10-a.) blocks. For example, many bird species have been lost along the Colorado River and others will be lost in the near future as island size stands of cottonwood-willow are reduced. Stands of 28 ha (70 a.) only begin to fill the needs of some bird species, allowing the presence of a few breeding pairs at best. For these reasons, habitat island size is important regardless of whether it is along small streams at high elevations or along rivers in the desert.



An example of continuous riparian habitat.

Continuity of riparian vegetation along the floodplain is extremely important to some species such as small mammals, reptiles, and amphibians. Small, discontinuous blocks may not fulfill the needs of many of these species, causing reductions in numbers and, possibly, extirpation of some populations attempting to use highly fractured riparian habitats as movement corridors. Amphibians and reptiles that need riparian habitats are extremely vulnerable to this fracturing and, as pointed out by Brode and Bury (1984), what were once continuous populations of some species in California are now isolated relict populations. Dispersal routes for pioneering individuals and gene exchange have essentially been halted because once continuous riparian habitats have been disrupted.

The edge or ecotone component may be of less concern because the very nature of riparian ecosystems or ribbons of habitat running through uplands is edge at its maximum. Some believe that riparian ecosystems are all edge, regardless of alluvial floodplain width, because the river constantly meanders across the first terrace, scouring old plant communities and depositing new soils that are revegetated with early stage plant communities. Continuing this productive, valuable wildlife habitat as edge for wildlife should be the most important factor in good management decisions.

Water may or may not be present aboveground in riparian ecosystems. When present, it is an important component for large mammals and, to a lesser degree, small animals. Most smaller vertebrates gain adequate moisture in their diet but will drink or bathe when the opportunity arises. The primary importance of water to terrestrial wildlife, whether above or below ground, is that it supplies terrestrial vegetation with the quality and quantity needed for health and growth.

Birds

As stated earlier, habitat features most important to wildlife are very difficult to extract from data sets and virtually impossible to extract and confirm from 1- to 2-year studies. What may appear to be an important habitat component one year may not even be a significant component again in a 5- or 10-year study. Bird habitat components were derived from one large river system studied for at least 7 years with intensive monthly sampling over that time span. These data have been tested on other large desert riparian systems, including a revegetation site in which the plant community contained all of the most important habitat components except snags for nest cavities. These were added by erecting nest boxes. The revegetation site is now about 6 years old, the cottonwood trees are more than 15 m (50 ft) high, and the area is replete with the avian species that it was designed to attract. Unfortunately, the area is too small (28 ha [70 a.]) to attract and house many pairs of species that require large areas for breeding territories—again demonstrating the importance of island size effect.

Keep in mind that these habitat components were derived for birds in desert riparian systems. Although similar data in a long-term study are being collected in quaking aspen stands in Colorado (Winternitz 1973, 1976; Winternitz and Cahn 1983), to our knowledge these kinds of data do not exist for birds at higher elevations. Not all of these components may be important at higher elevations and if they are, their order of importance may also differ. These habitat components should be used with caution at higher elevations, and where supporting data are available we have included the references. Again, other and better references may be available and should be used.

Frequently, biologists need bird species lists to illustrate the importance of riparian habitats, to reference particular species, or for other reasons. A list of desert riparian species in each desert and their dependency on riparian revegetation species in each desert is presented by Ohmart and Anderson (1982). Knopf (1985) provided a list of birds observed in a 2-year study along the Front Range in Colorado.

We have found the following habitat components, in the order given, most important for entire avian communities in desert riparian areas:

1. Tree species
   a. Fremont cottonwoods (*Populus fremontii*) and Goodding willows (*Salix gooddingii*)
   b. Honey mesquite
2. Shrubs
   a. Quail bush (*Atriplex lentiformes*)
   b. Iodine bush or inkweed (*Suaeda torreyana*)
3. Mistletoe (*Phoradendron californicum*)
4. Foliage density
5. Foliage height diversity (FHD)
6. Snags
7. Patchiness (PI)

Tree Species.

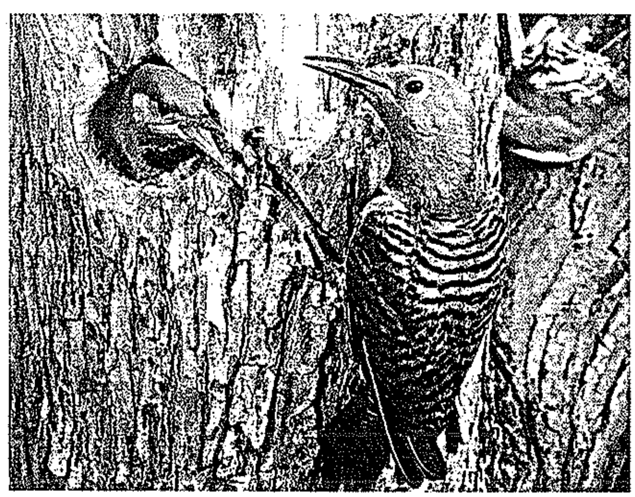
Cottonwoods and Willows. This tree component was widespread along most permanent streams and rivers at lower elevations in the western U.S. before European settlers. Its widespread distribution and antiquity in western North America (Axelrod 1958) undoubtedly provided many opportunities for an evolving insectivorous avifauna. A lush canopy provided shade, cover, and a myriad of insects. The rough, ever-sloughing bark attracts wood-boring larvae plus a number of other arthropods, which provide forage for bark-gleaning and trunk-scaling birds. The soft wood is easily excavated by woodpeckers and, when abandoned, secondary cavity-nesting species such as Lucy's warblers (*Vermivora luciae*), brown-crested flycatchers (*Myiarchus tyrannulus*), and elf owls (*Micrathene whitneyi*) have an array of vacant cavities for their nesting activities. Even in winter after leaf drop, the rough, splitting bark provides foraging opportunities for numerous bird species. In early spring the flowers, laden with pollen, are swarmed by arthropods, and wintering and migrant birds consume the pollen and insects attracted to the flowers. As gallery forests of these trees age, some die providing snags and light penetration to the forest floor. Shrubs, other trees, and annuals invade to provide patchiness that attracts other bird species.

These large (18-24 m [60-80 ft] tall and 2-3 m [6-10 ft] DBH), branching trees with their attendant insect fauna, bird life, and proximity to a stream with its aquatic life, also attract a number of wintering and breeding raptors. These birds, at the top of the food chain, find a rich and varied prey base upon which to feed.

Studies of this community type in California (Gaines 1977), Arizona (Carothers et al. 1974; Anderson and Ohmart 1984; Rice et al. 1984), New Mexico (Hubbard 1971; Hink and Ohmart 1984), and in Texas (Wauer 1977; Engel-Wilson and Ohmart 1978) attest to its wildlife value. As this community type becomes extirpated from the West Coast eastward, at least 10 bird species will be lost as well.

Robert D. Ohmart

Cottonwood-willow association.



Woodpeckers can easily excavate cavities in soft-wood trees, such as the cottonwoods.

Deciduous trees at higher elevations may be as important to birds as cottonwoods and willows are in desert riparian systems. Bull and Skovlin (1982), working in Oregon, reported that bird diversity and species composition changed with the amount of deciduous vegetation as it ranged from high (> 40%), to moderate (15-30%), to low (< 1%). Birds using deciduous vegetation in the area sampled were the only group highly dependent on this habitat component. A long-term study in quaking aspen stands in Colorado has documented the value of this deciduous tree to birds (Winternitz 1976).

A 2-year study by Knopf (1985), at elevations ranging between 1,200 and 2,750 m (3,973 and 9,022 ft), indicated that breeding birds in riparian habitats were more simplistically structured to habitat components at higher elevations than at lower elevations. He reported dramatic changes in species richness at intermediate elevations, which could indicate less structuring of avian communities at these elevations or that his study period was too short to fully document what was occurring at these elevations. At elevations above 1,909 m (6,263 ft), the importance of riparian habitat declined; the uplands contained a more diverse avifauna than the riparian areas. Further testing of these correlations are needed, but before wildlife biologists de-emphasize intermediate elevation habitats, we strongly recommend that the manager fully determine whether the wildlife values are indeed low and the potential for maximum riparian productivity on a site has been achieved.

Possibly, the entire western riparian avifauna has evolved more closely with deciduous tree species at various elevations than other habitat components. These trees provide the essentials for life, e.g., food, cover, and space for these insectivorous birds that can also obtain needed water from the riparian system. Box elder (*Acer negundo*), walnut (*Juglans major*), sycamore, narrow-leaf cottonwood, and others may be ecologically equivalent to cottonwood-willow at lower elevations. The importance of these trees to wildlife cannot be overstressed if they are true surrogates; riparian habitats should be managed to ensure healthy communities with young replacement structural types.

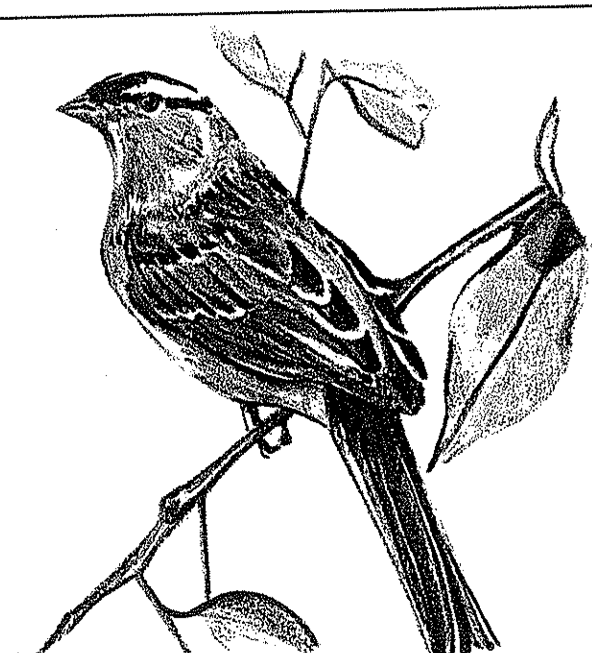
Honey Mesquite. This tree is deciduous in desert riparian habitats. It grows slowly and is found primarily on the highest terrace (second terrace) away from the river where channel cutting by the river seldom occurs. Again, the flowers attract wildlife, both by the pollen and the insects feeding on the flowers. The fruits or beans produced by this tree are rich in carbohydrates and are consumed by a wide range of wildlife species.


Robert D. Ohmart

Honey mesquite.

In low areas where floodwaters are trapped, colloidal materials are deposited and form heavier soils that support a mixture of shrub species, primarily quail bush, four-winged saltbush (*Atriplex canescens*), wolfberry (*Lycium* sp.), and inkweed. These shrubs provide important values to a number of wildlife species and enhance the avian productivity of the honey mesquite community.

Honey mesquite communities are also enhanced by numerous annual plants that have high seed production after a wet summer or winter. Seeds produced by these annuals are utilized by a large granivorous guild that includes white-crowned sparrows (*Zonotrichia leucophyrs*), Gambel's quail (*Callipepla gambelii*), and Brewer's sparrows (*Spizella breweri*).


white-crowned sparrow

Shrubs.

Quail Bush. In optimum growing conditions, quail bush reaches heights of 3 to 4 m (10 to 14 ft) and a single plant could cover 13 m^2 (140 ft^2). Although an evergreen, this shrub drops leaves and stems that over the years form a thick layer of composting material. This dense shrub shades the soil to help hold moisture that in turn expedites decomposition of the litter accumulation. Ground-dwelling birds, such as quail, thrashers (*Toxostoma* sp.), and towhees (*Pipilo* sp.), find protection and productive, insect foraging areas in the decomposing litter under this shrub. Small insectivorous birds forage extensively in and among the dense stems and leaves.

When this shrub is mixed with a community of trees, such as honey mesquite or salt cedar, it greatly enhances the wildlife values of the trees. Also, it forms a monoculture where quail and other ground-dwelling bird species can attain high densities. Its seeds are important to these birds as well because the plant is a prolific seed-producing species and the seeds fall to the ground throughout the year.

Iodine Bush or Inkweed. This 0.5- to 1-m (2- to 3-ft) tall shrub is used by numerous ground-dwelling birds, but is most important to sage sparrows (*Amphispiza belli*). Wintering sage sparrows actively select habitats containing this plant or revegetated areas containing inkweed (Meents et al. 1982). Seeds and plant parts of inkweed were found in sage sparrow gizzards, but why they actually select habitats with a preponderance of inkweed is unknown.

Mistletoe. Mistletoe is a parasite, widespread on trees and shrubs in the pea family (Leguminosae or Fabaceae). Although it can be found on many different host species, it appears to do best on honey mesquite trees. The dense clumps provide shelter for perching birds, nesting cover for breeding species, and berries for a number of frugivorous (fruit-eating) birds, especially Phainopepla (*Phainopepla nitens*; Anderson and Ohmart 1978). Although mistletoe may eventually kill some mesquite trees, its value to wildlife appears to offset its negative effects to mesquite. In healthy riparian systems, life and death are integral parts of a productive community. As mesquite trees die, they produce hardwood snags. The snags attract wood boring insects and can become potential nest sites for the ladder-backed woodpecker (*Picoides scalaris*). These snags also provide perches for hunting raptors.

Foliage Density. Until recently, the importance of foliage density (surface area of leaves and stems/area^3) or foliage height diversity could not be readily separated. In recent strip-clearing studies, foliage density was reduced by 20-40%, whereas foliage height diversity did not change. However, bird life in the area was drastically reduced (Anderson and Ohmart unpubl. ms). This seems to indicate that foliage density is more important in the higher vertical layers than foliage height diversity, as it provides better forage substrate for insect-gleaning birds, concealment from predators, and sites for nesting. Canopy and mid-canopy layers of vegetation are low quality to wildlife unless foliage density is moderate or high. It is generally believed that by increasing foliage density in each layer of vegetation, the carrying capacity of insectivorous birds is increased and new niches are added.

Foliage Height Diversity (FHD). Foliage height diversity measures how evenly foliage is distributed among the vertical layers. A plant community with little or no foliage density in the tree canopy layer would have a lower FHD value than a similar plant community with dense foliage at the understory, midstory, and canopy levels. Thus, foliage height diversity increases when foliage density values are nearly equal among all vertical layers of vegetation.


Robert D. Ohmart

Salt cedar community.

Figure 2 shows two communities with differing height diversities; the one on the left shows low-, mid-, and upper-canopy volumes while the community on the right shows some midstory volume and a little overstory.

This habitat component is unquestionably valuable to wildlife, but less so than foliage density. Other species of trees can have height density values similar to cottonwood and willow habitat, yet not have similar species richness values and bird densities. Rice et al. (1984) examined the importance of FHD, patchiness (PI), and individual tree species to avian communities. Response of individual bird

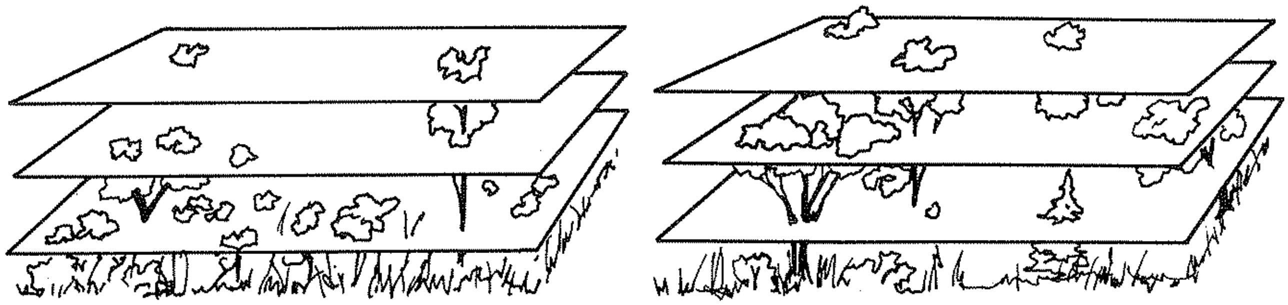


Figure 2. Two plant communities showing different foliage height diversities.

species was significantly higher with greater frequency of individual tree species than with other vegetation variables depicting structure. Although height densities correlated well with other tested habitat components, they were strengthened by adding individual tree species. Generally, it is assumed that as one adds layers of vegetation, these additional layers provide niches for additional species of birds.

Snags. Snags are extremely important to a number of species in riparian ecosystems. Many species use snags for nesting, feeding, roosting, as hunting and loafing perches, for hibernacula while overwintering, and as a moist refuge in dry summer months. Snags can be, and have been reported as, limiting to the presence and abundance of cavity-nesting birds (Haapanen 1965; Balda 1975; Conner et al. 1975; Evans and Conner 1979; Scott 1979; Mannan et al. 1980; Dickson et al. 1983). A wildlife snag symposium (Davis et al. 1983) provided a compilation of papers on this subject and should be referred to for more specific information.

Many of the above studies and others examining the importance of snags to birds have been conducted in upland habitats, but snags in riparian habitats are as limiting, if not more so, than those in upland areas and have the same effect on many primary and secondary cavity-nesting species. T.E. Martin (Arizona State University, unpubl. ms) examined the importance of snags in 13 riparian habitats where the riparian species were primarily big tooth maple (*Acer grandidentatum*), quaking aspen, and New Mexico locust (*Robinia neomexicana*), with an understory of golden pea (*Thermopsis pinetorum*) and raspberry (*Rubus strigosus*). Snags were primarily aspen and were significantly ($P < 0.001$) more abundant along streams on north-facing slopes than on south-facing slopes. Densities of snag-using species were greatest in snag-rich habitats, and more snag-using species were present.

Brush et al. (1983) found that this habitat component, especially softwood snags, is generally a limiting factor in heavily managed desert riparian systems. Fires, floods, and even removal of snags to protect water skiers has virtually eliminated this important component in the lower Colorado River riparian ecosystem.

Primary and secondary cavity-nesting species are vulnerable unless management is aware of their needs and places high value on ensuring large, quality snags for wildlife. Unfortunately, a prerequisite to snags is living trees; this handicap has been partly overcome and artificial snags are being excavated by some woodpeckers (Grubb et al. 1983; Peterson and Grubb 1983). Presence or absence of snags should be noted as riparian habitats and assessed for wildlife.

Snags provide essential habitat for about 85 bird species (Scott et al. 1977) that use natural cavities, excavate their own, or use holes excavated by other species. Many of these species are obligate riparian forms. In quaking aspen stands in Colorado, almost 40% of the breeding bird species using this type used nest holes, and trees containing these cavities were usually well over 100 years old (Winternitz and Cahn 1983).

Patchiness. Horizontal foliage diversity or intraplant community patchiness on the horizontal scale has long been recognized as valuable to wildlife. Figure 3 attempts to show patchiness in a plant community; the open areas between interlocking trees and some midcanopy vegetation produce a patchy effect in this forested habitat. Patchiness, like foliage height diversity, is thought to create additional niches for birds. Some species are found primarily in continuous riparian forests, whereas others are attracted to openings in the canopy where lesser trees or shrubs provide patches in an otherwise continuous canopy. These patches offer habitat space for new species that would otherwise be absent, because as patchiness increases so does species richness. Anderson et al. (1983) recently developed a method to quantify patchiness.

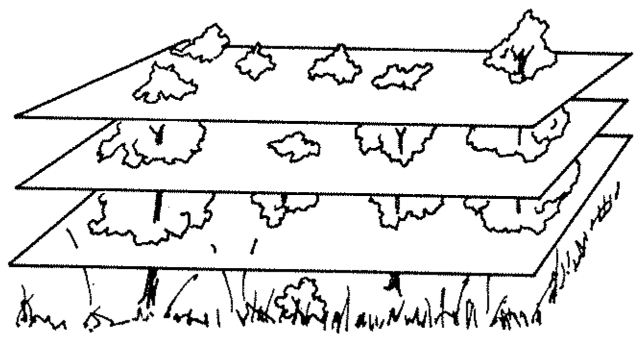


Figure 3. Patchiness in a plant community (diagrammatic).

Mammals

Large Mammals. The total importance of riparian habitats to large mammals is not fully understood, but undoubtedly these ecosystems provide three essential resources to this group: food, water, and cover. Dealy et al. (1981) pointed out that riparian habitats in general, and quaking aspens in particular, provide both thermal cover and forage for ungulates.

In the Modoc National Forest in northern California, Salwasser and Shimamoto (1984) examined animal use of wetlands that have developed since the 1920s behind water storage dams. They examined wetland use for three classes of large mammals: feral horses, domestic cattle, and pronghorn antelope (*Antilocapra americana*). Although these wetlands made up 10% of the available habitats, they were used heavily by all classes from midsummer through fall. Pronghorn antelope use peaked at 80% in August and remained over 40% into October. Feral horse use peaked at 78% in July and remained over 40% into early August. Cattle use peaked at 80% in August and exceeded 50% since late June. Annual use varied by the three classes, but all used the developed wetlands far more extensively than the wetlands that were available among habitats in midsummer to fall.

The extent to which elk (*Cervus elaphus*) use and depend on riparian habitats, other than as travel routes, in the nonsummer months is not well known. However, in summer in western Montana, 80% of elk use in July was within 0.4 km (0.25 mi.) of permanent water (Marcum 1975). Skovlin (1984) reported heavy preference for summer range within 0.8 km (0.5 mi.) from water. Whether the elk are attracted to riparian habitats for the green lush forage, water, or both is unclear; perhaps only lactating cows depend on free water sources at this time (Marcum 1975; Black et al. 1976; Thomas et al. 1976).

Studies examining habitat use by elk in mixed-forest types have shown that of 15 associated habitat types, riparian zones were most heavily used (Pederson et al. 1979). Riparian corridors also served as travel routes between areas.

Although elk will graze areas used by cattle, domestic livestock grazing appears to diminish use of the area by elk (Blood 1966; Nelson and Burnell 1975; Burbridge and Neff 1976; Skovlin et al. 1976). Diminished elk use of areas where cattle have grazed is probably related to season of use and grazing intensity by cattle before or during the time of elk use. Fall and winter use by elk declined significantly following cattle use in late spring and summer on pine-bunchgrass uplands near riparian zones in the Blue Mountains of Oregon (Skovlin 1984).

How much vegetation is removed in riparian habitats by big game is not well studied, but Skovlin (1984) indicated that in northeastern Oregon, deer and elk accounted for about one-third of the total browsing on riparian trees and shrubs. Cattle apparently removed the remaining two-thirds. He also reported that studies conducted near the above sites, where deferred or seasonal livestock grazing has been practiced, showed similar vegetation removal rates for big game and livestock.

Soil compaction from grazing by wild ungulates is normally not a problem in riparian zones in fall and winter, but some compaction damage of saturated or wet soils in the upland range in early spring may occur (Skovlin 1984). He also reported that shrub use by elk in early spring and summer, before grazing by domestic livestock, can significantly affect shrub survival during the ensuing growing season. Cattle browsing on the same shrubs grazed by elk could add to the shrub mortality problem.

Medium-Sized Mammals. Numerous medium-sized species of mammals are either obligate or facultative users of riparian systems at all elevations. For example, in Big Bend National Park in west Texas, 15 medium-sized species were reported using riparian ecosystems and one, the beaver (*Castor canadensis*), was a true obligate (Boeer and Schmidly 1977). Williams and Kilburn (1984) reported that of the 502 recent native species and subspecies of land mammals in California, about 25% (133 taxa) were limited to or largely depended on riparian and other types of wetland communities. They further stated that "No other general type of mammalian habitat in California approaches riparian and other wetland communities in importance to mammals. . . . " Of the 15 species they listed, 5 were in the medium-sized category. Similarly, in Mexico, seven medium-sized mammals, threatened with extinction, are confined to riparian ecosystems (Ceballos 1985).

Lack of any systematic and long-term studies of medium-sized mammals makes it difficult for managers to establish specific habitat management criteria that would ensure these species are not extirpated by water management, timber harvest, or grazing practices. As in most past management decisions, the best approach is to review natural history studies of these species and avoid eliminating habitat components that have been identified as important.

Many of these species are aquatic or semiaquatic and feed on plant and animal matter in or along the stream. Consequently, instream flows and water quality represent important habitat factors. Streamside vegetation also provides food and cover for these species, so severe vegetation removal by domestic livestock can be important. Therefore, to provide optimum conditions for these species, one must be cognizant of the specific needs for each species found in the area.

In California, five medium-sized mammal species considered obligate to riparian habitats have been recommended for special consideration (Williams and Kilburn 1984). One, the snowshoe hare (*Lepus americanus*), occurs in dense thickets of alders (*Alnus* sp.), willows, and other shrubs in the Sierra Nevada range (Orr 1940). Dense thickets of young conifers also serve as cover for this hare (Williams 1985). This species may not depend on riparian habitat in other portions of its range, which may not be unusual for some high-elevation forms.

The mountain beaver (*Aplodontia rufa*), also found along moist, forested habitats along the Pacific Slope, occurs in small colonies. It favors moist slopes, supporting lush growths of forbs, and often excavates its burrows next to a stream. Its diet includes a variety of forbs and the buds, twigs, and bark of willow and dogwood (*Cornus* sp.). It also cuts forbs to pile as hay (Grinnell and Storer 1924).

A number of medium-sized mammals use riparian ecosystems extensively although they occur in the uplands. Densities are lower in upland habitats than along riparian systems, as noted by studies of the gray fox (*Urocyon cinereoargenteus*) along Putah Creek near Davis, California (Hallbery and Trapp 1984). Two males and females with radio collars spent 76% of their nocturnal and 92% of their diurnal time in riparian habitats and the remainder in agricultural habitats. An example of the latter is exemplified in ringtails (*Bassariscus astutus*), where this species' densities range from 2.5 to 5 times greater in riparian ecosystems as opposed to upland habitats (Belluomini and Trapp 1984). Numerous other facultative riparian species obviously fit into these categories, stressing the importance of these habitats to medium-sized mammals.

The fisher (*Martes pennanti*) is poorly studied especially in the western U.S., but in general, is thought to depend on riparian habitats for travel and escape routes (de Vos 1951, 1952; Kelly 1977; Buck 1982; Mullis 1985). Of the studies conducted thus far, only Kelly (1977) has reported that the long axis of most home ranges in New Hampshire have tended to parallel drainages. Regardless, these riparian habitats are believed to be very important to this species.

In the West, fisher populations have been thought to be declining because of activities such as timber harvesting, road building, and overtrapping. In California the trapping season was closed in 1946, and in recent years these populations appear to have increased (Mullis 1985). Indications are that the marten (*M. americana*) may similarly need riparian habitats.

Beavers, once a dominant aquatic mammal in riparian systems, have virtually been eliminated in western streams through trapping, shooting, instream flow reductions, and other factors. The beaver needs streams 1 m (3 ft) or more deep, and timber for food, lodge, and dam construction. Its propensity to construct dams has frequently made it an undesirable riverine species. Although primarily preferring to live in lodges, the beaver will excavate dens in the riverbank (Nelson and Hooper 1976). Its damming activities frequently have flooded agricultural lands, forest lands, and damaged irrigation systems.

Parker et al. (1985) recently suggested that beavers might have played an important role in resisting minor perturbations in lower-order streams. Their model and arguments are not too difficult to visualize when the impact this species can have on streams and riparian trees is considered. Lang and Weider (1984) suggested that beavers have altered the structure of forests in West Virginia. Platts et al. (1985) supported the beaver model for large storm events. However, the Parker et al. (1985)

model needs further testing before it can be used as a possible management tool in resisting mild perturbations.

Scott (1984) justified the importance of beaver, mink (*Mustela vison*), and muskrat (*Ondatra zibethicus*) by examining the dollar return of these species in California. In some instances, the fur-return value of these species may represent up to 71% of an individual's annual income. In economically depressed communities this could be an important source of income.

Small Mammals. Soil texture, structure, and moisture seem to be important in habitat selection of many small mammals that burrow. Other rodents respond to riparian habitats in varying manners: sciurids respond more to tree species and height of trees; heteromyids, more to soil and open habitats; castorids, to water and forage availability; cricetids, to vegetation density and structure; and zapodidae, possibly to grass height and stem densities in moist soils.

Although identifying habitat components for all small mammals in riparian communities is far from complete, there is good evidence to demonstrate the importance of these habitats to small mammals. Cross (1985) found that riparian habitats in southwestern Oregon, composed of mixed conifer and deciduous broadleaf trees, invariably had greater species richness and total small mammal biomass than upland sites. Studies (Stamp and Ohmart 1979) in riparian habitats in the Sonoran Desert of Arizona show similar results.

Herptofauna

To our knowledge, there are no in-depth, long-term data from a riparian ecosystem at any elevation dealing with habitat factors important to an entire herptofauna. This is a serious omission in riparian studies in that reptiles and amphibians are probably as important, and possibly more so, than birds and mammals in energy flow and nutrient cycling. There are a number of autecological studies on specific species, however, which we used to delineate some of the most important habitat features for amphibians and reptiles. Until in-depth, long-term community ecology studies are conducted, we will be making many assumptions.

In the Hubbard Brook Experimental Forest in New Hampshire, Burton and Likens (1975) estimated salamander densities of 2,950/ha (1,180/a.), which exceeded density estimates of birds and mammals. Salamander biomass exceeded that of birds by 216 times and approximated that of small mammals. Similar densities of Siskiyou Mountain salamanders (*Plethodon stormi*) have been estimated at densities of 2,700/ha (1,080/a.; Nussbaum 1974) in optimum habitats in Oregon; and Murphy and Hall (1981) reported that in Oregon, the Pacific giant salamander (*Dicamptodon eusatus*) may make up as much as 99% of the total predator biomass in some streams.

Reptile densities are equally high in the West. The western pond turtle (*Clemmys marmorata*) has been reported at densities of 425/ha (170/a.; Bury 1979) and Sonoran mud turtles (*Kinosternon sonoriense*) in Arizona at 825/ha (330/a.; Hulse 1974). Southern ringnecked snakes (*Diadophis punctatus*) have been reported at densities of 1,000-1,500/ha (400-600/a.; Sullivan 1981).

In general, amphibians as a species group are more dependent on riparian ecosystems than are reptiles. Much of this revolves around their evolutionary life-style; they are aquatic or semi-aquatic and lay open eggs (nonshelled) in water or very moist areas. For aquatic species, many of the same needs of fishes would apply to these forms, e.g., shaded stream for cooler water and higher oxygen levels, productive stream bottoms, and escape cover. For more terrestrial forms, such as some salamanders, the presence of rotting logs and dense ground cover (litter or vegetation) is essential.

Because most species in this group are insectivorous and carnivorous, and most spend their active periods in shallow water, on the ground, or in trees, any action that reduces densities of trees, shrubs, or other vegetation and reduces high insect biomass has to be considered negative. On the Colorado River, actions that help birds were also considered to help this group, especially reptiles. This is probably not totally true, but revegetation sites that are primarily designed for birds and small mammals also support high populations of reptiles—higher than those found in most natural communities. Because many biologists believe that birds are nothing more than glorified reptiles, these results should not be surprising.

For some amphibians, the maintenance of backwaters with dense-to-moderate emergent stands of vegetation is essential. There should be stable levels of instream flow with good bank development stabilized with vegetation. Large, decaying logs in the floodplain and in the adjacent uplands are necessary habitat components for numerous amphibians, such as salamanders.

Many herpetile species either overwinter in the soil of the floodplain or in decaying wood under logs. Others overwinter in hibernacula in downed, decaying logs; snags; and even live trees with natural cavities or heart rot. These habitat features are important to amphibians for their overwinter survival. Loss of one or more of these critical habitat features can break the annual life cycle of a species, resulting in its local extirpation.

Another important feature of riparian habitats to amphibians and reptiles, frequently overlooked by managers, is the use of these systems as corridors for dispersal and genetic continuity between populations. Brode and Bury (1984) stressed the importance of continuous riparian ecosystems to help maintain genetic heterogeneity, and noted that habitat disruption has resulted in isolated populations of many species in California riparian habitats.

Although all the habitat components needed for species survival may be present along a stream, a population or species can be extirpated for a number of reasons: (1) their density is so low that an adequate number of matings do not occur to sustain population levels; (2) genetic drift; (3) genetic heterozygosity is not adequate to sustain a healthy population; and (4) some density-independent mortality factor eliminates the population, e.g., severe and prolonged freezing or drought. For this group, habitat continuity and patch size should be considered when making management decisions.

Habitat-Wildlife Correlations

A few years ago, MacArthur and MacArthur (1961) reported a strong correlation between eastern forest birds and FHD. Over the years, ecologists and managers have looked for one or more habitat features that highly correlated with wildlife. Bird species diversity (BSD) is identical in basic concept to FHD, but is based on the number of bird species (species richness) in the plant community and how evenly distributed the density of each species is among the total number of species. An avian community containing 15 species, where 2 or 3 make up 90% of the total birds, would have low BSD values compared with an avian community where the total bird numbers were more evenly distributed among the 15 species.

The BSD and FHD values and their relationships have not been well understood. For a brief period it was thought that the key to good management was to manage for high BSD values. The weakness of this approach becomes fairly obvious in the following example. In most habitat situations the density of rare or federally and state-listed species is low. Consequently, in the earlier example of 15 bird species in a community, the 2 or 3 species in very low density could be lost and hardly change the BSD value. Therefore, one can see the fallacy of trying to manage habitats or ecosystems based on BSD values. Keep in mind that BSD and species richness (number of species present) are very different terms and should not be used interchangeably.

Since high BSD-FHD relationships were reported by MacArthur and MacArthur (1961) in eastern forests, many studies have supported or refuted this relationship throughout North America. Many scientists collecting data have not looked at other habitat components and have been satisfied with relatively good correlations between BSD and FHD. A few other studies looked at important vegetation features, but these research results suffer from one or more of the following: lack of tight experimental design; limited data collection, such as only during the breeding season; and short-term studies, conducted for only 1 or 2 years. These are central criteria in judging the value of field data as applied to management situations. Much money, time, and effort have been and can be lost when management decisions are based on poorly conducted studies.

Many federal and state agencies have tried to reduce ecosystems to one or a few variables for management purposes. Our long-term research, plus that of others, argues persuasively that ecosystems, plant communities, and even small habitats are too complex to reduce to one or a few numbers for management purposes. We know of no shortcut approaches to good wildlife and habitat management and seriously doubt any will be found. Unless managing agencies discover this and proceed with the task at hand, which is the collection of in-depth, long-term changes in plant and animal communities, we as biologists will always be playing "catch-up biology" or patching data together along with our "gut feelings" to make important management decisions and recommendations.

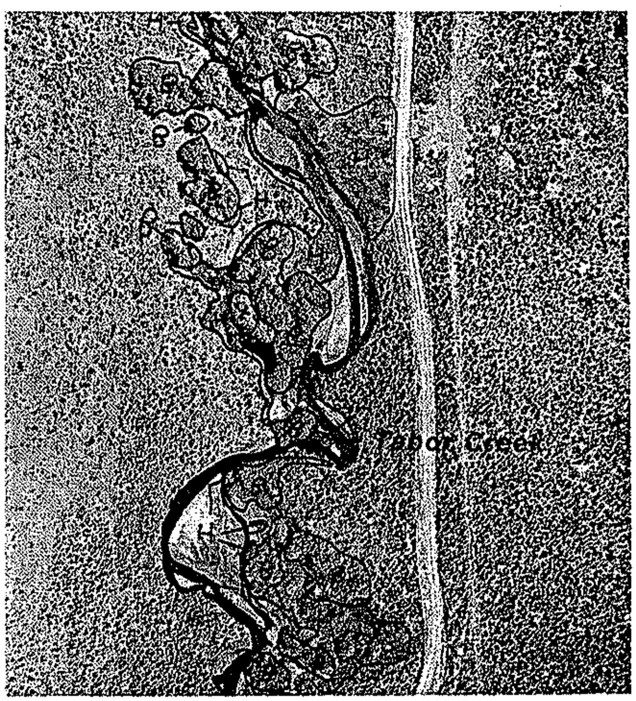
DATA COLLECTION PRIORITIES

Biologists are so frequently enthusiastic about wildlife that when presented with the opportunity to study an area, they immediately begin thinking of ways to census various classes of vertebrates, study life histories of animals, or collect fauna. Although important, highly desirable, and needed, these are probably the last steps that should be undertaken.

We have developed a list of priorities that we believe will help the land manager develop a data base on the riparian ecosystem and also document processes occurring or about to occur in the ecosystem. Since the limiting factor in any study is money, which is people, vehicles, equipment, or some other factors requiring funding, our list assumes that funds will be limited.

Developing Vegetation Maps

Develop a fine-grained map of the riparian vegetation ecosystem(s) under management consideration. By fine-grained, we mean a map depicting and naming the plant communities at a resolution of possibly 0.2 ha (0.5 a.) or less, if necessary, to show discrete plant communities. Common sense must prevail because overzealous type mapping could reduce a community to one tree, then to a limb, and to a leaf. If two tree species occur together along a stream or river, the community might be delineated as a cottonwood-willow association. Or if a tree willow grows in one area and a shrub willow grows in another, you would have Goodding willow (*Salix gooddingii*) as a separate community from coyote willow (*S. exigua*) and so forth. Because riparian systems are linear, and frequently vary in width from a few yards to many miles, maps must be scaled upward to include small communities that may support endangered wildlife species or very highly specialized species.



A large scale airphoto (1:2,400) provides a basis for mapping (B) brush, (H) herbaceous vegetation, and (X) bare ground, and (T) trees where present.

If numerous riparian ecosystems are under management consideration and funding only allows half of them to be adequately mapped or all to be superficially mapped, then we recommend prioritizing the streams and intensively mapping only half of them. Otherwise, a poor job on all of them provides little, if any, good information from which to make crucial management decisions and will probably be meaningless to future managers attempting to interpret and use the maps.

Good vegetation type maps should be accompanied by the criteria used in naming each major community. For example, if you elect to name cottonwood-willow associations based on cottonwoods being abundant to scattered in the community, this information should accompany the maps. Or you may elect to name the community as such if about 50% of the trees are cottonwoods and the other half willows. The important point is that good quantitative criteria should be established, adhered to in mapping, and always accompany the maps as legends or as an appendix. These maps will be invaluable to future managers as they attempt to assess and understand habitat changes. The probability is high that you will be transferred in a few years and the person replacing you must be able to interpret the information that you collected while working on riparian systems.

Classifying Plant Community and Structural Types

Quantify vegetation structure and tree species composition in a subset of available plant communities along the stream under management consideration. These data are important in naming communities and assessing structural configurations of vegetation. As riparian ecosystems are perturbed they tend to support less foliage volume at higher layers. For example, fires or floods tend to remove trees, reducing canopy foliage volume. Incoming shrubs or trees increase foliage volume at the herbaceous and shrub layers. Also, as man perturbs these habitats through reduction of instream flow or increased silt concentrations, the perturbations become manifested through vegetation structure as reduced foliage volumes in higher layers of vegetation or the tree canopy.

In our work with community structural types, we have used structural Type I as the mature, most structurally diverse community, and Type VI as the early stage of returning vegetation. A healthy riparian ecosystem will contain mature plant communities and structural types, intermediate types, and Type VI communities that will eventually replace old, decadent stands. In heavily grazed ecosystems, such as those along the Salt and Verde rivers in central Arizona, replacement cottonwood communities have been virtually eliminated and only mature, decadent stands remain. No replacement communities are forthcoming and remedial efforts, such as planting of cuttings, have been attempted to provide replacement cottonwood stands. Although riparian ecosystems can be revegetated more economically through natural flooding, federal agencies are supplementing regrowth through fencing and revegetation efforts to ensure riparian habitats are not lost forever.

Original type maps can be modified to show new plant communities and structural types. Your data on classification and criteria depicting structural types should be archived for subsequent use in the area.

Determining Vertebrate Species Richness and Relative Abundance (Breeding)

Determine vertebrate species richness and species composition for each plant community and structural type during the breeding season, and year-round when possible. Relative densities determined by a gradation of rare-to-common for each bird species is adequate. Small mammals can be assessed through snap trapping for three consecutive nights and expressing each species' relative values as X number of each species caught/number of trap nights (cumulative total). If small mammal trapping is undertaken, voucher specimens must be prepared and housed in a specimen collection where they are properly cared for. If certain community types are important to large mammals for feeding, thermal cover, or breeding grounds, these should be noted.

Attempt to determine relative densities of amphibians and reptiles through trap-and-release with can traps and observations. Values can be based on can-trap days, species and numbers observed per hour, or some other relative index.

Determining Vertebrate Species Richness and Relative Abundance (Winter)

Determine vertebrate species richness and species composition for each plant community and structural type in winter. These values will vary from winter to winter depending on the severity of the winter and the previous breeding success of the overwintering species. Rodents may hibernate and large mammals may move to lower elevations.

Censusing Vertebrates

Establish census lines for birds, snap-trap small mammals (make voucher specimens), and install can-trap grids for reptiles and amphibians. Bird transects must be censused no less than nine times per plant community and structural type per season. Number of census transects for birds should be in about equal proportion to the aerial extent of the community and structural types. Small-mammal trapping and can traps should also follow the same protocol.

Data should be collected for at least 2 years; 3 years is better. Seasonal and annual variation in animal numbers should be determined before realistic densities and habitat affinities can be made.

We believe if managers concentrated on priorities 1 through 3, they would be in a strong position to defend management decisions relating to domestic livestock grazing, presence or absence of endangered species, wildlife values of community and structural types, or wildlife values of areas behind proposed dams. As it is, managers often do not have enough data to demonstrate the high wildlife value of riparian ecosystems that are the most productive wildlife habitats in western North America.

EFFECTS OF LAND MANAGEMENT ACTIVITIES ON RIPARIAN SYSTEMS

Under the multiple-use concept, managers must be aware of impacts or potential impacts of ongoing activities on the riparian resource. Activities of recreationists, once considered harmless, now could be shown to have some profound effects on some vertebrate groups and plant species in the riparian zone. As with other activities, such as domestic livestock grazing and impoundments, we know many impacts can be mitigated to avoid or reduce some of the damage to riparian systems. We hope some of the activities covered in this section will help you avoid some of the major management problems or provide solutions to existing problems.

Domestic Livestock Grazing

Livestock grazing is a historic use on public lands. Overgrazing has been a problem in many areas of the West, however, and overgrazing in upland areas has caused the removal of virtually all nontoxic forage in adjacent floodplains. Reid and Pickford (1946) reported that cattle congregate and utilize riparian forage much more intensively than the vegetation of adjacent ranges. Biologists must be aware that the riparian ecosystem can potentially be much more productive for wildlife under better grazing strategies. Although other land-management activities have imposed losses or serious reductions in productivity of wildlife habitat, livestock grazing may be the major factor negatively affecting wildlife in the 11 western states (Oregon-Washington Interagency Wildlife Council 1978). We agree with Skovlin et al. (1977) that because of the highly limited area of riparian habitats in planning large pasture grazing approaches, riparian systems are sacrificed on areas of domestic livestock grazing on most state and federal land today.

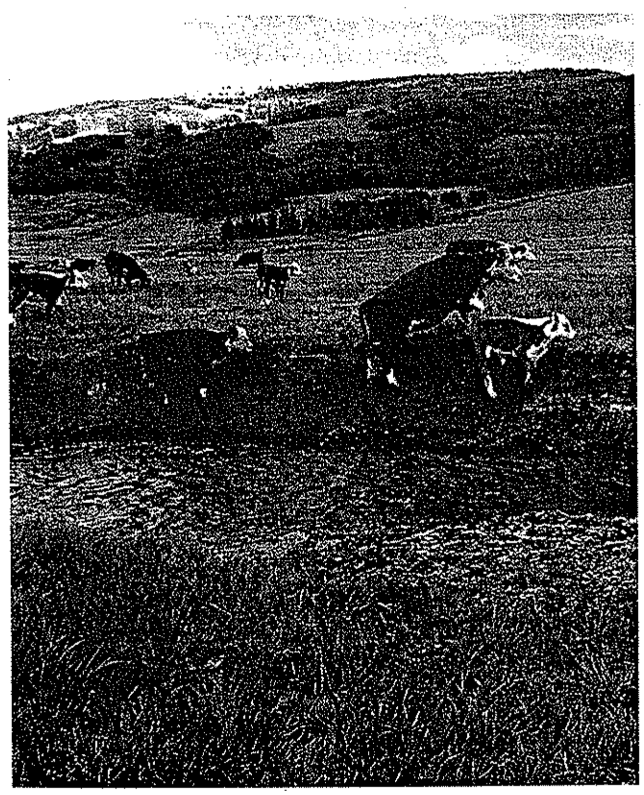
The value of these riparian systems to domestic livestock grazing (essentially the permittee) can only be appreciated through forage production values. Further, the difficulty in bringing about proper stocking levels is deeply embedded in historical and political realms. There are 1.62 million ha (4 million a.) of mountain meadows at elevations between 1,890 and 150 m (6,200 and 6,400 ft) in the 11 western states (U.S. Department of Agriculture, Forest Service 1972). These moist meadows support more beef per acre than any other range type (Skovlin 1984). In northeast Oregon, these meadows are so productive that 1 ha (2.5 a.) is equal in forage production to 10 to 15 ha (25 to 38 a.) of forested rangeland (Reid and Pickford 1946). Although only 1 to 2% of the summer range is meadow in the Pacific Northwest, it potentially produces 20% of the forage (Reid and Pickford 1946; Roath and Krueger 1982). Because of livestock concentrations, topographical constraints on livestock, and distribution of water, the forage in the riparian zone accounted for 81% of that removed by livestock in the Blue Mountain grazing allotment (Roath and Krueger 1982).

Cattle are probably attracted to the riparian ecosystem for the same reasons as other large mammals (Ames 1977; Severson and Boldt 1978). Many riparian plant species remain green and succulent longer than upland vegetation, and sedges (*Carex* sp.) contain higher sustained protein and energy content than important upland plant species (McLean et al. 1963; Skovlin 1967; Paulsen 1969).

Platts (1984) listed eight major approaches managers should consider in managing riparian-stream habitats under multiple-use systems. These range from eliminating grazing permanently or until after recovery to rehabilitating through revegetation and artificial stream structures. Most of these approaches are unacceptable to permittees today but may seem more reasonable with time or as public concern forces political action.

Two alternatives that may hold promise are changing season of forage use and changing kinds and classes of livestock. Siekert et al. (1985) reported that spring grazing showed no significant changes in channel morphology, whereas summer and fall grazing did. The level of grazing (30 cow-calf pairs on 48 ha [120 a.] for 10 days) and duration are probably unrealistic for most permittees. Further, in many riparian ecosystems, most if not all, tree seedlings would be eliminated under this approach. Marlow and Pogacnik (1985) reported that grazing of a riparian system in Montana after the streambanks had dried (< 10% soil moisture) protected the stream channel from damage. They recommended fencing riparian habitat, rest-rotation, light grazing (20% forage removal), and grazing after streambanks have dried to 10% moisture. Fencing has been ruled out by Skovlin (1984) in that it is too expensive regardless of ownership.

Stocking moderately with steers or trying different breeds might reduce damage to riparian ecosystems caused by cow-calf operations. Lactating cows with calves appear to concentrate in areas with green forage and water, whereas steers might range more into the uplands and not concentrate in riparian habitats. Neither of the above approaches will work unless stocking rates are reduced as well. Most examined riparian systems and their watersheds



Cow-and-calf herd in riparian zone.

were unquestionably overgrazed, and use of any management approach without AUM reductions appears to be a waste of time and money. Streams in overgrazed pastures are characterized by being wider and shallower; they contain more fine sediment and have more unstable banks, less bank undercut, and higher summer water temperatures (Marcuson 1977; Van Velson 1979; Platts 1979, 1984).

Large storm events and the response of riparian habitats have been of interest to biologists because of the effects of those events on riparian ecosystems (Gregory and Madew 1982; Lyons and Beschta 1983). An interesting data set has been reported for three streams under study in Nevada and Utah where historically the watersheds of these streams have been heavily grazed (Platts and Nelson 1983; Platts et al. 1983). Peak flows (2-14 times normal) occurred in Gance Creek in 1983 and 1984. Big Creek and Chimney Creek were not grazed, but Big Creek empties into Bear Creek. In 1983, flows of 3,630 cfs exceeded all recorded flows for the past 40-year records (Platts et al. 1985).

Chimney Creek had received heavy grazing until 1981 and showed little bank development. It was rested during 1982 and 1983, and the banks were developing some overhanging vegetation (Platts et al. 1985). Large decomposing aspen logs in the stream and on the banks were evidence of past forests that once lined the banks of Chimney Creek. Aspen forest return has probably been prevented by blowdown, beaver, and heavy grazing of sprouts by livestock (Platts et al. 1985). The severe floods in 1983 and 1984 straightened the meandering channel and widened the streambank, reducing the developing bank overhanging vegetation. The large aspen logs that helped hold the stream previously were decomposed or flushed from the stream by the high discharges.

The riparian vegetation along Gance Creek was dominated by large trees from the floodplain to the streambanks. Flood damage was previously vertical cutting and some lateral movement of the channel (Platts et al. 1985). Damage was minimal and the authors believed that had beavers still controlled the stream as they had done in the 1950s and 1960s, the flood damage would have been lessened.

Changes that occurred on Big Creek were most interesting because a portion of the study stream had been rested for about 10 years and was comparable to two other reaches (one above and one below the rested site) that had received normal grazing pressures. The rested section had dramatically recovered and showed good floodplain vegetation and streambank development. During the flood years, stream width in the grazed portions increased by 40% with extensive lateral stream movement and redeposition of bedload sediments. The rested section with improved streambanks was able to contain the high flows and showed only a slight increase in channel width (Platts et al. 1985). Floodplain vegetation and soils were altered dramatically in the grazed sections following the storm events, whereas the rested section showed little evidence of vegetation change or newly eroded sediments. Results from this study amplify the admonitions of Heede (1985) that managers should understand the interrelationships between vegetation and hydrologic processes in riparian ecosystems before attempting any type of management change that alters these natural systems.

The economic values of healthy riparian ecosystems and their attendant wildlife are difficult to establish (Everest 1977), but approaches have been made based solely on fisheries. Olson and Armour (1979) suggested that a hypothetical reach of 14,484 km (9,000 mi.) of depleted fishable streams on U.S. Bureau of Land Management land be set aside exclusively for recreation. Based totally on increased fishery visitor days due to restored habitat, they estimated a first-year benefit-cost ratio of 1:1.66. Or, for every $1.00 spent to fence the riparian corridor, there would be $1.66 generated by fishermen. Other values such as backpacking, camping, bird watching, erosion control, and improved water quality were not included in this economic return value.

The above approach needs further study and confirmation because, if true, the cost of fencing could be replaced by the economic return, making it a valid alternative. If fencing is not economical (Skovlin 1984), then it is entirely possible that only light or no livestock grazing of riparian systems is the ultimate answer if maximum wildlife productivity is the management goal. However, Armour (1977) quoted Harmay as stating:

> *Vegetation in meadows and drainages is closely utilized (by domestic livestock) under any stocking rate or system of grazing. Reducing the livestock or adjusting grazing season usually will not solve the problem ....*

Findings by Severson and Boldt (1978) support Harmay in that in the northern Great Plains the riparian habitats were excessively used, regardless of stocking rates. In eastern Oregon, Gillen (1981) reported that at a moderate rate, the meadows only produced 3 to 16 times more forage, again supporting the contention that regardless of stocking rate the riparian habitats will receive the greatest grazing pressures. Under continuous grazing (60-100% utilization) in Nevada and Utah, there was no evidence of riparian improvement and under present stocking rates with continuous grazing, the riparian-stream ecosystem continually deteriorated (Platts 1984).

If not limited by factors such as high salinity and no flooding, riparian habitat can recover following heavy grazing (Davis 1977; Glinski 1977; Crouch 1978). Eliminating grazing for 10-12 years may be necessary at higher elevations (2,650 m [4,800 ft]) in willow communities where grazing pressure was heavy and chronic (Knopf and Cannon 1981). Knopf and Cannon (1981) further pointed out that it is more difficult to improve a damaged riparian ecosystem by eliminating grazing than to maintain good conditions in one that is being grazed.

A number of studies have shown a dramatic increase in wildlife values where riparian systems were abused by domestic livestock grazing; the areas were fenced and monitored a number of years after domestic livestock removal. Numbers of small mammals, songbirds, and raptors increased by 350% (Winegar 1977; Duff 1979; Van Velson 1979) in an area fenced for 8 years after grazing. Game animals such as ring-necked pheasants (*Phasianus colchicus*), deer, and waterfowl increased as well (Van Velson 1979). On the South Platte River in Colorado, Crouch (1982) found more ducks, upland game, and twice as many terrestrial birds in areas fenced for 7 years compared with adjacent grazed habitats. Significant differences in bird species richness and foraging guilds have been reported between heavily grazed 2.5 cow-calf units/ha (1/a.) and lightly grazed (0.3 cow-calf units/ha (0.75/a.) riparian habitats. Total density was not significantly different indicating increases in some species that were already present and the extirpation of some species such as flycatchers, ground-foraging thrushes, and foliage-gleaning insectivores.

Small mammals are also adversely affected by domestic livestock grazing in riparian communities. Small mammal densities before and after grazing with a stocking rate of 5 to 6.25 a./AUM (2.0 to 2.5 ha/AUM) declined from 320 to 33/a. (800 to 83/ha) in a Douglas hawthorn (*Crataegus douglasii*)-dominated community, from 180 to 24/a. (450 to 60/ha) in a riparian meadow, and from 52 to 17/a. (129 to 42/ha) in a black cottonwood (*Populus trichocarpa*)-mixed conifer community. Ten months after grazing ceased, no significant difference was found between the small mammal densities in the grazed versus ungrazed plots.

Some grazing investigators have reported increased rodent species richness under moderate or heavy grazing pressures (Moulton 1978). We do not doubt some of these results but point out that small mammal species that are added or increase in numbers are usually habitat generalists whose habitat requirements are broad. Habitat specialists, such as many microtine rodents, are usually reduced or eliminated when grazing pressures are high. Under these grazing conditions, species in the genus *Peromyscus* and *Perognathus* may increase or be added because the former are generalists and the latter require more open habitat.

Moulton (1978) reported that moderate grazing (2.3 a./AUM [0.9 ha/AUM]) for 6 months in a cottonwood riparian system reduced prairie vole (*Microtus ochrogaster*) numbers and increased deer mouse (*Peromyscus maniculatus*) numbers. Eight species of small mammals were trapped in the grazed plot and four in the ungrazed control. The control site had been ungrazed for 11+ years, and the vegetation had moved toward a uniform, dense grass structure, unsuitable for a number of rodent species. Light or moderate grazing would have altered plant structure and species composition, making the habitat suitable to other rodent species.

Where grazing can be controlled in riparian habitats and seasonally light-to-moderate forage removal is practiced, the impact can be small to riparian vegetation and wildlife. But, as pointed out, by incorporating riparian areas into large pastures, these productive wildlife habitats become sacrifice areas where most, if not all, of the annual plant production is removed. As suggested by May and Davis (1982), riparian habitats should be separated and managed as distinct units.

Preliminary data on riparian populations of the wandering garter snake (*Thamnophis elegans vagrans*) on fenced (1972 and 1975) and unfenced plots on the Rio de los Vacos near Santa Fe, New Mexico, provided some interesting results (Szaro et al. 1985). The fenced plots (only cattle excluded) supported a stand (18%) of trees and shrubs composed of thin-leaf alder (*Alnus tenuifolia*), irrorata willow (*S. irrorata*), Scouler willow (*S. scouleriana*), coyote willow, and Mexican cliff-rose (*Cowania mexicana*). In contrast, 0.1% of the grazed plots supported a mixture of thin-leaf alder and irrorata willow. Herbaceous ground cover (71% versus 88%) and down and dead debris (0.4% versus 5%) was significantly ($P < 0.05$) different in grazed versus ungrazed plots, respectively. Streamside shrubs in the fenced plots filtered out debris during floods to form debris piles up to 4 m (12 ft) in diameter and 2 m (6 ft) high. These decomposing piles supported numerous worms and slugs that made up 62% and 18% of snakes' diet. Snakes were five times more abundant in the ungrazed versus the grazed plots, even though they were more difficult to find in the vegetation and debris. Other species of reptiles are undoubtedly affected by domestic livestock grazing as foliage for insects and cover for the reptiles are reduced or eliminated.

Impacts to wildlife by heavy domestic livestock grazing vary from moderate to extreme depending on whether grazing is seasonal or yearlong. Seasonal grazing may allow limited tree and shrub regeneration that provides some habitat and forage for wildlife, whereas heavy, yearlong grazing eventually leads to removal of most, if not all, of the palatable riparian vegetation. In the latter instance, forage and thermal cover for large mammals are slowly eliminated along with food and habitat for medium-sized and small mammals, birds, and herps. In seasonal heavy grazing, some forage and thermal cover may be left for large mammals, but food and cover for medium-sized and small mammals are generally eliminated. Mid-canopy and understory birds may be affected to the point of exclusion. Yearlong, heavy grazing on the Verde River in central Arizona has resulted in remaining stands of cottonwood-willow communities of structure Type I or mature communities tending toward decadence (Higgins and Ohmart 1981). Although floods produce good seedling development, these seedlings are consumed before they reach 0.6 m (2 ft) in height. Unless corrective measures are taken, in a few years the old decadent communities will expire and there will be no young replacement communities. Crouch (1978) reported a 50% reduction of cottonwoods in a grazed stream in Colorado over an 18-year period.

Birds, for example (Ohmart and Anderson 1982), are associated with four layers of vegetation on the lower Colorado River:

19 species are associated with the 7.6 m (25 ft) or taller layer,

10 species with the 4.6 to 7.6 m (15 to 20 ft) layer,

13 species with the 1.5 to 4.6 m (5 to 15 ft) layer, and

11 species with the 0.15 to 1.5 m (0.5 to 5 ft) layer.

The overstory or canopy group (19 species) are specialists and were absent or poorly represented when this layer was absent or foliage density highly reduced. The 23 species in the two middle layers and some of the 11 species in the understory group were generalists. Some of these species will be present even when their foliage layer is absent or poorly represented. Heavy grazing not only affects the herbaceous and shrub layers, but over time affects the upper canopy layers as riparian tree regeneration is stopped or curtailed.

Domestic livestock grazing in riparian habitats may be used as a management tool to enhance areas for wildlife. This approach has potential, but one would have to know more about the wildlife and its habitat needs than presently known or would have to experiment with different levels of forage removal to bring about the desired wildlife results. Moulton (1978) suggested that grazing in a riparian area in eastern Colorado may increase rodent species numbers by creating microhabitat diversity. He found eight species of small mammals in a grazed plot (2.3 a./AUM [0.9 ha/AUM]) and four species in the ungrazed plot. The grazed area had been stocked from July through December with spring use deferred for 17 years. This type of seasonal grazing, after maximum spring plant growth, allowed livestock selection of preferred species creating a patchy microhabitat. The ungrazed plot (11 or more years of rest) promoted a uniform vegetation structure without any horizontal patchiness. Prairie vole numbers were higher in the protected site but not excluded in the grazed site.

Colorado Chapter, The Wildlife Society

Prairie vole.

Another possible use of cattle grazing as a management tool has been reported by Krueger and Anderson (1985) in dense shrub-willow communities at high elevations on the North Platte drainage in Wyoming. Apparently, fish populations are not harmed by this activity, at least on the Little Deschutes River in Oregon (Lorz 1974), but this was not examined in the study by Krueger and Anderson (1985). Tunnels created by cattle grazing through the dense shrub-willow altered plant community structure, creating a more diverse set of ecological conditions for birds. Many species respond positively to this treatment except for the green-tailed towee (*Pipilo chlorurus*), which inhabits dense stands of vegetation.

These management tools need to be examined carefully to ensure that wildlife species targeted for enhancement receive the benefits. Domestic livestock grazing is so entrenched on public land that we doubt that use of domestic livestock grazing will become an important management tool in many ecological situations. First, we must reverse the general downward trend in riparian vegetation conditions before cattle are needed as a management tool on a broad basis. Fish habitat appears to be more sensitive to livestock grazing impacts than terrestrial habitats.

Mining

Mining can have profound effects on riparian ecosystems ranging from total sterility of the riparian system to intermittent effects following heavy precipitation. The effects vary in areas in the West and depend on the mineral(s) being mined. In the arid Southwest, the material is frequently sand and gravel; removal of these products has caused extensive channel cutting, reduced water quality, and even flooding and loss of homes. Ruptured holding ponds of leached materials from copper mines has resulted in virtually permanent losses of the flora and fauna in some streams.

Little advice other than extreme caution and a full knowledge of the mining operation, proximity of potential toxins to the stream, safeguards to avoid pollutants, and good common sense must reign in this situation. Also, be aware of potential and real secondary impacts.

An excellent approach is to inventory the resource intensively before any mining disturbance, including seasonal water quality samples (have a control stream if at all possible), and then monitor every 3-5 years thereafter. The control will provide normal variance data and a comparison should litigation ever occur.

Recreational Activities

Recreational activity and its effects on wildlife can range from relatively minor to so severe that virtually all the vegetation is destroyed locally. In many instances, the agency developing the recreational opportunities in riparian habitats builds roads through the habitats allowing vehicles total access to the recreational area. Consequently, users drive off the roads, camp at random, and many assume an attitude of "destroy anything you want, we won't ever return." Wood gathering for firewood consumes down and dead trees, limbs, snags, and many times standing live trees. Many forms of wildlife leave the area and others, such as lizards, snakes, frogs, and salamanders, are destroyed by children and pets.

The impacts of recreational use are poorly documented, but simply by viewing some recreational areas one is left with the impression that only the heartiest and persistent wildlife are left. Aitchison (1977) studied bird densities and species composition in a seasonal-use campground in Oak Creek Canyon in Arizona for 3 years. His control and recreational site primarily supported ponderosa pine (*Pinus ponderosa*), cottonwoods, and Arizona walnut at a 1,646-m (5,400-ft) elevation. The campground was opened from about Memorial Day to Labor Day each year which spans the bird breeding season. In the first year of study (first year the developed campground opened), there was a 40% decrease in bird density on opening day. Agency personnel destroyed 20% of the nests of the Steller's jay (*Cyanocitta stelleri*) by removing and slashing trees. Aitchison (1977:178) reported: "Campers destroyed 30 percent more of the Steller's jay nests and 20 percent of the robin (*Turdus migratorius*) nests by removing branches for firewood, making room for tents, and other reasons." Many species abandoned their nests but foraged in the campground area. Ultimately, bird species remaining in the campground were larger, different, and fewer than on the control site.

In highly stressed riparian systems, trailer park development can be positive to wildlife, especially birds, as was exemplified in one of our studies. Along the Colorado River, the cottonwood-willow association is rapidly disappearing and a wise developer planted native trees in the park for better tree survival and growth, and to attract birds for the enjoyment of the residents. This small oasis supports a few pairs of birds that were once common along the lower river (Grinnell 1914), but are now rapidly approaching extirpation (Anderson and Ohmart 1977). This type of action should be encouraged in developments where trees will be protected, but managers must plan for these developments.

Riparian systems are very attractive to recreationists in that the systems contain water, interesting plants and animals, shade, and numerous other enjoyable features in the otherwise arid and semiarid environments. Hoover et al. (1985) reported in a visitor information study that environmental attributes receiving highest user ratings were primarily ecological features present in healthy riparian ecosystems. Managers should educate the public of the fragile nature and unique values of these systems. This may seem impossible, but there are some guidelines available such as the Recreational Carrying Capacity in the California Desert (U.S. Department of the Interior, Bureau of Land Management 1978) and the California Desert Area Conservation Plan (U.S. Department of the Interior, Bureau of Land Management 1980).

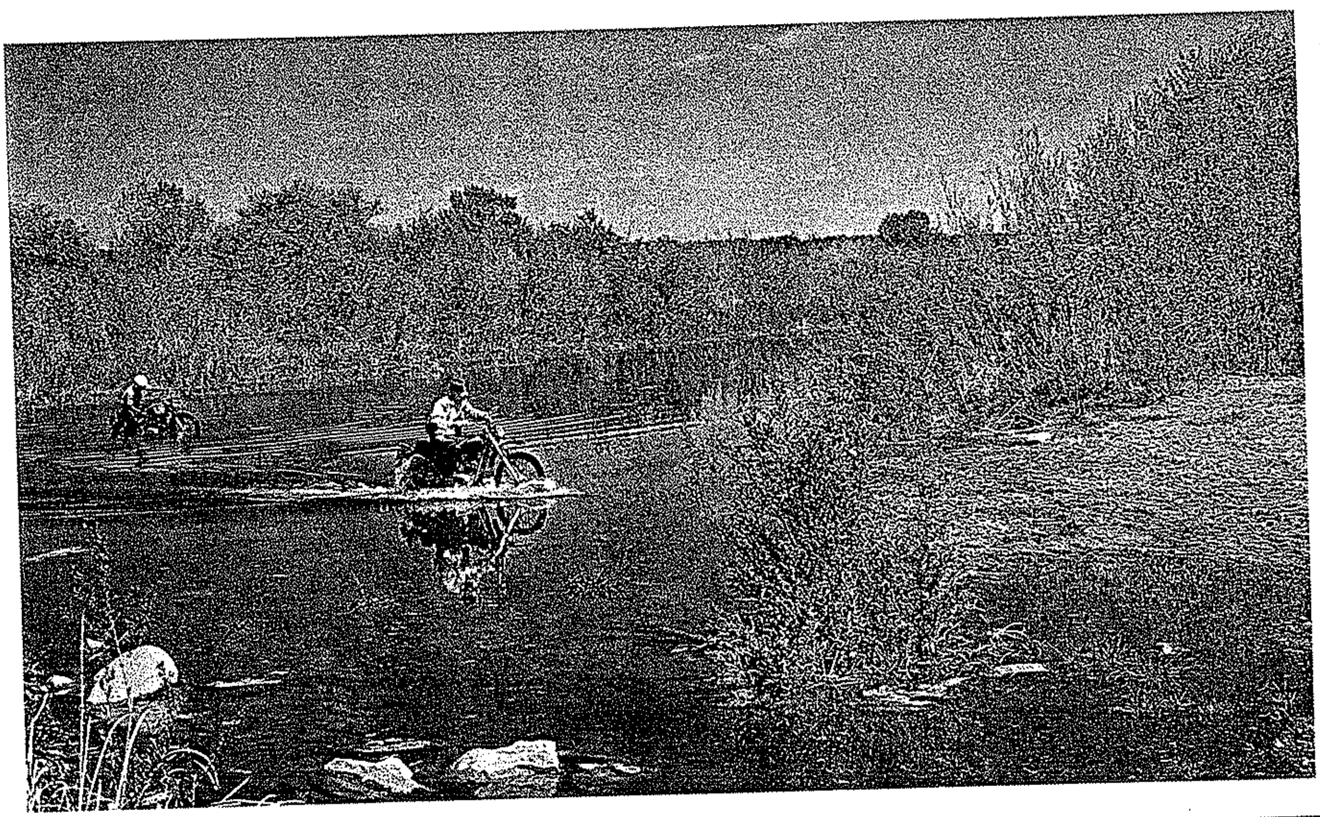
Martin (1984) provided an excellent approach in using recreation planning to restore and protect riparian systems. He recommended ways to control visitor use subtly and directly in an intensively used riparian system replete with wildlife values, water recreation, and large metropolitan areas nearby on the American River in California. Approaches and successes in the California State Park System (Barry 1984) and potential problems and questions in the proposed wildlife enhancement and recreational development at Oristimba Creek in California (Morris 1984) may also be helpful in better planning. If new campgrounds are absolutely necessary, Aitchison's (1977) suggestions may apply: locate new campgrounds in nonsensitive areas, periodically close to the campground to allow revegetation and reduce stress on wildlife; open the campground before or after the height of the breeding season; control visitors and agency habitat destruction; and educate the public through signs showing good camping procedures. We might add to disallow collection of wood for any reason.

Impoundment Construction

Impoundments are constructed for a number of reasons and some are multiple-use structures. Generally, each has regulations that outline its purpose and function such as flood control, hydroelectric power, and water storage for agriculture or municipalities. During construction, roads are built, recreational facilities may be installed, and numerous other secondary impacts to wildlife may occur, along with the eventual inundation of the vegetation in the storage reservoirs. In some instances, the secondary impacts of reservoirs to wildlife can equal or exceed primary impacts.

Reservoirs. Depending on how rapidly water surface levels fluctuate behind reservoirs, there may be a potential for productive wildlife habitats to develop. Rapidly and wildly fluctuating water levels are not conducive to the development of emergent plant communities such as cattails (*Typha* sp.) and bulrushes (*Scirpus* sp.). These types of reservoirs develop a "bathtub ring" for a shoreline where only annual plants grow and perennials are drowned. Reservoirs with slow fluctuating water levels generally develop good emergent plant communities that support animals such as muskrat, beaver, rails, and gallinules. Waterfowl tend to more heavily use reservoirs that have an abundance of emergent vegetation that provides cover and greater foraging opportunities. Reservoirs with rapidly fluctuating shorelines tend to attract only a few diving ducks.

Downstream. The wildlife value of areas below reservoirs tends to degrade slowly over the years. Generally, instream flows are lower than natural flows. Natural floods that provide new soil deposition and enrichment are stopped, and riparian plant health and vigor slowly decline. If controlled releases from the dam or floods do occur, they are generally greater than would have occurred without the dam, and the health of the riparian system may have degraded to a point that is no longer resilient to a heavy flood.



Recreational activities can affect riparian areas.

Another problem tends to occur below dams where instream flows are highly regulated and cessation of natural floods prevent leaching and soil rejuvenation. Total Dissolved Solids (TDS) tend to increase in areas where the water table is near the soil surface. If the stream carries high TDS loads, the process is relatively rapid and the TDS are wicked to the soil surface where they accumulate as the soil moisture evaporates. Sodium or salt levels eventually accumulate to a point that most native species, except halophytes (salt-tolerant plants), cannot germinate or survive. Natural floods generally leached and removed these deposits, and new soils were deposited in low areas.

In some situations below dams the riverbed is essentially dewatered until another major perennial tributary enters. The Salt and Gila rivers in central Arizona and the Rio Grande from about El Paso to Presidio, Texas, are classic examples. Water returning to these dry reaches is in one of two forms: agricultural waste waters high in chemicals and salts or impoundment releases because reservoirs are near or at capacity. Agriculture waste waters generally poison productive riparian vegetation and create conditions that favor growth of less desirable trees or shrubs. These waters seldom flow in the original channel and eventually the channel is obliterated.

During high rainfall years, releases from upstream dams must occur, and the dense, low-growing trees and shrubs that cover the floodplain and block the channel form a living dam that spreads the released water laterally to inundate everything in the floodplain. Floodwaters drain slowly (generally taking months) and frequently relict, productive native plant communities drown.

Logging and Roads

We stated earlier that riparian ecosystems can be and are affected by any major perturbation, whether it be natural (fire, storms) or man-made (logging, roadbuilding, or grazing). Therefore, management must consider all disturbances that could potentially or actually affect riparian ecosystems. Productive fisheries can be lost to high stream sediment loads, to stream channel and streamside vegetation destruction by floods following abuse of watersheds, and to perennial streams becoming intermittent because of continued abuse of watersheds.

Logging and roadbuilding on the watersheds and near riparian systems destroy the natural ground cover and churn and mix the soil to produce transportable sediment. Sediment entering a stream comes from both natural and man-made activities and its rate of passage varies depending on slope, size of area disturbed, severity of disturbance, kind and type of streamside vegetation to stabilize the transported materials, instream sediment traps, and the periodicity and duration of large streams. Dunn and Leopold (1978) estimated that 5 or more years are needed for a transportable sediment load to totally pass through a stream system. Mahoney and Erman (1984) reported that the sediment load currently moving through any stream is the product of past years' land-use activity and major storms.

Leaving buffer strips near riparian vegetation is apparently successful. Aubertin and Patric (1974) studied a 34-ha (14-a.) clearcut in West Virginia and reported only slight increases in stream turbidity following timber harvest. They attributed the success to leaving a 10 to 20-m (33 to 66-ft) forested strip adjacent to the riparian vegetation. Moring (1975) demonstrated similar results in his 15-year study in Oregon. He showed a 3.8-fold reduction in suspended stream sediments in the clearcut with a buffer strip versus a clearcut without the buffer strip.

A large study on streams in northern California examined macroinvertebrate changes relative to logging with buffered and unbuffered strips (Erman et al. 1977; Ruby et al. 1977; Newbold et al. 1980). Where buffer strips were > 30 m (> 98 ft) on logged sites, there were no differences between invertebrate populations in experimentals and controls. Where buffer strips were less, differences of invertebrate populations were detectable between experimentals and controls.

Buffer strips also reduce pollutants and other chemical substances from surface runoff (Young et al. 1980). Karr and Schlosser (1977) extensively reviewed literature on the value of near-stream vegetation on water quality and stream biology and should be consulted for more in-depth coverage.

Not only are buffer strips effective in reducing physical and, ultimately, biological damage to lower animals, they also protect small mammals from intensive logging operations (Cross 1985). Where buffer or leave strips varying from 12 to 70 m (39 to 230 ft) wide were retained, those remaining habitats supported small mammal communities comparable to undisturbed sites. These studies were conducted in southwestern Oregon in mixed-coniferous riparian vegetation. Harris (1984) suggested maintaining riparian corridors as a means of connecting forest habitat islands in similar stands of old-growth Douglas fir (*Pseudotsuga menziesii*).

Riparian Ground-water Withdrawals

Ground-water pumping may become the most serious threat to North American riparian systems. Water diversions and reduced instream flows can be devastating to riparian habitats, but pumping of riparian ground waters for industrial and municipal development will totally annihilate most, if not all, riparian plant species. Extensive mesquite bosques were killed around Casa Grande Ruins or the Casa Grande National Monument by ground-water pumping in central Arizona (Judd et al. 1971). The water table has receded at 2+ m (7+ ft) per year which, in turn, resulted in the death of this large mesquite forest.

Long-term vegetation changes are well documented by aerial photography for a 3.2-km (2-mi.) reach of the Carmel River near the Monterey Peninsula in California (Groeneveld and Griepentrog 1985). Time-series documentation for a 24-year period (1956-80) conclusively demonstrated a marked decline in riparian trees such as red willow (*S. laevigata*), black cottonwood (*P. trichocarpa*), California sycamore (*Platanus racemosa*), and white alder (*Alnus rhombifolia*). Along with reduced riparian plant cover was an invasion of weedy perennials, annuals, and xerophylic (arid-adapted) shrubs. The riverbanks have become noticeably eroded due to increased channel width.

Groeneveld and Griepentrog (1985) cited other unpublished studies where lowering of the water table by pumping had caused ecological change. This is a real and final threat to many riparian ecosystems in the West. The U.S. Geological Survey is currently studying the effects of ground-water withdrawal on native riparian species along the Owens River south of Bishop, California (Dileanis et al. 1985). Unfortunately, no tree species were involved in the study, but data for Nevada saltbush (*Atriplex torreyi*) and rubber rabbitbush (*Chrysothamnus nauseosus*) may provide insight into how sensitive obligate-riparian species are to gradual and drastic declines of the water table.

LITERATURE CITED

AITCHISON, S.W. 1977. Some effects of a campground on breeding birds in Arizona. Pages 175-182 *in* Johnson, R.R. and D.A. Jones, tech. coords. Importance, Preservation and Management of Riparian Habitat: A Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-43. 217pp.

ALMAND, J.D. and W.B. KROHN. 1978. The position of the Bureau of Land Management on the protection and management of riparian ecosystems. Pages 359-361 *in* Johnson, R.R. and J.F. McCormick, tech. coords. Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems: Proc. of the Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. WO-12., Washington, DC. 410pp.

AMES, C.R. 1977. Wildlife conflicts in riparian management: grazing. Pages 49-51 *in* Johnson, R.R. and D.A. Jones, tech. coords. Importance, Preservation and Management of Riparian Habitat: A Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-43. 217pp.

ANDERSON, B.W. and R.D. OHMART. 1977. Breeding bird use of a residential development. Pages 196-201 *in* Annual Report, submitted to U.S. Dep. Inter., Bureau of Reclamation, Boulder City, NV.

——— and ———, 1978. *Phainopepla* utilization of honey mesquite forests in the Colorado River valley. Condor 80:334-338.

——— and ———, 1984. Vegetation management study for the enhancement of wildlife along the lower Colorado River. U.S. Dep. Inter., Bur. of Rec., Boulder City, NV.

———,———, and W.C. HUNTER. 1983. Quantifying variables for classifying desert riparian vegetation. Pages 32-44 *in* Moir, W.H. and L. Hendzel, tech. coords., Proc. of the Workshop on Southwestern Habitat Types. U.S. Dep. Agric., For. Serv., Southwest Reg., Albuquerque, NM.

ARMOUR, C.L. 1977. Effects of deteriorated range streams on trout. U.S. Dep. Inter., Bur. Land Manage., Idaho State Off., Boise. 7pp.

ASMUSSEN, L.E., A.W. WHITE, Jr., E.W. HANSON, and J.M. SHERIDAN. 1977. Reduction of 2,4-d load in surface runoff down a grassed waterway. J. Environ. Qual. 6:159-162.

AUBERTIN, G.M. and J.H. PATRIC. 1974. Water quality after clearcutting in a small watershed in West Virginia. J. Environ. Qual. 3:243-249.

AXELROD, D.I. 1958. Evolution of the Madro-Tertiary geoflora. Bot. Rev. 24:433-509.

BALDA, R. 1975. The relationship of secondary cavity nesters to snag densities in western coniferous forests. U.S. Dep. Agric., For. Serv., Southwest Reg., Wildl. Habitat Tech. Bull. 1, Albuquerque, NM. 37pp.

BARRY, W.J. 1984. Management and protection of riparian ecosystems in the state park system. Pages 758-766 *in* Warner, R.E. and K.M. Hendrix, eds. California Riparian Systems: Ecology, Conservation, and Productive Management. Univ. California Press, Berkeley. 1035pp.

BELLUOMINI, L. and G. TRAPP. 1984. Ringtail distribution and abundance in the Central Valley of California. Pages 906-914 *in* Warner, R.E. and K.M. Hendrix, eds. California Riparian Systems: Ecology, Conservation, and Productive Management. Univ. California Press, Berkeley. 1035pp.

BENOIT, C. 1978. Fluvial sediment delivery as percent of erosion: The relationship between landslope and effective streamside bufferstrip width. U.S. Dep. Agric., For. Serv., Portland, OR. (typescript)

BLACK, N., R.J. SCHERZINGER, and J.W. THOMAS. 1976. Relationship of Rocky Mountain elk and Rocky Mountain mule deer to timber management in the Blue Mountains of Oregon and Washington. Pages 11-31 *in* Hieb, S.R., ed. Proc. Elk-Logging-Roads Symposium, Univ. Idaho, Moscow. 142pp.

BLOOD, D.A. 1966. Range relationships of elk and cattle in Riding Mountain National Park, Manitoba. Canadian Wildl. Serv., Wildl. Manage. Bull. Ser. 1, 19. 62pp.

BOCK, J.H. and C.E. BOCK. 1985. Patterns of reproduction in Wright's sycamore. Pages 493-494 *in* Johnson, R.R., C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.

BOEER, W.J. and D.J. SCHMIDLY. 1977. Terrestrial mammals of the riparian corridor in Big Bend National Park. Pages 212-217 *in* Johnson, R.R and D.A. Jones, eds. Importance, Preservation and Management of Riparian Habitat: A Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-43. 217pp.

BRADY, W., D.R. PATTON, and J. PAXSON. 1985. The development of southwestern riparian gallery forests. Pages 39-43 *in* Johnson, R.R., C.D. Ziebell, D.R. Patton, R.F. Ffolliott, and R.H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.

BRODE, J.M. and R.B. BURY. 1984. The importance of riparian systems to amphibians and reptiles. Pages 30-36 *in* Warner, R.E. and K.M. Hendrix, eds. California Riparian Systems: Ecology, Conservation, and Productive Management. Univ. California Press, Berkeley. 1035pp.

BROWN, D.E., C.H. LOWE, and C.P. PASE. 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the Southwest. J. Arizona-Nevada Acad. Sci. 14 (Suppl. 1):1-16.

BRUSH, T., B.W. ANDERSON, and R.D. OHMART. 1983. Habitat selection related to resource availability among cavity-nesting birds. Pages 88-89 *in* Davis, J.W., G.A. Goodwin, and R.A. Ockenfels, tech. coords. Snag Habitat Management: Proc. Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-99. 226pp.

BUCK, S.G. 1982. Habitat utilization by fisher near Big Bear, California. M.S. Thesis, Humboldt State Univ., Arcata, CA. 178pp.

BULL, E.L. and J.N. SKOVLEN. 1982. Relationships between anifauna and streamside vegetation. Trans. North. Am. Wildl. Nat. Resour. Conf. 47:496-506.

BURBRIDGE, W.R. and D.J. NEFF. 1976. Coconino National Forest—Arizona Game and Fish Department cooperative roads—wildlife study. Pages 44-57 *in* Hieb, S.R., ed. Proc. Elk-Logging-Roads Symposium, Univ. Idaho, Moscow.

BURTON, T.M. and G.E. LIKENS. 1975. Salamander population and biomass in the Hubbard Brook experimental forest, New Hampshire. Copeia 1975:541-546.

BURY, R.B. 1979. Population ecology of freshwater turtles *in* Harless, M. and H. Morlock, eds. Turtles: Prospectives and Research. John Wiley & Sons, Inc., New York, NY. 695pp.

CAROTHERS, S.W., R.R. JOHNSON, and S.W. AITCHISON. 1974. Population structure and social organization of southwestern riparian birds. Am. Zool. 14:97-108.

CEBALLOS, G. 1985. The importance of riparian habitats for the conservation of endangered mammals in Mexico. Pages 96-100 *in* Johnson, R.R, C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.

CHAIMSON, J.F. 1984. Riparian vegetation planting for flood control. Pages 120-123 *in* Warner, R.E. and K.M. Hendrix, eds. California Riparian Systems: Ecology, Conservation, and Productive management. Univ. California Press, Berkeley. 1035pp.

CONNOR, R.N., R.G. HOOPER, H.S. CRAWFORD, and H.S. MOSBY. 1975. Woodpecker nesting habitat in cut and uncut woodlands in Virginia. J. Wildl. Manage. 39:144-150.

CORBETT, E.S. and J.A. LYNCH. 1985. Management of streamside zones on municipal watersheds. Pages 187-190 *in* Johnson, R.R., C.D. Ziebell, D.R. Patton, R.F. Ffolliott, and R.H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.

CROSS, S.P. 1985. Responses of small mammals to forest riparian perturbations. Pages 269-275 *in* Johnson, R.R., C.D. Ziebell, D.R. Patton, R.F. Ffolliott, and R.H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.

CROUCH, G.L. 1978. Effects of protection from livestock grazing on a bottomland wildlife habitat in northeastern Colorado. Pages 118-125 *in* Graul, W.D. and S.J. Bissell, tech. coords. Lowland River and Stream Habitat in Colorado: A Symposium. Colorado Chap. Wildl. Soc. and Colorado Audubon Council. 195pp.

———. 1982. Wildlife on ungrazed and grazed bottomlands on the South Platte River in northeastern Colorado. Pages 186-197 *in* Wildlife-Livestock Relationships Symposium. Proc. 10, Univ. Idaho, For. Wildl. Range Exper. Sta., Moscow, ID.

CUMMINS, K.W. 1974. Structure and function of stream ecosystems. BioScience 24:631-641.

DAVIS, G.A. 1977. Management alternatives for the riparian habitat in the Southwest. Pages 59-67 *in* Johnson, R.R. and D.A. Jones, tech. coords. Importance, Preservation and Management of Riparian Habitat: A Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-43. 217pp.

DAVIS, J.W., G.A. GOODWIN, and R.A. OCKENFELS, tech. coords. 1983. Snag habitat management: Proc. of the Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-99. 226pp.

DEALY, J.E., D.A. LECKENBY, and D.M. CONCANNON. 1981. Plant communities and their importance to wildlife. Pages 1-66 *in* Wildlife Habitats in Managed Rangelands—The Great Basin of Southeast Oregon. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. PNW-120.

DE VOS, A. 1951. Recent findings in fisher and marten ecology and management. Trans. 16th North American Wildl. Conf. 16:498-507.

———. 1952. Ecology and management of fisher and marten in Ontario. Ontario Dep. Lands For. Tech. Bull. 90pp.

DICKSON, J.G., R.N. CONNER, and J.H. WILLIAMSON. 1983. Snag retention increases birds in a clearcut. J. Wildl. Manage. 47:799-809.

DILEANIS, P.D., F.A. BRANSON, and S.K. SORENSON. 1985. Methods for determining effects of controlled dewatering of shallow aquifers on desert phreatophytes in Owens Valley, California. Pages 197-200 *in* Johnson, R.R., C.D. Ziebell, D.R. Patton, R.F. Ffolliott, and R.H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.

DUFF, D.A. 1979. Riparian habitat recovery on Big Creek, Rich County, Utah. Pages 91-92 *in* Proceedings of the Forum—Grazing and Riparian/Stream Ecosystems. Trout Unlimited, Inc. Vienna, VA. 94pp.

DUNN, T. and L.B. LEOPOLD. 1978. Water in environmental planning. W.H. Freeman Co., San Francisco, CA. 818pp.

ENGEL-WILSON, R.W. and R.D. OHMART. 1978. Floral and attendant faunal changes on the lower Rio Grande between Fort Quitman and Presidio, Texas. Pages 139-147 *in* Johnson, R.R. and J.F. McCormick, tech. coords. Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems. Proc. of the Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. WO-12. 410pp.

ERMAN, D.C., J.D. NEWBOLD, and K.R. RUBY. 1977. Evaluation of streamside bufferstrips for protecting aquatic organisms. Contr. 165, California Water Resour. Center, Univ. California, Davis. 48pp.

EVANS, K.E. and R.N. CONNOR. 1979. Snag management. Pages 214-225 *in* DeGraff, R.M. and K.E. Evans, compilers. Management of North-Central and Northeastern Forests for Nongame Birds. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. NC-51.

EVEREST, F.H. 1977. How to demonstrate the importance of fishery resources to interdisciplinary planning teams. Fisheries 4:15-19.

GAINES, D. 1977. The valley riparian forests of California: Their importance to bird populations. Pages 57-85 *in* Sands, A., ed. Riparian Forests in California: Their Ecology and Conservation. Inst. Ecology, Univ. California, Davis. 122pp.

GILLEN, R. 1981. 1980 progress report to U.S. Forest Service Pacific Northwest Forest and Range Experiment Station. Under Coop. Aid Program 218, PNW Suppl. 218. Oregon State Univ., Corvallis. 10pp.

GLINSKI, R.L. 1977. Regeneration and distribution of sycamore and cottonwood trees along Sonoita Creek, Santa Cruz County, Arizona. Pages 116-123 *in* Johnson, R.R. and D.A. Jones, tech. coords. Importance, Preservation and Management of Riparian Habitat: A Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-43. 217pp.

GREGORY, K.J. and J.R. MADEW. 1982. Land use changes, flood frequency and channel adjustment. Pages 757-781 *in* Hey, R.D., J.C. Bathurst, and C.R. Thorne, eds. Gravel-bed. John Wiley & Sons, New York, NY.

GRINNELL, J. 1914. An account of the mammals and birds of the lower Colorado Valley with special reference to the distributional problems presented. Univ. California Publ. Zool. 12:51-294.

——— and T.I. STORER. 1924. Animal life in the Yosemite. Univ. California Press, Berkeley. 952pp.
GROENEVELD, D.P. and T.E. GRIEPENTROG. 1985. Interdependence of groundwater, riparian vegetation, and streambank stability: A case study. Pages 44-48 *in* Johnson, R.R., C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.
GRUBB, T.C., Jr., D.R. PETIT, and D.L. KRUSAC. 1983. Artificial trees for primary cavity nesters. Pages 151-154 *in* Davis, J.W., G.A. Goodwin, and R.A. Ockenfels, tech. coords. Snag Habitat Management: Proceedings of the Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-99. 226pp.
HAAPANEN, A. 1965. Bird fauna of the Finnish forests in relation to forest succession. I. Ann. Zool. Fenn. 2:153-196.
HALLBERY, D.L. and G.R. TRAPP. 1984. Gray fox temporal and spatial activity in a riparian/agricultural zone in California's Central Valley. Pages 920-928 *in* Warner, R.E. and K.M. Hendrix, eds. California Riparian Systems: Ecology, Conservation, and Productive Management. Univ. California Press, Berkeley. 1035pp.
HARRIS, L.D. 1984. The fragmented forest—island biogeography theory and the preservation of biotic diversity. Univ. Chicago Press, Chicago, IL. 211pp.
HAUPT, H.F. 1959. A method for controlling sediment from logging roads. U.S. Dep. Agric., For. Serv. Intermountain For. Range Exp. Sta., Misc. Paper 22, Ogden, UT. 22pp.
HEEDE, B. 1985. Interactions between streamside vegetation and stream dynamics. Pages 54-58 *in* Johnson, R.R., C.D. Ziebell, D.R. Patton, R.F. Ffolliott, and R.H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.
HEHNKE, M. and C.P. STONE. 1978. Value of riparian vegetation to avian populations along the Sacramento River system. Pages 228-235 *in* Johnson, R.R. and J.F. McCormick, tech. coords. Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems: Proc. of the Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. WO-12., Washington, DC. 410pp.
HIGGINS, A.E. and R.D. OHMART. 1981. Riparian habitat analysis: Tonto National Forest. U.S. Dep. Agric., For. Serv., Tonto Natl. For., Phoenix, AZ.
HINK, V. and R.D. OHMART. 1984. Middle Rio Grande biological survey final report. U.S. Army Corps of Engineers, Albuquerque, NM.
HOOVER, S.L., D.A. KING, and W.J. MATTER. 1985. A wilderness riparian environment: Visitor satisfaction, perceptions, reality, and management. Pages 223-226 *in* Johnson, R.R., C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.
HUBBARD, J.P. 1971. The summer birds of the Gila Valley, New Mexico. Nemouria 2. 35pp.
HULSE, A.C. 1974. An autoecological study of *Kinosternon soroniense* LeConte (Chelonia: Kinosternidae). PhD dissertation, Dep. Zool., Arizona State University, Tempe. 105pp.
JOHNSON, R.R. 1978. The lower Colorado River: A western system. Pages 41-55 *in* Johnson, R.R. and J.F. McCormick, tech. coords. Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems: Proc. of the Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. WO-12., Washington, DC. 410pp.
——— and S.W. CAROTHERS. 1981. Southwestern riparian habitats and recreation: Interrelationships and impacts in the Rocky Mountain region. Eisenhower Consortium Bulletin. U.S. Dep. Agric., For. Serv. Rocky Mountain For. Range Exp. Sta., Fort Collins, CO.
——— and D.A. JONES, tech. coords. 1977. Importance, preservation and management of riparian habitat: A symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-43. 217pp.
——— and J.F. MCCORMICK, tech. coords. 1978. Strategies for protection and management of floodplain wetlands and other riparian ecosystems. Proc. Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. WO-12. 410pp.
———, C.D. ZIEBELL, D.R. PATTON, P.F. FFOLLIOTT, and R.H. HAMRE, tech. coords. 1985. Riparian ecosystems and their management: reconciling conflicting uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.
JUDD, J.B., J.M. LAUGHLIN, H.R. GUENTHER, and R. HANDERGRADE. 1971. The lethal decline of mesquite on the Casa Grande National Monument. Great Basin Nat. 31:153-159.
KARR, J.R. and I.J. SCHLOSSER. 1977. Impact of near-stream vegetation and stream morphology on water quality and stream biota. Env. Res. Lab. EPA-600/3-77-097, U.S. EPA, Athens, GA. 91pp.
——— and ———. 1978. Water resources and the land-water interface. Science 201:229-234.
KELLERT, S.R. 1980. What do North Americans expect of wildlife management agencies? Proc. 70th Meeting Int. Assoc. Fish. and Wildl. agencies, Washington, DC. 9pp.
KELLY, G.M. 1977. Fisher (*Martes pennanti*) biology in the White Mountains National Forest and adjacent areas. Ph.D. dissertation, Univ. Massachusetts, Amherst. 178pp.
KENNEDY, C.E. 1977. Wildlife conflicts in riparian management: grazing. Pages 49-51 *in* Johnson, R.R. and D.A. Jones, tech. coords. Importance, Preservation and Management of Riparian Habitat: A Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-43. 217pp.
KNIGHT, A.W. and R.L. BOTTORFF. 1984. The importance of riparian vegetation to stream ecosystems. Pages 160-167 *in* Warner, R.E. and K.M. Hendrix, eds. California Riparian Systems: Ecology, Conservation, and Productive Management. Univ. California Press, Berkeley. 1035pp.
KNOPF, F.L. 1985. Significance of riparian vegetation to breeding birds across an altitudinal cline. Pages 105-111 *in* Johnson, R.R., C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.
——— and R.W. CANNON. 1981. Structural resilience of a willow riparian community to change in grazing practices *in* Peek, J., ed. Livestock-Wildlife Relationships

Symposium. Univ. Idaho, Moscow.
KRUEGER, H.O. and S.H. ANDERSON. 1985. The use of cattle as a management tool for wildlife in shrub-willow riparian systems. Pages 300-304 *in* Johnson, R.R., C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.
LANG, G.E. and R.K. WEIDER. 1984. The role of beaver in vegetation patterning and development in *Sphagnum*-dominated wetlands in West Virginia. Bull. Ecol. Soc. Am. 65(2):243.
LAURENZI, A.W., R.D. OHMART, and V. HINK. 1983. Classification of mixed broadleaf riparian forest in Tonto National Forest. Pages 72-81 *in* Moir, W.H. and L. Hendzel, tech. coords. Proc. of the Workshop on Southwestern Habitat Types. U.S. Dep. Agric., For. Serv., Southwest Reg., Albuquerque, NM.
LI, R.M. and W.H. SHEN. 1973. Effects of tall vegetation and flow sediment. J. Hydraul. Div., ASCE, Vol. 9, No. HY5, Proc. Paper 9748.
LORZ, H.H. 1974. Ecology and management of brown trout in Little Deschutes River. Oregon Dep. Fish and Wildl. Fish. Res. Rep. 8. 49pp.
LOWE, C.H., ed. 1964. The vertebrates of Arizona. Univ. Arizona Press, Tucson. 270pp.
LYONS, J.K. and R.L. BESCHTA. 1983. Land use, floods, and channel changes, Upper Middle Fork Williamette River, Oregon (1936-1980). Water Resour. Res. 19:436-471.
MACARTHUR, R.H. and J.W. MACARTHUR. 1961. On bird species diversity. Ecology 42:594-598.
MAHONEY, D.L. and D.C. ERMAN. 1984. The role of streamside buffer strips in the ecology of aquatic biota. Pages 168-176 *in* Warner, R.E. and K.M. Hendrix, eds. California Riparian Systems: Ecology, Conservation, and Productive management. Univ. California Press, Berkeley. 1035pp.
MANNAN, R.W., E.C. MESLOW, and H.M WIGHT. 1980. Use of snags by birds in Douglas fir forests, western Oregon. J. Wildl. Manage. 44:787-797.
MARCUM, C.L. 1975. Summer-fall habitat selection and use by a western Montana elk herd. Ph.D. dissertation, Univ. Montana, Missoula. 188pp.
MARCUSON, P.E. 1977. The effects of cattle grazing on brown trout in Rock Creek, Montana. Project F-20-R-21-11-a. Montana Game and Fish, Helena. 28pp.
MARLOW, C.B. and T.M. POGACNIK. 1985. Time of grazing and cattle-induced damage to streambanks. Pages 279-284 *in* Johnson, R.R., C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.
MARTIN, K.E. 1984. Recreation planning as a tool to restore and protect riparian systems. Pages 748-757 *in* Warner, R.E. and K.M. Hendrix, eds. California Riparian Systems: Ecology, Conservation, and Productive Management. Univ. California, Berkeley. 1035pp.
MAY, B. and B. DAVIS. 1982. Practices for livestock grazing and aquatic habitat protection on western rangelands. Pages 271-278 *in* Wildlife-Livestock Relationships Symposium: Proc. 10, Univ. Idaho, Forest, Wildl., Range Exp. Sta., Moscow.
MCLEAN, A., H.H. NICHOLSON, and A.L. VAN RYSWYK. 1963. Growth, productivity and chemical composition of a subalpine meadow in interior British Columbia. J. Range Manage. 16:235-240.
MEENTS, J.K., B.W. ANDERSON, and R.D. OHMART. 1982. Vegetation relationships and food of sage sparrows wintering in honey mesquite habitat. Wilson Bull. 94:129-138.
MEGANK, R.A. and K.C. GIBBS. 1979. A methodology applied to the analysis of selected grazing management strategy and dispersed recreation. Final report to U.S. Dep. Agric., For. Serv., Pacific Northwest For. Range Exp. Sta. under Coop. Aid Prog. PNW-40, Suppl. 57. Oregon State Univ., Corvallis. 67pp.
MERRIAM, C.H. 1890. Results of a biological survey of the San Francisco Mountains region and desert of the Little Colorado in Arizona. U.S. Dep. Agric., North Am. Fauna 3:1-136.
MORING, J.R. 1975. The Alsea watershed study: Effects of logging on the aquatic resources of the headwater streams of the Alsea River, Oregon. Part II. Fishery Res. Rep. 9, Oregon Dep. Fish and Wildlife, Corvallis. 39pp.
MORRIS, R.H. 1984. Planning recreation development and wildlife enhancement in a riparian environment at Oristimba Creek. Pages 767-772 *in* Warner, R.E. and K.M. Hendrix, eds. California Riparian Systems: Ecology, Conservation, and Productive Management. Univ. California, Berkeley. 1035pp.
MOSCONI, S.L. and R.L. HUTTO. 1982. The effects of grazing on land birds of a western Montana riparian habitat. Pages 221-233 *in* Wildlife-Livestock Relationships Symposium: Proc. 10, Univ. Idaho For. Wildl. Range Exp. Sta., Moscow.
MOULTON, M. 1978. Small mammal associations in grazed versus ungrazed cottonwood riparian woodland in eastern Colorado: A symposium. Pages 133-140. Colorado Chap. Wildl. Soc. and Colorado Audubon Council, Greeley. 195pp.
MULLIS, C. 1985. Habitat utilization by fisher (*Martes pennanti*) near Hayfork Bally, California. M.S. Thesis, Humboldt State Univ., Arcata, CA.
MURPHY, M.L. and J.D. HALL. 1981. Varied effects of clearcut logging on predators and their habitat in small streams of the Cascade Mountains, Oregon. Can. J. Fish. Aquat. Sci. 38:137-145.
NELSON, J.R. and D.G. BURNELL. 1975. Elk-cattle competition in central Washington. Pages 71-83 *in* Range Multiple Use Management. Univ. Idaho, Moscow.
NELSON, L., Jr. and J.K. HOOPER. 1976. California fur bearers and their management. Univ. California, Coop. Ext. Serv., Leaflet 2721, Berkeley.
NEWBOLD, J.D., D.C. ERMAN, and K.B. RUBY. 1980. Effects of logging on macroinvertebrates in streams with and without bufferstrips. Can. J. Fish. Aquat. Sci. 37:1076-1085.
NUSSBAUM, R.A. 1974. The distributional ecology and life history of the Siskiyou Mountain salamander (*Plethodon stormi*), in relation to the potential impact of the proposed Applegate Reservoir on this species. Rep. submitted to U.S. Army Corps of Engineers, Portland, OR. 52pp.
OHMART, R.D. and B.W. ANDERSON. 1974. Vegetation management: Annual report. Submitted to U.S. Dep. Inter., Bureau of Reclamation, Boulder City, NV.
——— and ———. 1982. North American desert riparian ecosystems. Pages 433-479 *in* Bender, G.L., ed. Reference Handbook on the Deserts of North America.

Greenwood Press, Westport, CT. 594pp.
OLSON, R.W. and C.L. ARMOUR. 1979. Economic considerations for improved livestock management approaches for fish and wildlife in riparian/stream areas. Pages 67-71 *in* Cope, O.B., ed. Forum—Grazing and Riparian/Stream Ecosystems. Trout Unlimited, Inc. Vienna, VA. 94pp.
OREGON-WASHINGTON INTERAGENCY WILDLIFE COUNCIL. 1978. Managing riparian zones for fish and wildlife in eastern Oregon and eastern Washington. Unpubl. rep.
ORR, R.T. 1940. The rabbits of California. Occ. Papers. California Acad. Sci. 19:1-227.
PARKER, M., F. WOOD, Jr., B.H. SMITH, and R.G. ELDER. 1985. Erosional downcutting in lower order riparian ecosystems: Have historical changes been caused by removal of beaver? Pages 35-38 *in* Johnson, R.R., C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R. H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.
PAULSEN, H.A., Jr. 1969. Forage value on a mountain grassland aspen range in western Colorado. J. Range Manage. 22:102-107.
PEDERSON, R.J., A.W. ADAMS, and J. SKOVLIN. 1979. Elk management in Blue Mountain habitats. Oregon Dep. Fish and Wildl., Portland. 27pp.
PETERSON, A.W. and T.C. GRUBB, Jr. 1983. Artificial trees as a cavity substrate for woodpeckers. J. Wildl. Manage. 47:790-798.
PLATTS, W.S. 1979. Livestock grazing and riparian/stream ecosystems—An overview. Pages 39-45 in Cope, O.B., ed. Proc. of the Forum—Grazing and Riparian/Stream Ecosystems. Trout Unlimited, Inc., Vienna, VA. 94pp.
———. 1984. Riparian system/livestock grazing interaction research in the intermountain West. Pages 424-429 *in* Warner, R.E. and K.M. Hendrix, eds. California Riparian Systems: Ecology, Conservation, and Productive Management. Univ. California, Berkeley. 1035pp.
———, K.A. GEBHARDT, and W.L. JACKSON. 1985. The effects of large storm events on basin-range riparian stream habitats. Pages 30-34 *in* Johnson, R.R., C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R. H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.
——— and R.L. NELSON. 1983. Population and generic differentiation in the Humboldt cutthroat trout of Gance Creek, Nevada. Pages 15-19 *in* California-Nevada Wildl. Trans.
———, O. CASEY, and V. CRISPIN. 1983. Riparian-stream habitat conditions on Tabor Creek, Nevada, under grazed and ungrazed conditions. Pages 10-14 *in* Proc. Ann. Conf. Western Assoc. Fish and Wildl. Agencies. 63:10-14.
REID, E.H. and G.D. PICKFORD. 1946. Judging mountain meadow range condition in eastern Oregon and eastern Washington. U.S. Dep. Agric., Circular 748.
RICE, J., B.W. ANDERSON, and R.D. OHMART. 1984. Comparison of the importance of different habitat attributes of avian community organization. J. Wildl. Manage. 48:895-911.
ROATH, L.R. and W.C. KRUEGER. 1982. Cattle grazing influence on a mountain riparian zone. J. Range Manage. 35:100-104.
RUBY, K.B., D.C. ERMAN, and J.D. NEWBOLD. 1977. Biological assessment of timber management activity impacts and bufferstrip effectiveness on National Forest streams of northern California. Earth Resources Monogr. 1, U.S. Dep. Agric., For. Serv., Reg. 5, San Francisco, CA. 170pp.
SALWASSER, H. and K. SHIMAMOTO. 1984. Pronghorn, cattle and feral horse use of wetland and upland habitats. Pages 210-213 *in* Warner, R.E. and K.M. Hendrix, eds. California Riparian Systems: Ecology, Conservation, and Productive Management. Univ. California, Berkeley. 1035pp.
SCOTT, L.B. 1984. Economic values of three furbearers inhabiting California riparian systems. Pages 731-738 *in* Warner, R.E. and K.M. Hendrix, eds. California Riparian Systems: Ecology, Conservation, and Productive Management. Univ. California, Berkeley. 1035pp.
SCOTT, V.E. 1979. Bird responses to snag removal in ponderosa pine. J. Forestry. 77:26-28.
———, K.E. EVANS, D.R. PATTON, and C.P. STONE. 1977. Cavity-nesting birds of North American forests. U.S. Dep. Agric., For. Serv. Agric. Handbook 511, Washington, DC. 112pp.
SEVERSON, K.E. and C.E. BOLDT. 1978. Cattle, wildlife, and riparian habitats in the western Dakotas. Pages 94-103 *in* Management and Use of Northern Plain Rangeland. Reg. Rangeland Symp., Bismarck, ND.
SIEKERT, R.E., Q.D. SKINNER, M.A. SMITH, J.L. DODD, and J.D. RODGERS. 1985. Channel response of an ephemeral stream in Wyoming to selected grazing treatments. Pages 276-278 *in* Johnson, R.R., C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R. H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.
SKOVLIN, J.M. 1967. Fluctuations in forage quality on summer range in the Blue Mountains. U.S. Dep. Agric., For. Serv. PNW-Res. Paper 44.
———. 1984. Impacts of grazing on wetlands and riparian habitat: A review of our knowledge. Pages 1001-1104 *in* Committee on Developing Strategies for Rangeland Management. Natl. Resour. Council/Natl. Acad. Sci., Westview Press, Boulder, CO.
———, R.W. HARRIS, G.S. STRICKLER, and G.A. GARRISON. 1976. Effects of cattle grazing methods on ponderosa pine-bunchgrass range in the Pacific Northwest. U.S. Dep. Agric., Tech. Bull. 1531. Washington, DC. 40pp.
———, W.R. MEEHAN, J.C. BUCKHOUSE, and M. VAVRA. 1977. A method of study for determining the influence of grazing on riparian and aquatic habitats in the Blue Mountains of Oregon. Pages 164-169 *in* Livestock Interactions with Wildlife, Fisheries, and Their Environments. Proceedings of the Symposium. U.S. Dep. Agric., For. Serv. Pacific Southwest For. Range Exp. Sta., Berkeley, CA.
SMITH, F. 1977. A short review of the status of riparian forests in California. Pages 1-2 *in* Sands, A., ed. Riparian Forests in California: Their Ecology and Conservation. Inst. Ecol., Publ. 15, Univ. California, Davis. 122pp.
STAMP, N. and R.D. OHMART. 1979. Rodents of desert shrub and riparian woodland habitats in the Sonoran Desert. Southwestern Nat. 24:279-289.
SULLIVAN, B.K. 1981. Distribution and relative abundance of snakes along a transect in California. J. Herpert.

15:247-248.
SWANSON, F.J., S.V. GREGORY, J.R. SEDELL, and A.G. CAMPBELL. 1982. Land-water interactions: The riparian zone. Pages 267-291 *in* Analysis of Coniferous Forest Ecosystems in the Western United States. US/IBP Synthesis Series 14, Hutchinson Ross Publ. Co., Stroudsburg, PA.
SZARO, R.C., S.C. BELFIT, J.K. AITKIN, and J.N. RINNE. 1985. Impact of grazing on a riparian garter snake. Pages 359-363 *in* Johnson, R.R., C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R. H. Hamre, tech. coords. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. Proc. First North Am. Riparian Conf. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-120. 523pp.
THOMAS, J.W., C. MASER, and J.E. RODIEK. 1979. Wildlife habitat in managed rangelands—the Great Basin of southeastern Oregon-riparian zone. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RNW-80. 18pp.
———, R.J. MILLER, H. BLACK, J.E. RODIEK, and C. MASER. 1976. Guidelines for maintaining and enhancing wildlife habitat in forest management in the Blue Mountains of Oregon and Washington. Trans. North Am. Wildl. Nat. Resour. Conf. 41:452-476.
U.S. COUNCIL ON ENVIRONMENTAL QUALITY. 1978. Environmental quality. The ninth report of the Council on Environmental Quality. U.S. Govt. Printing Office, Washington, DC. (Stock No. 041-011-00040-8). 599pp.
U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE. 1972. Western regional working conference—results of work group sessions—delegate meetings. National Program of Research for Forest and Associated Rangelands. U.S. Dep. Agric., For. Serv. Intermountain For. Range Exper. Sta., Ogden, UT. 39pp.
U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF LAND MANAGEMENT. 1978. Recreational carrying capacity in the California Desert. U.S. Dep. Inter., Bur. Land Manage., Sacramento, CA. 115pp.
———. 1980. The California desert conservation area plan. U.S. Govt. Printing Office, San Francisco, CA.
U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION. 1979. Pecos River Basin water salvage project: Final environmental statement. U.S. Dep. Inter., Bur. Rec., Southwest Reg. Off., Amarillo, TX.
VAN VELSON, R. 1979. Effects of livestock grazing upon rainbow trout in Otter Creek, Nebraska. Pages 53-55 *in* Cope, O.B., ed. Proc. of the Forum—Grazing and Riparian/Stream Ecosystems. Trout Unlimited, Inc., Vienna, VA. 94pp.
WARNER, R.E., recorder. 1979a. Fish and wildlife resource needs in riparian ecosystems: Proc. of a workshop. Nat. Water Resour. Analysis Group, Eastern Energy and Land Use Team, U.S. Dep. Inter., Fish Wildl. Serv., Kearneysville, WV. 53pp.
———. 1979b. California riparian study program: Background information and proposed study design. Planning Branch, California Dep. Fish and Game, Sacramento. 177pp.
——— and K.M. HENDRIX, eds. 1984. California riparian systems: Ecology, conservation, and productive management. Univ. California Press, Berkeley. 1035pp.
WAUER, R.H. 1977. Significance of Rio Grande riparian systems upon the avifauna. Pages 165-174 *in* Johnson, R.R. and D.A. Jones, tech. coords. Importance, Preservation and Management of Riparian Habitat: A Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-43. 217pp.
WEBSTER'S NEW COLLEGIATE DICTIONARY. 1979. G.&C. Merriam Co., Springfield, MA. 1532pp.
WILLIAMS, D.F. 1985. Mammalian species of special concern in California. California Dep. Fish and Game, Nongame Wildl. Invest., Final Rep., Project E-W-4, IV-14.l. Sacramento. 184pp.
——— and K.S. KILBURN. 1984. Sensitive, threatened, and endangered mammals of riparian and other wetland communities in California. Pages 950-957 *in* Warner, R.E. and K.M. Hendrix, eds. California Riparian Systems: Ecology, Conservation, and Productive Management. Univ. California Press, Berkeley. 1035pp.
WINEGAR, H.H. 1977. Camp Creek channel fencing—plant, wildlife, soil, and water response. Rangeman's J. 4:10-12.
WINTERNITZ, B.L. 1973. Ecological patterns in a montane breeding bird community. Ph.D. dissertation, Univ. Colorado, Boulder.
——— 1976. Temporal change and habitat preference of some montane breeding birds. Condor 78:383-393.
——— and H. CAHN. 1983. Nestholes in live and dead aspen. Pages 102-106 *in* Davis, J.W., G.A. Goodwin, and R.A. Ockenfels, tech. coords. Snag Habitat Management: Proceedings of the Symposium. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-99. 226pp.
YOUNG, R.A., T. HUNTRODS, and W. ANDERSON. 1980. Effectiveness of vegetated bufferstrips in controlling pollution from feedlot runoff. J. Environ. Qual. 9:483-487.

14

NORTH AMERICAN DESERT RIPARIAN ECOSYSTEMS

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DESERT RIPARIAN ECOSYSTEMS have received little attention from ecologists. To our knowledge, no book on North American deserts has ever treated desert riparian areas as a distinct ecological system. In the late 1960s, Lowe (1968) appraised our overall knowledge of world deserts and ranked North American deserts as the best studied faunistically, but more than a decade later we still have little real knowledge of the total value of desert riparian ecosystems. To illustrate the importance of these ecosystems in North American deserts, we will pose a number of questions about desert riparian habitats and address them in this chapter. What are desert riparian ecosystems? Are they a separate ecological entity, and, if so, how do they differ from the remaining landscape, either physiographically or floristically and faunistically? How important are these areas to the desert fauna? Approximately what percentage of the arid Southwest is comprised of riparian habitats? What is their importance to man? Have these habitats been modified by man and, if so, to what extent? What is their current status and what does the future hold for them? Ultimately if these habitats are lost or almost completely eliminated, what would be the ecological impact on our North American deserts as a whole?

Desert regions of North America are characterized by aridity, high ambient temperatures, and generally a paucity of vegetation. Winter rains are usually gentle and widespread, whereas summer rains, if any, are convective in nature, usually of short duration, and result in highly localized and intensive precipitation patterns. Only a small amount of the summer rains penetrates the ground surface since the sparse vegetation and erosion pavement on the desert floor do little to slow surface runoff. Further, the high rate of evapotranspiration typically exceeds precipitation by a substantial percentage (Logan 1968).

As precipitation collects and drains from the desert floor, its action cuts drainage ways. Consequently the desert regions are topographically characterized by water courses, termed washes or arroyos, that drain the adjacent desert uplands and eventually converge to form larger transport systems, which empty into primary or permanently flowing rivers. These rivers have their headwaters located in high mountain areas where they also drain high elevational watersheds.

Desert riparian ecosystems are comprised of these drainages, their attendant vegetation, and the fauna supported by these riparian plant assemblages. The drainage system itself may have permanently flowing water, be intermittent, or seldom (if ever) flow. Nevertheless, the available soil moisture is higher in these alluvial floodplains than in the adjacent desert uplands and hence supports a flora distinctly different from that in the adjacent desert. A working definition is, "A riparian association of any kind is one which occurs in or adjacent to drainageways and/or their floodplains and which is further characterized by species and/or life-forms different than that of the immediately surrounding non-riparian climax" (Lowe 1964:62).

Riparian vegetation is frequently termed phreatophytic, which denotes a collective group of plant species that have their roots located in perennial groundwater or in the capillary fringe above the water table. The term has a negative connotation among water managers and refers to those plant species that transpire large quantities of water from the groundwater table. Consequently phreatophytes are commonly viewed as undesirable, and their removal has been viewed as positive because it constitutes water salvage or a reduction in water loss.

PHYSICAL CONSIDERATIONS

The fluvial geomorphology of desert landscapes has been studied in some detail, but the paucity of long-term records of our changing landscape under natural and man-related conditions leaves many questions unresolved. In general, fluvial

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systems are considered open, being characterized by input, cycling, and output of energy and materials, with component variables considered to be self-regulated (Cooke and Warren 1973). Schumm and Lichty (1965) have classified ten component variables (including time, initial relief, geology, and climate) of fluvial systems as either independent or dependent, with the interrelationships varying according to time span. They list three time spans: cyclic (encompassing an erosion cycle), graded (when grade and condition of dynamic equilibrium exists), and steady (a fraction of graded time). Of the ten variables, vegetation is the most germane to our discussion and is classified as dependent on cyclic time and independent relative to graded and steady time. The length and periodicity of cyclic time primarily dictates the amount of available soil moisture in flumes, which in turn exerts a strong influence on riparian plant species composition.

Surface Runoff

Water entering small drainage systems originates primarily from surface runoff from the adjacent desert upland and secondarily from percolated groundwaters. The size of the watershed and the amount of precipitation dictate the amount of surface flow and percolated waters that enter the drainage during each erosion cycle. In general, the amount and type of vegetational ground cover and the slope of the terrain are directly related to the percentage of water that will enter the drainage system as surface flow, or as percolated water, the latter being highest when the watershed has a good perennial grass cover and shallow slopes.

Good watersheds have a high roughness coefficient. The force of falling raindrops is reduced before they hit the soil, and the vegetation retards the flow of the surface water, allowing more time for the water to penetrate the soil. This slower, decreased surface water flow reduces the erosion of topsoil. The relationship among rainfall, watersheds, geology, and surface versus percolated water is by no means simple. For a discussion of desert drainage basins, their constituent parts, and an in-depth analysis of some of these systems, see Melton (1958) and Schumm and Hadley (1961).

Surface flows carry varying amounts of sediment, minerals, and organic materials that precipitate or are filtered out in the soils of the water course. The deposited soils are termed alluvial and are rejuvenated with new soils, minerals, and nutrients each time there is adequate rainfall to produce surface runoff. These alluvial soils are generally restricted to stream fans and floodplains along stream bottoms (Denny 1965). The alluvial soils along permanent rivers can be enriched either locally by small flood pulses from adjacent uplands or along the entire reach of the river by floods from the melting snowpack in the upper watershed.

Drainage systems, whether having permanent or intermittent flow, transport enough surface and subsurface moisture to support a flora that is different in growth form and species composition from the adjacent uplands (figure 10-1). In very small drainages the soil moisture level may be too low to

Figures 10-1A, B, C. Three types of riparian ecosystems in the Sonoran Desert.
Originals prepared by Lauren Porzer.

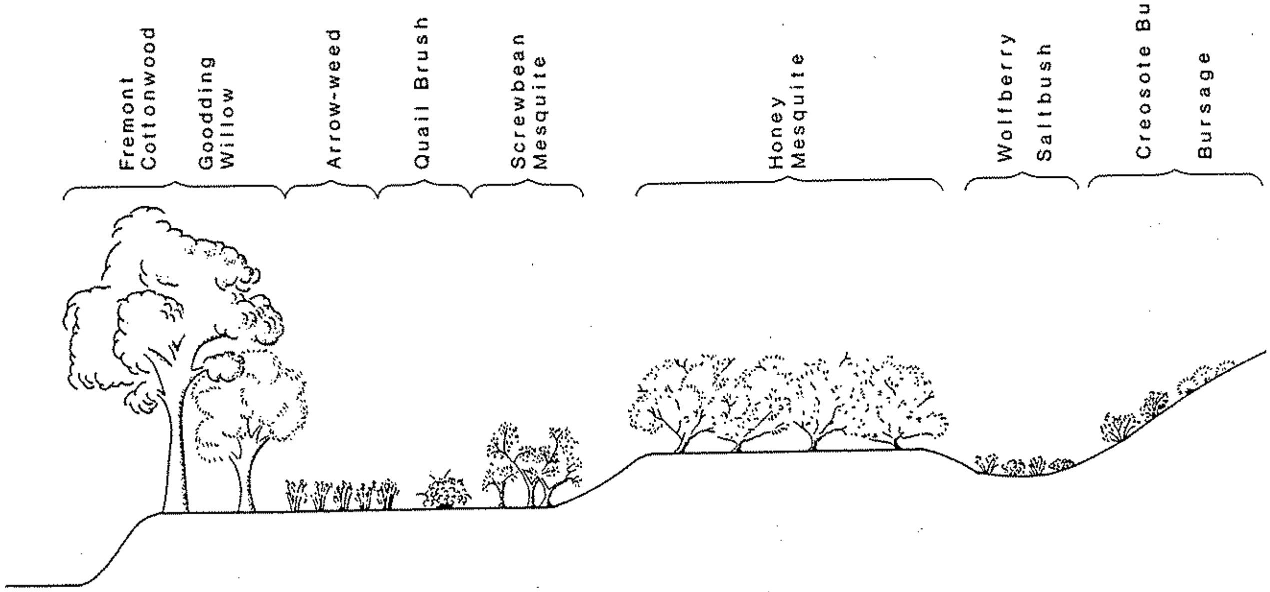

Figure 10-1A. A permanent or primary drainage showing the position of the riparian species on the first and second terraces.

support riparian species but will have higher moisture levels than will the adjacent upland. These drainages contain upland desert species that are usually more robust than their desert conspecies.

Soils

Desert uplands adjacent to riparian areas usually have poorly developed, shallow soils. Soil moisture varies greatly throughout the annual cycle but generally is very low. In contrast, the riparian soils, which are primarily alluvial in nature, are much deeper and highly variable in texture. The gentle surface runoff from winter rains transports more finely textured soils and small organic materials, such as leaves and rabbit and rodent droppings, whereas the heavier runoff from summer rains transports both coarse and finely textured soils and larger organic materials. The nature of alluvial soils is amply described by Dregne (1968:309):

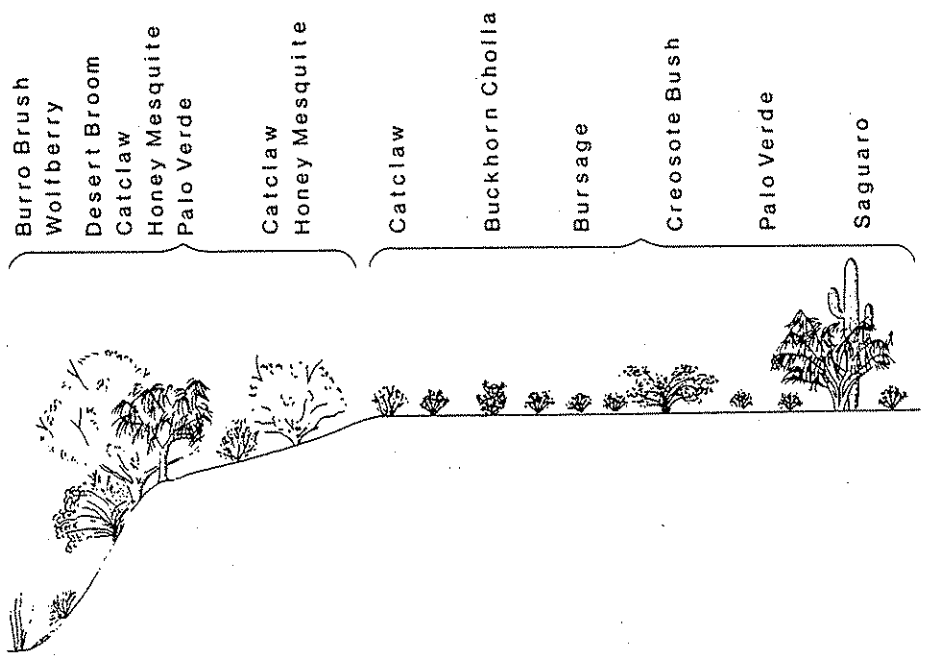

Figure 10-1B. A secondary riparian system illustrating the intrusion of a facultative riparian species, blue palo verde, into the riparian belt.

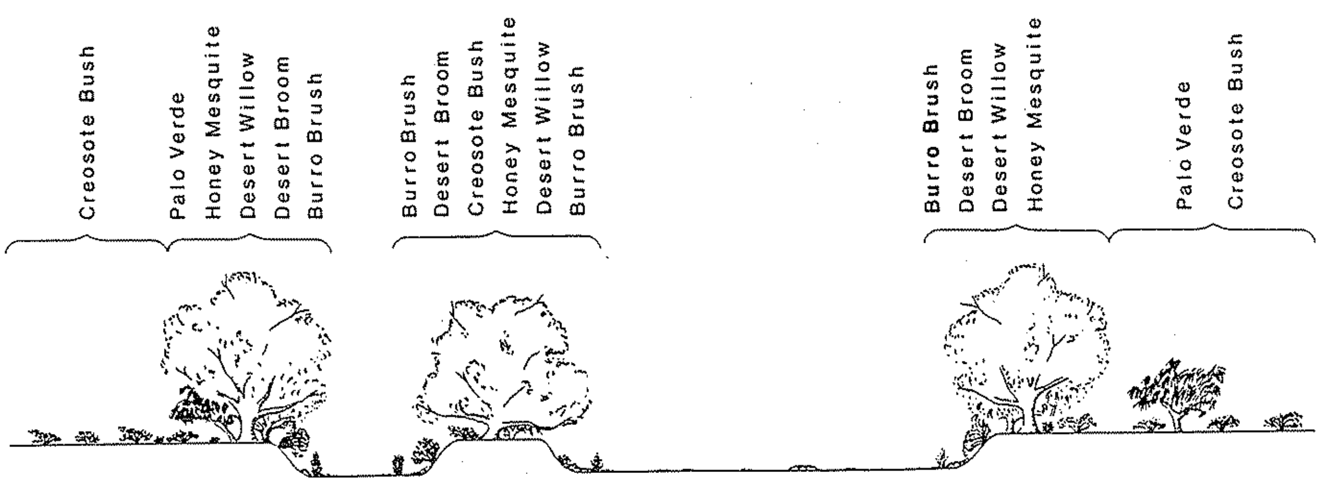

Figure 10-1C. A wide drainage system where an island of upland desert has either been cut away during periods of high water flow or alluvial soil deposits have built the island to an elevation where xerophytes have successfully invaded it.

Alluvial soils are commonly stratified, have textures that run the gamut from gravel to clay, and often are underlain by sand or gravel. Usually they are calcareous to the surface and contain moderate to low amounts of salt. Little or no development is apparent in them although they may contain moderate amounts of organic matter in the surface.

The high but fluctuating water table in the drainages generally contains enough soil moisture to allow decomposers to reduce the accumulated and transported organic materials to humus, which in turn provides soil nutrients and increased soil moisture holding capacity. The heterogeneous soil texture provides relatively good aeration, which promotes aerobic decomposition.

Flooding

In small riparian systems that drain desert uplands, flooding is highly erratic since the only input is from rainfall. Water enters the drainage as percolated or as surface flow. The magnitude of the riparian flow depends on the intensity and duration of the rainfall, the size of the watershed, and the width of the drainage system.

In permanent river systems, flooding is usually an annual occurrence, except during years of low snowpack on the watersheds. Depending on the depth of the snowpack and the duration of melt, the summer floods in larger systems can be of a relatively long duration, with peak flows usually occurring in June or July. Heavy flooding of long duration results in dramatic physical and biological changes. New channels are cut, and sharp river bends are frequently cut off to become ephemeral oxbow lakes. Previously formed oxbow lakes may be filled with transported sediment, boulders, and vegetation. Entire plant communities may be dislodged and washed away. As the flooding waters recede, new sediments rich in organic material are deposited to form the seedbeds for future plant communities.

The water in some of these streams may carry heavy loads of totally dissolved solids. Salt levels may be high enough to render the water unpotable. Input may come from the substrate over which the stream flows (Cole 1963; Sommerfield et al. 1974), from springs that feed into the river, and from agricultural drains with return flow into the river. The amount of salt input from each of these sources varies depending on the geological formations, the nature of springs that feed the system, and the amount of cultivated land along the stream course. For example, Feth and Hem (1963) estimated as high as 45,454 metric tons (50,000 tons) per year of dissolved solids being carried by the Salt River in central Arizona. Physical components such as timing of flooding, levels of salt, soil moisture availability, extreme winter temperatures, and duration of winter extreme temperatures appear to be some of the major factors that dictate plant species composition and vertical structure of the vegetation along riparian systems.

Drainage Types

North American desert drainage systems are a continuum ranging from mesic (with a permanently flowing river system) to xeric (where the stream channel seldom, if ever, carries surface flow).

PRIMARY DRAINAGES

For ease of discussion, we will term those drainages having headwaters located in mountain areas as primary drainages in which surface flow may be permanent or intermittent. Two or more primary drainages may converge to form a larger primary drainage; for example, of the Salt and Gila rivers in Arizona, the latter ultimately converges with the Colorado River.

SECONDARY AND LESS DRAINAGES

These are intermittent or nonsurface flowing systems that drain upland desert or semiarid areas and converge with primary drainage systems. Tertiary and quaternary systems drain smaller desert or semiarid watersheds and converge to form secondary drainage systems.

This very general classification allows us to visualize how major and minor drainages converge and transport water from desert areas. These drainage ways house the water- and wind-transported soil, which supports riparian-adapted plant species.

FLORAL CONSIDERATIONS

Riparian systems support a distinct flora, described by Lowe (1964:62) as "an evolutionary entity with an enduring stability equivalent to that of the landscape drainageways which form its physical habitat." Axelrod (1958) and Darrow (1961) have examined the origin and development of the vegetational communities of the Southwest, and Darrow has traced the phylogenetic relationships of the riparian vegetational complex.

Historical Development

The native tree and shrub genera that currently comprise our desert riparian ecosystems were derived from two different floras, the Arcto-Tertiary and Madro-Tertiary. The Arcto-Tertiary flora was a temperate mesophytic forest and was widespread over Canada, extending north to the Arctic Sea in the Early Cenozoic era. A number of genera were representative of this flora, but *Populus*, *Salix*, and *Atriplex* are some of the most important in desert riparian ecosystems. *Atriplex* became established in the central and northern Great Basin area as the forest and woodlands retreated.

The Madro-Tertiary flora appear to have evolved from subtropical species that persisted along dry margins in the tropics (Darrow 1961). Increasing aridity during the Oligocene epoch of the Cenozoic allowed strong differentiation of the Madro-Tertiary flora (Axlerod 1958), known first from fossil evidence in the Green River formation of the Eocene. Aridity continued to increase, and by the Late Cenozoic a number of important genera such as *Acacia, Baccharis, Cercidium, Condalia, Lycium,* and *Prosopis* were established in the Sonoran Desert.

By the end of the Cenozoic era vegetational patterns were well established in the desert regions of North America. Increasing aridity promoted the separation of the sagebrush of the Arcto-Tertiary flora in the Great Basin Desert and the development of the Mojave, Sonoran, and Chihuahuan deserts from the subtropical Madro-Tertiary flora. Some riparian-adapted species were not restricted from southward movement, and genera such as *Populus* and *Salix* penetrated southward into the Sonoran and Chihuahuan deserts. Why more of the Madro-Tertiary flora is not found in the Mojave and Great Basin deserts appears to be related to soil moisture availability and extreme winter temperatures. However, our knowledge of the requirements of these species is so imperfect that this is only speculation.

Fossil plants from the Pleistocene indicate an extension and reduction of floral communities rather than major shifts or extirpation of various plant species (Van Devender 1977). Riparian species from higher elevations may have descended to lower elevations along drainages, but as conditions became hotter and drier, these individuals died out, reducing the species' distribution to higher elevations.

Through evolutionary time, a number of plant species have become highly adapted to the rigors of living in riparian areas. Each species has its own limits relative to soil moisture availability, temperature, substrate type, and other physical characteristics. Systems with permanently high water tables and low to moderate salinities support such species as Fremont cottonwood (*Populus fremontii*), Goodding willow (*Salix gooddingii*), quail bush (*Atriplex lentiformis*), arrowweed (*Tessaria sericea*), screwbean mesquite (*Prosopis pubescens*), honey mesquite (*P. glandulosa*), and velvet mesquite (*P. velutina*).

Terracing

Shown diagrammatically in Figure 10-1a, the broad floodplain along permanent rivers (our example is drawn from the Colorado River) tends to contain two terraces. The first terrace may be 1 or more meters (m) below the level of the second terrace and is the primary area of river meanderings and water transport in normal flood years. Consequently, the first terrace continually undergoes change through natural bank cutting and soil deposition and from floodwaters cutting off oxbows to form new oxbow lakes. Older lakes with well-developed riparian communities slow the silt-laden floodwater, allowing the deposition of new soils to expedite hydric to xeric vegetational succession. Annual floods constantly changed the substrate along the first terrace, resulting in a heterogeneous assortment of first-terrace trees and shrubs.

FIRST TERRACE

At first the plant species occupying the first terrace in broad floodplains seem disorderly, but on closer examination, a relatively discrete separation of the available substrate by first-terrace plant species is seen (figure 10-1a). Willows and cottonwoods occupy the saturated soils lining the river's edge. The distribution of these trees depends on a number of factors, but an important one is the soil elevation above the water table. If soil elevation is too high, the air- and water-transported seeds of cottonwoods and willows cannot germinate. Sandy, water-saturated soils around newly formed oxbow lakes provide an ideal habitat for these rapidly invading species. Also, as the meandering river cuts into one tree-lined bank, the opposite shore is being formed as a sandy soil deposit. These new soils with a high water table are quickly invaded by cottonwoods and willows. Some bank areas may support either cottonwoods or willows as a monoculture, while in other areas the two species may occur as a mixed community.

Arrowweed forms extensive tracts parallel to the cottonwood and willow communities along higher portions of the first terrace and in slightly better drained soils. The roots are located only slightly below the soil surface and sprout to form dense stands (Gary 1963). These underground roots or rhizomes aid in rapid invasion of new habitats, along with the air- and water-transported seeds. The stems of this shrub may be from 2 to 3 m tall and straight as an arrow (they were used by early man for that purpose). This species usually forms a monoculture, and mature plants in a stand show little variation in height or stem size.

Farther from the river, the slower growing and maturing screwbean mesquite and quail bush occupy the remainder of the first terrace. Narrow or wide belts of screwbean mesquite flank either the arrowweed communities or the wider belts of cottonwood and willows. This slow-growing mesquite species appears to have been highly restricted as a small band in the more stable soils along the lateral edge of the first terrace. The distance to the water table is less than on the second terrace, and the more stable soils provide adequate time to allow the tree species to mature and produce fruit. The fruit of screwbean mesquite is corkscrew shaped and must be water or animal transported. Fruits are dropped year round, with a peak in early July. Rodents and coyotes (*Canis latrans*) are active dispersal agents. Well-developed spines on the trees appear to be a deterrent to browsing species such as mule deer (*Odocoileus hemionus*) and desert bighorn sheep (*Ovis canadenis*).

Quail bush is a shrub that may occur in a pure stand but usually forms a belt of scattered shrubs parallel to the river. A mature shrub seldom exceeds 2.5 m in height and may occupy an area of 10 square m. It is a dense evergreen that can tolerate and may prefer soils with a high salt content. Consequently low, moist areas with high salt levels some distance from the river's edge frequently support numerous shrubs of this species. The winged fruits are dispersed primarily by water or vertebrates.

Intermixed with the above dominants are such species as wild grape (*Vitis* spp.), wolfberry (*Lycium* spp.), inkweed (*Suaeda torreyana*), sprangletop (*Leptochloa fascicularis*), finger grass (*Chloris virgata*), careless weed (*Amaranthus palmeri*), and many others.

Marsh or wetland vegetation frequently can be found around the edges of backwaters, oxbow lakes, seeps, springs, and other slow-moving or standing water situations. Where surface water is shallow and relatively calm, the dominant emergent vegetation is usually cattail (*Typha domingensis*), but deeper slow-moving waters may support various species of bulrush (*Scirpus* spp.). Receding floodwaters annually leave cutoff oxbows replete. Those with high perennial water tables located near the river support mixtures of various species of emergent vegetation. Low areas with a high water table and saline conditions support a dense mat of saltgrass (*Distichlis* spp.).

SECOND TERRACE

Because of its increased elevation above the water table, the second terrace supports only those species with a highly developed and rapidly growing taproot that can follow the receding water table as flood levels wane. There is a more orderly appearance of the communities on this terrace, since the area is seldom cut by the river. The plant species occupying this terrace are slow-maturing and require relatively stable soils. Honey and velvet mesquite, which frequently form extensive forests, are the most highly adapted riparian species in this terrace. Plant species such as quail bush, wolfberry, and inkweed frequently become established in low areas along the secondary terrace where water may be trapped in flood periods or from adjacent upland runoff. Other more xerically adapted opportunists from the adjacent upland, such as creosote bush (*Larrea tridentata*) and xerophylic species of *Atriplex* and blue palo verde (*Cercidium floridum*), may invade these drier sites. But the primary riparian plant species along the second terrace are honey and velvet mesquite. These large-spined trees may reach a height of 6 to 8 m. The sweet pod surrounding the seed is dropped in July, and birds and mammals are the primary seed dispersers, but high floodwaters can also act as a dispersal agent.

Secondary and Lesser Drainages

Terracing, if it occurs, is usually poorly defined in secondary drainages. The lack of permanent surface flow, annual floods, and a broad alluvial floodplain does not promote terracing in secondary or lesser drainages. Along narrow secondary drainages, the riparian vegetation, if present, is forced back against the bedrock on the edge of the drainage. When surface flow does occur in narrow drainages, it is usually a high volume flow of short duration, and any vegetation that has become established in the middle of the drainage area since the end of the last erosion cycle is scoured from the wash. Broad secondary or lesser drainages usually have edges of riparian vegetation bordering them and may have islands of riparian vegetation scattered across the bed (figure 10-1c). Heavy floods frequently remove the vegetation and the islands, whereas gentle floods increase island size by depositing sediment on the downstream side.

Plant species composition is highly diversified on these islands, varying from a monoculture to a mixture of species. In many washes in the Sonoran Desert, facultative species such as palo verde and ironwood (*Olneya tesota*) may comprise a large percentage of the species composition. On older and more stable islands where soil deposition has been adequate to form higher and better drained soils, some of the adjacent desert species, such as creosote bush, may become established. Some of these islands are also the product of new channel formation, which has separated some of the adjacent desert vegetation. Riparian species then become established around the base of the island.

Lesser drainages that feed permanent riparian systems also support a distinct flora. In secondary drainages, cottonwood and willows may extend a short distance up the drainage but soon give way to other riparian plant species. In lesser drainages such as secondary, tertiary, and quaternary systems, plant species richness and vertical vegetation structure decline as compared to the primary drainage. Depending on the desert involved and many other factors, smaller riparian drainages may support honey mesquite, velvet mesquite, desert willow (*Chilopsis linearis*), catclaw (*Acacia greggii*), white thorn (*A. constricta*), seep willow (*Baccharis* spp.), brickel bush (*Brickellia californica*), *Apache-plume* (*Fallugia paradoxa*), burroweed (*Hymenoclea monogyra*), cheesebush (*H. salsola*), common saltbush (*Atriplex polycarpa*), rabbitbush (*Chrysothamnus paniculatus*), and others.

Some of the plant species from the adjacent desert upland frequently invade tertiary and quaternary drainage systems, as well as smaller drainages. The increased soil moisture level produces more robust individuals than conspecies on the adjacent upland. Examples in the Sonoran Desert are palo verde, ironwood, and saguaro (*Cereus giganteus*). Dick-Peddie and Hubbard (1977) have suggested differentiating between the true riparian forms as being obligate species and the opportunistic forms as being facultative species. Others have termed the latter as pseudoriparian species.

Salt Cedar

In the early 1800s an Old World plant species called salt cedar (*Tamarix chinensis*) was introduced into the United States for ornamental uses (Horton 1964). The species was preadapted to desert riparian systems, and in the intervening years it has spread throughout the deserts of North America. Graf (1978) has estimated the rate of spread in the Colorado Plateau region at about 20 kilometers (km) per year. Today salt cedar is the dominant species in many riparian plant communities. It is an aggressive species that invades rapidly on newly deposited alluvial soils, in many instances out-competing native willows and cottonwoods. Not only has it invaded primary drainages, but its soil moisture tolerance is such that it can also thrive in secondary and tertiary drainages. It matures rapidly and begins producing small wind- and water-transported seeds within a year. Robinson (1958) has estimated production at 600,000 seeds per plant per year. Because flowering and fruiting are not synchronous within a stand, seeds are produced for many months through the growing season.

Glands for excreting salt are located on the leaves, allowing the species to invade saline soils. The continual transport of salts to the leaves promotes salt accumulation on the soil surface, which deters the germination and growth of native species.

Salt cedar is deciduous and grows in dense stands. After fifteen to twenty years of establishment, the fuel level builds to such a point that fire is imminent. Heat from the fire kills the trunk portion of the mature tree, and within a few days suckers sprout from the root crowns. New growth is about 2 or 3 m the first year. Even flooding does not harm the stand, since all of the woody portions will develop adventitious roots if kept moist (Horton 1977). Consequently the species is highly adapted for both flooding and fires.

Examples of the dispersal rate of salt cedar are reported on the lower Gila River where in the early 1970s the species occupied over 50 percent of the total bottomland area (Haase 1972). Campbell and Dick-Peddie (1964) reported that salt cedar communities were dominant on the Rio Grande in southern New Mexico. Robinson (1965) reported salt cedar communities along the Pecos River in New Mexico and the lower Rio Grande in Texas. Anderson and Ohmart (1977a) show it as the dominant community type on the lower Colorado River. Christensen (1962) reported that the invasion of salt cedar around Utah Lake, the Great Salt Lake, the upper Colorado River, and Green River in Utah was rapid and occurred between 1925 and 1960.

Nomenclature

Numerous efforts have been made to develop a workable nomenclatural system to approach the difficult problem of classifying riparian communities. Many of these efforts have received little acceptance because they have lacked an evolutionary or phylogenetic approach.

Systems Level

Brown and Lowe (1974) developed a classification based on the phylogenetic relationships of riparian communities as we understand their origin (Darrow 1961). In the Brown and Lowe system, the Arcto-Tertiary-derived riparian habitat is included in their forest formation and separated at the next lower level as riparian deciduous forest, which contains the cottonwood-willow communities. The Madro-Tertiary element of the riparian community is in their woodland formation. They present a number of woodland types but the subtropical woodland contains the riparian deciduous woodland, which includes the mesquite community complex. Pase and Layser (1977) have further refined this classification system into additional subdivisions of natural communities. Additional refinement (Brown et al. 1979) has led to a digitized classification system, which includes the biotic communities of North America.

Community Level

Shreve (1942, 1951) in his classical works saw structure as an important framework in studying desert communities. Johnson (1976:137), as well as others, has commented on the importance of understanding and recognizing the structural component:

> Justification for viewing desert vegetation on the basis of structure and function in addition to the traditional communities of species distribution approach is supported by the fact that species and communities of species vary structurally and functionally in both time and space. This becomes important if we accept the proposition that a principal goal of biology is to gain an understanding of the relationship between structure and function at all levels of biological organization ranging from organelles up to and including whole communities.

In an effort to understand better how vegetational structure and plant species composition in riparian communities affect animal species at the community level, Anderson and Ohmart (1977a) developed a classification system for the riparian vegetation along the lower Colorado River. Quantitative data on foliage structure and foliage volume from over one-hundred sampled communities were used in a cluster analysis to separate the various structural community types, regardless of species composition. Six structural types were recognized (figure 10-2), with type VI being the earliest successional stage. As the newly developing community matures, it becomes a type V, IV, and so forth. Since all plant species do not attain the same height at maturity and some tall-growing species may have their vertical growth arrested by abiotic and/or biotic factors, each structural group may contain mature or arrested structural types in addition to developing communities. For example, Anderson and Ohmart's (1977a) type VI structural grouping contains the mature arrowweed community and arrested honey mesquite and salt cedar communities, plus early successional stages of all other community types. Type III contains mature honey mesquite with overstory and understory. Type II contains the mature salt cedar community, characterized by a heavy overstory and no understory, which is structurally analogous to a dense cottonwood gallery forest. Type I contains the mature cottonwood forest where some cottonwoods have died and opened the canopy; if mixed with willow, there may be a well-developed midstory as well as a shrub understory.

This classification is easily understood and can be committed to memory for use in the field. Each division has quantitative limits. It is a happy medium between pooling all community and structural types and assuming there is no difference in wildlife use values, water evapotranspiration rates, or metabolic rates of young, developing communities versus mature ones. An alternative would be to develop specific profile classifications for each plant species and then make biological comparisions between all specific structural types. Eventually this may have to be done, but it will probably be too cumbersome to commit to memory for field operational purposes.

Regardless of how one approaches the problem of community structural classification, there is a definite need to recognize vegetation structure at the community level if ecological relationships in riparian communities are to be fully understood. The importance of sorting out vegetation structure and wildlife use values has been well documented (MacArthur and MacArthur 1961: Anderson and Ohmart 1977a, 1977b).

In summary, riparian systems are discrete ecological units within our North American deserts and can be defined by both physiographic and biological criteria. Physically they are drainage courses throughout deserts and transport water, which is a limited resource; flow may be surface or totally subterranean. Within these drainage systems there has evolved a number of specialized plant species derived from two distinct paleofloras.

GENERAL DISTRIBUTIONS AND STRUCTURAL DEVELOPMENT

Many factors operate either singly or in concert to limit the distribution of the riparian plant species that are found in the four North American deserts. The availability and timing of the availability of soil moisture is a very critical factor, and chemical or physical barriers that affect the limitation of soil moisture play a key role in dictating the presence or absence of riparian species. When available soil moisture and duration of its presence are coupled with extreme winter temperatures, duration of temperature extremes, levels of total dissolved solids, and other important physical constraints, it becomes difficult to understand the importance of each factor and which, if not all, are limiting distributions.

Soil moisture also affects structural development in communities. Permanent standing water prevents the establishment and growth of large woody species and supports low-growing sedges and grasses. Low soil moistures or short durations of availability disallow the establishment of large woody species as well. In instances of marginal soil moisture conditions, woody species may become established, but their growth and development is curtailed because of limited soil moisture. Other physical factors function singly or coupled to reduce the growth of woody species. The reduction in growth of these woody species prevents vertical development of the community, as well as foliage volume development on the horizontal plane.

Mojave Desert

Riparian habitats in this desert are poorly developed because of low annual rainfall. Orographic barriers produce a rain shadow effect, which reduces the amount of winter rainfall (Reitan and Green 1968). Summer rainfall from the Gulf of Mexico does not penetrate far enough northward to bring precipitation during the summer period; consequently the Mojave Desert receives most of its rainfall in the winter months (Reitan and Green 1968).

Soil moisture availability, possibly coupled with extreme winter temperatures, has limited the plant species composition and vertical complexity of riparian habitats in the Mojave Desert. Soil moisture availability appears to be the major factor since the Mojave River, a primary drainage through the Mojave Desert, supports a riparian forest of cottonwoods and willows (D. E. Brown personal communication).

In general, washes in this desert support nearly pure stands of cheesebush (Hunt 1966), or mixed communities of cheesebush, common saltbush, rabbitbush, and catclaw (Johnson 1976). On the eastern side of the Mojave Desert, in Death Valley, Hunt (1966) described mixed riparian habitats as containing honeysweet (*Tidestromia oblongifolia*), spurge (*Euphorbia* sp.), pygmy cedar (*Peucephyllum schottii*), desert trumpet (*Eriogonum inflatum*), bebbia (*Bebbia juncea*), stephanomeria ((*Stephanomeria parryi*), stingbush (*Eucnide urens*), sticky-ring (*Boerhaavia annulata*), and cheesebush.

More mesophylic riparian species were recorded near springs on the gravel fans (Hunt 1966). Species such as desert baccharis (*Baccharis sergiloides*), willow (*Salix* spp.), screw-

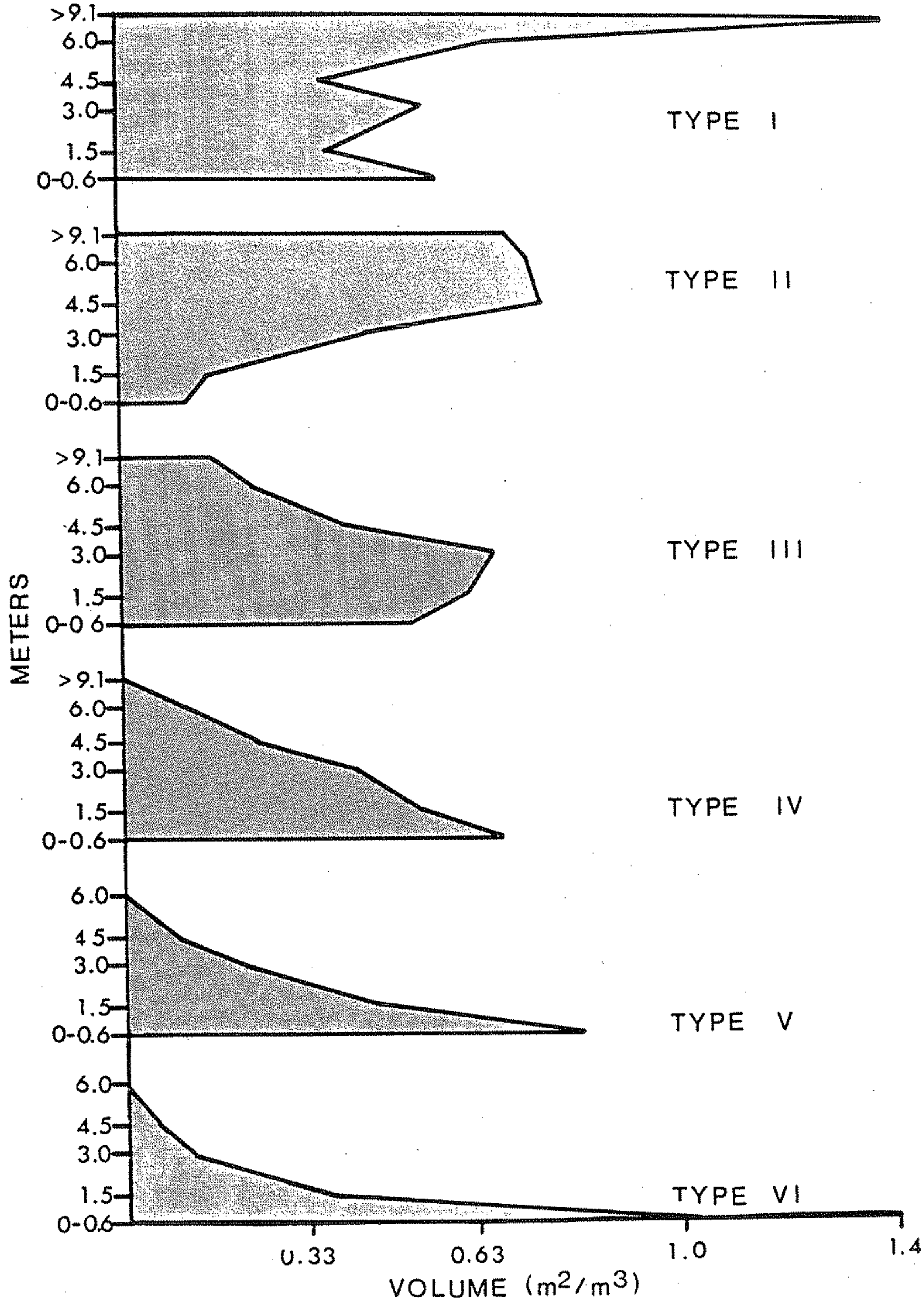

Figure 10-2. Foliage volume characteristics of six vegetation structural types of riparian plant communities found along the lower Colorado River.
Prepared by Lauren Porzer.

bean mesquite, and common reed (*Phragmites communis*) were found in these sites where soil moisture availability was higher.

Areas with high salinity and the water table only a short distance below the soil surface supported honey mesquite, arrowweed, four-winged saltbush (*Atriplex canescens*), salt cedar, inkweed, desert saltgrass (*Distichlis stricta*), rush (*Juncus cooperi*), and pickleweed (*Allenrolfea occidentalis*). The more halophytic species such as saltgrass, pickleweed, salt cedar, and inkweed were located in areas of higher salt concentrations, while honey mesquite and arrowweed were located in sites containing less salts (Hunt 1966).

The Mojave Desert is characterized by a poorly developed riparian flora. Willows and other trees or treelike species are restricted to areas around springs where soil moisture is high. Though some Mojave Desert riparian situations may support trees or treelike species, there is a general absence of riparian trees that provide foliage layers and foliage volume in the vertical profile. This absence of vegetational layering reduces the structural complexity of the riparian communities and hence lessens the importance and suitability of these habitats to many species of wildlife. This is not to imply that riparian habitats in the Mojave Desert are not important; they are, and they support a distinct and varied fauna as compared to the adjacent upland. The fact that they are so limited amplifies their importance to wildlife, and in many instances the vertebrate species that would be classified as riparian obligates primarily occur in man-made habitats (such as sewage ponds, agricultural fields, and drainage ways).

Great Basin Desert

Physiographically this desert is a large basin comprised of over a hundred smaller basins separated by fault-block mountain ranges (Billings 1951). Much of the drainage is into the many small interior basins, which are permanent lakes, playas, or saline flats. The Great Basin itself is bounded on the west by the Sierra Nevada and on the east by the Wasatch Range.

The tall and extensive north-south range of the Sierra Nevada lies in the path of Pacific cyclonic storms, which produce the rain shadow climates of the Great Basin Desert (Billings 1951). This orographic barrier is the most important factor affecting the distribution of winter and spring rainfall (Reitan and Green 1968). Summer moisture is infrequent because as cyclone tracks shift northward, the moist air brought from the Gulf of Mexico cannot extend far enough to benefit the Great Basin Desert consistently (Reitan and Green 1968).

Riparian vegetation in the Great Basin Desert is comprised of two types: emergent or wetland communities growing around the permanent lakes and playas, and the forests growing along the primary drainages that transverse this desert. Examples of the latter drainages are the Truckee River and the upper Colorado River.

The primary drainages transversing the Great Basin Desert support a flora with a well-developed structural profile. The presence of both the Fremont and narrowleaf cottonwood (*P. angustifolia*) provide a tall vertical component, while a number of species of willow (*S. lascolepis, S. nigra, S. exigua,* and *S. gooddingii*) form the midstory and understory. Daubenmire (1942:642) studied the vegetation in the northern portion of the Great Basin Desert and though the riparian descriptions are minimal, he reported "species of *Populus* and *Salix* form a thin and very discontinuous fringe along the banks of permanent streams, or other habitats where a relatively non saline water is near the surface at all times." He also lists *Cornus, Betula, Ribes,* and other ligneous genera forming tangled thickets along some stream sides. Principal species along other streams were *Crataegus douglasii, Betula microphylla, Alnus tenuifolia,* and *Amelanchier florida.*

More extensive descriptions of the riparian flora along the upper Colorado River are given by Hayward et al. (1958). They reported three lakes on Kanab Creek in Utah as supporting Fremont cottonwood, gambel oak (*Quercus gambelii*), willow clumps (*Salix* spp.), cattails, rushes (*Juncus* spp.), sedges (*Carex* spp.), and salt cedar. Other studies provide riparian community descriptions in the Glen Canyon Reservoir Basin on the Colorado River (Woodbury et al. 1959), the Flaming Gorge Reservoir basin in Utah and Wyoming (Woodbury et al. 1960; Flowers 1960), the Navajo Reservoir basin on the San Juan River in Colorado and New Mexico (Flowers 1961), and the Curecanti Reservoir basins on the Gunnison River in western Colorado (Woodbury et al. 1962). All of these papers are replete with descriptions of the riparian cottonwood-willow complex, with its rich understory of shrubs that line these primary drainages and form broad forests where the floodplain widens.

The smaller basins within the Great Basin contain few, if any, halophilic mesophytes (Shreve 1942). Kearney et al. (1914) studied the zonation of the vegetation as it related to soil salt content along the shore of the Great Salt Lake. Soils along the shore, where salt concentrations were highest, supported low-growing and open stands of *Salicornia rubra, S. utahensis,* and *Allenrolfea occidentalis.* Soils with lower salinities supported colonies of saltgrass (*Distichlis spicata*) and alkali sacaton (*Sporobolus airoides*). Greasewood (*Sarcobatus vermiculatus*) and shadscale (*Atriplex confertifolia*) occurred as dense, low-growing shrubs in less saline soils.

Sonoran Desert

The added possibility of both winter and summer rainfall in the Sonoran Desert has allowed a more diverse species composition and vertically developed riparian component in secondary and lesser drainages. Along the western edge of the Sonoran Desert, the vertical component of the riparian vegetation is increased by the invasion of facultative species such as ironwood and blue palo verde. Shreve and Wiggins (1964) pointed out that the height of this vegetation varies from 1 to 5 m and that height is proportional to the width of the drainage.

Winter rainfall is the major source of precipitation along the western edge of the Sonoran Desert (Reitan and Green 1968), and not many riparian obligates can tolerate such low levels of soil moisture. The major shrub or treelike species is the smoke tree (*Dalea spinosa*), which grows in the middle of the gravel and sandy bottoms of large drainages (figure 10-3). It appears to be able to invade and survive in the wash bottom for one of two reasons. First, it grows primarily in broader wash bottoms, which are less prone to highly destructive floods. Second, the rainfall occurs primarily in the winter, and unlike summer rains, it is widespread and gentle. Smoke tree must be able to survive periods of very low soil moisture availability because the other dominant species in these riparian ecosystems are ironwood and blue palo verde, which grow mostly along the edge of the drainage.

In drainages with a permanent water supply in southwestern California and possibly as far east as central Arizona, the native Washington palm (*Washingtonia filifera*) has been able to persist (figure 10-4). Like giants marching down a drainage, this relict species (Axelrod 1950) can still be found in a few localities. Fire may be beneficial or even essential to this species. Following fire, seedlings become established after the dense understory has been removed (Vogl and McHargue 1966). Possible competition for water may also be reduced following fire.

To the east toward central Arizona, as the probability of summer rainfall increases, other shrub and tree species such as desert willow and mesquite make up a greater percentage of the riparian flora. Primary drainages in the Sonoran Desert support a complex and species-rich riparian flora. Gallery forests of cottonwood intermixed with willow line the primary drainages of the Colorado River in western Arizona, as well as other primary drainages throughout the Sonoran Desert.

Chihuahuan Desert

Primary drainages in this desert also support a species-rich riparian flora. Forests of cottonwood and willow line the river banks. Screwbean mesquite, honey mesquite, wolfberry, and species in the genus *Atriplex* may occur along these drainages as well.

Secondary and lesser drainages in the Chihuahuan Desert are similar to those in the Sonoran Desert. Many of the same genera and species are shared, and mesquites and desert willow provide the tallest vertical height in these drainage systems. Palo verde and ironwood are absent in the Chihuahuan upland desert flora, and the absence of these facultative riparian species reduces the complexity of secondary drainages in the Chihuahuan Desert. Shrubs in the genera *Acacia, Mimosa, Baccharis, Condalia,* and *Hymenoclea* frequently mix with

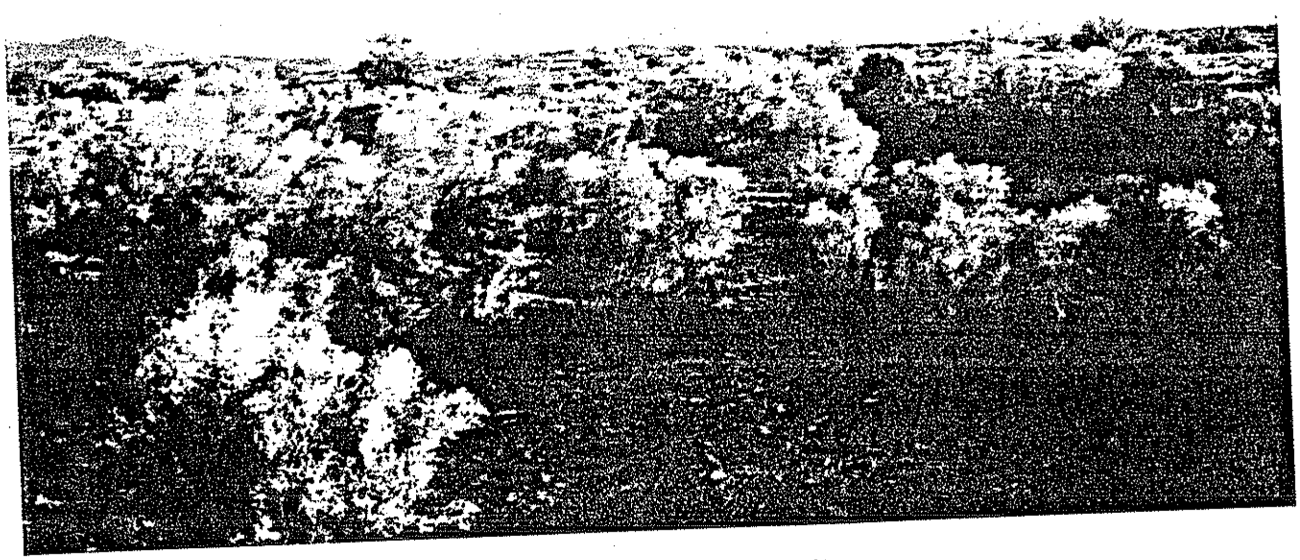

Figure 10-3. Broad riparian ecosystem dominated by smoke tree, with blue palo verde and iron wood bordering the floodplain.
Photograph taken near the Arizona-California border by R. Ohmart.

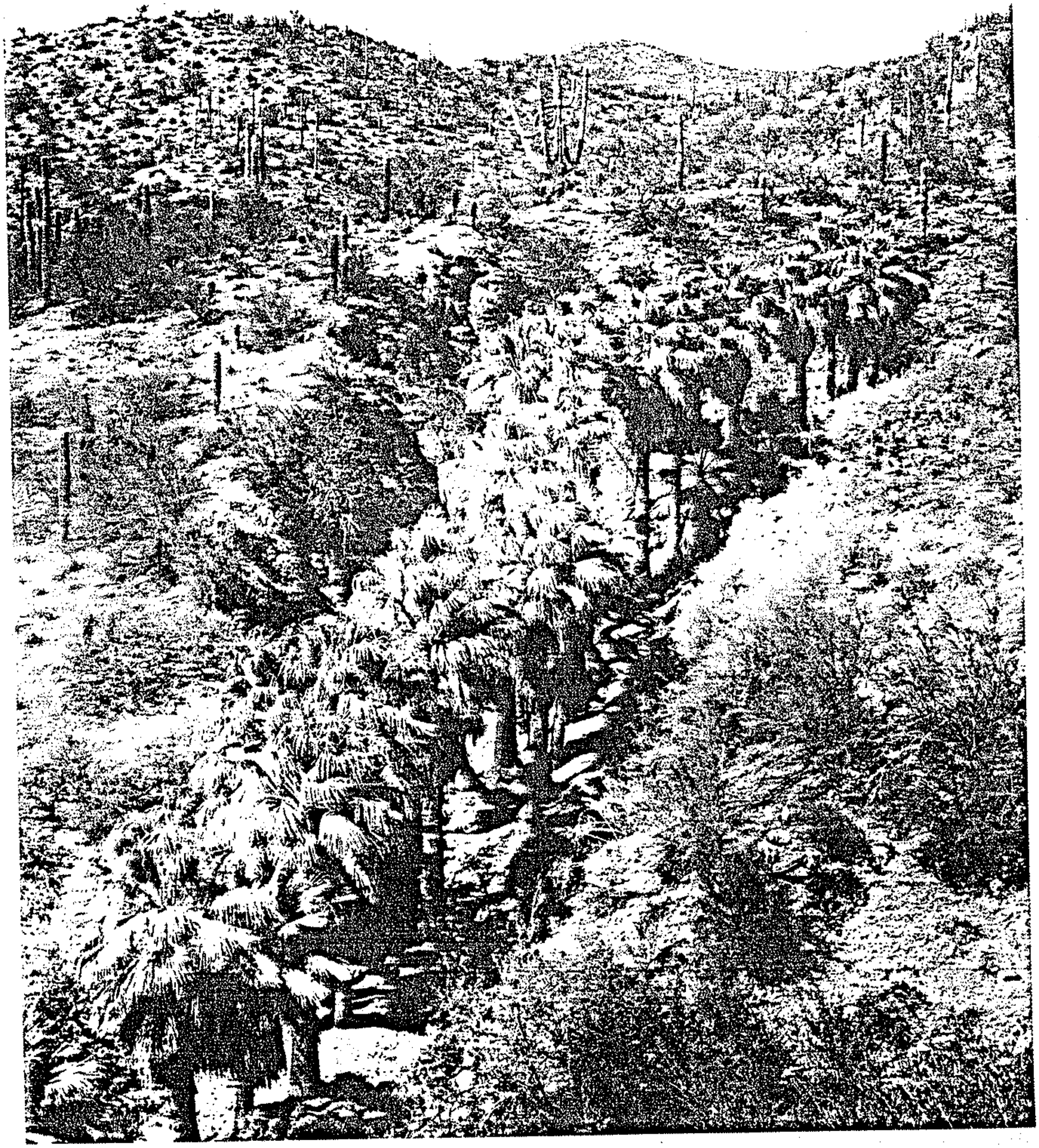

Figure 10-4. Washington palms at Alkali Springs, Yavapai County, Arizona.
Note the typical Sonoran vegetation on the dry hillsides. Photograph by David E. Brown.

desert willow and/or mesquite to provide an overstory and understory in the secondary drainages of the Chihuahuan Desert.

GENERAL CONSIDERATIONS

Some riparian species decline or increase in commonness and community extent from west to east, or east to west, across the Sonoran and Chihuahuan deserts. Arrowweed, for example, declines in abundance from the Colorado River to the Rio Grande in west Texas, although farther south and east along the Rio Grande at lower elevations it becomes more common (D. E. Brown personal communication). This type of distribution indicates that extreme winter temperatures may be limiting the species abundance in the Chihuahuan Desert. Desert willow is a common and robust tree in the Chihuahuan Desert, but westward into the Sonoran Desert it becomes less common. In this case, soil moisture availability at critical times of the annual cycle appears to limit its distribution. These intriguing distributional questions pose many interesting ecological problems for future research in riparian ecology.

FAUNAL CONSIDERATIONS

It is significant that riparian ecosystems are depicted as lines on maps of our deserts, for they are truly the lifelines for many vertebrate species, including man. The dependence of animals on riparian habitats ranges from none to total. In this range of animal use, riparian habitats may serve as travel corridors through the deserts, as a temporary refugium during extreme desert conditions, and as vital habitat providing all of its needs for its existence.

Interestingly enough, while man tends to avoid the deserts during the hot and dry summer, many vertebrates have evolved behavioral adaptations in order to avoid the winter period, which man considers the most hospitable. Many of the poikilotherms overwinter in a dormant state, either singly or in hibernacula, and a number of birds and bats move south to more favorable environments.

A primary reason for desert-dwelling animals not leaving the desert during the hot, dry summer months is that most never experience the extreme summer temperatures of the desert. Activity patterns are adjusted so as to avoid high ambient temperatures, and refugia such as cool, moist burrows or heavily shaded, moist areas are used. Many species live exclusively in the moist and heavily shaded habitats where primary and secondary production is high in a warm, arid environment. These habitats are riparian ecosystems. The amount of dependence on the riparian community by desert animals is highly variable. In attempting to classify the species in each major group into obligate, facultative, or nonriparian, the extremes are easy, but difficulty arises with species that are intermediate.

Fishes

The distribution of native desert fishes is limited by geographic barriers or by need of tolerance to some environmental feature (Deacon and Minckley 1974). Of the approximately two hundred native species in western North America, only the speckled dace (*Rhinichthys osculus*) can be considered widespread (Miller 1959). Desert fishes are obligate to riparian habitats, being found in permanent streams or springs. During ephemeral wet periods, they may expand into intermittent drainages, but as drier periods return, their distribution is reduced.

Hubbard (1977) examined native fish numbers in Arizona and New Mexico and pointed out that the nearly thirty native fish species in Arizona (Minckley 1973) represent 5 percent of the fish fauna of the United States. New Mexico, with fifty-nine recorded species, represents 9 percent of the total United States fish fauna. These totals are impressive for two arid states: about half of Arizona is in the Sonoran Desert and about half of New Mexico is in the Chihuahuan Desert.

Many of the fish species found in the North American deserts are in the minnow family (Cyprinidae) and range in size from tiny minnows to the Colorado River squawfish (*Ptychocheilus lucius*), which has attained weights greater than 25 kg (Minckley 1973).

Desert fishes show a broad set of morphological characters for existing in desert riparian ecosystems. Fishes in torrential streams may have sucking discs or hooks to prevent them from being washed away, while in slower-moving or quiet waters, the fish may be deep-bodied and lethargic (Deacon and Minckley 1974). In slow-moving, turbid waters, barbels or other types of sense organs may be developed for nonvisual sensory input. In fast-flowing, turbid streams, fish may possess a leathery skin with minute, embedded scales, presumably to reduce the abrasive nature of the sand-laden waters (Hubbs 1940, 1941).

In desert streams with small surface flows in summer months, the processes of evapotranspiration may demand all the surface flow during the daylight hours (Campbell and Green 1968). This would essentially eliminate the fish fauna, but some species, such as the longfin dace (*Agosia chrysogaster*), can survive these dry periods under saturated mats of algae and debris (Deacon and Minckley 1974). Minckley and Barber (1971) observed an alternating wet and dry fourteen-day cycle in Sycamore Creek in Arizona; a small rain in August rejuvenated the flow, allowing the longfin dace that had survived in moist algal mats to repopulate the stream.

Because evapotranspiration from desert streams is so high and salinities can range from low to very high, it is not surprising that desert fish have evolved the capacity to tolerate high salt levels. La Bounty and Deacon (in Deacon and Minckley 1974) reported that a small *Cyprinodon* in Death Valley can survive in a salinity of 78 gm per liter, and Hunt et al. (1966) implied that these fish may experience salinities of

160 gm per liter at times. Deacon and Minckley (1974) reported *Cyprinodon atrorus* surviving concentrations up to 95 gm per liter in the Cuatro Cienegas basin. It appears that salinity levels in some closed basins limit the distribution of some fish. Freshwater fish are found in the tributary streams and deltas feeding the Great Salt Lake, but there are no fish in the open waters of the lake (Sigler and Miller 1963).

Amphibians and Reptiles

Species in these two groups have been combined because there are so few species of desert amphibians. The reproductive habits of these two classes differ greatly. Amphibians are closely tied to aquatic environments, whereas reptiles, with a cleidoic egg, are less dependent on surface aquifers. There are few reptiles that can be considered obligate riparian species.

The species list in appendix 10-A provides a compilation of the amphibian and reptilian species characteristic of each desert. Species were excluded whose distribution penetrated only a small portion of a particular desert or included only an isolated mountain range or two within a desert. Species found in the Anza Borrego region in southern California were also excluded. This region has a distinct herpetofauna and, if included, should possibly be considered a fifth desert. Only binomials were used, since each desert usually has its own subspecies. *Rana pipiens* sp. was used since the taxonomic status of this sibling species group is not clear. Subspecies were used only in the case of *Trimorphodon* because the specific epithet has recently been changed to *biscutatus* and previously held species are all considered subspecies currently.

The Great Basin and Mojave deserts, with a poorly represented riparian fauna, contain two and one species of amphibians, respectively. The Sonoran and Chihuahuan deserts, with more highly developed riparian ecosystems, more subtropical flora, and less extreme winter temperatures, contain eleven and ten amphibian species, respectively. In the Sonoran Desert about 80 percent of the total amphibians (eleven) are obligate or facultative, while in the Chihuahuan Desert these two groupings constitute 70 percent of the total (ten). Treefrogs (*Hyla* spp.) and species of frogs in the genus *Rana* contain those amphibians considered to be riparian obligates.

Of the reptiles, only two species of turtles (Sonoran mud turtle, *Kinosternon sonoriense*, and the spiny softshell, *Trionyx spinifer*), one species of lizard (*Holbrookia maculata*), and three snakes in the genus *Thamnophis* adhere to the criteria established to denote riparian obligates.

An example of productivity in riparian habitats is seen with respect to the Sonoran mud turtle. A life history study (Hulse 1974) in central and southern Arizona revealed that the species was opportunistic with respect to diet but tended to be carnivorous. Densities were 330 animals per hectare (ha-0.4 acre) at the Tule Stream study site. The densities attained by this population are an example of how much food must be produced in the stream to support such a population.

Mammals

A number of mammalian species are highly dependent on riparian habitats for food, water, shade, and cover. Many species can be considered facultative or even obligate in riparian habitats. Most mammals that use desert riparian habitats are wide ranging in the continental United States or are common at higher and moister elevations in desert mountain ranges. They occur primarily in the desert along moist riparian corridors. They may be found in parts of the upland deserts, but highest densities are attained in and around riparian ecosystems. Some of these are the raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), mule deer, cotton rat (*Sigmodon hispidus*), rock squirrel (*Spermophilus variegatus*), hog-nosed skunk (*Conepatus mesoleucus*), desert pocket mouse (*Perognathus penicillatus*), beaver (*Castor canadensis*), cactus mouse (*Peromyscus eremicus*), deer mouse (*Peromyscus maniculatus*), and the white-footed mouse (*Peromyscus leucopus*). Others, such as the desert cottontail (*Sylvilagus audubonii*), coyote, gray fox (*Urocyon cinereoargenteus*), bobcat (*Felis rufus*), and ring-tailed cat (*Bassariscus astutus*), may occur throughout the desert but are usually found in higher densities along riparian ecosystems. Many carnivores concentrate their predatory activities in and adjacent to riparian habitats where densities of many prey species are highest. Other small mammals, such as bats, feed extensively over and in riparian habitats. A number of bats also utilize the tall, dense riparian vegetation for daytime roosts. Riparian corridors may also be important in providing food and/or water during bat migration.

Birds

A compilation of the avian species found in the four North American deserts provides a comparison of the relative value of the riparian habitats within each of the deserts and their adjacent uplands (appendix 10-B). Other interesting comparisons emerge, such as the total number of breeding species in riparian habitats in each desert and total species in each desert. Some species vary their dependence classification throughout an annual cycle. Therefore, to simplify the data presentation, the category of highest dependency in the annual cycle was selected.

MOJAVE DESERT

A total of 215 avian species regularly occur within the Mojave Desert (Grinnell and Miller 1944; Small 1974). Of this total 68 species (32 percent) breed. Fourteen species (6 percent) are riparian obligates, and of these 12 are breeding species. 164 are considered facultative (76 percent) with 46 breeding, and 37 species (17 percent) are nonriparian forms with 15 as breeding species.

A number of the species that are considered riparian obligates in other deserts are considered facultative species in the Mojave Desert. Their riparian habitats are either poorly developed or absent in the Mojave Desert, and when the species do occur they are present in small numbers in limited habitats such as sewage or domestic livestock ponds.

GREAT BASIN DESERT

A total of 262 avian species regularly occur within the Great Basin Desert (Burleigh 1972; Hayward et al. 1976; Johnson 1978). Of the 262 species, approximately 148 (57 percent) are breeding species. Fifty-five species (21 percent) are obligate riparian species with 50 breeding, 159 (61 percent) are facultative riparian species with 81 breeding, and 48 (18 percent) are nonriparian species with 17 breeding. Of the total avian species regularly occurring in the Great Basin Desert, 82 percent are either totally or partially dependent on riparian habitats.

SONORAN DESERT

A total of 308 avian species regularly occur within the Sonoran Desert (Phillips et al. 1964 and updated records). Of this total, 56 (18 percent) are obligate riparian, 197 (65 percent) are facultative riparian species, and 55 (18 percent) are nonriparian species. In the Sonoran Desert, approximately 82 percent of the bird species that regularly occur are dependent on riparian habitats to a great extent.

Coarser grained comparisons of the relative value of the riparian habitats have been made by determining what percentage of the total number of nesting species in an arid environment is dependent on water-related habitats. Johnson et al. (1977) did this for the Sonoran Desert, and of the 166 total breeding species, 127 (77 percent) in some manner were dependent on water-related habitats. Slightly over 50 percent (84 of 166 species) were totally dependent on water-related habitats. The percentages reported by Johnson et al. (1977) for species that are dependent in some manner on water-related habitats (77 percent) are close to the 87 percent total, which represents those species pooled as obligate and facultative riparian species. Wauer (1977) presented similar results but confined his totals to those species known to breed in southwestern riparian habitats below 5500 feet. He listed 94 avian species breeding in southwestern riparian habitats, and of this total, 39 species (40 percent) nested in riparian habitats along the Rio Grande in west Texas. These studies indicate the general significance of riparian habitats to nesting birds.

CHIHUAHUAN DESERT

A total of 322 species regularly occur within this desert, with approximately 127 (39 percent) listed as breeding (Ligon 1961; Wauer 1973; Oberholser 1974; Hubbard 1978). Of the 322 species, 45 (14 percent) are riparian obligates with 38 breeding, 228 (70 percent) are facultative with 75 breeding, and 49 (15 percent) are nonriparian with 14 breeding. A total of 273 (85 percent) avian species in the Chihuahuan Desert are obligate or facultative species to riparian habitats.

Table 10-1 summarizes the totals for each desert. The largest percentage of riparian obligate species occurs in the Sonoran Desert and is closely followed by the Great Basin Desert. The Mojave Desert with a poorly developed riparian ecosystem has the fewest riparian obligates.

GENERAL AVIAN CONSIDERATIONS

The number of species and densities of birds are usually much higher in riparian habitats when compared to adjacent desert uplands. There is an observable disparity in primary productivity (gross biomass) between the riparian habitat and the adjacent desert upland.

Table 10-1
Summary of the dependency of the avifauna on riparian ecosystems in each North American desert

	RIPARIAN DEPENDENCY			
DESERT	OBLIGATE	FACULTATIVE	NONRIPARIAN	TOTAL
Mojave	14 (6)	164 (76)	37 (17)	215
Breeding	12 (18)	46 (68)	10 (15)	68
Great Basin	55 (21)	159 (61)	48 (18)	262
Breeding	50 (34)	81 (55)	17 (11)	148
Sonoran	56 (18)	197 (64)	55 (18)	308
Breeding	50 (37)	68 (51)	16 (12)	134
Chihuahuan	45 (14)	228 (71)	49 (15)	322
Breeding	38 (30)	75 (60)	14(11)	127

NOTE: Numbers in parentheses are percentages.

Density

Although no comparative data are available on insect biomass in riparian and desert ecosystems, an indirect measure of high insect abundance in riparian ecosystems is indicated by the density of breeding birds. Carothers and Johnson (1975) reported a breeding density of 1059 pairs per 40 ha on the Verde River in central Arizona, representing the highest reported breeding density of birds in the continental United States. Not only do these figures provide insight into insect productivity in riparian habitats, they also clearly demonstrate the value of these habitats to the breeding avifauna in our deserts.

Raptors

Another indirect indication of gross productivity in riparian habitats is the number of avian predators that are obligates to riparian habitats in desert ecosystems. The black hawk (*Buteogallus anthracinus*), gray hawk (*Buteo nitidus*), bald eagle (*Haliaeetus leucocephalus*), cooper hawk (*Accipiter cooperii*), zone-tailed hawk (*Buteo albonotatus*), and Mississippi kite (*Ictinia mississippiensis*) feed and nest in riparian habitats in desert communities. These raptors may require free drinking water and large trees or cliffs for nesting in most desert situations; however, in the Sonoran Desert where these species reach their highest densities in desert habitats, there are alternate nest sites available in the tall saguaros and palo verde or ironwood trees in the adjacent upland.

Preliminary food habit studies of these large raptors indicate that the major portion of their food resources comes from the biotically rich riparian habitats. The small breeding population of bald eagles (eight to ten active nests) in the Sonoran Desert along the Salt and Verde rivers in Arizona feed primarily (about 75 percent) on channel catfish (*Ictalurus punctatus*) and carp (*Cyprinus carpio*) (Hildebrandt and Ohmart ms.). The nesting black hawk feeds primarily on a mixture of aquatic and terrestrial riparian vertebrates (Glinski and Ohmart ms). The gray hawk specializes in terrestrial vertebrates from the riparian habitat (Glinski ms.), while the recently invading Mississippi kite primarily eats cicadas (*Diceroprocta apache*) that emerge from the floodplain soils (Glinski and Ohmart ms.).

Migration

It has been postulated that primary drainages may play an important and possibly a vital role for species that migrate across North American deserts. The lush riparian habitats provide needed water, food, or resting areas for migrants. They may also serve as north-south navigational guides through arid habitats. Little quantitative data are available, but there are few continuous mountain chains in desert areas, and the lasting physiographic feature of a primary stream course might well be used as an orientation cure for migrating species. Johnson et al. (1977) examined densities of migrant birds in the adjacent desert upland versus riparian areas in the Sonoran Desert and reported 10.6 times as many migrants per hectare in riparian habitats as in adjacent desert habitats. These data are convincing as to the value of riparian habitats to migrants, but more research is needed regarding the importance of the riparian habitat to each migratory species. Western desert riparian habitats may be more valuable to some species, while eastern desert riparian corridors may be more important to others. We also need to know the total number of migrants that use these corridors.

While many species migrate up and down riparian corridors, a number of species overwinter in these habitats. In a study (Anderson and Ohmart ms.) spanning more than seven years on the Colorado River in Arizona, researchers have examined habitat and niche breadth of visitors, including both winter and breeding, versus permanent residents. It was found that avian visitors in terrestrial habitats are generally much more specialized in their habitat requirements than are permanent residents. Consequently any habitat modifications of the riparian vegetation tend to have a more direct and dramatic effect on breeding and wintering visitors than on permanent residents. Species such as the bell vireo (*Vireo bellii*), yellow-billed cuckoo (*Coccyzus americanus*), clapper rail (*Rallus longirostris*), black rail (*Laterallus jamaicensis*), black hawk, and gray hawk are much more sensitive to habitat change than are the Abert towhee (*Pipilo aberti*), Crissal thrasher (*Toxostoma dorsale*), and black-tailed gnatcatcher (*Polioptila melanura*).

Wetlands

Waterfowl and shorebirds migrating and wintering in desert environments are highly dependent on wetlands and riparian habitats. The arid Southwest is generally not thought of as an important flyway or wintering area, but a number of species with relatively high densities rely on rivers, backwaters, and impounded bodies of water, either during migration or for overwintering sites. Little quantitative data exist considering the importance of such habitats, but a few studies do focus on this point.

Quantitative data of timing in use of various wetland habitats, number of species using them, and total number of birds have been reported by Ohmart and Anderson (1980) for the lower Colorado River. The eight riparian types of habitats examined ranged from natural wetland communities to those highly modified by man and included such habitats as reservoirs, riprapped and dredged areas, rivers in canyons, undisturbed river with adjacent riparian vegetation, old river channel, river immediately below dams. *Phragmites* marshes, bulrush (*Scirpus* spp.) marshes, dense cattail (*Typha* spp.) marshes, and moderately dense cattail marshes.

A summary of these data in table 10-2 demonstrates the value of these wetland habitats to birds. There is a general tendency for more avian species and higher densities to be present in aquatic habitats, where there is dense emergent vegetation, than in an open water situation.

Both species richness (number of species) and density must be used in evaluating these habitats, since high avian densities in different kinds of marsh habitats are a reflection of feeding and roosting densities of species such as red-winged blackbirds (*Agelaius phoeniceus*) and yellow-headed blackbirds (*Xanthocephalus xanthocephalus*). For example, a moderately dense cattail marsh will support a mean of 35.9 species and a mean density of 345 birds per 40 ha, whereas a bulrush marsh may contain 469 birds per 40 ha, with only 13 species.

The lower Colorado River and its associated habitats support between 75,000 and 100,000 water-related birds during peak months of use, with highest densities found in undisturbed wetlands. Although some of the man-made habitats studied did not support species numbers or densities equaling undisturbed habitats, they did provide a habitat that, before modern technology, was absent. Deep-water habitats (reservoirs and areas below dams) support species such as loons, grebes, and diving ducks, which do not normally inhabit shallow-water habitats.

VEGETATION LAYERING

The tall and multilayered habitats that grow along the alluvial floodplain are extremely important to the avian species. Tall riparian forests provide a number of layers of foliage that attract and support a high density of breeding and wintering avifauna. Anderson and Ohmart (ms) recently found that riparian birds responded to four layers of vegetation as opposed to the usually considered three layers (MacArthur and MacArthur 1961). Using Pearson product moment correlations, they correlated the density of each avian species, assuming no layers, three layers, and four layers. They reported nineteen species associated with layers 7.6 m or more, ten species associated with the 4.6 to 7.6 m layer, thirteen species associated with the 1.5 to 4.6 m layer, and eleven species with the 0.15 to 1.5 m layer. The overstory group, comprised of nineteen species, was composed of specialists that were generally missing when this layer was absent or poorly represented. The twenty-three species in the two middle layers and some of the eleven in the understory group were generalists. These species might be present even if their layers were absent or poorly represented. Therefore vertical structure of the vegetation in riparian communities, as well as the volume of vegetation present in these layers, is important for high avian densities, Using principal components analysis, Anderson, Rice, and Ohmart (ms) reported that vegetation volume was generally more important as a predictor of both bird density and diversity than was foliage height diversity.

PATCHINESS

Another important vegetational component in these communities that has recently been quantified is intracommunity patchiness (Anderson and Ohmart ms). The data spanned fourteen seasons and the patchiness index correlated with avian species richness in twelve seasons and bird species diversity in

TABLE 10-2
Summary of the mean number of species and densities of birds in ten types of wetland habitats along the lower Colorado River

HABITAT TYPE	NUMBER OF SPECIES	MEAN DENSITY (NUMBER PER 40 HA)
Reservoirs	4.9	20
Riprapped and dredged	6.1	36
River in canyons	6.6	25
Undisturbed river with adjacent riparian vegetation	10.5	101
Old river channel	11.4	149
River immediately downstream from dams	11.8	164
Phragmites marsh	13.0	237
Bulrush marsh	14.0	469
Dense cattail marsh	30.5	204
Moderately dense cattail marsh	35.9	354

SOURCE: Wildlife use values of wetlands in the arid southwestern United States. Robert Ohmart and Bertin Anderson. *Proceedings of the National Symposium on Wetlands 1978*, 1980.

eleven seasons. They reported that the patchiness index was strongly correlated with total insect biomass and was significantly correlated with the number of insect families present. Thus relatively homogeneous communities with a lot of patchiness in the form of canopy or understory discontinuity or a few dead trees scattered throughout would have higher insect biomass and hence support more bird species than would a homogeneous monoculture with little patchiness. Monocultural communities tend to have little patchiness, while communities mixed with trees and shrubs have high patchiness values.

Dead trees or snags within a community promote patchiness. Anderson and Ohmart (ms) counted dead trees with a diameter breast high 15 or more cm but did not find a significant correlation between numbers of dead trees and patchiness. By grouping communities into high, medium, and low snag numbers, there was a significant correlation between patchiness and those communities having a high number of snags. It has been demonstrated that the presence of dead trees in a community attracts a number of cavity-nesting and insect-probing species (Yeager 1955; Flack 1976).

Another finding by Anderson and Ohmart (ms) was the predictive capabilities of the patchiness index with respect to avian densities, species diversity, and species richness. Predictions of avian densities had an average error of 29 percent. Climate was an important variable with respect to predicting avian densities in desert riparian communities, since harsh winters dramatically reduced avian numbers. Harsh winters also affected permanent residents; there were lowered population numbers carried into the next breeding season. Socially regulated populations were less severely affected than species that did not appear to have evolved social mechanisms for population regulation (Anderson, Fretwell, and Ohmart ms). It is not surprising that climate has such an important effect on avian densities in desert riparian habitats, since insect availability was found to be very low during harsh winters (Anderson and Ohmart unpubl.) and many of the wintering species are insectivores.

Anderson and Ohmart (ms), using the patchiness index as a predictor of bird species diversity, reported an average error of 5 percent. The index overpredicted in nineteen of twenty-three plant community and structural types and was exceedingly high in the introduced communities of salt cedar. This exotic species does not support the avian species diversity predicted from high foliage height diversity and patchiness index values.

In predictions of species richness (number of species) using the patchiness index, there was an average error of 15 percent. The predictions were too high in salt cedar communities and too low in cottonwood-willow communities.

In general, riparian habitats support the highest number of avian species, the highest densities, and bird species diversities of any other types of desert habitats. The values in table 10-3 provide some insight into the densities, number of species, and bird species diversities in these riparian communities.

FLORAL AND FAUNAL SPECIALISTS IN RIPARIAN HABITATS

Not only are there plant community attributes that are valuable to wildlife, but there are also intrinsic values of a particular plant species to specific wildlife species. It is widely accepted that an animal species, needs food, water, cover, and space to exist. Many individual plant species may provide one or more of these components, but if a particular plant species or community provides all of these components for an animal species, the animal may then be thought of as a habitat or plant species specialist. Because of the evolutionary history of riparian communities and the specialization that has occurred in riparian plant species, it is not surprising that some animal specialists have evolved with this flora.

Honey Mesquite

This important riparian species occurs in southwestern Utah, southern Nevada, extreme western Arizona, and southeastern California into Baja, California. It also occurs in southern, central, and eastern New Mexico, as well as in all of west and central Texas and extends throughout Chihuahua, Mexico in the Chihuahuan Desert (Simpson and Solbrig 1977). Velvet mesquite is found in western and southern Arizona south into Sonora, Mexico.

The rapidly growing and highly specialized mesquite taproot has been demonstrated to grow up to 50 m (Phillips 1963). Lateral roots measured at over 18 m long (Fisher et al. 1959) grow just under the soil surface to utilize subsurface moisture. The highly developed root system allows this slow-maturing species to invade successfully second terraces along desert rivers where the water table may be 6 m or more below the soil surface or to grow along the edge at secondary and tertiary drainage systems that may have deep and highly fluctuating water tables.

Leaf bud burst and leaf drop show genetically based variation in timing (McMillan and Peacock 1964; Peacock and McMillan 1965). Individuals from widely separated localities reared under uniform conditions retained leaf initiation and leaf drop characteristics similar to individuals at the natural sites. Fall dormancy in southern mesquite populations appears to be induced by temperature rather than photoperiod. Soil moisture, prior drought, and temperature appear to act in concert to initiate leaf drop in other populations.

The leaves of velvet and honey mesquite are grazed by insect herbivores. One specialist, reported by Cates and Rhoades (1977) in two study sites in Arizona, was a meloid beetle (*Epicauta arizonica*). A variety of sprays from all of the woody legumes were presented to the meloid beetle, it consumed only the leaves of velvet mesquite. The insect herbivores grazing on mesquite leaves provide a food source for higher trophic levels such as predaceous insects, birds, and small mammals.

Both honey and velvet mesquite produce tiny, greenish-white flowers that are clustered along a spike. Each spike is about 7 cm long and supports hundreds of small flowers. The spikes may occur singly, or there may be up to eighteen spikes per leaf axil. It has been estimated that a single highly branched velvet mesquite tree will produce about 6000 inflorescences or spikes during an annual cycle (Simpson et al. 1977). Time of flowering for velvet mesquite is highly variable in Arizona. Flowering was reported in late April one year and in about the first week in June the previous year (Simpson et al. 1977). These abundant and energy-rich flowers provide an important resource for insects, and the resultant fruits are an important food source for vertebrates.

On a per-tree basis, velvet mesquite provides one of the richest pollen and nectar sources in the Arizona desert (Neff, et al. 1977). Simpson et al. (1977) reported that velvet mesquite produces more pollen per floral unit than most other insect-pollinated desert shrubs in North America. During peak production each inflorescence produces 2.4 mg of nectar per day. The pollen is high in protein, which is important for insect reproduction and larval growth.

A large number of insects utilize this rich food resource while it is available. Simpson et al. (1977) found that more animals were associated with *Prosopis* flowers than with any other plant species in Sonoran Desert habitats. They reported that a single inflorescence may support hundreds of thrips and a host of other species. Solitary bees are a principal group, and over 160 different species have been recorded visiting the flowers of *Prosopis* (Moldenke and Neff 1974). At least five species of small bees have been classified as *Prosopis* flower specialists (Simpson et al. 1977), and it is common to see thousands of individuals in the subgenus *Perdita* hovering around and alighting on a flowering *Prosopis* (Cockerell 1900). The drab-colored flowers may not attract human eyes, but the pollen of *Prosopis* reflects ultraviolet light and appears as bright dots to the compound eye of an insect that can detect short wavelength light (Simpson et al. 1977).

Not all mesquite flowers produce fruit. It has been estimated that fewer than 3 percent of the millions of flowers produced initiate fruit development and from one-half to one-third of this group produce fruit (Solbrig and Cantino 1975). Apparently the level of soil moisture and rainfall during the

Table 10-3
Breeding bird densities, species richness, and bird species diversity in various riparian communities in North American deserts

COMMUNITY	DENSITY (BIRDS PER 40 HA)	SPECIES RICHNESS	BIRD SPECIES DIVERSITY	DESERT	SOURCE
Cottonwood	847	26	2.98	So	Carothers et al. 1974
	684	28	3.15	So	Stamp 1978
	425	20	2.68	So	Carothers et al. 1974
Cottonwood-willow	354	27	2.67	Ch	Engel-Wilson and Ohmart 1978
	197	10	2.76	So	Ingles 1950
Cottonwood-willow-mesquite	197	37	3.15	So	Goldwasser 1978
	435	48	2.77	So	Anderson and Ohmart 1977a
Willow-mesquite	520	8	1.62	So	McKernan 1978
Mesquite	11	13	2.35	Mv	Austin 1970
	49	12	2.33	Mv	Austin 1970
	244	19	2.60	So	Stamp 1978
	190	31	2.74	So	Anderson and Ohmart 1977b
Salt/Cedar	243	28	2.16	Ch	Engel-Wilson and Ohmart 1978
	199	22	2.03	So	Anderson and Ohmart 1977a
Screwbean mesquite-salt cedar	1176	26	1.40	So	Anderson and Ohmart 1977a
	427	32	1.98	So	Anderson and Ohmart 1977a
	278	34	2.43	So	Anderson and Ohmart 1977a
Arrowweed	87	25	2.67	So	Anderson and Ohmart 1977a

SOURCE: Wildlife use values of wetlands in the arid southwestern United States. Robert Ohmart and Bertin Anderson. *Proceedings of the National Symposium on Wetlands 1978*, 1980.

NOTE: So = Sonoran Desert; Mv = Mojave Desert; Ch = Chihuahuan Desert.

flowering period affects flower development and fruit production (Mooney et al. 1977). Low soil moisture promotes heavy flowering and good fruit production, while the opposite condition produces low fruit production. Rainfall during the flowering period also reduces flowering and fruit production.

The fruits of both velvet and honey mesquite are indehiscent pods with a thin outer layer (exocarp), a thick and spongy middle layer (mesocarp), and a thin inner layer (endocarp) surrounding the hard and stony seed. Pods vary in number and length, but when mature they constitute a large biomass rich in stored nutrients. Glendening and Paulsen (1955), over a four-year period, sampled thirty young velvet mesquite trees with a crown diameter of 4 m, and these trees produced a mean of 0.7 kg dry weight of pods per tree per year. The pods contained an estimated 5000 seeds. They estimated that more mature trees with crown diameters around 6 m would produce more than 16 kg of pods per tree per year, or about 140,000 seeds.

Chemical analysis data amplify the importance of this food resource to desert animals. *P. velutina* contains 16 percent sugar and 12 percent protein in total pod analysis, and *P. glandulosa* shows values ranging from 19 percent (Texas) to 31 percent (California) in sugars and 13 percent (Texas) to 9.5 percent (California) in protein (Walton 1923). The mesocarp contains the major portion of the sugars and starches. The pods are highly sought after by a number of vertebrate species, and once the pod is consumed, it is transported from the parent tree; eventually the seeds are deposited in a fecal pile. This process selectively benefits the mesquite in two ways: the seeds are dispersed in a nutrient-rich source, and seed density around the tree is reduced, thereby avoiding mass insect destruction, especially by bruchid beetles (Coleoptera: Bruchidae).

Bruchid beetles, both in number of species and individuals, are by far the most specialized insects that feed on the seeds of *Prosopis* (Kingsolver 1964, 1967, 1972). Of the estimated 1000 species in the Bruchidae, most are known to develop in the pods of the Leguminosae (Fabaceae) (Cushman 1911; Zacher 1952). Three genera of bruchids are obligates to *Prosopis* (Kingsolver et al. 1977). Kingsolver et al. (1977) reported that twenty-nine species have been found in *Prosopis* fruits and that twenty-seven species (93 percent) are obligates. The larvae of the bruchid (*Algarobius prosopis*) inflicted up to 43 percent seed mortality for a given tree (Kingsolver et al. 1977). A pod predator, the leaf-footed bug (*Mozena obtusa*), occurs in both the Chihuahuan and Sonoran deserts; damage caused by this insect to honey mesquite was estimated at 50 percent of the potential fruit production (Swenson 1969). The adult leaf-footed bug pierces the buds and sucks out the fluids, causing a premature fruit drop.

The value of *Prosopis* as a niche component has been examined by Mares et al. (1977:149), who reported, "We doubt that the other desert trees have as persuasive an influence upon other organisms as does mesquite." They listed the small mammals associated with mesquite communities in the Mojave, Sonoran, and Chihuahuan deserts and discussed the species diversity of small mammals associated with this community type. No differences in the three parameters of food, body size, and adaptation were found between the arid creosote bush and the velvet mesquite habitats (Mares et al. 1977). They did not report on the importance of the mesquite pod resource to large mammals.

Both mule deer and desert bighorn sheep consume the pods of mesquites, and recent data (Ohmart and Anderson ms.) from scat analysis of coyotes along the Colorado River in California and Arizona show that honey mesquite pods may comprise as much as 90 percent of the total volume in the coyote diet during the fall months. Woodward and Ohmart (1976) reported honey mesquite comprising over 20 percent of the July and August diet of wild burros (*Equus asinus*) adjacent to the Colorado River.

The availability of pod resource to these large vertebrates might or might not be significant to each animal species, but it does represent a mechanism by which large mammals transport the seeds away from the parent tree, thus enhancing the possibility of seedling establishment. The percentage of seeds that are destroyed by large mammals in the mastication and digestive process is unknown but may not be too great. Feeding trials with horses, cows, and ewes revealed 91, 79, and 16 percent, respectively, of the seeds consumed passed through the digestive system unharmed (Fisher et al. 1959). Of the seeds that passed through unharmed, 82 percent in the horse, 69 percent in the cow, and 25 percent in the ewe germinated (Haase et al. 1973). Germination success in shelled, undigested seeds was only 26 percent. If the endocarp is not broken during the digestive process, the seeds may remain viable for up to forty-four years (Martin 1948).

The action of mastication and digestion in vertebrates simulates the natural scarification process that occurs when mesquite pods are water transported during floods. The wetted mesocarp is softened, and as the pod is washed along the stream, the stony endocarp is scaled by rocks and gravel. Scarification dramatically improves seed germination, and pods used to grow mesquites in nurseries are either given a light acid treatment or notched with a knife or file to allow water penetration of the endocarp.

Phainopepla

Along the lower Colorado River between southern California and western Arizona, individuals or whole communities of honey mesquite may become parasitized by mistletoe (*Phoradendron californicum*). Although mistletoe parasitizes other species of legumes, it grows into larger clumps when growing on honey mesquite trees. Mistletoe produces a berry that ripens in the winter. Species of fruit-eating birds consume the berries, but one in particular, the Phainopepla (*Phainopepla nitens*), has a specialized digestive tract for processing mistletoe berries (Walserg 1975).

The Phainopepla has been recognized as being capricious, appearing in an area to breed and then disappearing. Walsberg (1977) studied the species in the Mojave Desert in southeastern California and reported a buildup of the population in April. Along the Colorado River where the Mojave and Sonoran deserts merge, Anderson and Ohmart (1978) reported that for three years Phainopeplas began arriving along the river in September, and after breeding began to leave the Colorado River valley in April and May of the following year. Walsberg (1977) has developed a working hypothesis relative to these movements. He suggests that the climatological shift to increased aridity over the past few thousand years caused changes in plant community patterns. During this period, breeding Phainopeplas might have been very local or altitudinal migrants, but with geographical alterations in plant communities, the birds adapted by making longer and seemingly strange migratory movements. Present migratory patterns may seem nonsensical but are more clearly understood when viewed in the context of shifting vegetational patterns through time.

During the period of September through May when the Phainopeplas live and breed in the Colorado River valley, they show distinct habitat preferences in the mesquite communities (Anderson and Ohmart 1978). On their arrival, the birds are loosely associated with mesquite trees, with and without mistletoe. Through the winter, there is a significant relationship among honey mesquite trees, mistletoe, and Phainopeplas. During March and April, Phainopeplas are associated with mistletoe and dense vegetation for nesting. Birds without young begin leaving the area in April, while those feeding young are significantly associated with wolfberry (*Lycium* spp.), whose spring-produced fruits are ripening.

During a three-year study of the Phainopepla (Anderson and Ohmart 1978), a severe winter occurred in which the major portion of the mistletoe berry crop froze and was unavailable as a food resource. The Phainopepla population declined dramatically during that winter, and there was little successful reproduction the following spring. The subsequent winter the returning population was lower, indicating that some or all of the population decline may have been due to mortality.

The relationship between mistletoe and mesquite is a parasitic one. Older mesquite trees appear to be most vulnerable to being parasitized by mistletoe. The mistletoe, in turn, has a symbiotic relationship with the Phainopepla. The densely branched mistletoe occurs in varying sized clumps, with mature plants occupying about 0.3 m^3 of space. The numerous berries produced by each plant are eaten by Phainopeplas, and then as the birds perch on the upper branches of the host tree or adjacent trees, the seeds may be defecated onto suitable sites for seedling development. The mistletoe provides a winter and early spring food source for the Phainopepla, as well as a dense sphere of vegetation for Phainopepla nest placement.

Cottonwood-Willow

Much less is known about other riparian plant species and exactly how animals are dependent on these plants, but one very important community to animals is the cottonwood-willow habitat. Both plant species at maturity provide a tall vertical community profile combined with a high canopy volume. The two tree species also support a high insect biomass (Anderson and Ohmart unpubl.). Vertical profile, high foliage volume in the canopy layer, and high insect productivity in communities dominated by either cottonwoods, willows, or a mixture of the two species promotes higher annual bird species numbers and densities than do other riparian communities. Patchiness index predictions of bird species richness were consistently too low, and deviations from the predictions showed cottonwood and/or willow having an additive effect to species richness in early summer and a negative effect in late summer.

The Summer tanager (*Piranga rubra*) and the yellow-billed cuckoo (*Coccyzus americanus*) are habitat specialists within the mature or nearly mature cottonwood-willow communities. The two bird species are closely and consistently associated with mature or maturing cottonwood-willow communities. Exactly why this bird-community relationship exists remains obscure, but the vertical height of the communities, a large foliage volume in the canopy layer, and the high insect production (Anderson and Ohmart unpubl.) appear to be essential factors.

Salt Cedar

The introduced salt cedar, though not supporting any animal specialists, does have an interesting relationship with wildlife. Cohan et al. (1978) in a three-year study concluded that native birds responded to salt cedar communities in a number of ways. Some species showed a preference for or did not avoid salt cedar; these were primarily ground feeders, granivores, or species such as doves. A large number of those species utilizing salt cedar belong to genera of the Old World where salt cedar evolved. Frugivores did not utilize salt cedar at all, which is not surprising since no fruits or berries are produced by this plant. Salt cedar also frequently occurs as a monoculture. Very few insectivores used salt cedar communities, although a number of palatable insects (cicadellids) may be present temporarily in large numbers. Cohan et al. (1978) concluded that the New World avifauna, especially insectivores, may be avoiding salt cedar monocultures because of the sticky exudate produced by the salt glands on the leaves. Possibly native bird species can tolerate intermittent foraging in salt cedar when it is mixed with native vegetation; mixed communities containing salt cedar supported more bird species and had higher densities than did salt cedar monocultures.

Salt cedar is most valuable to wildlife in those areas that are in the geographical distribution of the white-winged dove (*Zenaida asiatica*). This dove is a plant structural specialist and selects nest sites in communities that have maximum foliage volumes between 3 and 6 m high with a lack of vegetation above 9 m. At maturity salt cedar, honey mesquite, and screwbean mesquite provide the vegetative profile required by this dove for nest placement. Butler (1977) examined nest placement and nest density of white-winged doves in salt cedar communities along the Colorado River and found a strong correlation between nest placement and the preferred maximum foliage volume between 3 and 6 m. Nests located above or below maximum foliage volume suffered much higher rates of predation or had reduced fledging success. Similar results have been reported on the Rio Grande in the Chihuahuan Desert in west Texas (Engel-Wilson and Ohmart 1978).

Doves comprise such a large portion of the avifauna inhabiting mature salt cedar communities that this disproportionate number depresses bird species diversity values computed for these communities. A correction factor has been developed by Anderson, Higgins, and Ohmart (1977), based on random counts and behavior of doves in salt cedar communities. The correction factor was derived by estimating the number of doves that were actually feeding in salt cedar communities versus the percentage that were nesting or involved in some behavior other than feeding. The correction factor of removing 90 percent of the doves when calculating diversity values provides a more realistic bird species diversity value for salt cedar communities as compared with native communities.

Along the lower Colorado River (Anderson, Higgins, and Ohmart 1977) and the Rio Grande in west Texas (Engel-Wilson and Ohmart 1978), salt cedar communities do not support as high a density of native bird species, do not provide significant habitat for rare or unique species, and, even with a correction factor of using only 10 percent of the doves, do not have as high a bird species diversity value as most native communities. During the winter period, the salt cedar is leafless, and very few birds forage in it. Other than its value for nesting doves, it is more comparable in wildlife use values to the native arrowweed, which generally forms a monocultural stand and seldom grows taller than about 3 m.

Mature salt cedar stands generally attain a height of about 8 m and are a monoculture with a heavy overstory and very little, if any, understory. The wildlife use values of the mature communities are higher than those of the younger or less-developed stands. But because of the deciduous nature of the species and in the absence of flooding to remove the litter during the fifteen to twenty years it takes the community to mature, there is a tremendous accumulation of litter. This litter buildup renders these communities highly susceptible to accidental or intentional fires. The heat from these fires is intense enough to kill the above-ground portion of the tree, resulting in heavy sucker growth from the root crown. The higher wildlife use value of the mature community is then lost for another ten to fifteen years until the community again reaches maturity. This fire cycle and loss of wildlife values has prompted Ohmart and Anderson (ms) to suggest periodic burning of this community type at five- or seven-year intervals. This would eliminate the litter accumulation prior to the point where the heat produced by the fire kills the above-ground portions of the tree, thus extending the potential productivity for dove nesting and other wildlife use values.

Quail Bush

Anderson et al. (1978) reported quail bush as another example of the value of a plant species to birds. Similar plant community types were studied with comparable foliage structures that differed only in the presence or absence of quail bush. Communities containing quail bush contained significantly ($p < 0.001$) higher densities of Abert towhees, blue grosbeaks (*Guiraca caerulea*), blue-gray gnatcatchers (*Polioptila caerulea*), brown-headed cowbirds (*Molothrus ater*), crissal thrashers, gambel quail, orange-crowned warblers (*Vermivora celata*), ruby-crowned kinglets (*Regulus calendula*), verdins (*Auriparus flaviceps*), and white-crowned sparrows (*Zonotrichia leucophrys*). This dense evergreen shrub provides cover and shade, and it may also harbor high densities of foliage arthropods, as well as numerous arthropods in the moist litter under the dense foliage. Though the plant-animal relationship is not clear, the presence of quail bush in a community enhances the habitat for a number of avian species.

Inkweed

Anderson et al. (1978) also reported another interesting bird-plant association: the relationship of inkweed (*Suaeda torreyana*) and the sage sparrow (*Amphispiza belli*). Why this relationship exists is not known, but wintering sage sparrows are consistently present in riparian areas that support inkweed and are largely absent in areas without inkweed along the lower Colorado River.

AERIAL ESTIMATES OF RIPARIAN COMMUNITIES

To determine the amount of riparian habitat in each desert would be a monumental task, and we do not know of published works that contain this information. Lowe (1968) has estimated that North American deserts cover about 176,000 (440,000 ha) square miles. Szaro (in press) reported that less than 0.005 percent of the land area in Arizona is represented by riparian ecosystems. We have taken aerial photographs at random in the Sonoran Desert and planimetered them to determine riparian zones versus desert vegetation. Preliminary estimates indicate that about 1 percent of the Sonoran Desert is comprised of riparian vegetation. Numerous random blocks should be planimetered in this manner for more definitive estimates, but preliminary figures indicate the paucity of riparian habitats in the Sonoran Desert. This figure is probably an overestimate for the Mojave and Great Basin deserts and may be slightly conservative for the Chihuahuan Desert. It has been estimated that riparian vegetation constitutes about 138,800 ha (347,000 acres) or less than 0.005 percent of the total land area in Arizona (Smith in Sands and Howe 1977). An estimate of the amount of riparian habitat in 117,554 ha (293,866 acres) of Lower Sonoran Desert in the Aquarius Mountain Planning Unit in Arizona shows that less than 7 percent is riparian and only 0.5 percent is cottonwood-willow (Bureau of Land Management 1980). Numerous drainages arise in the Aquarius Mountains, making the desert area rich in riparian habitats and inflating the riparian habitat-upland desert ratio. Although definitive values on areal extent of riparian habitats are lacking, they are highly restricted in desert environments.

IMPORTANCE AND MODIFICATION OF RIPARIAN ECOSYSTEMS BY MAN

Riparian ecosystems are vital to man. Without riparian communities we could not survive in desert environments. Like many other animals, we are dependent on riparian ecosystems for water, food, and living space. These ecosystems provide drinking water, rich lands for agricultural purposes, forage for livestock production, recreational opportunities, and a host of other uses. Indians, Spanish, and white settlers congregated along these riparian habitats and could not have survived in the desert environment without the water and high plant and animal productivity provided by these ecosystems.

Indians who lived in the southwestern riparian communities modified riparian habitats in varying degrees. Some tribes farmed and cleared parcels of land (Kroeber 1939; Forbes 1965), depending on their industriousness at farming. Because they did not practice flood control or river management, there were no significant modifications of the riparian floodplain.

Spanish influence on riparian habitats was of greater significance than that of the Indians. Permanent settlements were established that concentrated the Spanish and Indians around forts and churches. Prior to the Spanish influence, the Indian was more nomadic, except in tribes with sophisticated farming technology, moving along the riparian corridor as resource needs dictated. Once permanently settled by the Spaniards, the local area was used more intensively to produce natural foods such as mesquite pods, game, and fish. Agricultural practices were also heavily relied on for food production. The domestic livestock brought by the Spanish were dependent on the forage along the rivers. Riparian trees were used for fuel, building materials, and timbers for mining operations.

Though localized, these permanent Spanish settlements began to have a significant impact on the riparian resources. Large numbers of domestic livestock depleted forage reserves. Mesquite pods were highly prized by both livestock and Indians, thus causing constant turmoil between the two groups along the lower Colorado River. Spanish expeditions herding large numbers of domestic livestock continually arrived on the Colorado River with supplies depleted. The animals were grazed on the best lands and consumed the mesquite crops. In July 1871, the Indians revolted and killed the Spanish settlers; a major reason was the constant conflict caused by the Spanish settlers and their domestic livestock competing with the Indians for food (Forbes 1965). Farming operations do not mix well with domestic livestock without good fencing, and this interaction must have been a continuing source of conflict since agricultural practices were relegated to the Indians.

White settlement began in about 1860, and by 1900 ranching and farming were major activities in the Southwest. For example, in 1886 the governor of the Arizona Territory reported, "In Arizona by 1883-84 every running stream and spring was settled upon, ranch houses built, and adjacent ranges stocked." (Report of Governor 1896:21). Mining flourished during the 1870s, and goods had to be transported overland or, where available, along navigable streams on wood-powered steamboats. Any type of activity in the riparian floodplain was constantly hampered by the annual floods in primary systems. Consequently river management was deemed essential, and attempts began in the early 1900s, but it was only with the construction of major dams such as Roosevelt Dam on the Salt River, Hoover Dam on the Colorado River, and Elephant Butte Dam on the Rio Grande that true river management was achieved. Other storage reservoirs promptly followed, and new river channels were developed to expedite water transport. The banks of the new channels were riprapped or lined with rocks to prevent bank cutting and river meandering.

Livestock Grazing

Massive domestic livestock grazing by white settlers began about 1880. Examples from the Sonoran Desert illustrate the growth of this industry and provide an indication of the density of domestic livestock that were introduced to desert rangelands. In 1870 there were only an estimated 5000 cattle in the entire Arizona Territory (U.S. Bureau Census 1872:III, 75). New settlers and army posts increased the demand for red meat over the supply, and in 1872 four herds totaling about 15,500 head (Wagoner 1952:36) were brought into Arizona. By 1885 there were about 652,500 cattle in the territory (Report of

Governor 1896:21). A census report in 1890 showed 1,095,000 cattle in the Arizona Territory (U.S. Bureau of Census 1895:I, 29). Overstocking of the range was obvious, and between depleted forage reserves and reduced summer rains in 1883, the herds began dying. "Dead cattle lay everywhere. You could actually throw a rock from one carcass to another" (Land 1934). This did not deter the cattlemen, and Ames (1977) reported that in 1900 there was a peak number of 173,000 head grazing Pima and Santa Cruz counties in southern Arizona.

Overstocking of desert range lands continued even after national forests were established (circa 1895) and state lands were assigned by the federal government and turned over to the respective states. The Bureau of Land Management (BLM) was established as a livestock managing agency under the Taylor Grazing Act of 1934. State and federal agencies were charged with the wise use and management of the natural resources on these public lands. But the cattle industry was and still is very powerful, and in most instances management agencies have either made no effort to regulate and control domestic livestock numbers on their lands or have failed.

Overgrazing of riparian habitats and their watersheds results in a number of degradative modifications of the ecosystem. When one or more portions of an ecological system are disrupted, other portions are affected as well. When a number of interactive parts are modified, the system may be severely interrupted, and the health of the ecosystem is impaired.

The action of overgrazing reduces the roughness coefficient in the watershed and results in more surface runoff, greater amounts of soil erosion, and ultimately massive floods in the riparian habitats. Davis (1977:61) stated that "overstocking and the consequent loss of vegetative ground cover on the adjacent watersheds is probably the main reason for the frequency of high intensity floods resulting in drastic changes in the density and composition of riparian bottoms." The watersheds degenerate from overgrazing as plant health is lost, and ultimately native perennial grasses are replaced by annual grasses, forbs, and shrubs. Reduction of the perennial grass cover, which serves as a soil stabilizer, allows more soil erosion through greater amounts of surface runoff from the watershed. Conversion from a perennial grass type to annuals and shrubs also results in a reduced carrying capacity for domestic livestock and wildlife.

Perennial streams with overgrazed watersheds are continually charged with heavy sediment loads that reduce the productivity in the stream. Suspended sediments reduce light penetration to plants needing solar energy for photosynthesis and reduce the oxygen carrying capacity of the water. This results in selection for fish and invertebrates species that can tolerate lower dissolved oxygen levels (see Kennedy 1977 for a review). All of these impacts reduce the productivity of desert streams.

Sediment loads from abused watersheds in dry or intermittent desert streams remain in the stream channel until another flood pulse carries them farther downstream and closer to a reservoir, they displace space that could be used for water storage, thereby reducing the life and capacity of the impoundment; eventually these sediments must be mechanically removed, at high cost.

Cattle not only overgraze the watershed but also consume the succulent and verdant foliage of the riparian vegatation. Most desert habitats are grazed all year, and during the summer months the riparian ecosystems provide forage, shade, and water to domestic livestock. Intensive, concentrated use by livestock in the floodplain prevents regeneration of riparian vegetation. Davis (1977:60) wrote, "Continued over use of riparian bottoms eliminates essentially all reproduction as soon as it becomes established." Carothers (1977:3) wrote that "the most insidious threat to the riparian habitat type today is domestic livestock grazing." And Ames (1977:49) concluded that "protection of the riparian type where grazing is an established use only can be effectively achieved through fencing."

As the watershed deteriorates from overgrazing and the tree density in riparian systems is reduced by grazing and through natural loss of old trees, the magnitude and destructive forces of floods are increased. A healthy watershed absorbs most of the falling rain, and a dense riparian habitat dissipates the energy of flood waters. But the poor watersheds and thinned riparian vegetation are more vulnerable to floods; large trees and whole riparian communities may be ripped out and washed downstream during a flood. This expedites riparian degradation since cattle are concentrated in the riparian areas each spring to consume newly established seedlings. Riparian communities are quick to recover following livestock removal. Unfortunately perennial grasses are slow to reinvade the dry and degradated soils on the eroded watershed.

Overgrazing also aids the spread and establishment of exotic species such as salt cedar. Domestic livestock will browse the new growth of salt cedar, but they do not take enough new material to reduce its vigor (Gary 1960). Consequently overgrazing by domestic livestock promotes the elimination of native riparian species and aids the establishment of the exotic salt cedar. Ultimately salt cedar attains such tall, dense growth that domestic livestock are reluctant to enter it (Gary 1960).

Arroyo Formation

Domestic livestock grazing has been interpreted as being the primary cause of entrenching or arroyo formation in the West (Dodge 1910; Thornber 1910; Rich 1911; Duce 1918; Leopold 1921; Cooperrider and Hendricks 1937; Cottam and Stewart 1940). Many primary and secondary streams in desert areas are entrenched or are beginning to show signs of entrenchment. This is not to be confused with erosion patterns associated with climatic changes that have been traced through alluvial stratigraphy since the last glaciation (Haynes 1968). These entrenchments are the vertical walled channels that have been cut since the beginning of white settlements (Cooke and Warren 1973). The increased cutting is a result of increased flow velocity, an increase in erodibility of soils, or a combination of both (Cooke and Warren 1973). Flow velocity could be increased by increasing discharge or slope, reducing surface roughness, or increasing depth of flow. "Increased erodibility of valley-floor materials might have arisen through the reduction of riparian vegetation" (Cooke and Warren 1973:170). Altering surface roughness by removal of perennial grasses on the watershed would result in increased surface flow, which would increase erosion and ultimately increase slope. As Cooke and Reeves (1976) point out changes in depth of flow were probably influenced by man-made modifications in the drainage system. Increased rainfall (Huntington 1914) would produce similar, but possibly not as drastic, surface flows. But some argue that the climate may have become drier (Bryan 1925). If the climate had become wetter or drier, there should have been compensating changes in the vegetation, but to our knowledge only degradational changes have been reported (Hastings and Turner 1965).

There are probably many causes of entrenching, and they appear to vary from drainage to drainage (Cooke and Reeves 1976), but there is little doubt that most entrenchment is a result of past and present land use practices by white settlers. One strong influence of entrenching in many desert drainages appears to have been the destruction of western watersheds by overgrazing of domestic livestock.

An example of entrenchment is seen on Sonoita Creek (figures 10-5 and 10-6), which flows into the Santa Cruz River a few kilometers north of the U.S.-Mexican boundary. The history of the land use of this stream has not been synthesized, but Glinski (1977:121) commented that "the overgrazed hillsides that border Sonoita Creek no doubt assist in increasing the floodwater velocity since they support relatively less vegetation to intercept precipitation."

Entrenchment not only results in habitat removal for riparian vegetation, but it results in a lowered water table, causing vegetational species shifts and collapse of mature trees adjacent to the bank as the soil erodes away from their roots. Following floods, seedlings of riparian species attempt reestablishment but are quickly eaten back by domestic livestock. Glinski (1977:121) observed numerous instances of seedlings

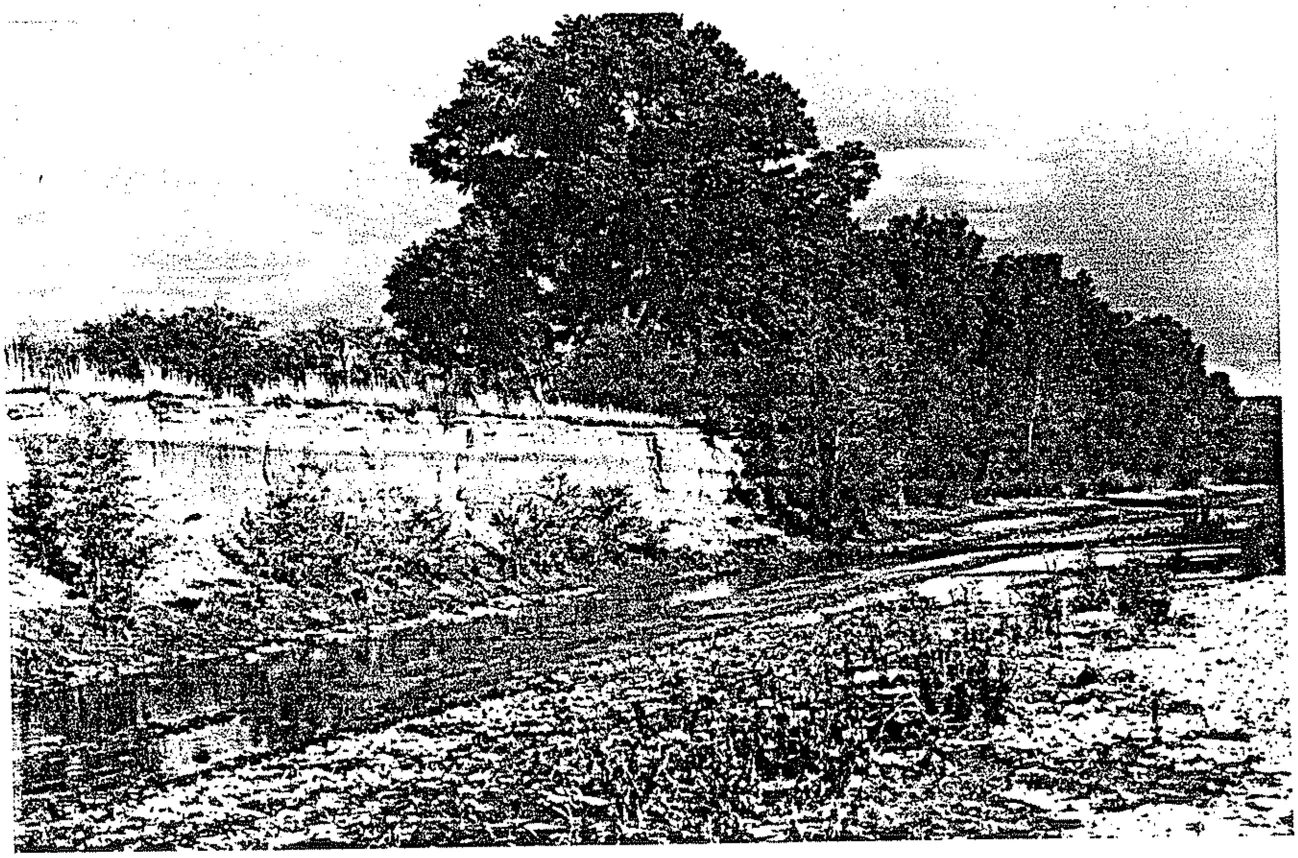

Figure 10-5. Entrenchment along Sonoita Creek.
1976 photograph by R. L. Glinski.

being eaten by cattle and stated that "grazing of small seedlings by cattle was the most obvious factor preventing regeneration of cottonwood."

The San Simon Basin lies in the Chihuahuan Desert and extends from extreme southwest New Mexico into eastern Arizona. The adjacent uplands currently support such woody species as creosote bush, mesquite, joint-fir (*Ephedra* spp.), and tarbush (*Flourensia cernua*). The valley floor sediments have been entrenched over most of the area from San Simon to Safford, Arizona, a distance of over 100 km. The entrenched drainage supports a few scattered cottonwood and salt cedars. Early descriptions of the valley indicate that the area was heavily vegetated with grasses, with water readily available in the stream for livestock. Hinton (1878), an early topographer, reported good grazing lands consisting of sacaton (*Sporobolus* spp.) and gramas (*Bouteloua* spp.) and some agricultural lands present along the valley floor. Barnes (1936) interpreted early records and described the valley in 1882 as being composed of meadows covered with knee-high grass, open areas dominated by tall gramas, and sacaton stirrup-high along the washes.

By the early 1900s the picture was changed from "pristine beauty" (Peterson 1950) to an upland habitat dominated by woody vegetation and a riparian system that was heavily entrenched and contained only scattered cottonwood trees. Olmstead (1919:79) was so disheartened that he stated, "Oh, Liberty, how many crimes are committed in thy name!" Peterson (1950:410) wrote, "Today's picture of the valley, from both the conservation and the range-use viewpoint, is one of devastation." Figures 10-7 and 10-8 show some of the entrenchment that has occurred along this drainage.

Entrenchment has occurred along some portions of the San Pedro River in southeastern Arizona. Evidence presented by Cooke and Reeves (1976) argues that some entrenching occurred on the San Pedro River prior to white settlement. The possible causes of further entrenchment after about 1880 are numerous, but the most plausible ones are man-made structures in the floodplain, which caused drainage concentration, climatic change, which caused severe floods during this period, and vegetation modifications from overgrazing by domestic livestock.

Figure 10-6. Vertical entrenchment on Sonoita Creek.
1976 photograph by R. L. Glinski.

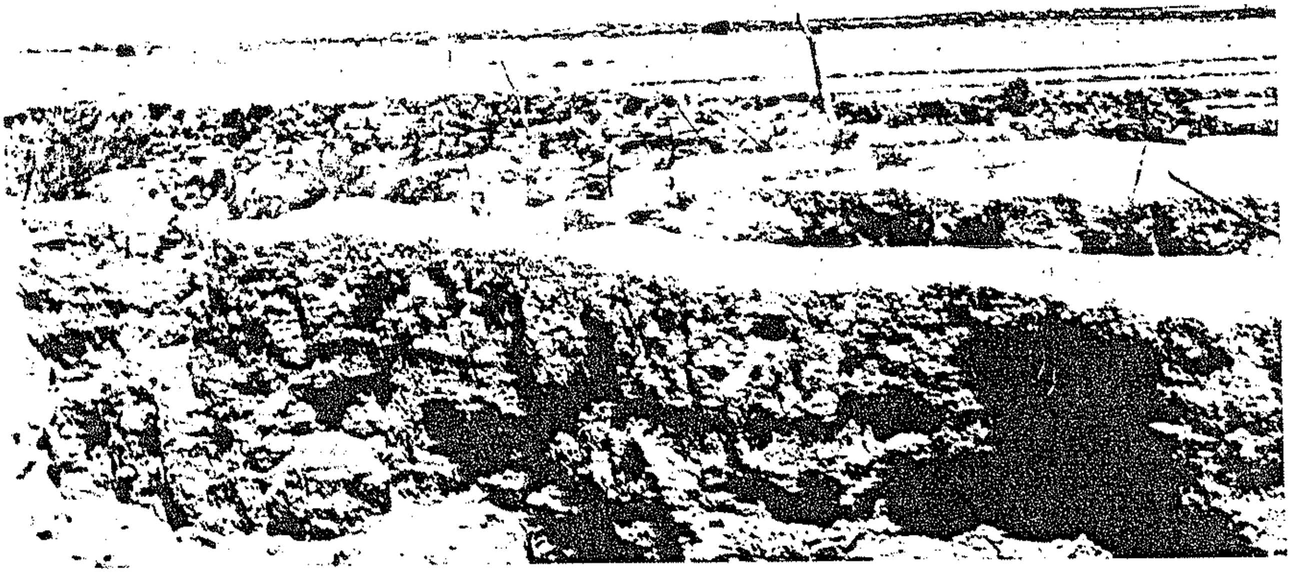

Figure 10-7. Entrenchment in the San Simon Valley in eastern Arizona.
The vertical walls are 3 to 4 m. The photograph was taken about 12 km upstream from the mouth in the mid-1960s by Bureau of Land Management personnel.

Figure 10-8. Aerial oblique of entrenchment conditions, San Simon Valley, eastern Arizona.
Note the riparian vegetation that has developed in the entrenched channel. The photograph was taken about 12 km upstream from the mouth in the mid-1960s by Bureau of Land Management personnel.

Hastings and Turner (1965) provide numerous matched photographs that illustrate extensive changes in the vegetative ground cover. Rodgers (1965) argues against climatic change before or after 1885, but the records are inadequate for firm conclusions. Structures were built in the floodplain, and these probably acted in concert with the other factors to cause entrenchment. Cooke and Reeves (1976:46) stated:

> There is a strong possibility that vegetation changes resulting from overgrazing within the watershed (especially south of Benson), cattle damage along trails and the river, and deforestation of some catchment areas for mining timber may have promoted entrenchment.

Caution must be used in interpreting the causes for entrenchment, and each case must be viewed with as much historical evidence as possible before coming to a conclusion. Even when this is done, the data are less than satisfactory.

River Management

The significance of the effect of agricultural practices on riparian habitats was relatively small until river management was utilized in the early 1900s. Until river management became a reality, farmers cleared and worked portions of the alluvial floodplain, but because of the expense and constant threat of flooding, only small tracts were worked, and these were confined to the second terrace. The primary terrace was flooded annually, and in extreme flood years, the second terrace was inundated.

Many methods were attempted to avoid the natural occurrence of floods. One strategy was to use water transport systems to conduct water away from the floodplain to other fertile areas. With this in mind, the All American Canal was built, stretching from Yuma on the Colorado River to the Mojave Desert in Imperial Valley, California, near the Salton Sink. But even these water transport efforts were not foolproof without flood control structures. The massive floods along the Colorado River in 1905 broke through the floodgates and became diverted into the All American Canal. The flooding waters filled the dry Salton Sink, converting it into the Salton Sea (Sykes 1937).

Major dams were built that converted riparian habitats into desert reservoirs and virtually halted natural flooding. This action slowed or stopped the reproductive cycle of some native riparian plant species. Broad, meandering rivers were channelized, banks were riprapped with stones, and the riparian communities along the second terrace were cleared for agricultural production. Levees were placed along the river at the natural division of the first and second terrace. Anything inside the levees was considered a potential flood zone, and this preserved some riparian habitats in the first terrace. Those communities on the second terrace were ripped out, raked into piles, and burned. One example of the magnitude of removal occurred in 1961 when 32,000 ha (80,000 acres) were cleared for farming along the lower Colorado River (Fox 1977). Anderson and Ohmart (1978) estimated that the mean removal rate of riparian vegetation along the lower Colorado River has been about 1200 ha per year. Ohmart et al. (1977) conservatively estimated that there were over 2000 ha (5000 acres) of cottonwood habitat along the lower Colorado River prior to white settlement. Anderson and Ohmart (1977a) estimated that fewer than 1100 ha (2800 acres) of cottonwood-willow communities remain, and that fewer than 200 ha (500 acres) are pure cottonwood habitats.

Similar examples exist along the Rio Grande slightly below El Paso, south and east to Presidio, Texas, a distance of about 450 km (275 mi) (Engel-Wilson and Ohmart 1978). Using written and photographic documentation, the cottonwood and willow communities were traced from about 1850 to the present; in slightly over one-hundred years these communities have been virtually extirpated. Water use upstream has left this reach of the river dry, and now the abandoned farmland in the alluvial floodplain supports only a monoculture of salt cedar. Cottonwoods are found only as scattered mature trees. There is no reproduction of native cottonwoods along this reach of river, and when the mature trees die, the area will be devoid of cottonwood.

A secondary impact of agricultural practices on riparian systems is the return flow to the river caused by flood irrigation. This irrigation practice leaches salts, fertilizers, and insecticides out of the land and deposits them in the river. The phosphates in fertilizers may help enrich some rivers, but the salts and pesticides pose future problems for water managers. As levels build, the aquatic biota will be modified and possibly eliminated.

In many instances, there is a general ecological succession in primary drainages where there is a high degree of river management. Natural plant communities are converted to agriculture and then to urban developments. If the Rio Grande in west Texas is any indication, urban development may not be the final stage. As water supplies are exhausted upstream, the lower river reaches become cesspools laden with industrial, municipal, and agricultural wastewater polluted with various levels of salts, heavy metals, pesticides, and other contaminants.

As river management became a reality and water storage became possible, many hydrologists began to cast about for further ways to ensure that every drop of water was conserved for man's use. Riparian habitats were identified as useless and wasteful because these plant communities transpired large quantitites of water from the groundwater table to the dry atmosphere. Massive programs were designed, and many undertaken, to remove phreatophytes for water salvage. Along the Pecos River in New Mexico, over 20,000 ha (50,000 acres) were cleared and have been maintained solely for the purpose of water salvage.

The actual amount of water saved through clearing phreatophytes to increase water flow is still unresolved. Lysimeters have been used to attempt to determine if water has been saved through riparian vegetation removal, but the data are confusing and conflicting. Many argue the merits of phreatophyte removal for water savings, while others question the validity of these claims.

Varied Effects

Mining activities were widespread throughout the desert Southwest, and the scars of these old mines are common along many of the desert drainages. The primary modification that mining causes in riparian habitats is stream pollution, but large operations have extensive spoil materials that, in some instances, have been dumped along streams covering existing riparian communities. In these instances and when stream pollution is high, the entire stream biota is killed, and the salts, heavy metals, and other toxins leach into the soil. This activity results in changes or elimination of the submerged and terrestrial plant communities along the stream.

Ultimately these polluted waters empty into reservoirs and lakes to become the water supply of metropolitan areas. In time, these pollution sources may become numerous enough or concentrated enough to affect the quality of the water supplies of large cities.

Avenues of transportation such as roads, highways, and railroads generally are placed adjacent to streams in the riparian ecosystem. These drainages provide the easiest and cheapest routes to cross areas with great topographic relief. The grade is usually not too steep, and the roadbed is built along the contour of the drainage.

Spoil materials from road construction activities are pushed downhill and eventually erode into the stream, causing turbidity problems. Unpaved areas cause the greatest problems because soil from these denuded areas is continually eroded into the stream.

Riparian areas have always been the focal points for recreation in arid environments, but it has become a serious problem only in the past two decades as human populations have increased in desert environments. Humans, like many other animals, concentrate in the primary drainages during long, hot summers. Areas receiving large concentrations of people are often denuded as wood is gathered for camp fires, and riparian areas became a place where all-wheel drive vehicles and egos are tested. Children and pets catch and usually kill any form of animal life discovered.

The exact faunal changes that take place when an area is converted to a campground and receives heavy human use are poorly understood. Aitchison (1977) examined a site in Arizona slightly higher in elevation than desert riparian habitats and found little difference between bird species composition in a control site as compared with a constructed campground that had not been opened. After the campground was opened, bird species composition and diversity decreased. Larger species of birds tended to persist after the area was opened. Information of this nature concerning desert riparian habitats is lacking.

Waterfowl use on the lower Colorado River appears to be strongly influenced by human use and river channel modification (Anderson and Ohmart unpubl.). As each factor increases, there is a direct and predictable reduction in the number of waterfowl, primarily ducks.

Current Status and Future

All primary and most secondary drainages in desert environments have been modified by man. The range of modification varies from moderate to severe destruction. All primary drainages are impounded, regulated, and managed to the point where any hope of natural regeneration of the most productive riparian habitats is unrealistic. Extensive mesquite bosques, which once covered the entire second terrace, have been or are being cleared for agricultural production. Even more alarming, river management has been so effective and enforcement so lax that agriculture and urban development have begun to penetrate into the areas between the levees. These areas are now being destroyed, and if water releases become necessary, homes, equipment, and crops will be washed away. Further, many planning and zoning commissions have allowed land developers to parcel and sell lots and homes to unsuspecting buyers. After a flood, the home owner is financially ruined and has little, if any, hope of restitution.

The once-extensive gallery forests of cottonwood and willow that lined our desert streams are either completely gone or persist as small relics. The dense and varied fauna they once supported have dwindled and now are state or federally listed as sensitive, threatened, or endangered species.

Barren and eroded watersheds supporting only annual plants and shrubs attest to the hoards of livestock that once trampled their slopes. Silt-laden reservoirs catch the eroded soils at lower elevations, and the newly deposited silt displaces the water-holding capacity of the reservoirs. Ultimately the life of the reservoir is shortened or the materials have to be removed; either alternative is very costly.

Heavily managed river systems that once supported extensive communities of cottonwood and willow now support dense communities of salt cedar. Cessation of natural floodings, higher salinities from return irrigation flow practices, domestic livestock grazing, and a reduction of in-stream flow amounts have favored the spread of the exotic salt cedar.

The wildlife these native communities once supported is now gone, but the total loss is unknown since there were no quantitative records of its existence. Nevertheless the existing riparian communities are still the most productive and impor-

Figure 10-9. Year-old cottonwood and willow trees revegetated with drip irrigation along the lower Colorado River in California.
Photograph taken in 1980 by R. Ohmart.

Figure 10-10. Two-year-old cottonwood trees revegetated with drip irrigation along the lower Colorado River in California.
Photograph taken in 1980 by R. Ohmart.

tant to desert wildlife in spite of their degraded state. Further degradation can be expected; Johnson et al. (1977) predicted the extirpation of 47 percent of the 166 species of nesting birds in the area studied. Many mammalian species would be reduced in density and others eliminated from our deserts. The same holds true for species of both reptiles and amphibians in desert environments.

The future of riparian communities is mixed. Lands under federal management are gaining more attention with respect to proper livestock use levels, restriction of recreational use and woodcutting, reduced use of off-road vehicles, and the elimination of the myriad of other destructive uses imposed on riparian systems.

Not only have there been federal laws passed that have reduced the destructive processes on federal lands (among them, the National Environmental Policy Act, the Endangered Species Act, and the National Wetlands Act), but there is a growing recognition among federal land managers of the value of the riparian vegetation to man and wildlife. Numerous federal agencies have begun to take steps to preserve existing remnants of riparian habitat, while others have begun the costly and slow process of attempting to revegetate bare areas with riparian plant communities (figures 10-9 and 10-10) valuable to wildlife (Anderson et al. 1978).

The greatest threat of continued destruction of riparian habitat is at the state, local, and private ownership level. When water rights were allocated, no one thought of or represented riparian communities or their dependent wildlife. Consequently no water was allocated to this valuable resource. Water managers and users view these riparian communities as stealing their water and believe that removal of this vegetation saves water. This type of attitude generally prevails at the state and local levels, and few desert states have laws that provide any protection to riparian ecosystems. Therefore, riparian ecosystems on state, county, and private lands are and will continue to be in jeopardy until an educated public and legislators act on this problem.

A classic case of finally recognizing the value of the riparian system and the constant problem of recurrent floods at the local level occurred in the mid-1970s in Scottsdale, Arizona. Virtually every method to control the flooding along the Indian Bend Wash had been exhausted when someone proposed making a green belt through the city and using it as open space instead of periodically inundated home sites. When the wash is dry, people picnic, ride horses and bicycles, and engage in other recreational activities along the wash. In three recent years of heavy flooding, it has acted as a conduit to drain the upland desert of its overburden of rainfall.

If the riparian resource is to be saved, it will only be through informative programs that make the public aware of the value of this habitat and the need to maintain as much of it is as possible. We can only hope that this awareness comes before it is too late.

REFERENCES

Aitchison, S. W. 1977. Some effects of a campground on breeding birds in Arizona. *USDA Forest Service, Gen. Tech. Rept.* RM-43:175-182.

Ames, C. R. 1977. Wildlife conflicts in riparian management: grazing. *USDA Forest Service, Gen. Tech. Rept.* RM-43:49-51.

Anderson, B. W.; Engel-Wilson, R. W.; Wells, D.; and Ohmart, R. D. 1977. Ecological study of southwestern riparian habitat: Techniques and data applicability. *USDA Forest Service, Gen. Tech. Rept.* RM-43:146-155.

Anderson, B. W.; Higgins, A.; and Ohmart, R. D. 1977. Avian use of salt cedar communities in the lower Colorado River valley. *USDA Forest Service, Gen. Tech. Rept.* RM-43:128-136.

Anderson, B. W., and Ohmart, R. D. 1977a. *Wildlife use and densities report of birds and mammals in the lower Colorado River valley.* USDI Bur. Rec., Lower Colo. Region.

———. 1977b. Vegetation structure and bird use in the lower Colorado River valley. *USDA Forest Service Gen. Tech. Rept.* RM-43:23-34.

———. 1978. Phainopepla utilization of honey mesquite forests in the Colorado River valley. *Condor* 80:334-338.

Anderson, B. W.; Ohmart, R. D.; and Disano, J. 1978. Revegetating the riparian floodplain for wildlife. *USDA Forest Service Gen. Tech. Rept.* WO-12:318-331.

Austin, G. T. 1970. Breeding birds of desert riparian habitat in southern Nevada. *Condor* 72(4):431-436.

Axelrod, D. I. 1950. The Piru Gorge flora of southern California. *Carnegie Inst. Wash. Publ.* 590:159-224.

———. 1958. Evolution of the Madro-Tertiary geoflora. *Bot. Rev.* 24:433-509.

Barnes, W. C. 1936. Herds in San Simon Valley. *Am. Forests* 42:456-457, 481.

Billings, W. D. 1951. Vegetational zonation in the Great Basin of western North America. *International Union Biol. Sci. Ser. B. Colloquia* 9:101-122.

Brown, D. E., and Lowe, C. H. 1974. The Arizona system for natural and potential vegetation—illustrated summary through the fifth digit for the North American Southwest. *J. Arizona Acad. Sci.* 9 *Suppl.* 3:1-7.

Brown, D. E.; Lowe, C. H.; and Pase, C. P. 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the Southwest. *Arizona-Nevada Acad. Sci. 14, Suppl.* 1:1-16.

Bryan, K. 1925. Date of channel trenching (arroyo cutting) in the arid Southwest. *Science* 62(1607):338-344.

Bureau of Land Management. 1980. *Aquarius unit resource analysis.* Phoenix, Arizona.

Burleigh, T. D. 1972. *Birds of Idaho.* Caldwell, Idaho: Caxton Printers.

Butler, W. I., Jr. 1977. A white-winged dove nesting study in three riparian communities on the lower Colorado River. Master's thesis, Arizona State University.

Campbell, C. J., and Dick-Peddie, W. A. 1964. Comparison of phreatophyte communities on the Rio Grande in New Mexico. *Ecology* 45(3):492-502.

Campbell, C. J., and Green, W. 1968. Perpetual succession of stream-channel vegetation in a semi-arid region. *J. Ariz. Acad. Sci.* 5(2):86-89.

Carothers, S. W. 1977. Importance, preservation and management of riparian habitat: An overview. *USDA Forest Service, Gen. Tech. Rept.* RM-43:2-4.

Carothers, S. W., and Johnson, R. R. 1975. Water management practices and their effects on nongame birds in range habitats. In D. Smith, *Proc. of Symp. on Management of Forests and Range Habitats for Nongame Brids*, pp. 210-222. *USDA Forest Service, Gen. Tech. Rept.* 1.

Cates, R. G., and Rhoades, D. F. 1977. *Prosopis* leaves as a resource for insects. In *Mesquite* ed. B. B. Simpson, pp. 61-83. *US/IBP Synthesis series*, 4. Stroudsburg, Pa: Dowden, Hutchinson & Ross.

Christensen, E. M. 1962. The rate of naturalization of *Tamarix* in Utah. *Am. Midl. Nat* 68(1):51-57.

Cockerell, T. D. A. 1900. Some bees visiting the flowers of mesquite. *Entomologist* 33:243-245.

Cohan, D. R.; Anderson, B. W.; and Ohmart, R. D. 1978. Avian population responses to salt cedar along the lower Colorado River. *USDA Forest Service, Gen. Tech. Rept.* WO-12:371-382.

Cole, G. L. 1963. The American Southwest and middle America. In D. G. Frey, ed., *Limnology in North America*, pp. 393-434, Madison: University of Wisconsin Press.

Cooke, R. U., and Reeves, R. W. 1976. *Arroyos and environmental change in the American Southwest.* Oxford Res. Studies in Geog. Oxford: Clarendon Press.

Cooke, R. Un., and Warren, A. 1973. *Geomorphology in deserts.* San Francisco: University of California Press.

Cooperrider, C. K., and Hendricks, B. A. 1937. Soil erosion and stream flow on range and forest lands of the upper Rio Grande watershed region in relation to land resources and human welfare. *USDA Tech. Bull.* 567.

Cottam, W. P., and Stewart, G. 1940. Succession as a result of grazing and of meadow desiccation by erosion since settlement in 1862. *J. Forestry.* 38:613-626.

Cushman, R. A. 1911. Notes of the host plants and parasites of some North American Bruchidae. *J. Econ. Entomol.* 4:489-510.

Darrow, R. A. 1961. Origin and development of the vegetational communities of the Southwest. Bioecology of the arid and semiarid lands of the Southwest. *New Mexico Highlands Univ. Bull.* 212:30-47.

Daubenmire, R. F. 1942. An ecological study of the vegetation of southeastern Washington and adjacent Idaho. *Ecol. Monogr.* (12)1:53-79.

Davis, G. A. 1977. Management alternatives for the riparian habitat in the Southwest. *USDA Forest Service, Gen. Tech. Rept.* RM-43:59-67.

Deacon, J. E., and Minckley, W. L. 1974. Desert fishes. In *Desert biology*, G. W. Brown, Jr., vol. 2, pp. 385-488. New York: Academic Press.

Denny, C. S. 1965. Alluvial fans in the Death Valley region, California and Nevada. *USGS Prof. Paper* 466.

Dick-Peddie, W. A., and Hubbard, J. P. 1977. Classification of riparian vegetation. *USDA Forest Service, Gen. Tech. Rept.* RM-43:85-90.

Dodge, R. F. 1910. The formation of arroyos in adobe filled valleys in the southwestern United States (abs.). *Brit. Assoc. Advanc. Sci. Rept.* 79:531-532.

Dregne, H. E. 1968. Appraisal of research on surface materials of desert environments. In *Deserts of the world*, ed. W. G. McGinnis, B. J. Goldman, and P. Paylore, pp. 287-316. Tucson: University of Arizona Press.

Duce, J. T. 1918. The effect of cattle on the erosion of canyon bottoms. *Science* 47:450-452.

Engel-Wilson, R. W., and Ohmart, R. D. 1978. Assessment of vegetation and terrestrial vertebrates along the Rio Grande between Fort Quitman, Texas and Haciendita, Texas. Submitted to Int. Boundary and Water Comm., El Paso, Texas. In fulfillment of Contract No. IBM 77-17.

Feth, J. H., and Hem, J. D. 1963. Reconnaissance of headwater springs in the Gila River drainage basin, Arizona. *USGS Water-Supply Paper* 1619-H.

Fisher, C. E.; Meadors, C. H.; Behrens, R.; Robison, E. D.; Marion, P. T.; and Morton, H. L. 1959. Control of mesquite on grazing lands. *Texas Agric. Exp. Sta. Bull.* 935:1-23.

Flack, J. A. D. 1976. Bird populations of aspen forests in western North America. *Ornith. Monogr.* 19:1-97.

Flowers, S. 1960. Vegetation of Flaming Gorge reservoir basin. In *Ecological studies of the flora and fauna of Flaming Gorge Reservoir basin, Utah and Wyoming*, ed. C. E. Dibble. *Univ. Utah Anthropol. Pap.* 48:1-48 (Upper Colorado Series 3).

———. 1961. Vegetation of the Navajo reservoir basin in Colorado and New Mexico. In *Ecological studies of the flora and fauna of Navajo Reservoir basin, Colorado and New Mexico*, ed. D. M. Pendergast. *Univ. Utah Anthropol. Pap.* 56:1-98 (Upper Colorado Series 5).

Forbes, J. 1965. *Warriors of the Colorado.* Norman: University of Oklahoma Press.

Fox, K. 1977. Importance of riparian ecosystems: Economic considerations. *USDA Forest Service, Gen. Tech. Rept.* RM-43:19-22.

Gary, H. L. 1960. Utilization of five-stamen tamarisk by cattle. *USDA Forest Service, Rocky Mt. Forestry and Range Exp. Sta., Res.* Note 51.

———. 1963. Root distribution of five-stamen tamarisk, seepwillow, and arrowweed. *For Sci.* 9:311-314.

Glendening, C. E., and Paulsen, Jr., H. A. 1955. Reproduction and establishment of velvet mesquite as related to invasion of semidesert grasslands. *USDA Tech. Bull.* 1127.

Glinski, R. L. 1977. Regeneration and distribution of sycamore and cottonwood trees along Sonoita Creek, Santa Cruz County, Arizona. *USDA Forest Service, Gen. Tech. Rept.* RM-43:116-123.

Goldwasser, S. 1978 Desert riparian-freshwater marsh and ponds. *Amer. Birds* 32(1):113-114.

Graf, W. L. 1978. Fluvial adjustments to the spread of tamarisk in the Colorado Plateau region. *Geol. Soc. of Amer. Bull., Doc.* 81005, 89:1491-1501.

Grinnell, J., and Miller, A. H. 1944. The distribution of the birds of California. *Pacific Coast Avif.* 27.

Haas, R. H.; Meyer, R. E.; Scifres, C. J.; and Brock, J. H. 1973. Growth and development of mesquite. *Texas Agric. Exp. Sta. Res. Monogr.* 1:10-19.

Haase, E. F. 1972. Survey of floodplain vegetation along the lower Gila River in southwestern Arizona. *J. Ariz. Acad. Sci.* 7(2):66-81.

Hastings, J. R., and Turner, R. M. 1965. *The changing mile.* Tucson: University of Arizona Press.

Haynes, C. V., Jr. 1968. Geochronology of lake-Quaternary alluvium. In *Means of correlation of Quaternary successions,* ed. R. B. Morrison and H. E. Wright, Jr., pp. 591-615. Salt Lake City: University of Utah Press.

Hayward, L.; Beck, D. E.; and Tanner, W. W. 1958. Zoology of the Upper Colorado River Basin. *Brigham Young University Publ. Biol. Series* 1(3).

Hayward, C. L., Cottam, C.; Woodbury, A. M.; and Frost, H. H. 1976. Birds of Utah. *Great Basin Nat. Memoirs* 1:1-229.

Hinton, R. J. 1878. *The hand-book of Arizona.* Reprinted 1954, Tucson: Arizona Silhouettes.

Horton, J. S. 1964. Notes on the introduction of deciduous-tamarisk. *USDA Forest Service Res. Note* RM-16, Fort Collins, Colo. Rocky Mt. For. and Range Exp. Stn.

———. 1977. The development and perpetuation of the permanent tamarisk type in the phreatophyte zone in the Southwest. *USDA Forest Service, Gen. Tech. Rept.* RM-43:124-127.

Hubbard, J. P. 1977. Importance of riparian ecosystems: Biotic considerations. *USDA Forest Service, Gen. Tech. Rept.* RM-43:14-18.

———. 1978. Revised check-list of the birds of New Mexico. *New Mexico Ornith. Soc. Publ.* 6.

Hubbs, C. L. 1940. Speciation of fishes. *Amer. Nat.* 74:198-211.

———. 1941. The relation of hydrological conditions to speciation in fishes. In *A symposium on hydrobiology,* ed. J. G. Needham, pp. 182-195. Madison, Wisc.: University of Wisconsin Press.

Hulse, A. H. 1974. An autoecological study of Kinosteron sonoriense Le Conte (Chelonia: Kinosternidae). Ph.D. dissertation, Arizona State University.

Hunt, C. B. 1966. Plant ecology of Death Valley, California. *USGS Prof. Paper* 509.

Hunt, C. B.; Robinson, T. W.; Bowles, W. A.; and Washburn, A. L. 1966. Hydrologic basin, Death Valley, California. *USGS, Prof. Paper* 494-A:1-162.

Huntington, E. 1914. The climatic factor as illustrated in arid American. *Carnegie Inst. Wash. Pub.* 192.

Ingles, L. G. 1950. Nesting birds of the willow-cottonwood community in California. *Auk* 67(3):325-332.

Johnson, H. B. 1976. Vegetation and plant communities of southern California deserts. In *Plant communities of southern California. Spec. Publ. 2.* Berkeley, Calif.: Calif. Native Plant Soc.

Johnson, N. K. 1978. Patterns of avian geography and speciation in the intermountain region. *Great Basin Nat. Memoirs* 2:137-160.

Johnson, R. R.; Haight, L. T.; and Simpson, J. M. 1977. Endangered species versus endangered habitats: A concept. *USDA Forest Service, Gen. Tech. Rept.* RM-43:68-79.

Kearney, T. H.; Briggs, L. J.; Shantz, H. L.; McLane, J. W.; and Piemeisel, R. L. 1914. Indicator significance of vegetation in Tooele Valley, Utah. *J. Agric. Res.* 1(5):365-417.

Kennedy, C. E. 1977. Wildlife conflicts in riparian management: water. *U.S. Forest Service, Gen. Tech. Rept.* RM-43:52-58.

Kingsolver, J. M. 1964. The genus *Neltumius* (Coleoptera: Bruchidae). *Coleop. Bull.* 18:105-111.

———. 1967. On the genus *Ripibruchus* Bridwell, with descriptions of a new species and a closely related new genus. *Proc. Entomol. Soc. Wash.* (D.C.) 69:318-327.

———. 1972. Description of a new species of *Algarobius* Bridwell (Coleoptera: Bruchidae). *Coleop. Bull.* 26:116-120.

Kingsolver, J. M.: Johnson, C. D.; Swier, S. R.; and Teran, A. L. 1977. *Prosopis* fruits as a resource for invertebrates. In *Mesquite,* ed. B. B. Simpson, pp. 108-122. *US/IBP Synthesis Series* 4. Stroudsburg, Pa.; Dowden, Hutchinson & Ross.

Kroeber, A. L. 1939. Cultural and natural areas of native North America, lower Colorado River. *Univ. Calif. Publs. in American Archaelogy and Ethnology,* 38:42-45.

Land, E. 1934. Reminiscences. Ms. in Arizona Pioneers' Historical Society, Tucson.

Leopold, A. 1921. A plea for recognition of artificial works in forest erosion and control policy. *J. Forestry* 19:267-273.

Ligon, J. S. 1961. *New Mexico birds and where to find them.* Albuquerque, N.M.: University of New Mexico Press.

Logan, R. F. 1968. Causes, climates and distribution of deserts. In *Desert biology,* ed. G. W. Brown, Jr., Vol. 1, pp. 21-51. New York: Academic Press.

Lowe, C. H. 1964. *The vertebrates of Arizona.* Tucson: University of Arizona Press.

———. 1968. Appraisal of research on fauna of desert environments. In *Deserts of the world,* ed. W. G. McGinnis, B. J. Goldman, and P. Paylore, pp. 569-604. Tucson: University of Arizona Press.

MacArthur, R. H., and MacArthur, J. 1961. On bird species diversity. *Ecology* 42:594-598.

McKernan, R. L. 1978. Willow riparian. *American Birds 32(1):85.*

McMillan, C., and Peacock, J. T. 1964. Bud-bursting in diverse populations of mesquite (Prosopis: Leguminosae) under uniform conditions. *Southwest Nat.* 9:181-188.

Mares, M. A.; Enders, F. A.; Kingsolver, J. M.; Neff, J. L.; and Simpson, B. B. 1977. *Prosopis* as a niche component. In *Mesquite,* ed. B. B. Simpson, pp. 123-149. *US/IBP Synthesis Series* 4. Stroudsburg, Pa.: Dowden, Hutchinson & Ross.

Martin, S. C. 1948. Mesquite seeds remain viable after 44 years. *Ecology* 29:393.

Melton, M. A. 1958. Geometric properties of mature drainage systems and their representation in an E_4 phase space. *J. Geol.* 66:35-54.

Miller, R. R. 1959. Origin and affinities of the freshwater fish fauna of western North America. In *Zoogeography,* ed. C. L. Hubbs, pp. 187-222. Washington, D. C.: American Association for Advanced Science.

Minckley, W. L. 1973. *Fishes of Arizona.* Phoenix: Arizona Game and Fish Department.

Minckley, W. L., and Barber, W. E. 1971. Some aspects of the biology of the longfin dace, a cyprinid fish characteristic of streams in the Sonoran Desert. *Southwest Nat.* 15.

Moldenke, A. R., and Neff, J. L. 1974. The bees of California: A catalogue with special reference to pollination and ecological research. *Origin and Structure of Ecosystems Tech. Repts.* 74-1, 74-2, 74-3, 74-4, 74-5, 74-6.

Mooney, H. A.; Simpson, B. B.; and Solbrig, O. T. 1977. Phenology, morphology, physiology. In *Mesquite,* ed. B. B. Simpson, pp. 26-43. *US/IBP Synthesis Series* 4. Stroudsburg, Pa.: Dowden, Hutchinson & Ross.

Neff, J. L., Simpson, B. B.; and Moldenke, A. R. 1977. Flowers-flower visitor system. In *Convergent evolution in warm deserts,* ed. G. H. Orians and O. T. Solbrig, pp. 204-224. *US/IBP*

Synthesis Series 4. Stroudsburg, Pa.; Dowden, Hutchinson & Ross.

Oberholser, H. C. 1974. *The birdlife of Texas.* Edited by E. B. Kincaid. Jr. Austin: University of Texas Press.

Ohmart, Robert D., and Anderson, Bertin W. 1980. Wildlife use values of wetlands in the arid southwestern United States. *Proc. Nat. Symp. Wetlands,* 1978.

Olmstead, F. H. 1919. Gila River flood control. 65th Cong. 3d sess., Senate Document 436.

Pase, C. P., and Layser, E. F. 1977. Classification of riparian habitat in the Southwest. *USDA Forest Service, Gen. Tech. Rept.* RM-43:5-9.

Peacock, J. T., and McMillan, C. 1965. Ecotypic differentiation in *Prosopis* (mesquite). *Ecology* 46:35-51.

Peterson, N. V. 1950. The problem of gullying in western valleys. In *Applied sedimentation,* P. D. Trask, pp. 407-434. John Wiley.

Phillips, A.; Marshall, J.; and Monson, G. 1964. *The birds of Arizona.* Tucson: University of Arizona Press.

Phillips, W. S. 1963. Depths of roots in soil. *Ecology* 44:424.

Reitan, C. H., and Green, C. R. 1968. Appraisal of research on weather and climate of desert environments. In *Deserts of the world,* ed. W. G. McGinnis, B. J. Goldman, and P. Paylore, pp. 3-17. Tucson: University of Arizona Press.

Report of the Governor of Arizona to the Secretary of the Interior. 1896. Washington, D.C.: Government Printing Office.

Rich, J. L. 1911. Recent stream trenching in the semi-arid portion of southwestern New Mexico, a result of removal of vegetation cover. *Am. J. Sci.* 32:237-245.

Robinson, T. W. 1958. Phreatophytes. *USGS Water Supply Paper* 1423.

———. 1965. Introduction, spread and areal extent of salt cedar (*Tamarix*) in the western states. *USGS Prof. Paper* 491-A. Washington, D.C.: Government Printing Office.

Rodgers, W. M. 1965. Historical land occupance of the upper San Pedro Valley since 1870. Master's thesis, University of Arizona.

Sands, A., and Howe, G. 1977. An overview of riparian forests in California: Their ecology and conservation. *USDA Forest Service, Gen. Tech. Rept.* RM-43:98-115.

Schumm, S. A., and Hadley, R. F. 1961. Progress in the application of land form analysis in studies of semiarid erosion. *U.S. Geol. Surv. Circular* 437.

Schumm, S. A., and R. W. Lichty. 1965. Time, space and causality in geomorphology. *Am. J. Sci.* 263:110-119.

Shreve, F. 1942. The desert vegetation of North America. *Bot. Rev.* 8:195-246.

———. 1951. Vegetation of the Sonoran Desert *Carnegie Inst. Publ.* 591:1-192.

Shreve, F., and Wiggins, I. L. 1964. *Vegetation and flora of the Sonoran Desert.* 2 vols. Stanford, Calif.: Stanford University Press.

Sigler, W. F., and Miller, R. R. 1963. *Fishes of Utah.* Salt Lake City: Utah State Department of Fish and Game.

Simpson, B. B.; Neff, J. L.; and Moldenke, A. R. 1977. *Prosopis* flowers as a resource. In *Mesquite,* ed. B. B. Simpson, pp. 84-107. *US/IBP Synthesis Series* 4. Stroudsburg, Pa.: Dowden, Hutchinson & Ross.

Simpson, B. B., and Solbrig, O. T. 1977. Introduction to *Mesquite,* ed. B. B. Simpson. *US/IBP Synthesis Series* 4. Stroudsburg, Pa.: Dowden, Hutchinson & Ross.

Small, A. 1974. *The birds of California.* New York: Colliers Books.

Solbrig, O. T., and Cantino, P. D. 1975. Reproductive adaptations in *Prosopis* (Leguminosae, Mimosoideae). *J. Arnold Arb.* 56:185-210.

Sommerfeld, M. R.; Olsen, R. D.; Olsen, and Love, T. D. 1974. Some chemical observations on the upper Salt River and its tributaries. *Ariz. Acad. Sci.* 3:78-81.

Stamp, N. E. 1978. Breeding birds of riparian woodland in south-central Arizona. *Condor* 80(1):64-71.

Swenson, W. H. 1969. Comparisons of insects on mesquite in burned and unburned areas. Master's thesis, Texas Technical College, Lubbock, Texas.

Sykes, G. 1937. The Colorado Delta. *Amer. Geographical Soc. Spec. Pub.* 19. Published jointly by Carnegie Inst. Wash. and Amer. Geographical Soc. of New York.

Szaro, R. C. 1980. Factors influencing bird populations in Southwestern riparian forests. In *Proc. of the workshop on management of western forests and grasslands for nongame birds. USDA Forest Serv. Tech. Rept.,* Intermountain Forest and Range Exp. Sta., Ogden, Utah. 86:403-418.

Thornber, J. J. 1910. The grazing ranges of Arizona. *Ariz. Agric. Expt. Sta. Bull.* 65.

U.S. Bureau of the Census. 1872. *Ninth census of the United States: 1870.*

———. 1895. *Eleventh census of the United States: 1890.*

Van Devender, T. R. 1977. Holocene woodlands in the southwestern deserts. *Science* 198(4313):189-192.

Vogl, R. J., and McHargue, L. T. 1966. Vegetation of California fan palm oases on the San Andreas fault. *Ecology* 47:532-540.

Wagoner, J. J. 1952. History of the cattle industry in southern Arizona, 1540-1940. *Univ. Ariz. Soc. Sci. Bull.* 20.

Walsberg, G. E. 1975. Digestive adaptations of *Phainopepla nitens* associated with the eating of mistletoe berries. *Condor* 77:169-174.

———. 1977. Ecology and energetics of contrasting social systems in *Phainopepla nitens* (Aves: Ptilogonatidae), *Univ. Calif. Publ. Zool.* 108:1-63.

Walton, G. P. 1923. A chemical and structural study of mesquite, carob, and honey locust beans. *USDA Bull.* 1194.

Wauer, R. H. 1973. *Birds of Big Bend National Park and vicinity.* Austin: University of Texas Press.

———. 1977. Significance of Rio Grande riparian systems upon the avifauna. *USDA Forest Service, Gen. Tech. Rept.* RM-43:165-174.

Woodbury, A. M.; Durrant, S. D.; and Flowers, S. 1959. Survey of vegetation in the Glen Canyon reservoir basin. *Univ. Utah Anthropol.* 36 (Glen Canyon Series 5).

———. 1960. A survey of vegetation in the Flaming Gorge basin. *Univ. Utah Anthropol. Pap.* 45. (Upper Colorado Series 21).

———. 1962. A survey of the vegetation in the Curecanti Reservoir Basins. *Univ. Utah Anthropol. Pap.* 56:1-106 (Upper Colorado Series 6).

Woodward, S. L., and Ohmart, R. D. 1976. Habitat use and fecal analysis of feral burros (*Equus asinus*), Chemehuevi Mountains, California, 1974. *J. Range Mgmt.* 29:482-485.

Yeager, L. E. 1955. Two woodpecker populations in relation to environmental change. *Condor* 57:148-153.

Zacher, F. 1952. Die Nahrpflanzen der Samenkafer. *Zeitschr. Angew. Entomol.* 33:460-479.

HABITAT RELATIONSHIPS OF NATIVE REPTILES AND AMPHIBIANS OF NORTH AMERICAN DESERTS

Obligate riparian species are those found exclusively along desert water courses. Most often, these are amphibians that depend on riparian situations for breeding. Facultative riparian species are those that are often found in riparian habitats but occur elsewhere and do not totally rely on riparian habitats. Nonriparian species are those that seldom, if ever, use riparian habitats. The four deserts are indicated as follows: GB, Great Basin Desert; Ch, Chihuahuan Desert; Mv, Mojave Desert; and So, Sonoran Desert.

SPECIES		RIPARIAN DEPENDENCY		
	DESERT	OBLIGATE	FACULTATIVE	NONE
Amphibians				
Scaphiopus couchi	So, Ch			x
S. bombifrons	Ch			x
S. hammondi	So, Ch			x
S. intermontanus	GB			x
Rana pipiens (sp.)	GB, So, Ch	x		
R. catesbeiana	So, Ch	x		
R. arenicolor	Ch	x		
Bufo punctatus	Mv, So		x	
B. debilis	Ch		x	
B. woodhousei	So, Ch		x	
B. cognatus	So, Ch		x	
B. retiformis	So		x	
B. alvarius	So		x	
Pternohyla fodiens	So			x
Reptiles				
Terrapene ornata	Ch			x
Kinosternon flavescens	Ch		x	
K. sonoriense	Ch, So	x		
Trionyx spinifer	Ch	x		
Coleonyx brevis	Ch			
C. variegatus	Mv, So			x
Holbrookia maculata	Ch	x		
Gopherus agassizi	Mv, So			x

SPECIES	DESERT	RIPARIAN DEPENDENCY OBLIGATE	FACULTATIVE	NONE
Xantusia vigilis	Mv, So			x
Sauromalus obesus	Mv, So			x
Dipsosaurus dorsalis	Mv, So			x
Callisaurus draconoides	Mv, So		x	
Uma scoparia	Mv			x
U. inornata	Mv, So			x
Phrynosoma m'calli	So			x
P. douglassii	GB, Ch			x
P. solare	So			x
P. coronatum	Ch			x
P. platyrhinos	GB, So, Mv			x
P. modestum	Ch			x
Cophosaurus texanus	Ch		x	
Cambelia wislizeni	GB, Mv, So, Ch		x	
Crotaphytus collaris	Ch		x	
C. insularis	GB, Mv, So			x
Sceloporus clarki	Ch		x	
S. occidentalis	GB		x	
S. graciosus	GB		x	
S. poinsetti	Ch		x	
S. undulatus	Ch		x	
Urosaurus ornatus	So, Ch		x	
U. graciosus	Mv, So		x	
Uta stansburiana	GB, Mv, Ch, So		x	
Eumeces obsoletus	Ch		x	
E. skiltonianus	GB		x	
Cnemidophorus tesselatus	Ch		x	
C. tigris	GB, Mv, So, Ch		x	
C. uniparens	Ch		x	
C. neomexicanus	Ch			x
C. inornatus	Ch			x
C. gularis	Ch			x
C. exsanguis	Ch		x	
C. sonorae	So, Ch		x	
C. flagellicaudus	So, Ch		x	
Charina bottae	GB		x	
Leptotyphlops humilis	Mv, So, Ch		x	
L. dulcius	Ch		x	
Lichanura trivirgata	Mv, So			x
Heterodon nascius	Ch		x	
Phyllorhynchus decurtatus	Mv, So			x
P. browni	So			x
Heloderma suspectum	So			x
Diadophis punctatus			x	
Masticophis flagellum	Mv, So, Ch		x	
M. taeniatus	GB, Ch		x	
Coluber constrictor	GB		x	
Salvadora grahamiae	Ch			x
S. hexalepis	GB, Mv, So, Ch			x
Pituophis melanoleucas	GB, Mv, So, Ch		x	
Arizona elegans	Ch, Mv, So			x
Elaphe subocularis	Ch		x	
Lampropeltis getulus	Mv, So, Ch		x	

SPECIES	RIPARIAN DEPENDENCY			
	DESERT	OBLIGATE	FACULTATIVE	NONE
Rhinocheilus lecontei	GB, Mv, So, Ch			x
Thamnophis marcianus	So, Ch		x	
T. sirtalis	GB	x		
T. eques	Ch	x		
T. elegans	GB		x	
T. cyrtopsis	So, Ch	x		
Sonora semiannulata	GB, Mv, So, Ch		x	
S. episcopa	Ch		x	
Ficimia cana	Ch		x	
Chionactis occipitalis	Mv, So			x
C. palarostris	So			x
Chilomeniscus cinctus	So		x	
Tantilla nigriceps	Ch		x	
T. planiceps	Mv, So, Ch		x	
Hypsiglena ochrorhyncha	GB, Mv, So, Ch			x
Trimorphodon biscutatus vilkinsoni	Ch			x
T. b. lambda	So			x
Micruroides euryxanthus	So		x	
Sistrurus catenatus	Ch		x	
Crotalus molossus	Ch		x	
C. lepidus	Ch		x	
C. viridis	GB, Ch		x	
C. scutulatus	Mv, Ch		x	
C. atrox	Mv, Ch		x	
C. cerastes	Mv		x	

HABITAT RELATIONSHIPS OF NATIVE BIRDS IN NORTH AMERICAN DESERTS

If a species regularly occurred in the desert area, it was included in the total; species with irregular sightings were excluded. An obligate riparian species was defined as one whose major portion of the species population is dependent upon the riparian habitat in the desert being considered. A facultative species is one that utilizes riparian habitat but is not totally dependent on it; it may use urban, desert, or agricultural habitats as well. The definition of obligate and faculative riparian species results in a different classification of riparian dependence in one desert versus another. For example, a species that may be listed as having obligate riparian habitat dependence in one desert may be listed as facultative in another in which its riparian habitat is not present, or is present to such a limited extent that the major portion of the population is using another habitat type such as urban or agricultural. Nonriparian species are those which occur within the desert without utilizing riparian habitats to any great extent.

An asterisk indicates a breeding species. The four deserts are indicated as follows: GB, Great Basin Desert; Ch, Chihuahuan Desert; Mv, Mojave Desert; and So, Sonoran Desert.

AVIAN SPECIES	RIPARIAN DEPENDENCY		
	OBLIGATE	FACULTATIVE	NONE
Common loon			Ch, GB, Mv, So
Arctic loon			GB, Mv, So
Red-throated loon			GB
Horned grebe			Ch, GB, So, Mv
Eared grebe	GB*	So	Ch, Mv
Least grebe		Ch, So	
Western grebe	GB*, So*		Ch, Mv
Pied-billed grebe		GB*, Ch, Mv*, So*	
White Pelican		GB	Ch, Mv, So
Brown Pelican			So
Double-crested cormorant	Ch*, So*	GB*, Mv	
Olivaceous cormorant	So*, Ch*		
Great blue heron	Ch*, GB*, So*	Mv	
Green heron	Ch*, Mv*, So*, GB*		

AVIAN SPECIES	RIPARIAN DEPENDENCY		
	OBLIGATE	FACULTATIVE	NONE
Little blue heron		Ch	
Cattle egret		So, Ch, GB, Mv	
Great egret	Ch*, So*	GB, Mv	
Snowy egret	Ch*, GB*, So*	Mv	
Louisiana heron		Ch	
Black-crowned night heron	Ch*, So*, GB*	Mv	
Yellow-crowned night heron		Ch	
Least bittern	Ch*, GB*, Mv*, So*		
American bittern	Ch*, GB*, So*, Mv		
Wood stork		Ch, So	
White-faced ibis	GB*	Ch, Mu, So	
White ibis		Ch	
Whistling swan		GB, So, Ch	Mv
Trumpeter swan		GB	
Canada goose	GB*, Ch*	So	Mv
White-fronted goose		GB, So, Ch	Mv
Snow goose		So, GB, Ch	Mv
Ross goose		GB, Ch	
Black-bellied whistling-duck	So*		
Fulvous whistling-duck		Ch, So	
Mallard		Ch*, GB*, Mv*, So*	
Mexican duck	So*, Ch*,		
Gadwall	GB*, So*, Ch*	Mv	
Pintail	GB*, Ch*	Mv, So	
Green-winged teal	Ch*, GB*	Mv, So	
Blue-winged teal		Ch*, GB*, Mv, So	
Cinnamon teal	So*	Ch*, Mv*, GB*	
American wigeon	GB*, Ch*	Mv, So	
Northern shoveler	GB*, Ch*	Mv, So	
Wood duck		Ch, Mv, So, GB	
Redhead	GB*, So*	Mv, Ch	
Ring-necked duck	GB*	Mv, So, Ch	
Canvasback	GB*		So, Ch, Mv
Greater scaup			GB, So
Lesser scaup			Ch, Mv, So, GB
Common goldeneye			Ch, GB, Mv, So,
Barrow goldeneye			GB, So
Bufflehead			Ch, GB, Mv, So
Oldsquaw			GB
White-winged scoter			GB, Ch
Surf scoter			So, Ch
Ruddy duck	GB*, So*, Ch*	Mv*	
Hooded merganser		GB, So, Ch	
Common merganser			Ch, GB, So
Red-breasted merganser			Ch, GB, Mv, So
Turkey vulture		Ch*, Mv*, So*, GB*	
Black vulture		So, Ch*	
Mississippi kite	Ch*, So*		
Goshawk		GB, So, Ch	

AVIAN SPECIES	RIPARIAN DEPENDENCY		
	OBLIGATE	FACULTATIVE	NONE
Sharp-shinned hawk		Ch, GB, Mv, So	
Cooper hawk	GB*, So*, Mv*, Ch*		
Red-tailed hawk		Ch*, GB*, Mv*, So*	
Broad-winged hawk		Ch	
Swainson hawk		Ch*, GB*, Mv, So*	
Zone-tailed hawk	Ch*, So*		
Rough-legged hawk			Ch, GB, Mv, So
Ferruginous hawk			Ch, GB*, Mv, So
Gray hawk	Ch, So*		
Harris hawk		Ch*, So*	
Black hawk	Ch*, So*		
Golden eagle			Ch*, GB*, Mv*, So*
Bald eagle	GB*, So*	Ch, Mv	
Marsh hawk		GB*, Ch*, Mv, So	
Osprey	GB*	Ch, Mv, So	
Caracara		Ch*, So*	
Prairie falcon		Ch*, GB*, Mv,* So*	
Peregrine falcon		Ch*, GB*, Mv, So*	
Aplomado falcon			Ch
Merlin		Ch, GB, Mv, So	
American kestrel		Ch*, GB*, Mv*, So*	
Sharp-tailed grouse			GB*
Sage grouse			GB*
Scaled quail			So*, Ch*
Gambel quail		Ch*, Mv*, So*	
Ring-necked pheasant			Ch*, GB*, So*
Chukar			GB*, Mv*
Sandhill crane		So, Ch, GB*	
Clapper rail	So*		
Virginia rail	Ch*, GB*, Mv*, So*		
Sora	Ch*, GB*, Mv*, So*		
Black rail	So*		
Common gallinule	Ch*, GB*	So*, Mv	
American coot		Ch*, GB*, Mv*, So*	
Semipalmated plover		Ch, GB, So	
Snowy plover		Ch*, GB*, So*	Mv
Killdeer		Ch*, GB*, Mv*, So*	
Mountain plover			Ch, GB, Mv, So
Golden plover		GB, So	
Black-bellied plover		Ch, GB, So	
Ruddy turnstone			GB

AVIAN SPECIES	RIPARIAN DEPENDENCY		
	OBLIGATE	FACULTATIVE	NONE
Common snipe		Ch, GB*, Mv, So	
Long-billed curlew		Ch, GB*, Mv, So	
Whimbrel		Ch, GB, So	
Upland sandpiper			Ch
Spotted sandpiper		Ch, GB*, Mv, So	
Solitary sandpiper		Ch, GB, Mv, So	
Willet	GB*	Ch, Mv, So	
Greater yellowlegs		Ch, GB, Mv, So	
Lesser yellowlegs		Ch, GB, Mv, So	
Pectoral sandpiper		Ch, GB, Mv, So	
Baird sandpiper		Ch, GB, Mv, So	
Least sandpiper		Ch, GB, Mv, So	
Dunlin		Ch, GB, So	
Short-billed dowitcher		GB, So	
Long-billed dowitcher		Ch, GB, Mv, So	
Stilt sandpiper		Ch, GB, So	
Semipalmated sandpiper		Ch, GB	
Western sandpiper		Ch, GB, Mv, So	
Marbled godwit		Ch, GB, Mv, So	
Sanderling American avocet		Ch*, Mv, So, GB*	Ch, So, GB
Black-necked stilt		Ch*, Mv*, So*, GB*	
Wilson phalarope		Ch, Mv, So, GB*	
Red phalarope			GB, So
Northern phalarope			GB, Mv, So, Ch
Parasitic jaeger			GB, So
Herring gull			GB, So
California gull			Mv, So
Ring-billed gull		GB*	Ch, Mv, So
Franklin gull	GB*		Ch, So
Bonaparte gull			Mv, So, Ch, GB
Sabine gull			GB, So, Ch
Forster tern	GB*	Ch, Mv, So	
Common tern			So, Ch, GB
Least tern		Ch*	
Caspian tern	GB*	So, Ch	
Black tern	GB*	Ch, So, GB	
Band-tailed pigeon			
Rock dove			Ch, GB, Mv, So
White-winged dove		Mv*, So*, Ch*	
Mourning dove		Ch*, GB*, Mv*, So*	
Ground dove		Ch*, So*	
Inca dove			Ch*, So*
Yellow-billed cuckoo	Ch*, GB*, So*		
Black-billed cuckoo		GB*	
Roadrunner		Ch*, GB*, Mv*, So*	
Groove-billed ani		Ch	

AVIAN SPECIES	RIPARIAN DEPENDENCY		
	OBLIGATE	FACULTATIVE	NONE
Barn owl		Ch*, GB*, Mv*, So*	
Screech owl		Ch*, GB*, Mv*, So*	
Great horned owl		Ch*, GB*, Mv*, So*	
Pygmy owl		GB	
Ferruginous owl		So*	
Elf owl		Ch*, So*	
Burrowing owl			Ch, GB, Mv, So*
Long-eared owl		Ch*, GB*, Mv*, So*	
Short-eared owl		Ch, GB*, Mv, So	
Buff-collared nightjar			So
Poor-will			So*, Mv*, GB*, Ch*
Common nighthawk		Ch*, GB*	
Lesser nighthawk		Ch*, Mv*, So*	
Chimney swift			Ch*, So
Vaux swift		GB, Mv, So	
White-throated swift			Ch*, GB*, Mv*, So*
Lucifer hummingbird		Ch*	
Black-chinned hummingbird		Ch*, GB*, Mv*, So*	
Costa hummingbird			Ch*, Mv*, So*
Anna hummingbird		Ch*, Mv*, So*	
Broad-tailed hummingbird		GB, Ch, So	
Rufous hummingbird		Ch, GB, Mv, So	
Calliope hummingbird		GB, So	
Broad-billed hummingbird		Ch, So*	
Belted kingfisher		Ch*, GB*, Mv, So	
Green kingfisher	Ch*, So*		
Common flicker		Ch*, GB*, Mv*, So*	
Gila woodpecker		So*	
Red-headed woodpecker		Ch*	
Acorn woodpecker		So	
Lewis woodpecker		GB, Mv, So, Ch	
Yellow-bellied sapsucker		Ch, GB*, Mv, So	
Hairy woodpecker		GB*, Ch	
Downy woodpecker		GB*	
Ladder-backed woodpecker		Ch*, Mv*, So*	
Eastern kingbird	GB*	Ch	
Tropical kingbird	So*	Ch*	
Western kingbird		Ch*, GB*, Mv*, So*	
Cassin kingbird		Ch, GB, Mv, So	
Thick-billed kingbird	So*		
Scissor-tailed flycatcher		Ch*	

AVIAN SPECIES	RIARIAN DEPENDENCY		
	OBLIGATE	FACULTATIVE	NONE
Wied crested flycatcher	Ch	So*	
Ash-throated flycatcher		Ch*, GB*, Mv*, So*	
Eastern phoebe		Ch, So	
Black phoebe	Ch*, GB*, So*	Mv*	
Say phoebe		Ch*, GB*, Mv*, So*	
Willow flycatcher	GB*, So	Ch, Mv	
Least flycatcher		Ch	
Hammond flycatcher		Ch, GB, Mv, So	
Dusky flycatcher		Ch, GB*, Mv, So	
Gray flycatcher		Ch, GB*, Mv, So	
Western flycatcher		Ch, GB, Mv, So	
Coues flycatcher		So	
Western wood pewee		Ch*, GB*, Mv, So*	
Olive-sided flycatcher		Ch, GB, Mv, So	
Vermilion flycatcher	So*	Ch*, Mv	
Beardless flycatcher	So*		
Horned lark			Ch*, GB*, Mv*, So*
Violet-green swallow		Ch, GB*, Mv, So*	
Tree swallow		Ch*, GB*, Mv, So	
Bank swallow		Ch*, GB*, Mv, So	
Rough-winged swallow		Ch*, GB*, Mv*, So*	
Barn swallow		Ch*, GB*, Mv, So*	
Cliff swallow		Ch*, GB*, Mv*, So*	
Cave swallow		Ch*	
Purple martin		Ch, GB, So*	
Blue jay		GB*, Ch	
Steller jay		GB	
Scrub jay		Ch, GB, Mv, So	
Black-billed magpie		GB	
Common raven		Ch*, GB*, Mv*, So*	
White-necked raven		Ch*, So*	
Common crow		GB*, So	
Black-capped chickadee		GB*	
Mountain chickadee		GB	
Black-crested titmouse		Ch*	
Plain titmouse			GB*
Bridled titmouse	So*		
Verdin		Ch*, Mv*, So*	
Bushtit		So, GB*, Ch	
White-breasted nuthatch	So*	Ch, GB	
Red-breasted nuthatch		Ch, GB, Mv, So	

AVIAN SPECIES	RIPARIAN DEPENDENCY		
	OBLIGATE	FACULTATIVE	NONE
Brown creeper		Ch, GB, Mv, So	
Dipper		GB	
House wren		Ch, GB*, Mv, So	
Winter wren	So	Mv, GB, Ch	
Bewick wren	So*	Ch, GB*, Mv*	
Cactus wren		Ch*, Mv*, So*	
Long-billed marsh wren	Ch, GB*, Mv*, So*		
Canyon wren		Ch*, GB*, Mv*, So*	
Rock wren			Ch*, GB*, Mv*, So*
Mockingbird		Ch*, GB*, Mv*, So*	
Gray catbird	GB*		
Brown thrasher		Ch	
Bendire thrasher			Mv*, So*
Curve-billed thrasher		Ch*, So*	
Le Conte thrasher			Mv*, So*
Crissal thrasher	So*	Ch*, Mv*	
Sage thrasher		Ch, GB*, Mv, So	
Rufous-backed robin		So	
American robin		Ch*, GB*, Mv, So*	
Hermit thrush		Ch, GB, Mv, So	
Swainson thrush		Ch, GB, Mv, So	
Veery	GB*		
Eastern bluebird		Ch*	
Western bluebird		Ch, GB, Mv, So	
Mountain bluebird		Ch, GB, Mv, So	
Townsend solitaire		Ch, GB, Mv, So	
Blue-gray gnatcatcher		Ch, GB*, Mv, So	
Black-tailed gnatcatcher		Ch*, Mv*, So*	
Golden-crowned kinglet		Ch, GB, Mv, So	
Ruby-crowned kinglet		Ch, GB, Mv, So	
Water pipit		Ch, GB, Mv, So	
Sprague pipit			Ch, So
Bohemian waxwing			GB
Cedar waxwing		Ch, GB*, Mv, So	
Phainopepla		Ch*, Mv*, So*	
Northern shrike			GB
Loggerhead shrike		Ch*, GB*, Mv*, So*	
Starling		Ch*, GB*, Mv*, So*	
Black-capped vireo		Ch	
Hutton vireo	So	Ch	
Bell vireo	Ch*, Mv*, So*		
Gray vireo			GB*, So
Solitary vireo		Ch, GB*, So	

AVIAN SPECIES	RIPARIAN DEPENDENCY		
	OBLIGATE	FACULTATIVE	NONE
Red-eyed vireo	GB	Mv, So, Ch	
Warbling vireo	GB	Ch, Mv, So	
Black-and-white warbler		Ch, Mv, So, GB	
Worm-eating warbler		Ch	
Tennessee warbler		Mv, Ch, So	
Orange-crowned warbler		Ch, GB*, Mv, So	
Nashville warbler		Ch, GB, Mv, So	
Virginia warbler		Ch, GB*, Mv, So	
Lucy warbler	Ch, GB, So*	Mv	
Northern parula		Ch, So, Mv	
Yellow warbler	Ch*, GB*, So*	Mv	
Black-throated blue warbler		Ch	
Yellow-rumped warbler		Ch, GB, Mv, So	
Black-throated gray warbler		Ch, GB*, Mv, So	
Townsend warbler		Ch, GB, Mv, So	
Black-throated green warbler		Ch, So	
Hermit warbler		Ch, GB, Mv, So	
Chestnut-sided warbler		Ch	
Blackpoll warbler		Ch	
Palm warbler		Ch	
Ovenbird		Ch	
Northern waterthrush	Ch, GB, So, Mv		
Kentucky warbler		Ch	
MacGillivray warbler		Ch, GB*, Mv, So	
Common yellowthroat	Ch*, GB*, Mv*, So*		
Yellow-breasted chat	Ch*, GB*, Mv*, So*		
Hooded warbler		Ch	
Wilson warbler		Ch, GB, Mv, So	
American redstart	GB*	Mv, So, Ch	
House sparrow			Ch, GB, Mv, So
Bobolink		GB*, Mv, Ch	
Eastern meadowlark		Ch	So
Western meadowlark		Ch, Mv, So	GB
Yellow-headed blackbird	GB*, So*	Ch, Mv	
Red-winged blackbird		Ch*, Mv*, So*, GB*	
Orchard oriole		Ch*	
Hooded oriole	Ch*	So*, Mv*	
Scarlet-headed oriole		So	
Scott oriole			Ch*, GB*, Mv, So*
Northern oriole	GB, So	Ch, Mv	
Brewer blackbird		GB*	So, Ch, Mv
Great-tailed grackle		Ch*, So*	
Brown-headed cowbird		Ch*, GB*, Mv*, So*	
Bronzed cowbird	Ch*	So*	
Western tanager		Ch, GB, Mv, So	

AVIAN SPECIES	RIPARIAN DEPENDENCY		
	OBLIGATE	FACULTATIVE	NONE
Summer tanager	Ch*, So*		
Cardinal	Ch*	So*	
Pyrrhuloxia		Ch*, So*	
Rose-breasted grosbeak		Ch, GB, Mv, So	
Black-headed grosbeak		Ch, GB*, Mv, So	
Blue grosbeak	Ch*, GB*, Mv*, So*		
Indigo bunting	GB*, So*, Ch*		
Lazuli bunting		Ch, GB*, Mv, So*	
Varied bunting		Ch*, So*	
Painted bunting	Ch*		
Dickcissel		Ch	
Evening grosbeak		GB, So	
Purple finch		So	
Cassin finch		GB, Ch, So	
House finch		Ch*, GB*, Mv*, So*	
Common redpoll		GB	
Pine siskin		Ch, GB, Mv, So	
American goldfinch	GB*	Ch, Mv, So	
Lesser goldfinch	GB*, So*	Ch*, Mv*	
Lawrence goldfinch	So*	Ch, Mv	
Green-tailed towhee		Ch, GB, Mv, So	
Rufous-sided towhee		Ch, GB, Mv, So	
Brown towhee		Ch*, So*	
Abert towhee	Mv*, So*		
Lark bunting			Ch, GB*, So
Savannah sparrow		Ch, GB*, Mv, So	
Grasshopper sparrow			Ch, GB*, So
Baird sparrow			Ch
Le Conte sparrow		Ch	
Vesper sparrow			Ch, GB*, Mv, So
Five-striped sparrow			So*
Lark sparrow		Ch*, GB*, Mv, So*	
Rufous-winged sparrow		So*	
Rufous-crowned sparrow			Ch*, So*
Botteri sparrow			So, Ch
Cassin sparrow			Ch*, So*
Black-throated sparrow			Ch*, GB*, Mv*, So*
Sage sparrow		Ch, GB*, Mv, So	
Dark-eyed junco		Ch, GB, Mv, So	
Gray-headed junco		Ch, GB, Mv, So	
Tree sparrow		GB	
Chipping sparrow		Ch, GB*, Mv, So	
Clay-colored sparrow		Ch	
Brewer sparrow		Ch, GB*, Mv,	

AVIAN SPECIES	RIPARIAN DEPENDENCY		
	OBLIGATE	FACULTATIVE	NONE
Field sparrow		Ch	
Worthen sparrow			Ch*
Black-chinned sparrow			Ch, So
Harris sparrow		Ch, GB, So	
White-crowned sparrow		Ch, GB, Mv, So	
Golden-crowned sparrow		GB, Mv, So	
White-throated sparrow		Ch, GB, Mv, So	
Fox sparrow	GB*	Ch, So	
Lincoln sparrow		Ch, GB, Mv, So	
Swamp sparrow	Ch, So, GB		
Song sparrow	Ch, GB*, Mv*, So*		
Lapland longspur			GB
Chestnut-collared longspur			Ch, GB, So
Snow bunting			GB

RIPARIAN HABITATS

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Importance, Preservation and Management of Riparian Habitat:

A Symposium

Tucson, Arizona

July 9, 1977

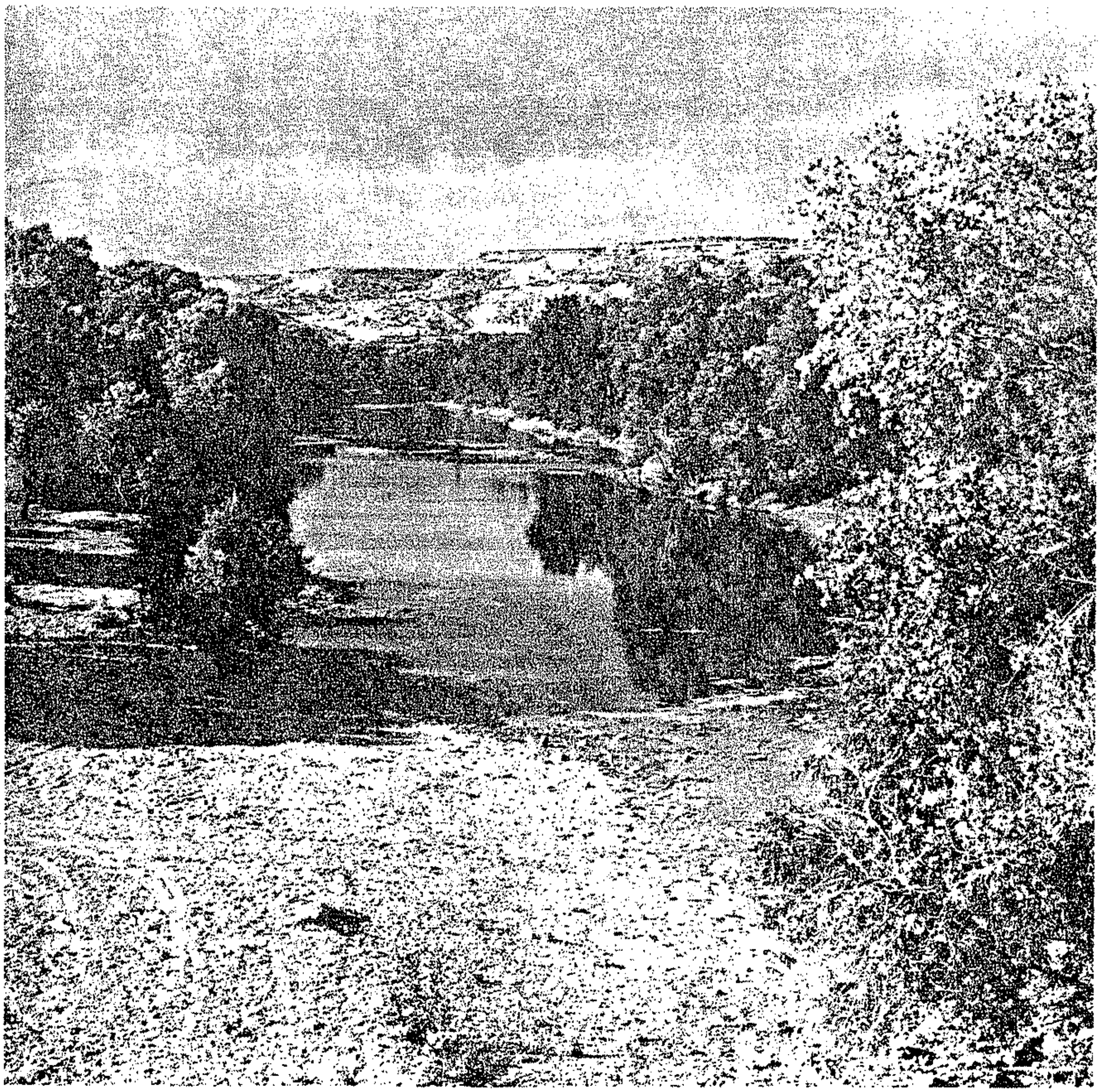

EXHIBIT C

Importance, Preservation, and Management of Riparian Habitats: An Overview[1]

Steven W. Carothers [2]

In the early 19th century, huge and numerous squawfish were being taken along the lower Gila; there was a commercial fishery of the humpback sucker in the San Pedro; wild turkeys hatched out of the waist-high grasses of the Auga Fria; and grizzly bears and mountain lions were encountered with alarming frequency in the riparian woodlands associated with some of these drainages. The historical literature that documents the early exploration and settlement of the southwestern United States is replete with similar accounts of the original condition of the area's rivers, streams and springs (see Lacey et al., 1975; Hastings and Turner, 1965, for original references).

The river valleys of the arid Southwest have undergone significant physical and biological changes since the early 1800's. This change has involved almost exclusively a deterioration of the natural resources. Drainages like the Gila and San Pedro Rivers that once supported pristine riparian communities are now, in many sections, dry and devoid of native trees and shrubs. Concomitant with the deterioration of the riparian habitats, the range habitats throughout the same area also reflect a decline in the production of palatable forage plants and an increase in topsoil erosion.

We can, and have, argued about the causes of deteriorating range quality. But there is, in my opinion, no controversy concerning the causes of the irrevocable consumption of the riparian habitat that has occurred in less than 150 years. The imminent demise of the riparian woodland can be most assuredly linked to the land utilization practices of man.

The title of this symposium indicates that we will address the "importance, preservation and management" of riparian habitats. The word "importance" here is meant to reflect the relative contribution of riparian habitats in a natural ecosystem; "preservation and management" refer to implementing land management practices that will forestall the possible extinction of these habitats. We are tempted to approach these issues in purely scientific definitions. But the issues extend beyond the realm of biology. Man has contributed, in large part, to these problems. It is only by examining how he views the riparian habitat as important to his economic base, and thereby consumes this resource, that we can understand why it is in danger of extirpation.

The settlement patterns of the native American Indians clearly reflect the initial consumptive use of riparian habitats. They first settled the river valleys, needing water for themselves, and subsequently drinking water for livestock and irrigation water for crops. This pattern of consumption accelerated greatly in the early 1820's, with the settlement of the early Anglo-Americans in the Southwestern river valleys. Prospectors, farmers, and ranchers all found uses for the limited water and its associated vegetation. The area was rapidly settled and in 1896 the Governor of Arizona Territory could report, "In Arizona by 1883-84 every running stream and spring was settled upon, ranch houses built, and adjacent ranges stocked." (Report of Governor, 1896:21 fide Hastings and Turner, 1965).

The settlers cleared large expanses of native vegetation, using some for building materials; but for the most part, they did not view the woodlands as a valuable resource, and removed them so that the soil of the alluvial bottom could be put into "production" for agricultural and domestic livestock grazing purposes. Eventually, farming and ranching became thriving concerns; river water was channeled into irrigation canals, wells were excavated and in time the water tables began to drop. Responding to changing water regimes, damaging floods, or in simple attempts to increase the yield of the land, dams were finally constructed, inundating and destroying even more riparian woodland and free-flowing streams and rivers. By the late 1920's, America had shifted from a rural to a predominantly urban population. The beginning of an urban-industrial civilization in the arid Southwest required the

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[1]Paper presented at the Symposium on Importance, Preservation and Management of the Riparian Habitat, Tucson, Arizona, July 9, 1977.

[2]Head of Biology Department, Museum of Northern Arizona, Flagstaff, Arizona 86001.

utilization of many innovative technological advances in developing veritable oases where once only parched deserts prevailed. As population centers experienced rapid and prolific expansion, terms such as water production, water management, and water salvage became very meaningful.

As recently as the late 1960's, belts of native riparian woodland along the river valleys of central and southern Arizona were still being actively removed by water salvage and flood control agencies. These "phreatophyte control" and channelization projects were easily justified when based on the standard cost/benefit ratio that was used for project evaluation at the time. The important parameters of these evaluations were: 1) streamside vegetation requires substantial amounts of water, water that is lost to the atmosphere through evapotranspiration; and 2) streamside vegetation impedes the rapid transport of flood waters and increases the apparent severity of floods by temporarily and partially damming channels, thus forcing high water into the adjacent floodplain lands.

The question of how much water is gained and to what degree floods are prevented by phreatophyte control and channelization has been a battle of the minds almost since vegetation removal was first suggested (see Lacey et al., 1975; Paylor, 1974, for references). Still, we have not seen the last of phreatophyte control and streambed channelization in the Southwest, and we know for certain that additional dams will consume even more of the still extant riparian areas. But the most insiduous threat to the riparian habitat type today is domestic livestock grazing. Many riparian areas appear to be in good health; on closer examination, we find that while the mature vegetation approaches senescence, grazing pressures have prevented the establishment of seedlings. We are very concerned that when many of these mature stands of trees die of natural causes, there will be no young forms to take their place. Heavy grazing pressures can and do produce even-aged, non-reproducing vegetative communities. Our concern for this habitat's survival can only mount until this situation is remedied.

For more than a century, then, the riparian habitats of the Southwest were viewed only in terms of their consumptive value, while their values for non-consumptive purposes--aesthetics, recreation, wildlife, and so on--were largely ignored. It was not until the mid-1960's that various agencies and individuals, particularly in the Arizona Game and Fish Department (see Bristow, 1969; Gallizioli, 1965) and the United States Forest Service (pers. communication, Dale Jones and Douglas C. Morrison) began to point out that substantial numbers of both game and non-game wildlife species were dependent upon riparian vegetation. And it was only in the fall of 1968 that efforts to quantify the impact of streamside vegetation removal on wildlife were first undertaken. It is for his efforts in this regard that this symposium is dedicated to the late Douglas C. Morrison.

Working through the wildlife staff on the Coconino National Forest, in 1968 Mr. Morrison participated in the design of a research project that would quantify the effects of phreatophyte control on breeding birds in the native riparian woodland of the Verde River. A Forest Service contract was awarded to the Department of Biology at the Museum of Northern Arizona in the spring of 1969. Through Mr. Morrison's efforts, the study was funded for two years by the Forest Service. After that time, the Arizona Game and Fish Department supported the project for an additonal three years.

The results of that study (see Carothers et al., 1974) substantiated, for the first time, two facts that had long been suspected by many wildlife biologists: 1) that vegetation manipulation in native riparian communites was extremely detrimental to breeding bird populations, the extent of the impact being significantly correlated with the degree to which phreatophytes were removed, and 2) that for a given number of acres of habitat, the riparian type supports higher population densities than any other forest habitat type. Indeed, the surprising discovery resulting from these studies is that the homogeneous cottonwood riparian type of the Verde River contains some of the highest avian population densities per unit area that have been recorded in the continental United States. Recently, other investigators working in the river valleys of the Gila (Hubbard, 1971), the Colorado (Anderson, Ohmart et al., this symposium; Carothers and Sharber, 1976) and the Salt (Johnson and Simpson, 1971) have demonstrated the remarkabley high wildlife potential of riparian habitat types.

The influence of the riparian type on wildlife is not limited to those animal species that are restricted in distribution to the streamside vegetation. Preliminary investigations conducted by us (see Stevens et al., this symposium), in both river valley and mountain riparian types, demonstrate that the population densities of birds in habitats adjacent to the riparian type are influenced by the presence of a riparian area. Our present interpretation of these preliminary data is that when a riparian habitat is removed or severely manipulated, not only are the riparian species of the area adversely influenced, but wildlife productivity in the adjacent habitat is also depressed. The actual width the zone of influence riparian habitats have on adjacent habitat wildlife productivity may, for some animal species, extend several hundred meters beyond the edge of the streamside vegetation. Under the auspices of the Forest Service, we are presently attempting to determine this for a variety of riparian types in Arizona and New Mexico.

Thus, the history of man's use of the riparian habitats in the Southwest indicate that it has been and continues to be an important and valuable asset to the settlement and progress of this country. On the other hand, ecological research on this habitat type has conclusively demonstrated that riparian areas are integral and indispensable components of desert and mountain ecosystems. Past riparian habitat management practices have resulted in widespread destruction of these areas. That they are non-renewable resources as suggested by Lacey et al. (1975) is a frightening possibility. And even though there are many Southwestern drainages still forested by riparian vegetation, current land use practices still threaten the future existence of these native communities.

We should not look back on the land management practices of the past with too much remorse and certainly with no blame. A summary of man's activities in and the destruction of woodlands, streams, and rivers simply reflects man's successful settlement of this arid land, allowing those of us who live and work in the Southwest the lifestyle we now enjoy. Land management practices of the past should, in fact, be a foundation for learning and understanding how to cautiously move forward in our interactions with the environment.

We are here today to exchange information. The time is at hand for the ecologist, economist, engineer, environmentalist and land manager to strike a compromise...a compromise that will provide a future for native Southwestern riparian habitat types. Accepting and assessing the environmental mistakes of the past, becoming aware of the intricate needs and associations of man and the environment can lead to the implementation of land management practices that will achieve this end.

LITERATURE CITED

Bristow, Bud. 1969. Land and water projects investigations, investigation of proposed projects. Ariz. Game and Fish Dept., Proj. FW-16-R-8, J1 Completion Report. Pp. 23-27.

Carothers, S.W., R.R. Johnson, and S.W. Aitchison. 1974. Population structure and social organization of southwestern riparian birds. Amer. Zool. 14:97-108.

Carothers, S.W. and N.J. Sharber. 1976. Birds of the Colorado River. In An Ecological Survey of the Riparian Zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs, Arizona. Final Research Report, National Park Service.

Gallizioli, S. 1965. Phreatophytes and wildlife. In Pacific Southwest Interagency Committee, Phreatophyte Subcommittee. Minutes of Phreatophyte Subcommittee Meetings. Vol. 2, Jan. 1960 through Dec. 1966. Pp. 317-319.

Hastings, J.R. and R.M. Turner. 1965. The Changing Mile. University of Arizona Press, Tucson. 317 pp.

Hubbard, J.P. 1971. The summer birds of the Gila Valley, New Mexico. Nemouria, 1-35. Occ. Pap. Delaware Mus. Natur. Hist.

Johnson, R.R. and J.M. Simpson. 1971. Important birds from Blue Point cottonwoods, Maricopa County, Arizona. Condor 73:379-380.

Lacey, J.R., P.R. Ogden and K.E. Foster. 1975. Southern Arizona Riparian Habitat: Spatial Distribution and Analysis. Univ. of Ariz., Tucson. 148 pp.

Paylore, P. (ed.) 1974. Phreatophytes: A Bibliography. Water Res. Sci. Info. Center, U.S. Dept. of the Interior. 277 pp.

Importance of Riparian Ecosystems: Biotic Considerations[1]

John P. Hubbard[2]

By biotic considerations I am referring to flora and fauna, and specifically I would like to probe the question of the importance that riparian ecosystems play in sustaining the rich biotas of the Southwest, i.e. Arizona and New Mexico. To begin, these two states are among the richest of any in the United States as far as their diversity is concerned in species of plants, terrestrial vertebrates, and many invertebrates. This biotic richness stems from several factors, including the great environmental variety of the region and the fact that several major biotic areas impinge on the area, i.e. the Great Basin, Rocky Mountains, Great Plains, Mexican Plateau, and the Southern (Chihuahuan and Sonoran) Deserts.

New Mexico is the fourth and Arizona the fifth largest of the United States, with areas of 121,666 and 113,909 square miles, respectively. In size these states are thus on a par with such well-known entities as the British Isles, Italy, and the Philippines. In elevation New Mexico ranges from 2800 to 13,161 feet above sea level, while Arizona ranges from near sea level to 12,670 feet. Although often through of as "deserts", both states support extensive montane forests, and New Mexico especially is crowned with alpine tundra in the north. On the other hand, aridity is a dominant climatic feature of the region, and particularly at elevations below 6000 feet surface water is scarce and naturally restricted to a few thousand miles of generally narrow drainageways in the two states.

Floristic diversity is revealed by the fact that New Mexico supports 3500 to 3600 species of higher native plants within its borders (Wagner, 1977), while the latest summary for Arizona lists 3438 (Kearney and Peebles, 1960). For the continental United States and Canada as a whole, an estimated 40,000 to 50,000 species of higher plants have been recorded. Thus, the floras of New Mexico and Arizona comprise about 7 to 9 percent of the total flora of what might be termed temperate North America.

Among terrestrial vertebrates one finds that even higher percentages of the overall temperate North American faunas are recorded in these two states (Table 1).

Table 1. Vertebrate Fauna of the Southwest, Including Species Totals and as Percentages of the Total Fauna of North America North of Mexico.[3]

Mammals	Arizona	New Mexico
species	134	139
percent	41.6	43.2
Birds		
species (all)	431	413
percent	62.0	59.4
species (breeding)	245	245
percent	38.0	38.0
Reptiles		
species	93	80
percent	35.2	30.3
Amphibians		
species	21	22
percent	13.5	14.2

As one can see, except for amphibians, Arizona and New Mexico harbor disproportionate portions of the terrestrial vertebrates of temperate North America, with figures ranging from about one-third to almost two-thirds among mammals, birds, and reptiles. Amphibians, which mainly depend on water for reproduction, in the two states constitute about one-sixth of the North American fauna.

[1]Paper presented in Importance, Preservation, and Management of the Riparian Habitat, Tucson, Az, July 9, 1977.

[2]Endangered Species Program Supervisor, New Mexico Department of Game and Fish, Santa Fe, N. Mex. 87503.

[3]Data sources include Findley et al., 1975; Hubbard, 1970; Lowe, 1964; Phillips et al., 1964; Stebbins, 1966.

Fishes, although they face an overall scarcity of habitats in the Southwest, are nonetheless well-represented in the faunas. Arizona has 32 native species (Minckley, 1973), while New Mexico has 59 species recorded within its boundaries (Koster, 1957). The latter area supports a richer fauna by virtue of its location in both the Atlantic and Pacific drainages of the continent. In fact, several species from the very rich Mississippian ichthyofauna reach western limits in New Mexico, including the blue sucker (Cycleptus elongatus). Even with their limited faunas, these two states still host--or hosted--reasonably rich percentages of the overall U.S. fish fauna in their boundaries, i.e. 5.3% in Arizona and 9.3% in New Mexico.

From the above it should be apparent that Arizona and New Mexico are truly diverse in their floras and faunas, even when one largely restricts the discussion of animals to vertebrates. Thousands of species of invertebrates also occur in the two states, including especially terrestrial arthropods. For example, Howe (1975) lists almost 700 species of butterflies from temperate North America, and of these about one-third are recorded from New Mexico and somewhat higher figure from Arizona.

In evaluating the biotic importance of a region, one approach is through the consideration of endemism, i.e. the degree to which species are restricted to an area in question. Both Arizona and New Mexico are host to endemic plants and animals, including vertebrates as well as invertebrates. Although I know of no compendium of such species, several examples illustrate some of the endemism. For example, among vertebrates New Mexico hosts the only known populations of such species as the White Sands pupfish (Cyprinodon tularosa), Jemez Mountain salamander (Plethodon neomexicanus), and Sacramento Mountain salamander (Aneides hardii). Both states boast endemic plants as well, while together they share a number of other endemics that occur nowhere outside the Southwest, including the minnow genera, Tiaroga and Meda, in the Gila Basin.

Although endemism is an important means of evaluating the biotic importance of an area, other considerations also pertain. For example, the kinds of assemblages of plants and animals are important, and in these two states virtually unique associations have arisen because of the interdigitation and/or mingling of diverse biotas. Such associations are interesting and important form evolutionary, ecological, and other biological points of view. Unique or unusual assemblages of plants and animals provide scientists and others the extended opportunity to understand better our ecosystems and life itself. An example of a notable biological assemblage is the breeding avifauna of the lower Gila Valley of New Mexico, where species characteristic of the Sonoran, Mexican Plateau, and Holarctic avifaunas occur side-by-side (Hubbard, 1971). That fauna has been compared to another in the ecologically similar San Juan Valley, 250 miles to the north and in the same drainage basin (i.e. Colorado River). Both avifaunas have similar numbers of species (i.e. 105 versus 112 in the Gila), but they differ importantly; for example, only 58.7% of the Gila species breed in the San Juan, while only 64.8% of the species in the latter area breed in the Gila (Schmitt, 1976).

The essence of the above comparisons is that not only are Arizona and New Mexico biotically diverse and host to certain endemics, but they also show significant and important area-to-area differences in the composition of biotas occupying similar situations. Each river valley, mountain range, hot spring, or alkaline playa is apt to differ from those occurring nearby, and this fact alone underscores even more the biotic importance of these two states. This is not to imply that other regions are lacking in biotic importance, for such is not the case. However, Arizona and New Mexico stand apart from most other states in having both very rich floras and faunas and in having many factors that promote ecological departures from the "norm", i.e. disjunct or limited habitats, varied biotic sources, and so on.

Having established the credentials of the Southwest in terms of richness and importance of its floras and faunas, let us turn to the question of how riparian ecosystems may be important in perpetuation of these features. In terms of any one group for which such riparian ecosystems must be regarded as essential, certainly no question exists that the most important would be fishes. I have already mentioned that Arizona hosts--or hosted--32 native species and New Mexico 59. Together these total 75 species when combined, no fewer than 6 of which are federally endangered, i.e. Colorado River squawfish (Ptychocheilus lucius), humpback chub (Gila cypha), woundfin (Plagopterus argentissimus), Gila trout (Salmo gilae), Gila topminnow (Poeciliopsis occidentalis), and Pecos gambusia (Gambusia nobilis), plus one species that is threatened, the Apache trout (S. apache). In addition, the New Mexico Department of Game and Fish lists 30 species of native fishes as endangered in the state, including the squawfish, Gila trout, topminnow, and gambusia mentioned above. On a percentage basis, about half of New Mexico's ichthyofauna is regarded as endangered at the state level, whereas 8 percent of the overall southwestern fauna is federally endangered.

It is obvious that riparian ecosystems are of paramount importance in the survival of native fishes in the Southwest, where the vast majority of the species are riparian (versus lacustrine) in their habitat occupancy. The major threat to the survival of these fishes involves degradation of the required habitats, including lowering of the water table, construction of dams, diversions, and reservoirs, vegetation clearing, pollution, roads, grazing, and the introduction of exotics. This degradation will no doubt continue, for it is partly an outgrowth of man's quest for water and the environments that it fosters. There is little that the dependent biota can do to stem this quest, and man continues to take the aqueous spoils and leave the biota high and dry. Obviously, this approach cannot continue if the ichthyological portion of the rich and important biota of the Southwest is to persist.

Next to fishes, there is no single large group of southwestern vertebrates so dependent for survival on water, that essential and basic element of riparian ecosystems. Yet, there are aquatic plants and invertebrate animals that are just as dependent, including invertebrates. Among the latter are certain mollusks and arthropods, such as Exosphaeroma thermophilum--an endemic crustacean confined to a warm spring run near Socorro, New Mexico. Some animal and plant species are seasonally dependent of riparian ecosystems, such as many amphibians which breed in water. The exact numbers of nonfish species dependent on aquatic habitats in the area has not been determined, but it is significant.

So far, the emphasis on the importance of riparian ecosystems to the biota of the Southwest has concentrated mainly on the question of surface water, as in the cases of fishes and of certain other animals and plants. However, there are other riparian features involved that should also be mentioned, and among the most important is the vegetation characteristic of these ecosystems. A great variety of plants utilize stream courses in the Southwest, including both obligate and facultative species. Typical of the obligates are cottonwoods (Populus spp.), willows (Salix spp.), alders (Alnus spp.), and other broadleaf trees. Facultative species are those that invade stream courses from other habitats, but which may survive without riparian systems. Over 100 kinds of woody plants occur regularly in floodplains in New Mexico, of which about 40% are obligates (Hubbard, ms.).

Riparian plants are biologically important from a number of standpoints. One aspect of their importance is an individual species, for some are restricted in range, numbers, or both. For such species, degradation of the riparian ecosystem could be especially detrimental, even critical to survival. Conversely, for some such species the continued availability of acceptable riparian ecosystems is essential if survival is to continue. Another aspect of importance is at the level of plant assemblages, such as vegetational communities. The matter of communities is especially important, for a great deal of diversity exists among riparian communities in the Southwest (Hubbard, ms.) and this deserves perpetuation. In addition, the assemblage concept is important from the standpoint of revealing evolutionary, ecological, and other biological information, such as any divergence among fragmented populations. There is even a historic (or prehistoric) consideration, in that we may view the broadleaf assemblages of trees and shrubs along many southwestern streams as the major remnant of the ancient Arctotertiary Flora that was dominant in North America 50 to 100 million years ago.

Besides assemblages of plants, aggregations of considerable biological importance are those involving animals as well. Perhaps the aggregation that has attracted most attention recently involves riparian vegetational communities and their attendant birdlife. Although virtually unstudied until recent decades, this biotic aspect of the Southwest has now become better known, and studies have included such streams as the Verde (e.g. Carothers and Johnson, 1973) and Colorado (Ohmart, mss.) in Arizona and the San Juan (White and Behle, 1961; Schmitt, 1976) and Gila (Hubbard, 1971) in New Mexico. All of these systems are extremely rich in breeding birds; for example these two New Mexico river valleys support 16-17% of the entire breeding avifauna of temperate North America over the course of only a few score of miles.

The requirements of these avifaunas involve both the aquatic and the vegetational aspects of riparian ecosystems, but the greater, direct dependence is on the plant communities. Actually, on both the San Juan and the Gila, aquatic habitats other than the river per se are limited, and thus few aquatic species are present. Considering both aquatic and vegetational aspects together as constituting together riparian habitats, one finds that in the Gila Valley some 25.0% of the 112 breeding bird species are restricted to them, while 24.1% occur in them primarily (Hubbard, 1971). Neither group of bird species, totalling 49.1% of the breeding avifauna, would probably occur in the area in the absence of these riparian habitats. The figures for the 105 breeding species in the San Juan Valley are similar, i.e. 26.5% and 19.4%, or a combined total of 45.9% showing riparian dependence (Schmitt, 1976). In addition, 22.3% of the Gila species and 28.6% of the San Juan species also show some to much utilization of riparian habitats, and several species achieve maximal numbers in them. Clearly, in these two areas the presence of riparian habitats is extremely important, and in essence they double the avian diversity that might otherwise be present. The same degree of importance no doubt pertains elsewhere in the Southwest, and is apparent that riparian ecosystems play a key role in maximizing avian diversity in the region.

Other riparian faunal-plant assemblages seem to have been little studied, but there is no doubt that others will show a strong relationship between biotic diversity and the presence of riparian ecosystems. For example, although there appear to be fewer southwestern mammals than birds with a strong riparian dependence, nonetheless there are certainly some species that do show this, e.g. water shrew (Sorex palustris), Arizona gray squirrel (Sciurus arizonensis), beaver (Castor canadensis), meadow vole (Microtus pennsylvanicus), muskrat (Ondatra zibethica), raccoon (Procyon lotor), mink (Mustela vison), and otter (Lontra canadensis). The same can be said of reptiles, such as various turtles (e.g. Kinosternon spp., Trionyx spp.), green snakes (Opheodrys spp.), water snake (Natrix erythrogaster), and garter snakes (Thamnophis spp.). On the other hand, amphibians show a pronounced dependence on riparian--or at least aquatic--ecosystems, because of the general need of water for reproduction, e.g. in various toads and frogs.

At this point, I believe that it has become readily apparent that riparian ecosystems are of paramount importance in producing and maintaining a large degree of the biotic diversity of the southwestern United States. Although this importance is perhaps most apparent in fishes and best quantified in birds, it is clear that, for many plants and animals, riparian ecosystems are critical for them to flourish or even survive in the region. I am hopeful that more studies will be done to quantify this importance, particularly with reference to the degrees of dependency that exist among biotic elements on these ecosystems and to the niches that are occupied. It goes without saying that the better we understand these aspects, the better we can anticipate the needs of the biota and manage for its preservation. We have already witnessed extremely widespread destruction and modification of riparian ecosystems in the Southwest, mainly as the result of man's activities over the last several decades. As population pressures and the demands on the riparian ecosystem grow, we will be hard-pressed to preserve what is left of the southwestern riparian biota. Yet, if we do not meet the challenge and achieve better preservation, we will have allowed one of the richest of all of the world's temperate floras and faunas to have been diminished.

The time to obtain data and take positive management steps is all too short, but at the same time it is not too late to act. For example, several important examples of riparian ecosystems remain in the Southwest, such as in the lower San Francisco Valley in southwestern New Mexico and southeastern Arizona. This particular tract lies in U.S. National Forest, and with more enlightened management it could provide along over 30 river miles of public land for the maintenance of the very rich lowland riparian biota. At the present time, grazing and off-road vehicles are causing much damage to the tract, which embodies everything about a wilderness or wild river except in terms of management. At higher elevations, more extensive riparian ecosystems lie on public land and are available for preservation, although management again is frequently not accomplishing this.

The sad fact is that even public lands have priorities upon them that are not in the best interest of preserving riparian ecosystems, and changing this outlook for even limited areas is often difficult. On private lands the situation is generally worse, although here and there some degree of preservation has been obtained for some tracts. There is a critical need for a better education of managers of both public and private lands supporting riparian ecosystems as to their importance and values, which range from esoteric to the practical. For example, points of practical importance and value include the role of vegetation in soil retention, effect on climate, and in the harboring species that provide both consumptive and non-comsumptive recreation. These practical uses combine with esoteric considerations to provide a telling argument in favor of better preservation of our native riparian ecosystems, fragmented and misused as they have become. Hopefully, individuals and agencies will soon join forces to ensure such preservation, which is long overdue and which cannot be delayed much longer.

BIBLIOGRAPHY

Burt, W. H. and R. P. Grossenheider. 1964. A field guide to the mammals. Houghton-Mifflin Co., Boston, Mass.

Carothers, S. W. and R. R. Johnson. 1973. A summary of the Verde Valley breeding bird survey, 1971. Arizona Game and Fish Department Land and Water Projects Investigations. Progress Report 7-1-76 to 6-30-72.

Conant, R. 1975. A field guide to reptiles and amphibians of eastern and central North America. Houghton-Mifflin Co. Boston, Mass.

Eddy, S. 1957. How to know the freshwater fishes. W. C. Brown, Dubuque, Iowa.

Findley, J. S., A. H. Harris, D. E. Wilson, and C. Jones. 1975. Mammals of New Mexico. Univ. New Mexico Press, Albuquerque.

Howe, W. H. 1975. The butterflies of North America. Doubleday and Co. Garden City N.Y.

Hubbard, J. P. 1970. Check-list of the birds of New Mexico. New Mexico Orn. Soc. Publ. 3.

Hubbard, J. P. 1971. The summer birds of the Gila Valley, New Mexico. Nemouria No. 2.

Kearney, T. H. and R. H. Peebles. 1970. Arizona Flora, Univ. Arizona Press, Tucson.

Koster, W. J. 1957. Guide to the fishes of New Mexico. Univ. New Mexico Press, Albuquerque.

Lowe, C. H. (editor). 1964. The vertebrates of Arizona. Univ. Arizona Press, Tucson.

Minckley, W. L. 1973. Fishes of Arizona. Arizona Game and Fish Dept., Phoenix.

Phillips, A. R., J. Marshall, and G. Monson. 1964. Birds of Arizona. Univ. Arizona Press, Tucson.

Robbins, C. S., B. Bruun, and H. S. Zim. 1966. Birds of North America. Golden Press, New York.

Schmitt, C. G. 1976. Summer birds of the San Juan Valley, New Mexico. N. Mex. Orn. Soc. Publ. No. 4.

Stebbins, R. C. 1966. A field guide to western amphibians and reptiles. Houghton-Mifflin Co., Boston.

Wagner, W. L. 1977. Floristic affinities of Animas Mountains, southwestern New Mexico. Unpub. M.S. Thesis, Univ. New Mexico, Albuquerque. XI+180 pp.

White, C. M. and W. H. Behle. 1961. Birds of the Navajo Reservoir basin in Colorado and New Mexico, 1960. Univ. Utah Anthro. Paper 55:129-154.

Wildlife Conflicts in Riparian Management: Water[1]

Charles E. Kennedy[2]

INTRODUCTION

This paper is a summary of observations of the need for a better understanding of the interactions of stream-riparian-vegetation-energy-nutrients-water production-aquatic life and terrestrial life. Most of the riparian ecosystem interactions have had very little attention in Arizona and New Mexico.

WHAT IS WATER

In its pure form water is a colorless, clear liquid compound of hydrogen and oxygen. Water in the riparian zone is never just H_2O. It is a building block for photosynthesis by riparian and aquatic vegetation. It carries assorted dissolved salts (many of which are nutrients). Water carries dissolved organic matter, fine and coarse particulate organic matter, and supports numerous aquatic life forms, vertebrate and invertebrate, large and small (fish plankton, bacteria, etc.) Water, through the riparian vegetation, supports a wide assortment of interesting and valuable terrestrial wildlife species. Water is an energy source in itself as it forms natural, meandering channels and transports particles, large and small.

ENERGY-RIPARIAN ECOSYSTEM

A number of studies have shown that fish production is much lower where grazing occurs in the riparian zone. For example, in the Rock Creek Floodplain Investigation (Marcuson 1970) there were 63 pounds per acre of brown trout in the heavily grazed area as compared to 213 pounds per acre in the ungrazed area.

Bob Phillips (USFS) and others demonstrated the presence of 31 steelhead in a 100-foot heavily grazed section and 75 steelhead present in a nearby lightly grazed section (personal communication).

(Fisher 1970) demonstrated that 99% of the annual energy budget for Bear Brook comes from the surrounding forested watershed or from upstream areas. Even in large streams, such as the Missouri River, fifty-four percent of the organic matter ingested by fish is of terrestrial origin (Berner 1951).

(Cummins 1974) diagrammed the fate of heterotrophic stream organic materials (dissolved and particulate) and showed a conceptual model of stream ecosystem structure and function.

(Ensign 1957) found that in Mt. Vernon Creek, southern Wisconsin, where cattle were free to graze the streambanks, terrestrial insects made up only 4% of the annual food of brown trout. In Black Earth Creek (a few kilometers from Mt. Vernon Creek) where streambanks were protected from grazing, terrestrial insects comprised 15% of the annual diet of brown trout.

Thus, we find in the literature that streams are often energy dependent upon the riparian vegetation and the watershed. (Likens and Bormann 1974) have demonstrated the nutrient linkages between streams and watersheds. They state clearly that the key to wise management of aquatic ecosystems is wise management of the watershed.

We can extrapolate these works and assume that many streams in Arizona and New Mexico will also be dependent upon the riparian zone and their associated watersheds for their primary energy sources. But in this area, we have streams which can begin at elevations up to 11,000 feet on Mt. Baldy on the Apache National Forest (where they are comparable to streams in Northern United States or Canada) descend to intermediate elevation where they support warm water species comparable to southern and Midwestern United States streams. Others, purely desert streams, are unique in the United States. Just as Arizona and New Mexico are rich in the number of wildlife species produced in the wide diversity of habitats, Arizona and New Mexico streams are also rich in diversity running the gamet from high altitude, cold, clear, mountain streams, through warm, algae rich mid-elevation reaches, finally to low elevation pure desert reaches. For

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instance, we have grayling, an arctic fish, in a lake above the Mogollon River; while only 50 miles away there are channel catfish, a warm water species, in the Verde River.

Energy interdependence will follow a similar gradation. The high streams are most likely to be dependent on outside sources of energy for the aquatic organism food base. The mid-elevation streams may have somewhat more ability to capture energy in the stream through algae, diatoms, and rooted vegetation. The low desert streams with riparian vegetation and with tributaries supporting riparian vegetation may fix substantial energies in the aquatic environment, but will also receive substantial inflows of plant detritus during storm flows. (Burns 1977)

We need to develop a stream classification system which incorporates these energy sources as a significant criteria, and we need to study stream energy budgets on typical reaches of several stream types, i.e. cold water, intermediate, and warm water to document the stream-energy system sources and gradations of dependence upon terrestrial sources.

No doubt we will find streams which are largely dependent upon the riparian vegetation for a substantial portion of their organic-energy and partially dependent upon the watershed for dissolved organic matter.

As I said earlier, fish weigh less and are less abundant in grazed portions of streams. Putting this fact with the dependence upon energy from the riparian zone, we can understand that plant material eaten by cattle in the streamside strip will not be available for food for aquatic organisms in the stream. Fish will have less food. I used the term "streamside strip" here because on many miles of our streams in the southwest free choice grazing by cattle has brought about complete type conversions in those immediate areas alongside streams.

After many years (50 to 100 or more) of grazing in this "most palatable area" the old riparian trees have died, seedlings are eaten and killed until only the most "grazing resistent" unpalatable grasses and/or trees remain. This type conversion at higher altitude has eliminated alders and willows, leaving only associated grasses. In the middle elevations the sycamore cottonwood and others are often entirely missing to be replaced by bermuda grass-desert willow-seep willow and at some elevations, tamarisk. Thus, grazing is a significant force in altering streamside composition - just as it is throughout the watersheds.

Actual streamside composition varies from those areas where all of the natural species are gone with no seed sources remaining, to other streams that have a few decadent widely scattered specimens with most species present. Fencing alone will start the stream toward recovery, but plantings of seedlings will be needed on many.

In figure 1 we see only a few remnants of willow and narrowleaf cottonwood. The stream is appropriately called the Rio de las Vacas and is on the Cuba District of the Santa Fe National Forest, at elevations from 7000 to 9000 feet. The loss of shade for the stream, the loss of bird habitat and the premption by cattle of often the only source of green feed is obvious. The loss of energy to the stream is not so obvious. In fact, all too many times little thought has been directed towards learning how energy used by the stream flows through the ecosystem.

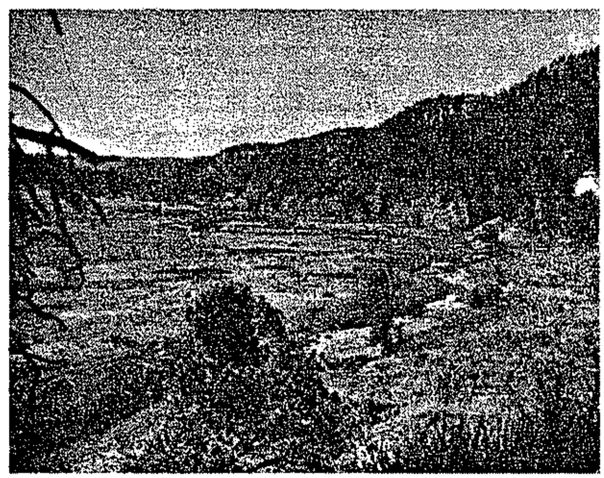


Figure 1

STREAM MORPHOLOGY

Another, more subtle, impact on the fishery occurs when riparian trees are eliminated by continual grazing. The stream is less confined to its banks and will have a more constant sediment load, especially from unvegetated stream banks. Overgrazing in associated watersheds creates higher peak storm flows. Overgrazing combined with hydraulic force of these peak storm flows plus the grazing by cattle on young seedlings keeps many streams in a young, undeveloped and raw condition.

Region 3 of the Forest Service (Arizona and New Mexico) has in National Forest streams approximately 4000 fish habitat improvement structures to make more pools in the miles and miles of flat, shallow streams.

An alternative to these structures and their maintenance is to fence cattle out of the narrow riparian zone so that the streams can progress through successional stages toward more stable conditions. As vegetation and trees become established in the immediate water edge area, the stream will, over time, become more narrow and deeper provided the associated watershed is properly grazed. Grazing levels must provide for suitable vegetative cover to insure soil protection and retard rapid runoff. The number of pools and their suitability for fish habitat will improve. Figures 2 and 3 show an area along a one mile reach of the Rio de las Vacas that has cattle fenced out. Stream profiles, photos, etc., are being established to document changes in stream morphology and riparian composition. Water temperatures in June 1977 reached 70°F. in this area. Narrowleaf cottonwood (Populus angustifolia), Arizona alder (Alnus oblongifolia) and willow (several species) comprise the bulk of the remaining riparian tree species. There are only about 50 individual specimens of narrowleaf cottonwood remaining in eight miles of the stream.

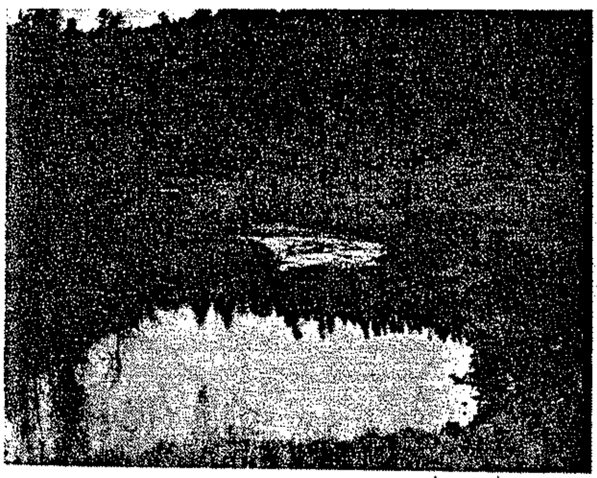


Figure 2

Figure 3 shows the remnants of an old trash catcher type stream improvement structure, entering the water at the arrow. Stones, silt, etc., caught by the fence posts and wire have somewhat constricted the stream making a slightly deeper spot just to the left of the fence. How much better for the fishery, the bird life, the esthetics, and the cattle if the dead trees had survived and reproduced until the roots provided cover, formed a pool and dropped leaves and insects into the stream.

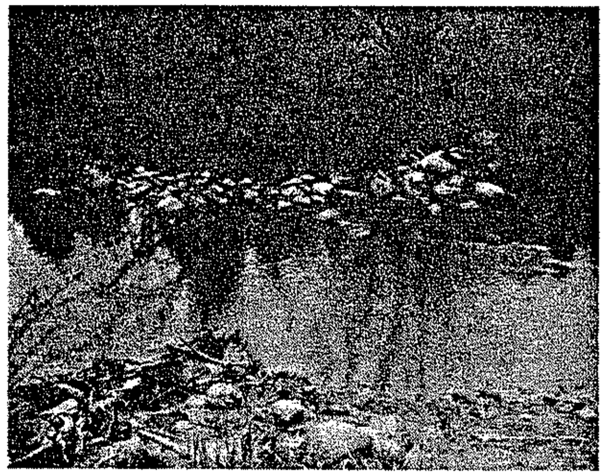


Figure 3

(White and Brynildson 1967) have documented successional stages with drawings which clearly demonstrate the process (see figure 4). Time in these changes will no doubt be faster in Arizona and New Mexico at low elevations with long growing seasons and perhaps slower on the Rio de las Vacas at 8500 feet with a short growing season.

A great deal of research has gone into ways to produce more water on National Forests in Arizona. Much has been written about the evapotranspiration of water by riparian species, native and introduced. There have been no concentrated, integrated efforts to determine which mixture of riparian species might best serve the needs of all resources, the fishery, the bird and wildlife resource, esthetic needs and water production.

As manipulations are applied to watersheds (chapparal and timber) to produce more water, it will become more important to manage the riparian zone (which in one aspect becomes a water "pipeline") to insure all the intrinsic values while producing the maximum amounts of high quality water for downstream users. It is certain that a vigorous stand of well established riparian trees will produce the amenities we are interested in.

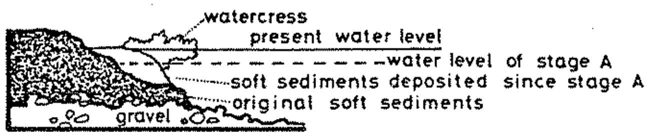
There may be ways to improve tree composition to favor energy flows for the fishery, reduce evapotranspiration for water production, and provide habitat for the bird life and other animal needs for green forage and cover. Perhaps leaves from Arizona walnut transpire less water and are better food for aquatic insects. Maybe the leaves have a higher calorie count - a better mix of nutrients.

Some stages in natural development of a fertile lowland Wisconsin trout stream from overgrazed (A) to very productive (D-E-F) to overforested (G&H) when protected from grazing. A hypothetical 14-foot wide cross-section plus adjacent bank shown.

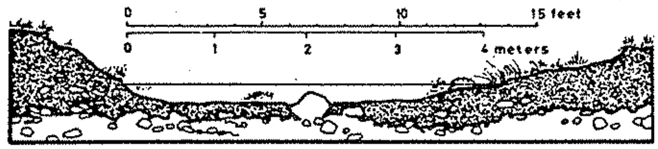
The complete sequence from stage A to stage E-F has been observed on Black Earth and Mt. Vernon Creeks near Madison.

Later succession — stages G and H with many intermediates — is to be seen on other streams. Details of this succession vary from stream to stream, especially after stage E-F, but the passage from predominantly herbaceous to predominantly woody vegetation generally has the same detrimental effects. Good management for trout — and other wildlife — would be control of vegetation to maintain stages D-E-F.

KEY

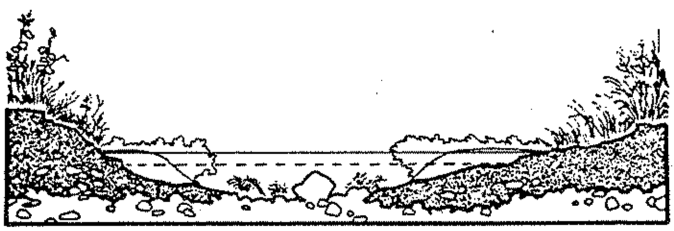


A



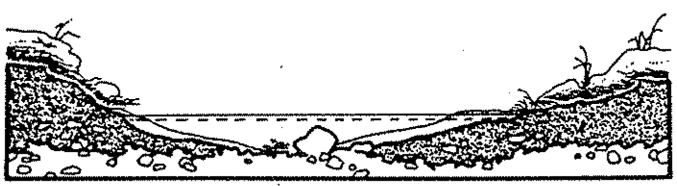
MIDSUMMER CONDITIONS UNDER HEAVY GRAZING BY LIVESTOCK: Bank vegetation and watercress grazed and trampled. Banks eroding, and stream bed mostly covered by shifting silts. Submergent plants grow poorly. Whole surface of water and stream bed exposed to sun. Greatest depth in cross-section only 9 inches (22 cm). These conditions offer trout no shelter, no place to spawn, little food, and frequently unfavorable temperatures.

B



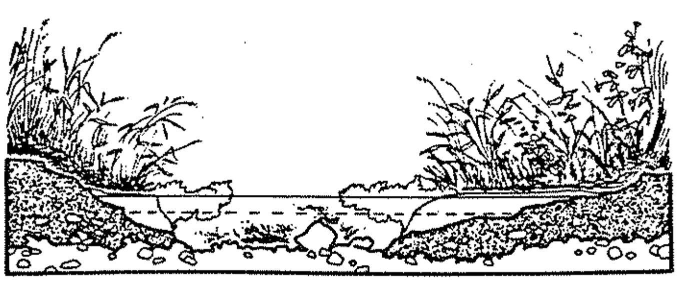
MIDSUMMER CONDITION AFTER 2 TO 4 YEARS OF PROTECTION AGAINST GRAZING: Bank vegetation forming a turf. Abundant watercress at edges of stream constricts channel, thus deepening and speeding water. Soft sediments scoured from much of stream bed and trapped in cress beds. Submergent plants thriving. Only about half the former stream width exposed to sun. Greatest depth about 20 inches (50 cm). Trout have ample shelter beneath watercress, beside rock, and among submergent plants. Firm stream bed and many plants provide substrate for many animals that trout eat. Newly exposed gravel is a place to spawn.

C



LATE IN THE NEXT WINTER: Watercress has withered and drifted away. The silts it held slump into the channel, smothering many of the trout eggs buried in gravel and preventing fry from emerging into stream. Food is scarce. Broad surface of water exposed to cold. Shelter for trout almost as poor as at stage A and will not redevelop until May or June.

D



MIDSUMMER CONDITION IN ABOUT 3RD TO 5TH YEAR AFTER GRAZING HALTED: Further scouring of fine sediments from stream bed. Silt bars at stream edges being tied down by reed canary grass with its tough system of roots and runners. Watercress flourishing, and submergents at peak of development. Only 4 feet of stream width exposed to sky, and this shaded much of day by high grasses. Greatest depth in cross-section about 2 feet (60 cm). For trout, shelter, food, and spawning gravels are ample.

Figure 4

This example reminds us that there are hundreds of plants which regularly grow in the riparian. We know very little about their intrinsic values and how they interact in a normal, managed (not overgrazed) riparian ecosystem. Certainly a shaded stream with a nearly closed canopy over a narrow, deep stream will produce cool, clear, water and less sediment will reach the reservoirs, extending their lifetime. The fate of many species such as the bald eagle may ultimately depend upon the subtle energy flows needed to produce the fish which the eagles are dependent upon. The fate of several fish like the endangered squawfish and others are also dependent upon a properly functioning riparian ecosystem.

This managed "riparian pipeline ecosystem" will hopefully produce ample quality waters for other downstream uses. The evapotranspiration in the pipeline is not wasted, society needs the products produced.

J. Stokley Ligon wrote 50 years ago, "Cold water fish and fishing streams are as seriously affected by overgrazed watersheds as is game. Not only do the extremes of low and high water, caused by floods and erosion, affect the normal flow and temperature of waters, but the destruction of willows, alders, weeds and grasses eliminates both food and shelter for cold water fish. No experienced angler fishes in sun-exposed streams where the water spreads shallow in unprotected flood-ravished watercourses; he seeks the cool shadows where the alders, willows or conifers overhang the banks, where the stream is narrow and banks with matted roots are secure along New Mexico's cold water streams today. Abuse by overgrazing of watersheds and watercourses, as no other cause, has deteriorated New Mexico's fishing."

The creation or perpetuation of the little winding stream jungles everywhere are a national as well as a state need. The space they occupy, whether on the farm, deep in the creek bottom, canyon course or on overflow lands, has no appreciable value from the standpoint of agriculture or stock raising, but as little jungles they have an intrinsic value. As boys how many of us got our greatest thrills and enjoyment from these little jungles - the jungles we resorted to at every opportunity to follow our dog after rabbits, squirrels or coons, or to hunt quail, fish, or to set our traps for furbearers? The intensity of the job and satisfaction thus derived demands that this little institution, the wasteland jungle, be perpetuated for the American boy and man. These little spaces, properly protected, are the only means of conserving the small game in reclaimed canyons and valleys as commercialism agressively overrides every weakling of Nature that does not have the sympathetic support of organized forces to oppose it."

CONCLUSIONS

1. The fishery resource is often energy dependent upon the riparian vegetation and the watershed.

2. Uncontrolled grazing brings about complete type conversions in the riparian zone and prevents streams from progressing to more stable conditions.

3. Trees and other vegetation in the riparian zone control sediments, provide stream stability and tend to narrow and deepen channel morphology, which benefits the fishery resource.

4. Research is vitally needed to document and study the interactive and intrinsic value of the many plant species in the riparian ecosystem.

5. The fishery, wildlife, esthetic resources, and water quality and quantity are dependent upon these interactions and our efforts to integrate the needs of the various resources. Free choice, uncontrolled grazing is incompatible with these resources.

LITERATURE CITED

Anderson, T. W. 1976. Evapotranspiration losses from flood-plain areas in central Arizona. USGS, Open-File Report 76-864.

Babcock, H. M. 1968. The phreatophyte problem in Arizona. 12th Annual Arizona Watershed Symposium Proceedings, September 18, 1968.

Bruns, Dale Anthony Robert. 1977. Distribution and abundance of benthic invertebrates in a Sonoran desert stream. Arizona State Univ.

Campbell, C. J. and Win Green. 1968. Perpetual succession of stream-channel vegetation in a semiarid region. J. Az. Acac. Sci. 5:86-98.

Carothers, Steven W. and R. Roy Johnson. 1975. Water management practices and their effects on nongame birds in range habitats. For. Serv. Gen. Tech. Rep. WO-1.

Chapman, Donald W. and Robert L. Demory. 1963 Seasonal changes in the food ingested by aquatic insect larvae and nymphs in two Oregon streams. Ecology, Vol. 44 No. 1

Cummins, K. W., J. J. Klug, R. G. Wetzel, R. C. Petersen, K. F. Suberkropp, B. A. Manny, J. C. Wuycheck, and F. O. Howard. 1972. Organic enrichment with leaf leachate in experimental lotic ecosystems. BioScience Vol. 22 No. 12.

Cummins, Kenneth W. 1974. Structure and function of stream ecosystems. BioScience Vol. 24 No. 11.

Endangered Species vs. Endangered Habitats: A Concept[1]

R. Roy Johnson[2], Lois T. Haight[2], and James M. Simpson[3]

Abstract. - Although the great diversity within riparian ecosystems was recognized earlier, their extreme productivity was not discovered until this decade. The highest densities of nesting birds for North America have been reported from Southwest cottonwood riparian forests. Complete loss of riverine habitat in the Southwest lowlands could result in extirpation of 47 percent of the 166 species of birds which nest in this region.

INTRODUCTION

Since 1600 more than 120 bird and mammal species have become extinct while more than 300 are now threatened (Fisher et al. 1969). In addition, dozens of fishes, amphibians and reptiles have become extinct or are endangered to say nothing of invertebrate species. Habitat disruption and destruction have been a major cause of extinction. Only 24 percent of the birds and 25 percent of the mammals became extinct through natural causes. Of the 76 percent of the birds and 75 percent of the mammals which died from human related causes, well over half have been through indirect means, such as introduction of exotic speices and habitat disruption (Fisher et al. 1969 and IUCN Red Data Books issued periodically).

In an attempt to reduce the numbers of species which will soon become extinct, several steps have been taken. A major step involves the formation of recovery teams, comprised of authorities on a given species, such as the Bald Eagle. The activities of these teams have apparently been beneficial in slowing down rates of loss in wildlife species. However, the efforts of recovery teams cannot possibly prevent continued extirpation if we continue to disrupt habitat through activities such as overgrazing, urbanization, "modern, clean" agricultural practices, dam construction and channelization. Continued research is needed to provide answers to questions posed by management regarding means through which critical wildlife habitat may be preserved.

DISCUSSION

Extirpation

The extirpation of wild animal species has been a cause for concern for decades. People only mildly interested in conservation can bring to mind the examples of the Passenger Pigeon (Ectopistes migratorius - extinct 1914), the Carolina Parakeet (Conuropsis carolinensis- extinct 1914), the Dodo (Raphus cucullatus- extinct 1681) and the Great Auk (Pinguinus impennis - extinct 1844). Dates for extinction are from Pettingill (1970) and Van Tyne and Berger (1971). An entire book has been written about the Passenger Pigeon (Schoerger 1955) and people are still trying to find out whether or not the Ivory-billed Woodpecker (Campephilus principalis) is now extinct. Several recent books have been written appealing to citizens of the world to help save these rapidly diminishing species (Greenway 1958, Fisher et al. 1969, Prince Phillip and Fisher 1970, Simon and Geroudet 1970, Tylinek and Ullrich 1972, and Ziswiler 1967). Information from the International Union for Conservation of Nature and Natural Resources (I.U.C.N.) Red Data Books (issued periodically) presents a dismal picture (Table 1).

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1. Paper presented at the Symposium on Importance, Preservation and Management of the Riparian Habitat, Tucson, Arizona, July 9, 1977.

2 National Park Service, Grand Canyon National Park

3 Associate, Museum of Northern Arizona, Flagstaff

Table 1.--A history of species' extirpation. (adapted from I.U.C.N. Red Data Books)

Date	Number of extinctions	Direct[1]	Indirect[2]
1600s	21	86%	14%
1700s	36	84%	16%
1800s	84	24%	76%
1900-1974	85	28%	72%

1 Direct = Hunting for food or commercial causes.
2 Indirect = Habitat disruption, introduction of exotics, etc.

Attempts to Prevent Extinctions

The concern over the increasing numbers of species being exterminated in the United States caused the U.S. Fish and Wildlife Service to begin work on classification of "threatened" wildlife in the early 1960's. The 1st edition of the "Redbook" was issued in July 1966. We use the words "threatened" and "endangered" in an unofficial sense (see U.S. Fish and Wildlife Service 1973 for official definition). Endangered species are assigned in the United States according to the Endangered Species Conservation Act of 1969 and listed periodically in the U.S. Federal Register by the U.S. Fish and Wildlife Service. It is not our intent to go into great depth regarding endangered speices programs. The forementioned I.U.C.N., U.S. Fish and Wildlife Service and others (e.g. American Committee on International Wildlife Protection, National Audubon Society and World Wildlife Fund) publish periodic information on endangered wildlife (e.g. Arbib 1976). Other governmental agencies besides the U.S. Fish and Wildlife Service publish information regarding endangered wildlife (Arizona Game and Fish Department 1977[4], Behnke and Zarn 1976, U.S. Forest Service 1975, U.S. National Park Service 1974). Symposia are held periodically focusing on general problems of endangered wildlife (New Mexico Game and Fish Department 1972) or even devoted to a single species such as the Peregrine Falcon (*Falco peregrinus*) (Hickey 1969) or the Red-cockaded Woodpecker (*Dendrocopos borealis*) (Thompson 1971). Periodically, reports are issued on endangered species such as the Southern Bald Eagle (U.S. Fish and Wildlife Service 1976). Recovery teams to address the problem of impending extinction have been set up by the U.S. Fish and Wildlife Service for many species of endangered wildlife. For example, several avian species are now being raised by methods of direct intervention such as egg manipulation (Zimmerman 1976). In addition, several agencies are now involved in establishing endangered plant lists.

In addition to teams concerned with the protection of terrestrial wildlife, such as the Peregrine Falcon and Southern Bald Eagle, other recovery teams have been organized to focus on one or more fish species. Recently, however (Johnson[5]) the U.S. Fish and Wildlife Service has designated teams which focus on river systems instead of individual species, e.g. the Colorado River Fishes Recovery Team. This approach has been advocated for years by many of us who have seen the wholesale extermination of species in certain areas as a result of habitat destruction. Nowhere is this chain of destruction more certain than in riverine ecosystems. This has long been recognized by ichthyologists such as Deacon and Minckley (1974), Holden and Stalnaker (1975), Minckley and Deacon (1968) and Sigler and Miller (1963).

Glen Canyon Dam: An Example

The construction of Glen Canyon Dam on the Colorado River above Grand Canyon is an outstanding example of habitat modification. The effect on the aquatic ecosystem has been devastating. The original heavy silt burden which rendered the Colorado River "too thick to drink and too thin to plow" is dropped in Lake Powell before the water enters Grand Canyon. The river waters are now clear. The reddish color for which the Colorado was named can be seen only after flooding from tributaries which enter below the dam. This has created an entirely new riverine ecosystem (Carothers et al. in press, Dolan et al. 1974 and in press, Johnson and Martin 1976,and Laursen and Silverston 1976). The management implications are staggering. On one hand, a new riparian ecosystem has developed, protected from the scouring and siltation of pre-dam floods. On the other hand this white water river has been converted from a stream which was warm in the summer and cold in the winter to a relatively constant 9-10°C (48-50°F) along most of its length. The only insect family recorded using these cold waters are Chironomid midges (Stevens 1976) while the

4 Arizona Game and Fish Department. 1977. Endangered and threatened species in Arizona; 3 p. memo

5 Johnson, J. Paper presented at New Mexico-Arizona section meeting, the Wildlife Society, Farmington, N.M., Feb 5, 1977.

small crustacean, *Gammarus lucustris*, abounds. The cold, clear water is conducive to the rapid growth of exotic species such as rainbow trout, which commonly reach lengths of more than 2 feet and weigh over 5 pounds (personal observation). While exotic fish flourish, our native species are declining. In the 277 miles of the Colorado River in Grand Canyon National Park several species listed in *Fishes of Arizona* (W. Minckley 1973 and pers. comm.) occur either in low numbers, or cannot be found at all, e.g. the Humpback Chub (*Gila cypha*), Bonytail Chub (*G. elegans*), Colorado Squawfish (*Ptychocheilus lucius*) and Razorback Sucker (*Xyrauchen texanus*) (Johnson 1977, C. Minckley and Blinn 1976, Miller 1975[6], and Suttkus et al. 1976).

Endangered Species and Related Acts

When the Endangered Species Act of 1973 (PL #93-205) was passed it was hoped by many of us concerned about extirpation of wildlife that this might prevent further wholesale extinctions through degradation of habitat. It seemed that the Endangered Species Act combined with the National Environmental Policy Act of 1969 (PL #91-190) should slow down direct extermination as well as massive destruction of the type that has converted nearly all southwestern rivers to poor or impossible habitat for most native species. Just how effective these laws will be remains to be seen. Legal decisions involving the case of the Tennessee Valley's Tellico Dam on the Little Tennessee River vs. the Snail Darter (*Percina tanasi*) may have important implications regarding the future interpretation of Section 7 of the Endangered Species Act, including possible amendation by congress (Holden 1977).

It seems inevitable that riverine ecosystems will become the battleground for those advocating the "progress of civilizing processes," e.g. hydroelectric and irrigation projects. Economic interests oppose those who advocate saving a few rivers to protect associated wildlife and recreational values and perhaps, "just to let them run."

The two forementioned acts coupled with the Wild and Scenic Rivers Act of 1968 (PL #90-542) would seem to be sufficient to reduce further decimation of river ecosystems. However, it is a difficult, uphill battle. Prevention of the use of streams for waste disposal is gradually becoming an accepted philosophy. Conversely, industrial, domestic and irrigation demands for water for a growing population continue to escalate.

Major Causes of Habitat Loss

The impact of dams on aquatic ecosystems has long been understood by biologists even if ignored by dam builders and water users. The area above the dam is converted into a lake, rapidly filling with sediment. The area below the dam too commonly becomes a dry stream bed, as is the situation with most of the Salt and Gila River dams of the Lower Colorado River drainage. Neither habitat is conducive to most of the pre-dam riverine plants or wildlife. Other rivers are greatly reduced in volume by practices such as pumping of underground water which dries up spring sources, or by modification of runoff patterns through overgrazing. The latter often results in the development of vegetation types which demand more water than the original vegetation. The area may be denuded, resulting in flash floods followed by quick drying up of streams rather than a slower, steady runoff. The effects of such practices on native fishes have been well documented (Minckley and Deacon 1968). However, we have only recently begun to understand the impacts on riparian ecosystems.

Recent work by various investigators (Boster and Davis 1972, Clary et al. 1974, and Hibbert et al. 1974) advocates the conversion of shrub types, commonly resulting from overgrazing, to grassland. This conversion to grassland usually results in increased water yield which, in turn, often results in an increase in acreage of riparian vegetation (personal observation, Sierra Ancha and Three Bar watersheds).

Some investigators propose large scale "phreatophyte control" projects as well as the conversion of shrub types to grassland (see Ffolliott and Thorud 1974 for discussion). These "water salvage" projects are often advocated even at the expense of both game and nongame wildlife values. Earlier work commonly featured "pure" scientists as well as "applied" scientists, all concentrating on single purpose management of watersheds and their runoff for man, his farms and cattle (Barr 1956, Duisberg 1957, and Warnock and Gardner 1960). In recent years there has been a gradual trend toward multiple use of this critical resource, water (Horton and Campbell 1974). The Arizona Annual Watershed Symposia reflect this change in philosophy (Arizona Water Commission; annually)

6 Miller, R.R. 1975. Report on fishes of the Colorado River drainage between Lees Ferry and Surprise Canyon, Arizona. Unpublished Grand Canyon Natl. Park Res. Rpt. 6 p.

placing increasing emphasis on wildlife values, recreation and even aesthetics (Arizona Water Commission 1972).

Riparian Exploration, Development and Research

It seems incredible that man would so badly mistreat riverine ecosystems. We have used them for exploratory routes, fur trapping, temporary settlements and forts, agricultural land and cities. Finally, we have dammed them up, dried them up, and turned them into sewers and garbage disposals.

Early explorers commonly were army officers, geologists, engineers or "soldiers of fortune" who left incomplete to poor records regarding the riparian habitat. This is true throughout the Southwest. Thus, early notes from rivers such as the Gila (Emory 1858) and even the mighty Colorado (Powell 1961) often mention vegetation and wildlife only in general terms. We do not even have good species' lists for the pre-dam ecosystems, much less information on population densities or other more sophisticated data. Even as late as the 1950's (Woodbury et al. 1959) scientists gathered information regarding the area to be inundated by Lake Powell, above Glen Canyon Dam. However, the more than 250 miles of river between Glen Canyon Dam site and the upper reaches of Lake Mead, which were also to be heavily impacted by the dam, were totally ignored.

Riverine environments, including their riparian ecosystems, have been ignored by biologists as well as geologists, explorers and laymen for many reasons. Riparian ecosystems have several characteristics which make them interesting but involved, difficult systems to study. Riparian habitat may be considered an ecotone between the aquatic habitat of the stream itself and the surrounding terrestrial habitat. As such, the riparian ecosystem contains elements of both the aquatic and terrestrial ecosystems plus retaining unique characteristics found in none of the other ecosystems exemplifying the edge effect. The concept of the edge effect is relatively new. Earlier treatises did not even mention this phenomenon and it was not until the mid-1900s that ecology texts, e.g. Allee et al. (1949) contained a discussion of the edge effect. Odum (1959) defines the edge effect as "the tendency for increased variety and density at community junctions."

Ornithologists and birders have long recognized the importance of riparian habitats to birds. We chose at random 20 inland Christmas Bird Counts for 1974 (National Audubon Society 1975). Nineteen (95%) of the 20 contained streamside and/or lake side vegetation. The large number of species utilizing riparian woodland has been documented by numerous studies (Carothers and Johnson 1975b). In California, Miller (1951) emphasized the importance of riparian avifaunas, stating "the number of species of birds associated with riparian woodland is larger than that of any other formation." However, the extremely high densities of riparian avian populations was not recognized until this decade (Carothers et al. 1974, Carothers and Johnson 1971 and 1975b, Gaines 1974, Johnson 1970, O'Brien et al. 1976, and Table 2).

The ecological analysis of riparian birds is complicated at best. Studies are further complicated by recent changes, some of which are related to man's activities and others which may be operating independently of man. One cannot help postulating however, that nearly all of the recorded recent changes are due to man's activities. For example, there are records for the arrival of several species of birds which have moved into Arizona as breeding species within historic times. This includes the Mississippi Kite, Inca Dove, Thick-billed Kingbird, Starling, House Sparrow, Great-tailed Grackle and Bronzed Cowbird. The Starling and House Sparrow are European introductions. The Inca Dove, Great-tailed Grackle and Bronzed Cowbird are closely associated with man and his animals. Their movements are discussed by Phillips et al. (1964) and Phillips (1968). Other cases are not as clear but may have profound effects on the native avifauna. The subtleness with which human activity may affect the natural ecosystem can be shown through a discussion of the Brown-headed Cowbird. Phillips (1968) discusses at length the historic expansion of range by Brown-headed Cowbirds. Of the 33 species of Southwestern lowland birds listed by Friedmann (1929) as hosts to the Brown-headed Cowbird, 22 (2/3) are obligate or preferential riparian nesting species. The role of these brood parasites in reducing populations of riparian birds in the Sacramento Valley, California, is discussed by Gaines (1974). Thus, Brown-headed Cowbirds may be suspected of causing problems in Arizona and other southwestern areas similar to those reported for California.

SUMMARY AND CONCLUSIONS

During our recent analysis of the dependency of the breeding avifauna of the Southwest lowlands on water related habitat (Table 3), we discovered some sobering facts. 166 species of nesting birds were analyzed from southern Arizona, southern New Mexico and west Texas, south through the lower

Table 2. -- A comparision of breeding bird densities in selected habitats. (After Carothers and Johnson 1975b).

Habitat Type (Community)	Locality	Authority	Breeding Bird Density Males or Estimated Pairs/40 ha [or 100 acres] nonriparian	riparian
Boreal Forest[1]				
Spruce-Alpine Fir	Arizona	Carothers et al. (1973)	178	-
Temperate Forest				
Spruce-Douglas Fir	Arizona	Balda (1967)	380	-
Ponderosa Pine	Arizona	Balda (1967)	336	-
Ponderosa Pine	Arizona	Haldeman et al. (1973)	232	-
Mature Deciduous	West Virginia	Audubon F.N. (1948)	724 [2]	-
Virgin Spruce	West Virginia	Audubon F.N. (1948)	762 [2]	-
Forest Bird Sanctuary	Germany	Bruns (1955)	5600 [2]	-
Relict Conifer Forest				
Cypress post climax	Arizona	Johnston and Carothers (1975)	93	-
Riparian Deciduous Forest				
Mixed Broadleaf	Arizona	Balda (1967)	-	304
Mixed Broadleaf	Arizona	Carothers et al. (1974)	-	332
Cottonwood	Arizona	Carothers et al. (1974)	-	847
Cottonwood	Arizona	Ohmart (no date)	-	683
Flood-plain Deciduous	Illinois	Fawver (1947)	-	216 [2]
Temperate Woodland				
Pinyon-Juniper	Arizona	Hering (1957)	33	-
Pinyon-Juniper	Arizona	Beidleman (1960)	30	-
Encinal	Arizona	Balda (1967)	224	-
Subtropical Woodland				
Mesquite Bosque (riparian)	Arizona	Gavin and Sowls (1975)	-	476 [3]
Mesquite	Arizona	Ohmart (no date) [5]	236	-
Grassland				
Temperate Grassland	Arizona	Balda (1967)	64	-
Tropical Grassland	Tanganyika	Winterbottom (1947)	4000 [2]	-
Desert Grassland				
Yucca/Grassland	Arizona	Balda (1967)	31	-
Chihuahuan Desert Scrub				
Creosotebush	New Mexico	Raitt and Maze (1968)	8.5-17.7	-
Sonoran Desert Scrub				
Paloverde/Sahuaro	Arizona	Tomoff(1974 & pers.comm.)	105-150	-
Temperate Marshland				
Cattail Marsh	Arizona	Carothers and Johnson (1975b)	-	175-176
Cultivated, Urban and Suburban Lands				
Park (zoological garden)	Germany	Steinbacher (1942)	1170 [2]	-
Bird Sanctuary (Whipsnade)	England	Huxley (1936)	5800 [2]	-
Urban	Arizona	Emlen (1976)	1230 [2]	-
Cottonwood	Arizona	Carothers and Johnson(1975a)	-	605.2 [4]

1 Arizona vegetation types after Brown and Lowe (1974).

2 Density given in number of adult birds per 40 hectares (100 acres) instead of males or nesting pairs (after Welty 1962).

3 Average density for April and May, the height of breeding activity in the mesquite bosque.

4 Riparian cottonwood habitat disturbed by urbanization. Two years prior, when the habitat was undisturbed, the density was 1058.8 pairs/100 acres.

5 Ohmart, R.D. and N. Stamp. No date. Final report on the field studies of the nongame birds and small mammals of the proposed Orme Dam site. Bur. of Recl. Proj., Boulder City, Ariz. 54 ms. p.

Table 3. -- Nesting birds of the Southwest Lowlands (Modified from Haight and Johnson 1977)[1]

WETLANDS (2%)

1. Clapper Rail *Rallus longirostris*
2. Black Rail *Laterallus jamaicensis*
3. American Avocet *Recurvirostra americana*
4. Snowy Plover *Charadrius alexandrinus*

WETLANDS AND OBLIGATE RIPARIAN (19%)

1. Least Grebe *Podiceps dominicus*
2. Pied-billed Grebe *Podilymbus podiceps*
3. Double-crested Cormorant *Phalacrocorax auritus*
4. Olivaceous Cormorant *Phalacrocorax olivaceus*
5. Great Blue Heron *Ardea herodias*
6. Green Heron *Butorides striatus*
7. Great Egret *Casmerodius albus*
8. Snowy Egret *Egreta thula*
9. Black-crowned Night Heron *Nycticorax nycticorax*
10. Least Bittern *Ixobrychus exilis*
11. Black-bellied Whistling-Duck *Dendrocygna autumnalis*
12. Mallard *Anas platyrhynchos*
13. Mexican Duck *Anas diazi*
14. Gadwall *Anas strepera*
15. Blue-winged Teal *Anas discors*
16. Cinnamon Teal *Anas cyanoptera*
17. Redhead *Aythya americana*
18. Ruddy Duck *Oxyura jamaicensis*
19. Osprey *Pandion haliaetus*
20. Virginia Rail *Rallus limicola*
21. Sora *Porzana carolina*
22. Common Gallinule *Gallinula chloropus*
23. American Coot *Fulica americana*
24. Black-necked Stilt *Himantopus mexicanus*
25. Killdeer *Charadrius vociferus*
26. Long-billed Marsh Wren *Cistothorus palustris*
27. Common Yellowthroat *Geothlypis trichas*
28. Yellow-breasted Chat *Icteria virens*
29. Yellow-headed Blackbird *Xanthocephalus xanthocephalus*
30. Red-winged Blackbird *Agelaius phoeniceus*
31. Song Sparrow *Melospiza melodia*

OBLIGATE RIPARIAN (26%)

1. Common Merganser *Mergus merganser*
2. Mississippi Kite *Ictinia mississippiensis*
3. Cooper's Hawk *Accipiter cooperii*
4. Zone-tailed Hawk *Buteo albonotatus*
5. Gray Hawk *Buteo nitidus*
6. Common Black Hawk *Buteogallus anthracinus*
7. Bald Eagle *Haliaeetus leucocephalus*
8. Spotted Sandpiper *Actitis macularia*
9. Red-billed Pigeon *Columba flavirostris*
10. Yellow-billed Cuckoo *Coccyzus americanus*
11. Violet-crowned Hummingbird *Amazilia verticalis*
12. Buff-bellied Hummingbird *Amazilia yucatanensis*
13. Broad-billed Hummingbird *Cynanthus latirostris*
14. Green Kingfisher *Chloroceryle americana*
15. Red-shafted Flicker *Colaptes auratus cafer*
16. Rose-throated Becard *Platypsaris aglaiae*
17. Tropical Kingbird *Tyrannus melancholicus*
18. Thick-billed Kingbird *Tyrannus crassirostris*
19. Kiskadee Flycatcher *Pitangus sulphuratus*
20. Black Phoebe *Sayornis nigricans*
21. Willow Flycatcher *Empidonax traillii*
22. Western Wood Pewee *Contopus sordidulus*
23. Vermilion Flycatcher *Pyrocephalus rubinus*
24. Northern Beardless Flycatcher *Camptostoma imberbe*
25. Bank Swallow *Riparia riparia*
26. Cliff Swallow *Petrochelidon pyrrhonota*
27. Bridled Titmouse *Parus wollweberi*
28. White-breasted Nuthatch *Sitta carolinensis*
29. Bewick's Wren *Thryomanes bewickii*
30. American Robin *Turdus migratorius*
31. Bell's Vireo *Vireo bellii*
32. Yellow-green Vireo *Vireo flavoviridis*
33. Tropical Parula *Parula pitiayumi*
34. Yellow Warbler *Dendroica petechia*
35. Hooded Oriole *Icterus cucullatus*
36. Northern Oriole *Icterus galbula*
37. Bronzed Cowbird *Molothrus aeneus*
38. Summer Tanager *Piranga rubra*
39. Blue Grosbeak *Guiraca caerulea*
40. Painted Bunting *Passerina ciris*
41. White-collared Seedeater *Sporophila torqueola*
42. Lesser Goldfinch *Carduelis psaltria*
43. Albert's Towhee *Pipilo aberti*

PREFERENTIAL RIPARIAN (26%)

1. Peregrine Falcon *Falco peregrinus*
2. American Kestrel *Falco sparverius*
3. Gambel's Quail *Lophortyx gambelii*
4. White-winged Dove *Zenaida asiatica*
5. Mourning Dove *Zenaida macroura*
6. Common Ground Dove *Columbina passerina*
7. White-fronted Dove *Leptotila verreauxi*
8. Greater Roadrunner *Geococcyx californianus*
9. Groove-billed Ani *Crotophaga sulcirostris*
10. Barn Owl *Tyto alba*
11. Common Screech Owl *Otus asio*
12. Ferruginous Pygmy Owl *Glaucidium brasilianum*
13. Lesser Nighthawk *Chordeiles acutipennis*
14. Black-chinned Hummingbird *Archilochus alexandri*
15. Anna's Hummingbird *Calypte anna*
16. Gila Woodpecker *Melanerpes uropygialis*
17. Golden-fronted Woodpecker *Melanerpes aurifrons*
18. Ladder-backed Woodpecker *Picoides scalaris*
19. Western Kingbird *Tyrannus verticalis*
20. Cassin's Kingbird *Tyrannus vociferans*
21. Wied's Crested Flycatcher *Myiarchus tyrannulus*
22. Ash-throated Flycatcher *Myiarchus cinerascens*
23. Rough-winged Swallow *Stelgidopteryx ruficollis*
24. Green Jay *Cyanocorax yncas*
25. Common Raven *Corvus corax*
26. Verdin *Auriparus flaviceps*
27. Northern Mockingbird *Mimus polyglottos*
28. Long-billed Thrasher *Toxostoma longirostre*

29. Curve-billed Thrasher *Toxostoma curvirostre*
30. Crissal Thrasher *Toxostoma dorsale*
31. Black-tailed Gnatcatcher *Polioptila melanura*
32. Phainopepla *Phainopepla nitens*
33. Common Starling *Sturnus vulgaris*
34. Lucy's Warbler *Vermivora luciae*
35. Lichtenstein's Oriole *Icterus gularis*
36. Brown-headed Cowbird *Molothrus ater*
37. Cardinal *Cardinalis cardinalis*
38. Pyrrhuloxia *Cardinalis sinuata*
39. Indigo Bunting *Passerina cyanea*
40. Lazuli Bunting *Passerina amoena*
41. House Finch *Carpodacus mexicanus*
42. Olive Sparrow *Arremonops rufivirgatus*
43. Rufous-winged Sparrow *Aimophila carpalis*

SUBURBAN AND AGRICULTURAL (4%)

1. Black Vulture *Coragyps atratus*
2. Rock Dove *Columba livia*
3. Inca Dove *Scardafella inca*
4. Barn Swallow *Hirundo rustica*
5. House Sparrow *Passer domesticus*
6. Great-tailed Grackle *Quiscalus mexicanus*

NON-RIPARIAN (23%)

1. Turkey Vulture *Cathartes aura*
2. Red-tailed Hawk *Buteo jamaicensis*
3. Swainson's Hawk *Buteo swainsoni*
4. Ferruginous Hawk *Buteo regalis*
5. Harris' Hawk *Parabuteo unicinctus*
6. Caracara *Caracara cheriway*
7. Prairie Falcon *Falco mexicanus*
8. Common Bobwhite *Colinus virginianus*
9. Scaled Quail *Callipepla squamata*
10. Great Horned Owl *Bubo virginianus*
11. Elf Owl *Micrathene whitneyi*
12. Burrowing Owl *Athene cunicularia*
13. Long-eared Owl *Asio otus*
14. Poor-will *Phalaenoptilus nuttallii*
15. Pauraque *Nyctidromus albicollis*
16. White-throated Swift *Aeronautes saxatalis*
17. Lucifer Hummingbird *Calothorax lucifer*
18. Costa's Hummingbird *Calypte costae*
19. Gilded Flicker *Colaptes auratus chrysoides*
20. Say's Phoebe *Sayornis saya*
21. Horned Lark *Eremophila alpestris*
22. Purple Martin *Progne subis*
23. White-necked Raven *Corvus cryptoleucus*
24. Cactus Wren *Campylorhynchus brunneicapillus*
25. Canyon Wren *Catherpes mexicanus*
26. Rock Wren *Salpinctes obsoletus*
27. Bendire's Thrasher *Toxostoma bendirei*
28. LeConte's Thrasher *Toxostoma lecontei*
29. Loggerhead Shrike *Lanius ludovicianus*
30. Eastern Meadowlark *Sturnella magna*
31. Western Meadowlark *Sturnella neglecta*
32. Scott's Oriole *Icterus parisorum*
33. Varied Bunting *Passerina versicolor*
34. Brown Towhee *Pipilo fuscus*
35. Grasshopper Sparrow *Ammodramus savannarum*
36. Lark Sparrow *Chondestes grammacus*
37. Rufous-crowned Sparrow *Aimophila ruficeps*
38. Cassin's Sparrow *Aimophila cassinii*
39. Black-throated Sparrow *Amphispiza bilineata*

166 Total

(Information from A.O.U. 1958, Bailey 1928, Bent-various dates, Hubbard 1970 and 1971, Johnson et al. 1973[2], Johnson et al.-manuscript[3], Monson and Phillips 1964, Monson-personal communications, Oberholser 1974, Phillips et al. 1964, Rea 1977, Todd 1975 and undated, Wauer 1973, and Wolfe 1956)

[1] Haight, L.T. and R.R. Johnson. Paper presented at annual meeting of the Arizona Academy of Science, April 17, 1977.

[2] Johnson, R.R., S.W. Carothers and D.B. Wertheimer, 1973. The importance of the Lower Gila River, New Mexico, as a refuge for threatened wildlife. Unpubl. Rpt. to U.S. Fish and Wildl. Serv., Albuquerque. 53 p.

[3] Johnson, R.R., J.M. Simpson and J.R. Werner. Unpublished manuscript. Birds of the Salt River Valley, Maricopa Co., Arizona

Rio Grande Valley. Habitats up through desert grasslands were considered, stopping at the lower edge of woodland and forests. 127 (or 77%) of the 166 nesting species were in some manner dependent on water related habitat. Of this 77% dependent on water related habitat well over half, 84 of the 166 species, are completely dependent on water related habitat. Only 39 species are non riparian nesting birds. Thus, if water dependent habitats were completely destroyed in the Southwest (not including suburban and agricultural) we could completely lose 47% of our lowland nesting birds while only 23% of our lowland nesting species would probably not be affected. 43 (26%) of the 166 species would be partially affected. Granted, several of the species which are preferential riparian at lower elevations, such as the Western and Cassin's Kingbirds, extensively use non riparian habitat at higher elevations. Still, the overall populations of these species would diminish with the reduction or loss of riparian habitat at lower elevations. In a dissertation on "Historic Changes in the Avifauna of the Gila Indian Reservation," near Phoenix, Rea (1977) uncovered the following information. Through the use of archaeological, ethnographic and historic sources he found that 101 species breed or have bred on the reservation with 5 more species that probably bred and 7 species that could have bred, based on biogeographic distributions. During the past 100 years, 22 breeding species were extirpated of which 18 were related to the former riverine ecosystem. Six speices of non-nesting birds dependent on the Gila River, now dry, are also gone. At least 13 species have recently recolonized the area as a result of reestablishment of a depauparate form of the original riparian habitat. This newly established habitat has developed as a result of the use of the Salt and Gila Rivers for disposal of effluent from the Phoenix sewage treatment plants.

Others, e.g. Hubbard (1972) have pointed out the lack of attention given to song birds when designating threatened and endangered species. However, to our knowledge, ours is the first attempt to quantify the number of species threatened or endangered by practices which greatly modify or destroy riparian habitat.

Some proponents of water salvage projects have pointed out that many breeding species of the Southwest lowlands are at the northern limits of their range. This, of course, is an attempt to justify phreatophyte control, channelization, dam construction, grazing and other practices which reduce riparian vegetation and consequently riparian wildlife. The main populations are found in Mexico for a large percentage of the birds that also occur in the Southwest lowlands. Thus, it is argued, even complete loss of riparian and marshy habitat should cause no great problem at the total population level for that species. No argument could be further from the truth. The destruction of riparian habitat in northern Mexico is progressing at an alarming rate. One need but drive a few hundred miles south from the United States-Mexico border to observe the frantic rate at which Mexicans are draining their streams and clearing riparian forests and woodlands in an attempt to feed a rapidly expanding population. One reads with nostalgia Sutton's book, "At a Bend in a Mexican River" (1972). His accounts from travels in Mexico only four decades ago tell of ferrying across rivers such as the Rio Purificacion and of the lush growth in the Valley of the Rio Corona. The riparian groves along these rivers are being cut at a rapid rate to make room for houses and fields. Rivers throughout Mexico as well as the United States are being dammed to provide water for municipal and industrial use and for large irrigation projects.

Thus, the same basic stages of "development of natural resources" which took place in the United States during two centuries promise to occur in Mexico in a matter of decades. When adding the available improved technology to Mexico's great wealth of natural resources, synergism may result. This may effect an even greater cummulative ecological disaster in a much shorter period of time than we have experienced in riverine ecosystems in the United States. Thus, when evaluating the ecological health of riparian species we must approach the problem from the standpoint of a systems analyst. One may start with his or her area of responsibility whether it be a few yards of small stream or several hundred miles of a large river. However, we must be cognizant of the resources up and downstream from our area. We must show concern for the entire drainage system, even if primary responsibility for its management rests elsewhere. The managers of resource plots, cities, counties, states, and countries need to recognize that streams commonly flow thru lands in different ownership and across political boundaries.

MANAGEMENT RECOMMENDATIONS

1. The riparian habitat is the most productive and possibly the most sensitive of North American habitats and should be managed accordingly. Due to the complexity of riverine ecosystems, scientists have only recently

developed techniques to document the importance of these ecosystems to wildlife.

2. In addition to the importance of riparian habitat from an ecological standpoint, other values include:

(a) Recreational uses including hunting, fishing (Meehan et al. this symposium) and bird watching.
(b) Reservoirs for preservation of gene pools and to allow recolonization of areas hit by disasters such as forest fires, severe droughts and storms.
(c) Aesthetic values including painting, photography and just looking, listening, smelling, etc.

Thus, recreational, wildlife, and aesthetic values should be weighed against other values and alternative uses. This is especially important in land use planning for a habitat which has high pressures from alternative uses such as water for industrial and domestic purposes, irrigation, grazing and urbanization.

3. Use interdisciplinary teams, including recreation specialists, economists, etc., to develop improved means for determining wildlife values. This is especially important in figuring cost-benefit ratios for determining the best use for an area. We hope there will never be a need for putting a dollar figure on everything in order to establish its "value." (What is the value of 2 or 3 days vacationing along a streamside?) However, economic values have been placed, in part, on recreation such as hunting, fishing, and "general rural recreation" (Davis 1967, and Martin et al. 1974). Attempts to quantify these values should make them more competitive with other uses, such as those mentioned in No. 2 (above).

4. Finally, encourage investigations to clarify areas of knowledge which are currently poorly, if at all, known. We have discussed the complexity of riverine ecosystems and further reasons for the late development of this area of ecology.

Problems which need to be solved include:

(a) The minimum area and suitable configurations necessary to retain both plant and wildlife values in different riparian habitats.

(b) The maximum distance which can separate islands of a given habitat type before the loss of wildlife species or a great reduction in populations occurs.

(c) Optimal as well as minimal requirements for enhancing wildlife values for a given habitat type. These include ground cover, trees and shrubs per hectare, foliage volume, plant species present, and disturbance types and frequencies.

We will close by quoting Carothers and Johnson (1975a),

> "Determining these factors may be the most important problem facing us today. All the 'threatened species recovery teams' we can possibly amass will not prevent many species from becoming extinct in their native habitat if we degrade their habitats past the point of no return."

LITERATURE CITED

Allee, W.C., A.E. Emerson, O. Park, T. Park and K.P. Schmidt. 1949. Principles of animal ecology. W.B. Saunders, Philadelphia. xii + 837 p.

American Ornithologist's Union. 1957. Checklist of North American birds. Fifth ed. A.O.U. Baltimore. xiii + 691 p.

Arbib, R. 1976. The bluelist for 1977. Amer. Birds 30:1031-1039.

Arizona Game and Fish Department. 1977. Memo concerning endangered and threatened species in Arizona. Ariz. Game and Fish Dept., Phoenix. 3 p.

Arizona Water Commission. 1972. 16th Annual Arizona Watershed Symposium Proc. Ariz. Water Comm. Rpt. 43 p.

Bailey, F.M. 1928. Birds of New Mexico. N. Mex. Dept. Game and Fish. Judd and Detweiler, Inc., Wash., D.C. xxiv + 807 p.

Barr, G.W. 1956. Recovering rainfall, Part I, Arizona watershed program. Coop. Proj. Ariz. State Land Dept., Water Div., Salt River Valley Water User's Assn., Univ. of Ariz. 33 p.

Behnke, R.J. and M. Zarn. 1976. Biology and management of threatened and endangered western trouts. USDA For. Serv. Tech. Rpt. RM-28, Rocky Mtn. For. and Range Exp. Sta., Ft. Collins, Colo. 45 p.

Bent, A.C. Various dates. Life histories of North American birds. Dover Publ., New York. (Republication of U.S. Natl. Mus. Bulls. issued from 1919-1968).

Boster, R.S. and L.R. Davis. 1972. Soil-loss considerations in chaparral-to-grass conversion, p. 243-250. In Proc. Watersheds in Transition Symp., Am. Water Resour. Assoc., Urbana, Ill.

Carothers, S.W.,S.W. Aitchison and R.R. Johnson. In press. Natural resources in Grand Canyon National Park and river management alternatives on the Colorado River. In Proc. First Conference on Scientific Research in the National Parks. USDI Natl. Park Serv., Wash. D.C.

Carothers, S.W. and R.R. Johnson. 1971. A summary of the Verde Valley breeding bird survey. Ariz. Game and Fish Dept. Land and Water Projects Investigations. Verde River Studies. Project FW-16-10. 20 p.

Carothers, S.W., R.R. Johnson and S.W. Aitchison. 1974. Population structure and social organization of southwestern riparian birds. Amer. Zool. 14:97-108.

Carothers, S.W. and R.R. Johnson. 1975a. Water management practices and their effects on nongame birds in range habitats, p. 210-222. In Proc. of Symp. on Management of Forest and Range Habitats for Nongame Birds. USDA For. Serv. Gen. Tech. Rpt. No. 1. Wash., D.C.

Carothers, S.W. and R.R. Johnson. 1975b. The effects of stream channel modification on birds in the southwestern United States, p. 60-76. In Proc. of Symp. on Stream Channel Modification. USDI Fish and Wildl. Serv., Off. Biol. Serv., Wash., D.C.

Clary, W.P. et al. 1974. Effects of pinyon-juniper removal on natural resource products and uses in Arizona. USDA For. Serv. Res. Paper RM-128. Rocky Mtn. For. and Range Exp. Sta., Flagstaff, Ariz. 28 p.

Davis, W.C. 1967. Values of hunting and fishing in Arizona in 1965. Coll. of Business and Public Adm., Ariz. State Univ., Tempe. vii + 91 p.

Deacon, J.E. and W.L. Minckley. 1974. Desert fishes, p. 385-488. In Desert Biology. Academic Press, New York.

Dolan, R., B. Hayden, A. Howard and R.R. Johnson. In press. Man's impact on Colorado River fluvial deposits within Grand Canyon. In Proc. First Conference on Scientific Research in the National Parks. USDI Natl. Park Serv., Wash., D.C.

Dolan, R., A. Howard and A. Gallenson. 1974. Man's impact on the Colorado River in the Grand Canyon. Amer. Sci. 62:392-401.

Duisberg, P.C., Ed. 1957. Problems of the upper Rio Grande: an arid zone river. Report of AAAS in coop. with UNESCO, U.S. Comm. for Arid Resour. Improvement and Development. Wash., D.C. 69 p.

Emory, W.T. 1858. Notes of military reconnaissance from Fort Leavenworth in Missouri to San Diego in California. Wendell and Van Benthvysen, Wash., D.C. 614 p.

Ffolliott, P.F. and D.B. Thorud. 1974. Vegetation management for increased water yield in Arizona. Agr. Exp. Sta., Univ. of Ariz., Tucson. iii + 38 p.

Fisher, J., N. Simon and J. Vincent. 1969. Wildlife in danger. Viking press, New York. 368 p.

Friedman, H. 1929. The cowbirds. Thomas Publ., Baltimore, Md. xv + 421 p.

Gaines, D. 1974. A new look at the nesting riparian avifauna of the Sacramento Valley, California. Western Birds. 5:61-80.

Greenway, J.C. 1958. Extinct and vanishing birds of the world. Amer. Comm. for Int. Wildl. Protection, Spec. Pub. No. 13. New York. 518 p.

Hibbert, A.R., E.A. Davis and D.G. Scholl. 1974. Chaparral conversion potential in Arizona Part I: Water yield response and effects on other resources. USDA For. Serv. Res. Paper RM-126. Rocky Mtn. For. and Range Exp. Sta., Ft. Collins, Colo. 36 p.

Hickey, J.J., Ed. 1969. Peregrine Falcon populations, their biology and decline. Univ. of Wis. Press, Madison. xxii + 596 p.

Holden, C. 1977. Review of law triggered by Tellico impasse. Sci. 196:1426-1428.

Holden, P.B. and C.B.Stalnaker. 1975. Distribution and abundance of mainstream fishes of the middle and upper Colorado River basins, 1967-1973. Trans. of the Amer. Fisheries Soc. 104(2):217-231.

Horton, J.S. and C.J. Campbell. 1974. Management of phreatophyte and riparian vegetation for maximum multiple use values. USDA For. Serv. Res. Paper RM-117. Rocky Mtn. For. and Range Exp. Sta., Ft. Collins, Colo. 23 p.

Hubbard, J.P. 1970. Checklist of the birds of New Mexico. New Mexico Ornith. Soc. Publ. No. 3. McLeod Printing Co., Albuquerque. 108 p.

Hubbard, J.P. 1971. The summer birds of the Gila Valley, New Mexico. Nemouria, Occas. Papers of the Delaware Mus. Nat. His. 2:1-35.

Hubbard, J.P. 1972. Southwestern songbirds, p. 79-96. In Proc. of Symp. on Rare and Endangered Wildlife of the Southwestern United States. New Mexico Game and Fish Dept., Santa Fe. 167 p.

Hubbard, J.P. 1977. A biological inventory of the Lower Gila River Valley, New Mexico. New Mexico Dept. Game and Fish, 56 p.

Johnson, R.R. 1970. Tree removal along southwestern rivers and effects on associated organisms. Amer. Phil. Soc., Yearb. 1970. p. 321-322.

Johnson, R.R. 1977. Synthesis and management implications of the Colorado River research program. Colo. R. Res. Tech. Rpt. No. 17. USDI Natl. Park Serv., Grand Canyon Natl. Park. 50 ms. p.

Johnson, R.R. and S.P. Martin. 1976. The Colorado River research project: a National Park Service multidisciplinary, interdisciplinary research project, p. 29-41. In Proc. of the 3rd Resources Management Conf. USDI Natl. Park Serv., Wash., D.C.

Laursen, E.M. and E. Silverston. 1976. Hydrology and sedimentology of the Colorado River in Grand Canyon. Colo. R. Res. Tech. Rpt. No. 13, USDI Natl. Park Serv., Grand Canyon Natl. Park. 27 p.

Lowe, C.H., Ed. 1964. The vertebrates of Arizona. Univ. of Ariz. Press, Tucson, 270 p.

Martin, W.E., R.L. Gum and A.H. Smith. 1974. The demand for and value of hunting, fishing, and general rural outdoor recreation in Arizona. Agr. Exp. Sta., Ariz. State Univ., Tempe. ix + 56 p.

Miller, A.H. 1951. An analysis of the distribution of the birds of California. Univ. of Cal. Publ. Zool. 50:531-643.

Minckley, W.L. 1973. Fishes of Arizona. Ariz. Game and Fish Dept., Phoenix. xvi + 293 p.

Minckley, C.O. and D.W. Blinn. 1976. Summer distribution and reproductive status of fish of the Colorado River in Grand Canyon National Park and vicinity during 1975-76. Colo. R. Res. Tech. Rpt. No. 14, USDI Natl. Park Serv., Grand Canyon Natl. Park. 17 p.

Minckley, W.L. and J.E. Deacon. 1968. Southwestern fishes and the enigma of "endangered species." Sci. 159:1424-1432.

Monson, G. and A.R. Phillips. 1964. Species of birds in Arizona. In The Vertebrates of Arizona. Univ. of Ariz. Press, Tucson. 270 p.

National Audubon Society. 1975. The seventy-fifth Christmas bird count. Amer. Birds 29(2):151-638.

New Mexico Game and Fish Dept. 1972. Proc. of the Symp. on rare and endangered wildlife of the southwestern United States. New Mexico Game and Fish Dept., Santa Fe. 167 p.

Oberholser, H.C. 1974. Bird life of Texas, E.B. Kincaid, Jr., ed., Vol. I and II. Univ. of Texas Press, Austin. 1069 p.

O'Brien, J. 1976. Observations on furbearers within the riparian habitat of the upper Sacramento River. Calif. Dept. Fish and Game Memo Rpt. iii + 12 p.

Odum, E. 1959. Fundamentals of ecology. W.B. Saunders Co., Philadelphia. xvii + 546 p.

Pettingill, G.S. 1970. Ornithology in laboratory and field. Burgess Publ. Co., Minneapolis. xvii + 524 p.

Phillips, A.R. 1968. The instability of the distribution of land birds in the Southwest, p. 129-162. In Collected Papers in Honor of Lyndon Lane Hargrave, Papers of the Arch. Soc. of N. Mex.: 1. Mus. of New Mexico. Press, Santa Fe. v + 170 p.

Phillips, A., J. Marshall and G. Monson. 1964. The birds of Arizona. Univ. of Ariz. Press, Tucson. xviii + 212 p.

Powell, J.W. 1961. The exploration of the Colorado River and its canyons. Dover Publ., Inc., New York. xiv + 397 p. (Unabridged republication of work publ. in 1895 by Flood and Vincent, Canyons of the Colorado).

Prince Phillip and J. Fisher. 1970. Wildlife crisis. Hamish Hamilton Ltd., Cowles Book Co., Inc., and World Wildlife Fund., Chicago and New York. 256 p.

Rea, A.M. 1977. Historic changes in the avifauna of the Gila River Indian Reservation, Central Arizona. Doctoral Dissertation, Univ. of Ariz., Tucson. xiii + 346 p.

Schorger, A.W. 1955. The passenger pigeon: its natural history and extinction. Univ. of Wisconsin Press, Madison. xiii + 424 p.

Sigler, W.F. and R.R. Miller. 1963. Fishes of Utah. Utah Dept. of Fish and Game, Salt Lake City. 203 p.

Simon, N. and P. Geroudet. 1970. Last survivors: the natural history of animals in danager of extinction. World Publ. Co., New York. 275 p.

Stevens, L.E. 1976. An insect inventory of Grand Canyon, p. 123-128. In An ecological survey of the riparian zone of the Colorado River between Lees Ferry and Grand Wash Cliffs. Colo. R. Res. Tech. Rpt. No. 10, USDI Natl. Park Serv., Grand Canyon Natl. Park. 251 p.

Suttkus, R.D., G.H. Clemmer, C. Jones and C.R. Shoop. 1976. Survey of fishes, mammals and herpetofauna of the Colorado River in Grand Canyon. Colo. R. Res. Tech. Rpt. No. 5. USDI Natl. Park Serv., Grand Canyon Natl. Park. 48 p.

Sutton, G.M. 1972. At a bend in a Mexican river. Paul Eriksson, Inc., New York. xvii + 124 p.

Thompson, R.L., Ed. 1971. The ecology and management of the Red-cockaded Woodpecker. USDI Bureau of Sport Fisheries and Wildlife, Tall Timbers Res. Sta., Tallahassee, Fla. ii + 188 p.

Todd, R.L. No date. Field checklist of Arizona birds. Ariz. Game and Fish Dept. Proj. W-53-R-26. 4 p.

Todd, R.L. 1975. The species of birds and mammals occurring on the watersheds comprising the Colorado River drainage of Arizona. Ariz. Game and Fish Dept. Spec. Rpt. W-53-R-26. 53 p.

Tylinek, I. and W. Ullrich. 1972. Endangered species. Hart Publ. Co., Inc., New York. 284 p.

U.S. Fish and Wildlife Service. 1968. Rare and endangered fish and wildlife of the United States. USDI Fish and Wildl. Serv., Bur. of Sport Fisheries and Wildl., Wash., D.C. xi + 171 p.

U.S. Fish and Wildlife Service. 1973. Threatened wildlife of the United States. USDI Fish and Wildl. Serv., Bur. of Sport Fisheries and Wildl., Office of End. Species and Int. Activities, Wash., D.C. xiii + 289 p.

U.S. Fish and Wildlife Service. 1976. The Southern Bald Eagle in Arizona: a status report. End. Species Rpt. No. 1. USDI Fish and Wildl. Serv., Div. of Wildl. Serv., Phoenix, Az. 33 p.

U.S. Forest Service. 1975. Endangered and unique fish and wildlife of the southwestern national forests. USDA For. Serv. Wildl. Habitat Manag. Staff Group, Albuquerque, N. Mex. viii + 203 p.

U.S. National Park Service. 1974. Threatened wildlife in the Western Region of the National Park Service. USDI Natl. Park Serv. West. Reg. Office, San Francisco. vi + 68 p.

Van Tyne, J. and A.J. Berger. 1971. Fundamentals of ornithology. Dover Publ., Inc., New York. xi + 624 p.

Warnock, B.H. and J.L. Gardner, Ed. 1960. Water yield in relation to environment in the southwestern United States. In Proc. of Symp. SWARM Section AAAS, Sul Ross St. Coll, Alpine, Texas. 74 p.

Wauer, R.W. 1973. Birds of Big Bend National Park and vicinity. Big Bend Nat. Hist. Assn. xv + 223 p.

Welty, J.C. 1975. The life of birds. Second ed. W.B. Saunders, Philadelphia. xv + 623 p.

Wolfe, L.R. 1956. Checklist of the birds of Texas. Intelligencer Print. Co., Lancaster, Pa. 89 p.

Woodbury, A.M. et al. 1959. Ecological studies of the flora and fauna in Glen Canyon. Univ. of Utah Anthro. Papers (Glen Canyon Series No. 7), Univ. of Utah Press, Salt Lake City. 226 p.

Zimmerman, D.R. 1976. Endangered bird species: habitat manipulation methods. Sci. 192:876-878,

Ziswiler, V. 1967. Extinct and vanishing animals. Springer-Verlag Press, New York. ix + 133 p.

The Importance of Riparian Habitat to Migrating Birds[1]

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Abstract.--Seven pairs of study sites in riparian and adjacent, nonriparian habitats were censused for spring migrant passerines. Riparian plots contained up to 10.6 times the number of migrants per hectare found on adjacent, nonriparian plots. Stop-over habitat selection is indicated by differing migrant densities and species diversities in various habitats. Passerine migration strategies are discussed.

INTRODUCTION

Field investigators have long noted that migrating passerines show a decided preference for riparian habitats over nonriparian habitats; however, virtually no data have been published concerning the nature of this preference. Riparian habitats provide an important source of food and cover for migrants and these habitats are being eliminated at such an alarming rate that the damage to migrant populations may be significant. The aim of this paper is to illustrate the importance of stop-over riparian habitats to migrant passerines in the Southwest. Only a few aspects of migration of western passerines are mentioned here but it is hoped that the data presented will stimulate additional research in this important field.

Many researchers have contributed to our knowledge of the timing of migration in southwestern passerines (Phillips 1951, Phillips et al. 1964, Hubbard 1971, Johnson and Simpson 1971, and others), but as yet no large-scale synthesis of migration patterns has been attempted. A growing concern for improved riparian habitat management practices has provided the impetus for a number of studies on riparian habitats by various government agencies (Johnson et al. 1974[6], Carothers and Johnson 1975, Lacey et al. 1975, Smith 1975, Carothers et al. 1976, Pace 1977[7], and others). Nearly all studies to date have ignored migrant passerines and their relationships to stop-over habitats in the Southwest (Sprunt 1975).

Migration, as Emlen (1975) indicated, is a multifaceted phenomenon. Some aspects of vernal (spring) migration related to stop-over habitat selection include migratory strategy, the influence of weather, and the development of migration routes. Literature for eastern North America indicates that passerines generally migrate nocturnally, resting and foraging during the day (Helms 1959, Able 1970, Welty 1975, and others). Gauthreaux (1972) suggested that vernal migrant passerines generally fly singly or in small, unispecific flocks. Vernal nocturnal migration in land passerines has been correlated with atmospheric stability and wind direction (Raynor 1956). Pleistocene speciation of Parulidae was discussed by Mengel (1964) and contemporary continental migration patterns were reviewed by Dorst (1962).

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6/ Johnson, R.R., S.W. Carothers, and D.B. Wertheimer. 1974. The importance of the lower Gila River, New Mexico, as a refuge for threatened wildlife: a multiple agency land management program. Unpublished, 53 pp.

7/ Pace, C.P. 1977. Classification, restoration and management of riparian habitats in southwestern forests. Rocky Mountain Forest and Range Experiment Station Study Plan 1710-44. Tempe. Unpublished, 44 pp.

Parnell's (1969) investigation of habitat selection in migrant eastern Parulidae (the North American wood warblers) demonstrated some correlation between warbler species and the stop-over habitat-niche chosen. Unexpectedly, he could not clearly demonstrate selection of major habitat types by migrant warblers in eastern forests.

METHODS

During the spring of 1977 a total of seven pairs of study areas were censused to determine migrant passerine densities and migrant diversities in stop-over habitats. The study sites, ranging in size from 1.6 hectares to 20.0 hectares, were located throughout Arizona. One site of each pair was situated in mature, riparian growth and the other in adjacent, nonriparian growth. Four pairs of study plots, those being used in the Rocky Mountain Forest and Range Experiment Station (RMFRES) riparian habitats study program, were examined in greater depth using the spot-map method (Williams 1936, Kendeigh 1944, and Franzreb 1976). The remaining three pairs of study sites were censused using a modified Emlen (1971) transect technique wherein an absolute count of birds was made. Data on the vegetation of the four paired RMFRES sites were gathered using the plotless point-quarter method of Cottam and Curtis (1956) and are included in Table 1. Tree heights were measured with a clinometer.

In addition, observation data on the spring migration of paulids for the Blue Point cottonwood stand was gathered from 1969 through 1974.

STUDY SITE DESCRIPTIONS

Terminology follows that of Hubbard (1971) with modifications. Study site sizes are included parenthetically.

1. Wet Beaver Creek (WBC) - Sullivan Ranch near Camp Verde, Yavapai Co., elev. 1250 m. A heterogeneous riparian forest with Platanus-Fraxinus overstory (4.1 hectares).

Wet Beaver Creek Adjacent (WBCA) - a mixed microphyll (valley and slope mesquite)-evergreen woodland of Prosopis, Juniperus and Canotia (3.0 hectares).

2. Ash Creek (AC) - Rincon Mountains, Coronado Forest, Pima Co., elev. 1200 m. A heavily grazed heterogenous riparian woodland of Prosopis, Fraxinus and Celtis (4.1 hectares).

Ash Creek Adjacent (ACA) - A heavily grazed, mixed microphyll (valley and slope mesquite)-evergreen-xeric shrubland of Prosopis, Mimosa, Quercus and Fouquieria (20.0 hectares).

3. Rucker Canyon (RC) - Chiricahua Mountains, Coronado National Forest, Cochise Co., elev. ca. 1600 m. A heterogenous, mixed riparian and evergreen forest with Quercus-Platanus overstory (5.0 hectares).

Table 1.--Vegetation of four RMFRES study sites

STUDY SITE	TREE SPECIES COMPOSITION	# TREES /HA	AVERAGE HT. TREES (METERS)	SHRUB SPECIES COMPOSITION	# SHRUBS /HA	AVERAGE HT. SHRUBS (METERS)
WBC	Platanus (25%) Juniperus (21%) Fraxinus (20%)	193	13.8	Mimosa (19%) Fraxinus (18%) Rubus (17%)	489	1.8
WBCA	Juniperus (68%) Prosopis (19%)	54	3.2	Canotia (28%) Juniperus (19%) Prosopis (17%)	1290	1.1
AC	Prosopis (52%) Fraxinus (23%) Celtis (17%)	124	5.3	Mimosa (41%) Baccharis (25%)	1510	0.9
ACA	Prosopis (86%) Quercus (14%)	59.3	3.6	Mimosa (44%) Gutierrezia (20%)	2638.5	0.8
RC	Juniperus (45%) Platanus (20%) Quercus (20%)	142	9.3	Rhus (43%) Juniperus (23%)	476	1.4
RCA	Quercus (61%) Juniperus (34%)	228	5.0	Rhus (36%) Nolina (33%)	691	1.3
TC	Juglans (31%) Prosopis (28%) Platanus (26%)	121	11.1	Juglans (48%) Prosopis (13%) Mimosa (12%)	490	1.6
TCA	Prosopis (33%) Quercus (32%)	29.4	4.4	Arctostaphylos (36%) Mimosa (27%) Prosopis (11%)	809	1.5

Rucker Canyon Adjacent (RCA) - a heavily grazed evergreen woodland of Quercus and Juniperus (6.0 hectares).

4. Turkey Creek (TC) - Rincon Mountains, Cornado National Forest, Pima Co., elev. 1250 m. A grazed homogeneous riparian forest with Platanus-Fraxinus overstory (5.9 hectares).

Turkey Creek Adjacent (TCA) - A grazed, mixed microphyll (slope mesquite)-evergreen shrubland of Prosopis, Quercus and Arctostaphylos (11.4 hectares).

5. Watson Lake (WL) - Near Prescott, Yavapai Co., elev. 1600 m. A homogeneous riparian forest with Populus-Salix overstory (7.5 hectares).

Watson Lake Adjacent (WLA) - A grazed, xeric grassland (7.1 hectares).

6. Blue Point (BP) - On the Salt River near Fort McDowell, Maricopa Co., elev. 400 m. A grazed, homogeneous riparian forest-woodland of Populus and Prosopis (10 hectares).

Blue Point Adjacent (BPA) - A grazed, xeric shrubland Cercidium association (10 hectares).

7. Indian Gardens (IG) - Grand Canyon National Park, Coconino Co., elev. 1150 m. An island of homogeneous riparian forest with Populus overstory (1.6 hectares).

Indian Gardens Adjacent (IGA) - A xeric, Coleogyne shrubland association (1.6 hectares).

RESULTS AND DISCUSSION

Tables 2, 3, and 4, and Figures 1 and 2 present the results of our 1977 spring migrant passerine survey. Residents and all possible breeding individuals and species were combined in the breeding bird category. This constitutes a significant overestimation of breeding bird populations and an underestimation of MPDen (migrant passerine density) and MPSD (migrant passerine species diversity) because some migrants were treated as breeding birds. Thus, in terms of migrants, these data are extremely conservative.

Table 2 presents the migrant species seen on the fourteen study plots. Note the generally higher MPSD of insectivores and the uniformly higher total MPSD on the riparian plots.

Table 3 and Figure 1 present MPDen data. The total number of migrant individuals in riparian habitats is shown to be uniformly greater (by up to 10.6 times) than the total number in adjacent, nonriparian habitats, with one exception. The open understory on the Turkey Creek plot attracted large flocks of Chipping Sparrows (Spizella passerina) and White-crowned Sparrows (Zonotrichia leucophrys) from the surrounding grasslands. Table 4 and Figure 2 show that the MPSD on all riparian study areas was distinctly higher than the MPSD on adjacent plots.

Other trends in these data can be observed. As in Table 2 insectivorous migrants generally preferred riparian habitats (WBC, TC, IG) and a higher insectivorous MPSD was also evident in most of those habitats. The larger number of granivorous individuals and smaller species diversity (WBCA, AC, TCA) of this group is an indication of flocking behavior in Fringillidae (the Finches, Sparrows and their allies). Granivores displayed habitat selection by avoiding dense riparian forest and woodland situations (WBC, BP); they tended to concentrate in adjacent shrublands (WBCA, WLA) and open, riparian forests (TC, IG). The importance of riparian habitats to breeding birds is also shown; in general, at least twice as many breeding individuals and species occurred in the riparian plots as did on the nonriparian plots.

Figures 1 and 2 illustrate differences in migrant use of heterogeneous and homogeneous habitats. Heterogeneous deciduous riparian habitats (WBC, AC) had generally higher MPDen and higher MPSD than did uniform stands of riparian growth (TC, WL, BP). Mixed riparian and evergreen forest habitats (RC) had lower MPDen and MPSD. Heterogeneous deciduous vegetation offers the greatest variety of habitat-niches for migrants, thus it is not unreasonable to expect substantial migrant use of these habitats. While uniform stands of riparian growth may be expected to support a lower MPSD the extremely low numbers on the Blue Point plot reflect inadequate sampling and poor weather conditions. Inaccessibility to migrants may account, in part, for the limited usage of the Rucker Canyon study area. Able (1970) has shown that 75% of eastern passerines migrate below an altitude of 920 meters and the same is probably true in the Southwest. A narrow canyon at a higher elevation may not be used by many migrants simply because the birds fly between mountain ranges rather than over them.

Moderately high MPDen and MPSD occurred in the only island stand of riparian vegetation studied (IG). It is not surprising that high MPDen and MPSD were found in riparian islands because these situations provide the only available food and cover for passage birds. The high percentage of granivores may reflect differences in migration patterns between fringillids and the insectivorous passerines.

Adjacent habitat depauperacy promotes a higher concentration of migrants in riparian habitats. Adjacent, nonriparian habitats which were not heavily grazed (WBCA and, to a lesser extent, TCA) supported a higher MPDen and MPSD than did those areas which were more heavily grazed (ACA, RC, WLA).

Patterns of migration in the Southwest have not been explored in depth. We observed only one wave migration of parulids in a five-year study of the Blue Point cottonwood stand; this concurs with Parnell's (1969) observation that wave migration is quite uncommon in eastern North American parulids. More frequently, though still not commonly, we have observed wide fronts of single species of parulids and fringillids. Most spring migration through the Southwest probably occurs in small, unispecific flocks,

Table 2.--Migrant passerine species occurrence and number of censuses per plot

MIGRANT PASSERINE SPECIES	Paired (riparian and nonriparian habitats) study sites[1]													
	Heterogeneous						Homogeneous						Island	
	WBC	WBCA	AC	ACA	RC	RCA	TC	TCA	WL	WLA	BP	BPA	IG	IGA
Empidonax spp.	X	X	X	X	X	X	X	X			X			
Western Wood Pewee (Contopus sordidulus)											X			
Olive-sided Flycatcher (Nuttalornis borealis)			X											
Mountain Chickadee (Parus gambeli)					X								X	
Hermit Thrush (Catharus guttata)											X			
Western Bluebird (Sialia mexicana)			X											
Blue-gray Gnatcatcher (Polioptila caerulea)					X									
Ruby-crowned Kinglet (Regulus calendula)			X		X			X						
Cedar Waxwing (Bombycilla cedrorum)					X									
Solitary Vireo (Vireo solitarius)	X	X									X			
Warbling Vireo (Vireo gilvus)	X	X	X		X	X	X		X					
Virginia's Warbler (Vermivora virginiae)	X	X												
Lucy's Warbler (Vermivora luciae)					X									
Yellow-rumped Warbler (Dendroica coronata)	X	X	X	X	X	X	X	X	X				X	
Black-throated Gray Warbler (D. nigrescens)	X		X				X							
Townsend's Warbler (D. townsendi)							X				X			
Hermit Warbler (D. occidentalis)											X			

Table 2.--continued

MIGRANT PASSERINE SPECIES	Paired (riparian and nonriparian habitats) study sites[1]													
	Heterogeneous						Homogeneous						Island	
	WBC	WBCA	AC	ACA	RC	RCA	TC	TCA	WL	WLA	BP	BPA	IG	IGA
MacGillivray's Warbler (Oporornis tolmiei)				X					X					
Wilson's Warbler (Wilsonia pusilla)	X		X	X	X		X	X			X			
Western Tanager (Piranga ludoviciana)	X		X	X	X		X				X			
Black-headed Grosbeak * (Pheuticus melanocephalus)	X		X						X		X			
Lazuli Bunting (Passerina amoena)					X		X							
Pine Siskin (Carduelis pinus)	X												X	
Green-tailed Towhee (Pipilo chlorurus)		X	X	X				X	X					
Dark-eyed Junco (Junco hyemalis)			X			X								
Chipping Sparrow (Spizella passerina	X	X	X	X			X	X		X			X	
Brewer's Sparrow (Spizella breweri)										X				
White-crowned Sparrow (Zonotrichia leucophrys)									X				X	
Total # migratory insectivorous species	9	5	10	5	10	3	7	4	4	0	9	0	2	0
Total # migratory granivorous species	2	2	3	2	1	1	2	2	2	2	0	0	3	0
Total # migratory species	11	7	13	7	11	4	9	6	6	2	9	0	5	0
Total # breeding passerine species	18	11	19	11	14	12	20	23	15	8	14	6	10	2
Total # passerine species	28	18	32	18	25	16	29	29	21	10	23	6	15	2
Total # censuses/plot	1	1	2	2	3	3	3	3	1	2	2	1	2	2

* Insectivorous migrant species through Black-headed Grosbeak; granivorous migrant species below Black-headed Grosbeak.

1 Study sites are of varying sizes and are not comparable.

Table 3.--Spring migrant and breeding passerine densities in riparian and adjacent nonriparian habitats

		Heterogeneous						Homogeneous						Island	
		WBC	WBCA	AC	ACA	RC	RCA	TC	TCA	WL	WLA	BP	BPA	IG	IGA
Average # migrant birds/ha	Insectivorous	34.7	5.0	4.3	0.3	1.7	0.3	3.4	0.8	4.1	0	1.5	0	1.8	0
	Granivorous	0.7	7.0	3.5	0.8	0.5	0.3	5.3	13.0	0.4	0.5	0	0	8.8	0
	Total	35.4	12.0	7.8	1.1	2.2	0.6	8.7	13.8	4.5	0.5	1.5	0	10.6	0
Average # breeding birds/ha *		12.4	7.7	11.1	2.9	8.4	3.8	18.0	7.0	6.1	0.6	7.0	0.4	9.9	1.3
Average total # birds/ha		47.8	19.7	18.9	4.0	10.6	4.4	26.7	20.8	10.6	1.1	8.5	0.4	20.5	1.3

* Including all potentially breeding passerine individuals

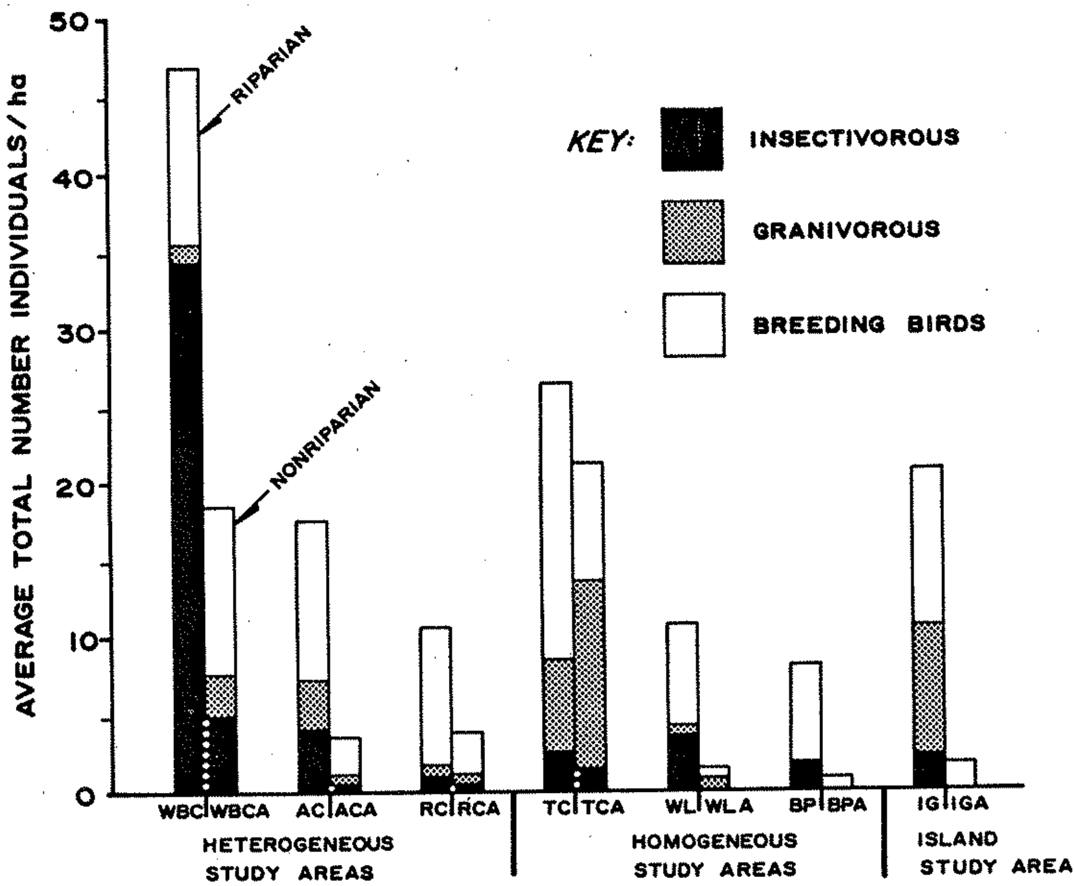

Figure 1.--Spring migrant and breeding passerine densities/ha in riparian and nonriparian habitats.

Table 4.--Spring migrant and breeding passerine species diversities/ha in riparian and adjacent, nonriparian habitats

		Heterogeneous						Homogeneous						Island	
		WBC	WBCA	AC	ACA	RC	RCA	TC	TCA	WL	WLA	BP	BPA	IG	IGA
Average # migrant species/ha	Insectivorous	2.7	1.7	1.2	0.3	0.7	0.2	0.8	0.5	0.8	0	0.9	0	0.6	0
	Granivorous	0.2	0.7	0.4	0.1	0.2	0.1	0.2	0.2	0.3	0.1	0	0	1.6	0
	Total	2.9	2.4	1.6	0.4	0.9	0.3	1.0	0.7	1.1	0.1	0.9	0	2.2	0
Average # breeding species/ha *		4.4	3.7	2.3	1.0	2.7	1.2	2.9	2.1	2.6	0.4	1.4	0.5	6.2	1.3
Average total # species/ha		7.3	6.1	3.9	1.4	3.6	1.5	3.9	2.8	3.7	0.5	2.3	0.5	8.4	1.3

* Including all potentially breeding passerine species

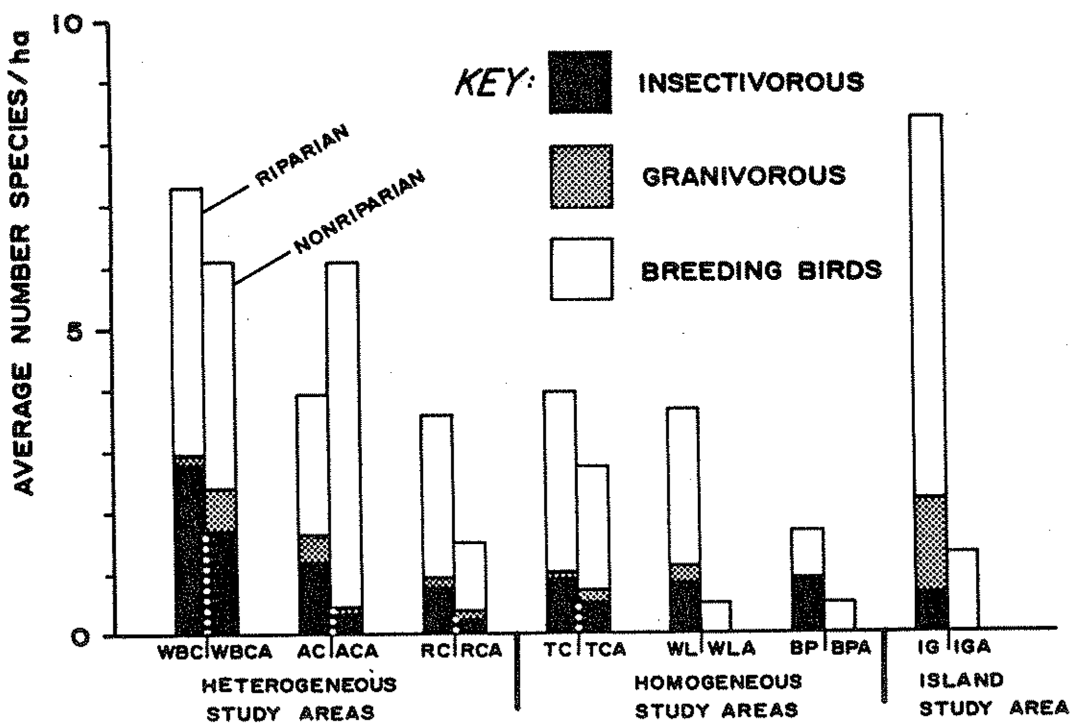

Figure 2.--Spring migrant and breeding passerine species diversities/ha in riparian and adjacent, nonriparian habitats.

as has been suggested by Gauthreaux (1972) for passerines migrating across the Gulf of Mexico.

CONCLUSIONS

From the data presented above it is evident that stop-over habitat selection by migrants occurs commonly in the Southwest. Riparian habitats support significantly higher MPDen and MPSD than do adjacent, nonriparian habitats. Insufficient data have been gathered as yet to substantiate the occurrence of niche selection, but the likelihood of this phenomenon is great. While Parnell (1969) could not clearly demonstrate habitat selection in migrant eastern warblers, habitat delineation is more distinct in the Southwest than in eastern deciduous and coniferous forests.

Parameters influencing migrant passerine use of riparian habitats include: specific habitat preferences of the bird (stop-over habitat selection); floral components (niche diversity and vegetational species composition); location of habitat (island situations and, perhaps, accessibility); and quality of the adjacent habitat (including the amount of grazing and other forms of impact).

The importance of riparian habitats to migrant passerines is substantial. Riparian habitat managers should consider the impact of proposed management not only on breeding species but also on migratory species. As Balda (1975) suggests, managers must be concerned with the quality of the avian populations they are indirectly managing through habitat manipulation. Riparian habitat management in vegetational islands and in heavily-grazed areas may have a greater effect on migrants and manipulation of these areas must be carefully evaluated.

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LITERATURE CITED

Able, K.P. 1970. A radar study of the altitude of nocturnal passerine migration. Bird Banding 41:282-290.

Balda, R.P. 1975. Vegetation structure and breeding bird diversity. In Proc. Symp. on Management of Forest and Range Habitats for Nongame Birds. U.S.D.A. Forest Service General Technical Report WO-1. Tucson, Arizona. Pp. 59-80.

Carothers, S.W. and R.R. Johnson. 1975. The effects of stream channel modification on birds in the southwestern United States. In Proc., Symp. on Stream Channel Modification (Corning, R.V., et al. eds.) Grottoes, Virginia. PP. 60-76.

Carothers, S.W. and S.A. Aitchison (editors). 1976. An ecological survey of the riparian zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs, Arizona. U.S. Dept. Int. NPS Technical Report No. 10.

Cottam, G. and J.T. Curtis. 1956. The use of distance measure in phytosociological sampling. Ecology 37:451-460.

Dorst, J.D. 1962. The Migrations of Birds (trans. by C.D. Sherman). Houghton Mifflin Co., Boston. 476 pp.

Emlen, J.T. 1971. Population densities of birds derived from transect counts. Auk 88:323-342.

Emlen, S.T. 1975. Migration: Orientation and Navigation In Avian Biology, Vol V. D.S. Farner and J.R. King, eds. Academic Press, New York. Pp. 77-128.

Franzreb, K.E. 1976. Comparison of variable strip transect and spot-map methods for censusing avian populations in a mixed coniferous forest. Condor 78:260-262.

Gauthreaux, S.A. 1972. Behavioral responses of migrating birds to daylight and darkness: a radar and direct visual study. Wilson Bulletin 84:136-148.

Helms, C.W. 1959. Song and Tree Sparrow weight and fat before and after a night of migration. Wilson Bulletin 71:244-253.

Hubbard, J.P. 1971. The summer birds of the Gila Valley, New Mexico. Nemouria, 1-35. Occ. Pap. Delaware Mus. Natur. Hist. May 13, #2.

Johnson, R.R. and J.M. Simpson. 1971. Important birds from Blue Point cottonwoods, Maricopa County, Arizona. Condor 73:379-380.

Kendeigh, S.C. 1944. Measurement of bird populations. Ecol. Monogr. 14:67-106.

Lacey, J.R., P.R. Ogden, and K.E. Foster. 1975. Southern Arizona Riparian Habitat: Spatial Distribution and Analysis. Univ. of Ariz., Tucson. 148 pp.

Mengel, R.M. 1964. The probable history of species formation in some northern wood warblers (Parulidae). In The Living Bird (3rd annual). Cornell. Pp 9-43.

Parnell, J.F. 1969. Habitat relations of the Parulidae during spring migration. Auk 86:505-521.

Phillips, A.R. 1951. Complexities of migration: a review. Wilson Bulletin 63:129-136.

Phillips, A.R., J.T. Marshall, and G. Monson. 1964. The Birds of Arizona. Univ. of Ariz. Press, Tucson. 212 pp.

Raynor, G.S. 1956. Meteorological variables and the northward movement of nocturnal land bird migrants. Auk 73:153-175.

Smith, D.R. (coord.) 1975. Proc. Symp. on Management of Forest and Range Habitats for Nongame Birds. USDA Forest Service General Technical Report WO-1. Tucson, Ariz. 342 pp.

Sprunt, A., IV. 1975. Habitat management implications of migration. In Proc. Symp. on Management of Forest and Range Habitats for Nongame Birds. USDA Forest Service General Technical Report WO-1. Tucson, Ariz. PP. 81-86.

Welty, J.C. 1975. The Life of Birds, 2nd edition. W.B. Saunders Co., Philadelphia. 623 pp.

Williams, A.B. 1936. The composition and dynamics of a beech-maple climax community. Ecol. Monogr. 6:317-408.

Southwestern Riparian Communities: Their Biotic Importance and Management in Arizona[1]

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Abstract.--The various riparian communities occuring in Arizona and the Southwest are described and their biotic importance discussed. Recommendations are made concerning the management of streamside environments and their watersheds. These include recommendations pertaining to the classification and inventory of riparian habitats; the determination of limiting factors for key riparian species; the establishment of study areas; the regulation and elimination of livestock grazing; the greater consideration of streamside vegetation in authorizing water management projects; and the more conservative use of our watersheds.

INTRODUCTION

No report on riparian habitats would be complete without a discussion of the characteristics and limiting factors of Southwestern riparian vegetation and its associated fauna. These biotic communities have an importance to wildlife and outdoor recreation greatly disproportionate to their limited linear acreage. While man's various manipulations and alterations have resulted in enormous changes in the riparian vegetation, so have his watershed practices affected riparian environments. The long-term effects of past and present land management practices are imperfectly known, but the current situation for many of our riparian communities cannot be termed less than disastrous when compared to conditions of even a short time ago (Freeman 1930, Phillips et al. 1964, Lowe 1964, Jordan and Maynard 1970, Hubbard 1971, Davis 1973, Minckley 1973, Turner 1974 and others). Some understanding of our remaining riparian communities is therefore necessary if we are to make intelligent judgments about the desirability of future watershed projects in Arizona.

The various riparian communities of Arizona may be represented as formations or vegetation types of forest, woodland, marshland, and even grassland and scrub. A riparian community or association is one that occurs in or adjacent to a drainageway and/or its floodplain and which is further characterized by species and/or life forms different from those of the immediately surrounding non-riparian climax (Lowe 1964). A riparian community may be composed either of constituents peculiar to the riparian situation, or an extension of a higher, climax association fingering downward into the drainageway; the latter type has been termed "pseudo-riparian" (Campbell and Green 1968) to distinguish its faculative nature from the obligate nature of purely riparian species. Examples of pseudo-riparian communities are (1) ponderosa pine (Pinus ponderosa) forests above the Mogollon Rim that follow canyons into the pinyon-juniper woodland, and (2) extensions of some Arizona upland desert scrub species such as palo verde (Cercidium floridum), ironwood (Olneya tesota) and saguaros (Cereus giganteus) in arroyos and along washes within creosote communities in Yuma County. Another regularly observed riparian community of this kind is the extension of encinal or oak woodlands along creeks into plains and desert grasslands in southwestern Arizona.

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It is the riparian communities proper, commonly with distinctive plant and animal components not found elsewhere, that are of greatest concern here. This concern stems from their unique character and the resulting changes brought about by modern man, who has reduced and eliminated them at an alarmingly rapid rate. Hopefully an increased awareness and enlightened attitude on the part of public-spirited citizens will prevail and many of the more interesting riparian communities remaining will be available for future enjoyment and study. The following discussion and summary of these riparian communities generally follows the classification outlined in Brown and Lowe (1974).

I. Temperate Deciduous Forests and Woodlands

Warm-temperate, winter-deciduous gallery forest and woodlands, where they still occur, are the most interesting and spectacular riparian communities in Arizona. Originally, interior riparian forests occupied most of the major drainages in the Southwest from the Mohave and Sonoran Deserts through submogollon Arizona, northeastern Sonora, southern New Mexico, northern and eastern Chihuahua to the Rio Grande and its tributaries in southwest Texas. Other, cold-temperate deciduous forests occupy streamsides in montane habitats and in the Great Plains and Great Basin. These forests are maintained along perennial or seasonally intermittent streams and springs and can be divided into two major communities: mix broadleaf and cottonwood-willow. Today only a few drainage systems, such as the undammed Rio Magdalena in Sonora and (to a lesser extent) the San Pedro River in Arizona, present extensive linear riparian forest development. Where streamflows are seasonally intermittent, riparian deciduous forests can be expected only where surface runoff occurs from November through March (Zimmerman 1969, Hibbert et al. 1974) and where the advent of the spring growing season can be expected prior to April 15 (warm-temperate). After mid-April increased evapotranspiration and phytotranspiration may result in only subsurface flow, especially during daytime hours. Summer precipitation usually does not result in sustained streamflow (Zimmerman 1969, Hibbert 1971, Hibbert et al. 1974), and riparian deciduous forests in the Southwest are vernal adapted. As such, Arizona's warm-temperate forests require abundant water during March and April, when most species set seed and germinate (Zimmerman 1969). Probably for this reason, these forests are poorly represented or largely absent from the westerm pediments of the Sierra Madres in southeastern Sonora and Sinaloa, where winter-spring precipitation is less than 25 percent of the total.

Interior mixed broadleaf communities are usually found in Arizona between about 3,500 and 6,500 feet along rubble-bottomed perennial and semiperennial streams (fig. 1). They are

Figure 1.--Interior riparian deciduous forest; mixed broadleaf series along Beaver Creek, Coconino National Forest, Yavapai County, Arizona; ca. 3850 ft., July, 1971. Arboreal associates at this locality in this warm-temperate "gallery" forest are alder, walnut, ash, cottonwoods and willows. Note the luxuriant understory and streamside vegetation without the presence of livestock.

represented in the western portions of the state along Trout, Francis and Burro Creeks in Mohave and Yavapai Counties, through the submogollon region to Rucker and Guadalupe Canyons in southeastern Cochise County. Arboreal constituents may be admixtures or stands of a variety of Holarctic genera consisting of sycamore (Platanus wrighti), ash (Fraxinus pennsylvanica velutina), cottonwood (Populus fremontii, P. angustifolia), boxelder (Acer negundo), alder (Alnus oblongifolia), bigtooth maple (Acer grandidentatum), willow (Salix spp.), walnut (Juglans major), mulberry (Morus microphylla), bitter cherry (Prunus emarginata), and other deciduous species intermingled with oaks and, to a lesser extent, conifers from the adjacent mountains. Arizona cypress (Cupressus arizonica) is not infrequent. Characteristic understory species include brackenfern (Pteridium aquilinum), scarlet sumac (Rhus glabra), poison ivy (Rhus radicans) and the deciduous vines, Virginia creeper (Pathenocissus quinquefolia) and canyon grape (Vitus arizonica).

Several species of wildlife are totally or largely dependent on this community. Among these are the Arizona grey squirrel (Sciurus arizonensis), otter (Lutra canadensis), zone-tailed hawk (Buteo albonotatus), black hawk (Buteogallus anthracinus), water ouzel or dipper (Cincius mexicanus), sulphur-bellied flycatcher (Myiodyrcaster luteiventris), summer tanager (Piranga rubra), Bullock oriole (Icterus bullocki), yellow warbler (Dendroica petechial), Arizona alligator lizard (Gerrhonotus kingi), Sonoran mud turtle (Klinosternon sonoriense), and canyon tree frog (Hyla arenicolor). These communities also provide major habitat types for white-tailed deer (Odocoileus virginianus), black bear (Ursus americanus), turkey (Meleagris gallopavo), as well as a myriad of nesting and migrating raptors and songbirds. Unfortunately, intensive investigations of the populations and nesting densities are lacking for most species of wildlife in this habitat type. An important exception is the lower Gila River in New Mexico where the biota has been inventoried by Hubbard (1977). Lowered streamflow has reduced a number of forests to scattered, individual constituents (woodlands), opening the canopy and presumably reducing its desirability to wildlife dependent on this type. Flash floods, such as the notorious Labor Day flood of September, 1970, have affected many miles of this beautiful streamside forest, and grazing by livestock has reduced the quality of the forest understory almost everywhere, curtailing or eliminating reproduction of some forest species.

Excellent examples of mixed broadleaf forests are still found in Arizona along Wet Beaver Creek above Rim Rock, along Oak Creek in Oak Creek Canyon, along Ash, Redfield, Eagle and Aravaipa Creeks and the San Francisco River. A revitalized forest along Rock Creek on the Three Bar Wildlife Area in the Mazatzal Mountains is especially worthy of mention. In 1959, after the elimination of grazing about 15 years before, the majority of the chaparral watershed burned; subsequent herbicide treatment prevented the rejuvenation of the nonriparian, climax chaparral community, and the sparsely forested vegetation along the drainage was transformed into a dense, excellent representative of mixed broadleaf deciduous forest. The area now provides habitats of importance to black bear and turkey, neither of which had utilized the area before the transformation (Gallizioli 1974). Since the streamflow was transformed from ephemeral to almost perennial prior to the application of herbicides (Pase and Ingebo 1965), the determining roles of fire and range restoration need further consideration.

Forests and woodlands in Arizona dominated by cottonwood and willow (Populus fremonti Salix gooddingii, S. bonplandiana and others) are confined primarily to riparian environments below 3,500 feet on clay or other fine soil and rock deposits [1] (fig. 2). Streamflows are perennial or nearly so. The understory may be a tangle of riparian trees or shrubs or relatively open and parklike. Once extensive, these forests have diminished greatly over the past 100 years with the diversion, interruption and elimination of streamflows. Descriptions taken from accounts telling of the extent of these forests along the Santa Cruz, Gila and Colorado Rivers prior to 1900 are indeed difficult to envision today (Davis 1973). Upstream impoundments, channel cutting, channelization, increased water salinity, irrigation diversions, and ground water pumping have made and continue to make massive inroads on these now relict communities. As in the mixed broadleaf community upstream, cattle grazing has negatively influenced the understory and the quality of remaining stands. Many remaining

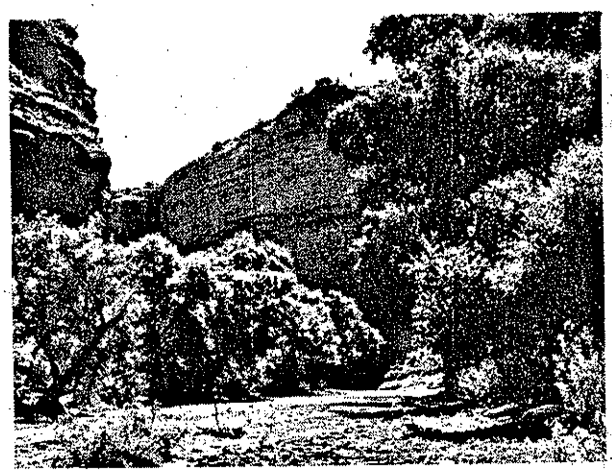

Figure 2.--Interior riparian deciduous forest; Cottonwood-willow series along Aravaipa Creek, Pinal County, Arizona; ca. 2800 ft., September, 1968. Willows, principally Salix gooddingii, outnumber cottonwood in this warm-temperate forest and woodland. The principal shrub is seep-willow and because of grazing, the understory vegetation is scant as oppossed to that shown in Figure 1. Photo by Richard L. Todd.

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[1] The limited woodlands of cottonwoods (Populus acuminata and others) willows (Salix lasiandra, S. lutea and others) and other deciduous trees north of the Mogollon Rim above 6,000 feet in northeastern Arizona are here considered extreme fasciations of riparian forest other than warm-temperate interior riparian deciduous forest.

mixed broadleaf riparian forests are under the jurisdiction of the U.S. Forest Service, where it is hoped future management of grazing and timber resources will give added consideration to these valuable environments (USFS 1969).

Interrupted examples of cottonwood-willow forests are still found along the Verde, Hassayampa, San Pedro, Bill Williams, Colorado and other rivers. Indications are that these communities are maintained through periodic winter-spring flooding. Stabilized water flows result in decadent stands, in which the dominant species are lacking in reproduction. Cottonwood regenerates itself principally from seed, unlike sycamore and other broadleaf riparian species that reproduce by sprouting, forming clones (Horton et al 1960). Further indications of the subclimax nature of this community are the "new" stands adjacent to portions of the Verde River and Santa Cruz Rivers, which were generated after heavy winter-spring runoffs on these drainages in 1965 and 1967 respectively. The presence of similar fasciations in California also indicates that these forests are vernal-adapted, and that late summer runoff is of little or no benefit to their regeneration.

Studies by Carothers and Johnson (1970) on the Verde River in Arizona have shown the importance of cottonwood-willow forests to breeding birds. More species are recorded as nesting in this vegetation type than any other; in Arizona several species such as the yellow-billed cuckoo (*Coccyzus americanus*) and blue-throated hummingbird (*Lampornis clemenciae*) are, for all practical purposes, restricted to it. A comparable study of the nesting birds of a cottonwood-willow community in California showed a similar importance to nesting birdlife (Ingles 1950). The importance of the cottonwood-willow community to avian species including raptors, particularly the black hawk (*Buteogallus anthracinus*), grey hawk (*Buteo nitidus*), and bald eagle (*Haliaeetus leucocephhalus*) is discussed by Todd (1969, 1970, 1971, 1972; Hubbard 1971) and others. The Sonoita Creek Natural Area retained by The Nature Conservancy along Sonoita Creek in Santa Cruz County is an over-mature example of the cottonwood-willow association and a mecca for observers of songbirds and other wildlife. Because of its proximity to Mexico, several peripheral species of birds such as the sub-tropical becard (*Pachyramphus agaiae*) are regularly observed here. The importance of these communities in maintaining environments for the Southwest's aquatic biota is imperfectly known, but studies by Minckley (1969) on Sonoita Creek and other drainages indicate that they may be of great consequence (also see Miller 1961).

II. Subtropical Deciduous Woodland

The famous mesquite bosques of pre-settlement Arizona are discussed by Brandt (1951), Phillips et al (1964), Lowe (1964), Davis (1973) and others. Unfortunately, the major bosques such as the ones at San Xavier, Komatke (New York Thicket), and Texas Hill are now mostly of historical interest (Brown 1970, 1974; Wigal 1973) (fig. 3). Remnants, some of which are nonetheless excellent examples, still occur along the San Pedro, Santa Maria and Verde Rivers, on the Robbins Butte Wildlife Area adjacent to the Gila River, along the upper middle Gila, and in scattered patches along other Lower Sonoran water courses (fig. 4). While winter deciduous, these bosques are very much subtropical and in Arizona are largely restricted to below 3,500 feet elevation within the Sonoran Desert, where they attain maximum development on the alluvium of old dissected flood plains laid down between the intersection of major watercourses and their larger tributaries (fig. 5).

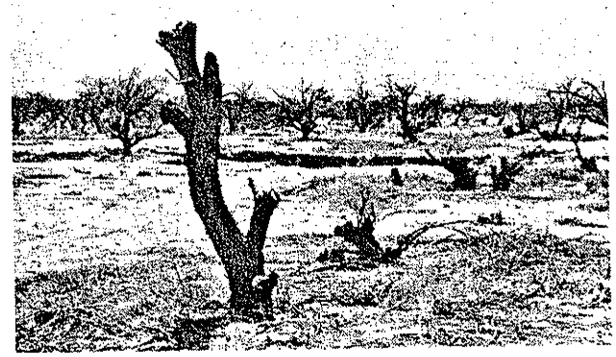

Figure 3.--Subtropical riparian deciduous woodland; remnant of the recently great mesquite bosque at Komatke (New York thicket) near confluence of the Gila and Santa Cruz Rivers, Gila River Indian Reservation, Maricopa County, ca. 1,050 ft., July, 1972. The rapidly dropping ground water table has resulted in this scene of dead and dying mesquites.

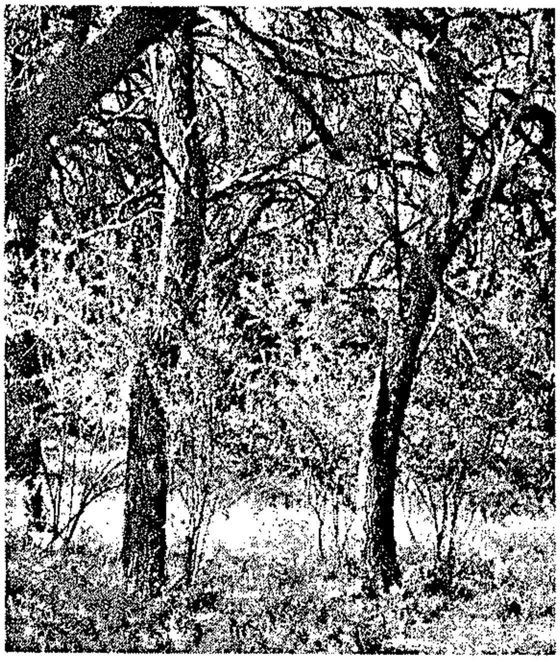

Figure 4.--Subtropical riparian deciduous woodland; interior view of mesquite bosque along San Pedro Rivers between Cascabel and Redington, Cochise County, Arizona; May, 1977. The thrifty appearance and abundant reproduction of the mesquites here is in marked contrast to most of the other bosques in Arizona. These bosques are being rapidly cleared for agriculture, however.

Figure 5.--Subtropical riparian deciduous woodland: mesquite bosque community along Gila River below its confluence with Bonita Creek, Graham County, ca. 3,100 ft., December, 1970. Note the sharp contrast between the riparian bosque and the nonriparian Sonoran desertscrub.

In the past these subtropic woodlands were almost completely dominated by mesquite (Prosopis juliflora velutina), once containing individuals of great size (see e.g., Brandt 1951). Hackberry (Celtis reticulata), screwbean (Prosopis pubescens), and increasingly the deciduous saltcedar or tamarisk (Tamarix chinensis) may now share dominance in local situations (Bowser 1957, Robinson 1965, Turner 1974). As in areas of former cottonwood-willow forest, riparian scrub and marshland, the introduced saltcedar now often exclusively constitutes a disclimax community (fig. 6) at the expense of native plant and animal diversity (see e.g., Phillips et al. 1964, Ohmart 1973).

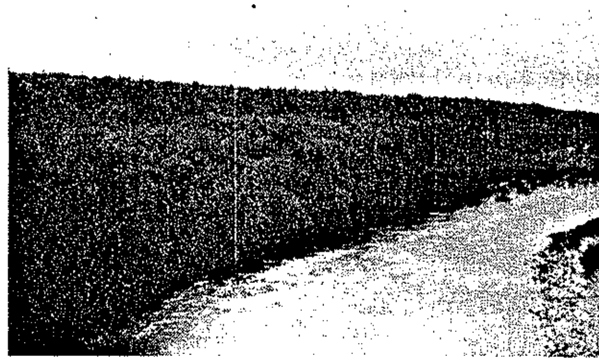

Figure 6.--Riparian deciduous scrubland; a subtropical disclimax consociation along the Salt River in south-central Arizona; September 1958. Scrublands and woodlands of the hybrid saltcedar (Tamarix chinensis) now occupy hundreds of miles of stream channels in the Southwest where they provide important nesting habitats for mourning doves, and in subtropical areas, mourning and white-winged doves.

Historically, saltbushes (Atriplex polycarpa, A. lentiformis), or annual and perennial grasses and forbs formed the ground cover in mature mesquite bosques; the understory was relatively open. Today, introduced annual forbs such as filaree (Erodium cicutartium), mustards (Cruciferae) and grasses, e.g. Cynadon dactylon, Bromis rubens, Schismus barbatus and others, are frequently encountered as understory species. Vines such as janusia (Janusia gracilis), canyon grape (Vitis arizonica), gourds (Cucurbita palmata) and others were, and still may be, conspicuous constituents. Individual cottonwoods, velvet ash and Goodding willow may be interspersed in more mesic sites within the bosque. Greythorn (Condalia lycioides) or a blue palo verde (Cercidium floridum) may occupy an occasional opening or sunny place.

The importance of this woodland type to colonial nesting white-winged (Zenaida asiatica) and mourning (Zenaidura macroura) doves is well documented (Neff 1940, Arnold 1943, Wigal 1973, Carr 1960 and others). Its importance to other avian species is discussed by Brandt (1951), Phillips et al. (1964), Gavin (1972) and others. This community too has suffered greatly from a variety of man-related causes including water diversion, flood control, agricultural clearing programs, and, principally, dropping water tables. This llast factor, including interrupted subsurface flow, has been responsible for the almost total destruction of the mesquite "forests" at San Xavier, Casa Grande Ruins National Monument, Komatke and Texas Hill (Phillips et al. 1964, Brown 1970, Judd et al. 1971).

The continued clearing of other bosques along the Gila and Colorado Rivers has resulted in their replacement by agricultural crops and other type conversions. It has been noted that where intermittent flooding and/or slowly receding summer surface flow occurs, saltcedar tends to replace mesquite. This is particularly prevalent after the woodlands have been cleared or burned and ground water is close to the surface and water storage facilities and agricultural tracts are present upstream. Whether this replacement is partially due to irreversible changes in water quality and soil chemistry, or is entirely due to the inherent ability of tamarisk to repopulate floodplains rapidly, is a matter for some discussion.[2]

Saltcedar in Arizona has hybridized; it sets seed and germinates throughout the long Southwestern growing season (Horton 1960, Horton et al. 1960), and it is hypothesized that storage facilities which hold back winter-spring runoff and release water irregularly during the summer months favor the establishment of this adventive at the expense of native riparian communties. The aggressive ability of saltcedar to outcompete native riparian species after summer flooding has been well demonstrated by Turner (1974) and Warren and Turner (1975). Nonetheless, saltcedar now provides satisfactory and important nesting sites for mourning and white-winged doves (Carr 1960, Shaw 1961, Wigal 1973 and others). Several thousand acres of federal land along the Gila River, much of which is saltcedar and mesquite, have been withdrawn for these species under Public Law 1015 as the "Fred Weiler Greenbelt". Other areas receiving some degree of protection include the mesquite bosques on the Black Butte Wildlife Management Area, maintained by the Arizona Game and Fish Department, and Tonto National Forest lands along the Verde River. The high demands placed on both mesquite wood and ground water, however threaten all remaining bosques (see e.g., Lacey et al. 1975).

III. Subtropical Evergreen Forest

This complex tropic-subtropic formation has its northern terminus in moist canyons and warm springs in and adjacent to the Sonoran Desert in Arizona and California, where it is represented by stands of California fan palm (Washingtonia filifera). In Arizona native groves--but not all individuals--are limited to two canyons in the Kofa Mountains (Benson and Darrow 1954, Smith 1974), to three sites at end near Alkali Springs in the Hieroglyphic Mountains (Brown et al. 1976) and possibly Cienega Springs near Parker (fig. 7). Because of their miniscule acreage and disjunct occurrence, these communities lack the characteristic vegetational and faunal associates of more southerly subtropic evergreen forests and possess instead distinctive Sonoran oasis associates (Vogl and McHargue 1966, Brown et al. 1976). That these relics of the Miocene and Pliocene remained at all in Arizona was due to the continual presence of abundant subsurface waters in favored tropic-subtropic microenvironments. One also suspects that the adaptibility of this species to alkaline waters may have been a competitive advantage with certain warm temperate forms.

Figure 7.--Subtropical riparian evergreen forest; California fan palm series at Cienega Springs, Yuma County, Arizona. Abundant reproduction frequently characterizes native palm groves in Arizona; the fan palms, tolerant of alkaline waters, have outcompeted their cottonwood-willow competitors over the years at this and other sites.

[2]For a discussion of the salt secretion abilities of saltcedar see Decker 1961.

California fan palms are attractive trees, and their adaptibility to cultivation has made them an ubiquitous ornamental landscape feature throughout the Southwest. The few native communities are considered botantical phenomena to be maintained with a minimum of disturbance. The palms in Palm Canyon, Hidden Canyon and elsewhere have had their shag of dead fronds burned but otherwise appear in good condition, with some reproduction noted. Palm groves and individuals in the Kofa Mountains are within the Kofa Game Range and are under the jurisdiction of the United States Fish and Wildlife Service. The palms at Alkali Springs and Cienega Springs are privately owned.

IV. Riparian Scrublands

While riparian scrub communities cover extensive areas of stream channels and flood plains, scientific investigations and resource managers have generally ignored them and concentrated on the more interesting and diverse communities upstream and downstream. They are, nonetheless, both interesting and important.

Above 8500 feet, a boreal riparian scrub is usually present along subalpine streams and in some wetlands. These scrublands are dominated by scrub willows (Salix bebbiana, S. scouleriana), although red-osier dogwood (Cornus stolonifera), blueberry elder (Sambucus glauca), rocky mountain maple (Acer glabrum) and thin-leaf alder (Alnus tenuifolia) may be locally important, particularly downstream as one approaches and enters more cold temperate conditions (fig. 8). Occasional trees such as blue spruce (Picea pungens) and aspen (Populus tremuloides) may stand out within the scrub. These streamside scrublands are nesting habitat for dusky flycatchers (Empidonax oberholseri), MacGillivary warblers (Oporornis tolmiei), orange-crowned warblers (Helminthophila celata), broad-tailed hummingbirds (Selasphorus platycercus), white-crowned sparrows (Zonotrichia leucophrys) and Lincoln sparrows (Melospiza lincolni). The perennial streams are themselves the habitat of the native Arizona trout (Salmo apache) and the now ubiquitous rainbow (Salmo gairdneri). These stream habitats are subject during the summer months to extensive and intensive livestock grazing, including use by sheep. Stream quality has also been altered by logging activity on adjacent watersheds, a situation which can be expected to increase with the demand for timber resources.

In temperate and subtropic situations in intermittent and perennial stream channels and in and along flood channels one also encounters riparian scrublands (fig. 9). Stream flows in these types are irregular and often occur in the form of flash floods. Dominant species are frequently but not necessarily seepwillow or batamote (Baccharis glutinosa), broom (Baccharis sarothroides or B. emoryi), arroweed (Pluchea sericea), and, increasingly, saltcedar. The reasons for the increase in saltcedar at the expense of the native seepwillow since 1940 have been discussed earlier and are well documented by Horton et al. 1960, Zimmerman 1969, Turner 1974, and Warren and Turner 1975. Riparian scrub may exhibit a dense "chaparral" aspect--scrubland--or present a very open one--desertscrub. Desert willow (Chilopsis linearis), mesquite, catclaw (Acacia greggi) and other arboreal species are frequent associates and may share aspect dominance. These trees as well as those of the riparian deciduous forest, if present, provide less than 15 percent of the ground cover. Faunal relationships within these riparian communities are poorly investigated, but there appears to be a considerable interaction with greater or lesser populations of adjacent or upslope nonriparian species. Bird species particularly well represented in riparian scrub include the Say's phoebe (Sayornis saya), crissal thrasher (Toxostoma dorsale), black-tailed gnatcatcher (Polioptila melanura), phainopepla (Phainopepla nitens) and the brown towhee (Pipilo fuscus). To date, little attempt has been made to "manage" these habitats.

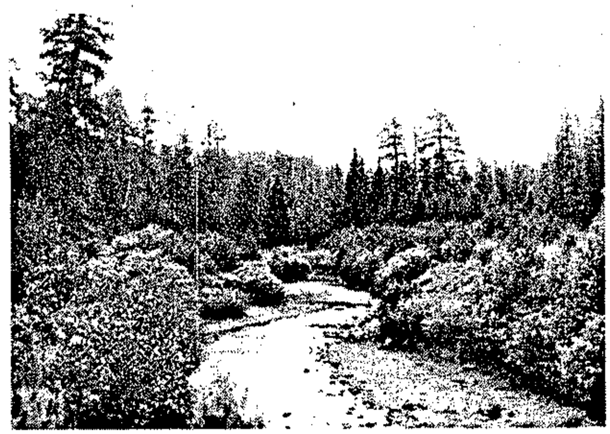

Figure 8.--Montane riparian deciduous scrubland; Mixed series along the North Fort of White River, Fort Apache Indian Reservation; ca. 7500 ft., July, 1977. Prevalent and dominant plants here include two willows, thin-leaf alder, blueberry elder, and hawthorn (Crataegus erythropoda).

Figure 9.--Evergreen riparian scrubland in the channel of the San Carlos River, San Carlos Indian Reservation; ca. 3200 ft., March, 1975. The thick "Chaparral" in foreground is largely seep-willow or batamote. The deciduous scrub is mostly saltcedar. Note the decadent stand of cottonwood along the bank in the distance.

Figure 10.--Saltwater marshland; Saltgrass series at Obed Meadows, Navajo County, Arizona. Saltgrass occupies wetland and riparian areas throughout Arizona's subtropic and temperate zones wherever alkaline habitats exist. The deciduous trees in background are the now ubiquitous saltcedar.

V. Marshlands

These wetland formations may be comprised if any of several boreal, temperate or subtropical emergent communities and are defined as aquatic communities, the principal plant constituents of which are emergents not trees, woody shrubs, or nonhalophytic grasses [3], and which normally or regularly have their basal portions annually, periodically or continually submerged. In the Southwest these include communities in both fresh or brackish water environments. They range from the more xeric and alkali communities of salt grass (Distichlis stricta), and alkali bulrush (Scirpus paludosus) through the carrizo or reed communities (Phragmites communis) of the Colorado River and elsewhere to mesic freshwater communities of rushes (Juncus spp.), sedges (Carex spp.). bulrushes (Scirpus spp.) and cattail (Typha spp.) (fig. 10, 11).

Figure 11.--Freshwater marshland; Topock Marsh looking north from north dike, Mohave County, ca. 550 ft. Bullrush and cattail are the principal vegetational constituents in foreground. This famous marsh is one of the few remaining on the Colorado River and is an important breeding area for the Yuma clapper rail. Photo by Richard L. Todd

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[3] Riparian grasslands of sacaton (Sporobolus wrightii), tobosa (Hilaria mutica) and other communities, while not discussed, occur in Arizona and the Southwest. See Lowe (1964) for a discussion of tobosa swales. Saltgrass communities are treated here as part of the marshland formation.

These rapidly disappearing communities are found in riparian and littoral situations only where streamflow is turgid, shallow and dependable enough to permit their establishment. Since they are the most mesic of Arizona's vegetational and biotic communities, they have suffered most from the resultant desiccation of the state's natural environment through water diversions and water "management" projects (see e.g., Ohmart ca. 1974). The few riparian marshland communities that remain are habitats for a number of species of Arizona's rare and vanishing wildlife, such as the Yuma clapper rail (Rallus longirostris), black rail (Laterallus jamaicensis), bitterns (Ixobrychus exilis, Botaurus lentiginosus), and Mexican duck (Anas diazi) (Todd 1972a). Numerous other rails, shorebirds, and waterfowl are highly dependent on these diverse environments, both during nesting and migration (Todd 1972a). These marshland oases are now frequently dependent on stored and/or recycled argricultural and industrail waste waters from diverted upstream flow. Examples in Arizona are Picacho Lake in Pinal County and Quigley Pond on the Gila River in Yuma County (see also Brown et al. 1977). Exceptions are a few sloughs and old oxbows of the San Pedro, lower Salt, Verde and Colorado Rivers, almost all of which are threatened by existing or planned projects. It is also an ironic fact that Arizona's most valuable wildlife habitats are too frequently subjected to trampling and grazing by livestock, in addition to hydrological limitations.

VI. Recommendations

It has become increasingly evident that the most valuable and interesting of Arizona's streamside environments are greatly in need of more enlightened management of both the actual riparian communities and the watersheds upon which they depend. Their present limited acreage and importance to endangered, threatened, and peripheral wildlife species have prompted a growing concern by wildlife-oriented groups and individuals in addition to the concern long voiced by professional biologists. This concern has now manifested itself in the political arena and requires that our riparian environments receive greater consideration from resource management agencies.

The following recommendations are suggested to perpetuate and enhance those riparian communities of greatest value to wildlife and public interest:

1. Identify and classify Arizona's riparian environments. Identification and mapping of streamside vegetation is presently either being considered or in the process of inventory by land management agencies, other public agencies, academic groups and ad hoc consultants. These efforts should be coordinated and classifications of the various types determined. A statewide inventory, including maps, of remaining habitats should be prepared and published.

2. Investigate factors determining the limiting specific riparian constituents and communities. The environmental requisities and limits of many of the major riparian plant species must be determined, at least in part. These would of necessity be long-range and continuous studies to provide an understanding of the factors controlling the various communities and their constituents. Only then can we hope to preserve and manage our riparian constituents through regulated discharges of water from reservoirs, selective cutting and other techniques.

3. Establish representative study areas containing all major riparian communities and their surface and groundwater requirements. In addition, as reserves these areas would provide "bench marks" and controls for comparison with "managed" or other "modified" ecosystems.

4. Grazing and other distruptive influences should be eliminated or controlled in riparian forests, woodlands and marshlands. Many of these have had their public values compromised through the degradation of their flora and fauna. Areas presently supporting little or no understory and showing no reproduction of major riparian constituents should be restored where still possible.

5. Riparian and watershed management project planners should reconsider the values both actual and potential of streamside vegetation before irreversible alterations. Several "phreatophyte clearing" projects have resulted in unwarranted destruction of native riparian associations with little or no documented water "salvage" or other claimed conservation measures accomplished (Campbell 1970, Horton 1972, Patrick 1971).

6. Increase the effort to avoid torrential summer and fall flooding through more conservative use of grazing and timbering watershed resources. Shrub invasions of Southwestern watersheds, due to livestock grazing pressures and suppression of fire, have long been documented (see e.g., Leopold 1924, Humphrey 1958). Through proper management, streamflows can be stabilized and increased to the benefit of our riparian resources. These management techniques should be applied now throughout our rapidly deteriorating Southwest riparian wonderland.

LITERATURE CITED

Arnold, L.W. 1943. A study of the factors influencing the management of and a suggested management plan for the western white-winged dove in Arizona. Ariz. Game and Fish Comm. 103 p.

Benson, L. and R. A. Darrow. 1954. The trees and shrubs of the Southwestern Deserts. 2nd ed. Univ. of Ariz. Press, Tucson, and Univ. New Mexico Press, Albuquerque. 437 p.

Brandt, H. 1951. Arizona and its birdlife. Bird Research Foundation, Cleveland, Ohio. 723 p.

Brown, D.E. 1970. Summary of white-winged dove banding and hunt information. Proj. W-53-R-20: WP3, J2. Spec. Rep. 1961-1969. Ariz. Game and Fish Dep. 28 p.

Brown, D.E. and G.C. Sanderson. 1974. White-winged dove (Zenaida asiatica) In Management of Migratory Shore and Upland Game Brids in North America. The Intern. Assoc. of Fish and Wildl. Agencies, Washington, D.C. p. 246-272.

Brown, D.E. and C.H. Lowe. 1974. A proposed classification for natural and potential vegetation in the Southwest with particular reference to Arizona. J. Ariz. Acad. Sci. 9(2). 11 p.

Brown, D.E., N.B. Carmony, C.H. Lowe, and R.M. Turner. 1976. A second locality for native California fan palms (Washintonia filifera) in Arizona. J. Ariz. Acad. Sci. 11(1): 37-41.

Brown, D.E., N.B. Carmony, and R.M. Turner. 1977. Drainage map of Arizona showing perennial streams and some important wetlands. Map. Proj. W-53-R, Ariz. Game and Fish Dep.

Bowser, C.W. 1957. Introduction and spread of the undesirable tamarisks in the Pacific southwestern section of the United States and comments concerning the plants influence upon the indigenous vegetation. Trans. of Amer. Geophy. Union. 38(3). 7 p.

Campbell, C.J. 1970. Ecological implications of riparian vegetation management. J. of Soil and Water Conserv. 25(2):49-52.

Campbell, C.J., and W. Green. 1968. Perpetual succession of stream-channel vegetation in a semi-arid region. J. Ariz. Acad. Sci. 5(2) 96-98.

Carothers, S.W. and R.R. Johnson. 1970. A summary of the Verde Valley breeding bird survey, 1970. Mus. of Northern Ariz. 13 p.

Carr, J.N. 1960. Mourning dove whitewinged dove nest surveys during the summer of 1960. Proj. W-53-R-11; WP3, J2. 6 p.

Davis, G.P. 1973. Man and wildlife in Arizona: the pre-settlement era, 1823-1864. Master of Sci. Thesis, Univ. of Ariz.

Decker, J.P. 1961. Salt secretion by Tamarix pentandra Pall. Forest Sci. 7:214-217.

Freeman, L.R. 1930. Down the Grand Canyon. Dodd, Mead and Co., N.Y. 371 p.

Gallizioli, S. 1974. Personal communication. Ariz. Game and Fish Dep.

Gavin, T.A. 1972. Avian and mammalian species composition in a mesquite bosque. Proj. 73, Quart. Rep. Ariz. Coop. Wildl. Res. Unit, Univ. of Ariz. unpubl.

Hibbert, A. R. 1971. Increases in streamflow after converting chaparral to grass. Water Resour. Res. 7(1):71-80.

Hibbert, A.R., E.A. Davis and D.G. Scholl. 1974. Chaparral coversion potential in Arizona, Part 1:water yield response and effects on other resources. USDA For. Serv. Res. Pap. RM-126, Rocky Mt. For. and rAnge Exp. Sta., Fort Collins. 36 p.

Horton, J.S. 1960. Ecology of salt cedar. In Watershed and Related Water Management Problems. Proc. 4th An. Ariz. Watershed Symp., Phoenix.

Horton, J.S., F.C. Mounts and J.M. Kraft. 1960. Seed germination and seedling establishment of phreatophyte species. USDA For. Serv. Sta. Pap. 48. Rocky Mt. For. and Range Exp. Sta., Fort Collins. 26 p.

Horton, J.S. 1972. Management problems in the phreatophyte and riparian zones of the Southwest. J. of Soil and Water Conserv. 27(2):57-61.

Horton, J.S. and C.J. Campbell. 1974. Management of phreatophyte and riparian vegetation for maximum multiple use values. USDA For. Serv. Res. Pap. RM-117. Rocky Mt. For. and Range Exp. Sta., Fort Collins. 23 p.

Hubbard, J.P. 1971. The summer birds of the Gila Valley, N.M. Occa. Pap. of the Delaware Mus. of Nat. His., Nemouria 2:1-35.

Hubbard, J.P. 1977. A biological inventory of the lower Gila River, N.M. Bur. of Land Manage. Bur. of Rec., New Mexico Dep. Game and Fish, Soil Conserv. Serv., U.S. Fish and Wildl. Serv. and U.S. For. Serv. 56 p.

Humphrey, R.R. 1958. The desert grassland. A history of vegetational change and an analysis of causes. Bot. Rev. 24(4):193-252.

Ingles, L.G. 1950. Nesting birds of the willow-cottonwood community in California. Auk 67(3).

Jordan, G.L. and M.L. Maynard. 1970. The San Simon watershed, historical review. Prog. Agric. in Ariz. 22(4):6-9.

Judd, I.B., J.M. Laughlin, H.R. Guenther and R. Handegarde. 1971. The lethal decline of mesquite on the Casa Grande Ruins National Monument. Great Basin Nat. 31(3).

Leopold, A. 1924. Grass, brush, timber and fire in southern Arizona. J. of For. 22(6):1-10.

Lacy, J.R., P.R. Ogden and K.E. Foster. 1975. Southern Arizona riparian habitat:spatial distribution and analysis. School of Renew. Nat. Resour. and Office of Arid Lands Studies. OALS Bull. 8:1-148.

Lowe, C.H. 1964. Arizona's natural environment; landscape and habitats. Univ. of Ariz. Press, Tucson. 270 p.

Miller, R.R. 1961. Man and the changing fish fauna of the American Southwest. Papers Michigan Acad. Sci., Art. Lett. 46:365-404.

Minckley, W.L. 1969. Aquatic biota of the Sonoita Creek Basin, Santa Cruz County, Ariz. Ecol. Studies Leaflet, No. 15. The Nature Conservancy. 8 p.

Minckley, W.L. 1973. Fishes of Arizona. Ariz. Game and Fish Dep., Phoenix. 293 p.

Neff, J.A. 1940. Range, population and game status of the western whitewinged dove in Arizona. J. Wildl. Manage. 4(2):117-127.

Ohmart, R.D. 1973. Observations on the wintering birds and mammals in the proposed Buttes Dam site, Central Ariz. Proj. Bur. Reclam., Boulder City, Nev. 16 p.

Ohmart, R.D. 1974 (ca.) Dynamics of marsh land formation and succession along the lower Colorado River and their importance and management problems as related to wildlife in the arid Southwest. Bur. of Reclam. Preprint 1-21.

Pase, C.P. and P.A. Ingebo. 1965. Burned chaparral to grass: early effects on water and sediment yields from two granite soil watershed in Arizona. Proc. Ariz. Watershed Symp. 9.

Patrick, R. 1971. The effects of channelization on the aquatic life of streams. Acad. of Nat. Sci. of Philadelphia. 12 p.

Phillips, A., J. Marshall and G. Monson. 1964. The birds of Arizona. Univ. of Ariz. Press, Tucson 212 p.

Robinson, T.W. 1965. Introduction, spread and areal extent of salt cedar (Tamarix) in the western states. Studies of Evapotranspiration Geol. Surv. Prof. Pap. 491-A.

Shaw, H. 1961. Influence of salt cedar on whitewinged doves in the Gila Valley. Spec. Rep., Ariz. Game and Fish Dep. 9 p.

Smith, E.L. 1974. Established natural areas in Arizona--A Guidebook for scientists and educators. Office of Econ. Plan. and Develop. Phoenix, 300 p.

Todd, R.L. 1969. Nongame investigations. Proj. W-53-R-19; WP5, J1. Prog. Rep. Ariz. Game and Fish Dep. 26 p.

Todd, R.L. 1970. Nongame investigations. Proj. W-53-R-20; WP5, J1. Prog. Rep., Ariz. Game and Fish Dep. 16 p.

Todd, R.L. 1971. Nongame investigations. Proj. W-53-R-21; WP5, J1. Prog. Rep., Ariz. Game and Fish Dep. 11 p.

Todd, R.L. 1972. Nongame investigations. Proj. W-53-R-22; WP5, J1. Prog. Rep. Ariz. Game and Fish Dep. 22 p.

Todd, R.L. 1972a. Biological report on a marsh near Tuzigoot National Monument. Proj. W-53-R-23; WP5, J1. Spe. Rep., Ariz. Game and Fish Dep. 4 p.

Turner, R.M. 1974. Quantitative and historical evidence of vegetation changes along the upper Gila River, Arizona. U.S. Geol. Surv. Prof. Pap. 655-H. 20 p.

U.S. Forest Service. 1969. Wildlife Habitat improvment handbook. USDA For. Serv.

Vogl, R.J. and L.T. McHargue. 1966. Vegetation of California fan palm oases on the San Andreas fault. Ecol. 47:532-540.

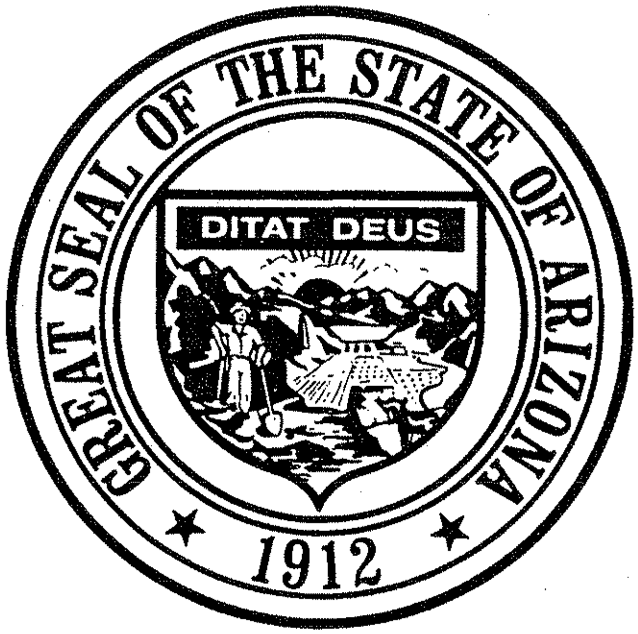
Warren, D.K. and R.M. Turner. 1975. Saltcedar (Tamarix chinensis) seed production, seedling establishment, and response to inundation. J. Ariz. Acad. Sci. 10(3):117-119.

Wigal, D.D. 1973. A survey of the nesting habitats of the whitewinged dove in Arizona. Spec. Rep. No. 2, Ariz. Game and Fish Dep. 37 p.

Zimmerman, R.C. 1969. Plant ecology of an arid basin Tres Alamos--Redington areas. U.S. Geol. Surv. Prof. Pap. 485-D. 51 p.

16

Arizona Statewide Comprehensive Outdoor Recreation Plan



Rose Mofford, Governor

Arizona State Parks
1989

BACKGROUND

Arizona is truly unique in its endless variety of outdoor resources. Canyons, deserts, mountains, forests are all available in abundance for use by residents and visitors alike. These features along with a rich cultural heritage and favorable climate combine to produce an outdoor life-style which has contributed to the state's rapid growth and development.

In order to assure the continued protection, enhancement, and enjoyment of the state's natural environment, it is essential that a comprehensive plan be developed. Statewide plans and priorities are important steps in the process of achieving the effective level of stewardship necessary to preserve these valuable natural resources for future recreation needs and demands. The Statewide Outdoor Comprehensive Recreation Plan (SCORP) is a vehicle through which the coordination of outdoor recreation planning and development can be achieved.

The importance of statewide comprehensive outdoor recreation planning has been recognized by federal, State, and local governments through the unique partnership established in the Land and Water Conservation Fund (LWCF) program. Created by Congress through the passage of the Land and Water Conservation Fund Act of 1965 (Public Law 88-578), the LWCF program makes federal financial and technical assistance available to states, and through the states, to local communities for acquiring and developing public outdoor recreation resources. The LWCF Act also requires states to undertake a comprehensive planning process at least once every five years.

The Arizona State Parks Board (ASPB) is responsibile for administering the LWCF program in Arizona and preparing its Statewide Comprehensive Outdoor Recreation Plan.

A federally-approved SCORP establishes the eligibility for Arizona and its political subdivisions' participation in the LWCF program. Since its inception, the LWCF program has provided funding for over 600 State and local projects representing a total recreation investment of over $ 86 million throughout Arizona. These projects have included the acquisition of over 5,000 acres of new park land and the construction of recreation facilities in 63 communities, 14 counties, and 20 State Park sites.

Planning provides more than just a means to access federal funds. In Arizona, like many other states, the SCORP becomes a forum for both allied and diverse interests to exchange points of view and express opinions. It also provides a factual backdrop for decisions that need to be made at all levels of government. Plans alone are meaningless without action, however. It is the actions, the resulting programs, budgets, ordinances, legislation, and enhancements SCORP can catalyze, that are the real values of the planning process.

The following list of SCORPs and related documents symbolizes a host of changes that occurred in Arizona since the program's inception:

- Initial Outdoor Recreation Plan, State of Arizona, 1965
- A Plan for Outdoor Recreation in Arizona, 1967
- Arizona Outdoor Recreation Plan, 1972

- Arizona Bikeways, 1973
- State Comprehensive Outdoor Recreation Plan, 1978 Needs Assessment Update, 1979 AORCC
- Safeguarding A Legacy: A Framework for Responsible Conservation, 1979
- Arizona State Parks Plan, 1980 Needs Assessment Update, 1981 AORCC
- Governor's Task Force on Parks and Recreation in Arizona-Final Report and Recommendations, 1982
- Statewide Comprehensive Outdoor Recreation Plan, 1983 Update

1989 SCORP

In designing the process that ultimately resulted in the 1989 SCORP, the following goals were adopted to help guide the plan's development:

- Participatory- facilitating extensive public involvement
- Future directed- anticipating the problems of tomorrow and choosing appropriate directions
- Resource focused- planning for appropriate recreation, cultural, natural, and human resources
- Action oriented- developing workable strategies
- Consensus based- reaching common agreement on the essential issues and strategies

Future Directed

A key element of SCORP was an assessment of Futures/Issues. This was accomplished by compiling extensive information about trends affecting recreation resources. The trends were used as a tool to elicit probable impacts and opportunities for key resources which might be expected to occur from unmitigated trends. Using these probable impacts identified by workshop participants it was possible to establish a future focus for the development of stategies.

Resource Focused

Decisions were made early on that indepth studies of key resources would be highly desirable. As a result special studies were undertaken to look at trails, lakes, natural areas, rivers, streams, and wetlands as separate resources. In addition, cultural resources and fish and wildlife resources also received special attention.

Action-Oriented and Consensus Based

Incorporating extensive public involvement in the process, was the most important factor in developing strategies and consensus for proposed actions. Many of the essential actors who ultimately need to be involved in implementing these actions served on the Steering Committee, Core Groups, or participated in the workshops.

Numerous federal, State, county, and municipal agencies, as well as a multitude of quasi-public and private interests are involved in providing public and private outdoor recreation opportunities and experiences. Extensive efforts were made during the preparation of this SCORP to obtain active participation and input from these groups as well as the general public. Participation was obtained through the SCORP Steering Committee which provided guidance for the development of the Issues and Futures section, Core Groups which were involved in the development of specialized resource studies, open houses and workshops which were held in five locations throughout the state in order to obtain regional perspectives on outdoor recreation issues, a random survey of Arizona households, and a culminating Town Hall event.

Arizona's 1989 SCORP consists of the following documents:

- Arizona Outdoor Recreation Participation Survey
- Arizona Trails Plan
- Arizona Natural Areas Study
- Arizona Rivers, Streams, & Wetlands Study
- Arizona Lakes Study
- Arizona Recreation Futures & Issues

Together, these documents provide a comprehensive framework for the orderly planning, acquisition, development, and administration of Arizona's outdoor recreation resources. The 1989 SCORP, therefore, is designed to accomplish the following:

- To present planning support to local governments and state agencies in developing effective outdoor recreation plans, resources, and facilities.
- To identify current recreation participation rates and trends for both residents and visitors alike.
- To identify existing and potential outdoor recreation resources throughout the state.
- To describe the roles and responsibilities of the numerous federal, State, and local agencies that are involved in providing outdoor recreation opportunities.
- To identify environmental concerns and make recommendations to protect and enhance the environmental quality of Arizona's natural resources.
- To facilitate the coordination of outdoor recreation planning and development at the local, State, and federal level.
- To qualify Arizona for participation in the Land and Water Conservation Fund and other appropriate federal grants-in-aid programs.

This Statewide Comprehensive Outdoor Recreation Plan is intended to serve as a common reference point for decisions relating to outdoor receation which will need to be made by numerous public and private individuals and organizations throughout the State. Elected local and State governmental officials, appointed members of recreation boards and commissions, and lay citizens who are responsible for making such decisions, as well as the recreation professional, should find the information contained in this Plan useful.

SUMMARY OF FINDINGS

The Scorp planning process was intended to lay the groundwork for the actions needed to steer Arizona towards desirable outdoor futures and away from other undesirable ones. This future focus was chosen primarily to avoid the pitfalls of previous plans and planning efforts. In the past, planners and decision-makers' attention was directed towards the solution of immediate problems and issues. This resulted in proposed solutions and actions that were largely reactive in nature. While reactive planning has led to some worthwhile change, it has not left planners and decision makers any better prepared for new, unanticipated issues and problems.

Adopting a more far-ranging planning horizon, one that looks beyond the immediate situation, can be useful in developing a sense of anticipation for changing circumstances and the proactive actions that can eventually influence the direction of change. This was the direction chosen for the 1989 SCORP. To instill and retain a focus on the future it was necessary to strategically place a futures and issues planning element at the heart of the overall planning process. Futures and Issues consisted of a sequence of planning activities involving a variety of publics and included the following major steps:

- compile from authoritative sources available information concerning the **Trends** influencing outdoor recreation resources and opportunities now and into the conceivable future;

- present this trend information to a variety of stakeholders (private and public groups and individuals most concerned about outdoor recreation) to elicit **Impacts** and **Opportunities** affecting essential outdoor recreation resources and opportunities that could foreseeably result from unmitigated continuance of the trends;

- analyze and evaluate impacts and opportunities into cause and effect schematic relationships and determine major **Issues**;

- propose a set of **Strategies** that could alter the underlying dynamics supporting the major issues, resulting in proactive involvement in determining future directions, and;

- design and secure agreement on a series of **Actions** to carry out priority strategies.

Trends

Exhaustive research into discernible trends that affect outdoor recreation resources and opportunities yielded the essential information needed to establish a context of future for the study participants. The complete results of this research is reported later in this Chapter. Although the information assembled was voluminous, several consistent themes emerged as supertrends. These supertrends were provided in advance to the involved publics and presented in some depth during regional workshops. Listed below is a summary of the supertrends and major supporting trends.

Dramatic Changes In How And Where People Live And An Increasing Population Are Creating New Recreation Demands.

- greater interest in personal health promotion
- rapid population growth
- increasing participation in outdoor recreation
- an aging population
- increasingly diverse motivations to recreate
- increasing ethnic diversity
- an increasingly urban population
- comparatively large youth population
- increase in dual-earner households
- growing number of single parents households
- more recreationally active women
- growing handicapped population
- rapidly decreasing leisure time

Recreation Resources Are Increasingly Threatened With Damage and Loss.

- overuse & destructive user behavior
- increasing overflights of recreation areas
- rising land prices
- diminished funding
- inadequate planning and uneven effort
- accelerated loss of wildlife habitats
- continued development of prime natural environments
- creation of unique and threatening urban conditions
- growing efforts to site incompatible public uses in park land

Government Is Playing A Growing Role In Outdoor Recreation.

- extensive holdings controlled by state and federal agencies
- increased emphasis on management for recreation
- expanding impact of government decision-making
- greater development of recreation resources on tribal lands
- more critical role of state agencies
- increasing land areas and populations within municipalities

Economic Trends Are Reducing Access To Recreation Opportunities And Are Changing How Recreation Is Provided.

- increasing economic value of recreation activities
- greater emphasis as part of economic development
- increased emphasis on business & financial aspects of recreation
- increased use of private contractors and concessionaires
- increase in members-only and resident-only recreation facilities
- growing numbers of corporate recreation programs
- increased closing of lands bordering public recreation areas
- growing interest in self-supporting programs & user fees
- concern with legal liability & risk management
- pressure to increase revenues from commodity uses of land
- growth of low-paying service and retail trade sectors
- increasing consumer debt

Conflict Over Recreation Resources Is Increasing, As Is Public Involvement In Solving Recreation Problems.

- growing conflict between resource users
- increase in activism & involvement of private citizens
- more localized decision making
- greater cooperation between agencies & sectors
- increasing developer & corporate responsibility
- greater integration of recreation & open space into urban settings
- greater use of land trades
- more efforts to maximize resource use (multiple uses, etc.)
- increasing research into ecological systems
- technological and engineering advances offering new solutions
- increased education in environmental issues

Impacts and Opportunities

To determine what possible effect these trends might have on outdoor recreation resources and opportunities in Arizona, a series of five regional workshops were held. A list of over 600 individuals, groups, and interests was compiled as potential participants whose assessment of the impacts of trends on their specific resource/opportunity needs would be helpful. Invitations to participate in a regional workshop was issued to this list, resulting in nearly two hundred attendees. In addition, regional open houses were held on days preceding the workshops. The open houses offered static display information summarizing trends, knowledgeable resource study representatives, as well as the preliminary resulting of concurrent resource studies. Response sheets were provided to collect feedback from the 400 individuals visiting the open houses.

In each of the five locations (Flagstaff, Lake Havasu City, Phoenix, Tucson, and Show Low) daytime and evening workshops were held. In many instances, multiple small groups needed to be formed to facilitate the collection of information from participants. In the small groups, individuals were encouraged to express both impacts, negative effects of trends, and opportunities, positive results of trends. A wide vareity of responses were gathered through the workshops. In addition, participants provided evaluative feedback about the importance and inevitability of the identified impacts which was useful in strategy development. A complete listing of the impacts and opportunities obtained from workshop participants is provided in the Appendices. In summary, the statewide impacts and opportunities that emerged common to all of the workshops included the following:

Impacts

- The increasing demand for recreation for a diverse and growing population is resulting in overcrowded and degraded recreation resources, conflict between recreationists, and loss of wilderness and solitude.

- The uniformed attitudes of many recreationists and land owners are resulting in environmental degradation and pollution and the loss of recreational and cultural resources.

- A number of trends, including closure of recreation areas, rising cost of liability insurance, increasing user fees, and private development of land are reducing public access to recreation opportunities.

- Water is an increasingly precious recreation resource and should be protected through regulation of level and flow as well as conservation and re-use programs.

- There is a lack of coordination, teamwork, and long-term perspective among recreation providers in the state.

Opportunities

- Land development should be managed to preserve open space and habitat developments can be the source of new recreation resources.

- The great expanses of public land in the state should be managed for increased recreation and habitat preservation.

- Environmental education should be provided in the public schools and through an assortment of programs for children and adults.

- Funding for recreation should be increased and there should be greater use of public-private partnerships, entrepreneurism, and volunteerism.

- There should be an increased emphasis on regional planning for recreation, with more flexibility and innovation, a long-range perspective, more inter-agency cooperation, and greater public involvement.

Issues

The rated impacts and opportunities generated in the regional workshops represent a dynamic system of influences which can both change and be changed. Understanding how change occurs in a dynamic system requires an appreciation for cause and effect relationships between the system actors. To establish these relationships cause and effect charts were drawn based on impacts and opportunities. This procedure was helpful in clearly revealing major issue areas. A summary of the major issues identified at the workshops includes:

Growth

- Increased demands
- Diverse needs
- Uniformed attitudes
- Affects quality of user experience
  - -overuse, user conflicts, loss of wilderness and solitude
  - -activities are either over-regulated or not controlled enough
  - -facilities are inadequate to meet demand
  - -environment becomes degraded and polluted; cultural resources are lost

Seasonal Use Patterns

- Create unusual pressures on systems and the environment

Restricted Access
- Distance from user
- Closure of recreation areas (for protection and management)
- Liability concerns
- User Fees
- Private development of land

Rural Economic Development
- Job creation
- Entrepreneurism

Land Development
- Loss of potential recreation area
- Regulate to preserve open space and habitat
- Source of new recreation areas

Water
- Control of flow and level
- Management as a limited resource

Environmental Education
- Children and adult

Funding
- Increase existing funding
- Locate new funding sources
- User fees

Technology
- Regenerate habitats: water re-use, etc.

Legislative Support
Public-Private Relationships
Enforcement and Regulation
Volunteerism and Activism

Planning and Management
- Coordination and cooperation between agencies
- Flexibility and innovation
- Long-range perspective
- Regional approach
- Equitable distribution of resources and funding
- Public involvement and responsiveness

Finally, the compilation of issues and cause and effect charts were presented to the SCORP Steering Committee. The three following long-term outcomes emerged from the data.

> There will be a loss of natural areas, open space, prehistoric and historic human-made resources, native species and native vegetation.
>
> There will be reduced public access to outdoor recreation.
>
> There will be degradation to the outdoor recreation experience.

To begin the process of counteracting these probable future outcomes, five issues were selected by the Streering Committee as the basis for strategy development. The five issues selected were:

> A lack of environmental awareness, understanding, and appreciation
>
> Lack of coordination and communication among recreation providers and inadequate public involvement in decision-making
>
> A lack of political support for recreation issues

Inadequate funding and other public and private resources

An imminent loss of recreation resources

Strategies

The five major issues selected by the Steering Committee represent key areas within the matrix of cause and effect relationships where changes to certain issue elements would create significant alterations in a variety of related outcomes. By concentrating on these key issue areas, a greater amount of overall potential change could be affected by a relatively limited set of actions. Therefore, specific strategies that would zero in on the five key issues were developed. A complete listing of all strategies is presented in the Appendices. The Steering Committee reviewed and prioritized these strategies, designating several strategies for development into actions.

Environmental Awareness and Responsibility

Work With School System
Institute Public Education Programs
Develop Media Programs
Expand Educational Value of Recreation Areas

Coordination of Effort and Increased Public Involvement

Expand Planning/Management Areas
Coordinate Plans, Policies, and Actions
Increase Communication
Share Knowledge and Experience

Political Strength

Educate Decisions-Makers
Expand and Organize Constituency
Recommend Public Policy
Exert Influence

Inadequate Public Funding and Other Resources

Increase Public Funding
Promote Partnerships
Promote Volunteerism
Target Revenues to Need
Expand Use of Existing Resources
Solicit, Encourage, and Reward Private Sector Contributions
Shift Burden to "Real Users"
Shift Burden to Other Entities

Endangered Resources

Address Critical Needs
Increase Public Awareness
Influence Public Policy
Develop Land Planning Strategies
Eliminate Destructive Land Uses
Restore Damaged Habitats

Actions

Proposing action is an important role of the Statewide Comprehensive Outdoor Recreation Plan. The Steering Committee reviewed the priority strategies and identified outcomes or recommendations under each issue for further development of specific actions and time frames. A complete listing of these actions, by major issue, is contained in Chapter 6. The Steering Committee recommendations to address each of the five major issues are shown below. Following the Issues and Recommendations for the Futures and Issues Study are summaries of the issues and recommendations from the **Trails, Natural Areas, and Rivers, Streams & Wetlands** studies.

Arizona Futures and Issues Study

Issues and Recommendations

Each of the general recommendations listed below is supported with a number of more specific strategies. The full text of these statewide strategies is contained in Chapter 6 of this document.

Issue **ARIZONA IS THREATENED WITH AN IMMINENT LOSS OF RECREATION RESOURCES.**

Recommendation Arizona should establish a policy to promote and coordinate the conservation and preservation of endangered recreation resources, including: riparian areas, cultural resources, natural areas, wildlife habitat, trails, open space, and recreation sites.

Issue **THERE IS A LACK OF COORDINATION AND COMMUNICATION AMONG RECREATION PROVIDERS AND INADEQUATE PUBLIC INVOLVEMENT IN DECISION-MAKING.**

Recommendation Recreation providers in the state should expand and coordinate regional, statewide, and interstate planning.

Issue **EXISTING LEVELS OF FUNDING AND OTHER PUBLIC AND PRIVATE RESOURCES ARE INADEQUATE TO MEET THE RECREATION NEEDS OF THE STATE.**

Recommendation The state should identify and pursue new sources of funding for recreation.

Issue **THERE IS A LACK OF POLITICAL SUPPORT FOR RECREATION ISSUES.**

Recommendation The Arizona Outdoor Recreation Coordinating Commission should prepare a statewide recreation economic impact assessment to establish the economic value of recreation in Arizona.

Issue **THERE IS A LACK OF ENVIRONMENTAL AWARENESS, UNDERSTANDING, AND APPRECIATION.**

Recommendation The state should establish a program in public schools to teach environmental and recreation ethics and natural and cultural heritage values using an integrated approach in K-12 curricula (with emphasis on K-3); should require testable proficiencies for secondary graduation; should require pre-service and in-service teacher training; and should support training and marketing efforts aimed at school boards,

Arizona Rivers, Streams, & Wetlands Study

Issues

Issue **RESOURCE SIGNIFICANCE**

- Arizona's streams and wetlands are economically vital to the commerce and industry of the state.
- Streams and wetlands have been essential to the survival and social well-being of Arizona's people since the beginnings of prehistoric settlement. Today, they continue to be critical to the quality of life for which Arizona is renowned.
- Natural streams, their associated riparian areas, and other wetlands constitute the state's richest environments in terms of the wildlife and fish diversity and plant and animal productivity.
- Streams and wetlands afford some of the most popular, diverse, and exceptional recreational opportunities, such as boating, fishing, hunting, camping, and hiking, in Arizona.

Issue **DECREASING RESOURCE AVAILABILITY AND QUALITY**

- Substantial losses in perennial streamflows and up to ninety-five percent loss of natural wetlands have resulted in dramatic losses — including some extinctions — of native fish and wildlife populations, accelerated soil erosion, degraded surface and groundwater quality, reduced groundwater recharge, and lost recreation values.

Issue **INCREASING RESOURCE DEMANDS**

- The importance of the state's diminishing streams and wetlands has increased greatly due to population growth, to expanded participation in water-based recreation, and to additional needs for water and watershed resources.

Issue **INCREASING CONFLICT FOR STREAMS AND WETLANDS USE**

- Growing demands for the use of streams and wetlands and associated water supplies have led to sharp competition for and conflict over these diminishing resources.

Issue **RECREATION DEPENDENT ON ENVIRONMENTAL QUALITY**

- The quality of recreational experiences associated with streams and wetlands is dependent upon maintaining and restoring the environmental integrity of the resources.

Issue **NEED TO MEET GROWING DEMANDS FOR RECREATION**

- Some streams and wetlands can support additional recreation use. However, other areas have already met or exceeded their capacity to support use without significant environmental deterioration. The critical task will be to accommodate additional use while conserving the basic integrity of stream and wetland resources.

Issue **NEED FOR ECONOMIC DEMAND, PARTICIPATION, AND ATTITUDINAL DATA**

- There is a critical need for stream- and wetland-based recreation data, particularly site-specific information.

Issue **NEED TO CONSERVE AND RESTORE RESOURCES**

- There is an urgent need to conserve the state's streams and wetlands and to utilize opportunities to restore streams and wetlands for future generations to use and enjoy.

Issue **NEED FOR CONSISTENT AND COORDINATED MANAGEMENT**

- The opportunities for consistent and coordinated management of streams and wetlands in Arizona have been limited by: (1) the many authorities and interests that influence the management and use of surface waters at all levels of government; (2) the lack of a common forum for communication among the complexity of authorities and interests concerned with streams and wetlands; and (3) inconsistencies and fragmentation in policy, purpose, and practice among thevarious authorities that manage and regulate the use of streams and wetlands.

Issue **NEED FOR COMMUNICATION AND COOPERATION**

- The consistent and coordinated management and equitable use of Arizona's streams and wetlands are dependent upon communication and cooperation between the many management entities, private landowners, resource users, and citizens of the state.

Issue **NEED FOR A STATEWIDE POLICY**

- A statewide policy is needed which: 1. Recognizes the importance of streams and wetlands to Arizona's heritage, economic growth, recreational opportunities, and quality of life; 2. Fosters communication and harmony, rather than conflict, among users; 3. Provides guidance to management entities so that they may, through coordinated and consistent efforts, achieve equitable, quality allocations of stream and wetland resources.

Study Recommendations

The Arizona Rivers, Streams, & Wetlands Study is recommending that four key management actions be initiated to ensure continued recreational use and proper conservation of our state's stream and wetland resources:

ENACTMENT OF A STATE STREAMS AND WETLANDS POLICY

- The State of Arizona should enact the following policy to promote the wise and equitable use of streams and wetlands. This policy will be the cornerstone for all other actions pertaining to streams and wetlands.

ESTABLISHMENT OF AN ARIZONA STREAMS & WETLANDS HERITAGE PROGRAM TO COORDINATE THE IMPLEMENTATION OF THE POLICY

- The State of Arizona should establish, with sufficient funding and staff, a statewide management program entitled, Arizona Streams & Wetlands Heritage Program. The purpose of the program will be to coordinate and promote implementation of the state's streams and wetlands management policy.

DEVELOPMENT OF A FORUM FOR INTERGOVERNMENTAL COORDINATION

- An intergovernmental agreement among the State of Arizona, the federal government, local governments, and Indian Tribes must be developed.

DEVELOPMENT OF AN EFFECTIVE FORUM FOR ACTIVE CITIZEN PARTICIPATION

- An Arizona Streams & Wetlands Council, composed of representatives of public interests concerned with the use, management, and conservation of streams and wetlands, should be created.

Arizona Natural Areas Study
Issues and Recommendations

Issue **ARIZONA STATE PARKS BOARD AWARENESS AND SUPPORT**

The Arizona State Parks Board has not taken advantage of the benefits such a program could provide nor has it given the Natural Areas Program the support and commitment the program warrants.

Recommendation The Arizona State Parks Board needs to provide the support and funding necessary to make the Arizona Natural Areas Program a viable, dynamic protection program and to reassess the program in terms of how it could interact within the agency.

Issue **NATURAL AREAS PROGRAM POLICY**

The current Natural Areas Program is so broad in scope that it is difficult to determine priority areas in need of protection.

Recommendation The goals and direction of the Arizona Natural Areas Program need to be clearly defined and a path charted to achieve those goals.

Issue **FUNDING**

Funding is a critical issue in the protection of the state's natural heritage and funding is needed for many elements such as planning and coordination, acquisition and management, restoration and research, and the staff needed to accomplish these responsibilities.

Recommendation The State of Arizona needs to secure adequate funding for a more aggressive Natural Areas Program to ensure a strong, statewide protection program.

Issue LEGISLATIVE AWARENESS AND SUPPORT
There is a general lack of environmental legislation in Arizona.

Recommendation The State of Arizona needs to increase legislative awareness and support for the need for natural areas protection.

Issue EDUCATION
There is a lack of an environmental awareness or ethic within the public and development community.

Recommendation The State of Arizona needs to actively seek opportunities to educate the public, planners, developers, government agencies, and others of the urgent need to protect the state's natural heritage now before more areas are lost.

Issue PROTECTION STRATEGIES
The protection of Arizona's natural areas will only be accomplished by making use of every conceivable option available.

Recommendation While continuing to utilize the considerable volunteer aspects of the current Natural Areas Program, the State of Arizona needs to also actively pursue other means of natural area protection, such as acquisition, dedication, conservation easements, cooperative programs, new sources of funding, etc.

Arizona Trails Plan

Issues and Recommendations

Issue Statewide Trail System
A comprehensive, integrated, statewide trails system does not now exist.

Recommendation The Arizona Hiking & Equestrian Trails Committee should seek passage of a state trails act which establishes legislative recognition, support, and protection of a statewide trail system.

Issue Funding
Decreased funding for trails over the last ten years has resulted in a deterioration of trail resources.

Recommendation The Arizona Hiking & Equestrian Trails Committee should take the lead in establishing a permanent Arizona Trails Fund as an element of the state trails act.

Issue Trail Volunteers
Volunteer programs for trail maintenance are not adequately funded or organized in many agencies.

Recommendation The Arizona Hiking & Equestrian Trails Committee should promote the expansion of current adopt-a-trail programs at all levels of government. Trail providers should establish part- or full-time trail coordinators.

Issue **Access**
Access to public trails has diminished, particularly near urban areas.

Recommendation Trail providers should consider the use of land exchanges, easements, donations, and acquisitions in securing trail access. The Arizona Hiking & Equestian Trails Committee should develop and disseminate a trails protection package.

Issue **Multiple Use Conflicts**
An increase in intensity and diversity of use has resulted in conflict between users on many trails.

Recommendation Trail providers should identify existing multiple use conflict on trails and establish strategies to resolve them.

Issue **Education/Promotion**
Poor trail ethics and inappropriate trail use has contributed to trail overuse and misuse.

Recommendation Trail providers should educate trail users on ethics, conflict, safety, and protection of natural and cultural resources. The Arizona Hiking & Equestrian Trails Committee should develop materials on trail ethics for distribution to trail providers.

Issue **Maintenance/Management**
Many trails in the State have unmet trails maintenance and reconstruction needs.

Recommendation Trail providers should use volunteers, service groups, and agency personnel to improve the maintenance of trails and trail heads. Trail providers should budget for adequate trail maintenance.

Arizona Outdoor Recreation Participation Study

ARIZONA RESIDENT SURVEY

- All activities, excluding tennis, baseball/softball, and skateboarding, showed increases in the percentage of Arizona resident population participating in the activity compared to 1976.

- The top ten activities ranked by the percentage of resident population who participated at least once in the activity are:
  1) hiking or walking for pleasure;
  2) picnicking;
  3) park or playground activities;
  4) swimming in a private pool;
  5) attending outdoor performance, visiting a zoo or outdoor amusement park;
  6) driving for pleasure or sightseeing;
  7) visiting historical or archaeological sites or monuments;
  8) attending outdoor sporting events;
  9) bicycling;
  10) swimming in a lake, river, or stream.

These activities have had relatively stable significance in the top ranked activities, although the percent of the population participating has increased dramatically.

- Attending activities, swimming, and land mobile activities dominate the top ten ranked activities. This is not surprising as these activities occur relatively close to home and seldom require specialized equipment.
- Lack of time is the major constraint to outdoor recreation participation by Arizona residents, although approximately one-third of theresidents express no limitations to participation
- Over one-third of respondents enjoy outdoor recreation because of opportunities to experience nature; approximately another twenty-five percent enjoy the health, stress reduction, and physical exercise aspects.

Future Participation Rates

- Forty-eight percent of all respondents anticipate spending more time in outdoor recreation pursuits in 1990, as contrasted with six percent who anticipate spending less time.
- A larger percentage of swimming enthusiasts believe their participation will stabilize than the percentage who believe they will increase their participation.
- The percentage of all respondents who say they were spending the same amount of time participating today as two years ago is equal (thirty-eight percent) to those who anticipate no change in participation in the future.
- Swimming, organized sports, and on-foot enthusiasts appear to be the least optimistic about increasing their level of participation in the future.

CHAPTER 2
STATEWIDE PROFILE

STATE FEATURES

The Human Community

Paleo-Indians, Arizona's first inhabitants, occupied the area as long ago as 12,000 years. The earliest known permanent settlements were built by the Anasazi, Hohokam, and Mogollon cultures. The Anasazi, ancestors of the present day Pueblo Indians, were pueblo and cliff dwellers and several examples of their villages are still intact in northern Arizona. The Hohokam who settled in the Gila and Salt River Valleys circa 1 A.D., were the first Indians known to build irrigation canals to water their crops. Thus began an agricultural tradition which has spanned almost 2,000 years and continues to play a vital role in Arizona's agricultural development. Many people believe today's Tohono O'odham (formerly known as Papago) and Pima tribes to be descendents of the Hohokam. The ancient Mogollon Indian culture developed in what is now eastern Arizona and New Mexico. The Apache and the Navajo Indians, perhaps Arizona's best known tribes, only migrated to the Arizona region from northern North America shortly before the arrival of the first European.

In 1539, the first European, Marcos de Niza, a Franciscan Friar, entered the region now known as Arizona. He made his way through the San Pedro Valley in search of the legendary Seven Cities of Cibola. Although he ultimately failed to achieve this goal, Marcos de Niza paved the way for others to follow and begin in earnest the exploration and settlement of the the region that would, eventually, become known as Arizona.

One year after de Niza's search for the Seven Cities of Cibola ended in failure, Spanish explorer Francisco Coronado set out from Compostela, Mexico with the same goal in mind. Although Coronado's party, weary and weak from hunger, eventually found Cibola, they were disappointed to find, not the golden city of legend, but rather a simple, stone Pueblo building crowded with Indians.

In 1692, Father Eusibio Kino, a Jesuit priest, travelled the Arizona region extensively. He made friends with the Indians and established missions in the area. Spanish troops established the region's first settlement, a fort at Tubac, in 1752. Later, in 1776, the Spanish took over an Indian village called Stook-Zone. Stook-Zone ultimately became Tucson, Arizona's second largest city today.

In 1821, as a result of the Mexican War of Independence from Spain, the region became part of Mexico. Until the advent of the Mexican-American War, the region was to remain wholly under Mexico's rule. Under the provisions of the Treaty of Guadalupe-Hidalgo in 1848, signed to end the war between Mexico and the United States, the Arizona territory, as far south as the Gila River, became a part of the Union. After the signing of the Gadsden Purchase in 1853, the region south of the Gila River to the present state boundary was added creating Arizona as we know it today. Ten years later, in 1863, John S. Goodwin became Arizona's first territorial governor.

During this early period of western migration in Arizona, the people lived in almost constant fear of Indians. Although many tribes conducted raids on white settlements, the two most feared were the Apache and Navajo tribes. After an exhaustive campaign lead by the famous Indian scout, Kit Carson, the Navajos were finally defeated in 1863. The Apaches, however, continued to plague the area with raiding bands led by such famous figures as Cochise, Mangus Coloradas, Victorio, the Apache Kid, and Geronimo. The last Apache encounter was in 1886 when the 57 year old Geronimo finally surrendered.

With the development of several irrigation projects, farming began to emerge as an important economic mainstay in the Salt River Valley as early as 1867. As farming and ranching progressed, Arizona experienced a "boom" period which led the territory to be peppered with small towns filled with people seeking opportunity and fortune. In 1877, the Southern Pacific Railroad made its first excursion into Arizona. The Arizona Territory, it seemed, was rushing headlong into statehood.

After two failed attempts, Arizona became the 48th State on February 14, 1912. Under the leadership of its first governor, George W. P. Hunt and with the benefit of federal assistance, the State began to develop numerous dams and irrigation systems. The largest of the many dams built over the years is Hoover Dam. Situated on the Colorado River, the dam was completed in 1936. The development of Arizona's water resources encouraged and stimulated the state's economy to grow with unexpected vigor.

The wartime economy caused by World War II saw the demand for Arizona's products, most importantly cotton, cattle, and copper, to increase significantly. Also, the population nearly doubled in the matter of a decade.

Because Arizona's climate provided ideal, year-round flying weather, several military training bases were built and a large number of military personnel was imported. Many of those stationed in Arizona during the war returned to establish post-war home in the State they had grown to love. One factor which made Arizona attractive to the new "settlers" was the advancement in technology to the point where the harsh climate could be somewhat controlled (ie: air conditioning and water control). Initially, this migration was mainly limited to the larger urban areas where water was more readily available.

Many corporations also found it advantageous to locate in Arizona. In the post-war period, Arizona began to be a favorite spot for manufacturing giants. This remains true today as the growth of Arizona's manufacturing industry exceeds that of the nation as a whole. Arizona has also capitalized extensively on its wonderful climate and tourism has become one of the State's most important businesses. These two factors, when coupled with continued agricultural expansion and other economic ventures, account for much of Arizona's phenomenal growth.

Today, Arizona is a symbol of growth and progress in the west and the nation as a whole. Its young and spirited population sustains an ever-expanding economy. Cultural and educational opportunities abound. Such a state, as an imperative, must have much to offer to its growing, active population with regards to recreation. A remarkable climate and topography contribute to the boundless variety of leisure time activities engaged in by residents and visitors throughout Arizona.

Arizona's Natural Environment

Nature has endowed the State of Arizona with a unique and diverse environment. The state's rich natural attributes present a vast and assorted backdrop for outdoor recreation. The Arizona environment presents recreation opportunities for users of all ages and interests. However, the combination of great natural diversity and high demand combine to create tremendous challenges for the many agencies and individuals charged with the responsibilities of managing the State's outdoor recreation resources.

With 113,575 square miles of land surface and 334 square miles of water surface, Arizona ranks as the sixth largest state in the country. Its land mass is greater than that of West Germany or Great Britain and all of New England and New York could fit within its borders. Located in the southwestern portion of the United States, Arizona shares common borders with Mexico on the south, California and Nevada on the west, Utah on the north, and New Mexico on the east. Colorado is also but scant feet away where, in Arizona's northeast corner, the two states join with Utah and New Mexico to converge at the Four Corners Monument. This is the only place in the United States where four states meet at a common point.

Arizona's climate has not only played a major role in the State's population and economic growth, but also significantly shapes the environments of many outdoor recreation activities. Variations in the State's physical geography have a direct bearing on its climate. The three basic climatic zones; desert, steppe, and highlands (Daubenmire), cause temperatures to vary from below zero in the higher elevations in the winter to well over 110 degrees Fahrenheit in the deserts during summer. Arizona often has the distinction of having the warmest and the coldest temperatures reported in the United States on the same day. The State's highest recorded temperature was 127 degrees Fahrenheit in Parker on July 7, 1905, and the lowest recorded temperature was 40 below zero degrees Fahrenheit at Hawley Lake (elevation 8,150 feet) on January 7, 1971.

The desert zone encompasses the entire southern part of the State as well as a corridor in the west bordering the Colorado River. This zone, occupying nearly one half of the State, is characterized by wide valleys interspersed with mountain ranges. Phoenix and Tucson, the State's largest cities are located in this zone. The elevation of the desert plains and valleys range from near sea level to 2,000 feet or more in the mountainous areas. While the desert mountains are generally less than 2,000 feet high, some exceed 7,000 feet in elevation. The low and barren mountain ranges of the southwest are separated by broad desert basins. This arid region of the State gets little rain and displays only sparse vegetation.

The steppe zone is located in northern Arizona and covers approximately 40% of the State. It consists of a series of plateaus with fairly level surfaces, among them is the Colorado Plateau, indiscriminately marked by a few craggy, peaked mountains and rough canyons. Most notable among the mountains is the rugged San Francisco range in Coconino County where, just outside of Flagstaff, Humphrey's Peak rises 12,670 feet above sea level. The deepest gorge is the mighty Grand Canyon, one of nature's greatest wonders and a monument of man's true insignificance. Some of the largest ponderosa pine forests in the United States can be found in the higher, cooler areas of the steppe zone. Although much of this mountainous area is forested, this zone also supports dry deserts with little vegetation. In the northeast, strange, awe-inspiring rock formations extend upward from the floor of a broad valley creating Monument Valley.

In the plateau, recreational opportunities are closely related to the seasons. In the winter, the weather lends itself naturally to cold weather and snow oriented activities such as skiing, sledding, and snowmobiling. In contrast, the cool mountain air and abundant forests provide relief for those seeking to escape the heat of the desert during Arizona's typically hot summer months. Non-residents as well as Arizonans recognize the recreational opportunities of this area. The number of scenic attractions and the various ancient Indian ruins are particularly popular with tourists.

Providing a transition between the deserts and the steppes are the highlands which are located in the central portion of Arizona. This area is often referred to as the Mogollon Rim (pronounced mug´-ee-own) even though it is wider than just the "rim" itself. This steep, rock escarpment falls almost 2,000 feet and extends for over two hundred miles from central Arizona into southwestern New Mexico. This zone is characterized by its rugged mountains running northwest to southeast and its vast stands of tall trees in the north and mixed conifers and desert vegetation in the south. Although generally lower in elevation, the topography of the Mogollon Rim is more rugged than that of the plateau.

Low humidity and an abundance of sunshine are just two of the positive attributes of Arizona's climate. Fog is uncommon and winds are usually light. In short, Arizona's climate allows a unique and enviable opportunity to participate frequently in outdoor recreational activities.

Lack of precipitation in the desert zone allows more comfort during extreme temperatures than would be the case in more humid zones. Rain that does fall in this region tends to occur in two distinct seasons, winter and summer.

Moisture for the state's winter rains comes from northerly directions and is associated with westerlies which bring Polar Pacific moisture to the state through Washington and Oregon. Winter precipitation tends to be more gentle in nature than that which occurs in the summer.

Summer precipitation generally falls between mid-May and mid-October though May and June can be totally without rain. Rain that falls during this season is often associated with thunderstorms which are usually intense and localized rather than widespread. This season of precipitation is known as the monsoons. Moisture is provided by air masses from the Tropical Atlantic (Gulf) or the Tropical Pacific. The Pacific moisture is sometimes derived from the edges of Mexican west coast hurricanes.

Geology and Mineralogy

The geologic history of Arizona is varied and long, spanning over two billion years. Portions of the state have been mud flats, ocean bottom, level plains, and the scene of intense volcanic activity. These actions and erosional processes have combined to form some of the most beautiful scenery in the world which serves as a constant enticement to hikers, campers, and sightseers. The Grand Canyon, Chiricahua National Monument, Petrified Forest, Oak Creek Canyon, and the Barringer Meteor Crater are outstanding examples of Arizona's spectacular geologic features.

Arizona's mountains and plains are rich in mineral deposits. The first mineral discovery was made by Antonio de Espejo during an expedition into the Verde Valley in 1582-83 when he discovered a silver deposit. Although copper has become a trademark of Arizona, the state has many other mineral resources among them: gold, lead, barite, zinc, uranium, turquoise, opal, coal, and many others.

Rock and mineral enthusiasts the world over go to great lengths to search out prime, Arizona specimens. The area south of the Quartzsite community in the western part of the state is one of many havens for rock hounds. Numerous gem and mineral clubs and societies in Arizona actively pursue their outdoor recreation on a year round basis.

Vegetation

Because Arizona is considered a "desert state", many people wrongly believe that only cacti and scrub brush are capable of growing here. In contrast to this misconception, however, six of the seven life zones identified by C. Hart Merriam can be found in Arizona. Some of the nation's largest forested areas, even larger than those found in Maine or Wisconsin, are located in Arizona. More than 25% of Arizona's landscape or some 20 million acres, are forested. Generally the forests are located in the mountainous region that generally bisects the state from the southwestern New Mexico border northwesterly to the San Francisco range near Flagstaff. The longest, unbroken stand of ponderosa pine in the United States is located along the Mogollon escarpment.

At timberline, on the San Francisco Peaks the bristlecone pine still thrives. Many of these trees took root over one thousand years ago and researchers have verified that some bristlecones have reached ages in excess of 4,500 years. This rivals the age of the oldest of California's Sequoias.

Below timberline, the large, robust Engelmann spruce, the prodigiously tall Douglas fir, and the white trunked aspen share in dominating the landscape. In the next stratum, the great ponderosa pine forests of Arizona are found. Still lower in elevation, the lopsided juniper and the scraggly pinyon pine are predominant. In the lowest elevations the mountainous areas give way to chaparral-oak woodlands and Sonoran desert vegetation.

It is, perhaps, for its Sonoran desert vegetation that Arizona is best known. This hardy vegetation covers more than one third of the State. Prickly pear, and cholla cactus as well as palo verde, yucca, and agave, all serve to enhance the slopes of low mountain ranges. On the alluvial slopes and plains, a wide variety of cacti live a desolate but durable life on the arid desert.

The saguaro, the proud symbol of the Arizona desert, is the largest of all North American cacti and its blossom is the State flower. Interestingly, the saguaro begins its lifespan in the shade of other plants. After ten years, a saguaro will stand only two feet tall, usually high enough to supplant its host. After a period of about 50 years has elapsed, a saguaro will stand six feet tall and after 75 years the first arms are produced. Most saguaros attain a height of 35 feet only after a century of growth. Some saguaros reach heights of over 50 feet and weigh more than ten tons. The saguaro cactus may live to be 250 years old or more.

The cactus is not the only plant that has adapted well to the heat and aridity of the desert. Desert stream beds are lined with the deep rooted mesquite, catclaw, desert willow, crimson blossomed ocotillo and the yellow flowered palo verde. Outstanding exhibits of these and other Arizona flora can be seen at the Arizona-Sonora Desert Museum near

Tucson, Boyce Thompson Arboretum near the town of Superior, Desert Botanical Garden in Phoenix, and Saguaro and Organ Pipe Cactus National Monuments.

Land Ownership

Arizona is blessed with an abundant supply of land suitable for a great diversity of outdoor recreation. Much of the State's most valuable resources are owned by State and Federal entities or local units of government. In fact, of Arizona's total land base, over 88 percent is held by Federal, State, and local government agencies or falls under the jurisdiction of Indian tribes.

The federal government has ownership of 44.1 percent (31.9 million acres) of the land in Arizona and various agencies including the U.S.D.A. Forest Service and the U.S.D.I. Bureau of Land Management are responsible for management duties. Indian Reservations account for 26.1 percent of Arizona's land with the Navajo Reservation being the largest. The State of Arizona owns only 12.8 percent with the remaining 17 percent belonging to communities, organizations, corporations, and private individuals.

Much of Arizona's government owned land is available to the public for recreational use. The Forest Service, National Park Service, U.S. Fish and Wildlife Service, Bureau of Land Management and State of Arizona Lands all have large areas that are available for recreation. For example, the Forest Service manages 11,270,714 acres in National Forests in the State. These National Forests provide opportunities for picnicking, camping, boating and other developed recreation. Other, undeveloped areas are open to dispersed recreation such as hiking and backpacking.

Of course, not all of the lands normally considered to be in public ownership actually are available for upbilc access and neither are they developed to support recreation. Recreational access at most military installations and Department of Defense lands, for instance, is strictly controlled and often restricted. State Trust Lands, which are managed for their maximum income to support the trust for public schools, cannot be considered to be truly public lands as they are open for recreation only through formal lease arrangements or by special permit. Large areas of the Indian Reservations are under strict supervision and public access is limited. Many of these "public lands" possess tremendous natural resource attributes and have enormous recreation potential, should they ever become available for public utilization.

Public lands are spread throughout the State and all 15 counties have significant amounts within their boundaries. The dispersion of public land holdings is a result of the original federal sectioning of land for public purposes. This system has created management problems for federal and state agencies due to the "checker board" pattern of their current holdings. Unconsolidated ownership often precludes use of these lands for recreation.

Arizona's system of water rights and land ownership also poses barriers to effective planning for outdoor recreation. Unlike many states where water is considered within the public domain and cannot be owned or controlled by adjacent land owners, surface water in Arizona is subject to the principle of appropriation or vested rights for development needs (irrigation, power, etc.) of property owners. The diversion or withdrawl of water for these uses lessens the availability of downstream flows for other potential users.

The right to use water only accompanies legitimate land ownership and the availability of unappropriated flows at the location of need. Unfortunately, the morass of legal entanglements over water rights is a severe deterrent to planning for future water-based recreation needs in Arizona.

Ecology and Environmental Concerns

The utilization of natural resources for recreational pursuits has been the subject of much attention and disagreement. Outdoor recreation has fueled a passionate dispute with extremist views on both sides, complete indifference on one hand and an utter hatred for any and all human contrived disruption of the native environment on the other. Often the dichotomy of views on the issues prevents any positive action.

The most dramatic example of ecological imbalance resulting from human manipulation occurred on the Kaibab Plateau in the northwest part of the State. A combination of factors, including logging, predator control and restrictions on hunting, created unnatural conditions which were extremely favorable to the deer population. With an abundance of food and relatively little pressure from predators, deer numbers rapidly increased beyond the area's ability to sustain them. Numbers remained high while vegetation declined toward a climax condition resulting in a reduction of available forage. Choice plant types became scarce and less common food species were utilized heavily. As a result the deer population tumbled. Evidence of the severe range damage which occurred during the peak deer populations can still be seen in some areas. Other changes in the ecological balance, some favorable some not, have resulted from the logging of the coniferous forests and the irrigation of the desert for purposes of agriculture.

As the state developed historically, the damming of the water courses created drastic changes for many species of wildlife, particularly those animals which depended on permanant streams for their habitat. One of the heavily impacted species, the squawfish, has been severely depleted. Once plentiful, the large fish, which often approached lengths of six feet and weights of 100 pounds or more, is now extremely rare. However, many man-made dams constructed over the years have provided new lakes where fish plantings by the Arizona Game and Fish Department have resulted in increased sport fishing opportunities. As living testament to the success of such programs, rainbow trout have, in the waters below the high dams of the Colorado River where the water is sufficiently cold, grown to 18 pounds. In Lake Powell, which was only recently filled, thousands of rainbow exceed 20 inches in length.

The survival of some species is of international concern. The Sonora Pronghorn antelope is found in this country almost solely on the Cabeza Prieta Game Range in Yuma and Pima counties. The remainder of its range is in the adjacent Mexican State of Sonora. Because it roams back and forth across the international border, its survival is a matter of concern both to the United States and to Mexico.

The Secretary of the Interior is responsible, by law, for management of all migratory birds and for identifying, protecting and propagating native species of fish and wildlife that are threatened with extinction. As defined in Public Law 89-669, a species is regarded as being in danger of extinction whenever its habitat is: "...threatened with destruction, drastic modification, or severe curtailment, or because of other factors, and that its survival requires assistance." The Land and Water Conservation Fund makes funds available for the acquisition of land as part of its support for the program. The Endangered Species Preservation Act of 1966 provided for an official listing of native fish and wildlife threatened with extinction. This list has been published by the Secretary of the Interior after consultations with the states, interested organizations, and individual scientists.

With the implementation of protective laws and proper management and supervision, both hunting and fishing can be useful tools in fostering and maintaining a reasonable ecological balance. Outdoor recreation should be compatible with the natural environment, and, through education and planning, both can co-exist.

Arizona's Economy

Outdoor recreation is affected by socio-economic factors in many ways. The level of personal income enjoyed by a group of people, for example, is a major factor in determining the type of recreation activity they will demand as well as the frequency of their participation. Being cognizant of Arizona's economic trends will facilitate decision making in our changing global economy.

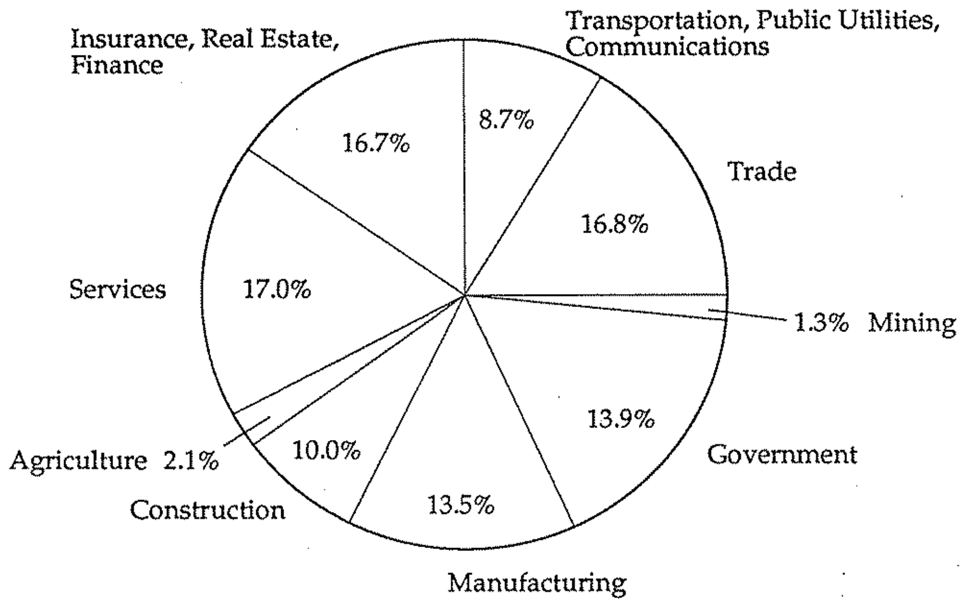
Arizona, like the nation, is in a state of transition. Two-thirds of the jobs created nationwide since November 1982 are in the service-producing sectors. The economy is being restructured from a goods-producing economy toward a more service-based economy. In Arizona, business services such as temporary employment agencies, public relations, advertising and janitorial services, as well as hotels, trade and financial services are the fastest growing. Historically, Arizona has relied on the 3 C's-cotton, copper, and cattle as the foundation of the economy. Today, while these industries still play a role, other industries are much more important. In 1986 ,the service sector's share of the state's economy was 17 percent while agriculture was two percent, just more than that of mining (Figure 1).

One of the myths associated with the Arizona economy is the importance of tourism. Tourism is often heralded as the states second largest industry. But the sort of data that allows for meaningful comparisons does not exist on tourism. This fact raises a point: no data exists to support the claim that tourism is the state's number two industry. Nonetheless, there are ways of determining the size of various industries. One way is the measurement of gross state product (GSP)- the gross market value of goods and services attributable to labor and property located in a state. This measure is similar to the gross national product.

According to GSP, of the nine major industries in Arizona, the largest are services, trade and FIRE (finance, insurance, real estate). The next major industries are government and manufacturing. The smallest industries are agriculture and mining. Tourism is not measured as an industry of its own; but one component that is measured- hotels and lodging- has been one of the slowest growing sectors during the 1980s, accounting for only one percent of the GSP. In terms of employment, tourism accounts for 5.5 percent of the state's total employment- hardly qualifying it for the distinction of Arizona's second biggest industry. Nonetheless, tourism is important to Arizona's economy.

Figure 1

ECONOMIC ACTIVITY BY INDUSTRY
Share of Gross State Product



Source: U.S. Department of Commerce, Bureau of Economic Analysis

In 1987 Arizona ranked among the leading states in three important economic indices of growth (Figure 2):

Growth of Personal Income
Growth of Population
Growth of Non-Farm Wage and Salary Employment

Arizona experienced a 204 percent growth in personal income between 1977 and 1987 which ranked first in the nation. Arizona's growth in population for the same period was 39.5 perecent which was second in the nation while growth of non-farm wage and salary employment rose 71 percent for a number one national ranking.

Many factors contribute to a growing healthy economy. One of those factors is quality of life. Though difficult to measure, it is becoming increasingly important. For example, corporations look at quailty of life when considering relocation decisions. Cities and towns are finding it difficult to retain employers in areas where the quality of life is being eroded. In Arizona, outdoor recreation opportunities enhance quality of life, and quality of life enhances the economy. Therefore, it is important to keep in mind the economic impacts outdoor recreation opportunities offer Arizona.

Figure 2

GROWTH OF PERSONAL INCOME
(In Thousands)

Rank	State	1977	1987	% Change
1.	**Arizona**	**$ 15,623,000**	**$ 47,502,000**	**204.1%**
2.	New Hampshire	6,004,000	18,110,000	201.6
3.	Florida	61,394,000	183,239,000	198.5
4.	Nevada	5,652,000	16,074,000	184.4
5.	Georgia	32,070,000	87,720,000	173.5

Source: U.S. Department of Commerce, Bureau of Economic Analysis and Bureau of the Census; Valley National Bank Planning Division; and U.S. Department of Labor, Bureau of Labor Statistics.

GROWTH OF POPULATION

Rank	State	1977	1987	% Change
1.	Nevada	678,000	1,007,000	48.5%
2.	**Arizona**	**2,427,000**	**3,386,000**	**39.5**
3.	Florida	8,889,000	12,023,000	35.3
4.	Alaska	396,000	525,000	32.6
5.	Utah	1,316,000	1,680,000	27.7

Source: U.S. Department of Commerce, Bureau of Economic Analysis and Bureau of the Census; Valley National Bank Planning Division; and U.S. Department of Labor, Bureau of Labor Statistics.

GROWTH OF NON-FARM WAGE AND SALARY EMPLOYMENT

Rank	State	1977	1987	% Change
1.	**Arizona**	**809,300**	**1,383,700**	**71.0%**
2.	Florida	2,933,200	4,852,500	65.4
3.	Nevada	308,200	499,000	61.9
4.	New Hampshire	337,100	513,600	52.4
5.	Georgia	1,926,400	2,763,300	43.4

Source: U.S. Department of Commerce, Bureau of Economic Analysis and Bureau of the Census; Valley National Bank Planning Division; and U.S. Department of Labor, Bureau of Labor Statistics.

ARIZONA RIVERS, STREAMS, & WETLANDS

Introduction

Arizona is one of the most arid of the fifty United States. Its name is often thought to come from the phrase "arid zone," but historical reports attribute it to the word arizonac, a derivation from Tohono O'odham words, ali meaning "small" and shonak meaning "place of the spring." So according to historical documents, Arizona actually means "place of the small springs." In reality, its rivers, streams, and wetlands — virtually the only natural aquatic environments in the state — cover less than 0.5 percent of its landscape. As a critical component of Arizona's desert biosystem, these surface waters deserve special attention by state and local policy makers and by the public at large.

Arizona's desert streams are often outlined with a band of green vegetation cutting through the earth-toned landscape. These stream beds may carry water year-round, seasonally, or only during storm run-off. Also present in Arizona, though rare, are nonstream wetlands known as cienegas. The riparian areas that border stream courses and cienegas constitute the most diverse and productive plant communities in the state. These waters and their adjoining riparian areas are prime habitat for fish and wildlife; here are found both the greatest diversity of species and the greatest abundance of individual animals. Indeed, almost all species in the state rely in some form on streams and wetlands for survival.

Humans also depend on these surface waters for their well-being; it is no accident that nearly all of Arizona's cities and towns were founded along waterways. Commerce, in the guise of early agriculture, cattle ranching, and mining, also followed waterways. Since the early days of settlement, many streams have been degraded, but they still perform a variety of functions that are essential to the state's citizens. They channel floods and recharge critical groundwater supplies; they provide water for agriculture and livestock; their valleys serve as avenues for roads and railways.

Arizona's waterways are also becoming increasingly important as recreational resources. Arizonans and visitors alike have come to view these waters as refreshing and revitalizing contrasts to urban and desert landscapes. In ever-growing numbers, people are pursuing water-related activities such as boating, tubing, hunting, fishing, hiking, and swimming. Rivers and streams also provide desirable opportunities for more passive pursuits including picnicking, camping, nature study, and general sightseeing.

In response to growing and changing recreation demands in the state, the Arizona State Parks Board initiated a major update of the Arizona State Comprehensive Outdoor Recreation Plan in 1987. Recognizing the importance of waterways to the state's overall outdoor recreation program, State Parks elected to focus a substantial portion of its efforts on a recreational and environmental evaluation of streams and wetlands. The Arizona Rivers, Streams, & Wetlands Study is the result of this initiative.

The basic objectives of the study were to: (1) determine the role that streams and wetlands can play in meeting Arizona's growing recreational needs, (2) identify problems pertaining to streams and wetlands recreation, and (3) recommend actions that might be taken to enhance future recreational use of these important and limited resources.

The study's fundamental conclusion is that Arizona's rivers, streams, and wetlands can provide a wide variety of high quality outdoor recreation experiences for both residents and visitors. However, careful planning will be required to address the intense competition for water resources and to coordinate the variety of water interests and water management authorities. If Arizona's waterways are to play a significant role in the state's recreational future, effective communication among water users and managers will be essential. The Arizona Rivers, Streams, & Wetlands Study recognizes the importance of this and has therefore made communication a primary focus of the conceptual management plan that is offered at the conclusion of the report.

Arizona's Streams & Wetlands — A Resource Heritage at the Crossroads

Recreational Significance of Streams and Wetlands

Arizona's streams and wetlands are vitally important as outdoor recreation resources. Over half a million of the state's residents fish and over one quarter million hunt. Without streams and wetlands, both of these recreational activities would be severely restricted. Perennial streams provide essential habitat for a variety of cold and warm water game fish. Anglers for both trout and largemouth bass, two of the most popular game fish, can find a number of streams in Arizona that will challenge their skills and provide ample return. Smaller mountain streams, many of which are located in National Forests, provide opportunities to fish for rainbow and the native Arizona trout. Larger streams, including the Colorado River below Glen Canyon Dam, East Verde River, and Eagle Creek, also possess significant coldwater fisheries. Significant warm water fisheries include the Colorado River downstream of Lake Mead, the Gila River, and the Salt River.

Hunters also are attracted to streams and wetlands. Waterfowl, big game, and upland game species all can be found in the riparian areas adjacent to these waters and often in greater numbers than in other, less hospitable habitats. In addition, some eighty percent of Arizona residents consider themselves to be "non-consumptive" wildlife users; that is, they find pleasure in simply observing or photographing wildlife. Again, given the density of living creatures along watercourses, these areas are often the destination of choice for those wishing to observe birds and other wildlife species.

In 1987, one-third of the state's residents participated in camping; one-quarter participated in either hiking or backpacking. Federal land managers in National Parks and Forests report that stream corridors are immensely popular for these activities. Some stream courses, such as Aravaipa and Paria Canyons, provide superlative wilderness experiences. Other streams, including Sabino and Fish Creek, also offer opportunities for either day or overnight hikes. Oak Creek Canyon and parts of the Verde and Blue Rivers, among others, are popular areas for family tent or recreational vehicle camping.

Boating and tubing are becoming increasingly popular in Arizona. The Grand Canyon of the Colorado River is one of the finest and most popular whitewater boating rivers in the world. Other sections of this river offer quality canoe touring, jet boating, and water-skiing. Whitewater boating is also becoming increasingly popular on the Salt, Verde, Gila, and Little Colorado Rivers, and other smaller and sometimes seasonal rivers. Recreational boating on the Salt River, as one example, has been increasing annually by approximately half over the past few years.

Tubing is a fairly recent phenomenon. The Salt River downstream of Saguaro Lake is the premier example of this recreational activity. More than 20,000 people from the Phoenix metropolitan area visit on any given summer Saturday or Sunday to enjoy this and other recreational pursuits.

Sabino Creek, near Tucson, is another example of a stream that is receiving high recreational use from the residents in the adjacent urban area. On this small stream, thousands of people visit annually to picnic, hike, watch birds, and otherwise enjoy nature.

A Resource in Crises

In its native condition, Arizona's landscape was not as parched as what we experience today. Little more than a century ago, rivers and streams flowed year around in nearly every area of the state. The Santa Cruz River in Tucson, the Salt River in Phoenix, and the Gila River in Safford were, at one time, all perennial streams. For centuries, these and other perennial streams had been the mainstays of native American cultures. Later, Hispanic and fledgling Anglo-American communities relied on the streams. Perennial streams and the extensive riparian forests that they supported provided water for domestic needs, fish and game for food, pelts for clothing and trade, fertile soils and water for agriculture, water and forage for livestock and industry, and wood for lumber, fence posts, and fuel.

Over the past century, Arizona has lost much of its rich natural heritage. Moreover, there is no indication that this trend is abating. Expanding requirements of agriculture, mining, industry, and cities have redesigned the state's streams and wetlands. Flows in all of our major rivers and many of the lesser streams have been impounded, regulated, and diverted. Perennial streams and wetlands have disappeared as groundwater pumping drained the water from underlying aquifers and land use practices altered the surface hydrology. Many of these activities served a beneficial public use, such as flood control, water storage, or power production. Unfortunately, others simply resulted from poor or uninformed land use and management actions.

Regardless of cause, the restructuring of Arizona's native stream and wetland system has resulted in drastic alterations to natural values. Most telling has been the impacts on native fish and wildlife. Native fishes, the fastest disappearing wildlife group in the United States today, have suffered the most. Due to diminished and altered streamflows, one of Arizona's thirty-five species of native fish is now extinct, five others are gone from the state, and twenty-one of the remaining twenty-nine species are officially listed as federally threatened or endangered or are under consideration for this dubious distinction. While the major threat to Arizona's native fish is human competition for water, the introduction of many non-native fish species and pollutants into our streams has also compromised native populations.

Along with the loss of stream flow has come major destruction and alteration of the riparian areas that border the state's streams. While much of this has been a direct result of the loss of water, other activities, including wood harvest, grazing, urbanization, and the introduction of exotic plant species, have also contributed to the degradation of riparian areas.

It is estimated that only five to ten percent of Arizona's original native riparian areas in the lower elevations remains today. As a result, riparian communities now comprise only a very small portion of the total Southwestern landscape, between 0.1 and 0.5 percent. Riparian areas are now Arizona's most threatened natural communities. Cottonwood-willow gallery forests, which once formed lush canopies along all of the state's major desert river systems, are now the rarest forest type in North America. Mature mesquite bosque stands have suffered similar declines and are now the fourth rarest plant community in the United States. This change in habitat has resulted in significant changes and reductions to native animal and bird species and therefore had a decidedly negative effect on recreational hunting.

Fishing and hunting are not the only recreational activities to suffer from degradation of stream resources. Without adequate flow, boating is impossible; without healthy vegetation, campers lose shade and scenic quality suffers. Clearly, there is a relationship between environmental quality and diversity of recreational opportunities; a relationship that must be taken into account in planning for future stream and wetland recreation.

The Future for Stream and Wetland Recreation

Given the importance of water and its scarcity in Arizona, one can only conclude that the continued wise use and conservation of Arizona's streams and wetlands is in the best interests of all the citizens of the state.

In planning for the recreational use and conservation of their streams and wetlands, Arizonans must address a series of urgent resource, policy, and management issues. Many of the resource issues have been discussed above, In essence, the availability of stream and wetland resources is already severely depleted through previous actions. In addition, the supply and quality of these resources continue to diminish, chiefly from the loss of water to competing water uses and from land use practices that destabilize riparian communities. Paradoxically, as the water base for recreation diminishes, the population continues to grow at a rate that is among the highest of any state in the nation and the demand for stream and wetland recreation also accelerates.

From these resource issues emanate a number of policy and management issues. Paramount is the growing need to address the use and management of our remaining stream and wetland resources in a comprehensive and forward thinking manner. From a policy perspective, there are no means to balance competing uses and conserve significant streams and wetlands. From a management perspective, there exists no institutional framework for statewide planning for stream and wetland use and conservation, nor for communication and coordination between the various water management authorities.

A number of obstacles stand in the way of such policy and management arrangements. Multiple and sometimes conflicting resource use demands are, of course, among these. Another is the multitude of management authorities, which include private, local, state, federal, and tribal entities, who are in a position to make decisions that affect not only their own interests, but those of others.

Wise waterway management aimed at meeting multiple demands, including providing for quality recreation for Arizona's citizens and visitors, will require cooperation among all levels of government, private interests, and concerned citizens. An effective solution will require: (1) statewide policies to guide actions by the various management authorities, (2) improved mechanisms for communication and coordination, and (3) a timely strategy to arrest further unacceptable degradation of those streams and wetlands that retain natural values and provide quality recreational opportunities. Former Governor Bruce Babbitt recognized the need for a comprehensive program to address issues pertaining to the state's waterways. In his forward to the First North American Riparian Conference held in Tucson in 1985, he wrote:

> *What is needed is the implementation of a comprehensive legislative mandate for the protection, conservation, and rehabilitation of riparian ecosystems. Previous efforts have addressed only pieces of the whole. Legislation must include all aspects of riparian systems and address all levels of involvement—federal, state, local, and private—to be effective.*

Arizona has ignored the growing need to comprehensively address the use and management of our remaining stream and wetland resources for a long time. In the interim, these resources have suffered much damage and loss. This study was initiated because there is a growing understanding among the leaders and citizens of Arizona for the need to take positive action on stream and wetland issues, and was designed to give impetus and direction to that effort.

Study Process

The Arizona Rivers, Streams, & Wetlands Study seeks to both clarify the state's waterways issues and to suggest possible strategies to ensure that recreation and resource conservation will be fully considered in future water management decisions. To accomplish these ends, the study had two basic elements: first, an inventory of existing information regarding stream and wetland resources and their management, and second, the development of a conceptual plan for future management of these resources.

To provide guidance for this study, the Arizona State Parks Board organized a Streams and Wetlands Advisory Core Group. This group was made up of knowledgeable individuals representing recreation and conservation interests, federal land management agencies, and state resource agencies. The role of the Advisory Core Group was to provide the study team with technical information about the status of stream and wetland recreation in Arizona, clarify major recreation issues, and identify potential solutions for these issues. Five meetings of this group were held between September of 1987 and March of 1988. A final meeting in August of 1988 allowed the Advisory Core Group to critique the final draft study report.

Inventory information and opinions about the conceptual management plan were also solicited from resource managers with the Bureau of Land Management, U.S. Forest Service, National Park Service, U.S. Fish & Wildlife Service, and state agencies including the Arizona Department of Water Resources and the Arizona Department of Mines & Mineral Resources. Twenty-eight states known to have stream or wetland programs were also contacted for information about their laws, policies, and programs.

Input was also provided by the public through a series of public meetings held throughout the state where the draft study findings were made available and discussed.

Study Findings

In summary form, the study's basic findings are as follows:

Resource Significance

Economic Significance

Arizona's streams and wetlands are economically vital to the commerce and industry of the state. They are also unequalled for their natural abilities to minimize flooding, prevent erosion, and enhance water quality; and are essential conduits for groundwater recharge.

- Fifteen million tourists visit Arizona annually.

- Water-based recreation is a major component of the tourist industry.

- Tourism generates over five billion dollars of income annually, the second largest source of income in Arizona.

- Recreation is a sustainable industry because it is based on renewable natural resources.

- Streams and wetlands play a vital role in the protection of property from natural hazards. In recognition of this, Pima County has enacted tough controls to protect remaining natural riparian drainages as a measure to greatly reduce the danger of future floods.

Cultural Significance

Streams and wetlands have been essential to the survival and social well-being of Arizona's people since the beginnings of prehistoric settlement. Today, they continue to be critical to the quality of life for which Arizona is renowned.

- Nearly all communities in Arizona can trace their origins to a stream or wetland that provided sustenance for life and the early tools for development.

- Many of the state's most significant archaeological sites are located along waterways.

Environmental Significance

Natural streams, their associated riparian areas, and other wetlands constitute the state's richest environments in terms of the wildlife and fish diversity and plant and animal productivity.

- At least sixty percent of the vertebrates in the Southwest are dependent in some capacity on streams or wetlands.

- All of Arizona's twenty-nine remaining native fish species depend solely on streams and wetlands for their survival.

- More bird species nest in the cottonwood-willow riparian community than in any other North American vegetation type.

- Pima County has enacted tough controls to protect remaining natural riparian drainages as a measure to greatly reduce the danger of future floods.

Recreational Significance

Streams and wetlands afford some of the most popular, diverse, and exceptional recreational opportunities, such as boating, fishing, hunting, camping, and hiking, in Arizona. These opportunities are vital to Arizonans.

- Nonconsumptive wildlife users in Arizona number almost 2,000,000.
- Over 812,000 Arizonans camp and over 620,000 Arizonans backpack.
- Arizona hunters number 225,000; anglers number more than 505,000.

Resource Issues

Decreasing Resource Availability and Quality

Substantial losses in perennial streamflows and up to ninety-five percent loss of natural wetlands have resulted in dramatic losses — including some extinctions — of native fish and wildlife populations, accelerated soil erosion, degraded surface and groundwater quality, reduced groundwater recharge, and lost recreation values.

Increasing Resource Demands

The importance of the state's diminishing streams and wetlands has increased greatly due to population growth, to expanded participation in water-based recreation, and to additional needs for water and watershed resources.

- The number of registered boats has tripled since 1969.
- All land and resource management agencies report increasing use of water-based recreation sites.
- Population in Arizona has grown from 499,261 in 1940 to 3,386,000 in 1987; an almost seven fold increase.

Increasing Conflict for Streams and Wetlands Use

Growing demands for the use of streams and wetlands and associated water supplies have led to sharp competition for and conflict over these diminishing resources.

- A 1985 statewide survey of Arizona residents revealed that "competition for water" and "water conservation" were issues of greatest concern.

Recreation Dependent on Environmental Quality

The quality of recreational experiences associated with streams and wetlands is dependent upon maintaining and restoring the environmental integrity of the resources.

Policy and Management Needs

Need to Meet Growing Demands for Recreation

Some streams and wetlands can support additional recreation use. However, other areas have already met or exceeded their capacity to support use without significant environmental deterioration. The critical task will be to accommodate additional use while conserving the basic integrity of stream and wetland resources.

- Limits to additional recreation use have already been imposed in Grand Canyon National Park, Aravaipa Canyon, and Paria Canyon Wilderness Area to prevent unacceptable environmental degradation.

Need for Economic Demand, Participation, and Attitudinal Data

There is a critical need for stream- and wetland-based recreation data, particularly site-specific information. This information is important if Arizona is to plan for the increasing recreation demands that will come with the projected growth in population.

- There has been no statewide comprehensive survey of stream and wetland recreation participation and demand.

Need to Conserve and Restore Resources

There is an urgent need to conserve the state's streams and wetlands and to utilize opportunities to restore streams and wetlands for future generations to use and enjoy.

Need for Consistent and Coordinated Management

The opportunities for consistent and coordinated management of streams and wetlands in Arizona have been limited by: (1) the many authorities and interests that influence the management and use of surface waters at all levels of government; (2) the lack of a common forum for communication among the complexity of authorities and interests concerned with streams and wetlands; and (3) inconsistencies and fragmentation in policy, purpose, and practice among the various authorities that manage and regulate the use of streams and wetlands.

Need for Communication and Cooperation

The consistent and coordinated management and equitable use of Arizona's streams and wetlands are dependent upon communication and cooperation between the many management entities, private landowners, resource users, and citizens of the state.

Need for a Statewide Policy

A statewide policy is needed which: (1) recognizes the importance of streams and wetlands to Arizona's heritage, economic growth, recreational opportunities, and quality of life; (2) fosters communication and harmony, rather than conflict, among users; and (3) provides guidance to management entities so that they may, through coordinated and consistent efforts, achieve equitable, quality allocations of stream and wetland resources.

ARIZONA NATURAL AREAS

Introduction

One hundred pound, six-foot-long fish in the Salt and Gila Rivers, abundant beavers and a commercial fishery on the San Pedro River, grizzly bears and herds of antelope roaming the grasslands of southeastern Arizona, the cry of the wolf in the Madrean evergreen woodlands?

These are all spectacular examples of losses to Arizona's natural heritage that have occurred during the last century.

More recently, vast riparian woodlands and wetlands on the Santa Cruz and Gila Rivers have vanished, and biologically rich and unique cienegas have become weed-infested pastures. A total of 116 species of native wildlife (approximately twelve percent of the state's total vertebrate animal species) are currently listed among the threatened native wildlife of Arizona, and more than four hundred species of native plants (approximately ten percent of the state's total plant species) are included on various lists of species of concern. All represent losses or potential losses within one of the most ecologically diverse states in the country — Arizona.

These changes in Arizona's natural diversity have been formed by numerous factors acting alone and in cooperation with each other: human population growth and its accompanying demand for developable land; groundwater overdraft; damming and diverting of streams; agriculture and overgrazing; mining; and a multitude of other, less obvious factors. The population of Arizona has increased sevenfold in the last forty years and is expected to increase by more than two million by the year 2000, resulting in even greater demands for land, water, and places for people to go for recreation, natural history education, and solitude.

It is not too late for Arizona to save many of the remaining examples of her rich biological, geological, and hydrological diversity, but the threat, in many cases, is imminent. It is necessary to act swiftly and decisively to save the remaining natural jewels for the future enjoyment, education, and enhancement of life for all of Arizona's citizens. These jewels, "natural areas," are public or private areas of land or water which have retained their natural character, although not necessarily completely natural and undisturbed, or which are important in preserving rare or vanishing flora, fauna, geological, natural, historical or similar features of scientific or educational value.

Arizona's natural areas are incredibly diverse, ranging from the constantly changing Yuma sand dunes and the starkly beautiful Pinacate lava flows in southwestern Arizona; the green hills of Canelo Hills Cienega and the Chiricahua Mountains' birding paradise, Cave Creek, in southeastern Arizona; Eagle Creek's birds of prey and Escudilla Mountain's alpine meadows and spruce and fir trees in eastern Arizona; the fossil deposits and rare cacti habitats in northeastern Arizona; Arizona's only tundra ecosystem on the San Francisco Peaks and the volcanic cinder cones in the north; to the lush green ribbons of riparian forest habitat along the Verde River in central Arizona.

Unaltered ecosystems—the storehouses of natural diversity—are highly evolved, interactive associations of the land and its species. These associations cannot be duplicated in an artificial setting. Society cannot afford to lose these living parts of the natural environment before it understands them fully. Examples of these complex ecological systems may be invaluable to future generations in ways we cannot foresee.

Many discoveries of practical value to humans have come from the study of seemingly insignificant species. Medicines, disease resistance for crops, control of pests; these are some of the benefits derived from the genetic diversity of the natural world.

From this practical perspective, natural areas can and do serve as areas for scientific research—research that could uncover extraordinary values in common species of plants, leading to the discovery of new medicines, sources of lubricants (e.g., the common desert jojoba plant was recently found to produce a very fine grade of oil that is now used in cosmetics and for lubricating precision machine parts), or other products to enhance our lives. Natural areas can be (and are) used for outdoor environmental education where Arizonans of all ages and backgrounds can learn about the natural world that surrounds them.

Natural areas have a wide variety of values that are similarly important to a wide variety of people. Many of the values are without monetary definition and relate to aesthetic, philosophical, and spiritual human needs. People enjoy the experience of being in a natural place far removed from their everyday urban existence. There is a need to be a part of the natural environment, to sit by a babbling brook, to see a hawk soaring overhead, or hear a lone coyote howling in the still of the night.

Natural areas can also serve to sustain the natural diversity of plant and animal life that is characteristic of Arizona; here again, preserving examples of different plant and animal communities that represent unique adaptations to the environments in which they live, or preserving areas that contain gene pools of rare species cannot be easily expressed in terms of dollars. Once considered a common occurrence along Arizona's streams and rivers, the riparian cottonwood-willow forests are now the state's, and the nation's, most threatened habitat.

It has long been known that preservation of natural diversity increases the stability of environments. The consequences of violating this principle can be devastating, such as the practice of slash and burn agriculture in Central and South America where mature, highly diverse tropical forests are cut down and burned in order to plant agricultural crops. After several years, the thin tropical soils cease being able to sustain crops, or are washed away, and the cutting and burning process is repeated. The abandoned croplands are often invaded by a single, dominant species of palm—in contrast to the original forest that may have supported hundreds of species of trees and shrubs. Similar situations have occurred in Arizona where riparian forests have been cleared for agriculture. When the land is no longer useful for crops, tumbleweeds and saltcedar take over what was once a lush green riparian forest. Wildlife species that once were common in these riparian forests can no longer find suitable habitat in these changed environments, threatening their very existence.

Clearly, preserving a series of natural areas in different habitat types in Arizona will not only help preserve natural diversity but can provide a benchmark against which man-caused changes in similar, unprotected habitats can be measured.

Natural lands are becoming scarce even as laws, regulations, and agencies dealing with their protection and use grow and become increasingly complex. The result is not always constructive, in part because some basic questions remain unanswered. For example, which areas within the state deserve protection and which do not? How should those places be protected? In the past few years, disagreement about these questions has cost millions of dollars in litigation and delayed or aborted projects. More importantly, it has also cost the state the loss of irreplaceable components of its natural heritage. We manage, develop, and use it; yet, in "using" this natural heritage, we may succeed only in destroying that which we seek.

It makes good ethical and business sense to preserve the high quality of Arizona's natural environment. To do this, representative examples of the full array of natural systems, species, and other elements of natural diversity must be protected.

Our natural heritage can be preserved without sacrificing necessary development, as long as careful planning accompanies growth. Quite often, the natural areas most desirable for protection have limited commercial value. Some of the richest, most diverse areas are small in acreage, so preserving Arizona's natural heritage need not always entail setting aside large tracts of land.

The Arizona Natural Areas Study was initiated in August 1987 with the goals of inventorying natural areas, identifying threats to Arizona's remaining natural areas, understanding the current management of those areas, and developing an action plan aimed at assuring their continued existence.

The study effort was assisted by the Natural Areas Core Group, composed of scientists, educators, and resource experts from state, federal, and private agencies.

Both the natural areas study and resultant action plan are critical at this point in Arizona's history. Arizona is one of the fastest growing states in the country and also relies very heavily on tourism, the second largest source of income for the state. In order for the state to meet the demands of growth and still continue to provide the quality of environmental experience that many people move to, or visit Arizona for, it is essential that we carefully plan a means to provide that experience for all. It was a significant goal of the Arizona Natural Areas Study to provide a foundation upon which that planning could be based.

Study Process

The Natural Areas Study consisted of two basic elements. First, was an inventory of natural areas in Arizona (the current Arizona State Parks Natural Areas Program has operated for some years from a list of 125 areas and listings of potential, new areas were desirable), including an analysis of management goals for existing areas and identification of trends and issues affecting natural area protection in the state. The second element was an Action Plan directed toward enhanced natural area protection into the 21st century.

The Natural Areas Core Group assisted in all phases of the study providing expertise and review. A total of six Core Group meetings were held between September 1987 and August 1988. Information obtained from the public during workshops held in May and June, 1988 and from survey questionnaires were incorporated into the study.

In addition to Core Group input, a number of entities were contacted in order to obtain information regarding management of existing or proposed natural areas under their jurisdiction.

Reviews were also made of other state natural area programs to determine the types of programs in place and the nature of funding for those programs. Potential sources of funding for the Arizona Natural Areas Program were also reviewed and the most promising incorporated into the Action Plan.

Inventory of Arizona Natural Areas

A part of the study was the identification of sensitive natural areas and critical habitats, especially those in need of protective management. Locational data and natural values were identified for a total of 334 natural areas. Field evaluations were not a part of this study.

Of the 334 total areas considered during the inventory phase of the study, twenty-seven currently unregistered areas were identified by the Core Group as being the most significant areas in the state. These twenty-seven areas are currently unprotected by any agency and represent some of the most sensitive, highly diverse, and potentially threatened areas in the state. The majority of the areas (ninety-three percent) have, as their focalpoint, a wetland, stream, or riparian vegetation element, underscoring the Core Group's highly significant concern for the continued existence of such areas in a state where water is a most precious commodity.

Potential threat to the top rated twenty-seven areas is considered to be moderate at fourteen sites, high at ten, low at three, and unknown at two of the sites. The nature of threat relates to water use (pumping, diversion, etc.) at sixteen of the sites and grazing on twenty of the sites. Other identified threats at one or more of these potential natural areas include real estate development, agricultural development, recreation (ORV use), and mining development.

Alternative Scenarios

The Arizona Natural Areas Program has been functioning for twelve years with the volunteer assistance of the Natural Areas Advisory Council and a part-time staff position. While some strides have been made with regard to the inventory, Natural Area Register, interagency coordination, and recognition of the importance of natural areas by landowners, planners, and the development community, there has been little achievement by the program of permanent protection of identified natural areas.

This kind of lasting protection can only be achieved by such means as acquisition, site dedication, and legislation. The current program has no statutory authority, no legally binding regulatory legislation, no funding, insufficient staff, and an incredibly demanding natural area protection agenda.

Over the last twelve years, the state has undergone tremendous changes, especially with regard to population growth, land use, and development. Many areas considered "wilderness" a decade ago are now experiencing constant recreational and commercial pressures resulting in environmental degradation.

Without immediate planning and protective management, many of the pristine natural areas that have become an indicator of Arizona's quality of life will be irreparably impacted. The purpose of this study is to explore options for the effective protection and management of the state's natural heritage.

As a result of the above situations, the Arizona Natural Areas Study explored several alternative scenarios for the Natural Areas

Program's future. During the review of possible courses of action for the Natural Areas Program, several questions were asked:

- Should the Arizona Natural Areas Program be continued?
- What changes and actions need to be accomplished to create a successful, dynamic program?
- What state agency can best manage the Arizona Natural Areas Program?

Scenarios

The five scenarios that were considered as potentials for the Natural Areas Program are listed below.

A) Continuation of program at present funding level with Arizona State Parks as lead agency (if this scenario is chosen, the Core Group recommended that the program be disbanded as natural area protection efforts will be ineffectual).

B) Stronger level of commitment and support for the Natural Areas Program with the Arizona State Parks Board as the lead agency (this scenario should optimally be considered as an interim step to the fully-supported program outlined in Scenario C).

C) Aggressive, fully-supported Natural Areas Program emphasizing acquisition of critical areas and cooperative programs with other regulatory and land managing agencies with Arizona State Parks as lead agency.

D) Aggressive, fully-supported Natural Areas Program focusing on acquisition and protection of critical habitats and cooperative programs with other regulatory and land managing agencies with the Arizona Game & Fish Department as lead agency Action Plan.

E) A state Natural Areas Program focusing on acquisition and protection of critical areas and utilizing a wide range of cooperative programs between private organizations and public agencies with the private sector taking the lead.

Action Plan

The protection of Arizona's natural heritage has been recognized as one of the primary objectives for the Arizona State Parks as well as that of a number of other agencies. In three separate surveys, Arizona residents overwhelmingly supported the acquisition and protection of critical areas by the State of Arizona. Each of these surveys is discussed in detail in the accompanying document Arizona Natural Areas Study. How that objective is achieved has yet to be decided. Each state agency involved with the management of the state's natural resources has its own mandates, policies, and priorities.

The purpose of this study was to update and study ways of redirecting the Arizona Natural Areas Program to become a more productive and focused program. The goal of this action plan is to strategically develop the recommendations to resolve the major issues identified during the study process and to outline a viable and functional mechanism for the protection of the state's critical natural areas. This plan outlines the recommendations that will assist in obtaining that goal for the protection of the state's critical areas, regardless of which state agency administers the natural areas program.

The results of this study—analysis of factors influencing natural area protection in Arizona, the current management status of established natural areas, examination of other state programs, Core Group discussion and input, all coupled with the continuing growth of the State of Arizona and continued emphasis on consumptive use of natural resources—have led to the development of the Natural Areas Action Plan.

Findings

The issues addressed during the course of the study were critically assessed during the formation of the Action Plan and some reformatting was considered necessary to achieve the needed recommendations. The following six issues, identified as key elements that need to be considered in the restructuring of the Natural Areas Program, are modifications of the initial issues.

- Arizona State Parks Board Awareness and Support
- Natural Areas Program Policy
- Funding
- Legislative Awareness and Support
- Education
- Protection Strategies

Issue: Arizona State Parks Board Awareness and Support

In review of the history of the Natural Areas Program and the questionnaire responses, one issue overshadows the others—the Arizona State Parks Board has not taken advantage of the benefits such a program could provide nor has it given the Natural Areas Program the support and commitment the program warrants.

Issue: Natural Areas Program Policy

The current Natural Areas Program is so broad in scope that it is difficult to determine priority areas in need of protection. The loss of natural areas in Arizona has progressed at such a rapid rate and has received such a low level of statewide support that the program cannot afford to look at all the important sites, both representative and rare, but should concentrate on those critical areas under immediate threat.

Also, the current program is restricted to a voluntary natural areas registry program, but the program has no authority or mechanism to ensure site protection. Most other states utilize both a registry and acquisition program. Arizona should aggressively pursue an acquisition program to protect the state's critical areas.

Issue: Funding

Funding is a critical issue in the protection of the state's natural heritage and funding is needed for many elements such as planning and coordination, acquisition and management, restoration and research, and the staff needed to accomplish these responsibilities.

Issue: Legislative Awareness and Support

There is a general lack of environmental legislation in Arizona. This fact is underscored by the lack of funding and policies to protect the state's critical natural areas. With strong legislative support and protective policies, the Natural Areas Program could effect significant changes and progress in the protection of the state's natural heritage.

The ultimate goal is the passage of an Arizona Natural Areas Protection Act that will create a fully functional critical areas program complete with a mechanism for funding necessary critical area acquisition and stewardship activities. In order for a natural areas program to go beyond a marginal, minimally effective program in relation to non-federally owned lands, legislation authorizing a state critical areas program must be passed.

Issue: Education

There is a lack of an environmental awareness or ethic within the public and development community. Some agencies have established educational programs designed to increase the public's awareness concerning the particular agency's mandate, such as wildlife or water, but these efforts are limited in scope. Natural areas represent ecological systems that include soil, rocks, minerals, water, air, plants, animals, and human influences. A more holistic educational approach that includes all aspects of the environment needs to be implemented that reaches all segments of the public. People need to understand the purpose and goals of the Natural Areas Program and how protection of the state's natural heritage benefits every citizen.

Issue: Protection Strategies

The protection of Arizona's natural areas will only be accomplished by making use of every conceivable option available. The current Natural Areas Program relied solely on a registry program, but had insufficient staff to make the program a successful one. Voluntary site registration increases landowner awareness and appreciation for natural area values, but it is only successful if there is adequate staff to initiate and maintain contact with landowners and provide technical assistance if a problem should arise.

There are many protection strategies that could be implemented to make this program a more effective one. Some of the more common protection tools in use today are acquisition, cooperative agreements and programs, registry programs, site dedication, and conservation easements.

The emphasis should be on natural area acquisition as that is the best way to ensure long-term protection, but the program should be an integrated one, employing a full range of protective strategies. Several of these strategies have been mentioned in the above issues, but are also relevant here. The following are some options worthy of exploration, but they should not be considered a complete listing of protection strategies.

A Vision Of Natural Areas Protection In Arizona

It is the year 2000 and the State of Arizona supports nearly four and a half million people. Tourism and the pursuit of outdoor recreation opportunities is Arizona's biggest industry. Visitors come from all over the world to experience the state's incredible natural attractions like the Grand Canyon, Colorado River, Petrified Forest, Monument Valley, Oak Creek Canyon, Mogollon Rim, Organ Pipe National Monument, our state's deserts, lakes, and forests, and the wonderful year-round weather.

Recognizing the tremendous value of its diverse natural resources, the State of Arizona has enacted the Arizona Natural Areas Protection Act to conserve and protect its natural heritage. The Act outlines the mission of the Arizona Natural Areas Program and provides funding for natural area acquisition and management and for a natural areas staff to administer it.

The Arizona Natural Areas Program manages the State Natural Areas System, which includes all lands owned and managed by the state for the purpose of natural area protection. Coordination with other agencies is accomplished by the Natural Areas Coordinating Council, an interdisciplinary, interagency group, which works closely with the other land managing entities within the state.

The Natural Areas Program is responsible for the planning and protection of identified natural areas throughout the state and for a variety of programs aimed at increasing natural area diversity and protection. Program functions consist of many components, working together to ensure protection and enhancement of the state's natural heritage. An inventory database is maintained by the Arizona Game & Fish Department's Nongame Database Management System.

Programs include: a Natural Areas Registry program managed by The Arizona Nature Conservancy; an acquisition and management program jointly administered by the Arizona State Parks Board and the Arizona Game & Fish Department; creative methods, such as university research programs, volunteer study projects, dedications, grants, and exchanges; landowner incentives, such as conservation easements and tax incentives; and an educational program to increase the public's awareness and understanding of the important part these critical natural areas play within the state.

The Natural Areas Program is funded by an innovative blend of state general fund monies, private industry, foundation support, special revenue programs, income tax check-off program, severance tax, new motor vehicle registration tax, real estate transfer tax, federal grants, and volunteer support.

There is an annual legislative appropriation for necessary staff to monitor, study, and evaluate the state's natural resources, to conduct site inventories and assessments, and to reimburse expenses of the Natural Areas Coordinating Council. Staff consists of a program coordinator/director, biologists, botanists, zoologist, geologist, land stewardship coordinator, database manager, and office support.

Close working relationships with other agencies, universities, private landowners, and organizations ensure the necessary assistance and funding with field studies and projects, enforcement of regulations, and coordination with adjacent land uses and management practices.

The Natural Areas Program protects the state's threatened and sensitive ecosystems: critical areas which are habitats for rare or vanishing species of plants and animals; reservoirs (gene pools) of natural materials; natural laboratories for environmental education and scientific research; special sites where people can learn about the natural environment and observe wildlife; and provides places to enjoy spending leisure time in a scenic, natural environment and participate in outdoor recreation activities.

The Natural Areas Program manages these areas for the public benefit and enjoyment and coordinates planning and management with landowners of natural areas not in state ownership. Areas within the Natural Areas System are well protected from outside impacts through monitoring and patrolling, fencing, and placement of appropriate signs, nature trails, or other facilities as needed.

Public and private entities plan and manage for this variety of opportunities and enforce regulations that are necessary to preserve the integrity of the natural resources and the experiences sought by various users and to minimize multiple-use conflicts.

Quoting from the Arizona Natural Areas Protection Act:

"It is, therefore, the public policy of the State of Arizona to secure for the people of present and future generations the benefit of an enduring resource of natural areas by establishing a system of natural area preserves, and to provide for the protection of these natural areas."

TRAILS

Introduction

Arizona's history is rich with accounts of famous frontier towns such as Prescott, Tombstone, Jerome, and Yuma. Settlement of these and other towns largely depended upon overland routes for trade and travel. Trails, such as the Beale Wagon Road and the General Crook Trail, carried supplies, settlers, and the military to the growing frontier towns. Other early trails were established to extract or protect natural resources. For example, in the early 1900s the Forest Service built trails in the state for fire fighting, timber harvesting, and rangeland improvement.

After World War II, interest in outdoor recreation exploded, and many Arizonans "hit the trail" for hiking and horseback riding. Trails previously used predominately for natural resource management became recreation corridors. Some government agencies took note of this growing interest and began building trails. Thousands of miles of trails were designated for use in Arizona between 1950 and 1970.

In 1971, the Arizona State Parks Board, recognizing the popularity of trail recreation, established the Arizona Hiking & Equestrian Trails Committee (AHETC). The primary mission of the AHETC was to study, inventory, and designate a statewide system of trails. By 1988, the AHETC had inventoried over 500 trails in the state and designated 263 as State System Trails.

In 1986, Governor Bruce Babbitt commissioned the Task Force on Recreation on Federal Lands. The Task Force's report identified trails as being "one of the most economical means of providing outdoor recreation" and recommended that trail maintenance and construction be given a higher priority in federal land management agency budgets, that several trails be studied as potential long-distance trails, and that rail-to-trails, adopt-a-trail, and historic trail programs be accelerated.

In 1986, the Arizona Outdoor Recreation Coordinating Commission recommended that a state trails plan be completed. With concurrence by the Arizona State Parks Board, funds were committed to the effort and a trails plan was initiated in 1987 as an element of the Statewide Comprehensive Outdoor Recreation Plan.

Study Process

The trails plan was developed with assistance, guidance, and technical input from the Trails-2000 Planning Group. Four planning group meetings were held from September 1987 through March 1988. Additionally, five open house meetings were held at locations across the state in May/June 1988 to obtain general public comment on the draft study results. In June, the planning group reviewed input from the public meetings and made modifications to the plan.

In addition to the information generated by the Trials-2000 Planning Group, data on trends, trail providers, trail locations, etc. was solicited from the Forest Service, National Park Service, Bureau of Land Management, National Wildlife Refuges, Arizona State Parks, Tribal Nations, counties and municipalities, private clubs and organizations, and a variety of other trail providers. Information on trail programs and trail legislation from over a dozen states was also collected and reviewed.

Findings

The goal of this plan was to establish policies regarding trail provision and use in Arizona. The process used for policy development was designed to achieve consensus of opinion from the members of the Trails-2000 Planning Group on issues affecting trails. The planning process employed a modified-delphi technique to build consensus on a diverse range of policy issues. The resulting policy statements defined constraints and limitations for decision making. Issues relating to trail use were used to focus the attention of trail providers and policy makers on action steps or strategies to resolve them.

Issues were also identified through agency and user group interviews conducted in the first months of the study.

Issue: State Trail System Development

A fully coordinated state trail system is made difficult because of the number of agencies and landowners involved in trail provision. Over a dozen agencies and organizations manage more than 500 designated trails, totalling over 5,000 miles. For the most part, these agencies do not share common methods of trail signage, maintenance, construction, or information dissemination. Trails, such as the cross-state Arizona Trail, traverse lands managed by a variety of agencies and private landowners.

As Arizona's population grows and trail use continues to rise, trail expansion will need to occur, especially near urban areas. A variety of open space corridors have excellent potential for expansion of the state's trail network. Canals, railroad rights-of-way, historic routes, utility rights-of-way, and other corridors traverse the state and need to be examined for trail feasibility.

Information on the trails network in Arizona has historically been difficult for users to obtain because of the vast numbers of agencies providing the information. A recent statewide recreation participation study indicated that as many as 73% of residents in the state possess "none" or "a little" information on trails. A number of excellent guidebooks on trails are available, but they usually cover specific regions of the state and are not consistently updated. An updateable computerized trail "guide" has been tested with success in the State of Washington. Called the Trail Resource Information System (TRIS), this system was jointly pioneered by the Forest Service and Recreation Equipment, Incorporated. TRIS allows trail users to access a user-friendly database program through computer terminals in public libraries. The system makes available current information on trails in a nearby national forest. A similar system would be beneficial in Arizona.

More than 25 states have legislation recognizing a statewide trail system. In 1986, the Arizona State Legislature funded a statewide trails coordinator position, but has not yet recognized the fledgling Statewide Trail System with legislation. Legislation would enhance the Trail System by ensuring quality trail resources for Arizonans now and in the future.

Issue: Funding

Funding is a critical issue that cuts across all trail activities from trail development, reconstruction, and maintenance to the planning and coordination of a statewide system. Trail funding can come from a variety of sources both public and private.

Private sources, such as foundations or corporate donors, sometimes fund all or parts of trail projects. The Kaibab Plateau Trail on the Kaibab National Forest recently received significant funding for tread development and signage from Kaibab Forest Products, a timber harvesting company. Several states and regional governments have open space and greenway foundations that fund trail development.

While federal and state funding programs are shrinking, some monies are available, especially for heavily used and special-use trails. User fees are a largely untapped source of funding for trail development. While difficult to administer in remote areas, this source of funding has potential if various legal, budgetary, and policy constraints can be resolved.

A variety of state initiatives have provided funding for trail development. The State of Colorado receives funds each year through the state lottery. A bond issue in California in 1988 provided $5,000,000 for trail projects. In 1987, the Florida legislature appropriated $3,000,000 to the Florida Department of Natural Resources to purchase abandoned rail lines for conversion to trails. The Michigan Department of Natural Resources works with utility companies in purchasing easements for trails along fiber optic corridors. A snowmobile registration fee in Utah has provided millions of dollars for the development of snowmobile trails. For many of the states mentioned, trail development is synonymous with tourism and economic development.

Issue: Trail Volunteers

One of the most efficient and economical methods to maintain trails is to enlist the assistance of volunteers. In Arizona, adopt-a-trail programs are administered by a variety of agencies. Organizations that participate in these programs include equestrian groups, hiking clubs, 4-wheel drive clubs, scout troops, schools, churches, and service organizations. Adopters are normally responsible for regular maintenance of a trail or segment of trail.

Adopt-a-trail programs are generally coordinated by an agency volunteer coordinator. In the absence of such a coordinator, volunteer programs generally fail. Volunteer programs may also fail because agency coordinators do not have adequate information and resources to coordinate the effort. Programs may fail if volunteers are not properly rewarded for their work. A workshop recently developed by the Arizona Parks & Recreation Association (APRA) provides training to agency officials on developing a successful volunteer program.

In addition to local and regional adopt-a-trail programs, the Arizona Hiking & Equestrian Trials Committee coordinates the statewide Adopt-a-Trail Program and publishes the Adopt-a-Trail Handbook. While the program has proven to be successful, several agencies do not participate. This lack of coordination is confusing to some potential user groups.

Issue: Access/Easements

Access to trails on public and private land is rapidly diminishing in Arizona. Urban areas crossed by informal, undesignated trails are being subdivided and developed with a resulting loss of trails. This has caused a great deal of alarm and concern on the part of trail users who see opportunities to reach public trails through private land rapidly disappearing. Trail access in rural areas and adjacent to publicly administered lands is also threatened.

The problem of access is exaggerated in counties with large, urban populations where demand for trails is high. Studies are currently underway to identify access problems and to develop alternatives to trail access already lost. The intent is to strengthen conformance to a trails master plan in the zoning process for proposed developments.

The use of recreation or conservation easements has largely been unused in the state as a way to protect or create trail access. The conservation easement statute in Arizona (A.R.S. § 33-271) provides tax incentives for individuals who provide easements on their lands for conservation, recreation, or preservation purposes. Another state statute exempts landowners from liability if they allow recreation access across their properties.

Issue: Multiple Use

Multiple use has held wide appeal with resource management agencies for many years. If a trail can be constructed to service a number of user groups, it is more economical than developing two or more separate trails.

The most highly reported problem concerning multiple use is conflict between motorized and non-motorized users, or high-speed versus low-speed uses. The advent of the mountain bicycle and all-terrain vehicles also pose special problems and opportunities for trail providers. These non-traditional uses are not adequately planned or provided for in the state.

A recent recreation participation study documents that the demand for outdoor recreation is increasing with the state's growing population. The future virtually guarantees that problems associated with overuse, resource protection, and user conflict will increase. Provision of an adequate diversity, as well as an adequate quantity, of trails will help alleviate this problem.

Issue: Education/Promotion

A key element in the success of a comprehensive trails system is the educating of trail users on the considerate and thoughtful use of trails. Minimum standards for trail design, construction, and maintenance are also critical.

A few inconsiderate users can negatively affect the experience of other users and degrade the trail environment. The willingness of private landowners to participate in cooperative efforts with agencies and trail groups can be negatively affected by abusive users. The problem of making users aware of trail standards and ethics, and motivating them to follow such a code needs to be approached from a number of directions. Trail clubs and organizations are usually the most well-versed in trail ethics and generally educate their members. Schools, church groups, scouts, and community service groups are obvious targets for trail ethics programs.

Effective trail ethics education will do more to ensure that users have a high quality experience than perhaps any other single factor. Education can also be an effective means to reduce conflicts on multiple use trails. If users understand the necessity of allowing a variety of uses on a single trail corridor (as is necessary in many urban areas), there will likely be a higher level of understanding and tolerance.

Issue: Maintenence/Management

A number of trail maintenance and management related issues are surfacing in Arizona. Increasing demand for trails, high use of some popular trails, and decreasing budget allocations combine to pose serious threats to the state's trail resources. Trails throughout the state are maintained at less than desirable levels for most users. Trail head facilities and vehicles are sometimes vandalized.

The cost of trail maintenance is often overlooked or underestimated in agency budgets. Creative programs and policies are needed to improve current infrastructure maintenance. As Arizona's trail system grows, trail providers and users will need to jointly recognize the importance of maintaining trails. Minimum standards for trail design, maintenance, and construction will need to be developed and implemented among trail providers in the state.

Because of their linear nature, the maintenance and management of trails requires a dedication of time and effort that often exceeds other types of recreational facilities. Perhaps the most efficient manner to monitor and maintain trails is to enlist the aid of volunteers. User groups and service organizations may "adopt" trails or trail segments. Their responsibilities may include trail maintenance, development, or monitoring.

A Vision of the Arizona Trails Program In 2000

The State Trails Program, coordinated by the Arizona Committee on Trails (ACT) of the State Parks Board, is recognized by the State Legislature with the Arizona Trails Act. The act outlines the mission of the program and provides for a trails staff to administer it. The trails program is responsible for the planning and coordination of over 500 designated trails throughout the state and a variety of programs aimed at improving trail opportunities statewide. The system is integrated based upon the demonstrated demand for specific types and locations of trails. Urban trail systems are well-planned and maintenance by the various trail providers is coordinated with the ACT. The Arizona Trails Act provides for the creation of a trails fund to further the important goals of the trails program.

Trail users enjoy a diverse spectrum of trail opportunities that range from primitive to motorized experiences. Public and private agencies plan and manage for this variety of trail opportunities and enforce regulations that are necessary to preserve the experiences sought by various users and to minimize multiple-use conflicts. Trailheads and facilities are well-constructed and maintained, and uniform trail signage exists on each designated trail. A variety of maps and user guides are available in published and computerized format to inform users of trails and their associated natural and cultural resources. The computerized trails information system, managed by the trails staff, is used to annually update a trails booklet and maps. The income from the sale of the booklet covers the printing costs and maintenance of the computer system.

Trails, including their associated sensitive resources, are protected through a combination of law enforcement and educational programs on trail safety and ethics. Specialized trails are abundant and provide opportunities for the disabled, the mountain bicyclist, and the airsport enthusiast (e.g., hang gliding corridors). Historic and interpretive trails provide users with the opportunity to explore the state's heritage. The trail network may include canals, utility corridors, abandoned railways, washes, rivers, and other linear features throughout the state. Long-distance trail opportunities are found throughout the state (e.g., the Arizona Trail and the Black Canyon Sheep Trail).

The Trails Program is funded by an innovative blend of state general fund monies, private industry, foundation support, the state lottery, special revenue programs, federal grants, and user fees. Worthy projects and programs within the overall Trails Program are recommended for funding by ACT. Special consideration is given for the funding of easements to protect and provide access to trail corridors. This appropriated funding is coordinated with and in support of existing agency programs at all levels of government. Trail signage, access to trails (e.g., easements), trail construction, planning and coordination, and law enforcement are examples of programs and projects that are strongly financed by the trails fund.

Volunteer programs exist in local park and recreation departments, as well as private, state, federal, and tribal resource management units in the state. Adopt-a-Trail programs are responsible for most maintenance in the statewide system and receive strong support from user groups. Coordinators, trained by ACT, manage a wide range of volunteer programs. For their efforts volunteers receive appropriate recognition.

The core of the state's trail constituency is ACT, which represents user groups and trail providers, and pursues a common goal of protecting and enhancing trail opportunities statewide. This is accomplished by consideration of users as partners in a joint effort to research, monitor, plan, and maintain trails.

FISH AND WILDLIFE RESOURCES

Trends Affecting Fish and Wildlife Resources

Throughout the 20th century Arizona's population growth has shown a steady, if not spectacular growth. At present an estimated 3.3 million people reside in the Grand Canyon State. For the last five years of the 1980s, the state's population increased 16.7%, nearly 88,000 people added each year. This growth shows no signs of leveling off and it is estimated that there will be 5.5 million people living in Arizona by the year 2000.

This growth and the development that goes with it will have a significant affect on the state's fish and wildlife resources. These new people will require space to live and space to recreate. Many will want to hunt, fish, and use Arizona's wildlands to recreate in. This growth and requirement for space will impact the natural habitat that supports the state's wildlife resources.

This kind of growth has changed Arizona from a rural-based population to centralized urban state with most of the population centered in the Phoenix and Tucson areas. Today, three of four Arizona residents live in either Maricopa or Pima County. The change from a farming, ranching, rural community to an urban society has changed how Arizona's citizens feel about wildlife and the outdoors. A smaller percentage of Arizona's new population will be interested in hunting and fishing activities, and more people will be involved in the passive uses of Arizona's outdoor resources. All of the outdoor recreation special interest groups can have an affect on the wildlife resources and the people that use and enjoy those resources.

Every year new laws are created at both the federal and state levels that will impact outdoor recreational activities and wildlife resources. These new laws tend to restrict the uses of public lands and to require land management agencies to place more regulatory controls on management practices. The two major federal land management agencies, the Bureau of Land Management and the U. S. Forest Service, are preparing comprehensive land management plans that will have closely monitored objectives related to land that will affect management programs for wildlife. Close coordination between state and federal agencies will be required.

One future piece of legislation designed to offset the effects of Arizona's growth that will impact wildlife recreation users is "wilderness." The creation of more wilderness areas in Arizona will result in some changes in use patterns and wildlife management programs. Although wilderness designation does preserve and protect those areas for the future, it also limits access for maintenance of wildlife habitat enhancement projects.

Current Roles and Responsibilities of the State's Fish & Wildlife Resources Managers, including the Management Status of the Wildlife Resources

Under the authority of the Arizona Revised Statutes, Title 17, the Arizona Game and Fish Commission and Department have the sole management responsibility for all wildlife, meaning all wild mammals, birds (including their nests and eggs), reptiles, amphibians, mollusks, crustaceans, and fish. The only exception to this authority are wildlife on Indian reservations and fish and bullfrogs impounded in private ponds. The U.S. Fish and Wildlife Service, under the migratory bird treaties, have final authority over migratory bird and threatened and endangered species.

Land management agencies such as the U.S. Forest Service, the Bureau of Land Management, and the Arizona State Land Department have the authority to manage land uses and habitat, and as such, exert a significant influence on the welfare of the wildlife resources. Other agencies or private land holders also manage land uses and control the kinds of uses on their lands, which in turn impact wildlife resources and the use of those resources.

The Forest Service and Bureau of Land Management are going through extensive planning processes to develop land management plans. These plans will spell out in detail land management practices that will have a great effect on the future of the wildlife resources and outdoor recreation. Many of these plans have wildlife management objectives that will result in positive benefits for Arizona citizens.

The Game and Fish Commission and Department are also going through a planning process to identify the critical needs for the future and develop activities and plans to prepare for the 21st Century. These plans have identified the need to work with land management agencies to identify critical habitats in order to protect and preserve them for the future.

Current Fish and Wildlife Conditions

Fish and wildlife are a product of the land and water in what wildlife managers call habitat. For an animal, that means a combination of things to eat and drink; places to hide; places to take shelter; and places to breed and give birth. Some animals, like the coyote, are very adaptable and can survive in a wide variety of habitats. Other species have very strict habitat requirements and any small change in environmental conditions can result in the threat of the extinction of a species.

Humans have a great and significant impact on wildlife habitat. Humans may see wildlife habitat as a place to build houses or roads, build dams, or a place to farm or graze livestock. When habitat is changed through human use, wildlife or fish communities also change. Most wildlife and fish habitat in Arizona has been changed or altered since statehood. In some cases, wildlife has benefited by these changes, but most of Arizona's native species have not.

In July 1988, the Arizona Game and Fish Department published "Threatened Native Wildlife in Arizona" which lists 116 species or subspecies of wildlife. Most are listed because of significant habitat losses or threats. These species will require special attention to protect their habitat and to ensure their continued existence.

Arizona is a state rich in fish and wildlife resources. Over 800 different vertebrate species are found in Arizona and they include 22 species of amphibians, 85 different fishes, 94 reptiles, 136 mammals, and nearly 500 bird species. This great diversity of wildlife is a result of the varied landscapes, climatic patterns, and elevations within the state.

The Arizona Game and Fish Department has published, or is in the process of preparing, strategic plans for the following categories of wildlife: Big Game, Small Game, Predators and Furbearers, Nongame, Cold Water Fish, and Warm Water Fish. These documents discuss the history, status, and management objectives for these groups of wildlife. These plans also identify the management problems and issues that may prevent the Department from achieving the management objectives. For almost all species, the management and protection of habitat is the critical issue for the future.

The habitat type that is of most critical concern to wildlife managers are riparian zones (the Natural vegetated areas surrounding water courses). Riparian habitat is critical to many species of wildlife and represents a habitat type that has been significantly altered or reduced by man's activities. It is said that 90-95 percent of Arizona's historically riparian habitat has been lost, and that which remains is constantly threatened.

The second habitat type that has great potential for future changes are the desert and upland grassland types that support antelope and other grassland species. Much of these grassland areas have been subjected to heavy grazing in the past that has altered the vegetative composition converting many areas to less productive habitat types. Also, because of land ownership patterns, these grassland habitats are subject to changing land uses, management practices, and changes in ownership or development.

The Game and Fish Department Strategic Wildlife Plans, and the federal land management agencies, discuss issues related to wildlife resources and purpose plans and actions to improve the habitat capability for Arizona's wildlife.

Economics of and Dollar Investments in Fish & Wildlife Resources in Arizona

Wildlife means more than just a natural resource, it is also an economic resource for Arizona. An estimated $620 million was spent on wildlife-related recreation in Arizona in 1986. People spending money include wildlife photographers, fishermen, bird watchers, hunters, bird feeders, and others. This total does not include expenditures by tourists, hikers, campers, sightseers, and others, whose recreation was enhanced by wildlife, and who, as a result, are more likely to recreate in Arizona again.

Over $326 million was spent on fishing in Arizona, another $170 million was spent on hunting, and $124 million was spent in more passive wildlife recreation, such as feeding and photographing wildlife, and trips specifically to see wildlife. When you consider these benefits with Arizona Game and Fish Department's present budget; every dollar spent to manage wildlife results in more than thirty-six dollars being returned to the economy of Arizona in money spent for wildlife recreation.

Wildlife plays a more subtle role as a reason for other recreation, such as sight-seeing, camping, and hiking. Wildlife and wildlands are a part of the quality of life identified with Arizona. Approximately 15 million tourists visit Arizona and spend more than $5 billion annually. Anything which makes people more likely to vacation in Arizona, return to

Arizona, or stay longer is important to Arizona's business community. Wildlife can increase the enjoyment of tourists and indirectly contribute to the tourist industry.

Expenditures on wildlife recreation increased approximately 44% from 1980 to 1985. The largest increases were in the more passive types of recreation trips to see or photograph wildlife.

As an industry, the trend looks very good for wildlife recreation as long as wildlife and wildlands remain healthy and abundant. With the growth and development pressures that the near future has in store, careful strategies must be implemented to ensure the vitality and availability of Arizona's natural and wildlife resources.

There are many agencies in Arizona that spend money, either directly or indirectly, for the management of the state's wildlife resources. The Arizona Game and Fish Department, U. S. Fish and Wildlife Service, Bureau of Land Management, and U.S. Forest Service have budgets that are specifically targeted for wildlife management programs. Arizona Indian Reservations also spend considerable amounts of dollars managing tribal wildlife resources. There are other agencies like the U. S. Bureau of Reclamation, the U.S. Army Corps of Engineers, and the Soil Conservation Service that have funds in their budgets for wildlife purposes. Other agencies such as the Arizona Department of Environmental Quality, Maricopa County Flood Control District, and Arizona State Parks may spend money either directly or indirectly for wildlife. Even private companies such as the Salt River Project and Arizona Public Service Company have spent money on wildlife. Private wildlife conservation organizations also have spent thousands of dollars to support wildlife in Arizona. Organizations such as The Nature Conservancy, Arizona Desert Bighorn Sheep Society, Rocky Mountain Elk Foundation, Trout Unlimited, Anglers United, Ducks Unlimited, The Arizona Wildlife Federation, and Quail Unlimited have contributed funds to improve or acquire wildlife habitat.

The Arizona Game and Fish Department's budget for 1988 is just over $24,000,000. (Of that total, $1,279,000 is directed toward the watercraft program.) The U.S. Fish and Wildlife Service spends over $3,650,000 in Arizona administering their refuge programs and other wildlife programs. The other agencies have wildlife funds integrated within their budgets that include such activities as grazing and timber management programs.

Current Levels of Recreational Use of Fish & Wildlife Resources In Arizona

According to the "1985 National Survey of Fishing, Hunting and Wildlife Associated Recreation" conducted by the U.S. Fish and Wildlife Service and the U.S. Bureau of the Census, more than 1,900,000 Arizona residents, 16 years and older, are vitally interested in wildlife, and of these, only 600,000 hunt or fish. In addition, 370,000 individuals under the age of 16 participate in wildlife-associated recreation with their family or friends and of these 136,000 hunt or fish.

The "1985 National Survey" indicates a 3.4% increase in the number of licensed and non-licensed Arizona anglers to about 519,000 people. Fishing license sales indicate strong growth, keeping pace with Arizona's population over the past 25 years. Based on the trends of the last several years, nearly 580,000 fishing license buyers are expected by 2012.

Anglers in Arizona spend about 7,800,000 days fishing on the state's lakes, rivers, and streams. About 55 percent of these angler days are for warm water fish species in the large reservoirs of Central Arizona and along the Colorado River.

The "1985 National Survey" indicates a 6.3 percent increase in the total number of licensed and non-licensed hunters to about 235,000 residents. License sales records are less optimistic about this group. Recent sales of hunting licenses have been in a mild decline.

Declines in participation rates have been occurring as the population of Arizona becomes more urban, parallelling national trends. Trends of the last several years indicate that resident hunters could number about 171,000 by the year 2012. The trend is significant, because the income derived directly and indirectly from these license buyers has traditionally been the exclusive source of funding for big game and small game management.

Hunters spend almost 3,500,000 days hunting in Arizona. Of this total about 1.2 million days are spent for big game hunting, 1.5 million days for small game, 600,000 days hunting migratory birds, and 500,000 days for other animals.

Since 1972, the Arizona Game and Fish Department has had responsibility for registration of boats, enforcement of boating safety laws; and providing for navigational safety on Arizona's waterways. This has been a significant task because the number of boats registered in Arizona has more than tripled since 1969.

The magnitude of the responsibility becomes clearer when one considers that resident boats were on the water for nearly 1.3 million days on Arizona's waterways, and an additional 234,000 boat use days were added by Californians, Nevadans, and other non-residents. All of this accounted for nearly 5.5 million boating recreation user days. If the historical trends continues, there could be twice the current number of registered boats by 2012. Boating enforcement, and particularly boating safety work, will have to increase significantly if the boating waters are to be safe for all recreation users.

Some trends discussed are obviously tied to the Game and Fish Department, but the appreciation of Arizona's "wildlife and wildlife habitat" is not limited to the traditional groups associated with hunting, fishing, and boating. Nearly 5 million camping days were reported on U.S. Forest Service, BLM lands, and in the State Parks. The "1980 National Survey" showed that for 58 percent of these participants, the presence of wildlife was important. The DataPol survey (conducted for Western Savings) showed that 34 percent of Arizonans camped, and 26 percent backpacked during the last year. This kind of recreation, while not directly related to Game and Fish is intimately associated with the responsibility to conserve, protect and manage all of the State's wildlife. Undoubtedly, the features of Arizona's "wildlife and wildlife habitat" are important to recreationists other than hunters and fishermen, and the department is the only State agency charged with ensuring that Arizona's wildlife (and the habitat upon which it depends) is conserved for Arizonans of today and tomorrow. Preliminary information from the 1985 National Survey indicates an 8.8 percent increase in the numbers of Arizonans who are passive wildlife users from 1,776,000 in 1980, to 1,933,000 in 1985. That represents over 70 percent of the State's population.

Many non-Arizonans come to Arizona to enjoy the mild winter climate. Many of these visitors spend time in the out-of-doors bird watching or doing other wildlife-related recreational activities. The "1985 National Survey" estimates that non-residents spent just over 4.4 million days in wildlife-related activities. That number exceeds the number of days that residents spent in wildlife-related activities that were not associated with hunting or fishing by 1.1 million days. The total participation of 7.9 million days in Arizona for passive wildlife recreation is really significant in terms of contribution to the state's economy and terms of future wildlife management implications.

Current and Future Issues Related to Fish and Wildlife Resources

The Arizona Game and Fish Department is the sole State agency that has the legislated responsibility to protect, manage and ensure that Arizona's wildlife and wildlife habitat remain healthy and available for present and future generations. Protecting wildlife and wild areas is necessary because of the rate at which important areas are being lost and because of the influence small key areas can exert over much larger regions. In a desert state, key areas will often include water or wet areas.

The loss of wildlands and the loss of agricultural land are both losses of wildlife habitat. The acreages planted to citrus in Arizona dropped 37% from 1975 to 1985, and the acreage planted to grains 54% in the same period. From 1975 to 1985 overall acreages in cultivation dropped about 20%. The losses of wetlands and riparian habitats are even more important to wildlife, but very hard to document. These riparian and wetland losses may be the most detrimental and rapidly progressing habitat losses. These losses and others describe the past, and could, if uncontrolled, describe the future of wildlife habitat in Arizona. How productive and important these lands are becomes clear when it is realized that 70% of Arizona's antelope, 50% of Arizona's javelina, and 38% of Arizona's mule deer live on lands vulnerable to development. These wild animals, and most other game and nongame animals, do not easily tolerate land development.

Even when the lands that animals live on and the waters that fish live in remain useable, access to those areas for recreation can be a problem. Currently an estimated 1.4 million acres of public lands in Arizona are not accessible to the public. This total includes 439,000 acres of U.S.Forest Service lands, 238,000 acres of Bureau of Land Management lands, and 757,000 acres of State Land. This total has the potential to grow to 4.5 million inaccessible acres by 2012. The causes of this problem are diverse and often complex. The roots of a decision to resist public entry on a specific piece of land may be found in vandalism, theft, carelessness, differing opinions on proper use, greed, concern about resources, or any combination of these concerns.

The state must ensure that the public will continue to have the opportunity to enjoy wildlife recreation activities. This not only means ensuring access to public lands and recreation sites, but also ensuring that there is adequate habitat to and wildlife for future recreation demands. Conflicts between wildlife and outdoor recreation demands will have to be resolved.

The management of sport fish and wildlife must be intensified to compensate for the increasing human population. The pressures which come with increasing human populations not only reduce the land available for wildlife, but also reduce the lands available for increasing wildland recreation. An increase in the intensity of management of land, animal, and people is required to produce the same or greater amount of wildlife and recreation on less land.

The number of wildlife watchers has been increasing faster than hunters and fishermen. The management of watchable wildlife must be expanded.

The state must take a leadership role in the planning and use of lands in Arizona as the advocate for our wildlife habitat. The Arizona Game and Fish Department already reviews project proposals ranging from gravel pits and timber sales to major projects like the Central Arizona Project to ensure that wildlife values are considered in project planning.

Programs must be developed to increase appreciation and knowledge of Arizona's wildlife and wildlife habitat, and provide for associated recreation in and near urban areas. Few Arizonans grew up here and fewer still grew up in rural Arizona. Many people have not been exposed to the beauty, wonder and values of rural Arizona. Only through an understanding of what Arizona is, can public and private decisions be made wisely and carefully.

Enforcement programs must be upgraded to protect and serve the increasing numbers of people who enjoy recreation in Arizona's wildlands. As a number of people using our wildlands increase, the conflicts between people and wildlife, property lands, and other people also increase. We have a responsibility to protect and serve recreationists and other land users in Arizona's wildlands.

It is clear, Arizona is changing! 'The Governors Task Force on Recreation on Federal Lands' described 20th Century Arizona as

> "...a diverse, complex, and in many respects fragile natural environment punctuated by sprawling metropolises, small towns, and rural communities."

Where will Arizona be in the 21st Century? If Arizona 's "fragile natural environment" is to survive into our second hundred years, someone must actively work to protect her wild heritage. If our wildlife and wildlife habitat are an important part of the quality of life in Arizona, we must be in a position to protect it as our population grows and our cities and rural communities expand and develop.

A crisis for Arizona's wildlife and wildlands is upon us all. As our State develops and grows, we threaten the fragile beauty that contributes to the quality of life in Arizona. Even as our population swells and the pressures on our wildlife and wildlands increases, the paying users are on the decline.

Actions and Strategies For Fish and Wildlife Resources

Providing habitat for fish and wildlife into the future in quantity and quality to satisfy the projected use is a primary objective of the Arizona Game and Fish Department. Since the Department is not a land manager or the manager of the habitat, a close coordinated working relationship must be maintained with the land management agencies.

Programs must be developed to provide fishing opportunities for the expected 720,000 anglers by the year 2000. The maintenance of aquatic habitat, including high water quality standards, must be continued. The upgrading and modernization of the state's fish hatcheries is a priority to maintain the quality of the state's cold water fisheries program.

It is expected that the 200,000 hunters will not increase by the year 2000, and may even decline. However, pressure on the habitat that supports game species will require aggressive re-introduction programs and biological skills, combined with effective management and enforcement efforts, to maintain game populations at the existing levels. Hunters may have to except a lower standard of success if hunter numbers and recreational days of hunting are to be maintained.

In order to maintain or improve wildlife habitat, an aggressive program will be required to identify and acquire critical habitats. This should be a coordinated effort between state and federal agencies and private groups. The emphasis should be in the acquisition of riparian and wetland habitats, important small game and nongame wildlife habitats near metropolitan ares, and pronghorn habitat.

In order to provide recreational opportunities, access to public lands needs to be maintained and improved. Many of the public lands in Arizona are not accessible, this should be a major program for the future.

Expanding the opportunities for the public to enjoy wildlife-related recreation is a high priority. Urban wildlife programs, in corporation with the appropriate metropolitan areas of Phoenix, Tucson , and other communities, are of critical importance in order to maintain a high interest in wildlife by Arizona citizens. This increased interest and an opportunity to use and enjoy wildlife will create public support for the maintenance of the state's wildlife programs. These programs must be directed toward the urban dweller.

In order to push future wildlife enhancement programs and provide the recreational opportunities for which Arizona citizens are expressing a desire, future funding sources must be found to pay for these programs. In the past, the anglers and hunters have paid for the large majority of Arizona's wildlife programs. They can not be expected to continue to be the provider of funds for an expanded state wildlife program that will benefit all the state's citizens and visitors.

ARIZONA'S CULTURAL RESOURCES

Arizona is known throughout the world for its spectacular natural resources. Less well known but equally important are Arizona's cultural resources — the tangible remains of the people and cultures who lived here in the past. Cultural resources include buildings, structures, objects, districts, and the remains of these things made by prehistoric or historic groups. While bountiful, cultural resources are not unlimited. Once destroyed, they cannot be replaced.

Over 15,000 historic cultural resources and more than 40,000 prehistoric cultural resources have been recorded in Arizona. These numbers represent only a fraction of the cultural resources believed to exist in our state. The diversity of these resources is reflected in such property types as archaeological sites, private homes, public buildings, bridges, forts, missions, commercial buildings, and industrial complexes.

These resources represent our state's history. They are our link with the past. They provide us with a sense of place and of the accomplishments of those who came before us. Many contain scientific information which gives us a special perspective on the past. Cultural resources can also provide economic benefits. Restored buildings and developed archaeological sites can promote tourism and act as catalysts for community revitalization.

Moreover, cultural resources are playing an increasingly important role in recreation. A recent poll revealed that Arizonans ranked the visiting of historic and archaeological sites seventh among favorite recreational pasttimes. During a one-week period in 1988 (Arizona Archaeology Week, March 20-26), at least 122,400 people in this state participated in archaeological events and activities. The increase in numbers of visitors to cultural resources documents a growing desire to learn about history and prehistory. The planning of new recreation areas should take into account the public's keen interest in Arizona's past.

Cultural resources become threatened as new areas of Arizona are developed and promoted for outdoor recreational use. Archaeological and historic sites in these areas may be damaged through deliberate acts of vandalism or through sheer carelessness. Forces such as these can strip our state of the cultural resources that symbolize its past. To avoid conflicts between recreational use and historic preservation, it is necessary to take cultural resources into account during recreation planning. It is also necessary to monitor the condition of cultural resources and to enforce the federal and state laws which protect them.

Above all, there is a need to educate the public to view historic and archaeological sites as fragile, irreplaceable, and endangered resources. Only by fostering this preservation ethic can the great majority of Arizona's cultural resources survive.

Findings - Arizona Residents

Statewide Trends

Trends in outdoor recreation are often difficult to discern. Data collected from one year to the next are often not parallel, limited by such factors as cost, changing information needs, and development of new opportunities and activities. As a result, direct comparisons must be qualified. The questionnaires developed for the 1987-88 Participation Study tried to balance new information needs with previous SCORP related participation studies.

Activity lists were comparable to most of the activity lists developed in previous studies, although some pursuits were combined for efficiency and information needs. Participation was recorded for 41 identified subactivities arrayed within larger categories. In some instances, information was synthesized from the subcategories to the larger activity grouping, and for other information needs respondents were asked specific questions about the larger group. An example is a question which requested that respondents indicate the importance of the larger activity grouping, and then a series of follow-up questions related to distances travelled, expenditures, and where they participated in the larger groupings that were important to them. Thus, some inconsistency from previous studies (i.e., national and previous SCORPs) had to be tolerated but comparisons for selected activities could be analyzed.

The data indicated that participation in outdoor recreation in Arizona continues to increase over previous years. Most activities have experienced moderate to large growth over 1976 participation levels both in numbers of participants and the percentage reporting participating in the activity in the previous year. For example, in 1976 approximately 37 percent of resident households reported having participated in picnicking, whereas 66 percent of residents from this year's study participated in picnicking. Part of this growth may be attributed to increased opportunities, but such increases generally follow national trends toward a more outdoor activity oriented populace. For example, the Market Opinion Research Study on participation for the President's Commission on Americans Outdoors, shows that approximately 76 percent of residents, nationally, participated in picnicking in 1985.

Some activities have experienced a decline in the percentage of participants who have engaged in the activity. Tennis, baseball/softball, and skateboarding showed slight declines from 1976 in the percentage of residents participating, even though small increases in actual participants were observed. Coupled with this decline is a relative static rate of participation in other team sports, such as football and soccer, and in court games, such as volleyball and basketball. Traditional sports and organized team activities appear to have stabilized in growth rates over the past decade within Arizona.

Contrasted with the stability in participation rates of organized sports is a large increase in participation rates for swimming, bicycling, off-road vehicle use, whitewater sports, hiking and walking for pleasure, and passive recreation pursuits. The popularity of swimming parallels that reported in national studies. Trail oriented activities are likewise experiencing large growth rates. Because these activities occur most frequently on the public estate, there will be a need for designated trails and associated policies covering use in the public sector.

The proliferation of participation in passive recreation activities (i.e., picnicking, park and playground activities, attending sporting events and outdoor performances, and visiting historic sites) has received little attention in the past. Additional facilities may be demanded in the future as the mass of people participating begin to overcrowd existing opportunities. Both the private and public sectors will need to address facility capacity concerns through development of new opportunities and improved management. Positive action will also need to be taken to protect historic and cultural resources while assuring access to greater numbers of interested citizens. Such cooperative ventures will need to be the standard rather than the exception in Arizona's future.

Statewide Participation Rates

For the resident survey, respondents were asked the number of days they participated in each of 41 activities during the previous 12 months prior to the telephone interview. Those responding were then asked a series of in-depth questions pertaining to the importance of the activities to them personally, motivations and constraints to participation, trends in participation, when and where they participate, how far they travel, and expenditures.

Statewide participation in outdoor recreation is extensive. People are participating in activities that were relatively unknown a decade ago. For example, hot air ballooning and windsurfing are now accounting for significant numbers of participants, whereas, 10 years ago they were obscure. As technology changes, new forms of outdoor recreation demand will need to be addressed by management authorities while they contend with an increasing demand for those activities already in existence today.

The main findings from the Arizona resident survey include:

- All activities, excluding tennis, baseball/softball, and skateboarding, showed increases in the percentage of Arizona resident population participating in the activity compared to 1976.

- The top ten activities ranked by the percentage of resident population who participated at least once in the activity are: (1) hiking or walking for pleasure; (2) picnicking; (3) park or playground activities; (4) swimming in a private pool; (5) attending outdoor performance, visit a zoo or outdoor amusement park; (6) driving for pleasure or sightseeing; (7) visiting historical or archaeological sites or monuments; (8) attending outdoor sporting events; (9) bicycling; and (10) swimming in a lake, river, or stream. These activities have had relatively stable significance in the top ranked activities, although the percent of the population participating has increased dramatically

- Attending activities, swimming, and land mobile activities dominate the top 10 ranked activities. This is not surprising as these activities occur relatively close-to-home and seldom require specialized equipment.

- Lack of time is the major constraint to outdoor recreation participation by Arizona residents, although approximately one-third of the residents express no limitations to participation.

- Over one-third of respondents enjoy outdoor recreation because of opportunities to experience nature; approximately another 25 percent enjoy the health, stress reduction, and physical exercise aspects.

Table 7 indicates statewide population activity participation rates and estimates for the number of Arizonans who participate in each of the activities. Findings of this study on a county-wide basis are included in Appendix B.

Status of Swimming Activities

Swimming activities garner a large percentage of Arizona resident participation. Private pool swimming is participated in by 59 percent of the population, while 43 percent of Arizonans participated in swimming in natural settings at least once in the previous 12 months.

- Self-identified swimming enthusiasts (54 percent of the resident population) cited exercise and climate as the reasons they enjoy swimming.

- Only 13 percent of these self-proclaimed enthusiasts use only public facilities; approximately 78 percent of this group use public facilities for swimming less than half the time and slightly less than half never use public facilities.

- Arizonans who feel swimming is important prefer private pool swimming. Slightly more than 25 percent of the population consider swimming an important activity and declared private pool swimming as the most important swimming activity. Only 5 percent of the population consider swimming important and declare public pool swimming as the most important swimming activity.

Status of Watercraft Activities

The participation rate for motorboating/ waterskiing or jetskiing far exceeded that of any other watercraft activity. Over 27 percent of the population participated in motorboat - related watercraft activities in the previous 12 months. This compares with a 17 percent rate for tubing, a 10 percent rate for canoeing or kayaking, and a 6 percent rate for sailing/ windsurfing. Whitewater sports show significant gains over the past decade in rates of participation and closely parallel rates at the national level.

- Only 32 percent of those responding to the survey indicated that watercraft activities were somewhat important or very important to them personally. Of this group, approximately 31 percent enjoy watercraft activities because of opportunities to experience nature.

- Twenty percent of the general population consider watercraft activities important and use only public facilities. This means that approximately 63 percent of the self-proclaimed enthusiasts use only facilities provided by federal, state, and local entities. In contrast, 16 percent of these enthusiasts use only private facilities.

- Slightly more than 3 percent of the total population cite watercraft activity as the most important

TABLE 7
Activity Population Participation Rates, Incidence of Participation, and Ranking

ACTIVITY	POPULATION PERCENTAGE WHO SAY THEY PARTICIPATED PRIOR YEAR	RANKING BY PERCENT THAT SAID THEY PARTICIPATE	INCIDENCE OF PARTICIPATION (Number of Participants)	APPROXIMATE TOTAL NUMBER OF USER DAYS (millions)
SWIMMING ACTIVITIES				
Swimming in Private Pool	59	4	1,864,400	42.9
Swimming in Public Pool	17	22	537,200	1.6
Swimming in Natural Setting	43	10	1,358,800	6.8
WATERCRAFT ACTIVITIES				
Motorboat/Jetski/Waterskiing	27	14	853,200	2.6
Sailing	6	35	189,600	0.2
Canoeing or Rafting	10	32	316,000	0.3
Tubing	17	24	537,200	0.5
LAND MOBILE ACTIVITIES				
Skateboarding or Rollerskating	9	33	284,400	0.4
Bicycling	45	9	1,422,000	25.6
Horseback Riding	17	23	537,200	1.9
OHV Driving	28	13	884,800	5.1
Driving for Pleasure	52	6	1,643,200	3.3
CAMPING ACTIVITIES				
Backpacking	15	27	474,000	0.6
RV/Trailer Use	22	16	695,200	2.4
Other Camping	26	15	821,600	1.8
ON-FOOT ACTIVITIES				
Hiking/Walking	68	1	2,148,800	64.0
Nature Study	16	25	505,600	1.7
Running/Jogging	21	17	663,600	7.4
Technical Rock Climbing	8	34	252,800	0.2
FISHING, HUNTING, or SHOOTING ACTIVITIES				
Fishing	33	12	1,042,800	5.9
Hunting/Trapping	13	28	410,800	7.4
Shooting/Archery	19	19	600,400	1.7
SPORTS or ORGANIZED GROUP ACTIVITIES				
Golf	20	18	63,200	0.4
Tennis	16	26	505,600	1.5
Other Court Games	34	11	1,074,400	8.7
Baseball/Softball	18	21	568,800	2.7
Football/Soccer	11	30	347,600	0.9
WINTER SPORT ACTIVITIES				
Sledding	19	20	600,400	0.7
Downhill Skiing	10	31	31,600	0.02
Cross Country Skiing	3	36.5	94,800	0.02
Ice Skating	1	39	31,600	0.003
Snow Mobiling	2	38	63,200	0.006
ATTENDING or VISITING ACTIVITIES				
Picnicking	66	2	2,085,600	14.8
Use Park/Playground	64	3	2,022,400	20.6
Attend Outdoor Sports	48	8	1,516,800	13.2
Zoo/Outdoor Performance	55	5	1,738,000	5.4
Historical Sites	49	7	1,548,400	5.1
AIR MOBILE ACTIVITIES				
Flying for Pleasure	12	29	379,200	0.4
Hang Gliding or Parasailing	1	40	31,600	0.0006
Skydiving	1	41	31,600	0.003
Hot Air Ballooning	3	36.5	94,800	0.009

NOTE: Readers are cautioned in their use of these figures as they reflect a simple multiplication of Arizona's 1985 estimated population by the percentage of the population who say they participated in the respective activities. Futhermore, the sampled population was restricted to those who were 12 years of age or older. A user day represents any day or part of a day that an individual participated in the activity.

outdoor recreational activity as contrasted with over 6 percent who cited swimming. This seems to indicate that swimming has more fervent support among the water-based enthusiasts.

- Lack of time, equipment, facilities, and excessive distance are listed as the major constraints to participation in watercraft activities.

- The rate of participation in watercraft activities by Arizona residents has increased significantly. All four of the specific watercraft activities increased over levels reported in 1976, but whitewater activities appear to have increased at a slightly faster rate than motorboating.

Status of Land Mobile Activities

Participation rates for land mobile recreation activities range from 52 percent of the population participating in driving for pleasure or sightseeing to 9 percent participating in skateboarding or roller skating. Over 45 percent of the population bicycle and 17 percent have been horseback riding in the past 12 months. Surprisingly, approximately 28 percent of the population participated in off-road vehicle use. This included trailbike use, four-wheeling, ATV use, and the now discontinued three-wheeled vehicles.

- Approximately 64 percent of Arizonans declare themselves as enthusiasts of land mobile activities by affirming that land mobile activities are "very important," or "somewhat important" to them personally. Bicycling and OHV use account for most of this support and indicate a fairly significant average number of days' participation for both activities.

- The self-identified enthusiasts in this category cite lack of time as the largest limitation to participation. Motivations for engaging in land mobile activities include experiencing nature (42 percent) and stress reduction/escape routine (16 percent).

- The population rates for land mobile activities have increased substantially since 1976, except skateboarding, which shows a decline in the population participation rate. This decline may be the result of a natural decline in the age cohort or the result of the activity peaking in popularity because it is a "fad."

- The proportion of the population engaging in these activities should be of concern to management. Both driving for pleasure and OHV use are activities engaged in at some distance from home (only campers travel greater distances to participate), and are dependent on fossil fuels. A change in pricing of fuels and/or supply could result in dramatic changes in participation rates. Moreover, as few designated facilities exist for OHV use, protection of natural resources will become paramount if this participation rate increases or the actual population increases and the rate remains stable.

Status of Camping Activities

Camping activities are still popular with Arizonans. Backpacking participation levels in Arizona (16 percent) parallel those found for the U. S. population as a whole, as detailed in the President's Commission on Americans Outdoors. The participation rate of camping in a recreation vehicle, motor home, or trailer was 22 percent. Similarly, approximately 26 percent of the Arizona resident population engaged in "other" camping (i.e., neither vehicle camping nor backpacking) during the 12 months prior to the survey. Camping has some fervent enthusiasts as evidenced by the aggregated 11 percent of the respondents who noted that these camping activities were the most important activity to them personally.

- Forty-three percent of the general Arizona population are self-proclaimed camping enthusiasts.

- Similar to campers in national studies, Arizona enthusiasts engage in camping to experience nature and to get away from the day-to-day routine and stress. They are contrasted from other activity enthusiasts in Arizona by the relatively large enjoyment they receive in developing skills and the opportunity to be creative (12 percent of the enthusiasts cited these two reasons).

- Similar to other activity enthusiasts, lack of time is cited most frequently as the limitation to participation for those who list camping as an important activity to them.

- Public facilities are used for camping by 20 percent of the population who consider camping important and use these facilities exclusively. This is contrasted with 7 percent of the total population who consider camping important and never use public facilities. Most campers use public facilities the majority of the time when they go camping.

- More Arizona camping enthusiasts travel greater distances to participate in their activity than any other activity enthusiasts (76 percent of enthusiasts travel 50 miles or more). The median distance traveled by enthusiasts exceeds 100 miles.

Status of On-Foot Activities

This group consists of respondents who participated at least once the previous 12 months in hiking or walking for pleasure (68 percent); nature study, birdwatching or rockhounding activities (16 percent); running or jogging (21 percent); and rock climbing or spelunking (8 percent). Hiking or walking for pleasure were participated in by more people than any other single activity. This is the result of the activity being inexpensive and that it may be engaged in close-to-home. Also, it does not require a great amount of investment in developing the skill. However, these levels of participation were substantially less than those reported for similar activities at the national level.

- Self-identified enthusiasts (43 percent) cited exercise and experiencing nature as prime reasons they enjoy on-foot activities. Almost half of the enthusiasts indicated they had no constraints to participation but 40 percent listed time as a limitation.

- Arizona residents who feel on-foot activities are important to them personally (43 percent) tended to use public facilities. Over 21 percent of all respondents to the survey (or 49 percent of the enthusiasts) felt on-foot activities were important and used public facilities exclusively.

- An aggregate of more than 20 percent of the population listed one of these activities as being the most important outdoor recreation activity. For example, 18 percent of respondents mentioned that walking for pleasure is the most important activity; another 1 percent mentioned running/jogging as the most important

- The population participation rates for Arizonans were higher than the 1976 levels for those activities which were similar (i.e., running/jogging and nature study).

- On-foot activities take place close-to-home - 76 percent of enthusiasts travel less than 25 miles to participate.

Status of Fishing, Hunting and Shooting Activities

The percentage of population who have engaged in either fishing, hunting, or shooting activities in Arizona over the previous year is less than the percentage engaged in these activities in studies done at the national level. Approximately 33 percent of Arizonans participated in fishing, 13 percent engaged in hunting or trapping, and 19 percent indicated they had participated at least once the previous 12 months in shooting or archery.

- Fishing, more than any other single activity, is listed as the most important activity - over 11 percent of the respondents. This is quite surprising because only 35 percent of respondents are self-proclaimed enthusiasts. This means that people who enjoy fishing have a great enthusiasm for the activity.

- Enthusiasts cite limitations of time (48 percent) as the major reason they don't participate as often as they would like in these activities. While experiencing nature is mentioned most frequently as the reason enthusiasts enjoy these activities, a wider range of response is given for reasons for enjoyment than in other activities. Unexpectedly, almost 15 percent of the enthusiasts enjoy the activities for competition.

- Approximately two-thirds of the enthusiasts use public facilities and areas for these activities 70 percent or more of the time they engage in the activities.

- More than two–thirds of the anglers, hunters, and shooters who rate these activities as important, usually travel 50 miles or more to participate.

Status of Outdoor Sports or Organized Game Activities

This activity group encompasses: golf; outdoor tennis; other outdoor court games such as basketball, volleyball, and handball; football and soccer; and baseball, softball, and teeball. The popularity of these activities has increased from the 1976 Arizona estimates, with the exception of baseball and softball which has experienced a slight decline in participation (from 20 percent in 1976 to 18 percent), and tennis which declined from 19 percent to 16 percent. Golf participation increased the most; advancing from 13 percent to 20 percent of the population participating at least once in the previous 12 months.

- The number of self-indicated enthusiasts in outdoor sports and organized games approaches 40 percent. The vast majority mentioned lack of time as the largest constraint on participation and cited competition, exercise, and to be with friends as the reason they enjoy these activities.

- Socialization with friends has long been noted as a reason why people play team and competitive sports and is again supported in this study.

- The most important single activity to the respondent is golf (6 percent identified golf as most important).

- Over half of the enthusiasts participate entirely on public provided facilities, and over two-thirds participate a minimum of 50 percent of the time on public provided facilities.

- The urban nature of most of these activities results in most people participating close-to-home (more than 92 percent of enthusiasts travel less than 25 miles).

<u>Status of Winter Sports or Activities</u>

Participation rates for winter activities vary from 19 percent for sledding and snowplay to approximately 1 percent for outdoor ice skating. Approximately 10 percent of Arizonans reported participating in downhill skiing, 3 percent reported cross country skiing, and 2 percent engaged in snowmobiling in the previous 12 months. Rates of participation have generally risen over those reported in 1976 and are similar to those published in the President's Commission on Americans Outdoors. For example, downhill skiing in Arizona has increased five-fold from 1976 while there have been few expansions of opportunities. Moreover, snow skiing is the sixth fastest growing sport nationwide.

- Only 19 percent of Arizonans declare that winter sports are important to them personally. Limitations to participation in winter sports include (in order of magnitude), lack of time, distance, not enough money, and no limitations. Experiencing nature and excitement are the two reasons most frequently mentioned for enjoying winter sports by Arizona resident enthusiasts.

- The geography and climate of Arizona are factors that require those who engage in winter activities to travel long distances. Over half of the enthusiasts travel in excess of 100 miles to participate.

- The percentage of enthusiasts who use public and private winter sports facilities is about evenly distributed.

Status of Attending Activities

This category encompasses a wide variety of activities, including: attending outdoor performances, visiting zoos or amusement parks; attending outdoor sporting events; picnicking; spending time in a park or playground area; and visiting historic sites or monuments. All of these activities are popular with Arizonans. Sixty-six percent of the population reported picnicking at least once over the past 12 months; 64 percent reported spending time in a park/playground; 55 percent indicated they had attended an outdoor performance or zoo; 49 percent had visited a historic site or monument; and 48 percent attended an outdoor sporting event.

- Participation in these activities is similar in magnitude to that reported in national surveys. Comparison with 1976 SCORP data indicates that passive recreational pursuits is growing. Picnicking and attending outdoor spectator events or zoos have experienced the largest growth in this category.

- Approximately two-thirds of respondents indicted they were enthusiasts, and 65 percent of these enthusiasts stated they used public facilities 100 percent of the time for activities they attended.

- Enthusiasts rated picnicking as the most important of these activities; visiting historic sites was rated the second most important activity in this grouping.

- Developing skills, to be with family, and to experience nature were the most frequently mentioned reasons for enjoying these activities by enthusiasts. The family orientation of these passive activities is well noted in the literature. The most frequently reported limitation to participation in these activities was lack of time.

- Not surprisingly, most participants engage in these activities relatively close-to-home (50 percent of enthusiasts travel less than 25 miles to participate).

Status of Air Mobile Activities

Twelve percent of Arizonans reported that they went flying for pleasure at least once in the previous 12 months. Interestingly, population participation rates for hot air ballooning was 3 percent, and hang gliding/ parasailing and skydiving each were 1 percent. Because of the relative "newness" and specialized nature of these activities, participation comparisons with previous SCORP studies and national studies is not meaningful.

- Approximately 12 percent of Arizonans are self-identified air mobile enthusiasts. They tend toward use of private facilities and are fairly evenly distributed in distances they travel to participate.

- Air mobile enthusiasts list lack of money and time as constraints on participation. Reasons for enjoying air mobile activities include excitement of the activity and opportunity to experience nature.

- Air mobile enthusiasts are already being regulated within Arizona. As their numbers increase, corollary demands for designated areas and corridors should be anticipated.

Past Participation in Activities

Changing Participation Rates

Enthusiasts in each activity grouping were asked to estimate if they thought they were spending more, less, or about the same amount of time participating in those particular types of activities compared to 1985. A similar question was asked regarding their estimate of their participation in the future (i.e., 1990).

A summary of the changing participation is provided in Table 8, denoting changes from past participation and respondents' anticipation for participating in the activities in the future. Contrasted with the previous table, the second column of Table 8 presents the percentage of respondents who stated the activities in the respective grouping were not important to them personally. Each additional column in the table reflects the population percentage who reported the activity grouping was important to them and who answered the particular category. For example, approximately 57 percent of the respondents in the survey indicated camping activities were not important to them personally; however, 13 percent of the total population reported camping was important to them and were participating in camping more now than they were in 1985.

- Few respondents felt that they were participating more in outdoor activities now than in 1985.
- The percentage of respondents who reported spending less time participating in watercraft activities in comparison to two years ago (1985), was more than double the number of enthusiasts who said they were spending more time participating in watercraft activities.
- Only two groups of enthusiasts reported spending "more" time participating today than in 1985, as contrasted with spending "less" time – land mobile and on-foot enthusiasts.

TABLE 8
Changes in Participation
(Percentage of Total Respondents or Population rate)

ACTIVITY CATEGORY	PRESENT vs. PAST PARTICIPATION					ANTICIPATED CHANGE IN PARTICIPATION			
	Outdoor Recreation Activity is Not Important	More (%)	Less (%)	About Same (%)	Don't Know (%)	More (%)	Less (%)	About Same (%)	Don't Know (%)
TOTAL POPULATION	4	24	33	38	1	48	6	38	4
Swimming	46	15	18	22	<1	24	3	26	1
Watercraft Activities	68	6	14	11	<1	18	2	11	<1
Land Mobile Activities	36	19	18	26	<1	34	3	26	1
Camping	57	10	17	15	<1	27	2	14	1
On-Foot Activities	57	13	12	17	<1	20	3	19	1
Fishing/Hunting/Shooting	65	9	13	13	<1	20	2	12	1
Organized Sports	60	11	15	14	<1	19	4	17	1
Winter Sports	81	5	7	8	0	11	1	6	<1
Attending Activities	34	17	21	29	0	34	3	28	2
Air Mobile Activities	88	2	3	6	0	6	1	4	<1

Future Participation Rates

Anticipated Participation

Respondents were asked to think ahead to 1990 and estimate if they would be spending more, less, or about the same amount of time participating in these types of activities. These estimates provide an indication of the future trends in participation in these activity categories, and is presented in Table 8.

- Forty-eight percent of all respondents anticipate spending more time in outdoor recreation pursuits in 1990, as contrasted with 6 percent who anticipate spending less time.
- A larger percentage of swimming enthusiasts believe their participation will stabilize than the percentage who believe they will increase their participation.
- The percentage of all respondents who say they were spending the same amount of time participating today as two years ago is equal (38 percent) to those who anticipate no change in participation in the future.
- Swimming, organized sports, and on-foot enthusiasts appear to be the least optimistic about increasing their level of participation in the future.

Decreasing Time

Respondents across all activity groupings cited lack of time as a primary constraint to participation. With the stabilization of the work week, increasing number of households where both spouses work outside the home, and the movement toward a service-oriented economy in Arizona, the time famine is anticipated to be greater. This suggests the increased rates of participation anticipated by respondents may be tempered as the reality of time constraints continues.

Economic Impacts

Significance of Recreation Expenditures by Activity Category

The survey respondents, who specified that an activity category was of importance to them, subsequently were asked a question regarding how much money they spent the last 12 months for the particular activity (including fees, clothing, equipment, travel, gasoline and lodging). For instance, the 54 percent of the population who indicated that swimming activities were important to them personally were asked to report how much they spent on swimming activities the 12 months prior to the survey. Respondents were asked to provide an approximation for only one activity grouping at a time and were not requested to differentiate expenditures for individual activities.

A wide range of recreation expenditure patterns have emerged. Enthusiasts' spending levels for each activity grouping are presented in Table 9. For each expenditure range, the percentage of enthusiasts who spend that amount of money is presented. Generally, the figures indicate that a larger percentage of on-foot activity and organized sports enthusiasts spend less money than enthusiasts from other categories. This may be the result of the preponderance of these activities that occur close-to-home and require little in the way of specialized equipment. Nineteen percent of land mobile enthusiasts, 17 percent of air mobile enthusiasts, 14 percent of camping enthusiasts, and 13 percent of watercraft enthusiasts spent in excess of $1000 on their respective activities in the past 12 months. Information was not collected on items of expenditures, but it is speculated that these enthusiasts have purchased expensive equipment that is often associated with these activities.

An aberration in the pattern of expenditures occurs in the air mobile group. A very high percentage (58 percent) of these enthusiasts spend a minimal amount. Yet, another fairly large percent (17 percent) spend in excess of $1000 creating some speculation that because of the nature of the individual activities in this category, some enthusiasts are obtaining "free rides."

TABLE 9
Enthusiasts Expenditures On Outdoor Recreation (Percentage of those who declared an activity important to them)

	Percentage Enthusiasts*	No Expenditures	Less Than $50	$50 to $99	$100 to $199	$200 to $299	$300 to $399	$400 to $499	$500 to $599	$600 to $699	$700 to $799	$800 to $899	$900 to $999	$1,000 or More	Don't Know
Swimming	54	17	22	11	11	11	6	2	4	<1	<1	2	<1	7	7
Watercraft Activities	32	25	13	9	9	9	6	3	3	<1	<1	<1	<1	13	6
Land Mobile Activities	64	8	11	9	9	11	8	6	6	2	2	2	<1	19	9
Camping	43	16	7	7	14	12	7	5	7	2	<1	<1	<1	14	5
On Foot Activities	43	26	28	12	12	7	2	2	2	<1	<1	0	0	2	5
Fishing/Hunting/Shooting	35	11	11	14	11	9	9	6	6	3	<1	<1	<1	11	6
Organized Sports	40	25	20	13	13	7	3	<1	5	<1	<1	<1	<1	7	5
Winter Sports	19	37	10	5	10	10	5	<1	5	<1	<1	<1	0	10	<1
Attending Activities	66	9	21	15	18	11	6	3	3	<1	<1	2	<1	6	8
Air Mobile Activities	12	50	8	<1	8	<1	<1	<1	<1	<1	<1	<1	<1	17	8

*Those respondents who said the activity was important to them personally.

prepared and changes made. Appendix D includes all public comments and written agency responses. These responses were reviewed and approved by the AORCC and State Parks Board.

RECOMMENDATIONS FROM THE RESOURCE STUDIES

Arizona Rivers, Streams, & Wetlands Study

Issues

Resource Significance

- Arizona's streams and wetlands are economically vital to the commerce and industry of the state.
- Streams and wetlands have been essential to the survival and social well-being of Arizona's people since the beginnings of prehistoric settlement. Today, they continue to be critical to the quality of life for which Arizona is renowned.
- Natural streams, their associated riparian areas, and other wetlands constitute the state's richest environments in terms of the wildlife and fish diversity and plant and animal productivity.
- Streams and wetlands afford some of the most popular, diverse, and exceptional recreational opportunities, such as boating, fishing, hunting, camping, and hiking, in Arizona.

Decreasing Resource Availability and Quality

- Substantial losses in perennial streamflows and up to ninety-five percent loss of natural wetlands have resulted in dramatic losses — including some extinctions — of native fish and wildlife populations, accelerated soil erosion, degraded surface and groundwater quality, reduced groundwater recharge, and lost recreation values.

Increasing Resource Demands

- The importance of the state's diminishing streams and wetlands has increased greatly due to population growth, to expanded participation in water-based recreation, and to additional needs for water and watershed resources.

Increasing Conflict for Streams and Wetlands Use

- Growing demands for the use of streams and wetlands and associated water supplies have led to sharp competition for and conflict over these diminishing resources.

Recreation Dependent on Environmental Quality

- The quality of recreational experiences associated with streams and wetlands is dependent upon maintaining and restoring the environmental integrity of the resources.

Need to Meet Growing Demands for Recreation

- Some streams and wetlands can support additional recreation use. However, other areas have already met or exceeded their capacity to support use without significant environmental deterioration. The critical task will be to accommodate additional use while conserving the basic integrity of stream and wetland resources.

Need for Economic Demand, Participation, and Attitudinal Data

- There is a critical need for stream- and wetland-based recreation data, particularly site-specific information.

Need to Conserve and Restore Resources

- There is an urgent need to conserve the state's streams and wetlands and to utilize opportunities to restore streams and wetlands for future generations to use and enjoy.

Need for Consistent and Coordinated Management

- The opportunities for consistent and coordinated management of streams and wetlands in Arizona have been limited by: (1) the many authorities and interests that influence the management and use of surface waters at all levels of government; (2) the lack of a common forum for communication among the complexity of authorities and interests concerned with streams and wetlands; and (3) inconsistencies and fragmentation in policy, purpose, and practice among the various authorities that manage and regulate the use of streams and wetlands.

Need for Communication and Cooperation

- The consistent and coordinated management and equitable use of Arizona's streams and wetlands are dependent upon communication and cooperation between the many management entities, private landowners, resource users, and citizens of the state.

Need for a Statewide Policy

- A statewide policy is needed which: 1. Recognizes the importance of streams and wetlands to Arizona's heritage, economic growth, recreational opportunities, and quality of life; 2. Fosters communication and harmony, rather than conflict, among users; 3. Provides guidance to management entities so that they may, through coordinated and consistent efforts, achieve equitable, quality allocations of stream and wetland resources.

Recommendations

The Arizona Rivers, Streams, & Wetlands Study is recommending that four key management actions be initiated to ensure continued recreational use and proper conservation of our state's stream and wetland resources:

- Enactment of a State Streams and Wetlands Policy

- Establishment of an Arizona Streams & Wetlands Heritage Program to coordinate the implementation of the policy

- Development of a forum for intergovernmental coordination
- Development of an effective forum for active citizen participation

Streams and Wetlands Policy

Enact a Statewide Streams and Wetlands Policy

The State of Arizona should enact the following policy to promote the wise and equitable use of streams and wetlands. This policy will be the cornerstone for all other actions pertaining to streams and wetlands.

Proposed Arizona Streams and Wetlands Policy Statement

The State of Arizona finds that the economic well-being and quality of life of its citizens depends on achieving and maintaining an equitable balance among the competing uses of the state's streams and wetlands while maintaining the natural integrity of these resources. This balance must:

- Recognize the traditional and changing interests in and uses of streams and wetlands.
- Recognize that the conservation and wise use of stream and wetland resources is in the best interest of all citizens of the state.
- Conserve stream and wetland waters for water-based recreational uses and for fish and wildlife habitat.
- Restore degraded streams and wetlands for future generations to use and enjoy.
- Expand and promote stream- and wetland-based recreational opportunities.
- Identify and conserve critical recreation, habitat, water quality, and instream flow water values of the state's streams and wetlands.

Further, to provide for this balance of uses the state will:

- Foster an atmosphere conducive to communication and cooperation among competing stream and wetland users so that an equitable allocation of these finite resources can be achieved.
- Provide guidance and authority for consistent and coordinated management of streams and wetlands.

State Programs for Streams and Wetlands Management

Create an Arizona Streams and Wetlands Heritage Program

The State of Arizona should establish, with sufficient funding and staff, a statewide management program entitled, Arizona Streams & Wetlands Heritage Program. The purpose of the program will be to coordinate and promote implementation of the state's streams and wetlands management policy. The program must be closely integrated with the Intergovernmental Coordinating Committee, the Arizona Streams & Wetlands Council, and Regional Advisory and Action Groups. In order to initiate this program, the state should:

Designate a Lead Administrative Agency. The State of Arizona must designate a lead administrative agency to coordinate the formulation and functions of the inter-governmental agreement and the Arizona Streams & Wetlands Council.

Establish a Position for an Arizona Streams & Wetlands Coordinator. Establish a position for an Arizona Streams & Wetlands Coordinator who should be hired with guidance from the Arizona Streams & Wetlands Council. The Coordinator will administer the activities of the Arizona Streams & Wetlands Council and the Intergovernmental Coordinating Committee.

Heritage program functions will include:

Foster Communication and Cooperation. Foster communication and cooperation among agencies, users, and landowners on issues concerning the state's streams and wetlands through the Council and its extended membership.

Educate and Inform Arizonans. Educate and inform Arizonans — including agencies, the public, private organizations, landowners, and business enterprises — on the diverse values and multiple uses of the state's streams and wetlands.

Share Technology and Expertise. Share technology and expertise with agencies, the public, private organizations, and business enterprises on matters concerning the management of streams and wetlands.

Identify and Promote Recreational Enhancements. Identify and promote means for enhancing stream- and wetland-based recreation including:

- Public Information. Develop and distribute information concerning stream- and wetland-based recreational opportunities.
- Access and Facilities. Monitor and address the need for improved or additional access and facilities, and other recreational needs.
- Interpretation/Education. Educate agencies and the public on minimal impact stream and wetland recreation.
- Site Quality and Safety. Monitor and investigate water quality problems, natural hazards, and other safety concerns related to streams and wetlands recreation.
- Reclamation and Restoration. Pursue opportunities to restore stream and wetland resources or create new habitats.

Recommend and Promote Coordinated and Consistent Management. Recommend and promote coordinated and consistent management policies and practices for the conservation and wise use of the state's streams and wetlands.

Maintain and Update the Database. Maintain and update the Arizona Streams & Wetlands Database which was initiated as a result of the Arizona Rivers, Streams, & Wetlands Study.

Establish and Maintain a Streams and Wetlands Library. Establish and maintain a streams and wetlands library containing up-to-date information on: current research; federal, state and local policies, programs, statutes, laws and regulations; and other relevant information.

Identify Critical Streams and Wetlands

Identify streams and wetlands possessing critical recreation, habitat, and instream flow water attributes and develop appropriate methods for ensuring their conservation.

Recommend Management for Critical Streams and Wetlands. Recommend appropriate, consistent, and coordinated management policies and practices for streams and wetlands identified as possessing critical recreation, habitat, or instream flow water attributes.

Facilitate Local and Site Specific Actions. Lend support and expertise to local and site specific efforts to develop recreational opportunities and conservation measures for streams or wetlands.

Streams and Wetlands Intergovernmental Coordination

Establish an Intergovernmental Streams and Wetlands Coordinating Committee.

An intergovernmental agreement among the State of Arizona, the federal government, local governments, and Tribal governments must be developed in order to:

- Facilitate Participation and Communication. Facilitate participation and communication among all federal, state, and local agencies and Tribes with management responsibilities for streams and wetlands.

- Promote Consistency. Promote intergovernmental consistency regarding policy and the management of streams and wetlands.

The signatories of the agreement should meet at least biannually to:

- Share Information. Provide and share information pertinent to streams and wetlands management.

- Exchange Viewpoints. Exchange viewpoints on streams and wetlands management goals.

- Identify Inconsistencies. Identify existing and potential inconsistencies in management purpose and practice.

- Review and Improve Management. Review and improve methods for management coordination and technology transfer.

Streams and Wetlands Citizen/ Government Partnerships

Establish an Arizona Streams & Wetlands Council

An Arizona Streams & Wetlands Council, composed of representatives of public interests concerned with the use, management, and conservation of streams and wetlands, should be created. The Council would:

Advise State Government. Provide a means for fully integrating public concerns into state stream and wetland planning and management activities, and for monitoring efforts to attain state policy goals for these resources.

Coordinate with the Intergovernmental Committee. Provide public perspectives on management purpose and priorities to the Intergovernmental Committee.

Resolve Conflicts. Provide a forum for the discussion and possible resolution of issues relating to the use and conservation of Arizona's streams and wetlands.

Encourage Local Streams and Wetlands Actions

Local streams and wetlands actions should be encouraged where needed in order to:

Enhance Local Management. Enhance local efforts to conserve, manage, and balance uses of streams and wetlands.

Incorporate Local Participation. Integrate local involvement into statewide policy, planning, and management.

Where appropriate, local actions could be promoted through stream and wetland committees. As appropriate, local or regional groups could focus on either: (1) action items on a specific stream or wetland, or (2) broader planning and coordination issues. The efforts of these groups should be coordinated with the Arizona Streams & Wetlands Council.

Arizona Natural Areas Study

Issue: Arizona State Parks Board Awareness and Support

In review of the history of the Natural Areas Program and the questionnaire responses, one issue overshadows the others—the Arizona State Parks Board has not taken advantage of the benefits such a program could provide nor has it given the Natural Areas Program the support and commitment the program warrants.

Recommendations

The Arizona State Parks Board needs to provide the support and funding necessary to make the Arizona Natural Areas Program a viable, dynamic protection program and to reassess the program in terms of how it could interact within the agency.

- The Arizona State Parks Board should strongly commit, through a Board resolution, to implement Scenario B as an interim step while working toward the ultimate goal of achieving the fully supported program described in Scenario C. Without a full-time position within Arizona State Parks committed to the Natural Areas Program, the program will continue to languish and be ineffective. If the Board cannot commit to the implementation of Scenario B or C, the program should either be disbanded or an agreement should be worked out with the Arizona Game & Fish Department to incorporate the program into a new Critical Areas Program under the Department's authority (Scenario D), or the program, as it is now administered, should be disbanded and private interests should be encouraged and supported to continue the protection of Arizona's natural areas (Scenario E).

- The Arizona State Parks Board should actively seek to acquire and protect, through a variety of means, significant natural areas within the state.

- The Arizona State Parks Board should prioritize the top twenty-seven natural areas identified by this study to

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Arizona Rivers, Streams, & Wetlands Study

Rose Mofford, Governor

Arizona State Parks
1989

Introduction

Arizona is one of the most arid of the fifty United States. Its name is often thought to come from the phrase "arid zone," but historical reports attribute it to the word *arizonac,* a derivation from Tohono O'odham words, *ali* meaning "small" and *shonak* meaning "place of the spring." So according to historical documents, Arizona actually means "place of the small springs." In reality, its rivers, streams, and wetlands — virtually the only natural aquatic environments in the state — cover less than 0.5 percent of its landscape. As a critical component of Arizona's desert biosystem, these surface waters deserve special attention by state and local policy makers and by the public at large.

Arizona's desert streams are often outlined with a band of green vegetation cutting through the earth-toned landscape. These stream beds may carry water year round, seasonally, or only during storm run-off. Also present in Arizona, though rare, are nonstream wetlands known as cienegas. The riparian areas that border stream courses and cienegas constitute the most diverse and productive plant communities in the state. These waters and their adjoining riparian areas are prime habitat for fish and wildlife; here are found both the greatest diversity of species and the greatest abundance of individual animals. Indeed, almost all species in the state rely in some form on streams and wetlands for survival.

Humans also depend on these surface waters for their well-being; it is no accident that nearly all of Arizona's cities and towns were founded along waterways. Commerce, in the guise of early agriculture, cattle ranching, and mining, also followed waterways. Since the early days of settlement, many streams have been degraded, but they still perform a variety of functions that are essential to the state's citizens. They channel floods and recharge critical groundwater supplies; they provide water for agriculture and livestock; their valleys serve as avenues for roads and railways.

Arizona's waterways are also becoming increasingly important as recreational resources. Arizonans and visitors alike have come to view these waters as refreshing and revitalizing contrasts to urban and desert landscapes. In ever-growing numbers, people are pursuing water-related activities such as boating, tubing, hunting, fishing, hiking, and swimming. Rivers and streams also provide desirable opportunities for more passive pursuits including picnicking, camping, nature study, and general sightseeing.

In response to growing and changing recreation demands in the state, the Arizona State Parks Board initiated a major update of the Arizona State Comprehensive Outdoor Recreation Plan in 1987. Recognizing the importance of waterways to the state's overall outdoor recreation program, State Parks elected to focus a substantial portion of its efforts on a recreational and environmental evaluation of streams and wetlands. The Arizona Rivers, Streams, & Wetlands Study is the result of this initiative.

The basic objectives of the study were to: (1) determine the role that streams and wetlands can play in meeting Arizona's growing recreational needs, (2) identify problems pertaining to streams and wetlands recreation, and (3) recommend actions that might be taken to enhance future recreational use of these important and limited resources.

The study's fundamental conclusion is that Arizona's rivers, streams, and wetlands can provide a wide variety of high quality outdoor recreation experiences for both residents and visitors. However, careful planning will be required to address the intense competition for water resources and to coordinate the variety of water interests and water management authorities. If Arizona's waterways are to play a significant role in the state's recreational future, effective communication among water users and managers will be essential. The Arizona Rivers, Streams, & Wetlands Study recognizes the importance of this and has therefore made communication a primary focus of the conceptual management plan that is offered at the conclusion of the report.

Arizona's Streams & Wetlands — A Resource Heritage at the Crossroads

Recreational Significance of Streams and Wetlands

Arizona's streams and wetlands are vitally important as outdoor recreation resources. Over half a million of the state's residents fish and over one quarter million hunt. Without streams and wetlands, both of these recreational activities would be severely restricted. Perennial streams provide essential habitat for a variety of cold and warm water game fish. Anglers for both trout and largemouth bass, two of the most popular game fish, can find a number of streams in Arizona that will challenge their skills and provide ample return. Smaller mountain streams, many of which are located in National Forests, provide opportunities to fish for rainbow and the native Arizona trout. Larger streams, including the Colorado River below Glen Canyon Dam, East Verde River, and Eagle Creek, also possess significant coldwater fisheries. Significant warm water fisheries include the Colorado River downstream of Lake Mead, the Gila River, and the Salt River.

Hunters also are attracted to streams and wetlands. Waterfowl, big game, and upland game species all can be found in the riparian areas adjacent to these waters and often in greater numbers than in other, less hospitable habitats. In addition, some eighty percent of Arizona residents consider themselves to be "non-consumptive" wildlife users; that is, they find pleasure in simply observing or photographing wildlife. Again, given the density of living creatures along watercourses, these areas are often the destination of choice for those wishing to observe birds and other wildlife species.

In 1987, one-third of the state's residents participated in camping; one-quarter participated in either hiking or backpacking. Federal land managers report that stream corridors are immensely popular for these activities. Some stream courses, such as Aravaipa and Paria Canyons, provide superlative wilderness experiences. Other streams, including Sabino and Fish Creek, also offer opportunities for either day or overnight hikes. Oak Creek Canyon and parts of the Verde and Blue Rivers, among others, are popular areas for recreational camping.

Boating and tubing are becoming increasingly popular in Arizona. The Grand Canyon of the Colorado River is one of the finest and most popular whitewater boating rivers in the world. Other sections of this river offer quality canoe touring, jet boating, and water-skiing. Whitewater boating is also becoming increasingly popular on the Salt, Verde, Gila, and Little Colorado Rivers, and other smaller and sometimes seasonal rivers. Recreational boating on the Salt River, as one example, has been increasing annually by approximately half over the past few years.

Tubing is a fairly recent phenomenon. The Salt River downstream of Saguaro Lake is the premier example of this recreational activity. More than 20,000 people from the Phoenix metropolitan area visit on any given summer Saturday or Sunday to enjoy this and other recreational pursuits.

Sabino Creek, near Tucson, is another example of a stream that is receiving high recreational use from the residents in the adjacent urban area. On this small stream, thousands of people visit annually to picnic, hike, watch birds, and otherwise enjoy nature.

A Resource in Crises

In its native condition, Arizona's landscape was not as parched as what we experience today. Little more than a century ago, rivers and streams flowed year around in nearly every area of the state. The Santa Cruz River in Tucson, the Salt River in Phoenix, and the Gila River in Safford were, at one time, all perennial streams. For centuries, these and other perennial streams had been the mainstays of native American cultures. Later, Hispanic and fledgling Anglo-American communities relied on the streams. Perennial streams and the extensive riparian forests that they supported provided water for domestic needs, fish and game for food, pelts for clothing and trade, fertile soils and water for agriculture, water and forage for livestock and industry, and wood for lumber, fence posts, and fuel.

Over the past century, Arizona has lost much of its rich natural heritage. Moreover, there is no indication that this trend is abating. Expanding requirements of agriculture, mining, industry, and cities have redesigned the state's streams and wetlands. Flows in all of our major rivers and many of the lesser streams have been impounded, regulated, and diverted. Perennial streams and wetlands have disappeared as groundwater pumping drained the water from underlying aquifers and land use practices altered the surface hydrology. Many of these activities served a beneficial public use, such as flood control, water storage, or power production. Unfortunately, others simply resulted from poor or uninformed land use and management actions.

Regardless of cause, the restructuring of Arizona's native stream and wetland system has resulted in drastic alterations to natural values. Most telling has been the impacts on native fish and wildlife. Native fishes, the fastest disappearing wildlife group in the United States today, have suffered the most. Due to diminished and altered streamflows, one of Arizona's thirty-five species of native fish is now extinct, five others are gone from the state, and twenty-one of the remaining twenty-nine species are officially listed as federally threatened or endangered or are under consideration for this dubious distinction. While the major threat to Arizona's native fish is human competition for water, the introduction of many non-native fish species and pollutants into our streams has also compromised native populations.

Along with the loss of stream flow has come major destruction and alteration of the riparian areas that border the state's streams. While much of this has been a direct result of the loss of water, other activities, including wood harvest, grazing, urbanization, and the introduction of exotic plant species, have also contributed to the degradation of riparian areas.

It is estimated that only five to ten percent of Arizona's original native riparian areas in the lower elevations remains today. As a result, riparian communities now comprise only a very small portion of the total Southwestern landscape, between 0.1 and 0.5 percent. Riparian areas are now Arizona's most threatened natural communities. Cottonwood-willow gallery forests, which once formed lush canopies along all of the state's major desert river systems, are now the rarest forest type in North America. Mature mesquite bosque stands have suffered similar declines and are now the fourth rarest plant community in the United States. This change in habitat has resulted in significant changes and reductions to native animal and bird species and therefore had a decidedly negative effect on recreational hunting.

Fishing and hunting are not the only recreational activities to suffer from degradation of stream resources. Without adequate flow, boating is impossible; without healthy vegetation, campers lose shade and scenic quality suffers. Clearly, there is a relationship between environmental quality and diversity of recreational opportunities; a relationship that must be taken into account in planning for future stream and wetland recreation.

The Future for Stream and Wetland Recreation

Given the importance of water and its scarcity in Arizona, one can only conclude that the continued wise use and conservation of Arizona's streams and wetlands is in the best interests of all the citizens of the state.

In planning for the recreational use and conservation of their streams and wetlands, Arizonans must address a series of urgent resource, policy, and management issues. Many of the resource issues have been discussed above, In essence, the availability of stream and wetland resources is already severely depleted through previous actions. In addition, the supply and quality of these resources continue to diminish, chiefly from the loss of water to competing water uses and from land use practices that destabilize riparian communities. Paradoxically, as the water base for recreation diminishes, the population continues to grow at a rate that is among the highest of any state in the nation and the demand for stream and wetland recreation also accelerates.

From these resource issues emanate a number of policy and management issues. Paramount is the growing need to address the use and management of our remaining stream and wetland resources in a comprehensive and forward thinking manner. From a policy perspective, there are no means to balance competing uses and conserve significant streams and wetlands. From a management perspective, there exists no institutional framework for statewide planning for stream and wetland use and conservation, nor for communication and coordination between the various water management authorities.

A number of obstacles stand in the way of such policy and management arrangements. Multiple and sometimes conflicting resource use demands are, of course, among these. Another is the multitude of management authorities, which include private, local, state, federal, and tribal entities, who are in a position to make decisions that affect not only their own interests, but those of others.

Wise waterway management aimed at meeting multiple demands, including providing for quality recreation for Arizona's citizens and visitors, will require cooperation among all levels of government, private interests, and concerned citizens. An effective solution will require: (1) statewide policies to guide actions by the various management authorities, (2) improved mechanisms for communication and coordination, and (3) a timely strategy to arrest further unacceptable degradation of those streams and wetlands that retain natural values and provide quality recreational opportunities. Former Governor Bruce Babbitt recognized the need for a comprehensive program to address issues pertaining to the state's waterways. In his forward to the First North American Riparian Conference held in Tucson in 1985, he wrote:

> *What is needed is the implementation of a comprehensive legislative mandate for the protection, conservation, and rehabilitation of riparian ecosystems. Previous efforts have addressed only pieces of the whole. Legislation must include all aspects of riparian systems and address all levels of involvement—federal, state, local, and private—to be effective.*

Arizona has ignored the growing need to comprehensively address the use and management of our remaining stream and wetland resources for a long time. In the interim, these resources have suffered much damage and loss. This study was initiated because there is a growing understanding among the leaders and citizens of Arizona for the need to take positive action on stream and wetland issues, and was designed to give impetus and direction to that effort.

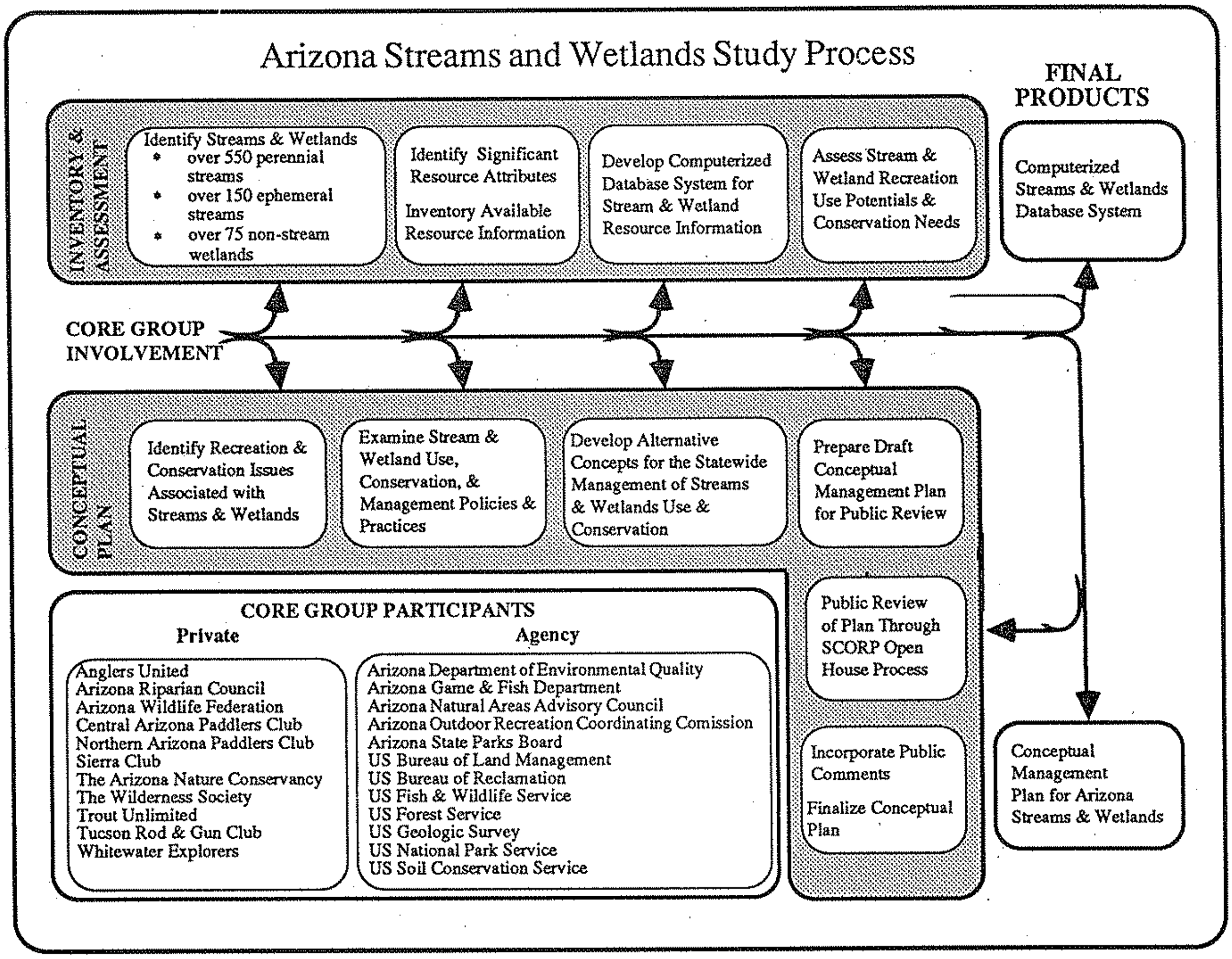
Study Process

The Arizona Rivers, Streams, & Wetlands Study seeks to both clarify the state's waterways issues and to suggest possible strategies to ensure that recreation and resource conservation will be fully considered in future water management decisions. To accomplish these ends, the study had two basic elements: first, an inventory of existing information regarding stream and wetland resources and their management, and second, the development of a conceptual plan for future management of these resources.

To provide guidance for this study, the Arizona State Parks Board organized a Streams and Wetlands Advisory Core Group. This group was made up of knowledgeable individuals representing recreation and conservation interests, federal land management agencies, and state resource agencies. The role of the Advisory Core Group was to provide the study team with technical information about the status of stream and wetland recreation in Arizona, clarify major recreation issues, and identify potential solutions for these issues. Five meetings of this group were held between September of 1987 and March of 1988. A final meeting in August of 1988 allowed the Advisory Core Group to critique the final draft study report.

Inventory information and opinions about the conceptual management plan were also solicited from resource managers with the Bureau of Land Management, U.S. Forest Service, National Park Service, U.S. Fish & Wildlife Service, and state agencies including the Arizona Department of Water Resources and the Arizona Department of Mines & Mineral Resources. Twenty-eight states known to have stream or wetland programs were also contacted for information about their laws, policies, and programs.

Input was also provided by the public through a series of public meetings held throughout the state where the draft study findings were made available and discussed.



Study Findings

In summary form, the study's basic findings are as follows:

Resource Significance

Economic Significance. Arizona's streams and wetlands are economically vital to the commerce and industry of the state. They are also unequalled for their natural abilities to minimize flooding, prevent erosion, and enhance water quality; and are essential conduits for groundwater recharge.

- *Fifteen million tourists visit Arizona annually.*
- *Water-based recreation is a major component of the tourist industry.*
- *Tourism generates over five billion dollars of income annually, the second largest source of income in Arizona.*
- *Recreation is a sustainable industry because it is based on renewable natural resources.*
- *Streams and wetlands play a vital role in the protection of property*

from natural hazards. In recognition of this, Pima County has enacted tough controls to protect remaining natural riparian drainages as a measure to greatly reduce the danger of future floods.

Cultural Significance. Streams and wetlands have been essential to the survival and social well-being of Arizona's people since the beginnings of prehistoric settlement. Today, they continue to be critical to the quality of life for which Arizona is renowned.

- *Nearly all communities in Arizona can trace their origins to a stream or wetland that provided sustenance for life and the early tools for development.*
- *Many of the state's most significant archaeological sites are located along waterways.*

Environmental Significance. Natural streams, their associated riparian areas, and other wetlands constitute the state's richest environments in terms of the wildlife and fish diversity and plant and animal productivity.

- *At least sixty percent of the vertebrates in the Southwest are dependent in some capacity on streams or wetlands.*
- *All of Arizona's twenty-nine remaining native fish species depend solely on streams and wetlands for their survival.*
- *More bird species nest in the cottonwood-willow riparian community than in any other North American vegetation type.*
- *Pima County has enacted tough controls to protect remaining natural riparian drainages as a measure to greatly reduce the danger of future floods.*

Recreational Significance. Streams and wetlands afford some of the most popular, diverse, and exceptional-recreational opportunities, such as boating, fishing, hunting, camping, and hiking, in Arizona. These opportunities are vital to Arizonans.

- *Nonconsumptive wildlife users in Arizona number almost 2,000,000.*
- *Over 812,000 Arizonans camp and over 620,00 Arizonans backpack.*
- *Arizona hunters number 235, 000; anglers number more than 250,000.*

Resource Issues

Decreasing Resource Availability and Quality. Substantial losses in perennial streamflows and up to ninety-five percent loss of natural wetlands have resulted in dramatic losses — including some extinctions — of native fish and wildlife populations, accelerated soil erosion, degraded surface and groundwater quality, reduced groundwater recharge, and lost recreation values.

Increasing Resource Demands. The importance of the state's diminishing streams and wetlands has increased greatly due to population growth, to expanded participation in water-based recreation, and to additional needs for water and watershed resources.

- *The number of registered boats has tripled since 1969.*
- *All land and resource management agencies report increasing use of water-based recreation sites.*
- *Population in Arizona has grown from 499,261 in 1940 to 3,386,000 in 1987; an almost seven-fold increase.*

Increasing Conflict for Streams and Wetlands Use. Growing demands for the use of streams and wetlands and associated water supplies have led to sharp competition for and conflict over these diminishing resources.

- *A 1985 statewide survey of Arizona residents revealed that "competition for water" and "water conservation" were issues of greatest concern.*

Recreation Dependent on Environmental Quality. The quality of recreational experiences associated with streams and wetlands is dependent upon maintaining and restoring the environmental integrity of the resources.

Policy and Management Needs

Need to Meet Growing Demands for Recreation. Some streams and wetlands can support additional recreation use. However, other areas have already met or exceeded their capacity to support use without significant environmental deterioration. The critical task will be to accommodate additional use while conserving the basic integrity of stream and wetland resources.

- *Limits to additional recreation use have already been imposed in Grand Canyon National Park and Aravaipa and Paria Canyon Wilderness Areas to prevent unacceptable environmental degradation.*

Need for Economic Demand, Participation, and Attitudinal Data. There is a critical need for stream- and wetland-based recreation data, particularly site-specific information. This information is important if Arizona is to plan for the increasing recreation demands that will come with the projected growth in population.

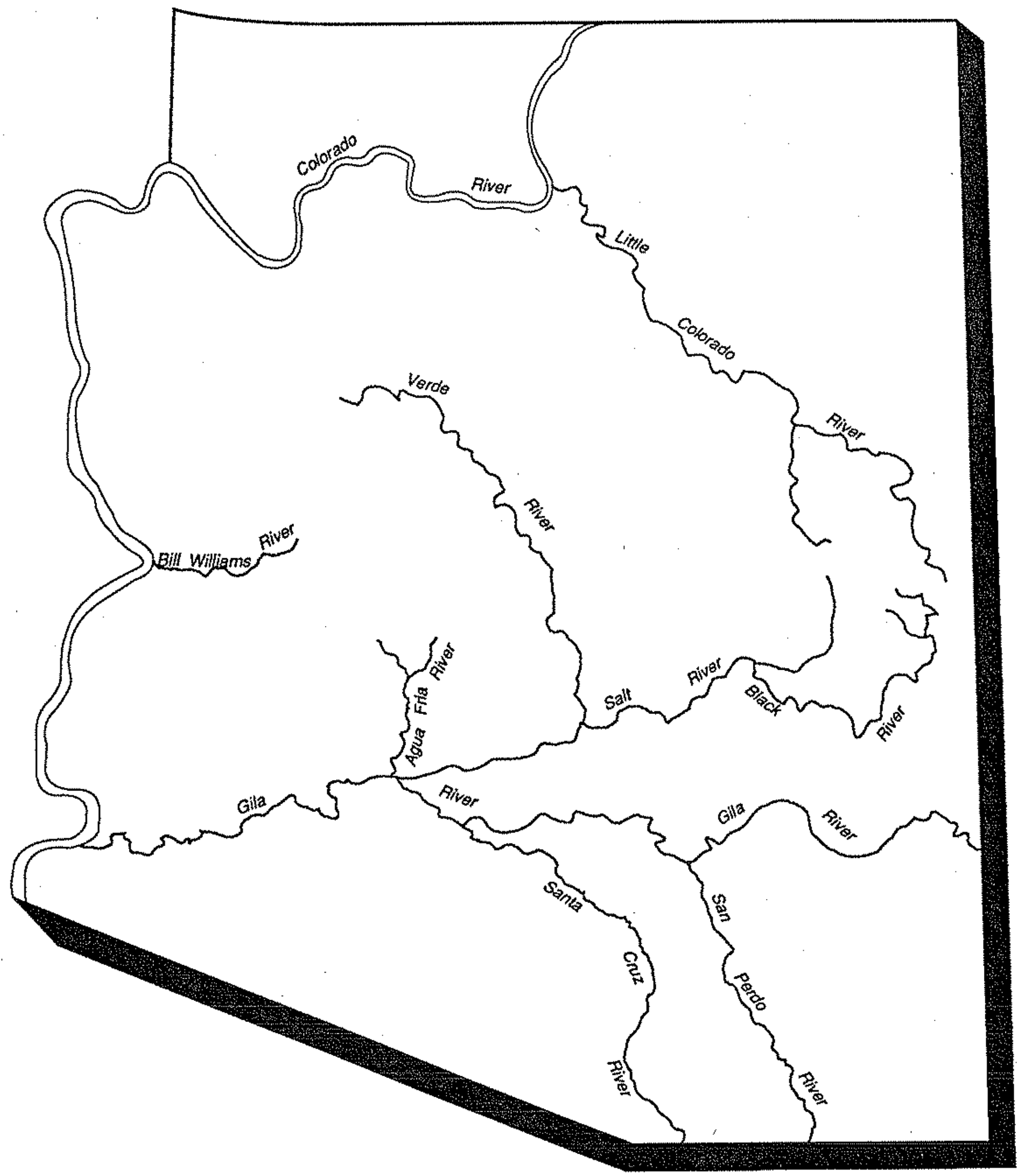
- *There has been no statewide comprehensive survey of stream and wetland recreation participation and demand.*

Need to Conserve and Restore Resources. There is an urgent need to conserve the state's streams and wetlands and to utilize opportunities to restore streams and wetlands for future generations to use and enjoy.

Need for Consistent and Coordinated Management. The opportunities for consistent and coordinated management of streams and wetlands in Arizona have been limited by: (1) the many authorities and interests that influence the management and use of surface waters at all levels of government; (2) the lack of a common forum for communication among the complexity of authorities and interests concerned with streams and wetlands; and (3) inconsistencies and fragmentation in policy, purpose, and practice among the various authorities that manage and regulate the use of streams and wetlands.

Need for Communication and Cooperation. The consistent and coordinated management and equitable use of Arizona's streams and wetlands are dependent upon communication and cooperation between the many management entities, private landowners, resource users, and citizens of the state.

Need for a Statewide Policy. A statewide policy is needed which: (1) recognizes the importance of streams and wetlands to Arizona's heritage, economic growth, recreational opportunities, and quality of life; (2) fosters communication and harmony, rather than conflict, among users; and (3) provides guidance to management entities so that they may, through coordinated and consistent efforts, achieve equitable, quality allocations of stream and wetland resources.



Study Recommendations

The Arizona Rivers, Streams, & Wetlands Study is recommending that four key management actions be initiated to ensure continued recreational use and proper conservation of our state's stream and wetland resources:

- Enactment of a State Streams and Wetlands Policy
- Establishment of an Arizona Streams & Wetlands Heritage Program to coordinate the implementation of the policy
- Development of a forum for intergovernmental coordination
- Development of an effective forum for active citizen participation

Recommendation—Streams and Wetlands Policy

Enact a Statewide Streams and Wetlands Policy

The State of Arizona should enact the following policy to promote the wise and equitable use of streams and wetlands. This policy will be the cornerstone for all other actions pertaining to streams and wetlands.

Proposed Arizona Streams and Wetlands Policy Statement

The State of Arizona finds that the economic well-being and quality of life of its citizens depends on achieving and maintaining an equitable balance among the competing uses of the state's streams and wetlands while maintaining the natural integrity of these resources. This balance must:

- Recognize the traditional and changing interests in and uses of streams and wetlands.
- Recognize that the conservation and wise use of stream and wetland resources is in the best interest of all citizens of the state.
- Conserve stream and wetland waters for water-based recreational uses and for fish and wildlife habitat.
- Restore degraded streams and wetlands for future generations to use and enjoy.
- Expand and promote stream- and wetland-based recreational opportunities.
- Identify and conserve critical recreation, habitat, water quality, and instream flow water values of the state's streams and wetlands.

Further, to provide for this balance of uses the state will:

- Foster an atmosphere conducive to communication and cooperation among competing stream and wetland users so that an equitable allocation of these finite resources can be achieved.
- Provide guidance and authority for consistent and coordinated management of streams and wetlands.

Recommendation—State Program for Streams and Wetlands Management

Create an Arizona Streams and Wetlands Heritage Program.

The State of Arizona should establish, with sufficient funding and staff, a statewide management program entitled, Arizona Streams & Wetlands Heritage Program. The purpose of the program will be to coordinate and promote implementation of the state's streams and wetlands management policy. The program must be closely integrated with the Intergovernmental Coordinating Committee, the Arizona Streams & Wetlands Council, and Regional Advisory and Action Groups. In order to initiate this program, the state should:

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> **Establish a Position for an Arizona Streams & Wetlands Coordinator.** Establish a position for an Arizona Streams & Wetlands Coordinator who should be hired with guidance from the Arizona Streams & Wetlands Council. The Coordinator will administer the activities of the Arizona Streams & Wetlands Council and the Intergovernmental Coordinating Committee.

Heritage program functions will include:

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Educate and Inform Arizonans. Educate and inform Arizonans — including agencies, the public, private organizations, landowners, and business enterprises — on the diverse values and multiple uses of the state's streams and wetlands.

Share Technology and Expertise. Share technology and expertise with agencies, the public, private organizations, and business enterprises on matters concerning the management of streams and wetlands.

Identify and Promote Recreational Enhancements. Identify and promote means for enhancing stream- and wetland-based recreation including:

- **Public Information.** Develop and distribute information concerning stream- and wetland-based recreational opportunities.
- **Access and Facilities.** Monitor and address the need for improved or additional access and facilities, and other recreational needs.
- **Interpretation/Education.** Educate agencies and the public on minimal impact stream and wetland recreation.
- **Site Quality and Safety.** Monitor and investigate water quality problems, natural hazards, and other safety concerns related to streams and wetlands recreation.

- **Reclamation and Restoration.** Pursue opportunities to restore stream and wetland resources or create new habitats.

Recommend and Promote Coordinated and Consistent Management. Recommend and promote coordinated and consistent management policies and practices for the conservation and wise use of the state's streams and wetlands.

Maintain and Update the Database. Maintain and update the Arizona Streams & Wetlands Database which was initiated as a result of the Arizona Rivers, Streams, & Wetlands Study.

Establish and Maintain a Streams and Wetlands Library. Establish and maintain a streams and wetlands library containing up-to-date information on: current research; federal, state and local policies, programs, statutes, laws and regulations; and other relevant information.

Identify Critical Streams and Wetlands. Identify streams and wetlands possessing critical recreation, habitat, and instream flow water attributes and develop appropriate methods for ensuring their conservation.

Recommend Management for Critical Streams and Wetlands. Recommend appropriate, consistent, and coordinated management policies and practices for streams and wetlands identified as possessing critical recreation, habitat, or instream flow water attributes.

Facilitate Local and Site Specific Actions. Lend support and expertise to local and site specific efforts to develop recreational opportunities and conservation measures for streams or wetlands.

Recommendation—Streams and Wetlands Intergovernmental Coordination

Establish an Intergovernmental Streams and Wetlands Coordinating Committee.

An intergovernmental agreement among the State of Arizona, the federal government, local governments, and tribal governments must be developed in order to:

- **Facilitate Participation and Communication.** Facilitate participation and communication among all federal, state, and local agencies and Indian Tribes with management responsibilities for streams and wetlands.

- **Promote Consistency.** Promote intergovernmental consistency regarding policy and the management of streams and wetlands.

The signatories of the agreement should meet at least biannually to:

- **Share Information.** Provide and share information pertinent to streams and wetlands management.

- **Exchange Viewpoints.** Exchange viewpoints on streams and wetlands management goals.

- **Identify Inconsistencies.** Identify existing and potential inconsistencies in management purpose and practice.

- **Review and Improve Management.** Review and improve methods for management coordination and technology transfer.

Recommendation—Streams and Wetlands Citizen/Government Partnerships

Establish an Arizona Streams & Wetlands Council.

An Arizona Streams & Wetlands Council, composed of representatives of public interests concerned with the use, management, and conservation of streams and wetlands, should be created. The Council would:

Advise State Government. Provide a means for fully integrating public concerns into state stream and wetland planning and management activities, and for monitoring efforts to attain state policy goals for these resources.

Coordinate with the Intergovernmental Committee. Provide public perspectives on management purpose and priorities to the Intergovernmental Committee.

Resolve Conflicts. Provide a forum for the discussion and possible resolution of issues relating to the use and conservation of Arizona's streams and wetlands.

Encourage Local Streams and Wetlands Actions.

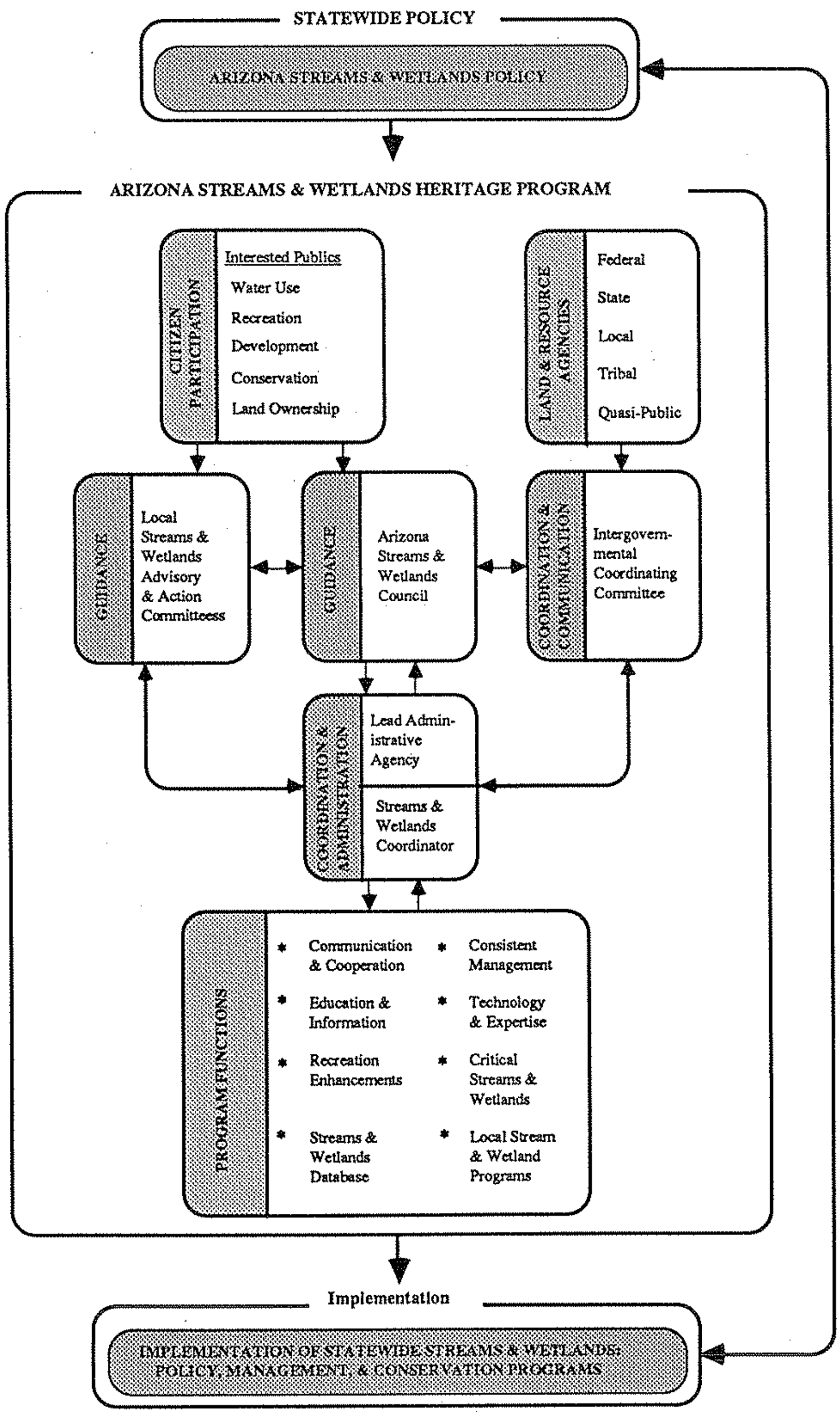
Local streams and wetlands actions should be encouraged where needed in order to:

Enhance Local Management. Enhance local efforts to conserve, manage, and balance uses of streams and wetlands.

Incorporate Local Participation. Integrate local involvement into statewide policy, planning, and management.

Where appropriate, local actions could be promoted through stream and wetland committees. As appropriate, local or regional groups could focus on either: (1) action items on a specific stream or wetland, or (2) broader planning and coordination issues. The efforts of these groups should be coordinated with the Arizona Streams & Wetlands Council.

A Conceptual Framework For Guiding Future Recreation Use & Conservation Of Arizona's Streams & Wetlands



RIVER, STREAM, AND WETLAND RESOURCES

This Chapter provides definitions relating to stream and wetland resources and an overview of the physical characteristics of streams and wetlands in Arizona. A discussion of the functions and values of these resources concludes this chapter.

Introduction

Arizona's streams and wetlands have historically served many of the basic resource needs of the state's inhabitants. The state's growth and prosperity have been assisted by the abundance and diversity of these resources. Although the supply of natural streams and wetlands in the state has been sharply diminished over the years, these resources continue to be important to the quality of life and economy of Arizona. The recreation and conservation benefits of streams and wetlands are among the values of these resources that are of increasing significance.

This chapter provides an overview of the stream and wetland resources of Arizona. Included are descriptions of their distributions, uses, and values.

Stream and Wetland Definitions

Streams

The terms *river* and *stream* are used synonymously in this study to refer to naturally occurring linear channels that contain surface water year round or at periodic or seasonal intervals as a result of direct precipitation, surface runoff, groundwater infiltration, or through dam-controlled releases from impounded reservoirs. The term *creek* is used in this report only as a proper noun when the river or stream has acquired this term as part of its title, such as the Oak, Beaver, or Rillito Creeks.

Perennial streams are streams that contain flowing surface water throughout the entire year. This type of stream originates principally in high mountain areas. As perennial streams descend to the desert plains, evaporative losses and seepage to the groundwater, combined with surface water diversions and groundwater pumping, greatly reduce or even eliminate surface flows.

As a result of natural and human-induced changes, *ephemeral streams* are far more numerous in Arizona. Also commonly called *washes*, these stream types flow occasionally and only in response to surface runoff from precipitation. *Arroyo* is a southwestern term for a flat-floored wash that has eroded into the valley plain and has steep sides.

Intermittent streams are streams that flow seasonally.

Interrupted streams are a hybrid of the perennial and ephemeral stream types. This fourth type of stream contains relatively short segments of perennially flowing water separated by dry channel segments. Interrupted streams occur in areas where the groundwater table alternately rises above and falls below the land surface.

Wetlands

As elsewhere in the nation, southwestern wetlands are among the most significant lands in terms of their wildlife production, water quality protection, soil stabilization, recreational opportunities, and numerous other resource-based functions and values. The characteristics of many southwestern wetlands cannot, however, be adequately described from the traditional viewpoints of such areas as marshes, swamps, bogs, or bottomlands. As defined by the United States Fish & Wildlife Service (FWS), these traditional wetland types

> *...have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year (Cowardin et al. 1979).*

Arizona and other southwest states have some wetlands that qualify under the above definition, but in the arid climate that dominates this region, these traditional wetlands constitute a minority of the highly important and limited lands that are suggested under a broader FWS definition. That definition describes wetlands as

> *...lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water (Cowardin et al 1979).*

The concept of wetlands as transitional zones between aquatic and drier upland habitats is more compatible with the following definition of southwestern wetlands by Minckley and Brown (1982):

> *Wetlands are periodically, seasonally, or continuously submerged landscapes populated by species and/or life forms differing from immediately adjacent biotas. They are maintained by and depend upon circumstances more mesic than those provided by local precipitation. Such conditions occur in or adjacent to drainageways and their floodplains (riparian zones), on poorly drained lands, along seacoasts, and in and near other hydric and aquatic situations, i.e., springs and their outflows, ponds, margins of lakes, etc.*

Extreme aridity and highly seasonal precipitation are the climatic characteristics that most significantly influence the attributes of southwestern wetlands. Accordingly, the relatively few perennial streams arise principally in the higher montane elevations and as they descend to the desert plains, evaporative losses and seepage to, rather than from, the groundwater table greatly reduces or often terminates surface flows. Far more numerous are ephemeral streams that flow periodically each year, or every several years or even decades, only in response to surface runoff from precipitation. Associated with both of these stream types, and the intermittent streams which are a hybrid of the two, are the most important southwestern wetlands types, as measured by extent. Although usually classified by the USFWS as palustrine forested and palustrine scrub-shrub in the National Wetlands Inventory, these wetlands are known regionally, and perhaps more appropriately, as riparian communities. As defined by Lowe (1964):

> *A riparian association of any kind (excluding marshes) is one which is in or adjacent to drainageways and/or their floodplains and which is further*

> *characterized by species and/or life forms different than that of the immediately surrounding non-riparian climax.*

The Arizona Riparian Council adopted a comprehensive definition of riparian systems as part of its constitution in 1986:

> *The term "riparian" is intended to include vegetation, habitats, or ecosystems that are associated with bodies of water (streams and lakes) or are dependent on the existence of perennial, intermittent, or ephemeral surface or subsurface water drainage.*

The agreement between Lowe's (1964) early definition of riparian associations and the much more recent explanation of southwestern wetlands by Minckley and Brown (1982) and the Arizona Riparian Council (1986) definition indicates a consistent trend in scientific thought that riparian communities in this arid region are indeed wetlands. Although dissimilar than the principal image of wetlands elsewhere in the country, these communities, which are commonly arrayed in varying widths along stream channels, can exist only in response to the wetter surface or subsurface conditions found there. Arizona riparian communities, often characterized by cottonwood-willow and mesquite series, are transitional between the perennial or ephemeral stream channel and the decidedly xeric desert upland. Based on recent studies and discussions, the FWS agrees that riparian vegetative communities constitute an extremely valuable resource and would be included as part of the National Wetlands Inventory. Traditional concepts appear to be expanding to include the wetlands situations in western states.

"Cienega" (Spanish for wetland/riparian marshland) is a southwestern term for a spring-fed marshland surrounded by dry lands, and is usually found adjacent to riverine environments. Hendrickson and Minckley (1985) defined cienegas as mid-elevation (1,000-2,000 m) wetlands characterized by permanently saturated, highly organic, reducing soils. Cienegas may support emergent types of vegetation, but are usually classified as palustrine forested or palustrine scrub-shrub types and are often found in association with larger riparian communities. They were once common in southern Arizona and provided a haven for fish and wildlife. These unique aquatic and semi-aquatic habitats have been reduced in recent times from a formerly widespread distribution to small, scattered remnants (Hastings 1959; Dobyns 1981). These desert marshlands are now considered to be almost extinct (Minckley and Brown, 1982).

Ohmart and Anderson (1986) have completed an extensive review of work on riparian habitats in the Southwest. They report that while such communities may comprise only 0.5 percent to less than 0.1 percent of the state's landscape, these habitats have suffered losses of up to ninety-five percent in Arizona.

Another unique type of wetland found in the Southwest is called a *playa* or *playa lake* . This wetland is an ephemeral lake associated with closed drainage basins (such as Willcox Playa and Red Lake) and with very shallow drainage depressions. The surface water of playa lakes comes from direct precipitation, and over time, it evaporates leaving tightly compacted fine sediments comprising the lake bottom.

For the purposes of this study, the term "wetland" will be used to include cienegas, playas, streamside riparian habitats, and other southwestern wetland types. The term is not meant to exclude those more xeric riparian areas unique to the Southwest that may not be included under the more traditional definition of a wetland.

Stream and Wetland Distributions

The stream and wetland resources of Arizona vary considerably with respect to their physical and flow characteristics. As the sixth largest state in the nation, Arizona contains striking contrasts in topography and climate within its boundaries which directly influence the type and occurrence of streams and wetlands found in our state. Following are overviews of the distribution of both of these resource types.

Stream Distribution

Of the 17,537 linear miles of Arizona streams identified by the Arizona Department of Health Services, an estimated 13,907 of these miles are ephemeral, and 3,630 miles are perennial.

The amount and location of surface water (and groundwater) are functions of three physical characteristics: physiography, geology, and climate (USGS 1986). Arizona may be separated into three water provinces (Plateau Uplands, Central Highlands, and Basin and Range), each with a unique combination of these three physical characteristics (Figure 2-1) (Arizona Water Commission 1975). Fifteen drainage basins are partially or wholly contained within these water (and physiographic) provinces (Figure 1-2).

<u>Plateau Uplands Water Province</u>

Containing forty percent of the land area in Arizona, the Plateau Uplands water province is contiguous with the flat-lying sedimentary rocks of the Colorado Plateau. Precipitation ranges from less than ten to more than twenty-five inches per year. Surface runoff varies from less than one-tenth to five inches per year, depending on location (USGS 1986). The Colorado and Little Colorado drainage basins and tributaries in the southern portion of the San Juan drainage basin are located in this province. Perennial streams and stream segments include the Colorado River and many of its Grand Canyon tributaries, upper segments of the Little Colorado River and some of its tributary streams, and a few tributary streams to the San Juan River (Brown et al 1981) (Figure 2-2). The Colorado River is regulated by numerous large- and small-scale dams throughout its course within and adjacent to Arizona. Numerous ephemeral streams and stream segments, including the large midsection of the Little Colorado River, are also located in this water province.

<u>Central Highlands Water Province</u>

Immediately south of the Plateau Uplands is the Central Highlands water province. The smallest of the three water provinces, with only fifteen percent of the land area in the state, the Central Highlands contains the northwest-trending, central mountainous region of Arizona. Annual precipitation ranges from fifteen to more than twenty-five inches (USGS 1986). Annual runoff can be up to five inches. About fifty percent of the state's streamflow originates in these mountains (Arizona Water Commission 1975), which accounts for the province's large abundance of perennial waters, particularly in the Salt and Verde basins (Brown et al 1981). The Salt and Verde drainage basins and portions of the upper Gila, Agua Fria, Bill Williams, and Little Colorado drainages are located in the Central Highlands (Figure 2-2).

region is defined as beginning downstream of Davis Dam (Brown 1985). The downstream segment is regulated by several dams which have completely altered the river's seasonally changing physical and biotic character. In 1980, the river-associated marshlands contained within the Havasu, Imperial, and Cibola National Wildlife Refuges constituted approximately eighty percent of the remaining riparian habitat along the lower Colorado River. The river segments between Topock and Lake Havasu, Headgate Rock Dam to Palo Verde Weir, Cibola Lake to Imperial Reservoir, and Yuma to Morelos Dam, are the last remaining riparian stretches in a "semi-natural" state (Brown 1985). Topock Marsh and the Ehrenberg mesquite bosque are two of the best remaining examples of what once was a common type of wetland along the Colorado River.

Land Management Jurisdictions

Land management jurisdictions determine to a very large degree the manner in which streams and wetlands and their watersheds are used, managed, and protected. The U.S. Forest Service, for example, has considerable authority to determine the fate of streams and wetlands within its lands, particularly those which begin there. In most circumstances, this agency can control the use of and access to streams and wetlands on National Forest lands and can prescribe the land use/management practices that will apply to the watershed supporting these resources. Further, the Forest Service may control the water rights to those streams and wetlands.

Other federal and tribal land management agencies have authorities similar to the Forest Service. Perhaps to a lesser but still very important degree, state, local, and private land managers or owners also have significant powers to determine the use and characteristics of streams and wetlands on their lands. There are exceptions to the authorities of land managers or owners to regulate the use or management of streams and wetlands on their lands. For example, surface water rights may belong to downstream users or diverters, certain public rights of navigation apply to some streams, and the state has the authority to regulate hunting and fishing on all Arizona lands and waters, with the exception of those occurring on tribal lands. Nevertheless, land jurisdiction determines much of what types of public recreation and conservation programs can be applied to streams and wetlands. When compared to the state's water provinces, land jurisdiction patterns in Arizona indicated some important trends for stream and wetland management (Figures 2-1 and 2-4). Most of the Plateau Uplands water province is under federal or tribal jurisdiction. Perennial waters that occur in this province are almost exclusively within these jurisdictions. The Central Highlands province, which includes the highest concentration of perennial streams in the state, and the headwaters of the Salt, Verde, Little Colorado, and San Francisco Rivers among others, is predominantly under the jurisdiction of the Forest Service and the White Mountain Apache Tribe. The Basin and Range water province is characterized by the most complex land ownership patterns in the state, with sizeable areas from all levels of jurisdiction/ownership being represented. Perennial stream waters are the most scarce in this province.

Some lands in Arizona have special protective or conservation status stemming from management designations that apply to them (Figure 2-5). Lands within National Parks and Monuments, National Wildlife Refuges, and Wilderness and Wilderness Study Areas are important examples of such designations. Streams and wetlands within lands with these or other similar designations will benefit from the applicable conservation requirements. The degree of protection that is afforded to streams and wetlands under different protective designations will, however, vary considerably. Appendix 2-A lists individual streams in Arizona that have some type of protective status.

Stream and Wetland Values and Uses

Streams and wetlands are valued and used for many purposes. To be valued, a stream or wetland does not have to be actively used by humans. Waters protected for endangered species habitat or scenic qualities are good examples of some important non-use values. Many stream and wetland values are, however, directly related to active stream uses. Boating, fishing, hydroelectric power generation, and water storage are common examples of these types of valued uses.

In many cases, multiple uses can be attainable from the same stream segments. Only a single use may be attainable from other situations. For example, both the Salt and Verde Rivers upstream of Lake Roosevelt and Horseshoe Reservoir, respectively, provide native and endangered species habitats; boating, fishing, and other recreation opportunities; and municipal water supplies, among other uses. Downstream of Granite Reef Dam, however, only water supply functions are extracted from the combined waters of these two streams. Managing for an appropriate compatible mix of stream and wetland values and uses is one of the most difficult challenges facing Arizona.

The following sections provide brief reviews of common stream and wetland values and uses. Included are flood control, water storage, and hydroelectric power; erosion control; surface and groundwater supplies; water quality enhancement; waterfowl, wildlife, and fish habitat; threatened and endangered species habitat; agricultural and livestock uses; recreation; historic and archaeological values; education and research; and open space and aesthetic values.

Flood Control, Water Storage, and Hydroelectric Power

When undeveloped and in a relatively natural condition, streams, their riparian corridors, and adjacent floodplains can convey flood waters from upstream to downstream points. Inland wetlands may store water during times of flood and slowly release it to downstream areas, lowering flood peaks. Riverine wetlands with adjacent open or relatively open floodplains often have relatively high flood storage and conveyance values. If flood conveyance and reduction functions of wetlands and riparian areas were fully utilized in areas yet to be developed, lives and property could be saved without the need for expensive engineered flood control structures. Important factors influencing the flood reduction role of a wetland include its size, location within the basin, texture of substrate, and connection with other wetlands (USFWS and EPA 1981, USFWS 1987).

Management for flood control purposes by emphasizing natural stream channel features are primary objectives of the Bureau of Land Management on the San Simon and San Pedro Rivers. The Pima County Flood Control District is placing a similar emphasis on the management of many eastern Pima County streams including perennial segments of Cienega and Pantano Creeks.

At the opposite end of the flood control spectrum are the massive dams on the Colorado, Gila, Salt, Verde, Agua Fria, and other rivers of the state (Figure 2-6). These structures and their resulting impoundments serve as flood control, water storage, and hydroelectric generating facilities. A variety of recreational and other uses are provided by the resulting reservoirs, but very significant stream and wetland values have been submerged in the trade-off. Downstream from some of these facilities, some stream and wetland values exist. They are, however, radically altered from their natural condition (see Chapter Four).

Erosion Control

Riparian vegetation plays an important role in reducing streambank erosion from overbank flow or high velocity currents during flooding or heavy runoff periods. The vegetation is able to achieve this by binding and stabilizing the soil with its root systems. The public value of this function usually is higher when development or expensive lands are located near wetland areas USFWS and EPA 1981, USFWS 1987).

Surface and Groundwater Supply

Streams and wetlands are important locations for groundwater recharge. The socioeconomic value of wetlands is higher when the public derives its groundwater supply from the wetland or a related groundwater aquifer. The water supply of wetlands provides various public benefits, such as water for public use, irrigation, livestock watering, and wildlife uses (USFWS and EPA 1981, USFWS 1987).

Water Quality

Naturally flowing streams and wetlands help maintain water quality or improve degraded water by removing, transforming, and retaining nutrients, sediments, and other natural and human-made pollutants. Aquatic and riparian vegetation filters sediment, organic matter, and chemicals while micro-organisms utilize dissolved nutrients and break down organic matter. Therefore, streams and wetlands act as natural water purification mechanisms.

Habitat for Waterfowl, Wildlife, and Fisheries

Streams and wetlands are among the state's most biologically productive of ecosystems and are crucial as habitats for fish and wildlife. Due to their unique and diverse habitats, wetland and riparian communities support a fauna disproportionate to their limited acreage. Research has demonstrated that even wetlands of less than one acre in size support an abundance of life forms. The high concentration of wildlife is due to the presence of the abundant water that is needed by all life forms, the rich and diverse vegetation which serves as the basis for food chains, the adequate cover provided by both wetland and shore vegetation, and the dynamic and transitional nature of constantly changing water levels.

Wetland and riparian areas are the most valuable wildlife habitats in Arizona (USFWS undated). Wetlands provide essential breeding, nesting, feeding, and predator escape habitats for many forms of waterfowl, mammals, and reptiles.

Riparian areas in Arizona can contain up to 10.6 times as many spring migrant birds per hectare as adjacent non-riparian habitats. Significantly, forty-seven percent of the 161 bird species frequenting certain studied riparian habitats in Arizona are dependent on these areas for nesting. Other avian studies in

Figure 2-6
Dams And Cities On Arizona Streams
Map Key

MAJOR DAMS ON ARIZONA STREAMS

Map Number	Dam Name	Stream Name	Map Number	Dam Name	Stream Name
1	Glen Canyon Dam	Colorado River	13	Stewart Mountain Dam	Salt River
2	Hoover Dam	Colorado River	14	Mormon Flat Dam	Salt River
3	Davis Dam	Colorado River	15	Horse Mesa Dam	Salt River
4	Parker Dam	Colorado River	16	Roosevelt Dam	Salt River
5	Headgate Rock Dam	Colorado River	17	Ashurst-Hayden Dam	Gila River
6	Imperial Dam	Colorado River	18	Coolidge Dam	Gila River
7	Laguna Dam	Colorado River	19	Waddell Dam	Agua Fria River
8	Morelos Dam	Colorado River	20	Bartlett Dam	Verde River
9	Alamo Dam	Bill Williams River	21	Horseshoe Dam	Verde River
10	Painted Rocks Dam	Gila River	22	Lyman Dam	Little Colorado River
11	Gillespie Dam	Gila River	23	Salt R. Diversion Dam	Salt River
12	Granite Reef Dam	Salt River			

SELECTED TOWNS AND CITIES ASSOCIATED WITH ARIZONA STREAMS

Community	Stream	Community	Stream
Alpine	San Francisco River	Marana	Santa Cruz River
Arivaca	Arivaca Wash	McNary	Gooseberry Creek
Arivaca Junction	Santa Cruz River	New River	New River
Bensen	San Pedro River	Nogales	Santa Cruz River
Black Canyon City	Agua Fria River	Nutrioso	Nutrioso Creek
Bullhead City	Colorado River	Page	Colorado River
Camp Verde	Verde River	Parker	Colorado River
Carefree	Cave Creek	Paulden	Verde River
Clarkdale	Verde River	Pinetop	Show Low Creek
Clifton	San Francisco River	Phoenix	Salt River
Cottonwood	Verde River	Prescott	Granite Creek
Douglas	Whitewater Draw	Prescott Valley	Agua Fria River
Flagstaff	Rio de Flag	Safford	Gila River
Fort Apache	White River	Scottsdale	Indian Bend Wash
Fort McDowell	Verde River	Sedona	Oak Creek
Fredona	Kanab Creek	Show Low	Show Low Creek
Gisela	Tonto Creek	Sierra Vista	San Pedro River
Gila Bend	Gila River	Springerville	Little Colorado River
Glendale	New River	St. Johns	Little Colorado River
Globe	Pinal Creek	Sun City	New River
Greer	Little Colorado River	Tacna	Gila River
Hayden	Gila River	Tucson	Santa Cruz River
Kearny	Gila River	White River	White River
Lake Havasu City	Colorado River	Wickenburg	Hassayampa River
Lakeside	Show Low Creek	Willcox	Ash Creek
Littlefield	Virgin River	Winslow	Little Colorado River
Mammoth	San Pedro River	Yuma	Colorado River

Arizona have inventoried eighty pairs of nesting birds per one hundred acres of partially cleared riparian areas, but the numbers dramatically jumped to 1,322 pairs per one hundred acres on uncleared riparian areas.

Riparian areas in Arizona provide unique habitat for many wildlife species. Several species of wildlife that are totally or largely dependent upon Arizona's riparian habitat include: Arizona gray squirrel, river otter, zone-tailed hawk, gray hawk, black hawk, water ouzel or dipper, Bell's vireo, sulphur-bellied flycatcher, elegant trogon, Bullock's oriole, yellow warbler, bald eagle, canyon tree frog, and many more.

The value of a stream or wetland as wildlife habitat depends upon: (1) the diversity and arrangement of vegetation; (2) the amount of open water; (3) the arrangement of the vegetation to the water; (4) the relationship of the wetland to topographic features, lakes, streams, and other wetlands; (5) the size of the wetland and surrounding habitat; (6) water chemistry; (7) permanence; (8) diverse wildlife species composition; and (9) abundant wildlife numbers or population (USFWS 1987).

Habitat for Threatened and Endangered Species

A large number of federally listed threatened and endangered species rely on streams and wetlands for their survival. As of July 1986, 209 animals and 109 plants were listed as threatened or endangered in the United States. Forty-five percent of these animals and twenty-six percent of these plants depend directly or indirectly on wetlands to complete their life cycles. In addition, of the more than 2,500 plants in need of federal protection, as many as seven hundred are dependent on riparian areas.

Many of Arizona's federally and state listed threatened or endangered species rely on stream or wetland habitat for survival. A partial list of some of the more well-known species includes the southern bald eagle, gray hawk, American bittern, buff-breasted flycatcher, black-bellied whistling duck, narrow-headed garter snake, tropical vine snake, humpback chub, Apache trout, woundfin, Gila topminnow, Yuma clapper rail, water shrew, Hualapai Mexican vole, river otter, and jaguar.

Agricultural and Livestock Uses

There are many agricultural and livestock uses of streams and wetlands. Floodplain soils are high in nutrients. Historically in Arizona, riparian vegetation has been cleared in large acreages to make way for agricultural crops such as cotton, alfalfa, and grains. Certain wetlands can produce hay crops, and riparian areas can support grazing under properly managed conditions. Because of the abundance of flowering vegetation, riparian lands are also significant for honey production (USFWS undated). Stream and wetland waters throughout the state have been impounded and diverted for crop production purposes.

Timber Production

Forested riparian areas in Arizona have historically served as important sources of fuelwood and hardwood lumber. Under sustained management, riparian forests in Arizona could produce between 60 dollars and 120 dollars per acre per year in fuel wood. Wood from mesquite bosques is also marketable and, under suitable environmental conditions, these bosques can be managed as a renewable resource. However, sound forest management and utilization practices must be implemented for a sustained yield of mesquite products. Historically, mesquite bosques in Arizona have not been managed, but have simply been cleared for firewood and cropland (see discussion in Chapter Four). In addition, in selected riparian sites in Arizona, there is potential for a substantial and sustained yield of walnut lumber and nut crops (USFWS undated).

Recreation

Streams and wetlands provide unique and comfortable places for recreation experiences in Arizona. Stream- and wetland-related outdoor recreation activities include hunting, fishing, boating, birdwatching, nature observation, all-terrain vehicle riding, recreational placer mining, picnicking, hiking, and horseback riding. The non-consumptive recreational use of streams and wetlands has greatly increased in recent years (see Chapter Five). Historically, hunters and trappers were the primary users of wetlands, but today there are many birdwatchers and wildlife observers, students and teachers, artists, and others who regularly visit wetlands. During 1978, nonresident wildlife observers made over 46,000 visits to just three riparian areas in southern Arizona: Ramsey Canyon, Madera Canyon, and Cave Creek in the Chiricahua Mountains. This resulted in over five million dollars in tourist revenue or approximately 12,370 dollars per acre in revenue generation (USFWS undated).

Historic and Archaeological Values

The majority of stream and wetland areas in Arizona are of historic and archaeological interest. Indian and early settlements were located near streams and wetlands that provided fish, game, and water. Riparian vegetation also provided food, shelter, tools, and fuel for fires. Agricultural fields and farms were built along rivers so that there would be a ready source of water to irrigate crops when there was insufficient rainfall. Nearly all of Arizona's historic communities originated on the banks of live streams (Figure 2-6).

Education and Research

Streams and riparian areas provide excellent educational opportunities for nature observation and scientific study. Riparian habitats are unparalleled as environmental study areas. They are accessible and offer a wide variety of habitats that contribute to a diverse and unique flora and fauna. In recent years, scientists and resource managers have begun to more thoroughly understand the importance of stream and riparian areas to the total animal and human environment.

Open Space and Aesthetic Values

The state's streams and wetlands offer plant and animal diversity, beauty, and open space for recreational and visual enjoyment. Lands adjacent to riparian areas are considered ideal living conditions by many Arizona residents who are willing to pay extra for such lands. These areas also offer some of the most spectacular scenery in the Southwest. The visual values of the resource area depend upon its type, size, landform, contrast, and diversity, as well as associated water body size and type, surrounding land use, and other factors (USFWS undated).

Conclusion

Arizona, because of its large size and physiographic, geologic, and climatic features, contains a wide variety of stream and wetland types. The state's streams range from steep, high elevation perennial waters to shallow ephemeral and intermittent waters with relatively lush riparian corridors. Wetlands also come in numerous shapes and sizes. Those supported by shallow groundwater or artesian springs may contain water year round. Others, like Willcox Playa, only occasionally hold water, but are still highly important for waterfowl and wildlife.

The values and uses of streams and wetlands are many, and vary with time, in space, and according to individual preferences. Stream and riparian areas have historically served the resource needs of the state's inhabitants, but until quite recently, the subtle and important ecological functions of these resources have gone unnoticed by the general public. Today, streams and wetlands are valued both for the natural resources that they provide and also for the many recreational opportunities that Arizonans enjoy.

"When technology has nothing more for man, then nature will go on showing him her wonders."

Eduardo Arango

inclusion in the system protected by existing authorities, management plans, or other appropriate actions until Congress has had the opportunity to determine final status of the river segment (President's Commission on Americans Outdoors 1987)

Stream and Wetland Conservation in Arizona

With an overview of how national river and wetland conservation values evolved and became institutionalized in federal policy, the discussion now turns to Arizona. Stream and wetland conservation values in Arizona have been evolving over more than a century and, reflecting the social, economic, and political character of the state, are still in a dynamic state of development.

The events and developments to date, however, may be separated into six major trends:

- The institutionalization of Anglo-American pioneer values into Arizona water law
- The reclamation era
- The era of federal water politics
- The institutionalization of recreation
- The initiation of river and wetland conservation activities and programs by government agencies and private groups
- The transition period in Arizona water policy

Anglo-American Values are Institutionalized into Arizona Water Law

Anglo-Americans first arrived in Arizona in the 1820s (Weber 1971), but it was the military explorations and the gold strikes of the mid-1800s that ushered in the era of Anglo-American domination of this state. The City of Phoenix was established in 1867 as a hay camp for Fort McDowell. Just two years later, an irrigation system was in place in the Salt River Valley, enabling Phoenix to grow as an agricultural food supplier to the bustling mining and military communities. Anglo-Americans began settling in Tucson in 1856, and they too cleared the land for irrigated agriculture.

Soon thereafter, the new settlers ventured into other communities and continued the resource-based economic activities of their predecessors. All of these activities were dependent on perennial streamflow and riparian resources. Irrigated crops and cattle required a dependable water supply. Cattle also required rangeland vegetation for their food supply. Placer miners worked stream channels in search of valuable minerals. As a result of these activities, demand for surface water in some locales began to outstrip supply, and conflicts between users began to develop in Arizona as they did elsewhere in the West.

Surface water diversion was necessary for nearly all economic activities to thrive, but it could not occur in a legitimate and orderly manner under the provisions of the riparian water law doctrine that was used in the eastern United States. The riparian doctrine prohibited diversion and mandated that, in times of shortage, all riparian landowners would equally share whatever water was available. What was needed was a water law doctrine that would allow non-riparian landowners to divert water to lands not adjoining the stream channel to bring the water to mineralized areas or to croplands, while also establishing a priority system of uses and users so that in times of drought, conflict could be avoided.

In 1864, the first Territorial Legislature responded by declaring the rivers, streams, and creeks of flowing waters to be public and to be used for the purposes of mining and agriculture. The Arizona Territorial Supreme Court further institutionalized the predominant water and resource values of the nineteenth century when, in 1888, it rejected the riparian doctrine in favor of the doctrine of prior appropriation.

This court decision came just prior to the most severe flood and drought episodes these new Arizona residents had ever faced. These climatic events occurred at a time when overgrazing was rampant, and irrigated agriculture and mining were in full force. Large riparian trees were being harvested everywhere for building materials, fuelwood, and to build railroads which had reached Arizona by 1880. The flood and drought sequence exacerbated the cumulative effect of these intensive land use practices, and consequently triggered a major episode of severe arroyo cutting and stream channelization (see discussion in Chapter Four).

Reclamation Era

The economic effects of these climatic events were most severely felt in the 1890s. As in other western states, the droughts contributed to heavy losses in the ranching industry. In 1893, livestock mortality rates in Arizona climbed to as high as fifty to seventy-five percent (Wagoner 1960). Meanwhile, the intense aridity prompted desperate farmers in the Salt River Valley (who by that time had over 100 thousand acres under cultivation) to seek federal aid for flood control and water storage on the Salt and Verde Rivers. The pleas of Arizona and other western farmers and ranchers were answered in 1902 when Congress passed the Reclamation Act, beginning the twentieth century era of federal involvement in western water reclamation projects. In the words of one expert on western water policy, "To resist a federal reclamation program was to block all further migration to the West and to ensure disaster for those already there..." (Reisner 1986).

Roosevelt Dam was the first federally funded reclamation project constructed by the new U.S. Reclamation Service. Completed in 1911, this dam began a reclamation era in Arizona that would lead to the damming and human-alteration of every major river in the state. By 1930, the five major dams of the Salt River had been built, as had the Waddell Dam (Agua Fria) and Ashurst-Hayden and Coolidge Dams (Gila River). The Bartlett and Horseshoe Dams on the Verde River were completed by 1946. And, the seven major dams of the lower Colorado River were built by 1963. Most of these dams were built by the Bureau of Reclamation (formerly the Reclamation Service), but the Army Corps of Engineers and the U.S. Soil Conservation Service constructed dams, levees, channels, and diversions on many of Arizona's smaller watersheds as well.

The Central Arizona Project (CAP), currently under construction, is the most expensive and most recent large-scale, federally-funded reclamation project in Arizona. During the more than sixty years that the CAP has been discussed, planned, and under construction, it has changed appreciably to reflect the changing values and priorities of the state and the nation. For example, elements of the project were eliminated or changed to protect Indian cultural values (Orme Dam) and bald eagle habitat (Orme Dam and Cliff Dam). The project is scheduled to be completed in 1991, when it is scheduled to deliver Colorado River water to Tucson.

Federal Water Policies Influence River and Wetland Conservation along the Colorado River

Between the 1920s and the 1960s, river and wetland conservation activities in Arizona were relatively few and originated principally at the national level in response to the numerous water development, channelization, and diversion projects on the Colorado River. The 1922 Colorado River Compact divided the River into two sub-basins, separated at Lees Ferry, Arizona. Each sub-basin was allocated 7.5 million acre-feet of water annually. In 1929, all signatories except Arizona ratified the Compact (Arizona ratified the agreement in 1944). Six years later, Boulder (Hoover) Dam was completed, the first of many large-scale water development projects on the Colorado, built in order to utilize the river water allocations established by the Compact.

To mitigate and balance the negative impacts that this dam and other impoundments, diversions, and channelization were having on the aquatic and riparian ecosystems of the lower Colorado River, Congress established the Havasu and Imperial National Wildlife Refuges in 1941 (Mann 1963). In 1964, Congress established the Cibola National Wildlife Refuge, the third and most recent National Wildlife Refuge on the lower Colorado River.

Federal water policies continued to shape events and river conservation values in Arizona in the 1960s due to the state's geographical connection to the Colorado River and its common border with Mexico. The gates of Glen Canyon Dam closed on the Colorado River above Lees Ferry in 1963, beginning the end of (or perhaps a lull in) the era of large-scale dam construction in the United States. Arizonans witnessed the defeat of two of the most controversial dam proposals in national history in 1968, when Congress decided not to build the Boulder Canyon and Marble Canyon Dams on the Colorado River in Grand Canyon National Park in exchange for support for the Central Arizona Project.

Colorado River water quality became an international issue in the 1960s. In 1962, the Mexican government protested the high salinity of the Colorado River water crossing the border. The degraded water quality resulted from American agricultural and water development practices. The Mexican government's concern eventually led to the International Boundary and Water Commission's Minute 242 agreement in 1973, which required the federal government to deliver the river water at a quality equalling that being diverted at Imperial Dam. Three years later, Congress authorized the Bureau of Reclamation to build and operate the engineering works to implement this agreement. Through these policies and a 1945 United States-Mexico treaty, the responsibility to deliver 1.5 million acre-feet of good quality water to our southern neighbors is shared by Arizona and other Colorado River basin states.

Population Growth Triggers Recreation Demands and Changes in the Water Code

As with the rest of the nation, the outdoor recreation needs of Arizona's growing urban populations began to be felt after World War II. City dwellers sought recreational amenities to complement the routine of their daily work activities (Mann 1969). In 1950, the National Park Service encouraged the state to begin planning for increased recreational needs that future population growth and urbanization would bring (National Park Service 1950). One result was the creation of the Arizona State Parks Board and the State Parks System in 1957, followed by the establishment of the Arizona Outdoor Recreation Coordinating Commission (AORCC) in 1965, to plan, coordinate, and administer an outdoor recreation program in Arizona.

In 1941, state legislators amended the State Surface Water Code to recognize "wildlife, including fish" as a legitimate beneficial use of Arizona surface waters. In 1956, the Arizona Game Protective Association passed a resolution requesting the Legislature to expand the Code further by including recreation as a beneficial use of surface water (Mann 1963). The code was so expanded by the Legislature in 1962.

Concern for river conservation and protection in Arizona formally began in 1965, the year the AORCC released Outdoor Recreation in Arizona, the first statewide outdoor recreation plan. The 1965 recreation study contained Arizona's first formal recommendation that portions of the state's streams be designated as natural rivers (AORCC 1965).

Private Groups and Government Agencies Initiate River and Wetland Conservation Activities and Programs

Between 1966 and 1988, a number of important stream and wetland conservation issues in Arizona were addressed by resource management and regulatory agencies and private interest groups.

In 1966, The Arizona Nature Conservancy was founded and this organization immediately established the first privately owned preserve in the state near Patagonia along Sonoita Creek. This preserve was established to protect the "very best remaining example" of a Fremont cottonwood riparian plant community and the endangered Gila topminnow. The Nature Conservancy established its second preserve in Arizona in 1969 at Canelo Hills to protect cienega habitat and the endangered Gila chub. This private organization has continued to play a significant role in wetland and riparian land acquisition in the 1970s and 1980s, establishing the Ramsey Canyon (1974), Mile Hi (1975), Muleshoe Ranch (1982), and Hassayampa River (1987) Preserves.

Government involvement in river and wetland conservation began as a result of the phreatophyte and vegetation clearing projects in the 1950s and 1960s. The primary goal of these projects, many of which were of an experimental nature, was to increase water yield. The Arizona Game & Fish Department was the first state agency to become concerned over these projects in the late 1950s because field biologists working for this agency were the first to become aware of the detrimental effects of riparian habitat loss on the wildlife populations (GCAE 1970). This agency's concern and involvement increased significantly in 1970 due to a drastic reduction in the white-winged dove population, a popular game bird whose habitat was being destroyed as a result of the "most controversial channelization project in the state," the Lower Gila River Channelization Project. Several towns along the lower Gila River depended on the out-of-state tourist dollars brought in by hunters during the hunting season for this bird (GCAE 1971).

In response to the ecologic and economic concerns, the Game & Fish Department requested a moratorium on the project. In addition, the Sierra Club and other conservation groups enjoined the Army Corps of Engineers against construction of the channel modifications. Soon thereafter, the Governor's Commission on the Arizona Environment requested that the Secretary of the Interior and the Bureau of Land Management preserve sixty thousand acres of public lands in the Gila River "Green Belt" (a riparian corridor along the lower Gila River between Liberty and Dateland, Arizona) and designate it as the Fred J. Weiler Green Belt Resource Conservation Area (GCAE 1971). The Green Belt was designated in 1970.

The Commission's involvement in riparian conservation began in 1969 when, through the urging of citizens, it began an investigation of phreatophyte control and chaparral management in the vicinity of Globe, Arizona (GCAE 1969). Although the initial concern of the Commission focused on the use and effects of chemical sprays, the membership soon realized that other activities, such as the direct removal of phreatophytes, riparian tree cutting, stream channelization, and flood control could have detrimental ecological, economic, and recreational impacts. By 1974, the Commission had had specific involvement in projects concerning the Wellton-Mohawk channelization, Salt River channelization, Gila River channelization, Verde River cottonwood cutting, and Topock Gorge dredging (GCAE 1974).

It was during the peak of the Commission's early involvement with riparian conservation issues that Senate Bill 1049, addressing riparian land protection, was introduced into the Senate Committee on Natural Resources and Environment. The bill was held in committee, but the following year the Commission adopted its first two resolutions concerning riparian conservation in Arizona:

> *Riparian vegetation should not necessarily be managed in the same manner as other more abundant vegetation communities.*
>
> *Major vegetation management programs should be analyzed through the National Environmental Policy Act process and evaluated on a multiple use basis* (GCAE 1975).

Also in 1975, the Arizona State Parks Board initiated the Arizona Natural Areas Program to protect and conserve riparian and other sensitive habitats. This program is now undergoing extensive review and modification as part of the 1989 SCORP. The new Natural Areas Program will include an emphasis for conserving riparian areas on state and private lands.

In 1976, the Arizona Game & Fish Department filed the first application for an instream flow water right, formalizing its recognition for the need to protect surface water protection in order to protect dwindling desert aquatic and riparian habitat. The Nature Conservancy filed the next two applications for instream flow water rights in 1979. In 1983, the Arizona Department of Water Resources (ADWR) provided administrative approval for instream flows when it issued its Decision and Order on The Nature Conservancy's applications for Ramsey and O'Donnell Creeks (Dishlip 1987). By January 1988, a total of thirty-nine instream flow applications had been filed with ADWR (ADWR 1988).

In 1978, House Bill 2326, authorizing County Boards of Supervisors to adopt standards to protect water courses and riparian environments, was introduced. Like the 1974 riparian protection bill, it was also held in committee.

The following year, the Governor's Commission on the Arizona Environment formed the Ad Hoc Committee on Riparian Legislation. After six working meetings, the Committee made the following recommendation to the full Commission and the governor:

> *That the governor establish a task force on riparian policy and that charges to that task force include: (1) develop definitions and criteria for riparian habitats in Arizona, to include evaluations of existing inventories; (2) authorize and implement a study to clarify the complex legal and jurisdictional tangle relating to riparian zones; (3) establish priorities for preservation or conservation of riparian communities in Arizona; (4) initiate a program in public awareness of the ecological significance and beneficial uses of riparian environments; (5) encourage research in riparian environments and identify means to fund and initiate that research; and finally, (6) make recommendations concerning policy and legislation necessary to preserve, enhance, and restore riparian communities and provide effective and feasible management regulations* (GCAE 1979).

The 1980s have brought the most public and government activity to Arizona with regard to river and wetland conservation. The United States Department of the Interior's Nationwide Rivers Inventory, designed to identify river segments of national significance which could qualify for inclusion in the National Wild & Scenic River System, was completed in 1982. This inventory included fourteen stream segments in Arizona:

- Black River
- East Fork of the Black River
- Chevelon Creek
- West Clear Creek
- Colorado River
- Little Colorado River
- Eagle Creek
- Gila River
- Paria River
- Salt River
- San Francisco River
- Tonto Creek
- Verde River
- East Verde River

A forty-mile reach of the Verde River was added to the National Wild & Scenic River System in 1984. Other segments within this list remain eligible for inclusion.

In 1981, the Arizona Water Quality Control Council passed a resolution establishing Arizona's Unique Waters Program (ADHS 1981). Administered by the Department of Environmental Quality (formerly the Department of Health Services), this program was established to protect high quality waters which are "of exceptional recreational or ecological significance" or that are "critical habitat for a threatened or endangered species which is historically or presently known to be associated with such waters." The West Fork of the Little Colorado River and Oak Creek have been designated as Unique Waters in Arizona. Three other streams—Peoples Canyon Creek, Francis Creek, and Burro Creek—are scheduled for designation in 1989. Several other streams (notably Cienega Creek) have been nominated and are in various stages of review.

In 1982, Governor Babbitt's Task Force on Parks & Recreation in Arizona issued recommendations regarding the future of water-based recreation activity:

> *The highest priority of the State Parks program should be placed on development of parks offering water-based recreation opportunities.*
>
> *The State should provide for an equitable and broad geographic distribution of water-based recreation development.*
>
> *The availability of surface water or groundwater for water-based recreation projects should be determined, and permission to utilize needed water should be secured at the earliest possible time .*

Shortly thereafter, the Governor's Task Force on Recreation on Federal Lands issued a recommendation for federal and state protection and legislation:

> *The State should press vigorously for congressional designation of all additional qualifying rivers into the National Wild & Scenic River System.*
>
> *The Governor should propose legislation to create a state wild and scenic river system. State Parks should conduct a rivers study of free flowing stretches in the state, including both those nominated by the Heritage Conservation and Recreation Service and any others that have not been identified to date for inclusion in a state wild and scenic river system* (Governors Task Force on Recreation on Federal Lands 1986).

In 1983, the Governor's Commission on Arizona Environment issued its most specific recommendations to date regarding riparian habitat protection in Arizona:

> *The Governor's Commission on Arizona Environment strongly supports the formation of a Governor's Task Force on riparian areas. The task force should be made up of technical experts, users of riparian areas, and local residents. The development of local concern groups should be encouraged and supported by the task force.*
>
> *Recreation and riparian habitat should be recognized as uses of water and given a value in water policy planning, with the same recognition designated to other state planning (education,*

transportation, and recreation).

Land exchange by the Arizona State Land Department which serve to protect riparian habitat should be supported.

Maintenance of riparian habitats should be supported through emphasis on cooperative efforts between state, federal, and local government agencies and private entities.

The non-game wildlife check-off on state tax forms should be continued. Part of these funds should be allocated for protection of riparian habitat.

Develop a definition of riparian habitat for use throughout Arizona.

Identify and integrate existing inventories of riparian areas in Arizona, identify information gaps, and determine how much riparian areas exist, where they are, who manages them, and what condition they are in. The Natural Heritage program in the Arizona Game & Fish Department may be the logical place to conduct this activity. The Arizona State Parks Natural Areas Program information should be used in this integrated inventory.

Investigate and document the legal bases in Arizona and other states for protection, controlling, and enhancing riparian habitats.

Develop a state system to evaluate and prioritize riparian habitats for protection and appropriate uses, and recommend management practices.

Develop recommendations addressing the teaching of riparian resource conservation as part of environmental education.

Identify needs for further research, including:
- Techniques to improve existing riparian habitat and establish new riparian habitats.
- Relationships between increased water yields and the condition of riparian habitat.
- Dynamics of riparian habitat.

Develop a state policy on riparian habitat management to guide federal, state, local, and private actions.

Recognize and support exchanges of State Trust lands containing riparian habitat for non-riparian federal lands. (This is currently being done and should be continued.)

Develop incentives for the appropriate management of privately owned riparian habitats including conservation easements, land exchanges, tax credits.

> *Develop recommended legislation and regulations to carry out the state riparian habitat management policy and establish incentives.*
>
> *Identify enforcement needs to protect riparian areas.*
>
> *Encourage cooperation between Arizona's Indian nations and the State of Arizona in the management of riparian habitat consistently and provide assistance as appropriate* (GCAE 1983).

The concerns of these task force groups and agencies were echoed in 1985, with the founding of the Arizona Riparian Council (ARC). The Council is a consortium of concerned individuals from government, industry, universities, conservation organizations, recreation groups, and other affiliated and unaffiliated interests. The purpose of ARC is to educate the public on the value of Arizona's riparian areas, to disseminate scientific information regarding riparian ecology, and to influence future public policy decisions.

Also in 1985, the University of Arizona sponsored the First North American Riparian Conference, which drew participants from throughout the United States. In the forward of the conference proceedings, Arizona's governor at that time, Bruce Babbitt, wrote the following:

> *What is needed is the implementation of a comprehensive legislative mandate for the protection, conservation, and rehabilitation of riparian ecosystems. Previous efforts have addressed only pieces of the whole. Legislation must include all aspects of riparian systems and address all levels of involvement - federal, state, local ,and private - to be effective* (Johnson et al 1985).

The United States Fish & Wildlife Service completed the Arizona component of the National Wetlands Inventory in 1986. That year also saw the defeat of the proposed Cliff Dam on the Verde River. The dam would have flooded relatively pristine portions of the river including bald eagle habitat.

The ranks of individuals and groups concerned about stream and wetland conservation in Arizona have since grown. Five special events in 1987 made it the biggest year ever for stream and wetland issues in Arizona. First, the Arizona Riparian Council held its second annual meeting in Wickenburg. Second, the Commission on the Arizona Environment (CAE) created another ad hoc committee on riparian habitat, which is again investigating riparian management issues. The theme of the Commission's 1988 annual summer conference was "Riparian Habitat: To Be Or Not To Be?" Recommendations for state policy concerning riparian habitat were to formulated at the conference and are to be forwarded to the legislature. Third, the Arizona Section of the American Water Resources Association held a conference in Tucson on instream flow water rights. Fourth, The Arizona Nature Conservancy announced its three million dollar fund-raising drive for its Streams of Life riparian lands acquisition program and opened the Hassayampa River Preserve. Finally, the Arizona Rivers, Streams, & Wetlands Study was initiated by Arizona State Parks as a component of SCORP.

State Water Policy In Transition

State legislative actions to date have addressed broad water policy issues, but have not yet dealt effectively with stream and riparian concerns. Senate Bill 1049 and House Bill 2326 were legislative attempts to provide for the protection of riparian areas. Neither bill was debated in committee, and similar bills have not been introduced since that time. The streambeds law of 1987 established a trust fund for riparian lands protection. However, many see this law as a give-away of state lands, an impediment to recreational access and use of riparian areas, and a threat to critical riparian habitat (Arizona House of Representatives 1987). The law is now being challenged in court on constitutional grounds.

The bulk of new Arizona water policies emerging in recent years have been written with the intent to accommodate changing demands and uses of water, to mandate water conservation, and to regulate water use and allocation. The major legislative actions dealing with water resources include a new Groundwater Code and water supply agency, and a new Environmental Quality Act and environmental quality agency. The Legislature is currently debating numerous bills proposing water transfer legislation.

Groundwater Code and Water Supply Agency

In 1980, Arizona Legislators enacted the Groundwater Management Code and created a new agency to administer surface and groundwater supplies, the Arizona Department of Water Resources. The Groundwater Management Code (and subsequent amendments) established regulatory jurisdictions in the form of four Active Management Areas (AMAs) and three Irrigation Nonexpansion Areas (INAs) in regions of intensive groundwater pumping. New groundwater conservation measures were established in these areas, and a goal of safe yield was established for the Tucson, Prescott, and Phoenix AMAs by the year 2025. Safe yield means that the amount of groundwater pumped from the aquifers does not exceed the amount replenished (through natural or artificial recharge). Strict conservation measures must be imposed in the coming decades if the safe yield goal is to be reached.

Environmental Quality Act and Agency

In 1986, the Legislators passed the Environmental Quality Act which established policy and regulations to manage the state's water, air, and environmental quality, and established a new agency, the Department of Environmental Quality, to manage these resources. The Department of Environmental Quality manages surface and groundwater quality by setting contaminant standards and through waste generator permit programs.

Water Transfers

In the 1970s and 1980s, the state courts began a long and arduous process of settling growing water rights conflicts among user groups through the general stream adjudications. The resulting court rulings will shape the future of Arizona water use and stream and wetland conservation issues into the next century and beyond.

In 1974, the Salt River Valley Water User's Association invoked Arizona's statutory general stream adjudication procedure to determine conflicting water rights on the Salt River above Granite Reef Dam. The Association initiated the same procedure on the Verde River drainage in 1976. Two years later, Phelps Dodge Corporation initiated adjudication proceedings on the Little Colorado and Gila River drainages.

These general stream adjudications and others initiated in the 1980s will take several decades to complete and are intended to determine the nature and priority of every water right in the state, particularly the currently unquantified federal reserve water rights held by federal agencies and Indian reservations. The magnitude of federal water rights is particularly important in a state like Arizona where nearly seventy percent of the land is federally owned or held in trust for Indian tribes (Valley National Bank of Arizona 1987). Most of Arizona's perennial waters and significant wetlands are located on federal lands.

In July 1988, Secretary of the Interior, Donald Hodel, announced a new policy by declaring that federal wilderness areas do not have inherent rights to the water that flows through them. The policy implies that Congress must specifically award water to a wilderness area when it sets aside such enclaves. The ruling means that federal wilderness areas will have to compete at the state level with agricultural, municipal, mining, and development interests for the appointment of water rights. Federal courts have held since 1899 that states may not impinge on the federal government's right to ample water for parks, monuments, military installations, Indian reservations, and other federal properties. Future court decisions involving federal reserve water rights will determine the fate of many of these critical aquatic resources (see discussion in Chapter Six).

Conclusion

This chapter has summarized the events and activities leading to the development of a stream and wetland conservation ethic in Arizona. Because of the state's geographic connection to the Colorado River and Mexico, Arizona water policies and politics have been strongly influenced by national events, programs, and policies. Water development projects—dam construction, channelization, vegetation manipulation, and flood control works—have altered nearly every major river in the state, and nearly flooded much of the world famous Grand Canyon National Park. On the other hand, it was federal policy that led to the establishment of Arizona's first protected wetlands on the lower Colorado River.

While the federal government and many states have institutionalized river and wetland conservation values into laws, Arizona has not. In the meantime, government agencies and private groups have initiated programs and created preserves to conserve and protect our aquatic and riparian resources. In addition, several studies of the state's riparian lands have also been undertaken since the late 1960s, by both governmental and nongovernmental groups, resulting in a very large set of specific recommendations for Arizona policy makers.

The increasing number of public agencies, environmental and recreational groups, and private citizens expressing concern over the fate of the state's stream and wetland heritage indicates that this issue is indeed important to Arizonans.

"Public lands are more than territory. They are an artifact of history, a source of beauty, inspiration, and greed."

Bernard Shanks
This Land Is Your Land

LOSSES OF STREAMS AND WETLANDS IN ARIZONA

This Chapter discusses the substantial impacts to Arizona's streams and wetlands that have resulted from numerous land and water use practices. These impacts include the loss of: (1) riparian habitat, (2) flowing and non-flowing surface waters and aquatic habitat, (3) surface water quality, and (4) fish and wildlife. These losses have reduced recreation opportunities associated with streams and wetlands such as nature observation, hiking and camping, and fishing and hunting.

Introduction

Arizona's landscape was not always as parched as it is today. Little more than a century ago, Arizona was blessed with a natural river drainage system that flowed year round and spanned nearly every part of the state (Figure 2-2). The perennial streams were the mainstays of the native American and Hispanic cultures that occupied the state at those and prior times and provided sustenance for a fledgling Anglo-American pioneer community. Perennial streams—and the extensive riparian forests that they supported—provided water for domestic needs, fish and game for food, pelts for clothing and trade, fertile soils and water for agriculture, water and forage for livestock and industry, and wood for lumber, fence posts, and fuel. Many of these needs were also met by the water and riparian resources of the many non-stream wetlands, or cienegas. In addition, bordering the many ephemeral streams were native riparian forests that also supported valued wildlife and woodland communities.

Unfortunately, Arizona has lost much of its rich natural heritage as the growing requirements of agriculture, mines, industry, and cities have resulted in the redesigning of the stream and wetland landscape of the state. The flows of all of our major rivers and many of the lesser streams have been impounded, regulated, and diverted. Many other perennial streams and wetlands have disappeared as groundwater pumping has drained the water from their supporting aquifers, and other land use practices have altered the hydrology of their watersheds. Some of these changes were implemented for flood control, water storage, hydropower, or related purposes believed to be in the best interests of the state. Still others simply resulted from poor or uninformed land use and management actions.

Regardless of the causes, the restructuring of Arizona's stream and wetland systems has had monumental impacts on the natural qualities and values of these resources. These impacts have:

- Greatly reduced opportunities for stream- and wetland-based recreation
- Destroyed valuable open space qualities in and around urban communities
- Diminished natural runoff retention which, in turn, has resulted in faster rising and higher flood peaks
- Eliminated some native fish and wildlife species from the state
- Severely depleted critical fish and wildlife habitat

This chapter examines the losses to streams and wetlands associated with these changes, including the loss or reduction of:

- Riparian habitat
- Flowing and non-flowing surface waters and aquatic habitat
- Surface water quality
- Fish and wildlife

Loss of Riparian Habitat

Seventy to ninety percent of the riparian habitat in the United States has been lost to human activities (USCEQ 1978, Warner 1979a). Riparian habitats are estimated to now comprise between one-tenth and one-half percent of the total western landscape (Ohmart and Anderson 1986). Though riparian habitat acreage has always been relatively small when compared to upland habitats, the habitat ratio has not always been so excessively disproportionate.

In Arizona, only five percent of the original riparian habitat is estimated to remain (Warner 1979b). About twenty years ago, there was estimated to be between 279 thousand (Babcock 1968) and 300 thousand (Ffolliott and Thorud 1974) acres of riparian lands in Arizona. At that time, riparian acreage occupied less than four-tenths of one percent of the state's total land area (Johnson and Carothers 1982). By 1971, only six to eight thousand acres of cottonwood-dominated riparian habitat were found to remain in the state (Barger and Ffolliott 1971).

Arizona's total riparian acreage has decreased during the last two decades, but the extent of the decrease remains to be quantified. Cottonwood-willow gallery forests, which once formed lush canopies along all of Arizona's major desert river systems, have become the rarest forest type in North America (The Arizona Nature Conservancy 1987). Mature stands of mesquite bosques have suffered similar declines and are now the fourth rarest plant community in the United States (The Arizona Nature Conservancy 1987).

Loss of riparian habitat, as suggested earlier, is attributable to many development pressures. Among the early demands on these areas was the use of riparian trees for fuelwood, railroads, and building supplies. Riparian areas were further degraded by a period of erosion and arroyo cutting around the turn of the century which greatly widened and deepened stream channels, decimated riparian habitats, and drained cienegas and marshes. In this century, lush riparian habitats have been, and continue to be, converted into agricultural lands. In the 1950s and 1960s, fears of water shortages prompted large-scale eradication (called phreatophyte control) of riparian vegetation along some of Arizona's largest watercourses to reduce transpiration losses. Presently, population growth and urbanization are creating intensive pressures for floodplain development and stream channelization, both of which lead to the purposeful removal of riparian plant communities. Riparian habitat has also been indirectly impacted by activities which contributed to streamflow depletion and the lowering of groundwater tables, depriving riparian vegetation of moisture.

Direct Impacts

Harvesting Trees for Fuelwood and Building Supplies

Many of southern Arizona's largest riparian forests were decimated as a result of the early settlers' fuelwood and timber needs. When Anglo-Americans arrived in southern Arizona in the mid- to late 1800s, they typically settled in areas with large mesquite forests (Dobyns

1981). Mesquite forests provided wood for fuel and building needs, and indicated the presence of fertile soil and plentiful supplies of shallow groundwater or perennial surface water. The settlers generally proceeded to cut down or burn the trees to prepare the land for crops.

Such was the fate of one of southern Arizona's most magnificent mesquite forests, located along the Santa Cruz River between the San Xavier Mission and its Tucson sub-unit, twelve miles to the north (Castetter and Bell 1942). Prior to the Anglo-Americans, the native Indians collected deadfalls and branches for their fuelwood needs. During the eighteenth and nineteenth centuries, the Spanish and Mexican peoples harvested mesquite for cooking, homes, furniture, and other purposes (Dobyns 1981).

Mesquite forest harvesting began in earnest, however, after 1856, when Anglo-Americans began to settle in Tucson. At the turn of the century a forest of "giant" mesquite trees, some up to sixty feet high, was still found along the Santa Cruz River south of Tucson in the vicinity of the Tohono O'Odham (formerly the Papago) Reservation (Swarth 1905). A deforestation program was begun around 1912, reducing the forest to about four-fifths of its former size (Dawson 1921, Johnson and Carothers 1982). By 1940, the highest of the remaining mesquite trees were only twenty-five feet tall and considerably decreased in numbers (Arnold 1940).

<u>Overgrazing of Riparian Vegetation</u>

Overgrazing of riparian lands continues to contribute to the loss of riparian habitat in Arizona. When unattended, cattle and other livestock will congregate in riparian areas for forage, water, and shade. Though cattle ranching has been an economic and cultural staple of the Arizona lifestyle, grazing of cattle in riparian areas has come under severe attack in recent years because of the considerable amount of impact mismanaged cattle can cause to riparian (and aquatic) habitats. These impacts are magnified in lower elevations where the arid and semi-arid seasons are long, and by mid-summer, the only available water and edible vegetation are found in riparian areas (Behnke and Raleigh 1978).

Former cattle ranching activities led to the destruction of riparian habitat in other ways as well. For example, large tracts of riparian forests were once burned to drive cattle into the open ranges for roundup (Wagoner 1949). Today, heavily grazed riparian areas typically result in the replacement of palatable forage species with undesirable brush and unpalatable forage plants (Behnke and Raleigh 1978). Overgrazing can also lead to a decrease in the reproduction of cottonwood trees and other vegetative species whose seedlings are eaten or trampled by livestock (Glinski 1977), resulting in a stand of old, even-aged trees.

In recent years, however, there have been some encouraging changes in livestock and rangeland management that reflect a more coordinated and integrated management approach. This new approach considers other resource values such as wildlife habitat. The majority of Arizona's federal and state lands are grazed, and rangeland conditions vary considerably. The fencing of certain riparian habitats, until impacted systems recover, has been proposed or actually implemented on various forests throughout the state. Also, many ranchers and agencies are implementing grazing systems which allow more intensive livestock and forage management. By dividing grazing allotments into numerous pastures, cattle can be concentrated into specific areas at different times of the year, resulting in improved range and habitat conditions. By providing creek bottoms a rest from grazing, through reduction in the time cattle spend in riparian zones, young tree seedlings and other riparian vegetation can be protected during the critical seedling and reproductive stages. To accommodate this style of management, alternate water sources for livestock must be made available away from the riparian zones.

Conversion to Croplands

Conversion of riparian habitat to croplands has also contributed to the cumulative loss of this habitat type in Arizona. Croplands in the state were historically located along streams and in floodplains where surface water was available and groundwater was most shallow. As previously discussed, the early settlers typically chose mesquite forests for their future cropland sites because these trees were indicators of rich soils and ample water supplies. Farmers proceeded to eradicate mesquite and other riparian vegetation to prepare the land for crops. Irrigated agriculture has been, and still is, a predominant economic activity in the southern and southeastern part of the state in all major river valleys.

Dry-land farming practices in Arizona have also contributed to the destruction of riparian habitat. One example of the impacts that dry-land farming can have may be found on the Navajo Reservation where approximately ten thousand acres of cropland are located within the major riparian zones (Jayne 1985). The Navajo impact on riparian lands essentially began with the development of dry-land farming after the turn of the century. Dry-land crops, watered by surface runoff or groundwater moisture, were located: (1) on floodplains or flat stream terraces of larger valleys; (2) on bottoms of small, deep, sandy canyons; and (3) near the upper ends of canyons or valleys; or (4) on outwash slopes. As with irrigated farming, the natural riparian vegetation was cleared to prepare the land for crops.

Inundation and Desiccation from Impoundments and Diversions

Numerous riparian habitats have been inundated or desiccated as a result of the many dams constructed since 1911 on the major rivers of the state and in several locations on the lower Colorado River (Figure 2-6).

The first of the many diversion dams, Ashurst-Hayden, was built in 1891 on the Gila River to transport water to the growing agricultural industry in the Salt River Valley. At that time, an estimated one hundred thousand acres were already being irrigated, but it was clear that agricultural development could not continue to grow without dams and impoundments capable of controlling and regulating the flow of erratic surface waters. Although the first dams were built for irrigation purposes, many of the latter impoundments were also used to produce hydroelectric power and to control flood waters (Arizona Water Commission 1975) (Figure 2-6). In recent decades, reservoirs have also provided flatwater boating and other recreation opportunities.

Granite Reef Diversion Dam, the first twentieth century dam in central Arizona, was built in 1908 on the Salt River downstream of its confluence with the Verde River. This dam permitted large diversions of the river, but allowed seasonal flooding to continue. Roosevelt Dam, the first federally funded reclamation project in the United States, was completed on the Salt River in 1911. This dam inundated an extensive cottonwood forest and a large prehistoric settlement known as the Solado Valley ruins (Johnson and Carothers 1982). After 1911, the riparian habitat downstream of the dam site to the confluence of the Gila River was deprived of natural streamflows and seasonal flood cycles.

Between 1923 and 1930, three more dams (Mormon Flat, Horse Mesa, and Stewart Mountain) were constructed downstream of Roosevelt Dam, causing further inundation and modification of the Salt River Valley riparian habitat. Coolidge Dam was built on the Gila River in 1928 to facilitate the San Carlos Irrigation Project. The dam inundated riparian habitat upstream of that site and essentially cut off perennial flows downstream to the confluence with the Colorado River. A similar fate soon befell the Verde River. The completion of Bartlett and Horseshoe Dams in 1939 and1946, respectively, flooded substantial riparian habitat, and modified streamflows for much of the river's length. Likewise, the Waddell Dam led to destruction or modification of significant areas of riparian habitat on the Agua Fria River.

Similar but even more intensive irrigation and power demands were made on the Colorado River because of its geographic proximity to three southwestern states and Mexico. Laguna Dam, the first dam on the lower Colorado, was completed in 1901, enabling large-scale diversions to begin through California's Imperial Canal. This dam, however, did not stop nutrient-rich seasonal floods. The flood waters continued to pass relatively unaltered along the length of the river until the construction of Hoover Dam and the All American Canal in the mid-1930s. Hoover Dam flooded vast acres of riparian habitat in the area now known as Lake Mead, and cut off seasonal flooding cycles for the remaining course of the River downstream to its delta in the Gulf of California. In addition, the building of Hoover and subsequent dams led to the continued and accelerated occupation and agricultural conversion of the Lower Colorado River Valley floodplain (Brown 1985).

Five more major dams (Davis, Parker, Imperial, Morelos, and Glen Canyon), a few smaller diversion dams, and several large-scale canal systems (the last being the Central Arizona Project) have since been built on the lower Colorado River. As a result of these projects and others, more than eighty percent of the remaining marshes on the lower Colorado River are now limited to the three National Wildlife Refuges. The riparian areas formerly considered to be the least valuable to wildlife are now considered to be the best because they are all that remain (Brown 1985).

Invasion of New Plant Species

A common sight in riparian areas associated with regulated streams is the invasion of saltcedar (Tamarix chinensis) and other vegetation less valuable to native birds and wildlife (Johnson 1978). Saltcedar was introduced into the United States more than one hundred years ago. By 1961, it had spread to fifteen of seventeen western states, occupying more than 900 thousand acres of riparian habitat. This exotic species is capable of eliminating native riparian species, like cottonwood and seepwillow (Turner 1974), and its prevalence and high water consumption requirements led to many of the recent phreatophyte control programs in the West (see the following discussion). Unfortunately, native riparian species have also been removed as a result of these programs. This human-induced process leads to a new riparian vegetation community commonly called the "reclamation disclimax."

Phreatophyte Eradication for Water Yield and Flood Control

Vegetation modification experiments, conducted since 1909, indicate that surface water yield may be increased by altering the amount and type of vegetation on a watershed (National Water Commission 1973). Post-World War II water demands, coupled with a prolonged drought and concern over the spread of non-native, water-loving saltcedar, led to considerable public fear of water shortages (Robinson 1958). The idea of eradicating vegetation to increase water yield first received serious attention in Arizona in the mid-1950s, following the release of the Barr Report which focused on vegetation manipulation in the Salt and Verde River watersheds (Barr 1956). Subsequent studies addressed the water yield effects of vegetation removal of several plant communities, including mixed conifer forests, ponderosa pine forests, pinyon-juniper, chaparral, and riparian phreatophytes (Ffolliott and Thorud 1974). The term "phreatophyte" was first defined by O.E. Meinzer in the mid-1920s as "a plant that habitually obtains its water supply from the zone of saturation, either directly or through the capillary fringe (of the soil)" (Meinzer 1923, 1927).

Phreatophyte eradication programs have had devastating impacts on riparian habitats in this state. In 1952, approximately 400 thousand acres of phreatophytes were found in Arizona (Arizona Water Commission 1975). By 1967, the state's phreatophyte acreage had been cut to just short of 280 thousand acres. After 1967, major phreatophyte eradication projects occurred, along the Gila River on the San Carlos Indian Reservation and on the Indian reservations bordering the lower Colorado River, for the purpose of agricultural land conversion (Arizona Water Commission 1975). Nearly two dozen major phreatophyte eradication projects had occurred in Arizona by 1969, the largest being a five thousand-acre clearing on the Gila River floodplain (Ritzi et al 1985). Most of the eradication programs were conducted by the Bureau of Reclamation, Army Corps of Engineers, and local water companies like the Salt River Project (Johnson and Carothers 1982).

Removal of phreatophytes has also been used to reduce the impacts of flooding in such areas as the Verde Valley (Johnson and Carothers 1982). Between 1967 and 1969, the Salt River Project removed mature cottonwood trees from the Verde River's streambank to prevent flooding of private lands. This project allowed flood waters to flow faster over affected lands with lower flood peaks, but it also caused many of the remaining native trees to wash out and increased soil erosion (Carothers et al 1974). In addition, as with urban channelized areas, these flood control measures increased the amount of damage suffered by downstream riparian landowners.

Though phreatophyte removal projects for increased water yield have lost much of their public support (Cortner and Berry 1978), at least one recent study indicates that vegetation manipulation in the Salt and Verde River watersheds could resurface as an issue due to growing municipal water demands (Meitl 1988). In fact, the Soil Conservation Service, in cooperation with other agencies, is just beginning a major study in Arizona of potential water yield from vegetation manipulation.

Floodplain Development for Urban Needs

As Arizona's population has grown and become more urbanized, the pressures for land development have increased tremendously. Floodplains and riparian lands have historically been sought after as scenic areas for homes and commercial development. As Tucson and Phoenix began to expand into areas formerly occupied by irrigated agriculture, croplands and undeveloped riparian lands were cleared for residential and commercial development. The extent of riparian habitat loss from urban floodplain conversion has not been documented.

Sand and Gravel Mining

The need for building supplies in urban and urbanizing areas has prompted the establishment of numerous sand and gravel companies. Population growth and urbanization after World War II, in conjunction with the Federal Highway Act of 1956 (which greatly stimulated road construction), led to enormous growth in the sand and gravel industry in Arizona (ABM 1969). Sand and gravel mining operations can be found all over Arizona, but are concentrated principally in urban areas and near small towns.

The most economically important sand and gravel deposits are found in stream terraces and in buried and active stream channels. The mining of sand and gravel in stream channels results in the direct removal of riparian vegetation and alteration of stream channel morphology. Consequently, open space and recreational values are often destroyed. Because many historic sand and gravel pits were later used for land fills, a number of these areas are also threats to surface water and groundwater quality.

Channelization and Flood Control

Development of riparian and floodplain lands has continued throughout the latter half of the twentieth century despite relatively frequent and devastating floods, which often lead to human injury and property damage. The amount of destruction to homes and property from flooding is particularly keen in urban areas as a result of increased runoff over paved and other hardened surfaces. Once floodplains are developed they can no longer function to naturally retard of surface runoff rates. When the channelized floodwaters finally do reach unmodified streambanks the streambanks are more easily eroded, riparian vegetation is more easily removed, and channels are more easily widened. Each new flood often results in damage to or destruction of homes, bridges, and other structures, as well as downstream vegetation in undeveloped areas.

Severe flooding typically prompts calls for channelization and flood control dams and levees to minimize future property damage. Channelization is the widening, deepening, straightening and usually hardening of stream channels to increase the channel's capacity to transport flood waters downstream of developed areas thus reducing property damage. Channelization projects can affect riparian habitat by draining wetlands, straightening and shortening stream channels, partially or totally removing riparian vegetation, and reducing groundwater tables (Schoof 1980). Soil cement is typically used with channelization to stabilize streambanks and prevent further erosion. Dams are also often constructed in urban areas to control releases of flood waters, and levees are sometimes used to prevent flood waters from rising over the streambank and onto the floodplain. In some cases, these structural approaches can actually exacerbate flooding, particularly in unchannelized segments downstream (Belt 1975, Schoof 1980).

Indirect Impacts

Widening and Deepening of Stream Channels

The use of fire by Indians to herd game animals, the decimation of riparian forests, and the overgrazing of range and riparian lands when combined with natural cycles of floods and droughts have been cited as some of the major causes of the severe channel cutting episodes of the late 1800s (Dobyns 1981). At least eight other land use practices have also been identified as contributing to more localized channel erosion, suggesting that the processes of desertification and channel-cutting in the Sonoran Desert are very complex (Dobyns 1981).

Three major flood events (1833, 1868, and 1891), numerous small, localized floods, and severe droughts occurred between 1833, the year of the first recorded and major erosive flood, and 1900 (Dobyns 1981). The largest of the floods cut wide, deep channels in stream courses that formerly could handle such flows with much less morphological change. Marshes were drained in the process, and fertile soils scoured away. In addition, groundwater tables were lowered below the discharge points of springs, drying up these sources of surface water, sometimes out of the reach of the roots of riparian vegetation. By 1916, the Gila River riparian systems and the riparian corridors of all its major tributaries had been drastically altered. Some of the more strident examples of channel cutting in southern Arizona are summarized below, as described in a classic paper on the historic losses of southwestern fishes (Miller 1961).

In 1857, the Gila River was a "large, essentially permanent stream of clear to 'sea green' water, with a well-defined narrow channel flanked by numerous cottonwoods and set off by a dense growth of willows and cane that rendered it difficult to approach. Along its course were numerous lagoons and extensive marshes that abounded in waterfowl, beaver, and fish life" (Miller 1961). In 1875, an area of 103 acres on the Gila River near Solomonville averaged 139 feet across. By 1916, this same channel segment averaged more than nineteen hundred feet across and occupied over fifteen hundred acres (Olmstead 1919).

Channel cutting took similar tolls on the major tributaries of the Gila River, draining many of the cienegas and marshes, and greatly reducing the habitat and size of those that remained (Brown 1985). By 1893, the San Pedro River below Fairbank had been cut from three to twenty feet deep for 125 miles. At the turn of the century, the river had deepened to ten to forty feet deep, and the riparian trees and underbrush had been destroyed or greatly reduced (Bryan 1925, Thornthwaite et al 1942).

In 1883, farmers near Solomonville dug a small canal four feet deep and twenty feet wide for a short distance in the San Simon Valley. By 1961, this same ditch was ten to thirty feet deep and six hundred to eight hundred feet wide for a distance of approximately sixty miles (Miller 1961).

Similar channel cutting episodes led to riparian habitat loss in other areas of the state as well. Natural marshes on the Navajo Reservation essentially disappeared between 1880 and 1910 as a result of the channel cutting (Brown 1985).

Lowering of Groundwater Tables

Groundwater pumping from aquifers hydrologically interconnected with streams has diminished streamflow by lowering water tables. Riparian vegetation dependent on surface flows or shallow groundwater have been detrimentally affected by aquifer reductions. While surface water diversions may conceivably be altered or stopped to accommodate new values and water uses, the effects of intensive groundwater pumping are long-term and essentially irreparable. The lowering of groundwater tables has been a particularly acute problem in the agricultural areas of southern Arizona.

Central and northern Arizona riparian habitats have also been negatively impacted by groundwater pumping. Obed Meadows, McDougal Springs, and Hugo Meadows are but a few wetlands in northern Arizona that have been altered by groundwater withdrawals (Brown 1985). By 1979, only Hugo Meadows remained. Bingham Swamp, Cook's Lake, and Mint Springs, the only known representatives of spring-fed swamps within the Eastern Deciduous Forest that still provide waterfowl habitat, are also threatened by groundwater pumping (Brown 1985).

Loss of Flowing and Non-flowing Surface Waters

The loss of flowing streams and non-flowing aquatic habitats (cienegas, springs, and marshes) is attributed to many of the same land and water use practices that have contributed to the loss of riparian vegetation. Depending on the cause, the changes and loss of aquatic habitat can be characterized as either slow and gradual or sudden and catastrophic (Behnke 1977). Slow and gradual losses of surface water have occurred mainly as the result of the cumulative impacts of riparian wood harvesting, overgrazing, irrigated agriculture, groundwater pumping, and other land use practices. The severe arroyo cutting episodes of the last century and the lowering of groundwater tables led to the majority of the slow and gradual losses. Sudden and catastrophic changes have occurred as a result of the building of dams and impoundments. The major dam-building events have already been identified in this chapter. Once the floodgates close on a dam, desiccation and the alteration of downstream areas begins because the physical, biological, and chemical characteristics of the regulated flows are much different from pre-dam flows.

Some of the more significant losses of flowing and non-flowing perennial waters in Arizona described below were taken principally from studies by Miller (1961), Hendrickson and Minckley (1984), and Brown (1985). The historic losses of major flowing streams are shown in Figure 2-2.

Loss of Natural Streamflows

Historically, the Santa Cruz River flowed year-round in interrupted segments from the international border to just south of its confluence with the Rillito River. Today, the Santa Cruz, with the exception of a small perennial segment at its headwaters, flows only in response to precipitation and discharged wastewater. The San Pedro River once flowed perennially from the Mexican border to Redington, and from a point half-way between Mammoth and Feldman to the confluence with the Gila River. Only a small portion of the San Pedro from Hereford to just south of Fairbank still carries perennial flows. The Babocomari River, a major tributary to the San Pedro, formerly contained surface water year-round for its entire length, but perennial flow on this stream is now confined to a small segment at the river's headwaters.

The Gila River once flowed perennially for the majority of its length across the state, but the construction of Coolidge Dam resulted in the desiccation of most of this river; only a relatively small segment of the Gila River east of Solomon, and a very short segment in the vicinity of the town of Geronimo now flow perennially.

The Salt River once flowed perennially through Phoenix to its confluence with the Gila River. This river is now regulated for most of its length, and is dry in the Phoenix vicinity, downstream of Granite Reef Dam.

The Little Colorado River was described in the 1850s as being "about thirty feet wide, flowing between alluvial banks eight to ten feet in height..." (Whipple 1856). By the early 1960s, the Little Colorado River was described as normally dry between Grand Falls and Winslow, deeply entrenched, and sparsely vegetated (Miller 1961).

One of the most severe examples of river modification is found on the Colorado River. Control of the Colorado River began with the completion of Hoover Dam in 1935. The numerous dams and impoundments that have since been built for irrigation, hydropower production, flood control, and flatwater recreation purposes have severely altered the chemical, physical, and biological character of this river. The regulated flows lack nutrients that are important to the river's native ecosystems. River temperatures have also been altered from widely varying seasonal patterns to a narrow range of much colder waters. For example, water temperatures on the lower Colorado River originally varied between fifty and ninety degrees Fahrenheit; they now range between fifty-four and sixty-two degrees Fahrenheit below Hoover and Davis Dams (Miller 1961). The completion of Morelos Dam in 1950 essentially dewatered the river southward to the international border (Brown 1985).

Loss of Non-Flowing Surface Waters and Cienegas

Southeastern Arizona

Losses of non-flowing surface water and aquatic habitat in cienegas and marshes have been equally severe as losses of flowing streams. By far, the most significant losses have occurred in southeastern Arizona, primarily as the result of groundwater pumping. Some of the more significant losses there and in other parts of the state are described below as discussed in a report by Hendrickson and Minckley (1984).

There were once eight cienegas along San Simon Creek and some of its tributaries, and two cienegas in the San Bernardino Valley, just north of the Arizona-Mexico border. San Simon Cienega is the only remaining cienega from these basins, and it is artificially maintained.

Moving west into the Sulphur Springs Valley, historic records show the occurrence of two cienegas bordering the Willcox Playa, and others located along Aravaipa Creek, Grant Creek, Ash Creek, West Turkey Creek, Leslie Creek, and Whitewater Draw. Today, only three remain: those on Ash Creek (Hooker Cienega), Leslie Creek, and in the Whitewater Draw drainage (in the San Bernardino National Wildlife Refuge and at Slaughter Ranch). All of these cienegas are artificially maintained.

Several natural marshes were once found along the San Pedro River from the border to just north of Cascabel in the vicinity of Redington, and at the confluence with Aravaipa Creek. The wetlands described at Redington (Bingham Swamp) and Feldman (Cook's Lake) on the San Pedro River are still present (Hendrickson and Minckley 1984), but are drying up rapidly. The Babocomari River once exhibited similar conditions for most of its length. The cienegas on the San Pedro River are now fewer and much smaller than occurred previously. Three cienegas remain on the Babocomari River.

Historic impacts to cienegas on the Santa Cruz River and its tributaries are much the same. Records show four extensive cienegas on the Santa Cruz, two smaller ones along Sonoita Creek, and large marshy areas along Cienega Creek, the Rillito River, and Arivaca Creek. Perennial waters and cienegas persist in the Santa Cruz drainage in the following locations: in the headwaters of the Santa Cruz River in San Rafael Valley (Sharp Spring Cienega, Sheehy Spring Cienega, and Bog Hole), in Arivaca Creek, in Sonoita Creek, and in Cienega Creek. However, these cienegas are much smaller and are highly modified from their historic natural conditions.

Extensive cienegas once existed along the middle and upper Gila River in the vicinity of Solomon and Geronimo, and also between the river's point of confluence with the Santa Cruz to its confluence with the Salt River. These have all since disappeared.

<u>Southern and South-Central Arizona</u>

Losses of non-flowing waters and cienegas in the remaining areas of Arizona are not nearly as well documented for the northern and south-central regions as they are for the southeast region of the state. Still, what information is available conveys a similar story, particularly in the arid northeast and western areas of Arizona. For example, most or all of the natural marshes that were once present on the Navajo Reservation have been destroyed, primarily as a result of channel cutting (Brown 1985). Spring-fed marshes south of the Little Colorado River between Joseph City and Winslow (Obed Meadows, McDougal Springs, and Hugo Meadows) have been impacted by groundwater pumping. Also, it has been reported that most of the natural oxbow lakes and marshes and spring-fed marshes in south-central Arizona have also disappeared (Brown 1985).

Loss of Surface Water Quality

Point Sources of Pollution

Rapid population growth and urbanization in Arizona have contributed significantly to the growth of wastewater treatment plants for industry and municipalities (ADHS 1986). Point source discharges of treated wastewater into streams are regulated by National Pollution Discharge Elimination System (NPDES) permits which are drafted by the Arizona Department of Environmental Quality and issued and enforced by the federal Environmental Protection Agency. The number of significant municipal and non-municipal facilities issued NPDES permits grew from zero to thirty between 1972 and 1984.

In 1984 and 1985, thirty-eight wastewater systems in Arizona were in violation of point discharge standards. Many of these systems are located in growing, higher elevation recreation communities, such as Globe, Mount Lemmon, Camp Verde, Pinetop, Snowflake, and Sedona. Wastewater treatment plants that are in violation of NPDES standards may be contributing excessive nutrients (nitrogen and phosphorous), organics, heavy metals, and other contaminants to streams.

Non-Point Sources of Pollution

Mining activity and residues are responsible for the non-attainment of water quality standards for 179 of 207 river-miles analyzed by the state (ADHS 1986). This includes seventeen river segments and seven drainage basins. A recent study of an abandoned mine on Boulder Creek in the Bill Williams Basin reported "devastating" ecological effects immediately downstream of the waste piles (Rampe and Runnels 1987).

Tailings and waste piles from inactive mines are found in numerous perennial and ephemeral stream channels throughout Arizona (ADHS 1986). Similar residues on hillsides are exposed to surface runoff, which then drains into stream channels. When direct precipitation and surface water runoff come into contact with these waste products, heavy metals and acidic waters can leach into the stream channel. "Strongly polluted waters" may be found immediately downstream from these areas, particularly during the summer months when the flows are diminished and the pollutants can become more concentrated (Rampe and Runnels 1987).

Since the end of World War II (when synthetic pesticides and commercial fertilizers entered the marketplace), there have been increasing numbers of studies showing how surface and groundwaters have been degraded in quality from agricultural runoff. Organic toxics, principally pesticides and their metabolites, have been detected in three surface water areas: on the Gila River between the confluence of the Salt River and Painted Rock Dam, at Painted Rock Borrow Pit Lake, and on the Salt River in the vicinity of 19th Avenue in Phoenix (ADHS 1986). High nutrient levels, attributed to agricultural fertilizers, wastewater treatment facilities, and other point and non-point sources, have also been detected in these stream segments. Excessive nutrients can lead to accelerated eutrophication in lakes and reservoirs, the biological process leading to diminished oxygen levels, and a decrease in aquatic species diversity (Welch 1952). Increased quantities of suspended sediments and the concomitant release of soluble salts, another water quality problem, can be attributed to accelerated erosion of surface soils brought on by intensified agricultural practices.

Overgrazing of riparian areas can also contribute to degradation of water quality. When cattle graze on riparian vegetation, they contribute to the decline of plant community stability and, through trampling, increase streambank instability and the propensity for soil erosion (Marlow and Pogacnik 1985). Increased surface runoff results from such overgrazed areas, accelerating the erosion of sediments and salts to the stream which can be detrimental to fish (Hubert et al 1985). Intensive livestock grazing has been identified as the greatest single cause of accelerated erosion and salt loading on the Colorado River (Johnson and Carothers 1982).

Loss of Fish and Wildlife

Fishes

Not surprisingly, native fish have been most severely impacted by aquatic habitat loss in the arid Southwest. Forty-five of sixty-seven fishes on the federal threatened or endangered lists live in the arid region of the United States (Minckley and Mefee 1987). There are only thirty-seven native species and subspecies of fishes remaining in Arizona and New Mexico (west of the Continental Divide), and fourteen of these species are endemic to the region (Minckley and Mefee 1987). At least four species and six subspecies of fishes have become extinct in the last forty years due to human-induced changes (Pister 1981).

A 1985 report published by the Arizona-Nevada Academy of Science lists 182 fishes of concern in North American deserts (Williams et al 1985)(Table 4-1). The North American desert region contains fifteen aquatic ecosystems that provide habitat for four or more of the identified fishes of concern. The aquatic ecosystems listed in Arizona include: (1) the Gila River drainage; (2) the Colorado River drainage; and (3) the Yaqui River drainage. Of the 182 fishes listed, forty-six are endangered, fifty-two are described as vulnerable, another forty-six are considered rare, and twenty of the species are of an indeterminate status.

Arizona's native fishes evolved slowly under specific natural habitat conditions influenced by such characteristics as: channel morphology, substrate type, water depth, water temperature, water velocity, water turbidity and chemistry, and cover (Behnke 1977). Native fish have developed the physiological means for surviving severe floods which tend to decimate the populations of introduced species (Minckley and Mefee 1987). Yet these fishes, because of their evolutionary development in rather isolated habitats with relatively few natural predators, lack the abilities to outcompete non-native species when the latter are introduced. Thus, in addition to coping with habitat destruction, Arizona's native fish fauna have also been depleted through the introduction of exotic species. Some examples of the devastating effects of non-native introductions and habitat alterations may be gleaned from the following information for some of Arizona's largest drainage basins (Miller 1961).

In 1854, there were seven native species present in the Colorado and Gila Rivers near Yuma. Between 1950 and 1955, only two native species were present, in addition to twelve exotics. Eleven native species were identified in the San Pedro River between Benson and Fairbank between 1846 and 1854, but by 1950, only three native species remained. A similar story can be told for the Salt River near Tempe—eleven native species were reported there in 1890, but by 1944, the same river segment contained only five exotics. The Santa Cruz was once perennial in the vicinity of the San Xavier Mission (south of Tucson), and had five native species in 1904. By 1950, even intermittent flows had disappeared; it reportedly went dry for the first time in 1941 (Lowe 1985).

Birds

An estimated 431 species of birds (including 245 breeding birds) are found in Arizona, representing sixty-two percent of the North American bird species (north of Mexico) (Hubbard 1977). The critical importance of riparian habitats to birds is evident when one considers that seventy-seven percent of nesting birds surveyed in a late 1970s study of southern Arizona, southern New Mexico, and west Texas were in some manner dependent on water-related habitat (Johnson et al 1977). Eighty-four of the 166 surveyed birds were completely dependent on riparian habitat. In fact, the number of species of birds associated with riparian habitats is greater than for any other habitat type (Carothers and Johnson 1975). Arizona's riparian habitats are also critical to migrating birds which require food and cover to continue on their migratory routes (Stevens et al 1977).

Native bird populations in Arizona have been negatively affected by the cumulative effect of a number of land use practices and impacts, including, but not limited to, agricultural land conversion, channelization, phreatophyte

Table 4-1
Fishes Of Special Concern In Arizona

Common Name	Scientific Name	Location	Status
Family -- Salmonidae: Trout			
Apache Trout	Salmo apache	Gila River	Vulnerable
Gila Trout	Salmo gila	Verde River	Endangered
Family --Cyprinidae: Minnow			
Humpback chub	Gila cypha	Colorado River Little Colorado River	Endangered
Sonora chub	Gila ditaenia	Rio Magdalena	Indeterminant
Bonytail	Gila elegans	Colorado River Gila River Drainage	Endangered
Gila Chub	Gila intermedia	Gila River Drainage Verde River Salt River	Vulnerable
Yaqui chub	Gila purpurea	Rio Yaqui	Indeterminant
Virgin River roundtail chub	Gila robusta seminuda	Virgin River	Endangered
Virgin River spinedace	Lepidomeda m. mollispinis	Virgin River	Vulnerable
Little Colorado spinedace	Lepidomeda vittata	Little Colorado Drainage	Vulnerable
Spikedace	Meda fulgida	Gila River Basin Salt River Verde River	Vulnerable
Yaqui beautiful shiner	Notropis formosus mearnsi	Rio Yaqui	Vulnerable
Woundfish	Plagopterus argentissimus	Virgin River Gila River (extinct)	Endangered
Colorado squawfish	Ptychocheilus lucius	Colorado River Gila River drainage (extinct)	Endangered
Loach Minnow	Tiaroga cobitis	Gila River Basin Salt River	Vulnerable

Table 4-1 (Continued)
Fishes Of Special Concern In Arizona

Common Name	Scientific Name	Location	Status
Family -- Catostomidae: Sucker			
Razorback sucker	Xyrauchen texanus	Rio Yaqui	Vulnerable
Family -- Cyprinodontidae: Killifish			
Desert Pupfish	Cyprinodon macularius	Gila River (extinct) Quitobaquito Spring	Endangered
Family -- Poediliidae			
Gila Topminnow	Poeciliopsis o. occidentalis	Gila River Drainage	Endangered

Source: AZ-NV Academy of Science,1985

control, and dam construction. Historic land use practices appear to have prompted the first movements of several bird species into Arizona (Mississippi Kite, Inca Dove, Thick-billed Kingbird, Starling, House Sparrow, Great-tailed Grackle, and Bronze Cowbird), some of which have contributed to the decline of native species (Johnson et al 1977). The following studies illustrate some of the impacts of human land use practices on Arizona's native bird species.

A study of breeding bird populations in honey mesquite areas that had been converted to agricultural lands along the lower Colorado River showed that certain birds (Yellow Warbler and Bell Vireo) were extirpated as a result (Anderson et al 1977). Agricultural land conversion destroyed considerable amounts of riparian habitat, causing most of the native birds and wildlife to disappear, while at the same time creating a new, though less diverse habitat, beneficial to introduced species (Ohmart, Anderson, and Hunter 1985). A comparative study of breeding bird populations along channelized and unchannelized segments of the Gila River and Tonto Creek found more than twice as many species and two to four times the number of birds on non-channelized areas of the same size and habitat (Carothers and Johnson 1975).

Avian populations show a similar negative response to phreatophyte control programs. A study of breeding bird relationships to mature cottonwood trees showed a direct correlation between cottonwood trees and nesting pairs; the fewer the trees, the fewer the birds (Carothers and Johnson 1971). Additionally, the loss of native cottonwood-willow forests and mesquite bosques on the Salt and Gila Rivers have led to the disappearance of the

Ferruginous Owl, Yellow-billed Cuckoo, Summer Tanager, and other species (Johnson 1978).

By far the most telling story of the effects of lost riparian habitat to birds is related through a study of the Gila River in the vicinity of the Gila River Indian Reservation, located upstream of the river's confluence with the Salt River (Rea 1983). The numerous causes of habitat destruction in this area include most of those listed above, and the most dramatic effect of these causes was the loss of a live stream and its associated riparian habitat stretching sixty-five miles across the reservation. The study identified eight major types of changes in the bird populations, including: (1) extirpations; (2) changes in population sizes associated with habitat deterioration; (3) local riparian recovery and recolonization; (4) northward movements; (5) changes in subspecies distributions; (6) changes in wintering status; (7) changes in departure times of winter residents; and (8) winter flight years. Prior to the impacts of the land use change, at least 101 species of breeding birds were present on the reservation (Rea 1977). In the past one hundred years, twenty-two breeding birds have been extirpated in this area. Eighteen of these twenty-two birds were related to the former riverine habitat. In addition, six non-nesting bird species known to be dependent on the river have been eliminated. Thirteen species have since recolonized the area.

Mammals

There are 134 species of mammals in Arizona, which includes over forty-one percent of the total number of mammal species in North America, north of Mexico (Hubbard 1977). Mammals require food, water, and cover to survive, but the extent that riparian habitats fulfill these needs is not fully understood (Ohmart and Anderson 1986). When compared with the number and types of studies documenting historic losses and impacts to fishes and birds from the degradation and loss of riparian and aquatic habitat, relatively few studies of a similar nature have been conducted for mammals. Results of some of these studies are presented below for large, medium-sized, and small mammals.

Large Mammals

Arizona's ephemeral desert washes have been documented as being very important habitats for desert mule deer, providing forage, thermal cover, and travel corridors for the animals (Krausman et al 1985). The importance of these riparian areas to mule deer is evidenced from data from one study site in the King Valley (Yuma County)--over ninety-nine percent of the located deer were found in desert washes. Elk also seem to show a preference for riparian habitats during the summer (Marcum 1975, Skovlin 1984), but their dependence on these habitats during other times of the year is not well understood. A few studies indicate that livestock grazing may diminish the use of riparian habitats by elk (Ohmart and Anderson 1986).

Medium-Sized Mammals

Extirpation of two medium-sized mammals (beaver and river otter) from parts of Arizona can be traced back to human causes (beavers still exist in many areas of Arizona). Both animals formerly occupied the Gila River and Colorado drainages. Beavers were extirpated in tributaries of the Gila River in the 1800s; their dams began to deteriorate as early as 1825, and all or most of them lacked maintenance by 1835 (Dobyns 1981). The disappearance of beaver is attributed to trapping and loss of aquatic and riparian habitat. The river otter formerly occupied the Gila River and Colorado River drainage basins, but its numbers were greatly reduced as a result of a loss of streamflows, and riparian habitat modification and destruction (AGFD 1982). Beaver and muskrat populations in Mexico are now also critically endangered as a result of trapping and habitat destruction (Ceballos-G 1985). A Lousiana subspecies of river otter is being re-established in Arizona through the efforts of the Arizona Game & Fish Department.

Studies of medium-sized mammals from other arid regions also give some indication of the importance of riparian habitat. Fifteen medium-sized mammals use the riparian ecosystem in Big Bend National Park in Texas, and one of these animals, the beaver, is totally dependent on the aquatic regime (Boeer and Schmidly 1977). In California, approximately one-fourth of the native species and subspecies (552 total) are dependent on riparian habitats, and five of these animals were medium-sized mammals (Williams and Kilburn 1984).

Small Mammals

Small mammal studies indicate that riparian habitats are also important to these species. Streamside riparian zones in low to mid-elevation mixed-conifer forests had greater diversity and density of small mammal species than other habitat types (Cross 1985). A study of the effects of channelization on medium- and small-sized mammals indicated greater diversity and density of small mammals in unchannelized riparian habitats (Barclay 1978). Changes in the small mammal population of Big Bend National Park have occurred over the past thirty years as a result of human use and trespass livestock grazing (Boeer and Schmidly 1977). Ord's kangaroo rat has since been eliminated from the area, while populations of two other rodent species (white-footed mouse and hispid cotton rat) have increased. The changes in the populations are attributed to the spread of saltcedar along the river corridor.

Reptiles and Amphibians

Until very recently, few studies had documented the impacts of lost and degraded riparian habitat in Arizona on reptiles and amphibians. The information presented here was taken from a collection of papers presented at a 1985 symposium on the management of riparian habitats (Johnson et al 1985).

The decrease and extinctions of riparian amphibian and reptile populations in Arizona is a result of the same land use practices that have led to the decrease and extinction of other wildlife and fish: (1) groundwater pumping; (2) dams and impoundments; (3) encroachment resulting from agricultural, reclamation, and urbanization practices; (4) pollution from acid rain, pesticides, and trace metals; (5) overgrazing; (6) wood cutting; and (7) the introduction of exotic species (Lowe 1985).

There are twenty-four species of amphibians in Arizona; most of these are frogs and toads, and a few are salamanders. Nearly all of these amphibians depend directly on surface water for their survival and reproduction (Lowe 1985). Additionally, ninety-three reptiles are found in the state, representing over thirty-five percent of all North American reptile species (north of Mexico) (Hubbard 1977). There are two native turtles (Yellow Mud Turtle and Sonoran Mud Turtle) and four native snakes (Mexican Garter Snake, Black-necked Garter Snake, Checkered Garter Snake, and the Narrow-headed Garter Snake) found in southern Arizona and Sonora, Mexico, which are dependent on riparian habitat. All are considered to be threatened species throughout their southwestern distributions (Lowe 1985). The extinction of local reptile species has been in progress for about the last twenty years. Four species of riparian-dependent amphibians and reptiles became extinct in Arizona during the 1960s and 1970s as a result of human-induced changes to the environment (Lowe 1985).

The few studies conducted on the effects of riparian habitat changes on reptiles and amphibians indicate that these animals do not adapt well to saltcedar habitats (Jakle and Gatz 1985), and that garter snakes can be negatively impacted by overgrazing (Szaro et al 1985). Saltcedar-dominated habitats have a dense canopy which reduces the amount of light penetration and inhibits the development of shrubs and ground cover, which lizards tend to prefer. Overgrazed areas lack the vegetative cover that fleeing snakes use for cover, and contain fewer numbers of earthworms and slugs upon which the snakes feed.

Conclusion

Historic losses of stream and wetland habitats in Arizona have been severe. Today, less than five percent of the state's original riparian habitat remains. In addition, perennial and intermittent streamflows have been lost, and much of the year-round flowing surface water that remains is regulated and devoid of its natural physical, chemical, and biological character. Native fish and wildlife have been severely impacted or often extirpated as a result of the losses in riparian and aquatic habitat.

Important recreational opportunities, including nature observation, hiking and camping, open space and scenery, fishing, and hunting, that are associated with the nonconsumptive and consumptive use of wildlife, dependent on the presence of flowing surface water, or associated with native riparian vegetation have been lost as a result of the degradation of streams and wetlands. These losses occur at a time when the demand for stream- and wetland-based recreation is increasing.

"The frog does not drink up the pond in which he lives."

Indian Proverb

STREAM AND WETLAND RECREATION

Arizona has a wide variety of streams and wetlands that offer diverse and highly desirable recreation experiences including among others: whitewater and quiet-water boating, hunting and fishing, camping, hiking, and nonconsumptive wildlife enjoyment. This chapter includes the available data documenting participation in, and the economic values of, stream and wetland recreation.

The popularity of stream and wetland recreation in Arizona is on the rise, and this type of recreation makes a considerable contribution to the state's economy. However, the outlook for stream and wetland recreation is uncertain. Impacts from the recreational use of these resources are many. There are indications that some streams and wetlands will suffer resource degradation from increased recreation use.

Introduction

In Arizona, nothing attracts recreationists like water. Every year, more than a million Arizonans and out-of-town visitors flock to the state's waters—to boat, float, fish, hunt, hike, wade, picnic, relax, play, and in the summer, to escape from the heat. The state's reservoirs are, of course, the principal attraction to many of the users, but, in increasing numbers, the recreationists are seeking stream- and wetland-based types of recreation.

Arizona has a startling variety of stream and wetland resource types that support a wide range of recreation activities. Boating and floating are very popular activities on whitewater and quiet-water stream segments, respectively. Stream fishing, especially for various trout species, is immensely popular. Hunters find waterfowl or other game along perennial and ephemeral stream reaches and at wetland sites. Those interested in wildlife observation also find streams and wetlands to be rich hunting grounds. River canyons and gorges are favorite destinations and travel ways of hikers and backpackers, and stream and wetland sites accessible by vehicle are frequented by day-users and car campers. Ephemeral stream channels are often choice routes for off-highway-vehicle drivers.

The value of Arizona's streams and wetlands for recreation is of increasing importance. Also increasing is the competition stream and wetland recreationists will encounter for the use of these resources in the face of various economic interests. The success of the state in providing for adequate opportunities for stream- and wetland-based recreation will depend on a thorough recognition and protection of the social and economic values of these resource uses. This chapter reports on stream- and wetland-based recreation activities in the state and their economic significance. Additionally, the environmental impacts that may result from recreation are reviewed.

Boating and Floating

Boating is one of the more popular outdoor recreation activities in Arizona. The state offers two kinds of stream boating experiences: whitewater boating and quiet-water boating.

Whitewater Boating

Whitewater boating, which includes the use of rafts, kayaks, whitewater dorries, and canoes to negotiate streams with swift-flowing currents, obstacles and rapids, has become

Figure 5-1
Boating Streams In Arizona
Map Key

Map Number	Stream Segment	Map Number	Stream Segment	Map Number	Stream Segment
1	Colorado River - Glen Canyon Dam to Lees Ferry	15	Gila River - US Hwy 666 to Bonita Creek	29	Bill Williams River - Alamo Dam to Lake Havasu
2	Colorado River - Lees Ferry to Diamond Creek	16	Gila River - Ashurst-Hayden Dam to Kelvin	30	Virgin River - Virgin River Gorge
3	Colorado River - Diamond Creek to Lake Mead	17	San Francisco River - Clifton to Gila River	31	Little Colorado River - Below Grand Falls to Above Black Falls
4	Colorado River - Hoover Dam to Willow Beach	18	Verde River - Perkinsville to Clarkdale	32	Chevelon Creek - Woods Canyon Lake to Little Colorado R.
5	Colorado River - Davis Dam to Lake Havasu	19	Verde River - Clarkdale to Camp Verde	33	East Fork of Black River - Diamond Rock to Buffalo Xing
6	Colorado River - Parker Dam to Headgate Dam	20	Verde River - Camp Verde to Beasley Flats	34	Eagle Creek - Along FS Road 217
7	Colorado River - Headgate Dam to Imperial Dam	21	Verde River - Beasely Flats to Childs	35	San Francisco River - Alma, NM to Clifton, AZ
8	Colorado River - Laguna Dam to Morelos Dam	22	Verde River - Childs to Horseshoe Reservoir	36	Little Colorado River - Cameron to Color-ado River, Very Haz.
9	Colorado River - Morelos Dam to International Border	23	Verde River - Horseshoe Dam to Bartlett Reservoir	37	Tonto Creek - Gisela to Rye Creek
10	Salt River - US Hwy 60 to Gleason Flats	24	Verde River - Bartlett Dam to Needle Rock to Salt River	38	East Fork of Black River - Buffalo Xing to Wildcat Point
11	Salt River - Gleason Flats to Horseshoe Bend	25	Wet Beaver Creek-Beaver Ranger Sta-tion to Beaver Creek	39	East Fork of Black River & Black River
12	Salt River - Horseshoe Bend to Diversion Dam Take Out	26	Beaver Creek - Wet Beaver Creek to Verde River	40	Blue River - Blue Crossing to FS Road 475
13	Salt River - Stewert Mountain Dam to Granite Reef Dam	27	Oak Creek - Pump Station Above Sedona to Cornville	41	Gila River - Coolidge Dam to Winkelman
14	Gila River - Virden NM to US Hwy 666	28	Oak Creek - Cornville to Verde River	42	E. Verde R. - US 87 to Verde R. Rugged & Very Hazardous

increasingly popular in recent years. Inflatable rafts and kayaks are the most popular paddle- or oar-powered craft. Commercial dories, whitewater canoes, and motorized rafts are also used in the Grand Canyon and elsewhere. Open canoes and inflatable kayaks are being paddled on other Arizona rivers with increasing frequency. This study has identified forty-two Arizona stream segments that provide whitewater opportunities for individuals of varying levels of boating skills (Tables 5-1 through 5-3).

Statewide, the number of boating registrations has increased from about forty thousand in 1970 to 172,413 in 1987 (Table 5-4) (AGFD undated). This table includes all types of motorized and non-motorized watercraft, most of which are suited only for lake use or use on quiet-water stretches of the lower Colorado River where motorized craft can operate. Approximately twenty thousand of the current boating registrations are for paddle- or oar-powered boats (Carr 1987). Separate license data for paddle- or oar-powered craft was not available for previous years.

With the exception of the Colorado River, the primary river running season in Arizona begins with the onset of snowmelt, usually in late January or February, and extends for most boaters until mid- to late May. Canoes and inflatable kayaks may be used in lower water levels during other times of the year. It is not uncommon to see river runners boating after a summer monsoon or a winter rain. Summarized below are descriptions of whitewater boating opportunities on Arizona rivers.

Colorado River through Grand Canyon

Since 1967, more than a quarter of a million people have taken the most famous whitewater river adventure in the world—the Colorado River through the Grand Canyon (Table 5-5). Private trips are so popular on this river that an individual often must wait several years to acquire a private permit. The National Park Service issues permits year-round for this river trip which is most popular between the months of April and October. The growth in technology of dry suits and other cold weather river running gear in the last several years may, however, contribute to an increase in boating participation during the colder seasons which, until recently, was minimal.

River running through the Grand Canyon (Lees Ferry to Diamond Creek) exploded in popularity from 1965 to 1972 when annual participation in river trips jumped from 547 to 16,432 persons (Table 5-5). The Park Service halted further increases by imposing a use ceiling of about twenty thousand persons annually. The ceiling and other use restrictions were necessary to maintain the quality of the Grand Canyon environment and the river running experience.

Use of the 17.8 miles of the Colorado River between Glen Canyon Dam and Lees Ferry has also soared over the last fifteen years from very limited numbers to over thirty-four thousand persons per year (Brickler and Tunnicliff 1980). Much of this use can be attributed to one-day tourist raft trips and to a blue ribbon trout fishery. Power boats are used on this segment of the river.

The Colorado River segment from Diamond Creek to Lake Mead is also experiencing increased use, although specific use figures are unavailable. This segment is popular with jet boaters from Lake Mead and river runners starting from Diamond Creek or continuing downstream from the Grand Canyon. The Diamond Creek put-in is accessible via the Hualapai Reservation.

Table 5-1.
Boating Streams In Arizona
(Established Streams)

STREAM SEGMENT	SEGMENT CHARACTERISTICS: River Basin*	Segment Length (miles)	Regulated, Unregulated or Diverted Flows	Boating Season (YR = Year Round)	Type of Boating (WW = Whitewater)	Fee / Permit Required	Hazards / Comments	Management agency**
Colorado River - Glen Canyon Dam to Lees Ferry	CR	15	R	YR	Rafts & Power Boats	No	Swift Currents Cold Water Sandbars	Glen Canyon NRA
Colorado River - Lees Ferry to Diamond Creek	CR	225	R	YR	Rafts, Motorized Rafts, & Kayaks	Yes - NPS	Swift Currents Cold Water Rapids	Grand Canyon National Park
Colorado River - Diamond Creek to Lake Mead	CR	15 R	R	YR	Rafts, Motorized Rafts, & Kayaks	No	Swift Currents Cold Water & Rapids in River	Grand Canyon National Park & Lake Mead NRA
Colorado River - Hoover Dam to Willow Beach	CR	101	R	YR	Canoes & Power Boats	Yes - Lake Mead NRA & BOR	Currents, Cold Water & Power Boat Wakes	Lake Mead NRA
Colorado River - Davis Dam to Lake Havasu	CR	54	R	YR	Canoes & Power Boats	No	Currents, Cold Water & Power Boat Wakes	Fort Mohave IR, Havasu NWR & Yuma District BLM
Colorado River - Parker Dam to Headgate Dam	CR	15	R	YR	Canoes & Power Boats	No	Currents, Cold Water & Power Boat Wakes	Yuma District BLM
Colorado River - Headgate Dam to Imperial Dam	CR	131	R	YR	Canoes & Power Boats	No	Currents, Cold Water & Power Boat Wakes	Yuma BLM, Color. River IR, Cibola & Imperial NWRs
Colorado River - Laguna Dam to Morelos Dam	CR	21	R	YR	Canoes & Power Boats	No	Currents, Cold Water & Power Boat Wakes	Yuma District BLM
Colorado River - Morelos Dam to International Border	CR	22	R	YR	Canoes & Power Boats	No	Currents, Cold Water & Power Boat Wakes	Yuma District BLM
Salt River - US Hwy 60 to Gleason Flats	SR	19	UR	Jan - May & Other	Kayaks, Rafts, WW Canoes & Inflatable Kayaks	Yes - Fort Apache Tribe	Rocks & Rapids	Fort Apache & San Carlos Apache IRs & Tonto NF
Salt River - Gleason Flats to Horseshoe Bend	SR	19	UR	Jan - May & Other	Kayaks, Rafts, WW Canoes & Inflatable Kayaks	Yes - Fort Apache Tribe	Rocks, Rapids & Quartzite Falls	Fort Apache IR & Tonto NF
Salt River - Horseshoe Bend to Diversion Dam Take Out	SR	14	UR	Jan - May & Other	Kayaks, Rafts, WW Canoes & Inflatable Kayaks	No	Rocks, Rapids & Diversion Dam at Take O	Tonto NF

* BW = Bill Williams River Basin CR = Colorado River Basin LC = Little Colorado River Basin SR = Salt River Basin UG = Upper Gila River Basin VR = Verde River Basin

** BLM = Bureau of Land Management IR = Indian Reservation NF = National Forest NRA = National Recreation Area NWR = National Wildlife Refuge

Table 5-1 (Continued)
Boating Streams In Arizona
(Established Streams)

STREAM SEGMENT	River Basin*	Segment Length (miles)	Regulated, Unregulated or Diverted Flows	Boating Season (YR = Year Round)	Type of Boating (WW = Whitewater)	Fee / Permit Required	Hazards / Comments	Management agency**
Salt River - Stewert Mountain Dam to Granite Reef Dam	SR	12	R	May-Sept.	Canoes, Kayaks Occasionally, Tubing Mostly	No	Crowding & Reckless Behavior	Tonto NF
Gila River - Virden NM to US Hwy 666	UG	30	UR	Feb-April	Kayaks, Small Rafts & WW Canoes	No	Barbed Wire & Strainers	Safford District BLM
Gila River - US Hwy 666 to Bonita Creek	UG	23	UR	Feb-April	Kayaks, Small Rafts & WW Canoes	No	Usually an Easy Novice WW Run	Safford District BLM
Gila River - Ashurst-Hayden Dam to Kelvin	UG	15	R	Vari-able	Small Rafts & Canoes	No	Easy Float	Phoenix District BLM
San Francisco River - Clifton to Gila River	UG	10	UR	Feb-April	Kayaks, Small Rafts & WW Canoes	No	Usually an Easy Novice WW Run	Safford District BLM
Verde River - Perkinsville to Clarkdale	VR	18	UR	Feb-April	Kayaks & WW Canoes	No	Barbed Wire, Rocks, Logs & Diversion Dams	Prescott NF
Verde River - Clarkdale to Camp Verde	VR	28	UR	Feb-April	Kayaks & WW Canoes	No	Barbed Wire, Rocks, Logs & Gravel Pit	Prescott NF
Verde River - Camp Verde to Beasley Flats	VR	8	UR	YR Vari-able	Kayaks, Small Rafts, Tubing & WW Canoes	No	Rocks, Periodic Low Flows	Prescott NF
Verde River - Beasely Flats to Childs	VR	18	UR	YR Vari-able	Kayaks, Small Rafts & WW Canoes	No	Rocks, Rapids, Periodic Low Flows	Prescott NF & Coconino NF -- Scenic Designation
Verde River - Childs to Horseshoe Reservoir	VR	41	UR	YR Vari-able	Kayaks, Small Rafts & WW Canoes	No	Rocks, Rapids, Periodic Low Flows	Coconino NF & Tonto NF -- Wild Designation
Verde River - Horseshoe Dam to Bartlett Reservoir	VR	14	R	Vari-able	Kayaks & WW Canoes	No	Rocks & Low Flows	Tonto NF
Verde River - Bartlett Dam to Needle Rock to Salt River	VR	4.5 18	R	Vari-able	Kayaks, Small Rafts & WW Canoes	No	Rocks & Low Flows	Tonto NF & Fort McDowell IR

* BW = Bill Williams River Basin CR = Colorado River Basin LC = Little Colorado River Basin SR = Salt River Basin UG = Upper Gila River Basin VR = Verde River Basin

** BLM = Bureau of Land Management IR = Indian Reservation NF = National Forest NRA = National Recreation Area NWR = National Wildlife Refuge

Table 5-2
Boating Streams In Arizona
(Limited Opportunity Streams)

STREAM SEGMENT	River Basin*	Segment Length (miles)	Regulated, Unregulated or Diverted Flows	Boating Season (YR = Year Round)	Type of Boating (WW = Whitewater)	Fee / Permit Required	Hazards / Comments	Management agency**
	SEGMENT CHARACTERISTICS							
Wet Beaver Creek-Beaver Ranger Station to Beaver Creek	VR	9	UR	Feb-April Other	WW Canoes & Kayaks	No	Rocks, Low Flows & Strainers	Coconino NF
Beaver Creek - Wet Beaver Creek to Verde River	VR	9	UR	Feb-April Other	WW Canoes, Kayaks & Tubing	No	Rocks & Low Flows	Coconino NF
Oak Creek - Pump Station Above Sedona to Cornville	VR	27	UR	Feb-April Other	WW Canoes	No	Rocks, Low Flows, Drops & Strainers	Coconino NF
Oak Creek - Cornville to Verde River	VR	8	UR	YR Variable	WW Canoes, Kayaks & Canoes	No	Rocks & Log Jams	Coconino NF
Bill Williams River - Alamo Dam to Lake Havasu	BW	36	R	Variable & Seldom	WW Canoes & Kayaks	No - Private Put-in & Take-out	Trees, Strainers & Barbed Wire	Army Corps Engineers & Yuma & Phoenix BLM
Virgin River - Virgin River Gorge	VIR	11	UR D	March April	Kayaks, WW Rafts & WW Canoes	No	Low Flows & Rocks	Arizona Strip District BLM
Little Colorado River - Below Grand Falls to Above Black Falls	LC	16	UR	March-April Other	Kayaks, Small WW Rafts & WW Canoes	Yes - Navajo IR	Muddy Water	Navajo IR
Chevelon Creek - Woods Canyon Lake to Little Colorado R.	LC	75	UR	Feb-March	Kayaks & WW Canoes	No	Cold, Low Flows & Fences	Apache-Sitgreaves NF
East Fork of Black River - Diamond Rock to Buffalo Xing	SR	6	UR	March-April	Kayaks & WW Canoes	No	Cold, Low Flows & Fences	Apache-Sitgreaves NF
Eagle Creek - Along FS Road 217	UG	12	UR	March-April	Kayaks & WW Canoes	No	Cold, Low Flows & Fences	Apache-Sitgreaves NF
San Francisco River - Alma, NM to Clifton, AZ	UG	30	UR	Feb-14 Mar?	Kayaks & WW Canoes	Yes - Gila NF. Closed 3/15 - 7/15	Cold, Low Flows & Fences	Gila NF - Closed for Black Hawk Nesting 3/15 - 7/15

* BW = Bill Williams River Basin CR = Colorado River Basin LC = Little Colorado River Basin SR = Salt River Basin UG = Upper Gila River Basin VR = Verde River Basin VIR = Virgin River Basin

** BLM = Bureau of Land Management IR = Indian Reservation NF = National Forest NRA = National Recreation Area NWR = National Wildlife Refuge

Table 5-3
Boating Streams In Arizona
(Hazardous And Limited Opportunity Streams)

STREAM SEGMENT	River Basin*	Segment Length (miles)	Regulated or Unregulated Flows	Boating Season (YR = Year Round)	Type of Boating (WW = Whitewater)	Fee / Permit Required	Hazards / Comments	Management agency**
Little Colorado River - Cameron to Colorado River, Very Haz.	LC	51	UR	Flood Stage	Expert Kayak Only	Yes - Navajo & Grand Canyon NP	Very Steep Gradient & Flash Floods	Navajo IR & Grand Canyon NP., May Not Be Sanctioned
Tonto Creek - Gisela to Rye Creek	SR	9	UR	Flood Stage	Expert Kayak Only	Yes - Tonto NF - Closed 1/1 to 6/30	Narrow, Wire, Few Eddies & Flash Floods	Tonto NF - Closed from 1/1 to 6/30
East Fork of Black River - Buffalo Xing to Wildcat Point	SR	12	UR	Feb-April	Expert Kayak & Rafts Only	No	Very Steep Gradient, Fences & Strainers	Apache-Sitgreaves Nf
East Fork of Black River & Black River	SR	90	UR	Feb-April	Expert Kayak Only for Most, Raft for Some	Yes - San Carlos & Ft Apache IRs	Variable - Steep Drops, Jams, Strainers	San Carlos & Fort Apache IRs, May Not Be Sanctioned
Blue River - Blue Crossing to FS Road 475	UG	34	UR	Feb-April	Expert Kayak & WW Canoe Only	No	Very Steep, Narrow, Floods & Strainers	Apache-Sitgreaves Nf
Gila River - Coolidge Dam to Winkelman	UG	28	R	Variable	Not Recommended Due to Dense Trees	No	Dense Trees & Twisting Channel -- Strainers	Safford District BLM
E. Verde R. - US 87 to Verde R. Rugged & Very Hazardous	VR	34	UR	Flood Stage	Expert Kayak Only - Isolated & 1 mi Portage	No	Very Steep!, Narrow, Floods Strainers	Tonto NF

* BW = Bill Williams River Basin CR = Colorado River Basin LC = Little Colorado River Basin SR = Salt River Basin UG = Upper Gila River Basin VR = Verde River Basin

** BLM = Bureau of Land Management IR = Indian Reservation NF = National Forest NRA = National Recreation Area NWR = National Wildlife Refuge

Salt River

While not as well known as the Colorado River, the segment of the Salt River from U.S. Highway 60 to the diversion dam just upstream of Roosevelt Lake has become very popular with river runners in Arizona and other western states. Every year, an increasing number of private boaters and commercial passengers experience the Salt River's whitewater and magnificent canyons. Increased popularity is probably inspired in part by recent publicity such as a magazine article in River Runner (Chiras 1987) and a citation in a southwestern river guide book (Anderson and Hopkinson 1987). Both sources promote the Salt River as an exceptional desert whitewater trip.

Table 5-4
Watercraft Registrations, 1973-1986

Year	Registered*	New	Renewal
1959-62	20,866	no data	no data
1962-65	26,876	no data	no data
1965-67	32,000	no data	no data
1968	31,193	no data	no data
1969	40,081	no data	no data
1970	45,390	no data	no data
1971	49,779	no data	no data
1972	55,749	no data	no data
1973	62,935	11,451	47,718
1974	68,649	11,061	56,035
1975	73,045	9,982	63,521
1976	77,214	10,157	67,128
1977	80,806	10,267	70,983
1978	86,018	11,222	75,251
1979	91,730	11,425	80,753
1980	95,839	10,374	85,889
1981	101,392	10,645	90,746
1982	103,844	9,995	93,849
1983	107,333	10,539	96,794
1984	112,707	11,942	100,765
1984-85**	110,618	9,228	101,390
1985-86**	119,990	13,655	106,335
Average:			
1972-76	67,518	10,663(73-76)	58,601(73-76)
1977-81	91,157	10,787	80,724
1982-86	110,898	11,072	99,827

* This figure includes new, renewals, transfers duplicates and changed licenses.
** Fiscal year accounting began in 1984.

Source: Arizona Game and Fish Department.

In the early 1970s, only a few individuals boated the Salt, but now hundreds of boaters can be counted at the put-in on sunny springtime weekends. Because there are several access points to the river, the river segment may be traveled as a multi-day, day, or half-day trip, allowing great flexibility to the river runner. Much of the dramatic rise in participation from out-of-state boaters and commercial outfitters is also due to the fact that the Salt and Verde Rivers flow at acceptable river-running levels and are accessible much earlier because they are not snow-bound (the season typically begins in mid-winter) like the major rivers in other states whose river-running seasons typically begin in May.

Table 5-5
Travel On The Colorado River Through Grand Canyon
1867-1987

Year	People	Year	People	
1867	1	1963-64	44	
1869-1940	73	1965	547	
1941	4	1966	1,067	
1942	8	1967	2,099	
1943	0	1968	3,609	
1944	0	1969	6,019	
1945	0	1970	9,935	
1946	0	1971	10,385	
1947	4	1972	16,432	
1948	6	1973	15,219	
1949	12	1974	14,253	
1950	7	1975	14,305	
1951	29	1976	13,912	
1952	19	1977	11,830	
1953	31	1978	14,356	
1954	21	1979	13,228	
1955	70	1980	no data	
1956	55	1981*	14,672	2,366
1957	135	1982*	15,014	1,935
1958	80	1983*	13,205	2,238
1959	120	1984*	13,628	2,324
1960	205	1985*	15,573	2,540
1961	255	1986*	18,484	2,684
1962	372	1987*	17,964	2,730

*Participation data for the years 1981 to 1987 was divided into commercial (left column) and private (right column) users.

Sources: Brickler and Tunnicliff 1980 and Grand Canyon National Park.

The White Mountain Apache Tribe, which issues permits for this segment of the Salt River, reports that river use has increased approximately fifty percent annually during the last few years (Caid 1988). In 1987, the segment of the Salt River permitted by the Tribe saw 2,453 user days (more specific data are not available due to the ongoing general stream adjudications). Existing data from the Forest Service is too incomplete to support in any meaningful analysis of river use.

However, the increased use and resulting impacts prompted the Tonto National Forest to recently issue an Implementation Plan proposing new regulations for the above-mentioned segment of the river (Tonto National Forest 1985).

The Forest Service has established a fairly complex commercial allocation schedule to reflect the various joint and exclusive jurisdictions of the Forest Service and the

White Mountain and San Carlos Apache Tribes. The Forest Service allows up to 2690 annual commercial service days through the wilderness portion of the river corridor and over thirty thousand service days upstream of this segment (the previous commercial limit was eight hundred service days). The Indian Tribes are not bound by this figure for the segments upstream off exclusively Forest Service Service land for which they have joint or exclusive jurisdiction. The Forest Service has not placed any limits on private river trips at this time.

There is one other segment of the Salt River which is increasingly being used by kayakers and canoers as a leisurely, though extremely crowded, mid-summer day trip. The segment between Stewart Mountain Dam and Granite Reef diversion dam (commonly thought of as the "tubers" run) has flowing quiet-water throughout most of the summer.

Verde River

Like the Salt River, the Verde River has also seen tremendous growth in boating use. A forty-mile segment of the Verde River from below Camp Verde to the confluence with Red Creek, is Arizona's only designated National Wild & Scenic River. The Camp Verde Chamber of Commerce receives phone calls from boaters all over the United States interested in boating Arizona's Wild & Scenic River (Nash 1988). To encourage this trend the town Chamber of Commerce has established a volunteer shuttle-driving service. A few outfitters offer commercial trips on the "Scenic" and Bartlett Dam segments of the river.

The Wild & Scenic River segment of the Verde River is only one of many segments with boating use. Some Arizona boaters also use segments upstream of Camp Verde. The upper segments of the river are especially popular with canoers. The Verde River's first canoe race was held in 1987 (Slingluff 1988). The Verde River segment from Childs to Horseshoe Dam is used by whitewater boaters who wish to extend their river trips into multi-day excursions. A fourth quiet-water river-running segment is located between Bartlett Dam and Needle Rock.

Gila River

There are several segments of the Gila River that, although hazardous because of barbed wire, overhanging trees, and submerged and semi-submerged debris, are nonetheless traveled by whitewater enthusiasts. The "Gila Box" segment extends from about four miles upstream of the San Francisco River confluence downstream to the confluence with Bonita Creek. Approximately five hundred people boated the Gila Box between February and May of 1986 (Knox 1988). Some people also boat the Gila River downstream of Coolidge Dam, and this segment is also noted for severe hazards; particularly, submerged logs and overhanging trees. The BLM vigorously recommends that no boating or floating should occur on this dangerous segment, as there have been several drownings.

Virgin River

The only other river in Arizona for which there is any river running participation data is the Virgin River in the extreme northwest corner of the state. Flowing alongside one of the most expensive and most scenic stretches of highway in the country and separating the Beaver Dam and Paiute Wilderness Areas, the Virgin River is boated by an estimated 160 to 420 persons during a four to six week spring runoff period in April and May (BLM Arizona Strip District 1986).

Other Arizona Rivers

Several other rivers, streams, and ephemeral washes in Arizona are floated seasonally, or during or immediately following the summer monsoons (Tables 5-2 and 5-3). In either case, timing is essential, as they may only be runable for a period ranging from a few hours to a few weeks. Some of these rivers, such as the East Verde, are very difficult and dangerous and are attempted by only the most experienced kayakers. Still others, like the Black River and the Little Colorado River, are located partially or wholly on Indian Reservations, and their use is not sanctioned by the tribes. The San Francisco River and Tonto Creek offer boating opportunities but are closed during the prime boating season to protect endangered species and other sensitive wildlife. Streams like Wet Beaver Creek, Beaver Creek, and Oak Creek,with very low flows, are boated principally with canoes.

Quiet-water Boating

Quiet-water boating is any type of boating that occurs in streams and rivers without rapids and other navigation obstacles. Canoes and inner tubes are two common types of quiet-water "boats." Power boats also use the quiet water stretches of the lower Colorado River between the reservoirs.

Canoeing

Canoeing is reported to be the second fastest growing participation sport in America (Harrison 1988). Nationally, an increase of fifty-seven percent in participation was observed between 1980 and 1986 (compared to a seventeen percent increase between 1966 and 1980). In 1986, nineteen million Americans canoed.

Though on a much smaller scale, a similar trend in canoeing participation is occurring in Arizona. At least three reasons have been postulated for the Arizona increase (Slingluff 1988). First, canoes are well adapted to the low stream water levels common in the drier months of the year, and are therefore used by many river runners to lengthen the boating season to a year-round sport. Second, the average person can canoe quiet-water rivers like the upper Verde, the lower Salt, and the lower Colorado Rivers with relatively little investment and minimal skill levels. In the Verde River valley, local residents have been canoeing the upper Verde River for years. Finally, the influx of people into Arizona from the Midwest and eastern United States, where open-boat canoeing is very popular, is also increasing statewide participation levels.

Canoeing is very popular on the remaining river segments of the lower Colorado River below Hoover Dam all the way to Yuma. This segment includes Lake Mead National Recreation Area and the Havasu, Cibola, and Imperial Wildlife Refuges, and receives very intensive general use with 3.5 million visitor days recorded in 1985 (EDAW Inc. 1986). The annual rates of increase in visitor days for recreation activities in various segments of this area have varied from a few percent to as high as sixty-eight percent and have averaged about fifteen percent. In 1986, eighteen thousand canoers (of 140 thousand boaters) were counted on the Colorado River at the Imperial Refuge (Table 5-6) (Vaniman 1988). Numerous canoe liveries are located on both sides of the river and collectively have a rental inventory of more than one thousand canoes (Doiron 1988). Canoe renters are joined by many private groups and individuals who own their own boats as well.

Two of the most popular canoe stretches on the lower Colorado, the Black Canyon and

Table 5-6
Participation In Boating, Fishing And Hunting On The Lower Colorado River, 1978-1987
(Cibola, Havasu And Imperial National Wildlife Refuges)

CIBOLA

Fiscal Year	Boating	Fishing	Hunting**
1976	1,290	6,570	480
1977	1,915	5,825	630
1978	4,420	3,375	1,535
1979	4,035	3,700	2,110
1980	15,300	8,775	3,834
1981	20,500	12,640	4,175
1982	69,900	10,580	15,010
1983*	9,900	10,015	2,824
1984	8,360	8,860	1,910
1985	8,798	11,050	2,655
1986	8,495	12,670	2,525
1987	35,675	13,050	1,930

HAVASU

Fiscal Year	Boating	Fishing	Hunting
1978	10,025	56,755	707
1979	NA	NA	NA
1980	241,215	90,230	3,087
1981	266,897	112,825	3,405
1982	233,575	102,450	3,042
1983*	88,085	92,000	2,280
1984	102,900	91,250	2,440
1985	299,250	125,850	1,835
1986	300,550	127,100	1,790

IMPERIAL

Fiscal Year	Boating	Fishing	Hunting
1978	2,446	14,829	530
1979	18,574	8,177	2,810
1980	6,330	6,300	200
1981	7,300	4,400	385
1982	9,930	8,870	1,700
1983*	23,590	12,000	410
1984	23,170	16,000	160
1985	77,914	59,920	244
1986	140,000	298,000	180
1987	132,675	103,000	177

* River closure due to high water levels

** Includes only general waterfowl and migratory birds

Source: Cibola NWR 1988, Havasu NWR 1988, and Imperial NWR 1988.

Topock Gorge segments, are located between Hoover Dam and Lake Havasu. The National Park Service regulates use on the Black Canyon segment of the Lake Mead National Recreation Area to thirty permits per day. There are currently no regulations through the Topock Gorge segment which passes through the Havasu National Wildlife Refuge. The Havasu National Wildlife Refuge estimates that approximately two percent of its boaters canoe, and that almost all of the canoeing occurs within Topock Gorge (Dinkler 1988). On a typical busy weekend during the summer or the holidays, between three hundred and five hundred canoes and six hundred to one thousand people will canoe through these two river segments (Doiron 1988). Resource managers at the Havasu National Wildlife Refuge anticipate additional canoeing in the Topock Gorge this year in response to an article published in the March 1988 issue of Arizona Highways magazine (Bell 1988).

Inner Tube Floating

Inner tube floating or "tubing" is an extremely popular summertime activity in Arizona. The most popular of the state's tubing runs is on the Salt River between Stewart Mountain Dam and the Granite Reef Diversion Dam. Within an hour's drive of metropolitan Phoenix, hundreds of thousands of city dwellers travel to the river every summer to escape the desert's heat. Portions of the Verde River above Camp Verde are also used for tubing, as is the Gila River below Coolidge Dam, despite hazard warnings from the Bureau of Land Management. Several people have drowned on the Gila River segment because of low overhanging trees and submerged logs which can catch and hold a person underwater (Knox 1988). Inner tubing is also popular on the lower Colorado River, and inner tube races are held in Yuma and Parker areas of the river.

Fishing and Hunting

Between 1955 (the year the U.S. Fish & Wildlife Service administered its first National Survey of Fishing and Hunting) and 1980, the number of fishermen in America increased from 20.8 million to 41.9 million (USFWS and BOC 1982). During that same period, the number of hunters increased from 11.8 million to 16.8 million. The 1980 survey also indicated that there is considerable overlap in participation; seventy-three percent of hunters also fished, and thirty percent of fishermen also hunted.

The 1980 survey results for Arizona showed that fourteen percent of the population fished, three percent hunted, and twenty-three percent fished or hunted. The 1985 National Survey cited a 3.4 percent increase in the number of licensed and non-licensed Arizona anglers (519 thousand people) and a 6.3 percent increase in licensed and non-licensed hunters (235 thousand people) (USFWS 1987). The vast majority of fishermen and hunters are state residents. A 1988 Arizona Game & Fish Department survey reported similar participation trends: 600 thousand Arizona residents hunt or fish, eighteen percent of the state's total population (3.3 million people).

Fishing

The Arizona Game & Fish Department has published a list of 149 rivers and streams that provide sport fisheries in Arizona, and identified another thirty-five streams as having potential for development as sport fisheries (AGFD 1980). These streams are available for public use. Sport fisheries may be separated into three categories based on the physical characteristics (especially temperature) of the stream: cold water, cool water, and warm water. Each stream type offers a unique sport fishing opportunity.

Data obtained from Game & Fish for fishing license and trout stamp purchases indicate that the growth in popularity of fishing is positively correlated with Arizona's increasing population. Fishing license sales to Arizona residents climbed from 114,104 in 1965 to 246,377 in 1985, a 116 percent increase (Table 5-7) (AGFD undated). Non-resident fishing license purchases have remained fairly constant during this same time period, averaging 4,727 purchases per year. The number of resident trout stamp purchases rose from 89,969 in 1965 to 127,663 in 1985, a forty-two percent increase (Table 5-7) (AGFD undated). Non-resident trout stamp purchases increased from 2,537 in 1967 (the first year of record) to 3,170 in 1970. Since that time, there has been a fairly consistent decline, with 627 non-resident trout stamps purchased in 1986. Trout stamps are required to fish for trout; trout are found in cold water streams and some of the larger reservoirs.

Table 5-7
Fishing License And Trout Stamp Purchases, 1965 - 1985

	Resident		Non-resident	
Year	**License**	**Stamp**	**License**	**Stamp**
1966	123,765	102,241	4,643	no data
1967	134,860	107,675	4,718	2,537
1968	142,277	111,116	4,964	2,650
1969	153,897	124,685	5,618	3,003
1970	167,757	134,009	5,892	3,170
1971	153,195	121,854	5,810	3,083
1972	165,810	110,567	5,429	2,264
1973	181,587	114,215	5,393	2,345
1974	181,783	114,272	4,922	1,180
1975	184,999	112,662	4,687	1,703
1976	176,445	107,540	5,037	1,700
1977	168,707	106,616	4,908	1,785
1978	175,507	111,229	5,571	2,036
1979	182,251	106,215	3,406	904
1980	193,608	106,797	3,777	877
1981	200,789	114,791	4,406	1,149
1982	215,761	121,524	4,714	1,314
1983	218,268	119,978	3,599	487
1984	229,423	126,672	3,768	451
1985	246,377	127,663	3,910	409
Average:				
1966-70	144,511	115,945	5,167	2,840 (67-70)
1971-75	173,475	114,714	5,248	2,115
1976-80	179,304	107,679	4,540	1,460
1981-85	222,124	122,126	4,079	762

Source: Arizona Game and Fish Department.

A 1981 Arizona Game & Fish Department Angler Preference survey indicated that seventy-five percent of the fishermen prefer to fish for trout (a cold water fish), and seventy percent prefer to fish for largemouth bass (a warm water fish) (AGFD 1981). Both species live in reservoirs and streams. A 1982 Department survey indicated that approximately sixty-five percent of Arizona anglers fished only in lakes, nine percent fished only in streams, and twenty-six percent fished in lakes and streams (AGFD 1982). It appears that a diversity of fishing environments are desired by Arizona residents.

Cold Water Stream Fisheries

The *cold water streams*, the most predominant of the stream types, are located in the upper elevations of the mountains and below the major dams on the Colorado River (AGFD 1980, 1985). There are 170 cold water streams (1,552 miles of stream excluding the Colorado River), divided into 202 Stream Management Reaches, that are managed primarily as trout fisheries. Over half (139) of these stream segments are located on Forest Service lands, eleven percent (twenty-eight) are on Indian reservations, and nearly twenty-three percent (fifty-eight) are on private lands (Arizona Game & Fish Department 1985). The remaining cold water stream segments are found on National Park Service, State, and Bureau of Land Management lands. One segment is found on a military reservation.

Each year, over 220 thousand licensed trout anglers harvest over three million trout in Arizona's cold water streams. This includes two species of native trout (Arizona and Gila) and several non-native species (such as rainbow, cutthroat, and brook) (AGFD 1985).

The Apache-Sitgreaves National Forest contains the most fishable cold water stream miles (450) of all the national forests in Arizona, and forty-four percent of the state's stream total miles (Apache-Sitgreaves National Forest undated). In 1977, this national forest ranked fifth when compared with all the nation's national forests in Recreational Visitor Days for cold water game fishing; tenth for total angling; and was the only national forest in the Southwest Region represented in the top ten of either of these categories.

Arizona's only blue ribbon cold water trout stream, defined as a fishery "providing the opportunity to catch trout that are larger than the average size provided by other management concepts" (AGFD 1985), is a 17.8-mile segment of the Colorado River, between Lees Ferry and Glen Canyon Dam. Fishing licenses issued exclusively for this area have expanded by twenty-two percent over fourteen years (Brickler and Tunnicliff 1980).

Cool Water Stream Fisheries

The second sport fishery type, *cool water streams* , is found in Arizona in only five tributaries to the Verde River: the lower reach of Wet Beaver Creek, Dry Beaver Creek, Fossil Creek, the lower reach of Oak Creek, and Sycamore Creek (AGFD 1980). These stream segments are located on Coconino National Forest Lands. Cool water fisheries are noted for smallmouth bass.

Warm Water Stream Fisheries

The *warm water streams* are located in the lower elevations of the mountains and in the dam-regulated segments of the Salt, Verde, Gila, Bill Williams, and lower Colorado Rivers (AGFD 1980). The majority of warm water fishing takes places in the reservoirs. Data from the National Wildlife Refuges located along the lower Colorado River indicate that warm water fishing participation has increased considerably during the last ten years (Table 5-6) (Cibola NWR undated, Havasu NWR undated, Imperial NWR undated). In 1987, nearly a quarter million anglers fished at the Imperial, Havasu, and Cibola NWRs. Warm water fisheries are noted for largemouth bass and catfish.

Hunting

With the exception of waterfowl hunting, it is difficult to directly correlate hunting activities specifically with the presence of streams and wetlands. A convincing argument can be made, however, that without streams and wetlands much of Arizona's wildlife would not survive. In fact, sixty percent of Southwest vertebrates depend directly on riparian areas, and another ten to twenty percent are indirectly dependent on these areas (Ohmart and Anderson 1986).

Arizona resident hunting license sales between 1965 and 1985 have fluctuated between 74,808 (1972) and 94,640 (1985), with a general increase in purchases since 1977 (Table 5-8) (AGFD undated). The data indicate that the total number of purchases by residents is strongly influenced by the cost of the license. Annual license purchases by non-residents has remained fairly constant during that twenty-year period, averaging 8,381 per year. Non-resident license purchases are less influenced by license cost, but the total annual number of purchases has generally decreased since peaking at 10,921 in 1978. Two price increases have been enacted since that time. Combined license purchases for both hunting and fishing show similar trends (Table 5-8). Combined license purchases by Arizona residents generally increased between 1965 (39,542) and 1980 (108,869), and have remained relatively stable since 1982. Non-resident purchases of the combined license have generally decreased.

<u>Waterfowl Hunting</u>

Waterfowl hunting in Arizona is directly associated with the occurrence of surface water in natural wetlands, reservoirs, and stock tanks (Smith 1988). Natural wetlands provide the optimum waterfowl habitat and nesting conditions (Brown 1985). Federal duck stamp purchases provide an indication of the level of interest in waterfowl hunting in Arizona. Duck stamps are required to hunt most waterfowl and are purchased by nearly all waterfowl hunters. As of 1987, waterfowl hunters have also had to purchase a state duck stamp. Annual federal stamp purchases rose between 1965 (7,859) and 1971 (15,465), and have since decreased by approximately one thousand hunters every five years (Table 5-8) (AGFD 1988). Stamp collectors and conservationists annually purchase between two and six percent of the total stamps sold.

Several factors may account for the decrease in duck stamp purchases (Smith 1988). First, there have been a few price increases in the cost of the stamp during the last three decades. Second, more restrictive hunting regulations were imposed in the 1980s. Third, the waterfowl population is declining in Arizona and the Pacific Flyway as a whole. The number of waterfowl hunters directly correlates with the Pacific Flyway waterfowl populations. Finally, new Arizona residents moving from wetter parts of the nation may not perceive this arid state to be a place for waterfowl hunting.

There is no site-specific data available for waterfowl hunting locations other than data from the Cibola, Havasu, and Imperial

Table 5-8
Hunting And Combined License and Duck Stamp Purchases, 1965 -1985

	Resident		Non-resident		Resident - Non-resident
Year	Hunting	Combined*	Hunting	Combined*	Duck Stamp
1965	86,298	39,542	5,727	844	7,859
1966	88,947	42,477	7,056	1,082	8,773
1967	90,972	47,750	8,519	1,259	10,281
1968	93,094	51,259	10,349	1,451	10,196
1969	96,778	58,179	11,205	1,772	12,745
1970	97,045	66,344	11,006	1,773	14,199
1971	76,453	65,919	9,982	1,781	15,465
1972	74,808	64,737	6,477	385	11,952
1973	85,637	73,772	7,421	349	11,059
1974	83,598	81,850	7,160	323	13,474
1975	81,477	89,493	7,351	350	11,924
1976	80,463	94,762	9,060	478	12,642
1977	80,038	95,893	10,164	469	10,566
1978	80,339	99,126	10,921	436	11,735
1979	83,437	106,139	9,,926	181	11,211
1980	84,749	108,869	8,856	181	11,580
1981	87,126	104,498	8,953	212	9,166
1982	86,803	94,824	8,316	201	11,711
1983	87,367	93,560	5,665	143	10,800
1984	89,836	95,034	5,794	174	10,877
1985	94,640	93,836	6,093	175	10,250
1986	94,459	93,505	6,786	181	10,561
Average:					
1967-1971	90,868	57,890	10,212	1,607	12,577
1972-1976	81,197	80,923	7,494	377	12,212
1977-1981	83,138	102,905	9,764	296	10,852
1982-1986	90,621	94,152	6,531	175	10,840

* Combined licenses include fishing and hunting.

** Philatelic sales accounted for approximately 2-3 % of purchases prior to 1985, and were 6.25 % of sales in 1985 and 6.27 % of sales in 1986.

Source: Arizona Game and Fish Department.

National Wildlife Refuges located on the lower Colorado River (Table 5-6). The number of waterfowl hunters using the Cibola Refuge increased from 480 in 1976 to 15,010 in 1982, but since the river closure in 1983, the Cibola Refuge has averaged 2,369 hunters per year. Total hunting participation on the Havasu Refuge appears to be decreasing in popularity since the early 1980s. The majority of hunting on the Havasu Refuge is directed towards waterfowl (Dinkler 1988). Data from the Imperial Refuge indicate that total hunting participation has generally decreased or leveled since 1978. Waterfowl hunting accounts for approximately thirty to forty percent of total hunting participation on the Imperial Refuge (Vaniman 1988).

Waterfowl hunting on the national forests is concentrated around lakes, the ends of reservoirs, and stocktanks (Wadleigh 1988). The amount of use, estimated in terms of Wildlife and Fish User Days (WFUDs) per year, and the types of water associated with WFUDs varies with the individual forests. The Apache-Sitgreaves National Forest has estimated ten thousand WFUDs per year. Pintail Lake is the most popular waterfowl hunting location on this Forest. Most of the remaining hunting is by jumpshooting stocktanks. The Coconino National Forest also reports approximately ten thousand WFUDs per year. Sixty to seventy percent of waterfowl hunting on that forest occurs in the Anderson Mesa Lakes, at Mormon Lake, and at Upper and Lower Lake Mary. The Prescott National Forest has an estimated 3,600 WFUDs per year. About one-half of the use occurs on the Verde River, and the remainder is concentrated around stocktanks. The Kaibab National Forest reports approximately eight hundred WFUDs per year, and the majority of waterfowl hunting occurs around Smoot, Sunflower, Coleman, Sholtz, and Davenport Lakes. There are no WFUD estimates available for the Tonto National Forest. Most of the waterfowl hunting on this forest occurs on the ends of the reservoirs, particularly Roosevelt and Bartlett Lakes, and along the Verde and Salt Rivers. Waterfowl hunting on the Coronado National Forest is relatively light and concentrated mostly around stocktanks. Bog Hole, Cloverdale, and Redington Pass and Oracle are some of the more heavily used hunting areas.

Other Recreation Activities

Nonconsumptive fish- and wildlife-related recreation is increasingly popular in the United States and in Arizona. Like hunting and fishing, nonconsumptive fish and wildlife recreation is dependent, in many cases, on the presence of riparian areas; nature observers, hikers, picnickers, and campers seeking wildlife contact are more apt to find it near streams and wetlands. Between 1980 and 1985, the number of Arizonans participating in nonconsumptive wildlife recreation rose from 1,776,000 to 1,933,000 (AGFD 1988). As such, nearly eighty percent of the state's residents participate in hunting, fishing, wildlife observation and photography, camping, hiking, boating, or other wildlife-related activities.

The 1980 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation stated that fifty-four percent of residents of the "Mountain Region" participated in nonconsumptive activities, far exceeding participation in hunting (fifteen percent) or fishing (twenty-nine percent) (USFWS and BOC 1982). The Mountain Region includes Arizona, New Mexico, Colorado, Utah, Nevada, Idaho, Wyoming, and Montana. Sixty-six percent of fishermen and sixty-two percent of hunters also participated in non-consumptive wildlife recreation. Two types of nonconsumptive activities were defined in the

1980 survey that could show some relation to stream and wetland visitor participation trends.

The first category of nonconsumptive activities, primary nonresidential, refers to trips of at least one mile for the primary purpose of observing, photographing, or feeding wildlife (excluding trips to zoos, circuses, aquariums, museums, and trips to hunt or fish). In 1980, nearly 28.8 million Americans and 2,125,000 (twenty-five percent) of the Mountain region residents participated in primary nonresidential activities. Figures from the 1985 National Survey indicate a thirty-eight percent increase in primary non-residential participation in Arizona; participants numbered 320,400 in 1980 and 441,000 in 1985 (USFWS 1987).

The second category of nonconsumptive activities, secondary nonresidential, refers to the enjoyment from seeing or hearing wildlife while on a trip or outing of at least one mile that is taken for another purpose (such as camping, hiking, scenic driving, or boating). In 1980, 69.4 million Americans (seventy-nine percent) and 4,290,000 (fifty-one percent) of the Mountain region residents reported enjoying wildlife on trips taken for some purpose other than observing, photographing, or feeding wildlife. The number of Arizona residents participating in secondary non-residential activities increased 7.6 percent between 1980 (1,286,000) and 1985 (1,384,000) (USFWS and BOC 1982, USFWS 1987).

General Visitation to Streams and Wetlands

State Park System

Thirteen of the twenty-five state parks in Arizona contain important streams and riparian areas (Table 5-9) (Thornburg 1988). Visitation to these and other state parks has fluctuated since 1979 (Valley National Bank of Arizona 1984, 1987). Patagonia Lake State Park and Lake Havasu State Park are the two most heavily used parks. The third most popular park, Catalina, contains four perennial streams including Romero Creek. The remaining parks with important riparian areas include: Alamo Lake (Bill Williams, Big Sandy, and Santa Maria Rivers), Boyce Thompson Arboretum (Ash Creek in the Gila River Drainage), Buckskin and Yuma (Colorado River), Dead Horse and the Verde River Greenway (Verde River), Lyman Lake (Little Colorado River), Painted Rocks (lower Gila River), Red Rock (Oak Creek), and Roper Lake (Gila River Drainage).

National Park System

The National Park Service manages eight units which contain hiking trails and camping and other recreational facilities associated with important stream and riparian areas: Canyon De Chelly National Monument (Canyon De Chelly Creek), Glen Canyon National Recreation Area (Colorado River), Grand Canyon National Park (Colorado River and tributaries), Lake Mead National Recreation Area (Colorado River), Montezuma Castle National Monument (a sinkhole, Beaver and Wet Beaver Creek), Organ Pipe National Monument (Quitobaquito Spring), Tuzigoot National Monument (Verde River), and Walnut Canyon (Walnut Canyon Creek riparian area) (Davis 1988). Annual visitation to these areas has generally increased since 1980, as it has for all National Parks and National Monuments in Arizona (Table 5-10) (Valley National Bank of Arizona 1984, 1987).

Backcountry use at Grand Canyon National Park increased between 1985 and 1987 (the

Table 5-9
Visitation To Arizona State Parks, 1979-1986

PARKS WITH IMPORTANT RIPARIAN AREAS †

Park	1979	1980	1981	1982	1983	1984	1985	1986
Alamo Lake	64,541	56,807	54,518	52,250	41,030	42,921	43,857	49,972
Boyce-Thompson	68,780	80,190	84,154	79,752	70,185	54,264	65,718	68,341
Buckskin Mt.	223,135	212,473	176,590	89,605	69,069	54,166	51,237	55,106
Catalina*	no data	no data	no data	no data	61,853	74,801	76,467	101,497
Dead Horse Ranch	15,165	21,745	31,931	25,684	24,204	27,566	28,275	36,736
Lake Havasu	1,060,732	894,997	1,097,231	858,622	1,000,423	875,972	934,908	1,084,460
Lyman Lake	107,899	41,611	28,315	28,914	38,075	20,368	20,148	21,150
Painted Rocks	13,871	17,800	12,049	16,798	33,539	35,930	17,818	16,459
Patagonia Lake	166,503	155,169	150,314	139,912	158,314	138,296	147,624	166,031
Roper Lake	48,610	54,185	58,782	73,652	49,353	29,491	37,766	36,378
Yuma Prison	146,065	141,314	145,073	153,354	150,533	131,727	134,783	132,597
TOTAL	1,915,301	1,676,291	1,838,957	1,518,543	1,696,578	1,485,502	1,558,601	1,768,727
PERCENT CHANGE		- 12.5	+ 9.7	- 17.4	+ 11.7	- 12.4	+ 4.9	+ 13.5

OTHER STATE PARKS **

Park	1979	1980	1981	1982	1983	1984	1985	1986
Fort Verde	22,064	22,816	27,406	29,082	28,238	27,291	21,653	22,960
Jerome	120,677	129,423	135,664	128,504	124,891	107,261	105,453	104,381
Lost Dutchman	94,713	118,221	125,457	48,698	71,861	36,368	37,494	41,467
McFarland	2,370	2,635	2,834	4,470	4,818	4,349	3,803	4,090
Picacho Peak	262,138	182,504	135,657	86,397	162,515	29,730	33,439	32,642
Riordan*	no data	no data	no data	no data	4,252	7,491	6,687	7,558
Tombstone	75,983	59,377	62,275	66,233	74,514	57,194	58,576	57,477
Tubac Presidio	27,391	24,299	26,745	25,835	24,868	20,035	13,309	15,279
TOTAL	605,336	539,275	516,038	389,219	495,957	289,719	280,414	285,854
PERCENT CHANGE		- 10.9	- 4.3	- 24.6	+ 27.4	- 41.6	- 3.2	+ 1.9

* These parks did not open until 1983
† Red Rock State Park and Verde River Greenway are not included in the table because they are not open yet.
** Slide Rock State Park just recently opened and Oracle, Kartchner Caverns and Homolovi Ruins are not open yet.

Sources: Valley National Bank of Arizona 1984 and 1987.

period for which data has been recorded). In 1985, 30,384 people spent an average of 2.5 nights in the backcountry. By 1987, this had risen more than sixteen percent to 35,343 people, who spent an average of 2.2 nights in the Grand Canyon backcountry (Ruan 1988).

Table 5-10
Visitation To National Parks System Areas In Arizona, 1979-1986

PARKS WITH IMPORTANT RIPARIAN AREAS

Area	1979	1980	1981	1982	1983	1984	1985	1986
Canyon de Chelly NM	723,562	624,980	773,326	846,398	872,702	972,354	1,057,601	1,372,546
Glen Canyon NRA	1,733,282	1,646,968	1,820,163	1,864,012	1,975,273	2,052,652	2,160,542	2,484,024
Grand Canyon NP	2,310,434	2,526,179	2,693,194	2,499,801	2,448,539	2,360,767	2,983,436	3,347,872
Lake Mead NRA	6,378,341	5,145,699	5,406,184	5,565,467	6,128,254	6,504,206	7,204,295	8,034,542
Montezuma Castle NM	383,441	415,241	473,407	455,279	480,368	528,883	546,455	642,519
Organ Pipe Cactus NM	134,010	150,687	180,126	154,310	207,466	184,387	177,957	222,288
Tuzigoot NM	71,755	76,327	81,373	82,654	83,369	85,270	92,413	99,132
Walnut Canyon NM	70,585	76,765	83,483	86,905	88,762	94,174	90,501	116,234
TOTAL	11,805,410	10,662,846	11,511,256	11,554,826	12,284,738	12,782,693	14,313,200	16,319,157
PERCENT CHANGE		- 9.7	+ 8.0	+ 3.8	+ 6.3	+ 4.1	+ 12.0	+ 14.0

OTHER NATIONAL PARK AREAS

Area	1979	1980	1981	1982	1983	1984	1985	1986
Casa Grande NM	114,600	111,326	104,886	107,308	121,347	135,804	144,370	163,054
Chiricahua NM	49,484	49,232	51,864	55,058	51,737	59,818	61,680	61,472
Coronado NMem	61,554	43,928	47,825	44,425	34,330	40,305	45,252	55,272
Fort Bowie NHS	5,889	5,108	5,157	5,059	4,923	5,044	5,635	7,364
Hubbell Trading Post NHS	73,461	110,942	166,841	159,640	151,920	149,339	125,057	143,395
Navajo NM	91,045	66,300	79,421	72,490	65,232	53,119	68,962	61,497
Petrified Forest NP	675,183	686,721	751,432	714,319	712,112	718,361	740,259	764,857
Pipe Spring NM	25,066	25,790	30,128	30,799	28,357	28,755	30,235	33,688
Saguaro NM	566,486	611,317	470,598	1,363,753	1,612,843	1,671,641	2,066,750	1,897,573
Sunset Crater NM	318,914	322,270	364,006	358,824	385,327	419,303	422,692	436,645
Tonto NM	69,847	60,328	70,528	68,844	70,039	69,665	73,606	82,784
Tumacacori NM	59,013	54,996	59,422	58,290	57,922	58,260	58,022	60,117
Wupatki NM	191,503	166,898	189,979	190,197	197,469	214,499	198,481	214,482
TOTAL	2,302,045	2,315,156	2,392,087	3,229,006	3,493,558	3,623,913	4,041,001	3,982,200
PERCENT CHANGE		+ 0.57	+ 3.3	+ 35.0	+ 8.2	+ 3.7	+ 11.5	- 1.5

Sources: Valley National Bank of Arizona 1984 and 1987.

NM - National Monument
NMem - National Memorial
NP - National Park
NRA - National Recreation Area

Limited site-specific data was available for one important Park Service riparian area, Quitobaquito Spring, in Organ Pipe National Monument. Two years of data from a traffic counter on the sole access road to Quitobaquito Spring indicate that an average of 6,302 vehicles (an estimated 19,536 people) visited the Spring in 1985 and 1986 (Mikus 1988).

National Forests

There are some visitation data for some National Forest areas with perennial streams that are used primarily for hiking and swimming. In the Coronado National Forest, these include Sabino Canyon, Madera Canyon, and Peña Blanca Lake. In 1984 and 1985, the average number of people purchasing bus tickets for the Sabino Canyon shuttle system was 142,799 (Sabino Canyon Recreation Area, Coronado National Forest 1988). The average number of bus ticket purchases for 1986 and 1987 was 310,906, an increase of nearly 46 percent. Visitation to Madera Canyon between 1976 and 1982 ranged between 12, 924 and 22,700, and averaged 19,354. Between 1983 and 1987, visitation ranged from 38,660 to 43,150, and averaged 41,448 (Nogales Ranger District, Coronado National Forest 1988). This average increase of 114 percent is attributed to the growth of the retirement community of Green Valley. Visitation to Peña Blanca Lake between 1983 and 1987 averaged 21,239. In the Coconino Forest, approximately 2.5 million people visit Oak Creek Canyon (Coconino National Forest) every year (Rose et al 1988).

Bureau of Land Management Riparian Areas

Recreational use has increased in at least two Bureau of Land Management wilderness areas known for backcountry hiking and perennial waters (Table 5-11). Visitation to Aravaipa

Table 5-11
Hiking Participation In Blm Wilderness Areas, 1971-1985
(Aravaipa Canyon And Paria Canyon)

	Aravaipa Canyon		Paria Canyon	
Year	Visitor Days	Visitors	Visitor Days	Visitors
1971	no data	no data	4,977	506
1972	no data	no data	6,534	671
1973	no data	no data	3,474	477
1974	6,232	3,116	6,650	872
1975	5,240	2,620	6,261	821
1976	7,456	3,737	9,496	955
1977	9,620	4,061	9,053	1,051
1978	8,053	3,238	11,528	1,577
1979	7,861	3,301	8,485	907
1980	10,089	3,597	7,574	1,125
1981	12,189	4,215	7,679	1,271
1982	14,072	4,940	8,046	1,302
1983	8,300	2,890	7,904	1,437
1984	5,865	2,091	8,580	1,654
1985	7,980	2,854	10,133	1,967
Average:				
1971-75	5,736 (74-75)	2,868 (74-75)	5,579	669
1976-80	8,616	3,587	9,227	1,123
1981-85	9,681	3,398	8,468	1,526

Sources: Aravaipa Canyon - BLM, Safford District 1987.
Paria Canyon - BLM, Arizona Strip and Cedar City District 1986.

Canyon Wilderness Area nearly doubled between 1976 (7,458 visitor days) and 1982 (14,072 visitor days) (BLM, Safford District 1987). As a result, user limits were imposed to protect the riparian resource and provide a high quality recreational experience. The agency issues permits to up to fifty persons per day in the Canyon, which serves the purpose of controlling use during weekends and other popular vacation times. In another BLM wilderness area, Paria Canyon, use has increased from 506 visitors in 1971 to 1,967 visitors in 1985, a 389 percent increase (BLM, Arizona Strip District 1986). Further use increases in this remote area are expected as a use ceiling has not been imposed. A third and less popular area, the Gila Box of the Gila River, receives approximately one hundred visitors every year (BLM, Safford District 1987).

National Wildlife Refuges

The total number of annual visitors (including hunters, anglers, boaters, and nonconsumptive wildlife users) to the Cibola and Havasu National Wildlife Refuges increased considerably between 1973 and 1982, and decreased slightly at Imperial Refuge (Table 5-12) (Gropper 1988). In 1983, visitation trends at the three refuges altered as a result of the high water levels on the Colorado River. Since that year, visitation at all three refuges has increased.

Table 5-12
Visitation To National Wildlife Refuges On The Lower Colorado River, 1973-1986

Year	Cibola	Havasu	Imperial
1973	7,390	167,545	31,211
1974	5,115	236,495	35,550
1975	8,695	291,863	28,540
1976	10,021	173,748	31,000
1977	13,305	175,477	31,100
1978	17,940	168,186	44,427
1979	20,567	162,239	44,856
1980	54,578	502,458	17,135
1981	76,733	576,585	12,050
1982	76,029	469,814	26,865
1983	45,831	304,125	45,593
1984	36,430	320,452	59,039
1985	36,978	542,991	187,436
1986	45,822	551,501	466,130
Total visitors:	455,434	4,640,479	1,060,932
Average:			
1973-77	8,905	208,425	31,480
1978-82	49,169	375,856	29,066
1984-86*	39,743	471,648	237,535

* High water year (1983) is not included in the averaged data.

Source: Gropper 1988.

The Havasu and Imperial Refuges receive the greatest number of visitors, principally because of the boating opportunities afforded by the Colorado River in these locations (Dinkler 1988). The Cibola Refuge is not as desirable for boating because the Colorado River is channelized and rip-rapped in the vicinity of that refuge. Most of the visitors to the Havasu and Imperial Refuges come from the Los Angeles and San Diego metropolitan areas, respectively (Dinkler 1988).

The average number of visitors to the Cibola Refuge jumped from 8,905 (1973-77) to 49,169 (1978-82), a 452 percent increase. Approximately thirty thousand fewer people visited the Refuge in 1983, but annual visitation has been on the rise since then.

Annual visitation to the Havasu Refuge is considerably higher than at Cibola, but the five-year average increase in visitors between 1973 (208,425) and 1982 (375,856) was not as overwhelming. Still, average visitation during this period increased eighty percent. Over 150 thousand fewer people visited the Havasu Refuge during the high-water year, but average visitation between 1984 and 1986 rose to 471,648, an increase of twenty-five percent over the 1978-82 period.

The Imperial Refuge shows very different visitation trends than the refuges further north. Five-year average annual visitation dropped 7.7 percent between 1973-77 (31,480) and 1978-82 (29,066). Almost twice as many people visited the refuge in 1983 (45,593) than in the previous year (26,865), and visitation has climbed dramatically since then—an average of 237,535 people annually visited Imperial Refuge between 1984 and 1986.

Privately Owned Nature Preserves

The Arizona Nature Conservancy reports that the nature preserves containing Ramsey Creek, Sonoita Creek, and Hassayampa River are the most popular preserves (Krause 1988). Visitation continues to increase in these and other Nature Conservancy preserves. For example, prior to 1985, the year National Geographic magazine wrote an article about Ramsey Canyon, the preserve had only received about fifteen thousand visitors per year. Partly in response to that article and partly as a result of the growth in nearby Sierra Vista, preserve visitation jumped to twenty-five thousand visitors in 1986 and thirty-one thousand visitors in 1987 (Reid 1988). The Nature Conservancy has since put a ban on publicity for Ramsey Canyon and believes that it may approach its annual carrying capacity of thirty-five thousand visitors in 1988. The Hassayampa River Preserve, which opened in November 1987, is already receiving six hundred visitors per week (which could mean an estimated twenty-nine thousand people per year), due in part to its proximity to Phoenix and to a publicity campaign in the Phoenix newspapers.

Slaughter Ranch (near Douglas Arizona), another privately owned preserve operated by the Johnson Historical Museum of the Southwest, attributes its popularity to magazine articles in Arizona Highways (Kaetz 1986) and Sunset (anonymous 1988). The Ranch officially opened in 1986 after four years of restoration work, and an estimated four thousand people per year are visiting the site noted for its colorful history, historic buildings, and riparian areas (Finks 1988). The Ranch is adjacent to the San Bernardino National Wildlife Refuge which is closed to the public, except for privately scheduled group tours, until 1990 (Robertson 1988). Both areas contain perennial thermal springs which feed small ponds supporting two endangered fishes.

All-Terrain Vehicle Driving

All-terrain vehicles, motorcycles, and four-wheel-drive vehicles are increasingly popular (and controversial) recreational vehicles in Arizona. Much of the off-highway use occurs in ephemeral stream corridors, both in urban and rural areas. A recently released survey cited several figures relating to the growth of off-highway vehicle participation (AGFD 1988). An estimated 73,400 motorcycles and all-terrain vehicles are used for off-highway recreation in Arizona. Additionally, about half of the 17,200 new motorcycles purchased in Arizona during 1984 were unregistered (presumably for off-highway use only). Approximately 104,000 four-wheel drive vehicles, which can also be used for off-highway use, are registered in the state. A previous survey, "Forecast Eighty-Six," indicated that more than sixteen percent of the state residents interviewed had been "trail biking or four-wheeling" during the previous six months.

Economic Benefits from Stream and Wetland Recreation

Stream- and wetland-based recreation is an important component of the Arizona tourist industry. Tourism and travel expenditures in Arizona contribute 5.18 billion dollars to the state's income, second only to manufacturing (Valley National Bank of Arizona 1987). Exactly what percentage of this figure is related to stream and wetland recreation is unknown. The following, however, is a summation of the available national and state economic data that are at least related to this concern. Additional economic studies related to the demand for, and benefits derived from, stream and wetland recreation are certainly warranted.

National Economic Trends

In 1980, wildlife-associated recreation contributed forty-one billion dollars per year to the American economy, including expenditures made by hunters, anglers, and nonconsumptive wildlife users (USFWS and BOC 1982). Hunters contributed 8.5 billion dollars; 638 million dollars of this total was related to migratory bird hunting. Fishing expenditures (including salt water and fresh water fishing) totaled seventeen billion dollars. Freshwater fishing expenditures in areas outside of the Great Lakes were estimated to total 2.3 billion dollars. Primary non-residential, nonconsumptive wildlife expenditures totaled four billion dollars, of which 307 million dollars were spent in the Mountain region of the United States.

The 1985 National Survey indicated a considerable increase in expenditures for all of the above-mentioned stream- and wetland-related activities, particularly for nonconsumptive wildlife recreation (USFWS 1987). Total wildlife-associated expenditures expanded by thirty-four percent (fifty-five billion dollars). Of this total, hunters contributed ten billion dollars (a seventeen percent increase), anglers contributed twenty-eight billion dollars (a sixty-five percent increase), and primary non-residential nonconsumptive wildlife expenditures totaled fourteen billion dollars (a 250 percent increase).

State Economic Trends

Between 1980 and 1985, the economic contribution from wildlife-associated recreation grew forty-four percent in Arizona

(AGFD 1988). Arizonans and out-of-state visitors spent 620 million dollars pursuing wildlife interests in 1986, and, following the national trend, the greatest increase was in passive wildlife recreation. Flatwater and flowing water boating expenditures totalled forty-seven million dollars. Off-highway motorcycle sales and service contributed sixty-two million dollars (AGFD 1988). Together, these three recreational expenditure figures total 729 million dollars, approximately fifteen percent of the total tourism and travel expenditures made in 1984 in Arizona. Slightly less than half of this money was for fishing expenditures (326 million dollars), and roughly a quarter of the expenditures were derived from hunting activities (170 million). Nonconsumptive wildlife recreationists contributed 124 million dollars of the total sum.

Although even rough estimates of the specific economic contributions made by recreationists participating in activities commonly associated with streams and wetlands are not available, the above figures provide an indication of the dollar value of activities that may be related to these resources in Arizona. What is important to remember is that national and state trends both indicate that the economic contribution of recreation is increasing significantly, and that this source of economic income is sustainable because it is derived from renewable resources.

Impacts of Recreation on Streams and Wetlands

As the demand for stream and wetland recreation sites and activities continues to increase, primarily as a result of increases in population and urbanization, there will be more impacts to these areas in terms of both social (such as crowding, noise, health hazards, and visual blight) and environmental (such as the degradation of water, soils, vegetation, and fish and wildlife) values.

When assessing the impacts of recreation on streams, wetlands, and riparian areas, it is useful to distinguish between the impacts of land- and water-based activities (Johnson and Carothers 1982). One should also remember that the degree of impact is a function of the cumulative patterns of use and the sensitivity of the resource being used. Specifically, impacts vary according to the: (1) specific visitor use patterns; (2) density of visitor use; (3) time and periodicity of use; (4) presence or absence of management practices mitigating negative impacts; and (5) natural capacity of streams to purge recreation impacts.

Land-based recreation includes activities like nature observation, camping, hiking, picnicking, off-highway vehicle driving, shoreland fishing, and the majority of hunting. These activities are often pursued in riparian areas because these areas offer unique opportunities afforded by the streamside and adjacent land areas. Riparian areas provide such amenities as shade for the camper or picnicker, increased diversity and density of wildlife for the nature observer and hunter, and scenic diversity for all recreational users. With the exception of backpacking, hunting, and other activities in which participants tend to travel and disperse in small groups away from common access points, one would expect physical impacts from land-based recreation to typically occur in relative proximity to access points and be concentrated around developed facilities. Typical social impacts would include crowding, noise, aesthetic and health problems from improper garbage and waste disposal, and crime and vandalism.

The second type of activity, water-based recreation, includes quiet-water and whitewater boating and floating, and fishing and hunting from watercraft. Recreationists pursuing these activities often have a secondary interest in the shoreland riparian area. The flowing or non-flowing surface water is the focal point of activity, used as a source of recreational pleasure and as a medium for travel. As a travel route, streams allow humans to enter wilderness areas and riparian habitats that are generally too remote for all but the most hardy of backpackers and hunters. The beaches and hiking areas chosen for day use or overnight camping by boaters and other water-based recreationists are typically undeveloped and used over and over again. Physical impacts to riparian lands from water-based recreation can therefore be distinguished from land-based recreation in that the impacts occur in undeveloped areas far removed from most access points and as a result of activities that are secondary to the water-based recreation experience (eating lunch on a beach or shoreline, day hiking, or overnight camping).

Social impacts related to water-based recreation would be expected to be a problem in areas where shoreline eating and camping sites are relatively scarce, and in heavily used hiking areas. Social problems related to water-based recreation include: (1) crowding; (2) visual, odor, and health impacts from improper human waste disposal and sanitation practices; and (3) visual impacts associated with other camping practices (fire debris, food, and garbage remnants, and other disturbances which leave a site looking unnatural or heavily used).

The physical impacts of land- and water-based recreation on streams and wetlands are discussed below in terms of the separate impacts to the major components of the riparian environment: water, soils, vegetation, and wildlife. The discussions of the causes and effects of impacts of land- and water-based recreation activities and mitigation measures to minimize these impacts is, in part, a summary of information presented in a report dealing exclusively with this subject, Riparian Habitat and Recreation: Interrelationships and Impacts in the Southwest and Rocky Mountain Region (Johnson and Carothers 1982). The reader should consult this publication for more detailed information and a bibliography of related papers on recreational impacts.

Water Quality

Degradation of water quality is a common impact to surface waters with heavy recreational use. Contamination can result from human and animal defecation of feces directly into water resources or onto watershed surfaces (Doyle et al 1985). Warm blooded animal feces potentially carry bacteria microbiological pathogens which can be transmitted by water to human users. The microorganisms can also be transmitted to human or animal hosts through the resuspension of bottom sediments through water play, swimming and other activities (Brickler and Tunnicliff 1980). People may contract diseases from these microorganisms through ingestion of contaminated waters, contact through bathing, swimming or wading, or inhalation of virus-containing aerosols (Craun 1984). Human feces and kitchen wastes may also be discharged into the water in areas used by recreational vehicles, particularly when waste disposal facilities are not made available (Rose et al 1988).

Particularly high levels of microorganisms may be found during high-use periods (weekends and holidays) (Brickler et al 1976; Rose et al 1988) and in quiet-water, low-flow areas where flow characteristics can temporarily concentrate suspended sediment (Brickler and Tunnicliff 1980).

Water quality degradation from recreation can also result in waters where body soaps and cleaning detergents can concentrate, contributing nutrients that can accelerate algae production, deplete oxygen levels, and lead to other chemical disturbances. The impacts of this type of degradation are primarily borne by fish and other aquatic organisms, though waters which become excessively green and algae-laden may not be as popular for swimming or waterplay.

The federal Environmental Protection Agency and the Arizona Department of Environmental Quality have set standards for recreational waters and are responsible for monitoring these waters to ensure that the standards are being met. Land management agencies are also responsible for protecting water quality and keeping the public educated and informed about water quality hazards (Utter 1985).

Mitigation measures to control water quality degradation can take many forms. Adequate sanitation facilities should be provided at all intensively used hiking and camping areas to prevent human waste from washing into the water. On heavily used rivers, boaters should be encouraged or required to carry out human waste. Personal water quality treatment information should be provided. Areas with potential health hazards should be posted. Finally, baseline water quality data should be gathered and a regular water quality monitoring program established in areas of frequent use. Recreational water quality studies of this type have been conducted in Sabino Canyon (Brickler et al 1976, Brickler et al 1977), Madera Canyon (Brickler and Morse 1979), Oak Creek Canyon (Rose et al 1988), the Grand Canyon (Brickler and Tunnicliff 1980; Tunnicliff and Brickler 1981), and on the boating segment of the San Juan River (Doyle et al 1985).

Soils

Impacts to soils from recreation users becomes a problem only on permanent shore areas found above the high water flow level of the stream (Johnson and Carothers 1982). Sandy beaches and gravel bars, on the other hand, are naturally renewed surfaces that can withstand much more intensive recreational use, because they are periodically flushed clean by high water flows and flash floods. The most common recreational impacts to permanent soils include: (1) surface soil compaction; (2) reduction in vegetative ground cover; (3) reduction in infiltration and hydraulic conductivity; (4) reduction in soil organic detritus; and (5) increase in soil density (Settergren 1977). The cumulative effects of these soil impacts is a denudation of the vegetation through a loss of water (due to decreased infiltration) and nutrients (due to a loss of organic matter), and a subsequent increase in the potential for erosion.

Studies of campgrounds in riparian areas of southern Arizona found severe soil impacts (in the form of reduced infiltration, compaction, denudation, root exposure, and erosion) in the vicinity of permanent campgrounds located above the high water mark of streams (Post 1979). On the Colorado River in the Grand Canyon, heavy recreational use of beaches in combination with nearly sediment-free dam releases may eventually result in the complete erosion of beaches and available campsites (Valentine and Dolan 1979). Fire charcoals, litter, human waste, and other camping debris scattered in the temporary and permanent shore areas are both unaesthetic and potentially hazardous to human health (Knudsen et al 1977, Phillips and Lynch 1977).

Impacts to soils can be mitigated through the following measures: (1) identifying sensitive soil areas (Craig 1977); (2) locating campsites and intensive-use facilities outside of sensitive soil areas (Settergren 1977); (3) rotating the use of campsites and other facilities (Craig 1977); (4) aerating and fertilizing soils that have been severely impacted (Post 1979); (5) establishing use-limits on certain areas based on the physical carrying capacity of the area (Marnell et al 1978); (6) requiring human waste, fire remnants, and garbage to be carried out of popular remote sites; and (7) providing adequate waste disposal and sanitation facilities in heavily used areas.

Vegetation

Impacts to vegetation from intensive recreational use of riparian areas may be attributed to either direct physical or mechanical injury or to a physiological response to soil changes (Johnson and Carothers 1982). There have been no long-term studies on the effects of intensive recreational use on vegetation, but several short-term studies have documented the following impacts: (1) reduced density and diversity of vegetative ground cover; (2) reduced vigor in trees; (3) total or partial reductions in seedlings and younger trees; (4) increased susceptibility of older trees to disease or parasites; (5) shifts in species diversity, favoring trees which are more tolerant of recreational use; and (6) invasion of exotic species (such as watermelons, tomatoes, and oats) as a result of camping activities or habitat alteration (such as saltcedar) (Johnson and Carothers 1982).

Mitigation strategies to reduce impacts to vegetation are similar to those strategies for reducing impacts to soils in that they focus on the importance of planning and site design. Resource managers should conduct studies to determine the effects of recreational use on different plant species and plant communities, and then design and locate overnight and day-use facilities in areas which are least susceptible to impact (Johnson and Carothers 1982). Similarly, trails can be located or re-routed into upland areas instead of through sensitive riparian plant communities. Another mitigation technique for alleviating impacts to riparian vegetation is a rest-rotation schedule for those areas which are most heavily used.

Wildlife

Impacts to wildlife from recreational use can occur indirectly through habitat degradation and destruction, or directly through human contact and disturbance. Recall from Chapter Four that sixty percent of all vertebrates in the arid Southwest depend directly on riparian habitats for their survival, and that another ten to twenty percent of the vertebrates occupy these habitats during certain times of the year (Ohmart and Anderson 1986). Riparian habitats also offer some of the highest breeding bird densities of all habitat types. Hence, the chance of encountering (and disturbing) wildlife in riparian areas is relatively high when compared to upland wildlife habitats. However, only a few studies have been conducted on the impacts of recreation on the population structure of wildlife communities or the impacts to specific species. Many of the studies that have been conducted were in response to major human-induced changes in the habitat (such as changes from a natural flowing river to a regulated flow regime) rather than studies on the impacts of concentrated recreational activities.

Those studies that have been conducted showed the following results in the study areas: (1) breeding bird diversity and density were reduced in the vicinity of campgrounds

(Aitchison 1977); (2) small mammal populations (rodents) contained more juvenile species in the vicinity of campgrounds (Boeer and Schmidley 1977); and (3) increases in populations of certain insects, lizards, mammals, and birds were found in heavily used campgrounds (Johnson and Carothers 1982).

Mitigation measures to reduce impacts to wildlife should be concentrated on prevention and planning. Recreational facilities should be sited or re-located in areas where impacts to habitat or direct encounters will be minimized, and activities, such as feeding or littering which impact the behavior or population structure of wildlife, should be discouraged (Johnson and Carothers 1982). The latter can only be achieved by educating the recreating public through such means as brochures, signs, direct contact with resource managers and rangers, school curricula, and other techniques as appropriate.

Conclusion

Arizona has a wide variety of streams and wetlands that provide diverse and highly desirable recreation experiences. The overall popularity of stream and wetland recreation in Arizona is on the rise, and the trends suggest that participation will continue to increase in response to projected population growth.

Some of the more significant participation trends documented in this chapter include the following. During the past three decades the total number of watercraft registrations has climbed from around twenty thousand to nearly 120 thousand. Whitewater and quietwater boating enthusiasts represent a significant portion of this increase in boating participation; approximately twenty thousand of the current registrations are for paddle- or oar-powered boats. The total number of visitors to parks, wildlife refuges, wilderness areas, and private preserves with important riparian areas has also increased during the past decade or more; in some cases, dramatically. Participation in fishing has increased considerably since 1966. At that time over 123 thousand Arizonans held a fishing license. In 1985, over 246 thousand fishing licenses were purchased by state residents. The number of Arizona hunters has steadily increased from over eighty thousand in 1977 to nearly ninety-five thousand in 1986. Combined hunting and fishing license purchases by Arizona residents peaked at nearly 109 thousand in 1980, and have since declined to under ninety-four thousand. Off-highway vehicle driving is also an important form of recreation in Arizona, as indicated by the number of vehicle registrations for motorcycles and all-terrain vehicles (73,400) and four-wheel drive vehicles (104 thousand).

With these participation statistics, it is no wonder that tourism and recreation have become so important to the Arizona economy. An estimated 729 million dollars goes towards recreational expenditures in Arizona.

Increasing enjoyment and participation in stream- and wetland-based recreation is not without a cost. There are indications that some streams and wetland areas have reached their capacity to support recreation. Research indicates that relatively pristine areas could indeed be impacted by intensive or unmanaged use. Impacts from recreation have been documented, but there is a need for more data on site specific problems.

"Ours has been the first, and will doubtless be the last, party of whites to visit this profitless locality. It seems intended by nature that the Colorado River, along the greater portion of its lonely and majestic way, shall be forever unvisited and undisturbed."

Lt. Joseph Christmas Ives
1857—Speaking of the Grand Canyon

Table 6-11
Historic And Projected Annual Water Use By County
1965 To 2005
(Thousands Of Acre-feet)

County	1965	1975	1985	1995	2005
Apache	26.0	30.6	25.8	38.6	44.5
Cochise	450.0	805.0	477.4	481.3	488.6
Coconino	29.4	44.0	59.1	59.7	64.1
Gila	27.5	28.5	31.7	32.8	33.7
Graham	272.7	368.3	226.9	227.8	228.3
Greenlee	68.0	63.0	58.0	58.0	58.2
La Paz	-----	-----	282.2	282.5	282.8
Maricopa	3,052.0	2,966.0	2,951.0	2,757.3	2,409.0
Mohave	22.6	34.7	93.0	96.0	99.0
Navajo	61.0	46.3	60.5	59.5	62.0
Pima	335.0	399.0	368.0	357.0	357.0
Pinal	1,318.0	1,510.0	1,440.0	1,775.1	1,674.6
Santa Cruz	13.4	13.0	19.9	21.6	23.9
Yavapai	50.0	31.0	51.2	52.7	56.3
Yuma	474.7	1210.5	934.0	937.0	941.0
Total	6,200.3	7,549.9	7,078.7	7,236.9	6,823

Source: College of Agriculture, University of Arizona, 1986.

increase should be highest in Apache County, followed by Santa Cruz and Pinal Counties.

Stream and Wetland Futures in Arizona

Collectively, the demographic, attitudinal, economic, and water use trends will result in further impacts on the state's streams and wetlands. The exact location, nature, and extent of these impacts are not foreseeable, but based on the previous discussion, there are definite potentials for the outcomes described below.

The population and urbanization trends may be expected to affect stream and wetland resources and the associated recreational opportunities in the following ways:

- Demand for stream and wetland recreation will continue to increase, particularly in locations in proximity to urban and urbanizing areas
- Municipal development will further encroach upon riparian areas due to pressures for floodplain construction for residential, commercial, and industrial activities
- Increased recreational use of streams and wetlands, especially in areas of rapid growth, could lead to the crowding and degradation of these resources

Table 6-12
Change In Water Use By County 1965 To 1985 And 1985 To 2005

County	1965-1985 (1000s af)	1965-1985 (percent)	1985-2005 (1000s af)	1985-2005 (percent)
Apache	- 0.2	- 0.77	+ 18.7	+ 72.48
Cochise	+ 27.4	+ 6.09	+ 11.2	+ 2.35
Coconino	+ 29.7	+ 101.02	+ 5.0	+ 8.46
Gila	+ 4.2	+ 15.27	+ 2.0	+ 6.31
Graham	- 45.8	- 16.80	+ 1.4	+ .62
Greenlee	- 10.0	- 14.71	+ 0.2	+ .34
La Paz	-----	-----	+ 0.6	+ .21
Maricopa	- 101.0	- 3.31	- 542.0	- 18.37
Mohave	+ 70.4	+ 311.50	+ 6.0	+ 6.45
Navajo	- 0.5	- 0.82	+ 1.5	+ 2.48
Pima	+ 33.0	+ 9.85	- 11.0	- 2.99
Pinal	+ 122.0	+ 9.26	+ 234.6	+ 16.29
Santa Cruz	+ 6.5	+ 48.51	+ 4.0	+ 20.10
Yavapai	+ 1.2	+ 2.4	+ 5.1	+ 9.96
Yuma	+ 459.3	+ 96.76	+ 7.0	+ 0.75

Source: College of Agriculture 1986.

- Increased recreational use of more remote or less well-known streams and wetlands could occur if more intensively used areas become crowded or degraded

The shift in and diversification of land use and resource values in Arizona could affect the management of stream and wetland resources in the following ways:

- Arizonans, with the exception of residents in a few of the smaller communities, may pressure for policies and management practices that reflect non-consumptive rather than consumptive uses of stream and wetland resources

- Conflict over the use and management of certain riparian areas may be intense in communities where old values and new values are at odds

Arizona's diversifying economy and the resulting water use patterns could have the following impact on the state's streams and wetlands:

- Increased use of water conservation measures, particularly in irrigated agriculture, should lead to a decrease in aggregate water consumption, leaving water available for recreation and fish and wildlife as well as other uses

- Conservation measures imposed by the Groundwater Management Act should lead to decreases in aggregate water consumption in the state's Active Management Areas

- Population and economic growth in smaller communities outside of the Active Management Areas will increase demand for water in these areas, leading to pressures for groundwater and surface water development

- Extensive groundwater development may occur in basins along the Central Arizona Project canal and in growing urban communities, particularly in the Basin and Range water province

- Surface water development and diversions may occur in higher elevations where local groundwater supplies are either unavailable or infeasible to develop for political or economic reasons

- Surface water and groundwater development may lead to depleted streamflows, diminishing stream-related recreational opportunities and aquatic and riparian habitat for fish and wildlife

Stream and Wetland Issues: Policy Variables

Four issue categories which concern the future conservation and protection of streams and wetlands for recreation and fish and wildlife purposes emerge from these potential trends. These categories include:

- Maintaining flowing and non-flowing surface waters and water table elevations

- Improving and enhancing surface water quality

- Conserving and protecting riparian habitat

- Providing and enhancing recreational opportunities

The resolution of these issues are dependent upon many variables relating to state policies and management actions. These variables are the focus of the following discussions.

Issue—Maintaining Flowing and Non-Flowing Surface Waters

One of the most important of today's aquatic and riparian habitat conservation issues concerns the need to conserve and protect Arizona's remaining natural flowing and non-flowing surface waters, particularly those streams which have been identified for significant resource and recreational values (see Chapter Nine and Appendix 9-A).

In this past century, many of Arizona's streams and wetlands, particularly in the southern part of the state, have been diverted or pumped dry due to pressures from consumptive land and water uses (see discussion in Chapter Four). The natural streamflows of Arizona rivers have been altered significantly through the construction of large- and small-scale dams and diversion works. Arizona's largest river, the Colorado, has been completely regulated and modified through numerous reclamation projects, including Glen Canyon, Hoover, Davis, Parker, Headgate Rock, Imperial, Laguna, and Morelos Dams.

The cumulative result is that few unmodified perennial or intermittent surface waters remain in the state. As demand for water increases, the need to conserve and protect the remaining streams and wetlands will intensify. Several factors, identified below, will determine the extent to which the depletion or altering of surface waters and groundwaters will impact aquatic habitats and stream and wetland recreation opportunities. These include:

- The extent to which federal reserved and state water rights are secured for recreation, fish and wildlife, and other stream and wetland amenity value
- The resolution of Indian water rights and water issues
- The time required for Arizona to establish a system for the conjunctive management of surface water and groundwater
- The impacts of future water transfers

Water Rights for Flowing and Non-Flowing Aquatic Habitats

The attainment of water rights for recreation, fish and wildlife, and other natural values is one of the most important variables affecting the future conservation of streams and wetlands in Arizona. There are two methods for securing non-consumptive water rights for flowing (streams) and non-flowing (seeps, springs, and cienegas) aquatic habitats in Arizona: (1) through the state permitting process, administered by the Arizona Department of Water Resources; and (2) through the ongoing general stream adjudications being held in the Superior Courts of Arizona.

Private landowners, state agencies, and some federal agencies must secure their water rights through the state permitting process. Surface water rights in Arizona, like in most other Western states, are governed by the doctrine of prior appropriation. The prior appropriation doctrine has five fundamental tenets which define the privileges and powers granted to the appropriator:

- Appropriators who are "first in time" are "first in right"
- Appropriators must not divert water away from the land to which the surface water right is attached
- Appropriators must put the water to a legally defined beneficial use
- In times of shortage, senior appropriators are entitled to a full allocation of their water rights before more junior appropriators are allowed to divert
- Appropriators must use their right or risk forfeiture through abandonment

The regulations governing water rights for non-consumptive uses deal primarily with the instream flow permitting process which is in the process of being formulated into administrative law. An Instream Flow Task Force was formed in December 1986 to recommend appropriate quantification methodologies and management guidelines. The Department of Water Resources intends to promulgate formal rules for the instream flow permitting process by the end of this year (Dishlip 1988). As of January 8, 1988, thirty-nine minimum instream flow permits had been submitted to the agency (Table 6-13) (ADWR 1988). Only two of these applications have been permitted, both to The Arizona Nature Conservancy (for Ramsey and O' Donnell Creeks). The status of the remaining applications is listed as: "application" (9), "defective application" (3), "candidate for permit" (3), "withdrawn" (1), or "protested" (21). In order to become a more effective tool for conserving live streams, the instream flow permitting rules need to be resolved soon.

Table 6-13
State Minimum Instream Flow Applications
(As Of 8 January 1988)

Applicant	Source	Status
Arizona Game & Fish Department	Silver Springs/Silver Creek	Application
The Nature Conservancy	Thomas Wash/Altar Wash	Application
The Nature Conservancy	Ramsey Creek/San Pedro	Permit
The Nature Conservancy	Sonoita Creek/Santa Cruz	Candidate for Permit
The Nature Conservancy	O'Donnell Creek/San Pedro	Permit
Coronado National Forest	Grant Creek	Withdrawn (8-83)
Bureau of Land Management-Safford District	Aravaipa Creek	Candidate for Permit
Winston Wheeler Living Trust	Cienega Creek/Pantano Wash	Protested
Tonto National Forest	Pinto Creek/Salt River	Protested
Bureau of Land Management-Safford District	Francis & Burro Creeks/Big Sandy River	Protested
Huachuca Audubon Society	San Pedro/Gila River	Protested
Coconino National Forest	Oak Creek/Verde River	Protested
Coconino NationalForest	East Clear Creek/Little Colorado River	Protested
Coconino National Forest	Walker Creek/Wet Beaver Creek	Protested
Coconino National Forest	Red Tank Draw/Wet Beaver Creek	Protested
Coconino National Forest	West Clear Creek/Verde River	Protested
Coconino National Forest	Sheepshead Creek/Oak Creek	Protested
Coconino National Forest	Wet Beaver Creek/Verde River	Protested
Coconino National Forest	Sycamore Creek/Verde River	Protested
Coconino National Forest	Spring Creek/Verde River	Protested
Bureau of Land Management-Safford District	Buehman Canyon	Protested
Bureau of Land Management-Safford District	Bonita Creek	Protested
Bureau of Land Management-Safford District	San Francisco River	Protested
Bureau of Land Management-Safford District	Mescal Creek	Protested
Bureau of Land Management-Safford District	Apache Creek	Protested
Tonto National Forest	Verde River	Protested
Tonto National Forest	East Verde River	Protested
Navajo County Parks & Recreation	Billy Creek/Little Colorado River	Protested
Bureau of Land Management-Phoenix District	Peoples Canyon Creek	Candidate for Permit
The Nature Conservancy	Mainstream Hassayampa River	Application
Southwest Arboretum & Arizona State Parks Board	Queen Creek, Gila River	Application
Sierra Club	Sabino Creek	Application
Coronado National Forest	Sabino Creek/Rillito Creek	Application
Arizona State Land Department	Cargodera Canyon, Catalina State Park	Application
Arizona State Land Department	Montrose Canyon, Catalina State Park	Application
Arizona State Land Department	Romero Canyon, Catalina State Park	Application
Arizona State Land Department	Alamo Canyon, Catalina State Park	Application
Arizona State Land Department	Sonoita Creek, Patagonia Lake State Park	Application

Source: Arizona Department of Water Resources 1988.

Existing applications need to be permitted and new applications should be encouraged.

Maintenance of flowing surface waters is one of two types of water use vital to the ecological integrity of riparian ecosystems.

Seeps, springs, cienegas, marshes, and ephemeral washes also require water rights to protect the associated recreational and ecological values. Surface water rights for non-flowing waters for recreation and fish and wildlife purposes may be obtained through the regular surface water rights application process (Dishlip 1988).

In addition to filing for a state permit, all water rights holders, including private individuals, businesses, government agencies, and Indian tribes, must submit their claims for streams, springs, wells, or intermittent runoff into the general stream adjudications of their respective drainage basins (Arizona Water Information Center 1986). The purpose of the adjudications is to determine the nature, priority, and extent of every existing water user's right. The cumulative impact of these water rights are complicated and essentially unknown because the rights were established through several pieces of legislation and numerous court decrees. The second and more important reason for holding the adjudications is to quantify the federal reserved water rights that are held by federal land management agencies (NPS, USFS, BLM, DOD, and FWS) and Indian tribes.

The creation of federal reserved water rights date back to a 1908 court case, Winters v. United States (28 S. Ct. 207 (1908)). This type of water right could initially be claimed only by Indian tribes and only for surface waters, but it has since been extended to include all federal reservations (Arizona v. California, 373 U.S. 546 (1963)) and groundwaters (Cappaert v. U.S., 426 U.S. 128 (1976)). The potential magnitude of these unquantified federal claims, and the very early priority dates that these rights often carry with them (extending back to the date of the creation of the federal reservation) leave all other claimants unsure of the status of their own water rights.

The fact that seventy percent of Arizona's land area is either owned by the federal government or held in trust for the Indian tribes means that federal reserve water rights are one of the most important variables affecting the future of streams and wetlands in Arizona (Table 6-14) (Wilkosz 1987). Most of the state's perennial waters flow through all or portions of federal lands. Important riparian areas are also managed by the federal government. Some protection is offered through special federal land designations (see discussion in Chapter Two), but such designations do not include the protection of surface waters or groundwaters unless a water right is obtained. Streamflow protection is important to fulfilling many of the purposes for which the federal reservations were established, and some federal agencies, like the National Park Service and the Forest Service, have submitted water rights claims for fish and wildlife, wilderness, recreation, and other purposes into the general adjudications. Other agencies, like the Bureau of Land Management and the Fish & Wildlife Service, have not (Edgar 1988, Muller 1988).

Indian Water Rights and Water Issues

There are twenty Indian Reservations in Arizona, totaling nearly twenty million acres of land (Figure 2-4). The fact that many of these reservations contain or are adjacent to rivers, streams, and wetlands means that Indian tribes will play an increasingly important role in the management of the state's waters.

Indian Reservations in Arizona contain 175 (or thirty-two percent) of the state's 554 identified perennial stream segments (see Table 7-1). The Fort Apache and the San Carlos Apache Reservations alone contain ninety-four (seventeen percent) of the state's perennial streams, while their land area constitutes only five percent of the state.

Out of the 589 miles of the Colorado River flowing through Arizona, 265 miles (or forty-

Table 6-14
Land Ownership In Arizona

LAND AREA SUMMARY

Total Land Area	113,508 square miles	or	72,645,120 acres
Total Water Area	492 square miles	or	314,880 acres (.04 percent of state total)
TOTAL			72,960,000 acres

LAND OWNERSHIP

LAND OWNER	ACREAGE	PERCENTAGE OF THE STATE
Federal Total	33,028,000	40
Forest Service	11,273,000	15
Bureau of Land Managemt	12,280,000	17
National Park Service	2,670,000	3.6
Fish & Wildlife Service	1,705,000	2.3
Bureau of Reclamation	1,500,000	2.0
Indian Reservations	20,429,000	28
State of Arizona	9,485,000	13
Private	12,000,000	17
Other Public (Municipal, County, etc.)	1,459,000	2

Sources: Adopted from College of Agriculture 1986 and Valley National Bank of Arizona 1987.

five percent) of its shorelines are on Indian Reservations. These Indian Reservations include the Navajo, Hualapai, Fort Mohave, Colorado River, and Cocopah. The Navajo and Hopi Reservations occupy large portions of the Little Colorado, Colorado, and San Juan drainage basins. The Fort McDowell, Salt River, Gila River, and Ak Chin Reservations straddle large riparian corridors on the lower Verde, lower Salt, middle Gila, lower Santa Cruz, and lower Gila Rivers respectively. The Tohono O'Odham and San Xavier

Reservations contain hundreds of ephemeral streams, as do most of the other reservations.

The future of Indian water rights is one of the most controversial water issues in the West. In the early 1980s, conflicts between Indian and non-Indian water users were present in at least sixty western water basins and involved over one hundred Indian communities (Folk-Williams 1982). The quantification of Indian water rights will probably be one of the most controversial aspects of the the general stream adjudications in Arizona as well. Through a series of court decisions and federal legislation, the tribes collectively hold title to a vast amount of water which is already being used by other groups for non-tribal purposes.

Other significant Indian water issues include:

- Regulatory authority of tribal governments over reservation waters
- Water quality issues relating to the protection of fisheries and the impacts of energy development
- Off-reservation water uses
- Ownership of river and lake beds
- Indian rights to water stored in federal reclamation projects (Folk-Williams 1982)

Because of their future role in the state's aquatic resources, Indians need to become active participants in the management of Arizona's streams and wetlands.

Conjunctive Management of Surface Water and Groundwater

The need for coordinated management and regulation of surface waters and groundwaters is another future issue facing Arizona.

Conjunctive management is important because surface water and groundwater are often hydrologically interconnected. This means that when surface water is diverted from a stream, there will be less water percolating to the underlying aquifers. The opposite relation also holds true; when groundwater is pumped from an aquifer which supports the water table of a surface stream, there will be less water permeating to the surface through the streambed and stream channels. The effect of one use upon another may be negligible if there are only a few people diverting or pumping water from the same hydrologic system. There is no need, in this case, to regulate and coordinate users, as the adverse impacts are usually negligible. As the number of water users increases (as in the growth of a municipality), or when a few users withdraw large quantities of water (e.g., for mining or agricultural purposes), conflicts are likely to occur.

Hydrologists have long recognized the interconnection between surface streams and aquifers. Unfortunately, the law does not acknowledge the interconnections in any adequate way. The issue of conjunctive management refers to the need to bring the legal water rights system into congruence with physical reality. The future locations and extent of such impacts are difficult to predict, but the coordinated management of surface waters and groundwaters to protect water rights and resource values is long overdue.

State groundwater law is divided into two categories. One body of groundwater law deals with "underground streams," and water rights for these waters are subject to the prior appropriation doctrine. "Percolating" groundwaters, on the other hand, are subject to the doctrine of reasonable use, meaning that the overlying landowner can pump as much water as is reasonable for the beneficial use to which it is applied. Underground streams are more of a legal definition than a hydrological reality, thus most groundwater pumping is governed by the doctrine of reasonable use. As such, the amount of water than can be legally pumped is essentially unquantified.

The doctrine of reasonable use has contributed to the dewatering of many of Arizona's streams, particularly in the southeastern part of the state. Because this region has limited precipitation to support surface water streams, the water supplies used by municipalities, agriculture, and industries in this region are primarily derived from groundwater. Southern Arizona is where conjunctive management is most urgently needed, particularly in communities like Sierra Vista, where the City's increasing thirst for groundwater may someday dry up the perennial waters of the interconnected San Pedro River. Numerous streams and cienegas have already succumbed to this fate (see Chapter Four). The state courts are expected to address this issue in the adjudications, but this may not happen for several decades. By then, it may be too late to conserve aquatic and riparian habitats along the San Pedro River and elsewhere in the state.

Water Transfers

Physical transfers of water from a diversion point along a stream to a distant point of use has been practiced since prehistoric times. Between 300 B.C. and 1400 A.D., the Hohokam Indians of the Salt River Valley used stone hoes to carve out over two hundred miles of canals (SRP undated). In the mid-1800s, intrabasin transfers were recognized as being so important to the settlement and development of the West, that the physical diversion and transfer of water were incorporated into the doctrine of prior appropriation.

The idea for interbasin transfers came soon thereafter. In the early part of this century, the City of Los Angeles acquired water rights in the distant Owens River Valley to ensure that the growth of the City would not be hampered by a water shortage (Kahrl 1982). Intense controversy and political battles were waged as a result of this transfer, the most recent of which concerns the fate of the ancient Mono Lake; waterfowl and wildlife have suffered severe impacts because of the lake's decreasing water levels.

The most expensive of all interbasin transfers is the Central Arizona Project (CAP). In the several decades since the idea for this canal system was first conceived, the purpose of this multi-billion dollar project has changed from supporting agriculture to supporting municipal growth (Folk-Williams et al 1985). The CAP could be Arizona's last big federally funded reclamation project. This does not mean, however, that the days of water transfers are over. They have only become more complex.

The state's supplies of surface water are finite and nearly fully appropriated. Groundwater supplies are being mined beyond the limits of natural recharge. Consequently, Arizona and other Western states in the same situation are investigating new ways to efficiently move water to its highest valued uses. Water resource experts from a variety of fields have responded by advocating a relaxation of the water laws that prohibit or restrain market transfers of water rights. A number of bills dealing with water transfers were introduced in the Arizona Legislature in February 1988. However, there is no consensus on either the scope or substance of the water transfer bills, so it is too early to determine the effects of the proposed legislation with regard to rivers and riparian areas in Arizona (Hawke 1988).

Potential intrabasin and interbasin surface water and groundwater transfers could detrimentally impact the rivers and riparian areas of the state in a variety of ways. For example, the marketing of water to its highest valued uses automatically prejudices against those uses for which there is no quantified market value. Wilderness, scenic views, conservation of riparian areas for future generations, migratory wildlife, and endangered species are but a few examples of resources and values that defy traditional economic market quantification. Resource economists are working on methods to quantify these resources and values, but this science is still relatively new. Such quantification is not well accepted by members of the public who consider wilderness and wild rivers an inalienable and priceless right, nor by others who value waters from streams and wetlands for development purposes. Even if a market system is not imposed upon the water resources of the state, interbasin transfers could still be facilitated through changes in administrative or statutory law.

Issue—Conserving and Improving Surface Water Quality

Much of the following discussion on surface water quality was taken from the Arizona Department of Environmental Quality's report, Water Quality Assessment for the State of Arizona, which covers the period between October 1983 and September 1985 (ADHS 1986).

Surface water quality standards are set by the Department according to the uses for which the water is to be protected. For example, surface waters that are used as a domestic water source have much higher standards than surface waters used for agricultural livestock watering. Accordingly, the agency has established six "protected uses" for surface water quality which are listed here in order of decreasing stringency for most constituents:

- Domestic water source
- Full body contact
- Incidental human contact
- Aquatic and wildlife
- Agricultural irrigation
- Agricultural livestock watering

River segments with water quality meeting or exceeding the protected use standards are considered by the Department of Environmental Quality to be "good quality waters," because they can be used safely for the designated protected uses. Additionally, the West Fork of the Little Colorado River, Oak Creek, and the West Fork of Oak Creek have been designated as Unique Waters of Recreational and Ecological Significance, receiving even higher levels of additional water quality protection.

The water quality in rivers and streams in eleven of the state's major drainage basins are periodically monitored to ensure compliance with the state's protected uses and Unique Waters standards. If the water quality standards are being met, the uses are said to be "supported." Stream segments in which most standards are being met are classified as "partially supported." When most or all of the standards are being violated, the protected uses are classified as "not supported."

Existing Water Quality Problems

In general, the causes of nonsupport for the protected uses may be separated into four categories: (1) unknown sources, (2) industrial sources, (3) nonpoint sources, and (4) municipal sources.

The sources of surface water contamination in southern Arizona, particularly along the San Pedro River, the Santa Cruz River upstream of Tucson, Vamori Wash, Indian Bend Wash, and the Salt River from 16th Street to 23rd Avenue, are unknown.

Industrial sources, principally from mining activities, contribute contaminants to the San Pedro River near Benson and to other small streams throughout the state.

Nonpoint sources of contaminants are associated with many land management practices. Irrigated agriculture contributes elevated levels of total dissolved solids in the Gila River near Yuma and downstream of Phoenix. On-site wastewater disposal systems, a second major source of nonpoint contaminants, has elevated nutrient and bacterial levels in the Parker Strip, Payson, Lakeside-Pinetop, and Greer areas. High erosional levels associated with mining activities have created nonpoint problems in the form of heavy metal contamination in the Puerco River, Little Colorado River, and Upper Gila River.

Municipal sources, the fourth major cause of non-attainment, contributes to one or more of the following: elevated levels of nutrients, low dissolved oxygen levels, synthetic organics, heavy metals, pesticides, and bacteria. The Salt and Verde Rivers near Phoenix, the East Verde River upstream and downstream of American Gulch, and the Nogales Wash are the principal rivers where municipal contaminants are found.

Water pollution is a function of natural processes and the economic activities occurring in a watershed. For example, low pH and heavy metals are often associated with active and abandoned mining operations. Turbidity and total suspended solids are caused by activities that lead to increased erosion, including clear-cutting, grazing, all-terrain vehicles, real estate development, and some recreational activities. The causes of low dissolved oxygen levels in southern Arizona rivers are unknown. Elevated nutrient levels can be attributed to discharge from municipal wastewater treatment facilities (human waste), agricultural return flows (fertilizers and animal waste), and urban runoff (lawn and turf fertilizers). Organic toxics, including pesticides and their metabolites, and volatile organic compounds (VOCs), are associated with agricultural and industrial activities, respectively. Radioactive compounds are associated with radioactive mining accidents and natural causes.

There are several water quality issues of special concern that are specific to certain physiographic regions of the state. Elevated levels of acids, heavy metals, and cyanides have been detected in the surface waters of the Central Highlands and Basin and Range water provinces. Rivers that have polluted waters from these contaminants include: the lower San Francisco River; the upper Gila River; Pinal Creek; the Salt River downstream of Pinal Creek, and west of Phoenix; the Santa Cruz River downstream of Nogales; the San Pedro River downstream of Palominas, and upstream of Aravaipa Creek; and the Puerco River from Lupton to Holbrook. Because placer and other mining activities have occurred throughout the state, heavy metals and other by-product contaminants may be present elsewhere (see discussion on the Basin and Range). Elevated levels of bacteria and nutrients are also of special concern in these provinces in rivers and streams with heavy recreational use and in areas of rapid population growth: the Slide Rock area of

Oak Creek; in the vicinity of Nogales; Vamori Wash; the Colorado River; and the Gila River south of Phoenix.

Two water quality problems have been identified in the Plateau water province. Colorado River salinity levels continue to be a problem, especially for southern Arizona communities that use or expect to use the water (via the CAP) for domestic or other municipal purposes. The second issue in the Plateau province concerns radiological contaminants in the Puerco and Little Colorado Rivers. The distribution and extent of these contaminants, which originate from both natural and human-induced sources, have not yet been specifically determined.

Contaminants from agricultural and industrial sources are the major water quality problems of the Basin and Range water province. Agricultural practices have contributed to elevated salinity levels in the Colorado River, to elevated pesticide levels in and downstream of the Buckeye area and in Indian Bend Wash in Scottsdale, and to elevated nitrate levels in the San Pedro River near St. David. Industrial activities associated with electronics and metal finishing have polluted surface waters and stream sediments downstream of Tucson and Phoenix, and in Indian Bend Wash in Scottsdale. At least one study has also indicated that contaminants draining from abandoned mines and tailings may also be a problem in some drainages in southern Arizona (Dean 1982).

River Mileage Monitored

To adequately assess the status of surface water quality, it is essential that Arizona have a statewide, comprehensive monitoring program. This type of program does not currently exist. The Arizona Department of Environmental Quality has identified 17,537 miles of rivers and streams in the state (ADHS 1986). All of these waters are protected by water quality standards. An estimated 3,630 of these miles contain perennial surface flow. However, only 1,412 miles (eight percent) of the total are currently assessed to determine if the standards are being met, and only 580 miles (or three percent) of the total are monitored. Even if most of the waters that are assessed or monitored are perennial, the state has no knowledge of water quality on a sizeable percentage of streams with year round flow and probable recreational use.

Periodic assessment and monitoring may not be warranted in watersheds in which land uses are not intensive or particularly damaging to the waters, but this needs to be determined, and at the very least, baseline data should be available for all surface waters to monitor, identify, and mitigate impacts should they occur.

Standards for Exceptional Recreational and Fish and Wildlife Waters

This study has identified streams and wetlands which have documented resource or recreational significance. They are included on the Preliminary List of Candidate Critical Streams and Wetlands prepared as an initial step in the formulation of a proposed statewide Critical Streams and Wetlands program (see Chapter Nine and Appendix 9-A). Maintaining or improving water quality in these streams and wetlands to a level that ensures the continued health and enjoyment of the recreation participants and the conservation of aquatic and riparian species should be a state priority.

The Unique Waters program administered by the Arizona Department of Environmental Quality was established specifically for these water quality purposes (see discussion in Chapter Seven). Designated Unique Waters are protected by exceptionally high water quality standards determined on a site-specific basis. To date, three surface water segments have been formally designated as Unique Waters—the West Fork of the Little Colorado River, Oak Creek, and the West Fork of Oak Creek. Three more segments, Peoples Canyon, Francis Creek, and Burro Creeks, are scheduled for designation in 1989, and two additional nominations are being prepared for Cienega and Bonita Creek. This program is making a significant contribution to the stream and wetland recreators of Arizona and it deserves continued support so it may grow to protect the quality of many more of our most significant waters.

Issue—Conserving Riparian Habitat

The third issue of importance to the future of streams and wetlands concerns the conservation and protection of riparian habitat. Impacts from the use of riparian lands can be attributed to both non-recreational and recreational land and water uses, and are discussed in Chapters Four and Five, respectively. The discussion here focuses on the variables that will affect the future status of riparian habitat in Arizona.

Streamflow and Groundwater Protection

Protection of surface water in streams and wetlands is important for ensuring the continued opportunity for aquatic recreation and the conservation of aquatic and riparian habitat for fish and wildlife. Perennial, intermittent, and ephemeral surface waters and groundwaters are also required to maintain and encourage the growth of riparian vegetation. The variables affecting the future of surface water flows and groundwater elevations previously discussed also apply to the conservation of riparian habitat.

Floodplain Development

Population trends point toward the continued expansion of large urban areas and the growth of recreation and retirement communities. As these areas grow, so will the need for land for residential, commercial, and industrial purposes. Despite an ever-present flooding hazard, riparian areas and floodplains have historically been considered prime development areas. When excessive development occurs, it is not long before the amenity values that may have first attracted people to the area are destroyed, as are the natural flood retention properties of the land. Communities have the ability to plan and regulate growth in these floodplains, and they should be encouraged to do so to preserve open space, recreational values, and wildlife habitat for all to enjoy.

Stream Channel Modifications

Concomitant with pressures for development in floodplains is the desire by some communities to modify stream channels. Channelizing and soil cementing stream channels have been used to control erosion of the stream banks and the migration of the channel which together contribute to a loss of property value. These techniques also increase the capacity of the channel to carry flows and prevent local flooding. However, downstream unchannelized sites often experience increased flooding as a result. Riparian vegetation is impacted through direct removal during the channelization project or as a result of subsequent floods (see Chapter Four).

The general pattern in Arizona seems to be that development is allowed to occur in the floodplain prior to major flood events. Large floods inevitably come and wash out homes and property, and sometimes lead to personal injuries. As a result, riparian property owners often instigate lawsuits against local governments to recover their losses, and then seek channel modifications, hoping to forego disaster when the next flood hits. This cycle could be prevented with the local regulation of development in the floodplain. The natural character of the stream channel could thus be retained and the channel used as a recreational corridor for hiking, horseback riding, and other activities.

Public Activities in the Riparian Corridor

Public use of riparian corridors needs to be better managed. The increasing demand for stream- and wetland-based recreation will lead to increased use of riparian areas for public recreation activities. Increased use of these areas will lead to a greater likelihood for disturbance and destruction of the vegetation and wildlife. Human impacts to the environment can be mitigated by locating picnic tables, trails, and other recreational facilities in a manner which directs use into those areas that are least vulnerable to disturbance (see Chapter Five).

Effluent Re-use

The re-use of effluent (reclaimed water) is another variable in urban and agricultural areas affecting the future of riparian habitat. Municipal and agricultural wastewaters have restored some surface flows to riparian habitats that were once naturally perennial (Figure 2-3). Effluent is not by any means a substitute for natural streamflow, but it may be used in areas where natural flows are no longer found.

However, with water supplies becoming increasingly scarce, effluent is seen as an increasingly viable water source that can be used to augment surface water and groundwater supplies. There is, and will continue to be, competition for effluent. Golf courses and residential lakes are being required to use effluent, and when the distribution infrastructure is in place, more municipal and industrial users may also seek or be required to use effluent. Consequently, efforts should be directed at studying ways to incorporate effluent re-use into public riparian areas and in private uses so that everyone may benefit. If this does not happen, streams which have historically received effluent for incidental rather than purposeful reasons may soon be threatened due to competition for this water for other purposes.

Watershed and Riparian Land Use Practices

The impacts of non-recreational and recreational watershed and riparian land use practices are many, and collectively, they can severely impinge upon the recreational and natural values of streams and wetlands. The regulation of land use practices is extremely controversial, and there are currently no economic incentives in place to discourage detrimental activities.

The level of controversy is intense in this transitional urbanization period; some Arizonans value the economic and cultural contributions of certain land use practices, while others, particularly more recent residents of the state, see the same land use activities as being highly detrimental to the land and water ecosystem and as degrading or destroying the areas they enjoy for recreational, spiritual, and other purposes. The result is that proponents and opponents of certain land uses become highly polarized, failing to try to understand alternative values and perspectives. As the potential for conflict over the use of streams and wetlands heightens, a governmental forum for resolving problems needs to be established and carefully nurtured by communities, interest groups, and land and resource management agencies. A program of this type is proposed in Chapter Eight of this document.

Issue—Providing and Enhancing Stream and Wetland Recreation

The final issue identified in this chapter is the need for protecting and enhancing stream and wetland recreation. Previous chapters have discussed the resource losses that have already occurred in this state, and the trends pointing to increased demands for stream- and wetland-based recreation. Because the Arizona Rivers, Streams, & Wetlands Study was initiated for the primary purpose of identifying and assessing recreation needs, an entire chapter of this document (Chapter Nine) is devoted to a presentation and discussion of techniques that could be used to provide the most optimum stream and wetland recreational opportunities, and to conserve the resources on which these opportunities are based. The discussion below is but a very brief summary of these techniques.

Planning for Demand

Data presented in Chapter Five indicate that continued population growth in Arizona will result in further demand for stream- and wetland-based recreational opportunities. Increased demand can be translated into more intensive use in some areas, especially in areas close to rapidly growing communities. To what degree, how quickly, and where this demand will manifest itself cannot be determined without more comprehensive and specific data.

To effectively plan for Arizona's stream and wetland recreation future, federal, state, and local resource management agencies should gather data using a standardized procedure of collection and analysis. This data could be used for many purposes. Participation and economic data could be used to justify funding requests for new programs, sites, and facilities. Participation and attitudinal data could be used to better plan for and manage stream and wetland resources according to the public's recreation preferences.

Providing and Enhancing Recreational Opportunities

To ensure that existing and future recreation areas maintain the natural aquatic and riparian characteristics for which they were originally acquired, management agencies must continually focus on the conservation of streamflow and habitat. This means utilizing all available methods for protecting surface waters and groundwaters and managing all types of land use practices.

In addition to conserving the aquatic and riparian habitats upon which the recreational experience is based, agencies could also seek to enhance the experience by producing and distributing information to recreational users. This information could be in the form of recreational guides, some of which are already available describing the sites and opportunities available, access and facilities, minimal impact recreation practices, regulations, and safety hazards. Information could also be provided on-site, particularly at the put-ins of flowing water boating sites.

Providing and enhancing stream- and wetland-based recreational opportunities could also be facilitated through more and improved access and facilities at existing sites, and by acquiring and designing new sites.

Conclusion

Managers of Arizona's streams and wetlands need to be aware of the trends and events that will shape the future of these valuable and threatened resources. The decisions that are made in response to pressures that originate from these trends will determine the fate of streams and wetlands in Arizona. Only with continued awareness and involvement in stream and wetland issues can resource managers hope to ensure the continued survival of streams and wetlands for recreation and habitat uses.

The major trends that were identified in this chapter include:

- Continued population growth and the urbanization of Arizona
- Shifting attitudes about land, water, and riparian resource uses and management
- A diversifying economy which is heavily oriented towards manufacturing and tourism
- Shifting and increasingly complex patterns of water use

These trends will collectively result in further, but somewhat unpredictable, impacts to the state's aquatic and riparian resources. These impacts are most likely to occur in proximity to urban and urbanizing areas and to affect the quality of recreational experiences. Population and economic growth in these areas will lead to continued and intensified conflict over water resources, posing further threats to flowing and non-flowing surface waters and riparian habitats.

The policy issues that will determine to what extent and in what direction the stream and wetland futures are actualized include:

- The attainment of water rights for recreation and fish and wildlife habitat
- The resolution of Indian water rights and water issues
- The conjunctive management of surface waters and groundwaters
- The impacts of future water transfers

"The West is arid and water is life, health, and wealth."

Bernard Shanks
This Land Is Your Land

A CONCEPTUAL FRAMEWORK FOR GUIDING THE FUTURE RECREATIONAL USE AND CONSERVATION OF ARIZONA STREAMS AND WETLANDS

This chapter responds to the statewide stream and wetland management deficiencies identified by the Arizona Rivers, Streams, &Wetlands Study. It recommends four key management actions to ensure the continued recreational use and proper conservation of our state's stream and wetland resources. These actions include:

- *Enactment of a state streams and wetlands policy*
- *Development of a forum for intergovernmental coordination*
- *Development of a vehicle for active citizen participation*
- *Creation of a process within the state to coordinate implementation of the policy and establishment of an Arizona Streams and Wetlands Heritage Program*

Introduction

Through its various institutions—federal, tribal, state, local and private—Arizona has many of the elements necessary to manage its streams and wetlands. The capability to coordinate and integrate these assets to ensure comprehensive and consistent statewide protection and management of these resources is, however, lacking in the state. A basic deficiency in this area is that there are no established requirements, incentives, or mechanisms causing stream and wetland managers to coordinate, communicate, or cooperate to develop a consensus on appropriate management. Without such a statewide focus, each player in the complex mosaic of governmental jurisdictions, land ownerships, and water and riparian use interests acts independently according to individual values and priorities.

A policy and management framework is needed to provide a statewide perspective and direction to the myriad of public and private entities with a stake in stream and wetland management. The framework proposed in this chapter would motivate and mobilize the state's technical and policy interests to plan for statewide stream and wetland recreation and conservation.

Towards this end, Arizona needs to establish a statewide streams and wetlands policy and develop a program to implement that policy. The policy would set goals for the management and use of streams and wetlands and would acknowledge the state's commitment to conserve these resources. Emanating from this policy, the streams and wetlands program would:

- Interject a statewide perspective into the stream and wetland management responsibilities of land and resource agencies by encouraging coordination and communication among agencies responsible for these resource
- Promote citizen-government partnerships for stream and wetland management

- Identify management processes, programs, and actions that will facilitate implementation of the state streams and wetlands policy

A statewide streams and wetlands policy and management program are proposed in this chapter. These proposals incorporate the existing capabilities of federal, tribal, state, and local agencies and sponsor new ways to increase citizen participation in the management process. By integrating existing agency capabilities, the management program can be assembled without creating new agencies or realigning jurisdictions. The proposed approach has the additional advantage of embracing all levels of governmental involvement with streams and wetlands. Citizen participation will help promote more equitable and comprehensive treatment of stream- and wetland-based recreation and conservation issues.

The proposed policy and program are presented in the following order (Figure 8-1):

- Policy — Arizona Streams and Wetlands Policy

- Program — Arizona Streams and Wetlands Heritage Program

- Participation — Citizen Participation
  Land and Resource Management Agencies

- Coordination — Intergovernmental Coordinating Committee
  Arizona Streams and Wetlands Council
  Local Action Committees
  Program Administration

- Program Functions — Communication and Cooperation
  Education and Information
  Recreation Enhancements
  Streams and Wetlands Database
  Consistent Management
  Technology Transfer
  Critical Streams and Wetlands System
  Local Streams and Wetlands Programs

- Implementation — Policy, Participation, Coordination, and Program

The policy, coordination, and program elements would each provide significant benefits to Arizona even if conditions dictated that they were to be implemented separately or in stages. The full effectiveness and benefits of the concepts presented here will, however, be achieved only if the entire proposal is implemented. Full implementation is necessary if the state is going to have a comprehensive program to address stream and wetland management issues. The components of the proposed statewide policy and management program are described in following sections.

State Streams and Wetlands Policy

Policy Benefits

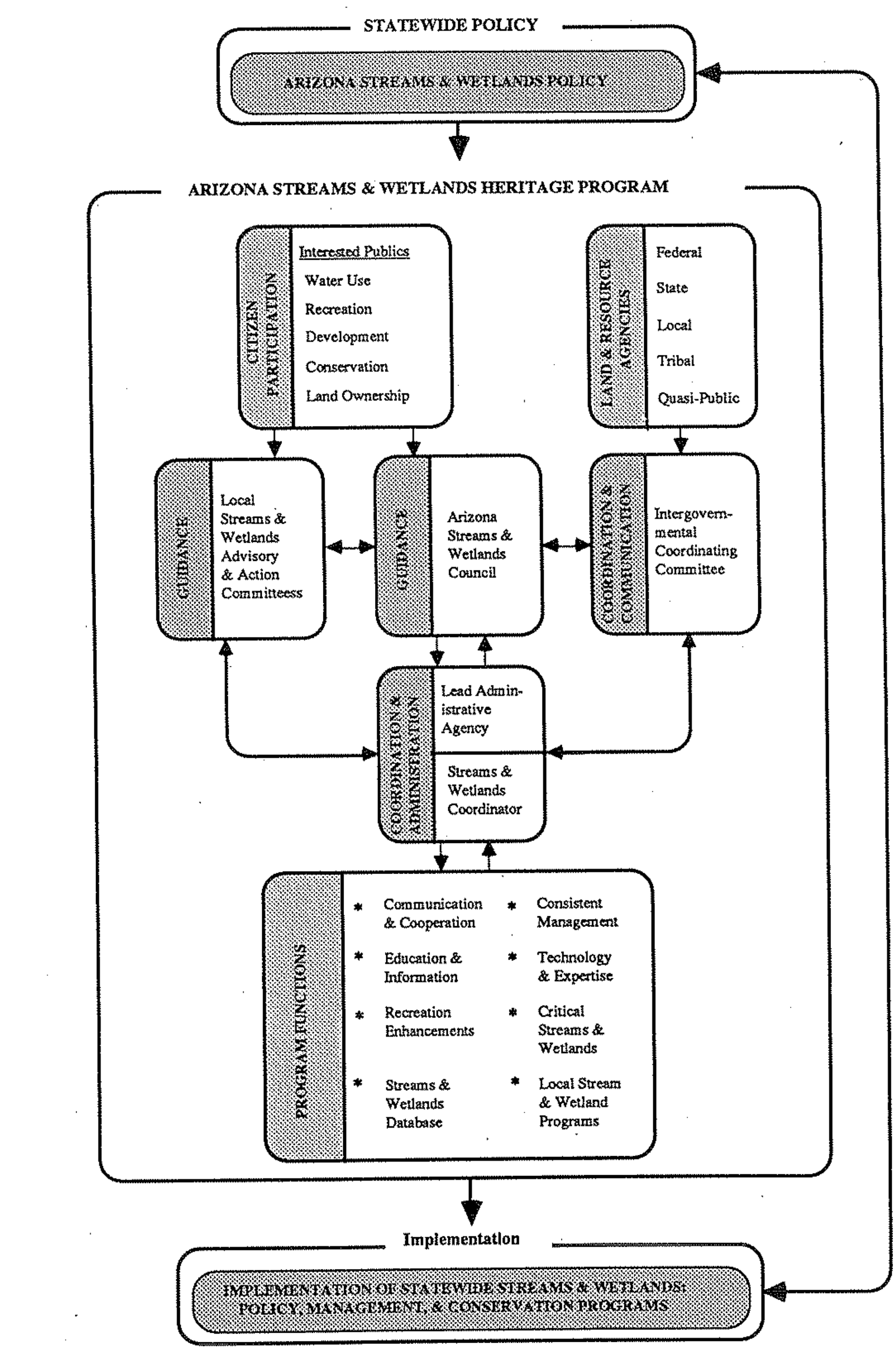
Establishment of a state policy for streams and wetlands will offer many benefits to those concerned with the wise use and conservation of these resources. Among other important benefits, a state policy will:

- Establish a statement of intent

- Provide a clarification of direction

- Establish a framework for problem solving

Figure 8-1.
A Conceptual Framework For Guiding Future Recreation Use & Conservation Of Arizona's Streams & Wetlands



By establishing intent, the state policy would give notice as to the will and resolve of the state, and define the purpose of the proposed program. Such a statement on behalf of streams and wetlands would help to establish consistency among state agencies in their individual and collective management efforts. For federal, tribal, and local agencies and for the public, the policy statement would be an important focal point that would greatly facilitate their response to and support of the state's desires for stream and wetland management and conservation.

The ability of policy to clarify direction is critical to establishing guidance for management and conservation programs. In this manner, the state streams and wetlands policy would further promote consistency among the efforts of agencies at the state and other levels of government.

As a framework for problem solving, the policy would provide a consistent standard against which the effects of management decisions could be weighed. State stream and wetland managers would benefit from clear guidance as to the intended purposes of the state. State policy would also inform public and private land managers of the support or concern they might expect from the state in response to their land and natural resource related activities. Overall, the consistency of a policy framework would lend evenness and clarity to solving stream and wetland management problems.

Policy Requirements

An effective state streams and wetlands policy must reflect the natural resource, economic, and social status of the state as well as various legal and political realities. Policy elements that address these important state characteristics are described below.

Policy Purposes

Two of the significant policy issues identified in this study stand out for their urgency and importance. First, is the over-riding concern for the conservation of the remaining streams and wetlands in Arizona. The expressed urgency of this need reflects the severe and disproportionate losses of Arizona's stream and wetland environments and the continuing threats to these resources. The second policy issue is that streams and wetlands are perceived as being vital to the well-being and quality of life of Arizonans.

Current state resource policies and management practices do not reflect the urgency or significance of these concerns. In response to these concerns, the primary purpose of the state policy statement proposed in this study is to recognize the great importance of streams and wetlands to Arizona's citizens and the critical need to conserve what remains of these dwindling and threatened resources.

Balanced Uses

If Arizona's supply of streams and wetlands was unlimited, there would be little need to balance or allocate use between competing uses. The supply of streams and wetlands in Arizona's arid environment is, however, extremely limited. In fact, the availability and integrity of these resources have been so severely depleted over the last century that there is virtually no reserve to compensate for the consequences of faulty decisions. Arizona has no choice but to take a position on how to best allocate its supply of streams and wetlands among competing and sometimes exclusive uses.

A policy that balances multiple uses could help to ensure that adequate consideration is given to the full range of user and resource consequences. A state requirement that decision-makers strike a balance among potential uses of streams and wetlands will ensure that recreation and conservation are considered legitimate and on a competitive par with resource development uses.

The balanced-use doctrine is well established in federal environmental law and administrative regulations and has provided important protection of stream and wetland recreation and conservation opportunities. Such a policy in Arizona would reinforce this doctrine on federal lands and provide direction for allocation issues on state and private lands.

Environmental Quality

Streams and wetlands are significantly influenced by human produced modifications of water courses and watersheds. Potentially impacted are the quality and quantity of waters as a result of changes in the composition or distribution of sediments and organic and inorganic nutrients or the introduction of human-made pollutants.

Existing state standards for stream and wetland environments offer only limited guidance for the management and conservation of these resources. State regulations for water quality, floodplain management, and fish and wildlife use exist, but these fall short of managing and regulating the aquatic and land components of riparian areas. An Arizona streams and wetlands policy could help correct this deficiency by establishing the state's resolve to maintain and restore the environmental integrity of these resources. Although the policy would not address specific regulatory actions, it could establish the direction necessary for formulating such actions.

Recreation and Fish and Wildlife Values

The protection of stream- and wetland-based recreation opportunities and fish and wildlife habitat could be significantly enhanced through an appropriate state policy. Arizona's streams and wetlands comprise less than one-half percent of the state's landscape yet they support many of the most popular, unique, and exceptional outdoor recreation experiences in the state. The significance of streams and wetlands as fish and wildlife habitat is related to the fact that they are essentially the only natural aquatic or aquatic-based environments in the state (all but two of the larger lakes are human-made). As such, streams and wetlands harbor Arizona's richest diversity of fish and wildlife species and support the greatest plant and animal productivity. Neither the essential importance of streams and wetlands as recreation sites nor as fish and wildlife habitat is now recognized as state policy. The proposed policy statement would confirm the importance of these resource values and mandate their conservation for the betterment of all citizens.

Critical Resources

Although Arizona is widely known for its desert landscape, its streams and wetlands are some of the most unique and outstanding natural environments in the state. Streams and wetlands are among Arizona's most critical fish and wildlife habitats and have been of great cultural significance since the earliest native peoples arrived in the state. Unfortunately, the state has lost much of its rich natural and cultural inheritance as the growing requirements of agriculture, mining, industry, and cities have redesigned extensive portions of the stream and wetland landscapes. The significance of these resources to contemporary Arizona life remains at the highest levels. Streams and wetlands continue to harbor populations of native fishes and wildlife, support increasingly popular recreation activities, moderate flood peaks and retard erosion, enhance groundwater recharge, and constitute open space and greenways in congested urban settings.

In order to protect the remaining native fish and wildlife in Arizona and conserve recreation opportunities and other special amenities, critical and outstanding streams and wetlands may require special management attention. This study has found a strong and positive need for the state to identify and manage selected streams and wetlands for the purposes of conserving recreation opportunities, habitat, water quality, stream flows, and other values. State policy is needed to lay the groundwork for such appropriate management programs.

Stream and Wetland Restoration

A critical finding cited throughout this report is that Arizona's native stream and wetland habitat has been severely depleted. The flows of all of our major rivers and many of the lesser streams of the state have been impounded, regulated, and diverted. Many other perennial streams and wetlands have disappeared as groundwater pumping drained the water from the supporting aquifers and land use practices altered the hydrology of the watersheds. Riparian habitats have suffered extremely disproportionate losses compared to upland areas. It is estimated that only five to ten percent of the original native riparian habitat in Arizona remains. Although once common, riparian habitats are now Arizona's most rare and threatened natural communities. Cottonwood-willow gallery forests, which once formed lush canopies along all of Arizona's major desert river systems, have become the rarest forest type in North America. Mature stands of mesquite bosques have suffered similar declines and are now the fourth rarest plant community in the United States.

Despite these losses, important opportunities still exist to restore streams and wetlands through techniques such as urban planning and storm runoff management, appropriate watershed and land use management practices, instream flow permitting, stream channel and bank protection measures, and modified release schedules from stream impoundments. The establishment of the state policy would enable the state to pursue the potential these opportunities offer to reclaim some of its lost inheritance and improve the quality of its environment.

Cooperation and Communication

The ability to adequately conserve and manage streams and wetlands in Arizona has been hindered by the numerous and diverse governmental jurisdictions, land ownerships, and water and riparian use interests that have no effective lines of communication or cooperation for stream and wetland management. The effective management of streams and wetlands will depend in part on the degree to which communication and cooperation among these varied parties can be augmented. A state streams and wetlands policy is one vehicle for promoting this important objective.

Proposed Policy Statement

Based on the findings of this study, the following policy statement is recommended as a first step in establishing a statewide framework for the management of streams and wetlands in Arizona.

Proposed Arizona Streams and Wetlands Policy Statement

The State of Arizona finds that the well-being and quality of life of its citizens depends on achieving and maintaining an equitable balance among the competing uses of the state's streams and wetlands, while maintaining the natural integrity of these resources. This balance must:

* Recognize the traditional and changing interests in and uses of streams and wetlands.
* Recognize that the conservation and wise use of stream and wetland resources is in the best interest of all citizens of the state.
* Conserve stream and wetland waters for water-based recreational uses and for fish and wildlife habitat.
* Restore degraded streams and wetlands for future generations to use and enjoy.
* Expand and promote stream- and wetland-based recreational opportunities.
* Identify and conserve critical recreation, habitat, water quality, and instream flow water values of the state's streams and wetlands.

Further, to provide for this balance of uses the state will:

* Foster an atmosphere conducive to communication and cooperation among competing stream and wetland users so that an equitable allocation of these finite resources can be achieved.
* Provide guidance and authority for consistent and coordinated management of streams and wetlands.

Arizona Streams and Wetlands Heritage Program

As stated previously, the purpose of the Heritage Program is to provide the means for implementing the state streams and wetlands policy. To accomplish this task, the proposed program is a management framework composed of four basic elements (Figure 8-1).

The program is designed to:

- Promote citizen and agency participation in statewide stream and wetland issues
- Increase communication and coordination between those involved with stream and wetland issues
- Emphasize and complement existing agency programs for stream and wetland conservation and management

- Establish needed programs (or functions) for stream- and wetland-based conservation and recreation

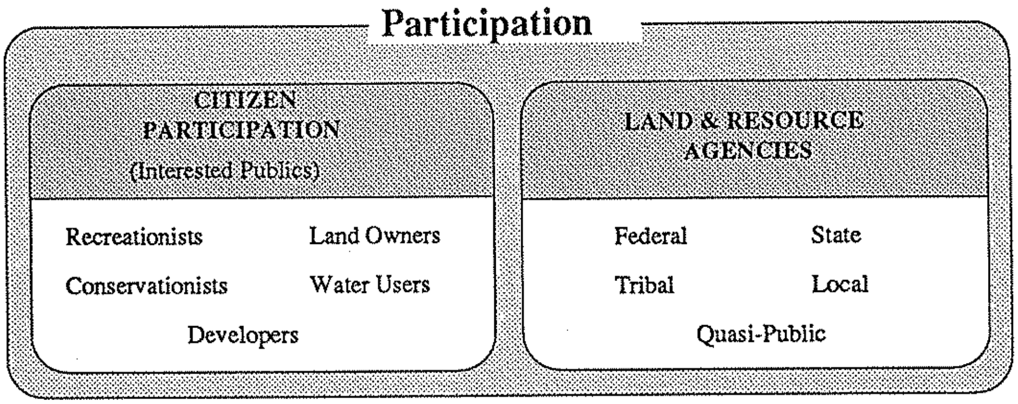
The program title, recommended by the Study Core Group, was selected to emphasize the significance of the state's stream and wetland heritage and the need to conserve the natural, cultural, and recreational values of these resources.

The proposed Heritage Program would not supplant existing authorities or programs, nor, as noted before, would it create a new bureaucracy. Rather, the program would support existing state, federal, and local programs by providing mechanisms for building consensus for consistent, directed actions. Once again, the overall goal would be to promote the wise use of Arizona's stream and wetland resources.

Program Participation

The management of Arizona's lands and waters is characterized and influenced by a complex pattern of land and natural resource agency jurisdictions at all levels of government, by diverse citizen landowners, and by recreation, conservation, and economic interests. A great deal of legal and behavioral autonomy separates the decisions and actions of many of these parties and, currently, there is no one jurisdiction or authority that can effectively direct or motivate their activities in support of a common statewide stream and wetland management effort.

The Heritage Program proposed by this study recognizes the implications posed by Arizona's diverse land and water management, ownership, and use patterns, and advocates a structure to integrate participation by representatives from all concerns.



Effective management of streams and wetlands in Arizona on a statewide basis will depend on the participation and cooperation of all of these parties. Recommended participants in the program are identified in two groups: (1) land and resource agencies, and (2) citizen participants.

<u>Land and Resource Agencies</u>

Agency participation in the Heritage Program could be incorporated through an intergovernmental agreement and intergovernmental coordinating committee as described later in this chapter. Agencies that have responsibilities relating to stream and wetland management and that should be given the opportunity to participate include the following.

Federal Land and Resource Management Agencies. Federal agency participation in the Heritage Program is essential as these agencies manage sizeable portions of

Arizona's landscape, regulate stream flows on a number of important Arizona rivers, and offer a wealth of expertise on stream and wetland management. An additional reason for federal involvement in this state-sponsored program is that state-federal-citizen interactions on Arizona stream and wetland issues will help to increase the visibility of the state's interests and priorities within the federal structure.

In Arizona, the federal agencies with responsibilities relating directly to stream and wetland management are:

- USDA Forest Service
- USDA Soil Conservation Service
- USDI Bureau of Land Management
- USDI National Park Service
- USDI Fish & Wildlife Service
- USDI Bureau of Reclamation
- DOD Army Corps of Engineers

Indian Tribes and Tribal Organizations. Arizona's Indian Tribes are located on twenty-one separate reservations, comprising twenty-eight percent of the state's total land area. These lands contain some of the most significant stream and riparian areas in the state. Tribal input to a state streams and wetlands program could be through Tribal Councils and their natural resources subcommittees and/or the Inter Tribal Council of Arizona, Inc.

State Agencies. Agencies of the State of Arizona have numerous responsibilities for stream and wetland management. Among these responsibilities are land ownership and stewardship, water quantity and quality regulation, fish and wildlife management, public parks and recreation, environmental quality, and tourism. State agencies that could most appropriately be involved in a statewide streams and wetlands program include:

- Arizona State Parks Board
- Arizona Game & Fish Department and Commission
- Arizona Department of Environmental Quality
- Arizona Department of Water Resources
- Arizona State Land Department
- Commission on the Arizona Environment
- Arizona State Historic Preservation Office
- Arizona Outdoor Recreation Coordinating Commission
- Arizona State Office of Tourism

Local Governments. Local governments could have a significant positive effect on the implementation of state policy and the enhancement of local stream and wetland recreation and conservation. Local government could also provide valuable insight and experience to state, tribal, and federal perspectives on statewide decision-making. Local participation in a state streams and wetlands program could occur at several levels within county or municipal government and local government associations. Potential participants could include:

- Counties: Park or Planning & Zoning Departments, or Flood Control Districts
- Cities: Parks, Planning & Zoning, Water and Wastewater, or Flood Control Departments
- The Councils of Government
- The League of Arizona Cities & Towns
- The Arizona Association of Counties

Salt River Project. The Salt River Project plays a major role in the management of significant portions of the Salt, Verde, and Agua Fria Rivers. This quasi-public agency could contribute greatly to cooperative stream and wetland management efforts and should be included in any intergovernmental coordination initiative.

Citizen Participation

It goes almost without saying that citizen participation is an essential ingredient in any state sponsored program. This is particularly true of a program with such diverse interests as there are with the state's water resources. The management framework presented here provides for public participation at both state and local levels, at the state level through a Streams & Wetlands Council, and at the local level through Streams & Wetlands Action Committees, corridor planning studies, and other stream specific activities. Details about citizen participation will be discussed in the following section on Coordination.

Representation on the Council and in local efforts could include a broad range of citizen interests. Among these are:

- River Boating Organizations
- Environmental Groups
- Mining
- Livestock Producers
- Anglers and Hunters
- Agriculture
- Off-Highway Vehicle Clubs
- Urban Development Interests
- Commercial Recreation Interests

Coordination

One of the principal functions of the proposed Heritage Program is to provide a process for coordinating the many and varied interests and capabilities within the state to focus on stream and wetland issues. The purpose of this process is to find more effective ways to enhance statewide opportunities for stream- and wetland-based recreation while also ensuring that the overall natural integrity of these resources is conserved.

The coordinating functions of the program would be performed by four entities (Figure 8-1):

- The Intergovernmental Coordinating Committee
- The Arizona Streams & Wetlands Council
- Appropriate local streams and wetlands actions
- A lead administrative agency and a program coordinator

The structures of these entities and the relationships among them have not been rigidly defined by this study. Rather, discussions here are limited to the broader conceptual functions and interrelationships that are envisioned for this coordinating component of the proposed framework. Descriptions of the four entities identified as having coordinating functions follow.

Intergovernmental Streams & Wetlands Coordinating Committee and Intergovernmental Agreement

An intergovernmental agreement among the State of Arizona, federal land and resource management agencies, Indian Tribes, quasi-public agencies, and representatives of local governments could be developed for the purposes of:

- Facilitating participation and communication among agencies and Indian Tribes with management responsibilities for streams and wetlands

- Promoting intergovernmental consistency regarding policy and the management of streams and wetlands

Both of these functions would do much to implement the streams and wetlands policy. Participants in the intergovernmental agreement should include the agencies identified in the Land and Resource Agencies section of this chapter. Representatives from these agencies would form an Intergovernmental Streams & Wetlands Coordinating Committee. A lead agency and Streams & Wetlands Coordinator (discussed later in this chapter) would provide administrative support to the Committee. This Committee would meet at least biannually to:

- Provide and share information pertinent to stream and wetland management
- Exchange members' viewpoints on stream and wetland management goals
- Identify existing and potential inconsistencies in management purposes and practices
- Develop strategies for improved intergovernmental management coordination, consistency, and technology transfer

This study has identified at least eleven federal and ten state agencies with either primary or ancillary involvement in the management of streams and wetlands in Arizona (Tables 7-1 and 7-2). Add to these figures, twenty-one Indian Tribes, fifteen counties, dozens of municipalities, and the Salt River Project, and the number of separate governmental units involved in or influencing the management of the state's streams and wetlands becomes quite large. Potential problems arising from attempting to run effective and efficient meetings with such a large group of concerned agencies could be minimized by utilizing executive committees, subcommittees, and, where possible, a single individual that could represent groups with similar concerns.

Although the level of involvement among these agencies with the Intergovernmental Coordinating Committee will vary, appropriate participation by each should be encouraged in order to promote the communication and consistency necessary for effective streams and wetlands management.

<u>Arizona Streams & Wetlands Council</u>

An Arizona Streams & Wetlands Council composed of public interest representatives concerned with the use, management, and conservation of streams and wetlands should be created. The Council would:

- Provide a means for fully integrating public concerns into state stream and wetland planning and management activities and for monitoring efforts to attain state policy goals for these resources
- Provide public advice on management purpose and priorities to the Intergovernmental Committee
- Provide a forum for the discussion and possible resolution of issues relating to the use and conservation of Arizona's streams and wetlands

Membership on the Council would be broad enough to include the major citizen interests in stream and wetland recreation, conservation, and use. Potential representation on the

Council is identified in the Citizen Participation section of this chapter.

The Council would be expected to play a strong role in developing state agendas for stream- and wetland-based recreation and conservation. In fulfilling this role, the Council would work in a close advisory capacity with the Intergovernmental Coordinating Committee. The State Streams & Wetlands Coordinator (described later in this chapter) would help facilitate Council activities. Interaction between the Council and the Intergovernmental Coordinating Committee would form the basis for a citizen-government partnership for the management of stream- and wetland-based recreation and conservation. The goals and efforts of both would benefit from the exchange.

Local Streams and Wetlands Actions

Experience in both Arizona and other states has shown that local conservation and promotional efforts for streams or wetlands are often among the most effective management strategies. The formation of local streams and wetlands action committees, where appropriate, would therefore be established in order to:

- Encourage local efforts to conserve, manage, and balance uses of streams and wetlands

- Integrate local involvement into statewide policy, planning, and management

The makeup and objectives of these committees could vary according to local needs. As appropriate, local or regional groups could focus on either: (1) action items on a specific stream or wetland, or (2) broader planning and coordination issues. The Arizona Streams & Wetlands Council could play an instrumental role in promoting the formulation of some local committees. Others would be formed from local initiative. Either way, the efforts of these groups should be coordinated with the Council to gain a broader basis of support and to ensure that the state is sensitive to local concerns.

Program Administration and Streams & Wetlands Coordinator

Successful implementation of new policies and programs require strong leadership and adequate staff support. These considerations are particularly relevant to an initiative such as the proposed streams and wetlands policy and program which will require both a great deal of coordination among agencies and the public and the facilitation of a variety of activities.

In Arizona, there are several state agencies whose missions closely parallel the objectives of the proposed streams and wetlands program. These are the Arizona Game & Fish Department, the Arizona Department of Environmental Quality, Arizona State Parks, and to a lesser extent, the Arizona Department of Water Resources and the Commission on the Arizona Environment. No one agency has the authority or mandate to accomplish such a program on its own. Several agencies have ongoing programs that complement the proposed program and all will likely benefit from actions taken through the new program.

The Arizona Game & Fish Department is responsible for managing stream fisheries and, as such, plays important roles in a range of stream conservation and use issues. The Department of Environmental Quality is responsible for managing all aspects of water quality. One component of this responsibility is the administration of the state's "Unique Waters" Program which seeks to protect high quality waters of streams with significant recreational or ecological values. Arizona State Parks sponsored the Arizona Rivers, Streams, & Wetlands Study. State Parks also has the responsibility to identify and conserve areas of natural features, scenic beauty, and historical and scientific interest for the education, pleasure, recreation, and health of the people. The Arizona Natural Areas Program, administered by State Parks, and a variety of other recreation programs relate directly to rivers and streams. The Arizona Department of Water Resources is responsible for adjudication of water rights and for determining instream flow rights. The Commission on the Arizona Environment gathers resource information and provides a forum for environmental issues. The latest emphasis of the Commission has been a comprehensive public involvement project centering around riparian issues.

Any one of these agencies could provide the leadership required to successfully implement the proposed streams and wetlands program. To ensure the effectiveness of such a comprehensive program, a lead agency needs to be designated that can provide the needed interagency coordination. An arrangement that would provide for joint sharing of responsibilities by these agencies might also be appropriate. Regardless of the lead agency, each agency should play a strong role in the program and incorporate elements of the program into ongoing activities.

One to two staff positions would likely be sufficient to carry out many of the proposed program's essential functions. At a minimum, the initiative will require an Arizona Streams & Wetlands Program Coordinator. The program coordinator would perform a series of essential tasks, including establishing and maintaining lines of communication between the participants identified earlier in this chapter, coordinating the activities of the Interagency Coordinating Committee and the Arizona Streams & Wetlands Council, facilitating local efforts, and otherwise attempting to ensure that stream and wetland policy objectives are met.

State Parks is budgeting for a Streams & Wetlands Coordinator position. Additionally, this agency is planning to sponsor, in the near future, at least one stream conservation project as recommended by this study. As State Parks anticipates taking a continuing strong role in statewide stream and wetland issues, that agency should continue its initiative, as established by this study, to promote the full implementation of the study recommendations. An appropriate and needed role for the first crucial years of the Heritage Program is that of facilitator and State Parks has already begun serving in that role through the creation of the Streams & Wetland Core Group that assisted with this study. Close coordination between State Parks and such agencies as Environmental Quality, Game & Fish, and Water Resources will be essential for successful implementation of the program.

Program Functions

As noted previously, the proposed Heritage Program has an open structure consisting of existing agencies and public interests and incorporating their programs and capabilities. Each of these programs and capabilities would lend strength and support to the framework of the Heritage Program. In reaching its full potential, however, the framework should establish its own management programs upon which its participants could focus. Among these management functions would be:

- Foster communication and cooperation among agencies, users, and landowners on issues concerning the state's streams and wetlands through the Council and its extended membership

- Educate and inform Arizonans—including agencies, the public, private organizations, landowners, and business enterprise—on the diverse values and multiple uses of the state's streams and wetlands

- Share technology and expertise with agencies, the public, private organizations, and business enterprises on matters concerning the management of streams and wetlands

- Identify and promote means for enhancing stream- and wetland-based recreation, including:

  Develop and distribute information concerning stream- and wetland-based recreational opportunities

  Monitor and address the need for improved or additional access and facilities, and other recreational needs

  Educate agencies and the public on minimal impact stream and wetland recreation

  Monitor and investigate water quality problems, natural hazards, and other safety concerns related to stream and wetland recreation

  Pursue opportunities to restore stream and wetland resources or create new habitats

- Recommend and promote coordinated and consistent management policies and practices for the conservation and wise use of the state's streams and wetlands

- Maintain and update the Arizona Streams & Wetlands Database, which was initiated as a result of the Arizona Rivers, Streams, & Wetlands Study

- Establish and maintain a streams and wetlands library containing up-to-date information on: current research; federal, state, and local policies, programs, statutes, laws and regulations; and other relevant information

- Identify streams and wetlands possessing critical recreation, habitat, and stream flow attributes and develop appropriate methods for ensuring their conservation

- Recommend appropriate, consistent, and coordinated management policies and practices for streams and wetlands identified as possessing critical recreation, habitat, or instream flow water attributes

- Lend support and expertise to local and site specific efforts to develop recreational opportunities and conservation measures for streams or wetlands

Outlining the priorities among the Heritage Program functions would be a key task of the Arizona Streams & Wetlands Council and the Intergovernmental Coordinating Committee. Selecting appropriate strategies to implement these functions would also require consultation between these two bodies. A fairly extensive listing and discussion of alternative strategies that could be used to accomplish the Heritage Program functions is presented in Chapter Nine.

Policy and Program Implementation

A series of steps for implementing the proposed streams and wetlands policy and program are outlined in this section. These steps are based on the assumption that the entire framework will be implemented. Full implementation is one alternative; other options include the implementation of selected elements of the framework and staged implementation.

Options

There are four basic options for implementing the proposed policy and management framework: legislation, executive order, Governor's directive, and the intergovernmental agreement.

Legislation

The State Legislature could pass an act establishing a streams and wetlands policy and management program. Depending on the language of the enabling act, the policy and program would be binding on state agencies, local governments, and private citizens and enterprises. Federal and tribal compliance would be voluntary. An intergovernmental agreement with federal agencies and Indian Tribes could be solicited to supplement state legislation.

The primary advantages of this implementation alternative are its relative permanence and its ability to set the stage for state budget appropriations for streams and wetlands programs. As part of the process for writing the bill, existing laws that affect the management of streams and wetlands could be reviewed and inconsistencies and conflicts resolved as part of the new legislation. In addition, legislative endorsement would indicate that stream and wetland management is indeed a statewide priority.

There are also disadvantages to this implementation technique. Several years are often required to pass legislation. The bill that is ultimately passed may no longer represent the original intent and provisions of the original proposal. Subsequent amendments to the legislation may be difficult to pass. In addition, while a legislative mandate may provide a justification for requesting state funding of an activity, it does not guarantee that funds will be appropriated. Thus, an agency may find itself with additional responsibilities, but lacking additional resources.

Executive Order

The Governor could also implement the streams and wetlands policy and program through an Executive Order. The policy would remain in force unless rescinded or amended by a subsequent Executive Order.

The advantages of this approach are that, next to legislation, it has the greatest permanence, and most closely represents the will of the governing body of the state. It does not, however, have the same force as law, as only those agencies directly under the Governor's supervision would be affected. Also, establishment by Executive Order is not considered to be adequate justification for state funding (other than for the Governor's discretionary funds). In addition, the implementation of the Executive Order is completely at the Governor's discretion; the Governor would, therefore, be the only one who could enforce compliance.

Governor's Directive

A Governor could also implement the framework by simply directing state agencies to comply with it. In this case, an executive order would not be issued and the framework would remain in effect only as long as the directing Governor continues to support it.

This approach has the advantage of Executive endorsement, but it has even less permanence than an Executive Order. The disadvantages are similar to those of an Executive Order. A Governor's directive is considered a weak approach and would be preferred only as an interim measure, pending legislation.

Intergovernmental Agreement

The conceptual framework could also be implemented through an intergovernmental agreement between some combination of state, tribal, federal, and local agencies. This agreement could be used to supplement state legislation or gubernatorial action or it could be used independently.

The primary advantage of this approach is that it could be done independently of the other implementation approaches at the initiative of any combination of federal, state, tribal, and local government agencies. However, the effectiveness of this approach depends upon the number of signatories and the nature of the agreement. Without support from the legislature or the Governor, some state agencies might be reluctant to participate in such a cooperative agreement. Other levels of government might not be motivated to join in an agreement that does not include all the relevant state agencies. An agreement is completely voluntary; there are no measures to ensure the participation or compliance.

Recommended Strategies

Legislation

Legislation is the primary goal of the policy and implementation section. *A legislative protection act that outlines the authority, funds, and agencies that should be involved in the implementation of the Streams & Wetlands Heritage Program needs to be passed.* The act will give permanence and a method for funding the needs of the program.

Policy

Prior to the passage of the protection act, however, a state policy that establishes the intent and provides clear direction for the management of the state's streams and wetlands should be acknowledged by the Legislature and the Executive Branch. The policy, established through legislative resolution and/or executive order, serves as an educational tool to bring the issue of stream and wetland management before the state's lawmakers. *The policy provides clear direction to state agencies to carry out all statutes carefully considering the protection of Arizona's stream and wetland resources.*

Intergovernmental Agreements

Intergovernmental agreements should only be considered as a *part* of legislation and the overall Heritage Program. Agreements by themselves, without legislation or an executive order to lend weight and authority, will probably not achieve the necessary goals.

An integrated approach, utilizing several strategies, is necessary to accomplish the comprehensive program outlined in this chapter.

Conclusion

Arizona urgently needs to establish a state policy supporting and promoting the conservation and wise use of streams and wetlands and recognizing their significance as natural, cultural, and recreational resources. Appropriate legislation towards this end is desirable, but as a more immediate, and perhaps interim solution, the Governor's support through an Executive Order should be sought.

Another important near-term priority is the formation of an Interagency Agreement to establish a forum for direct communication and cooperation among federal, tribal, state, and local agencies on stream and wetland issues. This step can be taken at agency initiative.

Formation of a Streams & Wetlands Council for citizen participation and the statewide level is also a first order of priority that could be initiated in the near future.

Together, the state policy, Intergovernmental Agreement, and Council form the heart of the proposed streams and wetlands program. These entities are purposefully people oriented. People, rather than new infrastructures, will build the Arizona Streams & Wetlands Heritage Program.

One other factor worth mentioning here that would contribute to the success of the Heritage Program is the need to find opportunities in the near future for the Intergovernmental Coordinating Committee and Citizens Council to contribute meaningfully to statewide management of streams and wetlands. Involvement in statewide studies, such as the effort reported in this document, would be a great springboard to launch the coordinating committee and council. Efforts to establish these bodies in the near-term so that they may contribute to work that will be occurring in the not-so-distant future could pay great dividends to the overall success of the statewide program.

"Support is required not just for a battle here, or a rear-guard action there, but for a fundamental and continuing program to make our country a better place in which to live, a cherished place of beauty passed on with pride from one generation to the next."

Henry Jackson

STRATEGIES FOR ENHANCING RECREATION USE AND CONSERVATION OF ARIZONA STREAMS AND WETLANDS

This Chapter describes strategies that could be used to enhance recreation use and conservation of Arizona's streams and wetlands. These strategies vary in their scope and effectiveness, and are intended to provide an idea of the range of opportunities available for managing streams and wetlands. Optional strategies are presented to enhance:

- *Stream- and wetland-based recreation*
- *Awareness of and knowledge about stream and riparian resources*
- *Local government and community involvement in stream and wetland conservation*
- *Conservation of critical streams and wetlands*

Introduction

This chapter presents a list of available and possibly applicable strategies for enhancing public recreation opportunities and conserving natural values associated with Arizona's streams and wetlands. The list is not all-inclusive. It does, however, include a range of options that respond directly to Arizona's needs and socio-economic realities. Four types of strategies are presented in this chapter: (1) strategies to enhance stream- and wetland-based recreation; (2) strategies to enhance awareness of and knowledge about stream and riparian resources; (3) strategies to enhance local government and community involvement in stream and wetland conservation; and (4) strategies to enhance and conserve critical streams and wetlands.

Not all of the strategies are likely to be implemented. Possibly some should not be. Some may contain aspects that are somewhat controversial; others will be readily accepted. Some may require authorization or special funding; others can be easily implemented through existing programs. Some could result in substantial resource and use enhancement; with others the change would be more modest. All deserve consideration as Arizona creates a program for the wise use of its streams and wetlands.

Strategies to Enhance Stream and Wetland Recreation

There are many techniques available to enhance and expand stream- and wetland-based recreational opportunities in Arizona. Seven possible techniques are discussed below. The first is the enactment of a statewide law to provide public access to streams and wetlands with significant recreational values. The second technique is an assessment of recreation and facility needs. The third concerns the need to incorporate public access into local, state, and federal programs. The fourth strategy deals with techniques for maintaining and conserving streamflows for recreational and ecological purposes. To ensure that the benefits of streamflows are enjoyed by the recreating public, the fifth strategy concerns the dissemination of streamflow information. Strategy number six focuses on recreation and nature appreciation brochures. Finally, to ensure that land and resource management agencies can keep abreast of the state's continually changing recreation needs, the seventh strategy deals with ongoing recreation research.

Recreation Access Law

The State of Arizona could enact a streams and wetlands public access law consistent with the rights of landowners to provide for public access to streams and wetlands with significant recreation potential.

Many of Arizona's rivers and streams that offer quality recreation opportunities are located on federal lands. In most instances, the public is allowed open access to these waters. Other significant rivers and streams, including most that are close to populated areas, flow through private lands. Here, access is more restricted. While the public would benefit from increased access to these waters, landowners are often hesitant to grant this access due to concerns that their properties might be damaged or that they might be held liable for injuries suffered on their lands.

The State of Montana has taken a novel approach to dealing with a similar situation by enacting a stream access law. The law says that rivers and streams capable of recreational use (such as fishing, hunting, swimming, and boating) may be used by the public regardless of streambank ownership. Recreationists can use these waterways up to the ordinary high-water mark. The law does not allow an indiscriminate right to cross private property to get to the water. The law also identifies certain responsibilities of recreationists regarding portage and respect for private property, and limits the situations in which a landowner may be liable for injuries to people using a stream flowing through private property.

Note: The State of Arizona passed H.B. 2017 relating to ownership of streambeds. This act is currently being challenged in the courts. The outcome of the judicial decision will have a significant bearing on the accessibility of the state's streambeds for recreational use.

Recreation Access and Facility Needs Assessment

Arizona State Parks could assess recreational access and facility needs associated with streams and wetlands, and develop a strategy for meeting these needs.

Access is a major determinant of the type and amount of recreational use that a river or stream will receive. In Arizona, the adequacy of access depends on a number of factors including terrain, availability of roads, and rights of passage. Another major determinant is the nature of the facilities provided for recreational users. A river having improved launch and take-out areas, campgrounds, and/or sanitary facilities will attract relatively more users and often alter the type of user as well.

An evaluation of existing access and facilities could support the state's efforts to provide its citizens with adequate and diverse recreation opportunities.

One successful example of an access and facility needs assessment was conducted in Maine. Using contracted services at a cost of $25,000, Maine's Bureau of Parks & Recreation surveyed access needs on approximately forty rivers and streams. The streams selected for this assessment came from a previous study that identified rivers and streams with high recreation and natural resource values. The findings from this study have been incorporated into the state recreation management plan. Selected access points have been established, and others are programmed for future action.

In Arizona the specific objectives of such an assessment would be to:

- Identify existing public access to rivers, streams, and wetlands with significant recreation potential
- Identify recreation facilities
- Assess current and future demands
- Evaluate the adequacy of existing access and facilities
- Develop strategies for increasing, or as appropriate, decreasing public access and providing for needed facilities

This study could build on the database developed through the Arizona Rivers, Streams, & Wetlands Study as well as other elements of the SCORP process, including the Statewide Trails Plan's identification of opportunities afforded by existing and abandoned rights-of-way.

Where additional access is found to be in the public interest, a number of implementation mechanisms could be employed including the donation, lease, or purchase of recreational access rights, and the acquisition of selected parcels by donation, purchase, or land exchange.

Funding for limited acquisition and improvements to facilities could be a shared responsibility of the state, local governments, private user groups, and private industry. Consideration should be given to augmenting funding through the U.S. Department of the Interior's Land & Water Conservation Fund and the State Lake Improvement Fund (SLIF). SLIF has been successfully used for such activities in the past, notably to improve recreational boating facilities along the Colorado River and at Beasley Flats on the Verde River. Funds were appropriated in 1988 to develop a rivers and streams guide that would highlight those streams with recreational boating potential and identify existing facilities.

Incorporating Public Access into Local, State, and Federal Programs

The Governor could direct all appropriate state agencies and encourage federal agencies to specifically consider recreational access needs in their planning and management activities and encourage federal agencies to do likewise.

Agencies, such as the Department of Transportation, could specifically incorporate recreation access into development programs. State and federal agencies with regulatory responsibilities could consider incorporating public access into their permit requirements.

Tying public access to facility development has been successfully applied in Massachusetts where the Department of Transportation provides funding for the purchase or improvement of areas adjacent to bridges scheduled for structural improvement.

To varying degrees, many states, including Arizona, currently utilize the regulatory process to increase public access opportunities. Oregon, Washington, and Montana are particularly aggressive in pursuing this strategy and could serve as models. Through their regulatory and planning functions, the U.S. Fish & Wildlife Service, the Army Corps of Engineers, and other federal agencies also have opportunities to help increase public access. These agencies should be encouraged to do so.

Streamflow Maintenance for Recreational and Ecological Purposes

The State of Arizona could actively pursue opportunities for maintaining and, in some instances, enhancing flow on river stretches possessing significant recreation and conservation values.

In Arizona, as in other western states with limited surface water resources, efforts to maintain or enhance streamflow for non-consumptive purposes face a myriad of difficulties. The issue of water rights is complex; on streams with intensive consumptive-use demand, actions to reserve flow can have major legal, economic, and political ramifications.

A detailed discussion of this topic is beyond the scope of this study. There are, however, a series of actions that could be taken within the existing legal and political frameworks that might provide benefits to stream and wetland ecology and recreational use.

To serve recreation and conservation needs, the Arizona Game & Fish Department and Arizona State Parks, in consultation with the Arizona Department of Water Resources, could:

- Promote the establishment of a formalized mechanism for integrating recreation and conservation needs into the state's water right application and permit process (see discussion under "Implementing a Critical Streams & Wetlands System" later in this chapter)
- Identify river and stream areas where recreation and conservation could benefit from secured streamflow. (Some of the more popular recreation areas are discussed in Chapter Four)
- Facilitate efforts by public and private organizations to secure water rights by providing expertise and logistical support to meet the technical requirements of the permit applications
- Promote efforts by private water rights holders and flow regulators to provide flows adequate for recreational and conservation purposes

Cooperative efforts with flow regulators might prove to be a particularly effective and realistic option. For example, rescheduled releases from dams could be negotiated where increased flow could provide or extend the time of a significant boating or tubing experience. Nationwide, several private and public water regulators have initiated programs of this type. In Arizona, of course, the classic example of this is the scheduled release program for the Colorado River through the Grand Canyon National Park, allowing for extended boating use throughout the year. Other impoundment sites in Arizona where this technique might be used include: (1) on the Salt River below Stewart Mountain Dam, (2) on the Bill Williams River below Alamo Dam, and (3) on the Verde River below Bartlett and Horseshoe Dams.

There are also examples of private water rights holders taking action to preserve streamflows. As one rather extraordinary example, the Pittsburgh & Midway Coal Mining Company donated its rights to flows in Colorado's Gunnison River to The Nature Conservancy. This generous action will help to conserve one of America's great river canyons, the Black Canyon of the Gunnison.

While opportunities such as this might be rare, there may be opportunities in Arizona for the state, possibly with assistance from an organization such as The Nature Conservancy, to arrange water rights donations, leases, or bargain purchases with large water rights holders who have no current need of the water and might benefit from the tax savings and public goodwill afforded by such actions. At the least, the Department of Water Resources could conduct an evaluation of potential opportunities for such mutually beneficial water rights exchanges.

Streamflow Information for Recreationists

The State of Arizona, in cooperation with federal and quasi-public water management agencies, could provide boaters, anglers, and other recreationists with timely information regarding flow levels of river segments with significant recreation opportunities.

Streamflow in many Arizona rivers fluctuates greatly, depending on season and rainfall. Others are dam controlled and fluctuate depending on water supply or energy needs. Recreationists often do not know when flows will be sufficient for boating, tubing, or other activities. Information on streamflow would thus greatly increase recreational opportunities.

Information could be provided through a pamphlet or recorded phone messages. The California Department of Water Resources' "Water Supply Outlook for Boaters" displays general seasonal flow conditions for each of forty-eight important river reaches.

Recorded messages could take the form of daily or weekly information on a specific stream reach provided by the entity controlling flows through that reach. As one example, the Central Maine Power Company provides boaters with recorded information as a public service on each of the three whitewater boating reaches where flows are controlled by that utility. In Arizona, a similar service is provided by the Salt River Project with regard to flows on the Salt and Verde Rivers.

A variation on this theme would be for one state agency to serve as a clearinghouse for stream flow information. This would function similar to ski resort reports with the management authorities for several river reaches providing weekly information to the clearinghouse and the clearinghouse synthesizing this into one recorded message. The Wisconsin Department of Natural Resources' stream report program provides a good model for this type of activity.

Recreation Guides and Nature Appreciation Brochures

The Arizona Game & Fish Department, Arizona State Parks, and local organizations could prepare public information brochures focusing on stream and wetland recreation.

Information on a variety of topics relating to river recreation could prove beneficial to recreational users. Possible topics include: (1) boating safety, (2) river and wetland ecology, (3) user-landowner relations, (4) a statewide guide to opportunities for fishing, boating, and other stream- and wetland-based recreational activities, and (5) recreation guides to specific rivers. The California Department of Boating & Waterways and the Ohio Scenic Rivers Program, among others, have produced simple yet useful brochures that could serve as models.

In Arizona, State Parks has prepared an Arizona Lakes Guide map and Other Lakes Guide book that could serve as a model. State Parks will be developing a rivers and streams recreation guide in 1989.

Recreation Research

Arizona State Parks could identify priorities for future river recreation research and facilitate individual research projects.

As recreational use of rivers continues to grow, new management pressures will be felt. In many instances, research is needed to fully understand the issues and define appropriate actions. Arizona State Parks could initiate an ongoing process to compile a list of priority recreation research needs. This list could be distributed to colleges and universities and to private organizations involved in research. Further, Arizona State Parks could actually conduct specific studies or encourage these studies through technical or financial support. Among the types of studies that might prove beneficial are: (1) corridor analysis of economic values of stream- and wetland-based recreation, (2) assessment of social and physical carrying capacities, (3) analysis of user conflicts, (4) attitudinal evaluations, (5) assessment of participation and demand, and (6) access evaluations (discussed separately in this chapter).

Strategies to Enhance Awareness of and Knowledge about Streams and Wetlands

Streams and wetlands are highly significant to Arizona's cultural heritage and quality of life. These resources offer unique recreational opportunities and are critical to fish and wildlife. To expand and enhance Arizonans' awareness of and knowledge about these special riparian resources, the following strategies are offered: (1) river celebrations and events, (2) a statewide streams and wetlands symposium, (3) river crossing sign program, (4) school programs for stream and wetland education, (5) streams and wetlands database maintenance and enhancement, and (6) streams and wetlands library.

River Celebrations and Events

Arizona State Parks could help to facilitate public river awareness programs on specific rivers around the State.

Across the nation, many states, local governments, and private groups celebrate the month of June as "American Rivers Month." To celebrate, organizations have organized a number of events including river parties, races, and cleanups. Many have become extremely popular annual events.

As one example, Cambridge, Massachusetts, holds an annual riverfront celebration on the Charles River, complete with picnicking, clowns, and musical entertainment. A similar event is held in Portland, Oregon, along the Williamette River. The Guadalupe River in Texas is the site of the annual "Texas Water Safari: The World's Toughest Boat Race," a one hundred-mile headwater-to-ocean canoe race complete with alligators! A somewhat less rigorous annual race is the "Kennebec River Whatever Race" sponsored by the Augusta, Maine, Chamber of Commerce where thousands of contestants compete as much to stay afloat, in bathtubs, decorated oil can barges, and the like, as to reach the finish line. A similar, not-too-serious race is held on the Colorado River at the Parker Strip. Rafting and tubing races are also held on the Colorado River near Yuma.

The most common river event, and possibly the most beneficial, is the annual river clean up conducted by youth groups and fraternal organizations on many of the nation's smaller rivers and streams. An Arizona example is an annual river clean up on the Verde River sponsored by State Parks. This event is

To support these voluntary conservation efforts, the State of Arizona could:

- Identify statewide or regional private non-profit organizations that could play a significant role in stream and wetland conservation
- Evaluate institutional impediments to conservation easements and similar programs and develop strategies to rectify identified problems
- Take steps to support efforts by private non-profit groups, including assisting in the identification of appropriate sensitive areas and providing biological or other expertise

Tax Incentives for Private Conservation Initiatives

The State of Arizona could enact a law to provide property tax incentives to landowners who take actions to protect riparian areas. Many states have adopted some form of a tax incentive program to encourage conservation of significant resources. These typically address agricultural lands, forests, and unique or critical natural features. The State of Oregon has the only program in the nation that focuses specifically on tax incentives for the protection of stream shorelands.

The Oregon Riparian Lands Tax Incentive Program was established pursuant to an act of the state legislature. Its purpose is "to protect or restore healthy riparian habitat on private lands adjacent to perennial and intermittent streams." Basically, the landowner must commit to a management program for a designated shorelands area which disallows livestock grazing, use of herbicides, stream bank alteration, new buildings, and most removal of vegetation. If the shoreland area is currently disturbed, it must be restored according to an agreed upon schedule. If a landowner adopts a stream management program that is acceptable to the Oregon Department of Fish & Wildlife, the land covered by the management agreement is exempt from property tax. To minimize the economic impact of lost tax revenue, limitations have been established regarding the amount of land that can be designated in any one year.

Landowner Stream Management Techniques

The state could develop and distribute a handbook on techniques that landowners might use to conserve and enhance riparian areas on their lands. The state could also provide or facilitate technical assistance to landowners with stream corridor problems.

Many stream-related problems could be resolved if owners of lands adjacent to these streams were better informed regarding stream ecology and shorelands management. Recognizing this, several states, including Michigan, Pennsylvania, Oregon, and Vermont, have prepared handbooks that describe practical stream management ideas for landowners.

The Streambank Stabilization and Management Guide for Pennsylvania Landowners, for instance, discusses: (1) benefits to landowners from conserving shorelands, (2) hydrologic processes and their effect on shorelands, (3) preventative maintenance, (4) specific stabilization techniques, and (5) the state stream alteration permit process.

In Vermont and Texas, among other states, County Extension Agents and the U.S. Soil Conservation Service have made great strides in providing technical advice to landowners regarding a range of site specific problems.

The state could explore opportunities with these and other organizations to develop appropriate educational materials and to supply timely technical advice regarding stream management issues faced by landowners.

Adopt-A-Stream Programs

The Arizona Game & Fish Department and appropriate federal land and resource management agencies could assist private citizens and organizations to "adopt a stream" for purposes of rehabilitating and conserving the natural ecology of that stream.

Adopting a stream is a means by which a group of individuals band together with a common interest in conserving the natural values associated with a particular stream. Often, the stream is in relatively close proximity to the community in which these people reside and offers local recreational opportunities in the form of fishing, boating, hiking, or wildlife observation. The activities that the stream's "adopted" family undertake may vary. One variation could follow the "Save-our-Stream" concept as pioneered in Maryland and Ohio, which emphasizes water quality monitoring.

In the Save-Our-Stream program, interested groups receive training in basic water-quality monitoring techniques including water chemistry, physical properties, insect populations, streamside vegetation, and streamflow. Sample sites are selected and sampling conducted on a regular schedule. Information is then transferred to the appropriate resource management agency using standardized reporting procedures.

Other variations could include fish habitat restoration projects, corridor clean-up projects, and recreational enhancement projects. Obviously, all such programs would require cooperation between landowners and appropriate resource management agencies.

Restoration projects of this type may be appropriate for a variety of organizations including local civic groups, boy and girl scout troops, and local chapters of environmental groups. Many of the most successful adopt-a-stream projects have been undertaken by river user groups such as local rod and gun clubs and paddlers groups. In Arizona, such statewide groups as Trout Unlimited and Anglers United may wish to consider initiating a coordinated program in several local areas. There is also no reason why an entire town or city could not adopt a stream.

On an individual basis, the Arizona Game & Fish Department has worked with volunteer groups to enhance and rehabilitate certain streams in the state. Canyon Creek and Trout Unlimited is a good example of a successful cooperative effort. The Department could support additional adopt-a-stream efforts by providing technical assistance and coordination. Possibly, the Department could also develop an adoption certificate that could be presented to groups that have committed to the concept.

Strategies to Enhance and Conserve Critical Streams and Wetlands

One of the more significant findings of the Arizona Rivers, Streams, & Wetlands Study is that certain streams and wetlands in the state warrant special management to protect critical recreational and resource values. A state program that focused on critical streams could significantly enhance statewide stream and wetland management and ensure that these resources could be enjoyed by present and future generations. Accordingly, strategies are offered to: (1) identify and assess critical streams and wetlands, and (2) manage critical streams and wetlands to provide continued public benefit.

Identification of Critical Streams and Wetlands

The State of Arizona could, in cooperation with other interested parties, undertake a systematic statewide assessment of rivers, streams, and wetlands in order to identify waters possessing critical recreation and environmental values.

All streams and wetlands are important components of the natural and human environment and should be managed with sensitivity and care. However, underlying the identification of "Critical Streams and Wetlands" is the fundamental belief that certain waterways and wetlands possess recreational or environmental resource characteristics that are so important to the public that they warrant special management attention.

Ultimately, the rationale behind the identification of critical resources is to foster a climate where integrated resource management occurs, where management has broad-based public support and is based on a clear set of priorities and strikes a thoughtful balance between competing interests.

In the present context, an "assessment" is an effort to determine the relative significance of a stream or wetland when compared to other similar resources. This is in contrast to an inventory which simply observes and records factual information.

An assessment involves making value judgements. As such, to conduct an assessment, there is a clear need for an understanding of the human element. The Arizona Rivers, Streams, & Wetlands Study has offered a recommendation for an organizational framework to guide stream and wetland management. Included in this framework is an Intergovernmental Coordinating Committee which would consist of representatives from land and resource management authorities. A council would also be formed and be comprised of persons representing a variety of interested publics. These groups could, and most properly should, provide the human element that is essential to a successful resource assessment; it would be these groups that would provide guidance to ensure that the study process would reflect an Arizonan's perspective on Arizona's waters.

As discussed previously, the Arizona Rivers, Streams, & Wetlands Study has created a streams and wetlands data management system and conducted an inventory of available information. This system and base of information could serve as the foundation for the assessment.

There is no one best way to conduct an assessment. There is, however, a generalized process that has emerged from the states that have conducted inventories and assessments during the 1980s. As adapted to the Arizona situation, this assessment model is as follows:

Step One: Identify Resources and Values to be Assessed

The Assessment should include a wide range of stream and riparian values that are important to the people of Arizona. Resources and values that might properly be considered include:

- *Recreation:* fishing, hunting, whitewater boating, quietwater boating, swimming, and land activities—camping, hiking, nature observation, scenic driving
- *Natural Values:* native fish and aquatic communities, wildlife, endangered and threatened plant species, riparian plant communities, geologic features (canyons, natural windows and arches, salt deposits), hydrologic features (waterfalls, rapids, hot springs), and unmodified stream systems
- *Cultural Values:* prehistoric sites, historic sites (fords, trails, structures), and urban waterways (open-space areas, public-use areas)
- *Water Values:* outstanding water quality, groundwater recharge areas, natural flood and erosion control, particularly sensitive waters

<u>Step Two: Develop a Spatial and Hydrologic Context for Conducting the Assessment</u>

Arizona is a large state with a variety of different river, stream, and wetland resources. It is important that the assessment recognize streams and wetlands of a variety of types and in a variety of locations. The assessment could be structured so as to explicitly address streams and wetlands from each of the following:

- *Physiographic Provinces:* Plateau Uplands, Central Highlands, and Basin and Range
- *Flow Regimes:* Perennial, intermittent, ephemeral, and regulated
- *Stream Types:* Young, mature, and old

<u>Step Three: Designate Persons, Agencies, and Organizations to Assess Stream and Wetland Resources</u>

No one person, agency, or organization possesses all of the knowledge of Arizona's stream and riparian areas that will be needed to undertake this assessment. It may, therefore, be advisable to divide the project into a series of smaller projects along the subject lines identified in Step One.

An appropriate state agency could be identified to coordinate the assessment for each of these components. For example, Arizona State Parks could assess certain types of non-wildlife-oriented recreation, and the Fisheries Branch of the Arizona Game & Fish Department could assess sport fisheries, native fishes, and aquatic habitat.

Again, for each resource value, resource experts and user groups would be identified to provide information for the assessment.

<u>Step Four: Identify Assessment Criteria and an Assessment Process</u>

Criteria would be established for each resource value that would be used to assess the relative significance of each stream or wetland. For example, one criteria for both fish and wildlife might be the presence of essential habitat for species listed by the state or designated by the federal government as being either threatened or endangered.

It is important that streams be assessed using a consistent classification and reporting system.

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RIPARIAN HABITAT ANALYSIS

Tonto National Forest

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ABSTRACT

A one-year riparian habitat analysis was conducted on the Tonto National Forest. The purpose of the two-part study was (1) to determine the extent, nature, and quality of riparian habitat existing on some 600+ miles of targeted waterways and (2) to provide information related to the composition and density of land vertebrates (birds, mammals, reptiles, amphibians) and the major riparian communities of the Salt and Verde rivers.

In Part I, aerial photographs were used to delineate potential riparian habitat, which was then classified (composition and structure), mapped, and assessed as to health and viability from the ground. Riparian communities on each stream were rated on a scale from one (Poor) to five (Excellent) based on the average score of seven quantified habitat attributes. Streams were divided into reaches based on the life zones through which they flowed (Lower Sonoran, Upper Sonoran, Transition). These reaches were evaluated and rated using the community ratings. Threatened and endangered species were also noted. Results indicated that 50 percent of the reaches were in a Poor condition in 1980, only 3 percent were considered Excellent. In 93 percent of the comparisons, the lower reaches were in as poor or poorer condition than the upstream sections, thus concentrating the more deteriorated sections in the lower altitudes. Eighty percent of the streams flowing through the Lower Sonoran Zone were in Poor condition, 46 percent of the reaches flowing through the Upper Sonoran Zone were Poor, and only 5 percent of the Transition Zone reaches were Poor.

Observations of three threatened or endangered plant species and five bird species were summarized. Recommendations included the establishment or initiation of (1) internal review of the USDA Forest Service policy, (2) primary use areas for special interest species, (3) pasture resting via rest-rotation, (4) improved range practices, (5) habitat improvement, and (6) a National Park in the Sierra Ancha range.

In Part II the ecological characteristics of five vegetation structure types are presented, based on data collected from 17-21 transects averaging approximately 2500 feet in length. The riparian communities were described by means of percent ground cover, relative foliage volume, foliage height diversity, horizontal foliage diversity, tree and shrub counts, timing of phenological events, and velvet mesquite pod production. Can traps and drift fences were used to sample reptile and amphibian populations. The cottonwood-willow community had the highest densities of both reptiles and amphibians, and eight of the nine species captured during the study occurred in this vegetation type. Small mammals were sampled by means of snap-trap grids. Nine species were captured, seven each during the summer and winter seasons. Species occurrence and densities may have been affected by the unusually lush herbaceous growth characterizing many of the study areas after the very wet winter of 1979-80. Bird densities were calculated for five seasons (winter, spring, summer, late summer, and fall). The cottonwood-willow community had the greatest number of species each season, averaging nearly 13 species more than the next richest community. The velvet mesquite structural type characterized by tall, dense trees had more species than the other types of velvet mesquite. The velvet mesquite bosque near Needle Rock on the Verde River supported obligate riparian bird species near the level observed in the cottonwood-willow community. It was recommended that (1) riparian areas on the Tonto National Forest not currently developed should be given protective status, (2) rest-rotation grazing procedures be implemented, and (3) release rates from Bartlett Dam on the Verde River should be maintained at 200 cfs.

PART TWO

ECOLOGICAL CHARACTERISTICS OF RIPARIAN COMMUNITIES ON THE SALT AND VERDE RIVERS

INTRODUCTION

In Part One of this report we provided information on the extent and condition of riparian habitat on the Tonto National Forest as of 1980. It has been estimated that in the state of Arizona, as a whole, only 15 percent of originally occurring riparian habitat remains (McNatt et al. 1980). The impact of man's developments and activities has been most devastating and debilitating to the riparian communities of the Lower Sonoran Zone, areas of great importance to many species of wildlife and of great intrinsic as well as economic value to man. The Salt and Verde are the two largest and most important rivers within the Lower Sonoran Zone and the Tonto National Forest. Most of the remaining riparian habitat of these rivers exists on the Fort McDowell Indian Reservation; important remnants occurring within the Tonto National Forest are found on the Salt River near Blue Point (Figs. 10-12), and on the Verde River near the Box Bar Ranch (CW II) and the VM III bosque near the Needle Rock area. All these areas are threatened by the proposed construction of Orme Dam and by other human activities.

Provision of recreational opportunities is an important part of the USDA Forest Service's multiple-use management philosophy. However, that does not mean that the value or quality of this or any particular use can continue without affecting the value or quality of the other uses. For example, Aitchison (1977) observed that the avian community of an area closed to campers changed in diversity and composition after the area was opened to campers. While it was not possible to conduct such a study on the Tonto National Forest the results do serve to demonstrate the need for information about the composition and density of avian, mammalian, amphibian, reptilian, and riparian communities in order to properly evaluate proposed actions or developments and to properly manage the resources entrusted to the USDA Forest Service by congressional charter. Such data are provided for the major riparian communities of the Salt and Verde rivers in the following sections of this report.

DESCRIPTION OF STUDY AREA

The study area was located on the lower Salt and Verde rivers, approximately 25 miles northeast of Phoenix, in Maricopa County, Arizona. Stands of cottonwood-willow, velvet mesquite, and salt cedar riparian vegetation along the river channels and on the first terrace were the subject of the study. The riparian communities occur in narrow strips up to 1.5 miles long and 50 to 700 feet in width, parallel to the rivers and bordering both present and old river channels. Cottonwood-willow and velvet mesquite occurred on both rivers, whereas salt cedar was largely restricted to a small area on the Salt River just above Granite Reef Dam. The cottonwood stands in particular represent remnants of formerly more extensive stands; attrition caused by the death of cottonwood trees and flooding continued during the study period. Trees were lost on both rivers in the February 1980 floods, including an entire 20-acre stand near the USDA Forest Service Granite Reef Campground, in which one of our transects had been located.

The cottonwood-willow communities are characterized by a semi-continuous canopy of cottonwood and willow trees up to 70 feet in height (Fig. 13). The understory is composed predominantly of velvet mesquite mixed with some _Baccharis_ spp. and salt cedar. Arrowweed (_Tessaria sericea_), desert elderberry (_Sambucus mexicana_), desert hackberry (_Celtis pallida_), _Condalia_ spp., and the tree tobacco (_Nicotiana glauca_) also contributed to the understory vegetation in different cottonwood-willow areas. Small patches of cat-tail (_Typha_ spp.) were present in the Blue Point and Granite Reef stands, both of which were protected from livestock grazing (Figs. 11 and 12).

The velvet mesquite stands are generally found in higher floodplain areas and on the first terrace. Mixed with 10- to 30-foot velvet mesquite trees, to a varying extent, are desert shrubs and trees, including ironwood (_Olneya tesota_), palo verde, acacia, condalia, bur sage, wolfberry (_Lycium_ spp.), _Opuntia_ spp., saguaro, desert hackberry, and creosote bush (_Larrea divaricata_). As the velvet mesquite communities yield gradually to desert shrub on higher ground, velvet mesquite densities decrease and tree size is reduced (Figs. 14, 15, and 16).

The single sizable salt cedar area consisted of a nearly pure, dense stand of trees about 15 feet high, with no understory vegetation.

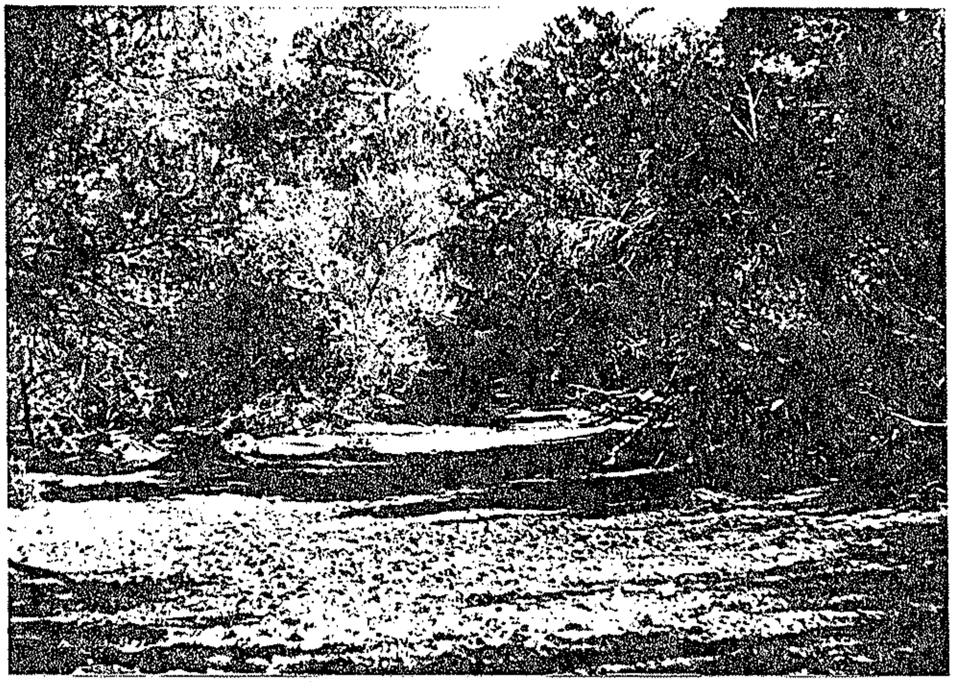

Figure 13. Cottonwood-willow II, Verde River. Note cattle tracks and lack of understory vegetation.

Figure 14. Velvet Mesquite III. Note height and density of trees.

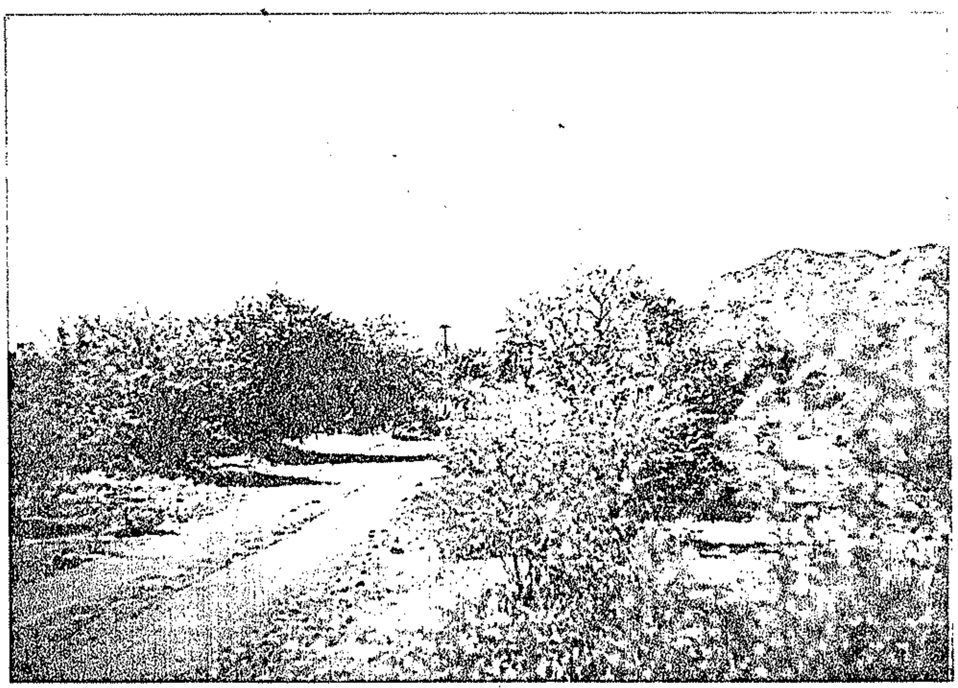

Figure 15. Velvet Mesquite IV. Trees relatively dense but shorter than in Type III.

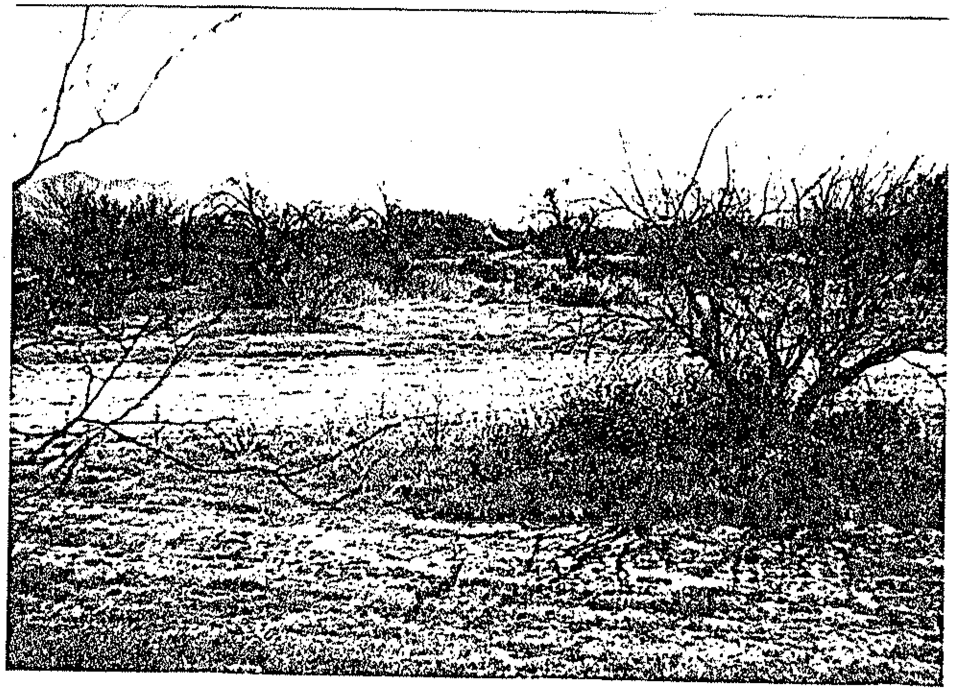

Figure 16. Velvet Mesquite V. Trees sparse, not tall. Community contains some desert vegetation.

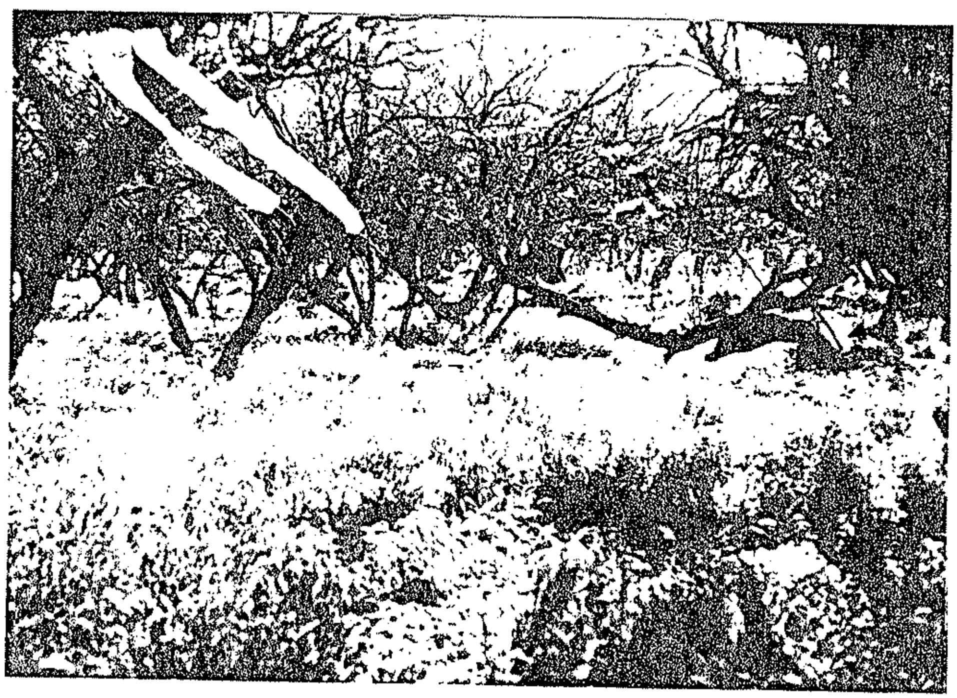

Figure 17. Velvet Mesquite III. After the floods of early 1980, unusually lush growths of herbaceous vegetation occurred.

Weather

Weather conditions during the winter of the study were unusual in that there was greater than normal rainfall on the Salt-Verde watershed, resulting in heavy flooding along the rivers. The floodplain transects were under several feet of water during the latter part of February, and high soil moisture levels may have contributed to an unusually lush growth of herbaceous vegetation and grasses (Fig. 17). It is possible that these conditions altered population density and/or distribution of terrestrial vertebrates either directly by flooding them out, or indirectly by permitting some individuals or species to move into areas that are normally too dry to support them. Phenological events may also have been affected by the unusually high rainfall and water levels.

METHODS

Transects

Transects were established in nearly all accessible, sufficiently-sized stands of relatively homogeneous riparian habitat along the lower Salt and Verde rivers. Each transect was classified according to its community type (based on dominant vegetation) and structural type (based on vertical structure and volume of foliage), based on field observations. These classifications were later checked with quantitative measurements, resulting in reclassification of two transects into different structural types. Although transects at least 2500 feet long are preferable and were established whenever possible, several of the existing stands of riparian vegetation, especially cottonwood-willow stands, were too small to accommodate a transect of this length. Consequently, it was necessary to use three 1500-foot transects and one 2000-foot transect to obtain a reasonable sample size for two of the rarer community-structural types. Twenty-one transects were established, but since four were lost during the course of the study (three washed away during the February flooding and access to another was blocked by a gravel mining operation), the majority of the data were collected on 17 transects in five different vegetation structural types. For the three major types (CW II, VM III, and VM IV), transects were established in campground areas which received substantial human use, and in less-used noncampground areas, in an effort to assess the effects of recreational use on wildlife. It was necessary to set up transects on Indian reservation land for noncampground velvet mesquite, because all accessible VM III and IV areas on the Tonto National Forest receive considerable recreational use. All transects established, together with their community-structural designations, lengths, locations, and period of data collection, are summarized in Table 10.

Vegetation Sampling

In order to standardize the collection of vegetation data from the transects, each transect was marked off in 500-foot intervals. A 2500-foot transect therefore had five 500-foot intervals, which were divided into left and right sides, yielding ten subplots. Measurements of the various vegetation parameters were made in each of the subplots.

Table 10. Transect characteristics. CG = campground, NCG = non-campground.

Transect	Community-structural type	Length (feet)	Location	Dates used/ reason for loss
TF-01	VM III NCG	2500	Salt River Reservation	Oct 1979-Sept 1980
TF-02	VM IV NCG	2500	Fort McDowell Reservation	Oct 1979-Sept 1980
TF-03*	VM III NCG	2500	Fort McDowell Reservation	Oct 1979-Sept 1980
TF-04	VM III NCG	1500	Salt River Reservation	Oct 1979-Feb 1980/ access barred
TF-05	CW II NCG	3000	Fort McDowell Reservation	Oct 1979-Sept 1980
TF-06	CW III CG	1500	Granite Reef Campground	Oct 1979-Jan 1980/ washed out
TF-07	SC IV	2500	Salt River near Granite Reef	Oct 1979-Sept 1980
TF-08	VM IV NCG	2500	Salt River near Granite Reef	Oct 1979-Sept 1980
TF-09	VM III CG	2500	Coon's Bluff	Oct 1979-Sept 1980
TF-10	CW II NCG	4000	Blue Point	Oct-Nov 1979/by USDA Forest Service/ Mar-Sept 1980
TF-11	VM V CG	2500	Coon's Bluff	Oct 1979-Sept 1980
TF-12	VM V CG	2500	Coon's Bluff	Oct 1979-Sept 1980
TF-13	VM V CG	1500	Coon's Bluff	Oct 1979-Sept 1980
TF-14	CW II NCG	3000	Box Bar (east side)	Oct 1979-Sept 1980

Table 10. (cont.)

Transect	Community-structural type	Length (feet)	Location	Dates used/ reason for loss
TF-15	Revegetation Site	2500	Box Bar (east side)	Oct 1979-Jan 1980/ flooded out
TF-16*	CW II CG	2000	Box Bar (west side)	Oct 1979-Sept 1980
TF-17	VM IV NCG	2500	Box Bar (east side)	Oct 1979-Sept 1980
TF-18	VM III CG	2500	Needle Rock Campground	Oct 1979-Sept 1980
TF-19	VM III NCG	1500	Blue Point	Oct 1979-Nov 1979/ by USDA Forest Service-then flooded out
TF-22	VM IV CG	2500	Coon's Bluff	Dec 1979-Sept 1980
TF-23	VM IV NCG	3000	Box Bar (east side)	Dec 1979-Sept 1980

* Indicates reclassification since the first bimonthly report was submitted.

Percent ground cover of trees and shrubs was estimated by means of line intercepts. At two points in each subplot, a 50-foot line intercept was established 25 feet from the transect line and parallel to it. The length of the line intersected by each tree and shrub species was estimated to the nearest foot. The maximum percent cover for a single species was 100 percent; however, overlapping layers of different plant species were determined separately so that total percent cover was frequently greater than 100 percent. Percent cover of a particular species was calculated for each community-structural type by averaging the number of feet of cover of that species on each of the 50-foot intercept lines in that type, yielding an overall mean and standard deviation for each species. Total percent cover for each community-structural type was calculated using the number of feet covered by all species combined.

Relative foliage volume was estimated using the MacArthur board technique (MacArthur and MacArthur 1961). Foliage volume was estimated at three points within each subplot, i.e., at three points on each side of every 500-foot interval. At each point, the distance to the nearest vegetation within the interval that would cover one-half of a 9 X 18 inch board at each of the following heights was recorded: 6", 2', 5', 10', 15', 20', 25', 30', 40', etc. The formula (0.69/distance) was used to convert distances to relative foliage volumes, yielding a measure of the amount of leaf surface area (square feet) per cubic foot of space.

For calculating foliage height diversity (FHD), foliage was divided into three layers: 0-2 feet (ground cover), 5-20 feet (shrub layer), and >20 feet (tree/canopy layer). FHD was calculated using foliage volumes derived above, and using the Shannon Weaver formula ($-\Sigma p_i \ln p_i$) as an index of diversity, where p_i is the proportion of the total foliage volume represented by a given layer.

Horizontal foliage diversity, or patchiness, was also calculated from foliage volume measurements. To calculate patchiness for a given foliage layer, the average foliage volumes for each subplot were summed. The variance of the subplot volumes was the patchiness value for that layer. Total patchiness is the sum of the patchiness values for each layer. (See Anderson et al. 1977 and Anderson et al. 1978 for a more complete discussion of methods of foliage volume measurements and associated calculations.)

All trees and shrubs within 50 feet of either side of each transect were counted separately by species and height class (greater or less than 10 feet). Counts were recorded in 50 X 500-foot sections (i.e., separately for each subplot), and presence or absence of mistletoe (Phoradendron flavescens) was also recorded. From the count data we calculated the average number of trees per acre for each transect and each community-structural type.

Thirty trees each of cottonwood, willow, and velvet mesquite were tagged for the collection of phenological data, 15 of each species on the Salt River and 15 on the Verde River. These trees were checked periodically and the timing of phenological events (e.g., leaf initiation, flowering, pod production, etc.) was noted. Unfortunately, February flooding caused the loss of some of the marked trees and loss of tags from others, particularly cottonwoods and willows on the Salt River, so that sample size for these species subsequent to flooding was decreased.

Velvet mesquite pod production was assessed by means of pod counts. Two different methods were employed. Early in the season, when most pods were on trees, the number of pods on a tree was estimated by passing a one-foot diameter hoop into the foliage at head height at each of the four compass points on the tree and counting the pods within the cylinder described by the hoop. Tree height, diameter, and height of the foliage above the ground were also recorded for each sampled tree. The volumes both of the cylinders ($V_c = \pi r^2 h$) and the tree (assuming the tree to be an oblate spheroid, $V_t = 4/3 \pi a^2 b$) were calculated, and the number of pods in the cylinder volume was extrapolated to estimate the number of pods in the entire volume of the tree's foliage. This procedure was applied to at least 15 randomly chosen trees of various sizes. The number of pods was estimated for each separately and the numbers per tree were averaged to yield the mean number of pods per tree for that vegetation type. Later in the season, after pods had dried and fallen to the ground, we employed the second method. All pods on the ground below the tree were counted within a sample plot of known area (5 X 5 feet or a series of 1-foot diameter circles). The diameter of the tree was also recorded, and the number of pods in the sampled area was extrapolated to obtain an estimate of the number of pods on the total ground area below the tree. Again, at least 15 trees were chosen randomly and used to calculate the mean, as above. A variation of this method was employed in an area where the velvet mesquite tree canopy was continuous and overlapping, such that an individual tree's pods could not be identified. In this case, all pods in ten randomly placed 5 X 5-foot sample plots were counted, and the average number per sample plot was calculated. The number of pods per tree was calculated using the known number of trees in the area obtained from the tree count.

Pods were sampled three times during the season on the same VM IV sample plot (interval 3 of TF-02) in order to monitor changes in pod crop over the production season. We used the first method twice and the ground sample plot method in the latter part of the season. This area was chosen for repeated sampling because it was considered to be typical of velvet mesquite habitat for the study area as a whole. Pod production was also estimated once each in VM V and CW II during the latter part of the season, for the purposes of comparing independent estimates obtained by the two different methods and attempting to assess production in different habitat types.

Reptile and Amphibian Sampling

Reptiles and amphibians were sampled by means of can traps and drift fences. A trap set consisted of two 5-gallon cans dug into the ground to form pitfalls, 100 feet apart, joined by a nylon mesh drift fence. One trap set was placed in a representative portion of both a campground and a noncampground transect in each of the three major community-structural types (CW II, VM III, and VM IV) for a total of six trap sets. One can open for one 24-hour period was considered a trap day. A total of 428 total trap days were compiled, divided more or less evenly among the different communities.

Each time a trap was checked, the area in the vicinity of the trap set was searched for additional individuals or species. Species sighted in the trap area but not captured were not included in relative densities, but were included in the total number of species for that community-structural type.

The total number of captures and the number of species captured were converted to capture rates (number of captures or number of species captured per 3 trap days) for each species separately and for all species combined (1) at each trap site, (2) for each community-structural type, (3) for lumped campground and noncampground sites, and (4) for all sites combined. The percent of total captures represented by each species was also calculated for each of the four category types.

Capture rate and species capture rates were standardized and then summed to yield a density/diversity index value. A second diversity value was calculated for each of the four category types using the Shannon Weaver index, $-\Sigma p_i \ln p_i$, where p_i was the proportion of total captures represented by a given species.

<u>Small Mammal Censusing</u>

Small mammal populations were sampled by means of snap-trap grids, each grid consisting of two 750-foot parallel lines 50 feet apart. There were 15 trap stations on each line, 50 feet apart, and three traps at each station (two museum specials and one rat trap per station), for a total of 90 traps per grid. Traps were baited with rolled oats and peanut butter and reset each day for 3 consecutive days. Each trap grid set out, therefore, yielded 270 trap nights' of data.

Mammal population data were grouped into two seasons: winter (November through March) and summer (April through October). Trap grids were set out at least once and usually twice a season in each community-structural type in both campground and noncampground areas. However, winter data are incomplete because four trap grids set out on the east side of the Verde River at Box Bar were washed away during flooding, after only one day's data had been obtained in each case. The loss of such a large number of traps sharply curtailed winter trapping efforts until we were able to replace the traps. Consequently, we lack data for the VM IV noncampground type for winter.

Relative rodent densities were expressed as the number of individuals caught per 270 trap nights. Data were summarized by season for each community-structural type, and for campground and noncampground transects.

Bird Censusing

Bird populations were estimated by means of a transect line census method based on Emlen (1971) and modified by us (Anderson et al. 1977). The observer walked the transect recording all birds detected along with their lateral distance from the transect line (in one of four distance intervals). The peak of distribution of detection points for a species occurred at that distance beyond which detectability of that species decreased. Conversion factors specific to each distance interval were used to extrapolate the peak number of detections over the entire census area. Population density was then expressed as the number of birds per 100 acres. This procedure was applied to each species separately and the species densities were then summed to yield total avian density on a given transect.

Bird densities were computed on a monthly basis, consisting of an average density based on two or three censuses, each by a different observer. Seasonal bird densities were derived by averaging the monthly density figures, and seasonal totals are the sum of the individual species' average densities for the season. Densities were calculated for each transect separately and also for each community-structural type, as a weighted mean of transect densities within that type. All density figures were rounded to the nearest whole number. Bird species which were present in densities of <0.5 per 100 acres for a month or season were not included in density totals.

RESULTS

Percent Ground Cover of Trees and Shrubs

Table 11 summarizes the contribution of each species present in the five community structural types. Total cover was greatest in the SC IV and CW II types (both 99 percent). The seeming discrepancy resulting from a comparison of the percentages of bare ground in these two vegetation types with total cover can be

Table 11. Percent cover of trees and shrubs. CWII = Cottonwood/ willow II; VMIII = Velvet mesquite III; VMIV = Velvet mesquite IV; VMV = Velvet mesquite V; SCIV = Salt cedar IV. Standard deviation (SD) in parentheses.

Species	CWII(SD)	VMIII(SD)	VMIV(SD)	VMV(SD)	SCIV(SD)
Prosopis velutina	55(32)	80(22)	41(27)	26(32)	0
Populus fremontii	19(30)	0	0	0	0
Salix gooddingii	13(16)	0	0	0	0
Tamarix chinensis	2(5)	0	3(7)	0	99(3)
Sambucus mexicana	0	<1	0	0	0
Bare ground	16(22)	17(23)	50(26)	68(29)	1(3)
Dead *Prosopis velutina*	<1	1(3)	2(4)	0	0
Dead *Populus fremontii*	2(6)	<1	<1	0	0
Dead *Salix gooddingii*	<1	0	0	0	0
Condalia spp.	<1	4(9)	1(5)	<1	0
Baccharis sergiloides	4(9)	0	0	0	0
Baccharis salicifolia	<1	<1	2(4)	0	0
Tessaria sericea	2(6)				
Celtis pallida	<1	2(7)	0	0	0
Clematis spp.	0	<1	<1	0	0
Cercidium floridum	0	<1	0	1(5)	0
Larrea divaricata	0	<1	2(5)	2(6)	0
Olneya tesota	0	1(9)	0	<1	0

Table 11. (cont.)

Species	CWII(SD)	VMIII(SD)	VMIV(SD)	VMV(SD)	SCIV(SD)
Phoradendron flavescens	2(5)	<1	0	<1	0
Nicotiana glauca	<1	0	0	0	0
Ambrosia deltoidea	0	0	0	2(5)	0
Lycium spp.	0	0	0	1(3)	0
Acacia greggii	0	0	<1	1(4)	0
SAMPLE SIZE	72	80	46	52	10
TOTAL COVER	99	88	51	33	99

explained by the presence of multiple layers of foliage and an understory composed of various plant species occurring in the CW II areas which was lacking in the SC IV type, which was a salt cedar monoculture.

Eleven plant species contributed to the total ground cover in CW II, ten species (not counting dead species) contributed in VM III, seven in VM IV, nine species in VM V (five of which were desert elements), and one species in SC IV.

Foliage Height Diversity (FHD)

Few surprises occur when one examines FHD results (Table 12). As expected, the salt cedar and VM V areas sorted out at the low end of the scale on all transects. The position of Transect 22 was somewhat unexpected, but this transect was located in the heavily used Coon's Bluff recreation area, near the two VM V transects. The fact that the vegetation was more dense in the Type IV area probably resulted in a greater impact and reduction of foliage volume here as opposed to the more sparsely vegetated Type V velvet mesquite areas where such a reduction was less likely to occur. Since there was not a great difference in tree height between the areas, a reduction of FHD was observed.

The velvet mesquite bosque at Needle Rock (TF18), although technically considered a campground area by us, nevertheless retained some areas in a near-natural condition. This fact was reflected in the FHD value, which was at the same level as those of the cottonwood-willow community (Table 12). The cottonwood-willow areas expressed the greatest FHD's.

Table 12. Foliage height diversities (FHD)[1] for riparian communities on the lower Salt and Verde rivers, listed in order of magnitude.

Transect	Vegetation community-structural type	FHD
22	VM[2] IV	0.574
7	SC IV	0.705
13	VM V	0.705
11	VM V	0.798
3	VM III	0.809
1	VM III	0.827
8	VM IV	0.880
9	VM III	0.910
2	VM IV	0.916
23	VM IV	0.948
17	VM IV	0.990
18	VM III	1.045
5	CW II	1.045
16	CW II	1.059
10	CW II	1.066
14	CW II	1.086

1 FHD intervals used in calculation of values were 6"-2' (first height interval), 5'-15', and 20'-100'.

2 VM = velvet mesquite, SC = salt cedar, CW = cottonwood-willow.

Volume of Vegetation

As can be seen in Table 13 the two VM V areas were again characterized by low values; however, the two campground VM III areas (TF19 and 18) possessed values at or near those of the Type V structural types. Conversely, the two noncampground VM III areas possessed volumes comparable to those of the cottonwood-willow transects. Salt cedar, which had a very low FHD value, nevertheless had a high volume of vegetation. The greatest volume occurred at TF1Ø, the ungrazed CW II stand near Blue Point on the Salt River.

The distribution of the foliage volume enables one to visualize the structural appearance of the major riparian communities (Fig. 18). The most dramatic comparison is that of campground versus noncampground VM III. Both are similar in terms of the distribution of vegetation above 15 feet. However, as a result of various thinning procedures, the campground VM III areas are more similar to VM IV and V structural types than noncampground VM III from the ground level to 15 feet.

Patchiness

Noncampground CW II exhibited the highest average patchiness values of all areas. SC IV was next highest, followed by noncampground VM III. Campground VM III had the lowest average patchiness values, just less than those of campground VM V (Table 14). The positions of noncampground and campground VM IV may be the result of artificially increased patchiness resulting from the same kinds of habitat disturbance that affected TF-22 (campground VM IV), as discussed above under "Foliage Height Diversity."

Table 13. Estimates of vegetation volume (ft^2/ft^3) for riparian communities on the lower Salt and Verde rivers, listed in order of magnitude.

Transect	Vegetation community-structural type	Volume
11	VM V	0.314
18	VM III	0.494
13	VM V	0.563
9	VM III	0.624
2	VM IV	0.640
8	VM IV	0.641
17	VM IV	0.730
22	VM IV	0.861
23	VM IV	0.989
5	CW II	0.986
7	SC IV	1.089
1	VM III	1.127
14	CW II	1.211
16	CW II	1.391
3	VM III	1.395
10	CW II	1.825

Figure 18. Foliage volume (ft^2/ft^3) profiles of riparian communities on the lower Salt and Verde rivers, Arizona. CG = Campground, NCG = Noncampground.

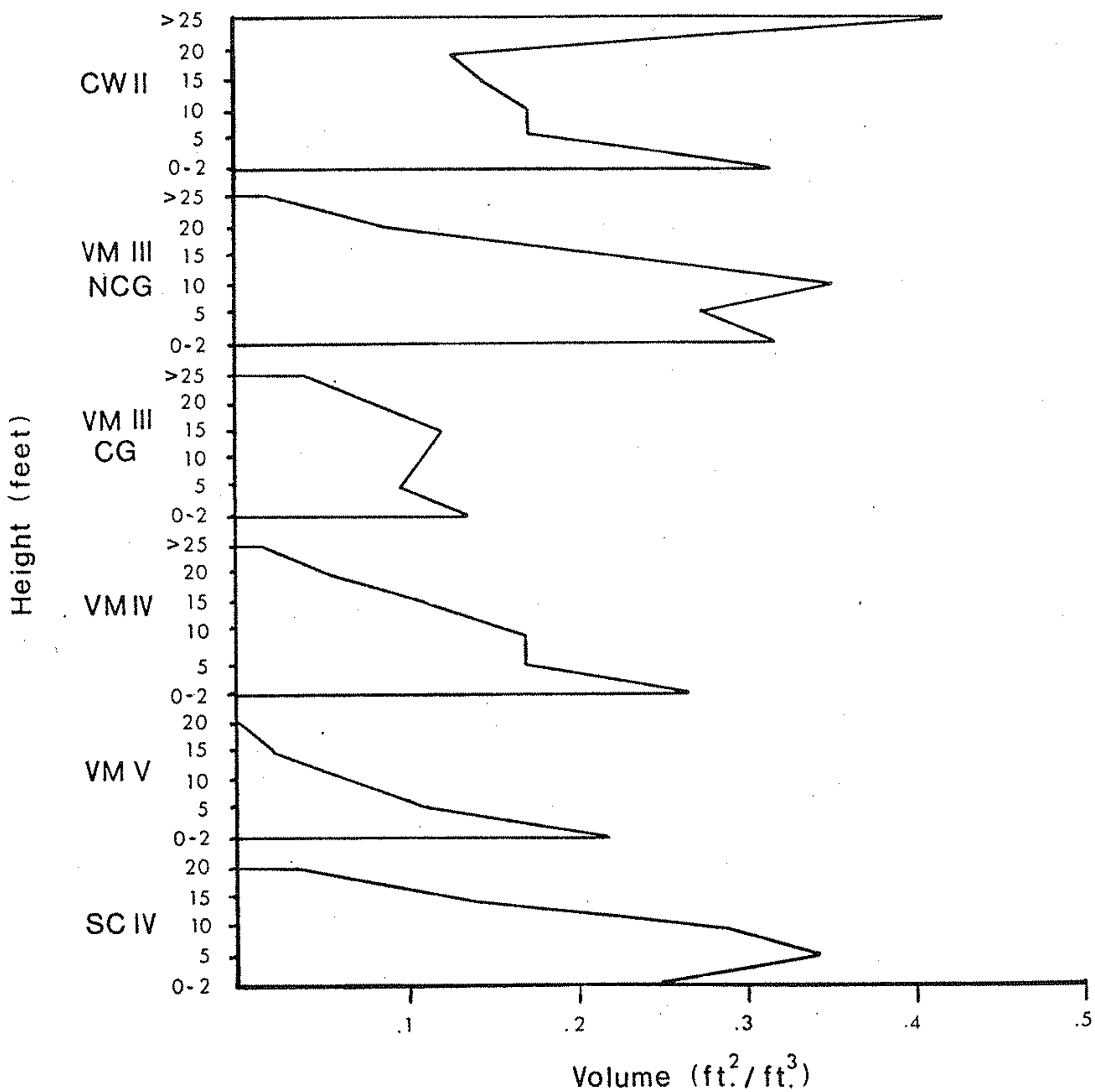

Table 14. Patchiness values for riparian communities on the lower Salt and Verde rivers, listed in order of magnitude.

Vegetation community-structural type	Recreational use	Patchiness
CW II	Noncampground	0.262
SC IV	Noncampground	0.230
VM III	Noncampground	0.162
VM IV	Campground	0.141
CW II	Campground	0.110
VM IV	Noncampground	0.074
VM V	Campground	0.021
VM III	Campground	0.015

Environmental patchiness as measured by this particular index may represent one of the important features used by birds in habitat selection. If so, these results are further evidence of the value of mature and undisturbed stands of native vegetation.

Tree Counts

Table 15 summarizes the results of tree counts by community-structural types. The greatest density of perennial plants and the greatest tree (>10 feet) density were found on the CW III transect, followed by SC IV. These high density communities had the fewest species, while VM IV, with the lowest total density, had the highest number of species.

There were four times as many cottonwoods and 30 times as many willows in CW III as in CW II, and about the same density of salt cedars was found in CW III as in the SC IV community. However, this community had only five species, fewer than any other except salt cedar. It was unusual also in that none of the trees was infested with mistletoe, and it was the only community where no velvet mesquite was present.

CW II, which was characterized by a relatively depauperate understory, had fewer total perennial plants than any community but VM IV, despite the fact that it had a high number of species. Its tree density was intermediate; although broad-leaf density was less than in CW III, the overall density of velvet mesquite was greater in this community than in any of the velvet mesquite-dominated communities. Mistletoe was present in 56 percent of the cottonwoods, 15 percent of the willows, and only 1 percent of the velvet mesquite.

Table 15. Average number of trees and shrubs/acre, lower Salt and Verde rivers.

Species	Community-structural type					
	SC IV	VM III	VM IV	VM V	CW II	CW III
Cottonwood <10 ft	0.0	0.0	0.0	0.0	0.7	0.3
Cottonwood >10 ft	0.0	0.0	0.04	0.0	3.0	12.2
Cottonwood with mistletoe >10 ft	0.0	0.0	0.0	0.0	3.8	0.0
Dead cottonwood	0.0	0.3	0.06	0.0	1.5	0.9
Willow <10 ft	0.0	0.0	0.0	0.0	0.1	5.2
Willow >10 ft	0.0	0.0	0.0	0.0	2.9	72.9
Willow with mistletoe >10 ft	0.0	0.0	0.0	0.0	0.5	0.0
Dead willow	0.0	0.0	0.0	0.0	0.1	0.6
Velvet mesquite <10 ft	0.0	30.8	54.5	14.5	42.4	0.0
Velvet mesquite >10 ft	1.7	77.5	45.9	12.7	73.0	0.0
Velvet mesquite with mistletoe >10 ft	0.0	3.4	2.2	1.9	0.9	0.0
Dead velvet mesquite	0.0	2.8	0.6	0.07	0.8	0.0
Salt cedar <10 ft	35.5	0.0	0.0	0.0	2.5	48.5
Salt cedar >10 ft	142.5	0.0	0.0	0.0	1.1	126.9
Dead salt cedar	0.0	0.0	0.0	0.0	0.0	2.9
Desert elderberry <10 ft	0.0	0.1	0.08	0.0	0.4	2.0
Ash >10 ft	0.0	0.0	0.04	0.0	0.0	0.0

Table 15. (cont.)

Species	Community-structural type					
	SC IV	VM III	VM IV	VM V	CW II	CW III
Desert hackberry <10 ft	0.0	0.0	0.2	0.0	0.9	0.0
Desert hackberry >10 ft	0.0	5.0	0.0	0.0	0.02	0.0
Netleaf hackberry <10 ft (*Celtis reticulata*)	0.0	0.0	0.0	0.0	0.2	0.0
Acacia <10 ft	0.0	0.7	0.0	6.0	0.0	0.0
Acacia >10 ft	0.0	0.0	0.0	0.3	0.0	0.0
Ironwood >10 ft	0.0	0.1	0.0	0.0	0.0	0.0
Palo verde <10 ft	0.0	0.7	0.3	0.8	0.2	0.0
Palo verde >10 ft	0.0	0.2	0.4	0.8	0.2	0.0
Bur sage (*Ambrosia deltoidea*)	0.0	0.0	0.2	96.7	0.0	0.0
Condalia spp.	0.0	27.6	11.1	6.6	0.7	0.0
Hymenoclea spp.	0.0	0.0	0.0	4.8	0.0	0.0
Creosote bush	0.0	6.1	7.1	11.6	0.0	0.0
Wolfberry	0.0	0.8	1.2	4.0	0.2	0.0
Tree tobacco	0.0	1.1	0.0	0.0	14.4	9.9
Opuntia spp.	0.0	0.04	0.7	2.9	0.0	0.0
Saguaro (*Carnegiea gigantea*)	0.0	0.0	0.1	1.0	0.0	0.0

VM III was second to CW II in velvet mesquite density, and the proportion of >10- to <10-foot velvet mesquites (2.51) was greater in this than in any other community, reflecting its characteristic of continuous velvet mesquite canopy cover. This community had the greatest density of trees of the VM types. Sharing with VM IV the highest number of species (12), it had a relatively dense and diverse understory of both desert and riparian shrubs. Four percent of the velvet mesquites were infested with mistletoe.

VM IV had the lowest total density of perennial plants and the second lowest density of trees. The density of velvet mesquites was intermediate among the velvet mesquite communities. It shared the high number of species with VM III, reflecting the incursion of more desert species than in the canopied velvet mesquite.

VM V with only 15.4 trees per acre had the lowest tree density, and also had the lowest density of velvet mesquite among the velvet mesquite communities, reflecting its position highest above the floodplain, grading into desert. It ranked third in total density of perennials due to intermixture of many small desert shrubs, particularly bur sage and creosote bush, among the short, sparsely distributed velvet mesquites. The number of species was low, since no riparian shrub or broadleaf species were present. Thirteen percent of the trees had mistletoe.

SC IV had a high tree density and high total density of perennials, but only two species were present. This community was an essentially monotypic stand of salt cedar with no understory and only an occasional velvet mesquite.

Phenology

Tables 16-18 summarize phenological data for the three major riparian tree species in the study area. Overall means are based on 30 trees, and means for each river are based on 15 trees, through February 1980, at which time several marked trees were lost. Beginning in March, sample sizes for cottonwoods and willows on the Salt River were 3 and 0 respectively, and 14 and 15 respectively on the Verde River.

The leaves of both broadleaf species began to change color in early November 1979, while velvet mesquite leaves remained green. None of the three species completely dropped their leaves during the winter of 1979-80, the broadleafs retained about 20 percent foliage and the velvet mesquites about 40 percent. The greatest percentage of leaf drop (>90 percent) was for Verde River cottonwood trees.

Cottonwoods began flowering in late January, prior to leafing out, and nearly all were flowering and leafing by mid-February (Table 16). At this time, willows were just beginning to put out leaves, and, in contrast to cottonwoods, flowered two to three weeks after they began putting out new leaves, around early March (Table 17). Cottonwoods were in full leaf in mid-March, willows by late March. Cottonwoods began dispersing seeds in early April.

Velvet mesquites showed essentially no change from early winter to April, although there may have been a small amount of leaf production in mid-March, possibly related to the heavy February rainfall. Most began leafing in early April and began

Table 16. Phenological data, lower Salt and Verde rivers, cottonwood (*Populus fremontii*).

Date	Observation
1979	
Nov 15-25	Beginning of leaf color change
Nov 20-30	Beginning of leaf drop
1980	
Jan 25-28	20.3 ± 19.5 percent leaves retained; 6.6 percent flowering
Jan 25	31.3 ± 19.9 percent leaves retained; 6.6 percent flowering (Salt)
Jan 28	9.3 ± 11.6 percent leaves retained; 6.6 percent flowering (Verde)
Feb 6-13	91 percent flowering; 88 percent leaf initiation
Feb 6	80 percent flowering; 92 percent leaf initiation (Salt)
Feb 13	100 percent flowering; 78 percent leaf initiation (Verde)
Mar 4	93 percent full leaf
Mar 20	100 percent full leaf
Apr 7	100 percent in fruit; cotton dispersing

Table 17. Phenological data, lower Salt and Verde rivers, willow (*Salix gooddingii*).

Date	Observation
1979	
Nov 15-25	Beginning of leaf color change
Nov 20-30	Beginning of leaf drop
1980	
Jan 25-28	20 ± 22 percent leaves retained; none flowering
Jan 25	20 ± 23 percent leaves retained (Salt)
Jan 28	21 ± 21 percent leaves retained (Verde)
Feb 6-13	37 percent leaf initiation; none flowering
Feb 6	17 percent leaf initiation; none flowering (Salt)
Feb 13	53 percent leaf initiation; none flowering (Verde)
Mar 4	100 percent leaf initiation; 87 percent flowering
Mar 20	100 percent full leaf

Table 18. Phenological data, lower Salt and Verde rivers, velvet mesquite (*Prosopis velutina*).

1980	
Jan 25-28	40 ± 24 percent leaves retained
Jan 25	42 ± 25 percent leaves retained (Salt)
Jan 28	37 ± 22 percent leaves retained (Verde)
Feb 6-13	No change
Mar 4	No change
Mar 18	No change (33 percent initiation?)
Apr 4-10	63 percent leaf initiation
Apr 4	93 percent leaf initiation (Salt)
Apr 10	20 percent leaf initiation (Verde)
Apr 25	80 percent leaf initiation; 15 percent flowering
May 5	100 percent full leaf; 75 percent flowering; no pods (Verde)
Jun 4	87 percent flowering; 53 percent initiating pod production (Salt); pods green, 2-6" long
Jul 4	None flowering; 87 percent with pods (3-8" long, dry) (Verde)
Aug 7	80 percent with pods (4-8" long, dry) (Salt)
Aug 26	100 percent with pods (4-8" long, dry) (Verde)

flowering from late April to early May, when they were in full leaf. A large proportion of the trees continued to flower into early June, by which time pod production had begun. New pods were being produced into early August (Table 18).

Pod Counts

Table 19 summarizes the results of pod counts in three community-structural types. Although they were obtained by different methods, pod count results were reasonably consistent. The estimated numbers of pods per tree obtained from three different sample plots and over a three-month period were well within one order of magnitude; the standard deviations overlapped. There was a substantial degree of variability among trees with regard to pod production in all the sampled communities. The differences among communities in pod production per acre reflect different densities of velvet mesquite trees in the three communities, indicating differences in production per tree to a lesser extent and only in one community.

The estimated number of pods per tree was greatest early in the season, and declined consistently over the course of the summer in the VM IV plot. This decline probably resulted from decreased pod production and/or consumption of pods by wildlife and livestock. Pod production per tree in VM V appears to be less than that of VM IV, since when sampled at a date intermediate between two VM IV samples, the resulting estimate of number of pods/tree was less than that obtained earlier and later in VM IV.

Table 19. Velvet mesquite pod production, lower Salt and Verde rivers, 1980.

Community/ structural type	Date	Mean pods/tree	Mean pods/acre	Pounds of pods/ acre
VM V	7 August	2712	70,512	427
VM IV	4 July	10,044	803,440	4,869
	26 August	6653	532,206	3,225
	29 September	594	47,520	288
CW II*	26 September	2715	8,182,926	49,593

* Data obtained from CW II represent the pod production estimate for VM III.

CW II had a large estimated number of pods per tree late in the season, about five times as great as for VM IV during the same time period (Table 19). This may be related to three factors. First, the proportion of >10-foot trees was higher in cottonwood-willow than in either of the velvet mesquite communities (see Table 15), and larger trees presumably produce more pods. Second, the CW II sample area was lower on the floodplain and immediately adjacent to a backwater area; greater moisture in this area may stimulate pod production. Finally, the CW II area was protected from livestock grazing, so one of the factors potentially causing a decrease in the standing crop of pods late in the season did not apply here. However, it must be noted that the VM V plot was also protected from grazing.

Reptiles and Amphibians

Tables 20(a-f) summarize species occurrence and relative densities of amphibians and reptiles as determined from trap data. Nine species (six reptiles and three amphibians) were captured in traps, and an additional three species (of snakes) were sighted in the vicinity of the traps but never captured. In addition to those listed in Tables 20(a-d), three other species were observed in different parts of the study area; western diamond-back rattlesnake (*Crotalus atrox*), coachwhip (*Masticophis flagellum*), and bullfrog (*Rana catesbeiana*).

Capture rates were relatively low, 0.40 per three trap days for all species together over all communities (Table 20d), with a maximum of 0.97 in campground CW II (Table 20c). Because of low capture rates, statistical analyses of the results were

Table 20a. Species occurrence and relative densities of reptiles and amphibians in VM III.

Species	Noncampground			Campground			Total		
	Number captured	Capture rate	Percent of total captures	Number captured	Capture rate	Percent of total captures	Number captured	Capture rate	Percent of total captures
Desert spiny lizard (*Sceloporus magister*)	3	0.16	100	0	0.00	0	3	0.16	30
Chihuahuan whiptail (*Cnemidophorus exsanguis*)	0	0.00	0	0	0.00	0	0	0.00	0
Western whiptail (*C. tigris*)	0	0.00	0	0	0.00	0	0	0.00	0
Tree lizard (*Urosaurus ornatus*)	0	0.00	0	0	0.00	0	0	0.00	0
Western blind snake (*Leptotyphlops humilis*)	0	0.00	0	0	0.00	0	0	0.00	0
Banded sandsnake (*Chilomeniscus cinctus*)	0	0.00	0	0	0.00	0	0	0.00	0
Red-spotted toad (*Bufo punctatus*)	0	0.00	0	2	0.08	29	2	0.05	20
Woodhouse toad (*Bufo woodhousei*)	0	0.00	0	5	0.20	80	5	0.11	50
Couch spadefoot toad (*Scaphiopus couchii*)	0	0.00	0	0	0.00	0	0	0.00	0
TOTAL	3	0.16	100	7	0.28	100	10	0.32	100

Table 20b. Species occurrence and relative densities of reptiles and amphibians in VM IV.

Species	Noncampground			Campground			Total		
	Number captured	Capture rate	Percent of total captures	Number captured	Capture rate	Percent of total captures	Number captured	Capture rate	Percent of total captures
Desert spiny lizard	2	0.09	29	2	0.07	50	4	0.08	36
Chihuahuan whiptail	0	0.00	0	1	0.04	25	1	0.02	9
Western whiptail	2	0.09	29	0	0.00	0	2	0.04	18
Tree lizard	2	0.09	29	0	0.00	0	2	0.04	18
Western blind snake	0	0.00	0	0	0.00	0	0	0.00	0
Banded sandsnake	1	0.04	15	0	0.00	0	1	0.02	9
Red-spotted toad	0	0.00	0	1	0.04	25	1	0.02	9
Woodhouse toad	0	0.00	0	0	0.00	0	0	0.00	0
Couch spadefoot toad	0	0.00	0	0	0.00	0	0	0.00	0
TOTAL	7	0.31	102	4	0.15	100	11	0.22	99

Table 20c. Species occurrence and relative densities of reptiles and amphibians in CW II.

Species	Noncampground			Campground			Total		
	Number captured	Capture rate	Percent of total captures	Number captured	Capture rate	Percent of total captures	Number captured	Capture rate	Percent of total captures
Desert spiny lizard	4	0.14	25	8	0.41	42	12	0.25	34
Chihuahuan whiptail	1	0.03	6	2	0.10	11	3	0.06	9
Western whiptail	1	0.03	6	0	0.00	0	1	0.02	3
Tree lizard	3	0.10	19	0	0.00	0	3	0.06	9
Western blind snake	0	0.00	0	1	0.05	5	1	0.02	3
Banded sandsnake	0	0.00	0	0	0.00	0	0	0.00	0
Red-spotted toad	3	0.10	19	0	0.00	0	3	0.06	9
Woodhouse toad	2	0.07	13	8	0.41	42	10	0.21	29
Couch spadefoot toad	2	0.07	13	0	0.00	0	2	0.04	6
TOTAL	16	0.54	101	19	0.97	100	35	0.72	102

Table 20d. Total species occurrence and relative densities of reptiles and amphibians.

Species	Noncampground			Campground			Total		
	Number captured	Capture rate	Percent of total captures	Number captured	Capture rate	Percent of total captures	Number captured	Capture rate	Percent of total captures
Desert spiny lizard	9	0.13	34	10	0.14	33	19	0.13	34
Chihuahuan whiptail	1	0.01	4	3	0.04	10	4	0.03	7
Western whiptail	3	0.04	12	0	0.00	0	3	0.02	5
Tree lizard	5	0.07	19	0	0.00	0	5	0.04	9
Western blind snake	0	0.00	0	1	0.01	3	1	0.01	2
Banded sandsnake	1	0.01	4	0	0.00	0	1	0.01	2
Red-spotted toad	3	0.04	12	3	0.04	10	6	0.04	11
Woodhouse toad	2	0.03	8	13	0.18	43	15	0.11	27
Couch spadefoot toad	2	0.03	8	0	0.00	0	2	0.01	4
TOTAL	26	0.36	101	30	0.41	99	56	0.40	101

Table 20e. Capture data for reptiles and amphibians. NCG = noncampground, CG = campground.

	VM III			VM IV			CW II			Grand Total		
	NCG	CG	Total	NCG	CG	Total	NCG	CG	Total	NCG	CG	Total
Number of trap days	56	76	132	68	82	150	88	58	146	212	216	428
Total number of captures	3	7	10	7	4	11	16	19	35	26	30	56
Number of species captured	1	2	3	4	3	6	7	4	8	8	6	9
Number captured per 3 trap days	0.16	0.28	0.23	0.31	0.15	0.22	0.56	0.98	0.72	0.37	0.42	0.39
Number of species captured per 3 trap days	0.05	0.08	0.07	0.21	0.11	0.12	0.24	0.21	0.16	0.11	0.08	0.06
Density/Diversity Index value	0.21	0.36	0.30	0.52	0.26	0.34	0.80	1.19	0.88	0.48	0.50	0.45
Species diversity ($-\Sigma p_i \ln p_i$)	0.000	0.598	1.030	1.352	1.040	1.635	1.841	1.120	1.755	1.852	1.294	1.801

Table 20f. Capture rates (N/3 trap days) of reptiles and amphibians in campground (CG) and noncampground (NCG) vegetation types.

	VM IV		VM III		CW II		
Species	CG	NCG	CG	NCG	CG	NCG	Effect of campground
Desert spiny lizard	0.07	0.09	0.00	0.16	0.41	0.14	None
Chihuahuan whiptail	0.04	0.00	0.00	0.00	0.10	0.03	Positive?
Western whiptail	0.00	0.09	0.00	0.00	0.00	0.03	Negative
Tree lizard	0.00	0.09	0.00	0.00	0.00	0.10	Negative
Western blind snake	0.00	0.00	0.00	0.00	0.05	0.00	---------
Banded sandsnake	0.00	0.04	0.00	0.00	0.00	0.00	---------
Red-spotted toad	0.04	0.00	0.08	0.00	0.00	0.10	None
Woodhouse toad	0.00	0.00	0.20	0.00	0.41	0.07	Positive
Couch spadefoot toad	0.00	0.00	0.00	0.00	0.00	0.07	Negative?
TOTAL	0.15	0.31	0.28	0.16	0.97	0.54	

inappropriate. The desert spiny lizard (*Sceloporus magister*) was the species captured most often, and it also had the broadest distribution, being captured at five of the six trap sites. Red-spotted toads (*Bufo punctatus*) with the third highest relative density (0.04) were captured at three of the sites, whereas other species had relatively restricted distributions of capture, occurring at only one or two of the sites. However, none of the species captured at only two sites was captured within a single community-structural type, e.g., only in VM IV (both campground and noncampground). Although they were relatively rarely captured, tree lizards (*Urosaurus ornatus*) had the broadest habitat distribution, having been either captured or sighted at all six sites and on all transects.

The cottonwood-willow community had the highest relative densities of both reptiles and amphibians, with both campground and noncampground sites equalling or exceeding all other sites in the number of species captured, overall capture rate, and species diversity (as calculated with the Shannon Weaver [1949] index; Table 20e). Eight of the nine species captured over the entire study period occurred in cottonwood-willow, and the noncampground site alone had seven (Table 20c). Although relative density of all species combined was greatest at the campground site, captures there included only four species, with two of these captured in relatively large numbers. In contrast, seven different species were captured at the noncampground site and their relative densities were more evenly distributed, so that the diversity index for this site is higher than that of the campground site.

VM IV was second to cottonwood-willow in overall number of captures, number of species captured (six), and species diversity (Table 20e). The capture rate for this community was approximately equal to that of VM III. The noncampground VM IV site had higher values than the campground site for all variables measured.

While capture rate in VM III was close to the value for VM IV, only three species were captured, with one species accounting for half the total number of captures (Table 20a). Consequently, the diversity value for this community was low. VM III was the only community in which the campground site had higher values for all measured variables than the noncampground site (Table 20e).

When results from all communities were pooled, campground areas had a slightly higher capture rate than noncampground (Table 20d). Noncampground areas, however, had a higher number of species and more even distribution of captures among species, resulting in a higher overall diversity value (Table 20e).

A comparison of capture rates in campground versus noncampground areas in the major community types is presented in Table 20f. We reiterate the dangers of making conclusive statements based on small sample sizes (in this study the total number of reptiles and amphibians captured was 56), however we may tentatively suggest the effect of recreational development on some species of reptiles and amphibians. Results indicate that the desert spiny lizard is probably not adversely affected by campground development, the greatest density occurring in campground CW II. The western whiptail (*Cnemidophorus tigris*) and tree lizard (Urosaurus ornatus) populations, however, appear to be negatively impacted in campground areas. The Woodhouse toad (Bufo woodhousei) is the only species which was clearly observed in higher numbers in campground riparian habitat (VM III and CW II; Tables 20d and 20f).

Small Mammal Sampling

Nine species of mammals were captured during the year in all communities, seven each in winter and summer. One of the winter species (Peromyscus maniculatus) occurred only in the revegetation site, an area subsequently lost during the floods. It is likely that this species would have been present during the summer period as well, which would have increased the summer total to eight species.

Total densities between seasons were fairly consistent except in CW II (Tables 21 and 22). Densities of Peromyscus eremicus were six times greater during the winter in CW II than during the summer. The next greatest change in density occurred in VM IV, which increased from two (winter) to seven (summer) captures/270 trap nights. This increase was the result of the increased activity of Perognathus penicillatus during the summer, and the movement of Sigmodon hispidus into the area in response (we believe) to the lush grass and herbaceous growth resulting from the winter rains and floods (Fig. 17).

Number of species observed in the major community-structural types (excluding the revegetation site) varied from one (salt cedar, winter) to four (salt cedar and cottonwood-willow, summer). However, one of the four species captured during the summer in CW II included Mephitis mephitis.

Table 21. Winter 1980 small mammal densities (captures/270 trap nights).

Species	Community-structural type					
	Revegetation site	SC IV	VM V	VM IV	VM III	CW II
Round-tailed ground squirrel (*Spermophilus tereticaudus*)	1.0	–	1.0	0.5	–	–
Desert pocket mouse (*Perognathus penicillatus*)	1.0	–	1.0	1.0	0.5	0.6
Merriam kangaroo rat (*Dipodomys merriami*)	4.0	–	–	–	–	–
Cactus mouse (*Peromyscus eremicus*)	22.0	7.0	–	–	1.3	31.8
Deer mouse (*Peromyscus maniculatus*)	1.0	–	–	–	–	–
Hispid cotton rat (*Sigmodon hispidus*)	–	–	–	–	0.8	–
White-throated woodrat (*Neotoma albigula*)	1.0	–	–	0.5	–	2.4
Number of species	6	1	2	3	3	3
Number of captures	30.0*	7.0	2.0	2.0	2.6	34.8

*Captures/180 trap nights.

Table 22. Summer 1980 small mammal densities (captures/270 trap nights).

Species	Community-structural type				
	SC IV	VM V	VM IV	VM III	CW II
Round-tailed ground squirrel	–	1.0	–	–	–
Desert pocket mouse	1.0	2.5	4.0	1.0	1.3
Western harvest mouse (*Reithrodontomys megalotis*)	1.0	–	–	–	–
Cactus mouse	4.0	–	–	–	5.8
Hispid cotton rat	–	–	3.0	1.3	–
White-throated woodrat	2.0	0.5	–	0.3	0.5
Striped skunk (*Mephitis mephitis*)	–	–	–	–	0.3
Number of species	4	3	2	3	4
Number of captures	8.0	4.0	7.0	2.6	7.9

The comparison of campground versus noncampground in the velvet mesquite and cottonwood-willow communities was of interest. The number of species in both community types was greatest in the campground areas during the winter. Campground densities were either greater than (velvet mesquite) or comparable to (cottonwood-willow) those of noncampground. The reverse was true during the summer. Density and number of species were greater in the noncampground areas in velvet mesquite, and densities were greater in noncampground in the cottonwood-willow community. Number of species in cottonwood-willow were the same, but one of the species included was *Mephitis mephitis* in the campground areas (Tables 23 and 24).

Bird Censusing

A total of approximately 115 species was detected while censusing the transects of the Salt and Verde rivers. Seasonal avian densities for each major community and structural type are presented in Tables 25-29. Totals are summarized in Table 30.

VM V had the highest average density of birds two out of five seasons (winter and spring), as did SC IV (summer and late summer; Table 30). Species contributing most heavily to the totals in VM V included Mourning Dove (*Zenaida macroura*) and wintering sparrows (Brewer Sparrow, *Spizella breweri*; White-crowned Sparrow, *Zonotrichia leucophrys*; Tables 26 and 27), whereas nonresident breeding species were of great importance in SC IV (White-winged Dove, *Zenaida asiatica*; Yellow-breasted Chat, *Icteria virens*; Brown-headed Cowbird, *Molothrus ater*) during the

Table 23. Winter 1980 small mammal densities (captures/270 trap nights), campground/noncampground comparisons.

	Velvet mesquite		Cottonwood-willow	
Species	Campground	Noncampground	Campground	Noncampground
Desert pocket mouse	1.0	-	1.0	-
Cactus mouse	2.5	-	22.0	31.0
Hispid cotton rat	1.0	0.5	-	-
White-throated woodrat	-	-	4.0	-
TOTAL	4.5	0.5	27.0	31.0*
Number of species	3	1	3	1

*Captures/180 trap nights.

Table 24. Summer 1980 small mammal densities (captures/270 trap nights), campground/noncampground comparisons.

	Velvet mesquite		Cottonwood-willow	
Species	Campground	Noncampground	Campground	Noncampground
Desert pocket mouse	1.5	0.5	1.5	1.0
Cactus mouse	–	–	3.0	8.5
Hispid cotton rat	–	2.5	–	–
White-throated woodrat	–	0.5	–	1.0
Striped skunk	–	–	0.5	–
TOTAL	1.5	3.5	5.0	10.5
Number of species	1	3	3	3

Table 25. Avian densities by community-structural type, October-November 1979. R = resident, WR = winter resident, SR = summer resident, T = transient.

Species	VM III	VM IV	VM V	CW II	CW III	SC IV	Status
Great Blue Heron[a]	–[b]	–	–	1	–	–	R
Sharp-shinned Hawk	0[c]	0	0	–	1	–	WR
Cooper Hawk	0	1	–	0	0	–	R
Red-tailed Hawk	–	0	–	–	–	–	R
Harris Hawk	–	1	0	1	–	–	R
Prairie Falcon	–	–	0	–	–	–	WR
American Kestrel	–	–	0	1	–	–	R
Gambel Quail	3	148	4	78	76	44	R
White-winged Dove	–	–	–	1	–	–	SR
Mourning Dove	6	4	81	6	–	–	R
Inca Dove	–	–	–	2	–	–	R
Roadrunner	0	1	–	1	3	–	R
Great Horned Owl	0	–	–	–	–	–	R
Anna Hummingbird	0	–	–	4	21	–	WR
Common Flicker	4	4	18	9	7	–	R
Gila Woodpecker	21	9	4	15	15	15	R
Yellow-bellied Sapsucker	3	1	–	0	–	–	WR
Ladder-backed Woodpecker	4	3	1	9	8	3	R
Ash-throated Flycatcher	2	–	1	0	2	–	SR
Black Phoebe	1	–	–	1	–	–	R
Say Phoebe	–	–	–	0	–	–	T
Gray Flycatcher	1	–	–	1	–	–	WR
Common Raven	0	0	–	0	–	–	R
Bridled Titmouse	0	–	–	2	–	–	WR
Verdin	13	12	7	19	30	5	R
Brown Creeper	1	–	–	1	–	–	WR
House Wren	5	2	1	7	29	18	WR
Bewick Wren	16	11	3	14	39	18	R
Cactus Wren	3	12	20	7	5	6	R
Long-billed Marsh Wren	–	–	–	3	12	–	R
Cañon Wren	3	0	–	5	5	–	R
Rock Wren	–	1	–	–	–	–	T
Curve-billed Thrasher	0	0	4	1	5	–	R
Crissal Thrasher	1	7	0	3	2	2	R
Hermit Thrush	–	–	–	–	3	–	T
Western Bluebird	–	–	–	1	–	–	WR
Blue-gray Gnatcatcher	0	1	–	0	–	–	WR
Black-tailed Gnatcatcher	5	3	3	1	–	–	R
Golden-crowned Kinglet	–	–	–	–	3	–	T
Ruby-crowned Kinglet	46	16	11	52	109	11	WR
Phainopepla	1	0	4	1	–	–	WR
Loggerhead Shrike	2	4	4	3	1	–	R
Starling	2	5	3	5	–	–	R
Hutton Vireo	–	0	–	0	2	–	WR
Solitary Vireo	–	0	–	–	–	–	T
Orange-crowned Warbler	4	–	–	11	12	–	WR
Yellow-rumped Warbler	12	3	1	9	54	5	WR
Black-throated Gray Warbler	–	1	–	1	–	–	WR
Western Meadowlark	–	–	2	–	–	–	WR
Brown-headed Cowbird	–	–	–	1	–	–	SR
Cardinal	6	3	–	4	6	3	R
House Finch	1	4	1	8	8	–	R
Lesser Goldfinch	0	–	–	–	–	–	R
Green-tailed Towhee	0	3	–	1	–	–	WR
Rufous-sided Towhee	0	3	–	0	5	–	WR
Abert Towhee	29	64	18	57	62	145	R
Vesper Sparrow	7	1	–	–	–	–	T
Lark Sparrow	–	10	–	–	–	–	T
Black-throated Sparrow	–	6	24	–	–	–	R
Dark-eyed Junco	20	6	2	2	–	–	WR
Brewer Sparrow	–	1	59	–	–	–	WR
White-crowned Sparrow	19	63	190	3	8	53	WR
Lincoln Sparrow	0	–	–	2	–	–	T
Song Sparrow	–	–	–	6	9	–	R
TOTAL DENSITY	241	411	466	360	542	328	
NUMBER OF SPECIES	29	33	24	42	29	13	

a See Appendix for common and scientific bird names.

b Dashed lines indicate that the species was not observed during the season in this community-structural type.

c Zeros indicate that the species was observed in this community-structural type, but calculated densities were <1.0/100 acres.

Table 26. Avian densities by community-structural type, December 1979-February 1980. See Table 25 for status abbreviations.

Species	VM III	VM IV	VM V	CW II	CW III	SC IV	Status
Great Blue Heron[a]	-[b]	-	-	1	0[c]	-	R
Sharp-shinned Hawk	-	0	0	1	-	-	WR
Cooper Hawk	0	0	0	-	0	-	R
Red-tailed Hawk	-	0	0	1	-	-	R
Harris Hawk	0	-	0	1	-	-	R
Bald Eagle	-	-	-	0	-	-	R
Osprey	-	-	-	0	-	-	WR
Prairie Falcon	-	-	0	-	-	-	WR
American Kestrel	0	0	-	-	-	-	R
Gambel Quail	4	34	6	17	5	26	R
Mourning Dove	10	1	52	1	-	12	R
Inca Dove	2	-	-	-	2	-	R
Screech Owl	0	-	-	0	-	-	R
Great Horned Owl	-	0	-	3	0	-	R
Anna Hummingbird	2	0	1	17	13	1	WR
Common Flicker	1	3	7	4	7	-	R
Gila Woodpecker	6	5	6	14	16	0	R
Yellow-bellied Sapsucker	2	-	-	3	3	-	WR
Ladder-backed Woodpecker	1	4	2	19	26	0	R
Ash-throated Flycatcher	1	-	1	-	-	-	SR
Black Phoebe	1	-	-	1	3	-	R
Say Phoebe	0	0	-	1	-	-	T
Gray Flycatcher	3	1	1	3	3	-	WR
Common Raven	0	0	1	-	-	-	R
Bridled Titmouse	-	-	-	6	-	-	WR
Verdin	10	6	6	14	15	-	R
Brown Creeper	3	-	-	-	-	-	WR
House Wren	0	-	-	2	13	4	WR
Bewick Wren	10	6	5	24	26	15	R
Cactus Wren	2	2	8	6	7	-	R
Long-billed Marsh Wren	-	-	-	2	8	-	R
Cañon Wren	1	0	-	3	8	-	R
Curve-billed Thrasher	0	-	1	2	3	-	R
Crissal Thrasher	0	3	0	4	-	2	R
Western Bluebird	1	6	2	8	1	-	WR
Mountain Bluebird	-	0	-	-	-	-	T
Blue-gray Gnatcatcher	-	1	-	5	10	-	WR
Black-tailed Gnatcatcher	1	1	1	-	-	-	R
Ruby-crowned Kinglet	36	18	15	72	142	3	WR
Phainopepla	8	14	6	4	-	-	WR

Table 26. (cont.)

Species	VM III	VM IV	VM V	CW II	CW III	SC IV	Status
Loggerhead Shrike	1	2	1	-	-	-	R
Starling	0	4	3	12	1	-	R
Hutton Vireo	1	1	-	4	3	-	WR
Solitary Vireo	1	-	0	2	-	-	T
Orange-crowned Warbler	1	0	0	17	40	-	WR
Yellow-rumped Warbler	8	3	4	31	55	4	WR
Black-throated Gray Warbler	0	-	0	5	-	-	WR
Western Meadowlark	0	0	22	-	-	-	WR
Cardinal	2	5	1	1	7	-	R
House Finch	8	1	26	4	3	-	R
Lesser Goldfinch	0	-	0	3	3	-	R
Green-tailed Towhee	0	2	0	-	-	-	WR
Rufous-sided Towhee	-	0	-	-	-	-	WR
Brown Towhee	-	0	-	-	-	-	T
Abert Towhee	34	55	7	45	73	101	R
Vesper Sparrow	1	0	-	-	-	-	T
Lark Sparrow	-	7	6	-	-	-	T
Sage Sparrow	-	-	3	-	-	-	WR
Black-throated Sparrow	-	3	10	-	-	-	R
Dark-eyed Junco	38	8	19	-	-	-	WR
Gray-headed Junco	0	-	-	-	-	-	T
Chipping Sparrow	3	-	-	-	-	-	WR
Brewer Sparrow	3	3	102	-	-	12	WR
White-crowned Sparrow	60	71	214	1	-	50	WR
Lincoln Sparrow	0	-	0	3	3	-	T
Song Sparrow	0	-	0	2	10	-	R
TOTAL DENSITY	266	270	539	369	509	230	
NUMBER OF SPECIES	33	28	30	41	29	11	

[a] See Appendix for common and scientific bird names.

[b] Dashed lines indicate that the species was not observed during the season in this community-structural type.

[c] Zeros indicate that the species was observed in this community-structural type, but calculated densities were <1.0/100 acres.

Table 27. Avian densities by community-structural type, March-April 1980. See Table 25 for status abbreviations.

Species	VM III	VM IV	VM V	CW II	SCIV	Status
Great Blue Heron[a]	-[b]	0[c]	-	9	-	R
Cooper Hawk	0	0	0	0	-	R
Red-tailed Hawk	0	0	0	0	-	R
Zone-tailed Hawk	-	-	-	1	-	T
Harris Hawk	0	0	-	-	-	R
Black Hawk	-	-	-	1	-	SR
Bald Eagle	-	-	-	0	-	R
Osprey	-	-	-	0	-	WR
American Kestrel	-	0	-	1	-	R
Gambel Quail	4	23	1	25	110	R
Spotted Sandpiper	-	-	-	0	-	WR
White-winged Dove	0	1	-	2	-	SR
Mourning Dove	10	26	53	20	38	R
Roadrunner	0	0	-	1	-	R
Barn Owl	-	-	-	0	-	R
Great Horned Owl	-	-	-	0	-	R
Black-chinned Hummingbird	2	3	-	12	-	SR
Costa Hummingbird	2	1	0	0	-	T
Anna Hummingbird	8	2	-	2	-	WR
Belted Kingfisher	-	-	-	0	-	WR
Common Flicker	1	2	3	1	-	R
Gila Woodpecker	5	5	4	13	1	R
Yellow-bellied Sapsucker	1	-	-	-	-	WR
Ladder-backed Woodpecker	4	5	3	17	3	R
Western Kingbird	-	1	0	-	-	SR
Ash-throated Flycatcher	7	4	7	9	-	SR
Black Phoebe	0	0	-	1	-	R
Say Phoebe	0	0	1	-	-	T
Hammond Flycatcher	-	-	-	1	-	T
Gray Flycatcher	1	0	0	1	-	WR
Western Wood Pewee	-	-	-	1	-	T
Vermilion Flycatcher	0	2	1	1	-	R
Rough-winged Swallow	-	0	-	0	-	R
Cliff Swallow	-	-	-	0	-	T
Common Raven	0	0	-	2	-	R
Verdin	5	5	7	6	-	R
House Wren	1	-	-	-	-	WR
Bewick Wren	2	3	4	11	12	R
Cactus Wren	1	0	5	0	-	R
Curve-billed Thrasher	-	-	1	-	-	R
Crissal Thrasher	0	3	1	0	-	R
American Robin	-	0	-	-	-	WR
Hermit Thrush	-	-	-	-	6	T

Table 27. (cont.)

Species	VM III	VM IV	VM V	CW II	SCIV	Status
Western Bluebird	4	1	-	0	-	WR
Blue-gray Gnatcatcher	-	-	-	1	-	WR
Black-tailed Gnatcatcher	-	1	-	-	-	R
Ruby-crowned Kinglet	14	5	6	31	-	WR
Phainopepla	9	21	7	-	-	WR
Starling	0	23	24	21	-	R
Bell Vireo	4	0	-	2	3	SR
Solitary Vireo	-	0	-	3	-	T
Orange-crowned Warbler	-	0	-	1	-	WR
Virginia Warbler	1	-	-	-	-	T
Lucy Warbler	61	81	14	83	26	SR
Yellow Warbler	0	-	-	9	-	SR
Yellow-rumped Warbler	6	1	-	21	3	WR
Black-throated Gray Warbler	-	1	-	-	-	T
Common Yellowthroat	-	-	-	0	-	SR
Yellow-breasted Chat	1	-	-	2	-	SR
Wilson Warbler	-	-	-	1	-	T
Summer Tanager	-	-	-	2	-	SR
Hooded Oriole	0	-	-	2	-	SR
Northern Oriole	2	1	-	6	-	SR
Brown-headed Cowbird	1	9	1	6	18	SR
Western Meadowlark	-	0	16	-	-	WR
Cardinal	7	7	1	8	29	R
House Finch	6	5	57	11	-	R
Lesser Goldfinch	13	5	16	23	23	SR
Lawrence Goldfinch	-	-	-	3	-	SR
Green-tailed Towhee	1	0	0	-	1	WR
Brown Towhee	-	-	-	1	-	T
Abert Towhee	28	43	15	50	55	R
Vesper Sparrow	1	-	19	-	-	T
Lark Sparrow	-	-	5	-	-	T
Dark-eyed Junco	9	2	3	1	-	WR
Black-throated Sparrow	-	0	3	-	-	R
Chipping Sparrow	2	-	13	-	-	WR
Brewer Sparrow	-	-	58	-	-	WR
White-crowned Sparrow	7	22	87	-	-	WR
Lincoln Sparrow	7	2	8	3	-	T
Song Sparrow	1	0	-	8	23	R
TOTAL DENSITY	239	316	442	437	349	
NUMBER OF SPECIES	36	32	31	46	15	

[a] See Appendix for common and scientific bird names.
[b] Dashed lines indicate that the species was not observed during the season in this community-structural type.
[c] Zeros indicate that the species was observed in the community-structural type, but calculated densities were <1.0/100 acres.

Table 28. Avian densities by community-structural type, May-July 1980. See Table 25 for status abbreviations.

Species	VM III	VM IV	VM V	CW II	SC IV	Status
Great Blue Heron[a]	-[b]	-	-	2	-	R
Green Heron	0[c]	-	-	-	-	R
Turkey Vulture	-	-	-	1	-	R
Cooper Hawk	0	0	0	3	-	R
Red-tailed Hawk	-	0	0	-	-	R
Harris Hawk	0	0	-	4	-	R
American Kestrel	-	0	-	-	-	R
Gambel Quail	21	82	49	24	132	R
White-winged Dove	13	27	6	20	159	SR
Mourning Dove	46	64	120	24	44	R
Yellow-billed Cuckoo	0	2	-	2	-	SR
Roadrunner	-	1	2	1	-	R
Great Horned Owl	0	0	-	4	-	R
Lesser Nighthawk	0	-	1	-	-	SR
Black-chinned Hummingbird	0	-	2	13	-	SR
Anna Hummingbird	1	1	-	3	-	WR
Common Flicker	1	1	0	1	-	R
Gila Woodpecker	3	5	5	14	-	R
Ladder-backed Woodpecker	6	4	9	11	-	R
Western Kingbird	-	2	4	1	-	SR
Wied Crested Flycatcher	8	9	13	24	-	SR
Ash-throated Flycatcher	7	8	12	6	-	SR
Black Phoebe	0	-	-	-	-	R
Hammond Flycatcher	1	-	-	1	-	T
Gray Flycatcher	-	-	0	-	-	WR
Western Flycatcher	-	1	-	-	-	T
Western Wood Pewee	1	-	-	-	-	T
Vermilion Flycatcher	-	0	-	2	-	R
Rough-winged Swallow	0	-	-	-	-	SR
Common Raven	-	0	0	2	-	R
Verdin	17	12	30	6	2	R
House Wren	-	-	-	1	-	WR
Bewick Wren	7	5	0	16	-	R
Cactus Wren	1	0	21	-	-	R
Mockingbird	0	-	-	-	-	R
Curve-billed Thrasher	-	0	2	-	-	R
Crissal Thrasher	1	2	-	2	-	R
Black-tailed Gnatcatcher	0	4	1	-	-	R
Ruby-crowned Kinglet	1	-	0	1	-	WR
Phainopepla	6	17	-	2	-	R
Loggerhead Shrike	-	0	-	-	-	R
Starling	0	5	3	5	-	R

Table 28. (cont.)

Species	VM III	VM IV	VM V	CW II	SC IV	Status
Bell Vireo	10	3	-	11	7	SR
Solitary Vireo	1	1	-	1	-	T
Warbling Vireo	1	-	0	1	-	T
Orange-crowned Warbler	1	-	-	-	-	WR
Lucy Warbler	112	97	25	74	27	SR
Yellow Warbler	1	1	-	34	-	SR
Yellow-rumped Warbler	1	-	2	2	-	WR
Black-throated Gray Warbler	2	0	0	2	-	WR
Townsend Warbler	2	-	-	1	-	T
Northern Waterthrush	-	-	-	1	-	T
MacGillivray Warbler	-	-	-	1	-	T
Common Yellowthroat	0	-	-	1	-	SR
Yellow-breasted Chat	5	11	-	9	162	SR
Wilson Warbler	2	2	1	2	-	T
Hooded Oriole	6	0	-	13	-	SR
Northern Oriole	11	12	8	28	-	SR
Great-tailed Grackle	0	0	-	-	-	SR
Brown-headed Cowbird	10	36	7	7	95	SR
Bronzed Cowbird	-	1	-	-	-	SR
Western Tanager	1	-	-	2	-	T
Summer Tanager	2	1	-	21	-	SR
Cardinal	11	19	2	15	21	R
Blue Grosbeak	1	3	0	1	16	SR
House Finch	7	11	13	11	4	R
Lesser Goldfinch	2	7	-	6	17	R
Lawrence Goldfinch	1	-	-	1	-	SR
Abert Towhee	45	70	10	52	153	R
Lark Sparrow	-	0	0	1	-	T
Chipping Sparrow	-	-	2	-	-	WR
Brewer Sparrow	-	-	8	-	-	WR
White-crowned Sparrow	-	-	5	1	17	WR
Song Sparrow	0	-	-	15	106	R
TOTAL DENSITY	378	527	369	509	962	
DENSITY 10% DOVES	326	446	255	469	779	
NUMBER OF SPECIES	39	34	27	55	15	

[a] See Appendix for common and scientific bird names.
[b] Dashed lines indicate that the species was not observed during the season in this community-structural type.
[c] Zeros indicate that the species was observed in this community-structural type, but calculated densities were <1.0/100 acres.

Table 29. Avian densities by community-structural type, August-September 1980. See Table 25 for status abbreviations.

Species	VM III	VM IV	VM V	CW II	SC IV	Status
Great Blue Heron[a]	–[b]	0[c]	–	1	–	R
Turkey Vulture	–	0	–	5	–	R
Sharp-shinned Hawk	–	–	–	0	–	WR
Cooper Hawk	1	1	0	0	1	R
Red-tailed Hawk	0	0	–	0	–	R
Swainson Hawk	–	–	–	0	–	T
Zone-tailed Hawk	–	–	–	1	–	T
Harris Hawk	1	0	0	4	–	R
American Kestrel	0	0	0	1	–	R
Gambel Quail	91	146	115	91	209	R
White-winged Dove	5	3	–	7	–	SR
Mourning Dove	18	30	110	26	–	R
Yellow-billed Cuckoo	1	–	–	1	–	SR
Roadrunner	2	5	2	2	3	R
Barn Owl	0	–	–	–	–	R
Great Horned Owl	1	0	–	1	–	R
Anna Hummingbird	–	1	–	1	–	WR
Belted Kingfisher	–	–	–	0	–	WR
Common Flicker	1	1	3	5	–	R
Gila Woodpecker	11	5	5	25	1	R
Ladder-backed Woodpecker	8	5	6	12	–	R
Western Kingbird	2	1	0	3	12	SR
Cassin Kingbird	–	0	–	7	–	T
Wied Crested Flycatcher	8	8	1	20	–	SR
Ash-throated Flycatcher	12	18	3	8	–	SR
Black Phoebe	0	–	–	1	–	R
Say Phoebe	–	0	–	–	–	T
Willow Flycatcher	2	–	–	2	–	T
Western Flycatcher	1	–	–	1	–	T
Western Wood Pewee	–	–	–	1	–	T
Vermilion Flycatcher	–	0	–	–	–	R
Common Raven	–	0	–	0	–	R
Verdin	27	22	17	23	53	R
White-breasted Nuthatch	–	–	–	1	–	WR
House Wren	1	1	–	13	6	WR
Bewick Wren	6	6	1	21	6	R
Cactus Wren	1	2	25	3	6	R
Long-billed Marsh Wren	–	–	–	1	–	R
Cañon Wren	0	–	–	–	–	R
Rock Wren	–	–	–	1	–	R
Mockingbird	1	–	0	2	–	R

Table 29. (cont.)

Species	VM III	VM IV	VM V	CW II	SC IV	Status
Curve-billed Thrasher	0	1	3	0	6	R
Crissal Thrasher	4	5	1	2	4	R
Blue-gray Gnatcatcher	1	0	1	1	6	WR
Black-tailed Gnatcatcher	–	0	1	–	–	R
Ruby-crowned Kinglet	0	–	–	1	–	WR
Cedar Waxwing	–	–	–	1	–	T
Phainopepla	3	1	0	2	–	R
Loggerhead Shrike	1	1	2	1	–	R
Starling	2	1	2	5	–	R
Bell Vireo	8	1	–	5	6	SR
Solitary Vireo	–	–	–	1	–	T
Warbling Vireo	1	–	1	5	–	T
Orange-crowned Warbler	1	–	–	3	–	WR
Nashville Warbler	–	–	–	2	–	T
Virginia Warbler	–	1	–	1	–	T
Lucy Warbler	3	8	1	9	18	SR
Yellow Warbler	1	0	–	6	3	SR
Black-throated Gray Warbler	–	–	–	1	–	WR
Townsend Warbler	–	–	–	1	–	T
MacGillivray Warbler	1	–	–	7	12	T
Common Yellowthroat	–	–	–	4	–	SR
Yellow-breasted Chat	1	1	–	8	13	SR
Wilson Warbler	1	2	0	15	12	T
Western Meadowlark	–	–	0	–	–	WR
Hooded Oriole	3	1	–	2	–	SR
Northern Oriole	4	2	–	6	5	SR
Brown-headed Cowbird	0	–	–	–	–	SR
Western Tanager	1	1	0	2	–	T
Summer Tanager	3	1	0	27	–	SR
Cardinal	14	9	0	24	22	R
Black-headed Grosbeak	1	2	0	2	–	T
Blue Grosbeak	2	8	0	2	18	SR
Lazuli Bunting	–	–	0	1	–	T
House Finch	2	2	8	3	15	R
Lesser Goldfinch	0	0	–	0	–	R
Green-tailed Towhee	–	1	–	1	–	WR
Brown Towhee	0	–	–	–	–	T
Abert Towhee	47	89	9	60	198	R
Vesper Sparrow	0	4	1	–	–	T
Lark Sparrow	2	4	12	1	–	T
Black-throated Sparrow	0	1	28	–	–	R
Sage Sparrow	–	0	–	–	–	T
Chipping Sparrow	–	–	0	–	–	WR

Table 29. (cont.)

Species	VM III	VM IV	VM V	CW II	SC IV	Status
Brewer Sparrow	1	4	12	-	-	WR
White-crowned Sparrow	-	-	-	1	-	WR
Lincoln Sparrow	-	-	-	1	-	WR
Song Sparrow	1	0	-	5	18	R
TOTAL DENSITY	309	406	369	510	653	
NUMBER OF SPECIES	46	40	25	67	24	

[a] See Appendix for common and scientific bird names.

[b] Dashed lines indicate that the species was not observed during the season in this community-structural type.

[c] Zeros indicate that the species was observed in this community-structural type, but calculated densities were <1.0/100 acres.

Table 30. Summary of seasonal avian species richness and density estimates (N/100 acres) in the major vegetation structural types of the lower Salt and Verde rivers. Density is in parentheses.

Season	VM III Number of species	VM IV Number of species	VM V Number of species	CW II Number of species	SC IV Number of species
Fall	29(241)	33(411)	24(466)	42(360)	13(328)
Winter	33(266)	28(270)	30(539)	41(369)	11(230)
Spring	36(239)	32(316)	31(442)	46(437)	15(349)
Summer	39(378)	34(527)	27(369)	55(509)	15(962)
Late summer	46(309)	40(406)	25(369)	67(510)	24(653)
AVERAGE	37(287)	33(386)	27(437)	50(437)	16(504)

summer period (Table 28). The Gambel Quail (Lophortyx gambelii) was the most numerous species in SC IV during late summer (Table 29).

CW II had the greatest number of species in each of the five seasons, averaging nearly 13 species more than the next richest community. Of the velvet mesquite structural types, Type III (tall, dense trees) had more species than the other two types four out of five seasons (winter, spring, summer, late summer; Table 30).

Total Vertebrates

Vertebrate richness totals were similar in VM IV and VM III (42 and 45 species, respectively) and greatest in CW II (67 species), as measured during the summer period (Table 31). The increasing values of such environmental features as foliage volume and percent ground cover found as one moves from VM IV to VM III to CW II evidently results in a concomitant increase in the desirability or suitability of riparian habitat to amphibians, small mammals, and birds. The same number of reptiles were observed in VM IV and CW II. It is obvious that the greatest diversities for all classes of land vertebrates existed within the cottonwood-willow community.

DISCUSSION AND MANAGEMENT RECOMMENDATIONS

Previous work related to the riparian vegetation of the Tonto National Forest is all but nonexistent. Except for a brief note by Johnson and Simpson (1971), scattered references in The Birds of Arizona (Phillips et al. 1964), an Orme Dam impact statement for the then Bureau of Reclamation by Ohmart (1976),

Table 31. Number of vertebrate species per vegetation type, summer 1980.

	Community-structural type		
Vertebrate group	VM IV	VM III	CW II
Amphibians	1	2	3
Reptiles	5	1	5
Mammals	2	3	4
Birds	34	39	55
TOTAL	42	45	67

and a few other minor publications, the nature of the characteristics of this important resource remained little known.

The most relevant of the above works is that of Ohmart (1976). Since the majority of the remaining habitat on the lower reaches of the Salt and Verde rivers is on Indian lands, much of Ohmart's work was carried out in these areas. Similar techniques were employed to sample small mammals, but a comparison of capture rates is not valid. Small mammal population levels and fluctuations are not understood by experts; numbers fluctuate in response to numerous known and unknown factors. Density estimates should be viewed as broad and relative indices at best. However, species occurrence can be compared with slightly more confidence. Species trapped by Ohmart during 1974-75 in cottonwood-willow, velvet mesquite, and salt cedar areas that were not trapped during 1979-80 in similar areas include Perognathus baileyi, Onychomys torridus, Mus musculus, Ammospermophilus harrisii, and Spermophilus variegatus. Species trapped during 1979-80 that were not observed during the earlier period (excluding Mephitis mephitis) were Peromyscus maniculatus and Reithrodontomys megalotis.

All of these species, except Perognathus baileyi, can be identified easily. We offer no explanation for its possible absence during 1979-80. All Perognathus appearing even slightly nontypical were keyed out, always to P. penicillatus. The last three of these species listed for the 1974-75 period were relatively scarce and may simply have been missed by chance during the present study. Also, some of the species are more typical of rocky hillsides or desert areas. These species may have abandoned the riparian zone because of the unusually lush conditions which existed, as previously noted.

The most interesting comparison, however, was that of *Onychomys* and *Sigmodon*. During 1974-75 *Onychomys* was common and widespread, whereas *Sigmodon* was restricted to marsh (Ohmart 1976). However, during 1979-80 *Onychomys* was not observed at all, whereas *Sigmodon* was common and widespread. It seems likely that the herbaceous growth, as illustrated in Figure 17, was viewed as an acceptable alternative habitat by *Sigmodon* and was so utilized, but this growth was not suitable for *Onychomys*.

Bird censusing techniques employed by Ohmart and his staff differed from those of this project; nonetheless the great value of riparian habitat to birds was evident in their results. They mentioned the similarity of avian densities and species richness in velvet mesquite areas, regardless of percent ground cover in the areas. This observation could be applied generally to the results of this study as well (Tables 25-29).

Bird communities should not be considered just from the standpoint of numbers only. There are a number of bird species which are restricted to certain types of riparian habitat and an examination of the distribution of these species helps to reveal the value of certain vegetation types. Ten obligate riparian bird species are listed in Table 32, along with densities in noncampground VM IV, three VM III areas, and CW II. It is quite evident that the Needle Rock velvet mesquite stand (TF18), described earlier as an area most reminiscent of a pristine

Table 32. Numbers (N/100 acres) of some obligate riparian bird species[a], with emphasis on the values observed in the Needle Rock velvet mesquite bosque.

Species	VM IV[b]	Velvet mesquite Type III TFØ1	TFØ9	Needle Rock	CW II
Cooper Hawk	-	-	-	1	1
Yellow-billed Cuckoo	1	1	-	<1	2
Black-chinned Hummingbird	-	1	-	-	10
Anna Hummingbird	-	-	-	3	2
Bell Vireo	2	-	1	40	8
Yellow Warbler	1	1	2	1	27
Yellow-breasted Chat	-	-	1	20	6
Hooded Oriole	1	1	1	25	10
Northern Oriole	11	10	16	10	26
Summer Tanager	-	8	-	-	21
TOTAL RIPARIAN OBLIGATES	16	22	21	100	113
TOTAL DENSITY	416	323	306	518	559
DENSITY WITH 10% DOVES	368	262	247	489	514
DENSITY OF GAMBEL QUAIL	80	6	10	-	61
NUMBER OF SPECIES	24	22	25	24	42

[a] See Appendix for common and scientific bird names.

[b] Data for noncampground areas, TFØ2, TF17, TF23.

velvet mesquite bosque and structural type, while not different in terms of species richness from other velvet mesquite areas, was vastly superior in terms of its value to these obligate riparian bird species. Of particular interest was the density of singing Bell Vireos (*Vireo bellii*), a species showing alarming population declines in much of the southwestern United States.

If the Needle Rock velvet mesquite stand were to be further developed for intensive campground purposes (involving the reduction of foliage volume below ten feet and the thinning of trees) an 88 percent reduction of the obligate riparian species densities listed in Table 32 could be expected. Species such as the Cooper Hawk (*Accipiter cooperii*), Yellow-billed Cuckoo (*Coccyzus americanus*), Anna Hummingbird (*Calypte anna*), Bell Vireo, Yellow-breasted Chat, and Hooded Oriole (*Icterus cucullatus*) would probably disappear. Other species would experience population reductions as well, including woodpeckers, flycatchers, and the Lucy Warbler (*Vermivora luciae*) and Abert Towhee (*Pipilo aberti*).

Recommendations

1. Those areas that remain on the Tonto National Forest that are not currently developed should be given protective status from any and all types of physical disturbance. This is particularly true for cottonwood-willow stands, and especially the velvet mesquite bosque near Needle Rock. This is one of the last remnants and the finest example of a true velvet mesquite bosque left on the Salt and Verde river

systems. This community-structural type is on the verge of extinction and should be zealously protected.

2. No estimates or techniques for aging riparian trees are currently available, but it is quite evident that a long period of time has elapsed since successful reproduction of these trees has occurred on the Salt and Verde rivers. Reproduction was widespread after the overbank flooding that occurred in 1980. However, after cattle were reintroduced that summer, all unprotected seedlings were eaten. We recommend that rest-rotation procedures be implemented to allow the establishment of whatever opportunistic reproductive activity may naturally occur and/or to allow artificially planted trees an opportunity to mature without grazing pressure.

3. During the last few years the trees of the lower Verde River have suffered a tremendously high mortality rate (see McNatt et al. 1980). It is apparent that a major reason for this decline is the irregular and extremely low water release rates from Bartlett Dam. We recommend that release rates be maintained at a minimum level of 200 cfs to maintain the remaining riparian habitat.

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Arizona Wetlands Priority Plan

An Addendum to the 1983 SCORP

Prepared by

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Statewide Planning Section

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In cooperation with the
Arizona Outdoor Recreation Coordinating Commission,
Arizona Game & Fish Department,
U.S. Fish & Wildlife Service, and
National Park Service

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CHAPTER III

WETLANDS RESOURCES IN ARIZONA

Southwestern Wetlands and Riparian Communities

As elsewhere in the Nation, southwestern wetlands are among the most significant lands in terms of wildlife production, water quality protection, soil stabilization, recreational opportunities, and numerous other resource-based functions and values. The characteristics of many southwestern wetlands cannot, however, be adequately described from the traditional viewpoints of such areas as marshes, swamps, bogs, or bottomlands. As defined by the USFWS, these traditional wetlands types

> *...have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year (Cowardin, et al , 1979).*

Arizona and other southwestern states have some wetlands that qualify under the above guidelines, but in the arid climate that dominates this region, these traditional wetlands constitute a minority of the highly important and limited lands that are suggested under a broader USFWS definition. That definition describes wetlands as

> *...lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water (Cowardin, et al, 1979).*

The concept of wetlands as transitional zones between aquatic and drier upland habitats is more compatible with the following definition of southwestern wetlands by Minckley and Brown (1982).

> *Wetlands are periodically, seasonally, or continuously submerged landscapes populated by species and/or life forms differing from immediately adjacent biotas. They are maintained by and depend upon circumstances more mesic than those provided by local precipitation. Such conditions occur in or adjacent to drainage-ways and their floodplains (riparian zones), on poorly drained lands, along seacoasts, and in and near other hydric and aquatic situations, i.e., springs and their outflows, ponds, margins of lakes, etc.*

Extreme aridity and highly seasonal precipitation are the climatic characteristics that influence the attributes of southwestern wetlands most significantly. Accordingly, the relatively few perennial streams arise principally in the higher montane elevations and as they descend to the desert plains, evaporative losses and seepage to, rather than from, the groundwater table greatly reduces or even terminates surface flows. Far more numerous are ephemeral streams that flow periodically each year, or every several years or even decades, only in response to surface runoff from precipitation. Associated with both of these stream types, and the intermittent streams which are a hybrid of the two, are the most important southwestern wetlands types, as measured by extent. Although usually classified by the USFWS as palustrine forested and palustrine scrub-shrub in the National Wetlands Inventory, these wetlands are known regionally, and perhaps more appropriately, as riparian communities. As defined by Lowe (1964):

> *A riparian association of any kind [excluding marshes] is one which is in or adjacent to drainageways and/or their floodplains and which is further characterized by species and/or life forms different than that of the immediately surrounding non-riparian climax.*

The Arizona Riparian Council adopted a comprehensive definition of riparian systems as part of its constitution in 1986:

> *The term "riparian" is intended to include vegetation, habitats, or ecosystems that are associated with bodies of water (streams and lakes) or are dependent on the existence of perennial, intermittent, or ephemeral surface or subsurface water drainage.*

The agreement between Lowe's (1964) early definition of riparian associations and the much more recent explanation of southwestern wetlands by Minckley and Brown (1982) and the Arizona Riparian Council (1986) definition indicates a consistent trend in scientific thought that **riparian communities in this arid region are indeed wetlands.** Although dissimilar than the principal image of wetlands elsewhere in the country, these communities, which are commonly arrayed in varying widths along stream channels, can exist only in response to the wetter surface or subsurface conditions found there. Arizona riparian communities, often characterized by cottonwood-willow and mesquite series, are transitional between the perennial or ephemeral stream channel and the decidedly xeric desert upland. Based on recent studies and discussions, the USFWS agrees that riparian vegetative communities constitute an extremely valuable resource and should be included as part of the National Wetlands Inventory. Traditional concepts of wetlands appear to be expanding to include the western states' wetlands situations.

"Cienega" (Spanish for wetland/riparian marshland) is a southwestern term for a spring-fed marshland surrounded by dry lands, and is usually found adjacent to riverine environments. Hendrickson and Minckley (1985) defined cienegas as mid-elevation (1,000-2,000 m) wetlands characterized by permanently saturated, highly organic, reducing soils. Cienegas may support emergent types of vegetation, but are usually classified as palustrine forested or palustrine scrub-shrub types and are often found in association with larger riparian communities. They were once common in southern Arizona and provided a haven for fish and wildlife. These unique aquatic and semiaquatic habitats have been reduced in recent times from a formerly widespread distribution to small, scattered remnants (Hastings, 1959; Dobyns, 1981). These desert marshlands are now considered to be almost extinct (Minckley and Brown, 1982).

Ohmart and Anderson (1986) have completed an extensive review of work on riparian habitats in the southwest. They report that while such communities may comprise only 0.5 percent to less than 0.1 percent of the landscape, when compared to upland areas, these habitats have suffered disproportionate losses of up to 95 percent in Arizona.

Wetlands Functions and Values

No part of Arizona's landscape provides so many benefits at so little cost to the public as do Arizona's wetlands and riparian areas. These areas are unique environments. The values of wetlands and riparian areas are usually taken for granted and often overlooked. Because of this, many of Arizona's wetlands and riparian areas have been drained, filled, or otherwise destroyed.

Wetlands "value" is not synonymous with wetlands "function." Wetlands function is what a wetland does, regardless of interpretation of its worth. Wetlands value is an interpretation of the relative worth of a wetlands function and can be positive or negative. The worth of a specific wetland can vary, depending on who does the judging. Size and interrelationships of wetlands must be considered. Because many wetlands are interconnected, impacts on a single wetland may not be isolated. There is an increasing tendency to look to a process for ranking the relative values of wetlands in order to identify those that should be given the greatest protection. Any ranking of this kind relegates some wetlands to a lower category and the conclusion often is that those in the lower ranks are of little value and can be sacrificed. Oftentimes, priorities must be set for acquisition or for immediate protection against imminent threat, but caution must be used when drawing conclusions as to relative importance of various wetlands. The assessment of values of wetlands is a complex undertaking and no system presently in use provides a full range of information about wetlands values.

Wetlands and riparian areas have many values that are lost when they are altered or destroyed. These values may be intrinsic or ecologically based and include wildlife production, recreation, aesthetics, agricultural uses, groundwater replenishment, pollution and sediment control, flood prevention, and educational and scientific uses. Intrinsic values are usually intangible, while ecological or resource values are more tangible and scientifically and economically demonstrable. The intrinsic qualities and resources values provided by wetlands can vary significantly from one wetland to another.

The economic value of wetlands is enormous. In the Emergency Wetlands Resources Protection Act of 1986, Congress found that wetlands contribute to a commercial marine harvest valued at over $10 billion, support a fur and hide harvest worth $300 to $400 million annually, and are the bases for over $10 billion in annual expenditures on nature study, fishing, hunting, and other outdoor recreation. The USFWS estimates that 55 million people spent almost $10 billion in 1980 observing and photographing waterfowl and other wetland-dependent species of birds. This is an annual expenditure of almost $200 per person (NWF, 1987). Wetlands are important to the Nation as aesthetic retreats and places of diversity for nature study and are central to the enjoyment of millions of Americans. These economic benefits are comparable to those derived from the commercial use of wetlands.

Two kinds of demands have historically been placed on riparian communities in Arizona: 1) consumptive demand for physiological and industrial uses; and 2) recreational demand. From these two contrasting demands, a conflict has tended to evolve with the biologist, ecologist, and environmentalist on one side, and the engineer, economist, and administrator on the other. Because the latter group has historically been able to discuss costs and benefits in monetary terms, they have consistently dominated the political scene that governs land use policies. Recently, cost figures for intrinsic riparian and wetlands values have been developed for specific development projects and in figuring land values. A more equitable decision-making process for land use planners may evolve in the near future. A description of some of the more important wetlands functions and values follows.

Flood Control and Storage

Riverine wetlands and adjacent floodplain lands often form natural floodways that convey flood waters from upstream to downstream points. Floodplains have been created by flood flows and provide a natural flood conveyance configuration. Structures or fills located within floodway areas block flood flows, causing increased flood heights on adjacent and upstream lands and increased downstream velocities. Inland wetlands may store water during times of flood and slowly release it to downstream areas, lowering flood peaks. Riparian vegetation can be particularly valuable in decreasing flood peaks in many instances. Riverine wetlands with adjacent open or relatively open floodplains often have relatively high flood storage and conveyance values. With the flood conveyance and reduction functions of wetlands and riparian areas, lives and property could be saved, especially in areas with developed floodplains. Important factors influencing the flood reduction role of wetlands include size, location within the basin, texture of substrate, and connection with other wetlands (USFWS, 1987; USFWS and EPA, 1981).

Erosion and Shoreline Damage Reduction

Inland wetlands, adjoining larger lakes and rivers, reduce the impacts of waves and currents before they reach upland areas. The wetlands vegetation plays an important role in reducing shoreline erosion from storm waves or high velocity water during flooding or heavy runoff by binding and stabilizing the soil with their root systems. The public value of this function usually is higher when development or high value lands are located near wetlands areas (USFWS, 1987; USFWS and EPA, 1981).

Surface and Groundwater Supply

Wetlands are increasingly important as a source of ground and surface water with the growth of urban centers and dwindling ground and surface water supplies. Manipulation of the watershed or intensive use of groundwater can drastically influence a wetland. Redirection of surface flows might eventually result in a reduction of the size of a wetland, and overutilization of groundwater in an area often results in the complete elimination of a wetland. The socioeconomic value of wetlands is higher when the public derives its water supply from the wetlands or related groundwater aquifer. The water supply of wetlands provides various public benefits, such as water for public use, irrigation, livestock watering, and wildlife uses (USFWS, 1987; USFWS and EPA, 1981).

Water Quality

Wetlands help maintain water quality or improve degraded water through removing, transforming, and retaining nutrients, sediments, and other natural and man-made pollutants. Wetlands vegetation filters sediment, organic matter, and chemicals while microorganisms utilize dissolved nutrients and break down organic matter; therefore, wetlands act as natural water purification mechanisms. It is important to recognize that wetlands have a finite capacity to perform these functions (USFWS, 1987; USFWS and EPA, 1981).

Habitat for Waterfowl, Wildlife, and Fisheries

Wetlands are among the most biologically productive ecosystems and are crucial as habitats for fish and wildlife. Wetlands provide essential breeding, nesting, feeding, and predator escape habitats for many forms of waterfowl, mammals, and reptiles. Aside from the threatened and endangered species that depend on wetlands for their survival, 5,000 species of plants, 190 species of amphibians, and 270 species of birds are estimated to occur in the Nation's wetlands. The high diversity of wildlife species is due to the presence of abundant water needed by all life forms, rich and diverse vegetation which serves as the basis for food chains, and adequate cover provided by both wetlands and shore vegetation. In fact, the reason wetlands are so productive is due to their dynamic and transitional nature - the constantly changing water level. Due to their unique and diverse habitats, wetlands and riparian communities support a fauna disproportionate to their limited acreage. Regardless of species, wetlands and riparian habitats are the most valuable wildlife habitats in Arizona (USFWS, undated). Research has demonstrated that wetlands of less than one acre in size support an abundance of life forms. These small natural wetlands, such as cienegas and springs, and man-made ones, such as livestock tanks and spreader dams, create valuable habitat in Arizona's desert environments where surface water is extremely limited. The loss of wetlands - both large and small - therefore impacts a broad array of plants and animals.

Over 40 percent of the state's wildlife species depend on riparian habitats for their survival (NWF, 1985). In North America, 41-43 percent of the mammal species, 38 percent of the bird species, 30-35 percent of the reptiles, and 13-14 percent of the amphibians are found in these areas (Jay Hair, NWF, 1985). Riparian areas in Arizona can contain up to 10.6 times as many spring migrant birds per hectare as found on adjacent non-riparian habitats. Significantly, 47 percent of the 161 bird species frequenting certain studied riparian habitats in Arizona are dependent on these areas for nesting. Other avian studies in Arizona have inventoried 80 pairs of nesting birds per 100 acres of partially cleared riparian areas, but the numbers dramatically jumped to 1,322 pairs per 100 acres on uncleared riparian areas. Riparian areas in Arizona provide nationally unique habitat for many wildlife species. Several species of wildlife that are totally or largely dependent upon Arizona's riparian habitat include Arizona gray squirrel, river otter, gray hawk, black hawk, water ouzel or dipper, Bell's vireo, sulphur-bellied flycatcher, elegant trogon, Bullock's oriole, yellow warbler, bald eagle, canyon tree frog, and many more.

The value of a wetland depends upon the following factors: the diversity and arrangement of vegetation; the amount of open water; the arrangement of the vegetation to the water; the relationship of the wetland to topographic features, lakes, streams, and other wetlands; the size of the wetland and surrounding habitat; water chemistry; permanence; diverse wildlife species composition; and abundant wildlife numbers or population (USFWS, 1987).

Habitat for Threatened and Endangered Species

A large number of federally listed threatened and endangered species rely on wetlands for their survival. As of July 1986, 209 animals and 109 plants were listed as threatened or endangered in the United States. Forty-five percent (94) of these animals and 26 percent (29) of these plants depend directly or indirectly on wetlands to complete their life cycles successfully. In addition, of the more than 2,500 plants in need of federal protection, as many as 700 are wetland-dependent or related.

Many of Arizona's federally listed threatened or endangered species and state listed sensitive species rely on wetlands or riparian habitat for survival. (A partial list includes the southern bald eagle, gray hawk, black-bellied whistling duck, narrowheaded garter snake, tropical vine snake, humpback chub, Apache trout, woundfin, Yaqui chub, loach minnow, Gila topminnow, Yuma clapper rail, water shrew, Hualapai Mexican vole, river otter, and jaguar.)

Agricultural Uses

There are many agricultural uses of wetlands; the most obvious is grazing. Floodplain soils are high in nutrients and historically in Arizona, riparian vegetation has been cleared in large acreages to make way for agricultural crops such as cotton, alfalfa, and grains. Certain wetlands can produce hay crops and some riparian areas can sustain grazing under properly managed conditions. Because of the abundance of flowering vegetation, riparian lands are significant for honey production (USFWS, undated).

Timber Production

Forested wetlands and riparian areas are an important source of fuelwood and hardwood lumber. Under sustained management, riparian forests in Arizona could produce between $60 and $120 per acre per year in fuel wood. Mesquite bosques represent a marketable product and, under suitable environmental conditions, could be managed as a renewable resource (Olson, 1940). However, sound forest management and utilization practices must be implemented for a sustained yield of mesquite products. Historically though, mesquite bosques in Arizona have not been managed, but have simply been cleared for firewood and cropland. On selected sites in Arizona, the potential sustained yield of walnut lumber and nut crops could be substantial (USFWS, undated).

Recreational Values

Wetlands and riparian areas provide unique and comfortable places for recreation experiences in Arizona. Participation in water- and wetland-related outdoor recreation activities includes hunting, fishing, boating, birdwatching, nature observation, ORV riding, recreational placer mining, picnicking, hiking, and horseback riding. The non-consumptive uses of wetlands and riparian areas have greatly increased in recent years. Historically, hunters and trappers were the primary users of wetlands, but today there are many birdwatchers and wildlife observers, students and teachers, artists, and others who regularly visit wetlands. During 1978, nonresident wildlife observers made over 46,000 visits to just three riparian areas in southern Arizona: Ramsey Canyon, Madera Canyon, and Cave Creek in the Chiricahua Mountains. This resulted in over $5 million in tourist revenue or approximately $12,370.00 per acre in revenue generation (USFWS, undated).

Wetlands and riparian habitats are highly desirable as recreation sites, but as a whole, they have been poorly managed for that activity. Varied land ownership, accessibility, and lack of facilities all contribute to the situation.

Historic and Archaeological Values

The majority of wetlands and riparian areas in Arizona possesses historic and archaeological interests. Indian and early settlements were located near wetlands and riparian areas which served as sources of fish, game, and water. Riparian vegetation also provided food, shelter, tools, and fuel for fires. Agricultural fields and farms were built along rivers so that there would be a ready source of water to irrigate crops when there was insufficient rainfall.

Education and Research

Wetlands and riparian areas provide excellent educational opportunities for nature observation and scientific study. Riparian habitats are unparalleled as environmental study areas. They are accessible, offer a wide variety of habitats which contribute to a diverse flora and fauna, are unique, and differ from the more common nonriparian communities. Water is especially attractive in Arizona due to its restricted distribution, so any natural habitat that offers flowing water has immense value for holding children's attention and interest (USFWS, 1987).

Open Space and Aesthetic Values

Wetlands and riparian areas are areas of great diversity and beauty and provide open space for recreational and visual enjoyment. Lands adjacent to riparian areas represent premium living conditions to many Arizona residents and people have demonstrated a willingness to pay inflated prices for lands in and near riparian habitats. Visual values depend upon wetlands or riparian type, size, landform, contrast, and diversity, as well as associated water body size and type, surrounding land use, and other factors (USFWS, undated).

Wetlands are an important part of our Nation's heritage and benefit all citizens of the United States. Like soil, air, and water, they are to be treasured; these precious resources cannot be squandered. Alternatives to wetlands conversion and protective mechanisms must be developed and implemented. Before these measures can be taken, though, we must know where the Nation's wetlands occur and to what extent they still exist.

Inventory

In 1954, the U. S. Fish & Wildlife Service conducted a nationwide survey of wetlands (commonly referred to as Circular 39) which focused on important waterfowl wetlands. This survey covered roughly 40 percent of the lower 48 states, being mostly concentrated in the Mississippi Flyway. This was not a comprehensive study, especially with regard to Arizona. Primary emphasis was on wetlands considered susceptible to drainage or other land use changes that destroy wildlife habitat. Lakes, streams, and reservoirs were not included as wetlands. Only a small percentage of the state was included in the survey with the primary areas surveyed along the Mogollon Rim, White Mountains, and the lower Colorado River. Arizona was shown to have only 28,400 acres of wetlands with value to waterfowl.

In 1974, the USFWS initiated the design of a new national inventory of wetlands with the scope considerably broader than the 1954 study. This new study was to provide basic data on the characteristics and extent of the Nation's wetlands and facilitate the management of these areas on a sound, multiple-use basis. A new national classification system was developed by Lewis M. Cowardin, et al, 1979, and wetlands were defined according to hydrophytic plants, hydric soils, and frequency of flooding. The National Wetlands Inventory project is to include two main products: 1) wetlands maps; and 2) wetlands status and trends analysis. Upon completion of the wetlands inventory in each state, the USFWS is to prepare and publish a state wetlands report. The state reports are to include wetlands statistics and detailed discussions of NWI techniques, wetlands plant communities, hydric soils, and wetlands values.

Until the USFWS completed the NWI for Arizona in the mid-1980s, there had not been a comprehensive effort to inventory the state's wetlands resources. Even this effort was limited in scope, though. The NWI does not include certain high value riparian communities, such as honey mesquite bosques, because, under the wetlands definition in the draft NWPCP, they do not qualify as wetlands. Region 2 of the USFWS has recommended that the NWI should be modified to include upper riparian vegetative communities. Currently, the NWI for the state is in map format only with no information or records available on those sites inventoried. The state report for Arizona has not been completed. The status of the NWI for Arizona has been recorded on the index map for U. S. Geological Survey 1:100,000 scale maps. Along some of the major river systems, however, large scale maps are available. All map products show the configuration, location, and type of wetlands found in a given area. The maps are prepared by stereoscopic analysis of high altitude aerial photographs, ground-truthed and reviewed by potential users. Wetlands are identified and classified on photographic overlays based on vegetation, visible hydrology, and geography. The minimum size of the wetlands mapped is dependent upon the quality of aerial photography used for the survey. Generally, the minimum size ranges from three to five acres consistently, although smaller features, particularly small ponds, may be shown.

A comprehensive compilation of wetlands acreages for the state has never been attempted. Individual land management agencies have classified many of the the resources within their jurisdiction, but each agency uses its own methods, classification, and mapping scheme, making interagency comparisons difficult. A number of the significant wetlands in the state are found on private land and other non-inventoried lands, further complicating the task. Vegetation maps of Arizona are characterized by their variability in accuracy and scale of map, identification and classification of plant communities, agency responsible for the map, and thus, in their inherent value for displaying riparian information. Because of the continuum nature of riparian vegetation and the occurrence of mosaics within a vegetation type, it is often physically impossible or impractical to delineate riparian communities on small-scale vegetation maps.

There were a number of studies undertaken in the last 40 years that classified and inventoried certain acreages of riparian and wetlands habitats for specific locales in Arizona. An examination of these reports enables one to document significant trends of wetlands losses for the state, but again, none are adequate to serve as statewide figures.

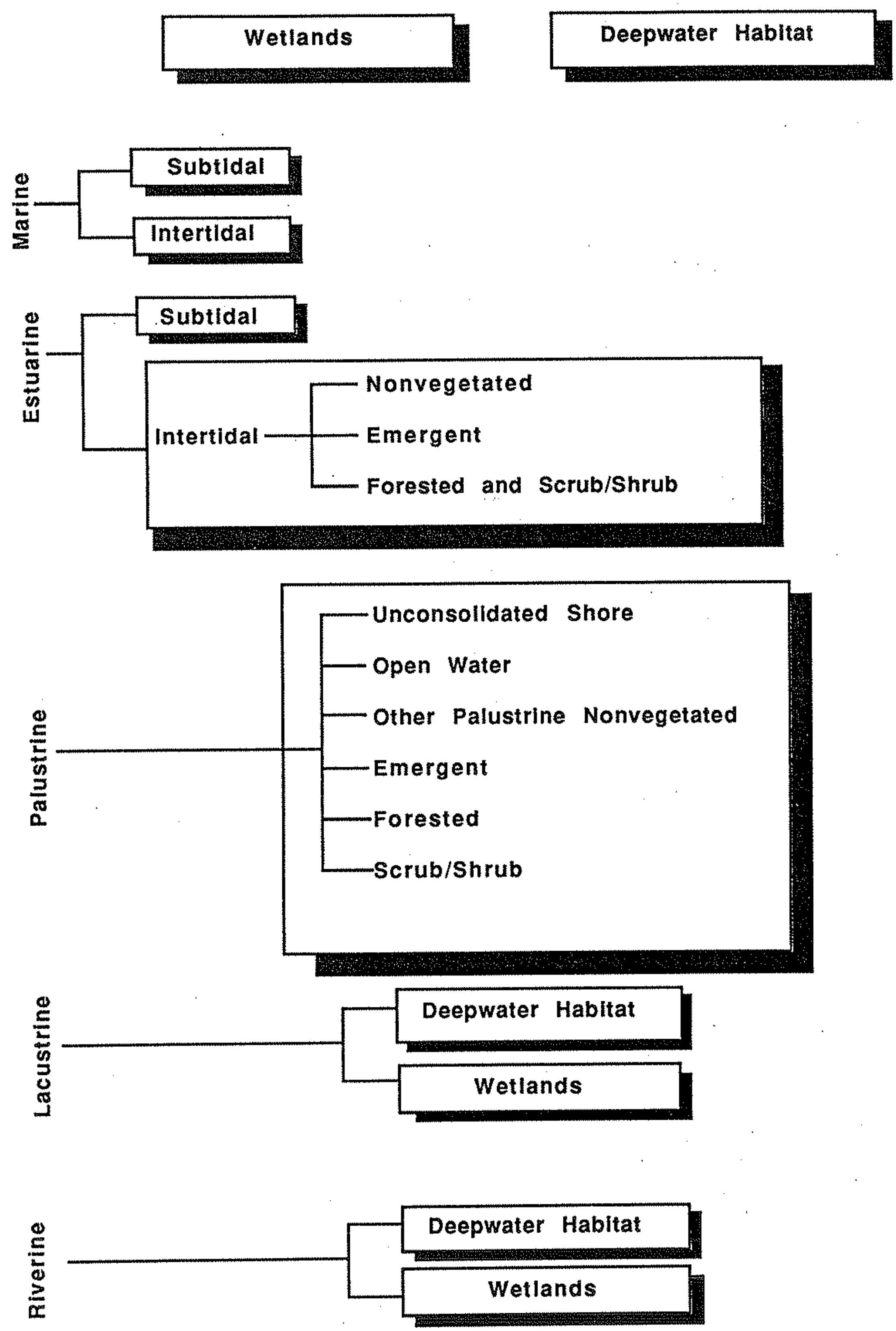
The Rivers, Streams, & Wetlands Study, a portion of the overall 1989 SCORP study currently in progress, has initiated a streams and wetlands inventory compiled from a variety of sources including the U. S. Fish & Wildlife Service, (NWI); U. S. Forest Service, (Run Wild); Arizona Game & Fish Department; Arizona Department of Water Resources; and numerous other sources. Over 100 wetlands sites not associated with stream drainages have been inventoried based on the information currently available. In addition, there are a large number of linear wetlands sites directly associated with the over 700 rivers and streams that are included in the inventory. For the majority of sites, there is little data known other than identification information such as location, water sources, and some general resource data. Other more well-known sites have a wealth of information accumulated that has been included in this inventory. The inventory format has been structured to facilitate addition of data as it becomes known. It is hoped that this study will serve as the beginning point for a functional, flexible inventory of Arizona's wetlands resources.

Distribution and Types of Wetlands of Arizona

Nationally, the most widely recognized and commonly used detailed classification system for wetlands and deepwater habitats is the USFWS' *Classification of Wetlands and Deepwater Habitats of the United States*. According to this classification, wetlands are grouped as marine, estaurine, riverine, lacustrine, or palustrine (Figure 1). Estuarine and palustrine wetlands are the nation's most abundant wetlands systems, comprising 99 percent of the total wetlands acreage if deepwater habitats are excluded. Palustrine forested wetlands are the most abundant wetlands type in the Eastern United States, comprising 40 to 90 percent of all wetlands types in some Mid-Atlantic states. Palustrine forested wetlands also are common along western rivers and streams, throughout much of Alaska, and occur sporadically in the prairie pothole region.

Arizona does not contain any marine or estuarine systems. Riverine systems include freshwater river and stream channels and are mainly deepwater habitats. Lacustrine systems include freshwater lakes, reservoirs, and deep ponds. The majority of freshwater wetlands fall within palustrine systems,

Figure 1. National Wetlands Classification
(Only Palustrine, Lacustrine, and Riverine found in Arizona.)



which include marshes, bogs, wet meadows, swamps, and shallow ponds. Palustrine wetlands can be grouped into three main types, which include emergent (marshlands, wet meadows, edges of rivers), scrub-shrub (bogs, thickets, woody swamps), and forested wetlands (bottomland hardwood forests, deciduous riparian forests, mesquite bosques).

There has been much discussion in the natural resource management community in Arizona regarding the classification of wetlands. Wetlands in Arizona rarely follow the typical Eastern-based systems and it was felt there was a need to develop a classification system oriented to Arizona's special conditions. There are several systems currently in use, each with its own definitions and purposes in mind. This document will follow the classifications set forth in the National Wetlands Priority Conservation Plan with reference to individual Arizona classification systems.

Wetlands are periodically, seasonally, or continuously submerged landscapes populated by species and/or life forms differing from immediately adjacent biotas. They are maintained by and depend upon circumstances more mesic than those provided by local precipitation. Such conditions occur in Arizona in or adjacent to drainageways and their floodplains (riparian zones), on poorly drained lands, and in and near other hydric and aquatic situations; i.e., springs and their outflows, ponds, margins of lakes, etc. The various wetlands and riparian communities may be represented as forest, woodland or scrubland, marshland or strand, or be composed largely or entirely of submergent vegetation. Although wetlands formations may be remarkably distinct, they are also often highly integrated, or occur as intermittent stands within other communities. In riparian habitats that pass through many biomes, high elevation species often extend downslope into grassland or desert within canyons that lead cooler and moister air downward (Brown and Minckley, 1982). Because of the great variations in wetlands habitats, the relatively small size of individual sites, and their widespread occurrence throughout the state, it is extremely difficult to clearly map Arizona's wetlands or generalize the diverse situations.

The National Wetlands Inventory conducted in Arizona undertook an enormous task to inventory and classify the state's wetlands. The majority of Arizona's wetlands are directly or indirectly associated with streams and their drainages. Unfortunately, the NWI did not include the majority of floodplain vegetation communities, only the vegetated islands within a stream channel. These riparian communities of old growth cottonwood-willow galleries and mature mesquite bosques, growing on the terraces above the actual channel, are just as dependent upon the existing aquifer for their survival as the more traditionally accepted wetlands vegetation. The riverine riparian areas in Arizona that were identified in the NWI were nearly all classified as palustrine forested. These riverine communities were specifically singled out in the 1985 report by Senator Jones to accompany the Emergency Wetlands Resources Act, clearly stating that **"...riverine habitats in the West are additional examples that deserve priority consideration."**

A further problem between the NWPCP and NWI is that the former states that Arizona does not contain any desert habitats classified as palustrine forested while the NWI identifies a large portion of Arizona's wetlands as palustrine forested. The NWPCP uses ecoregions that were developed by Lewis M. Cowardin, et al, 1979. These ecoregions are so broad that small habitats are largely ignored. In Arizona, the physical and arid nature of the state and the ever-increasing demand for water mandates that the majority of wetlands be extremely small and restricted in scope. Aquatic, riparian, and other wetlands biotic communities of the Southwest have rarely been differentiated or shown on maps. They tend to be small relative to other communities, but possess an importance and biological value totally disproportionate to their limited geographic occurrence. It becomes increasingly important then to accurately inventory and place high priority on the proper management and protection of the limited wetlands resources that exist in Arizona. [Editor's note: the NWPCP is being revised to reflect certain specific needs of Southwest wetlands and riparian areas.]

Arizona can be divided into fifteen major drainage basins (Table 3). Thirteen of these basins are directly related to river systems while two focus on closed systems (the Willcox Playa Basin and the Red Lake Basin). One of the fifteen, the Sonoran Drainages, includes two basins that are located primarily in Sonora, Mexico, but drain a few of Arizona's streams and springs (Figure 2). Within most of these basins can be found wetlands habitats that can be classed as palustrine, lacustrine, and riverine. Arizona has no marine or estuarine systems. Most wetlands classification systems now in use in Arizona relate singularly to either physiohydrological characteristics of streams or to the vegetation component. A draft classification system being developed by the Arizona Riparian Council is the first system proposed for Arizona that incorporates a wide variety of elements including Cowardin's classification types. This draft system integrates the abiotic factors (palustrine, lacustrine, geomorphological features, etc.) and the more familiar biotic factors (forest, strand, marsh, etc.) associated with wetlands. Until this system has been refined and accepted by the natural resources field, available information must be taken from existing classification systems (i.e., Brown & Lowe, 1973; Brown & Minckley, 1982).

Because lakes and large bodies of quiet water were unusual and typically ephemeral in the recent Southwest, the region's unique wetlands biota became largely stream adapted, or was physically restricted to remnant springs and seeps. Special note should be made of the state's riparian systems. All riparian systems in Arizona are to be included in the state's inventory of wetlands habitats. A riparian association of any kind is one which occurs in or adjacent to drainageways and/or their floodplains and which is further characterized by species and/or lifeforms different from that of the immediately surrounding non-riparian climax. The habitat is in and along the channels, their margins, and/or floodplains of the larger and/or better watered drainageways.

Table 3. Arizona Drainage Basins
(Source: Tunnicliff, 1987)

1. Agua Fria River Basin
2. Bill Williams River Basin
3. Colorado River Basin
4. Little Colorado River Basin
5. Lower Gila River Basin
6. Red Lake Basin
7. Salt River Basin
8. San Pedro River Basin
9. Santa Cruz River Basin
10. Upper Gila River Basin
11. Verde River Basin
12. Virgin River Basin
13. Willcox Playa Basin
14. Yaqui River Basin
15. Sonoran Drainages
    Rio Magdaleña Basin
    Rio Sonoyta Basin

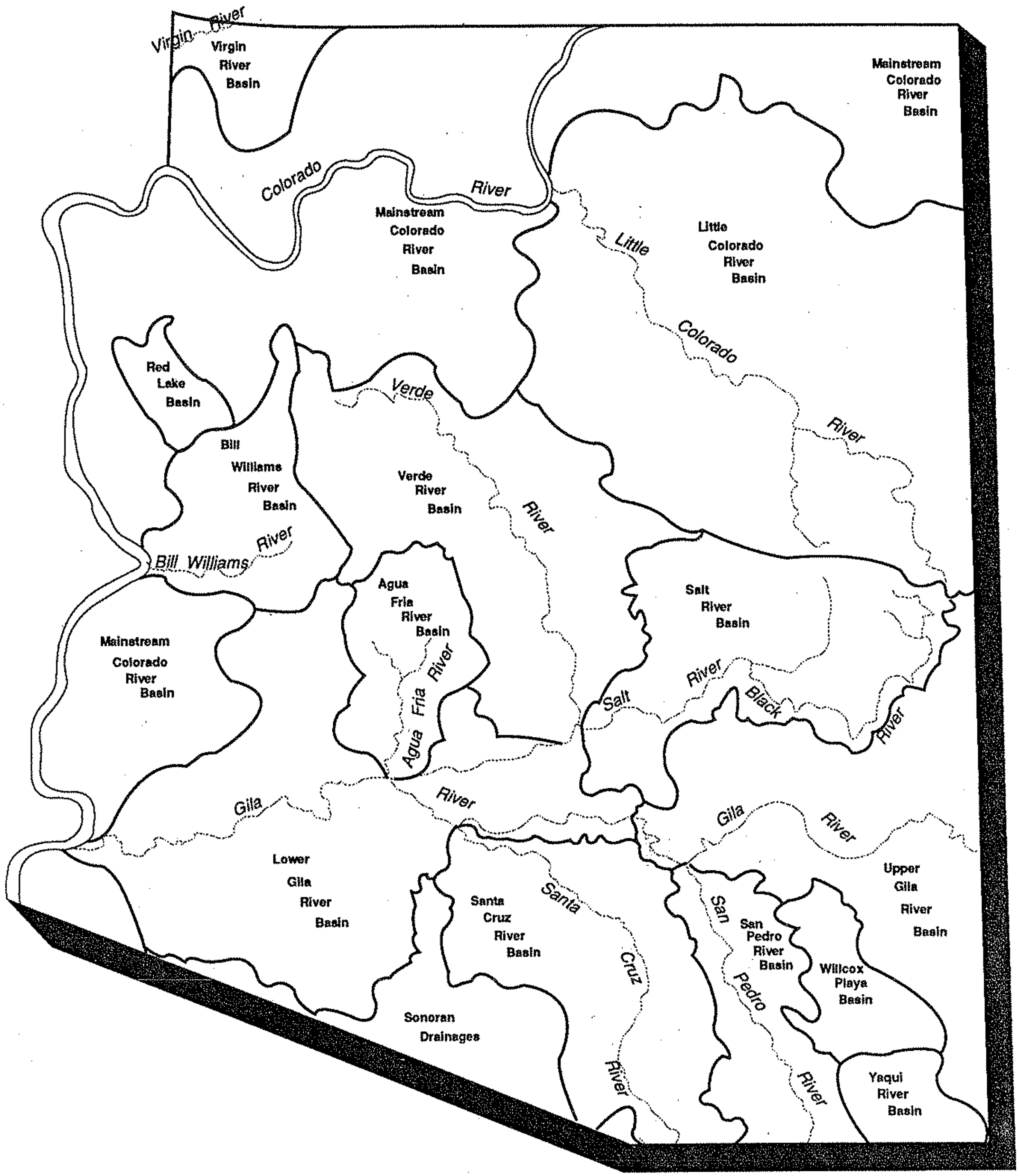
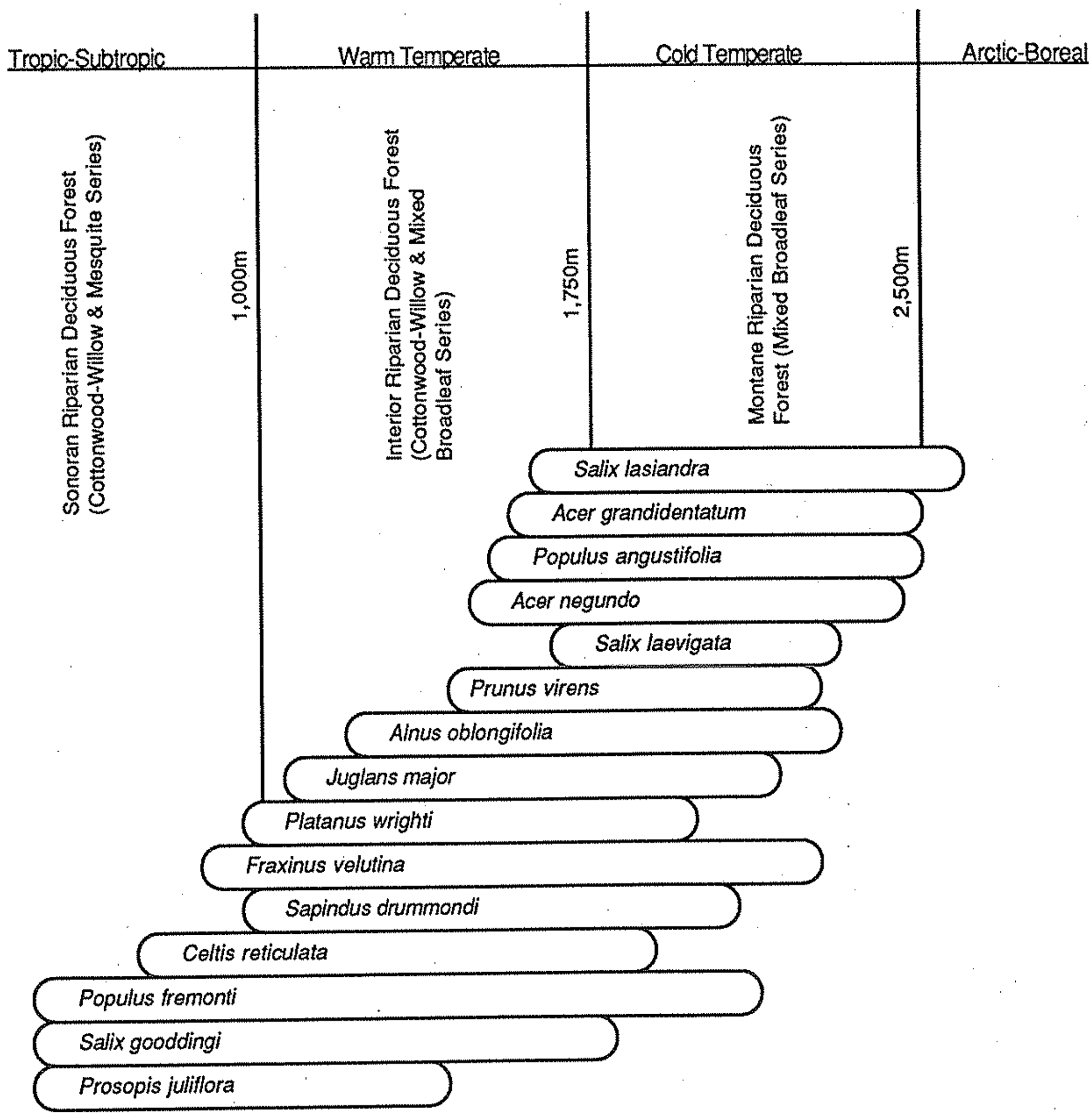


Figure 2. Major Rivers and Drainage Basins

A large portion of the riparian communities in Arizona, whether called forest or woodland, are composed of tall, winter-deciduous broadleaf trees that are the same species and/or genera as in the eastern deciduous forests of the United States. In the arid Southwest, these remnants of earlier widespread forests are restricted to streamways and drainages, and at some lakes and ponds that provide the necessary streamflow or underflow to support broadleaf forest species. Both their distinctive life-form and their riparian habitat distinguish these biotic communities from the evergreen western woodlands and coniferous forests through which they course fingerlike from the highest spruce-fir forests throughout the woodland and chaparral into the grasslands and deserts below. The composition and form of the riparian forest changes with elevation. It is incorrect to regard this biotic formation as merely a temporary unstable, seral community. It is an evolutionary entity with an enduring stability equivalent to that of the landscape drainageways which form its physical habitat (Figure 3).

Figure 3. Generalized altitudinal, climatic, and community distribution for some deciduous riparian trees in the sub-Mogollon Rim region of central Arizona.



Geographically, Arizona can be divided into two major geologic provinces: the Basin and Range Province and Colorado Plateau Province. The provinces are characterized by quite different stratigraphic framework and structural patterns and are separated by a narrow area of transition, which is commonly called the Transition Zone or Central Mountain Province (Figure 4). Within each of these are located the many mountain ranges, valleys, and plateaus that help create the geologic and biologic diversity found in Arizona (Figure 5). The Southwest encompasses part or all of eleven biotic provinces out of twenty-two found in North America (modified after Dice, 1943, and Dasmann, 1974). Six of these biotic provinces occur in Arizona: Chihuahuan, Great Basin, Interior (Mogollon), Madrean, Mohavian, and Sonoran (Figure 6).

The description of wetlands types and biotic provinces as stated below primarily follows the systems developed by Brown & Lowe, 1973; Brown & Minckley, 1982; Dice, 1943; and Dasmann, 1974. Wetland types found in Arizona are classified as Arctic-Boreal wetlands, cold-temperate wetlands, warm-temperate wetlands, tropical-subtropical wetlands, and other wetland types.

Arctic-Boreal Wetlands

In the highest elevations, the number and length of subalpine streams in Arizona are limited by the relatively small watershed areas of sufficient elevation and size, and sometimes by geologic situations. Wetlands of this type are restricted to the few high elevation mountain ranges and plateaus in Arizona, such as the San Francisco Peaks, the Kaibab Plateau, the Chuska Mountains, the Pinaleño Mountains, and the White Mountain area (see Figure 5). Within and adjacent to subalpine forests and grasslands are numerous perennial streams and other aquatic situations bordered by shrub willows and other winter deciduous scrub. While these alpine and subalpine riparian scrublands may be punctuated by blue spruce, aspen, and other tree species of the subalpine conifer forest, distinctive riparian tree life forms are generally absent from this zone. Boreal scrublands along watercourses are important and distinctive biomes and, in the Southwest, provide the southern-most breeding habitat for many characteristic northern avifauna. Many subalpine grassland meadows possess high water tables, so small marshy ponds or cienegas are common features. Natural lakes are few (a number of small subalpine lakes exist in the White Mountains and Kaibab Plateau) and are greatly outnumbered by small, artificial reservoirs and tanks designed for recreational fishing and livestock use.

Cold-Temperate Wetlands

Riparian and other wetlands communities in the Montane (Mogollon) and Great Basin biotic provinces of the Southwest are characterized by winter-deciduous trees as well as shrubs and aquatic plants. These ecosystems, while often structurally diverse, are of relatively simple species composition when compared to some riparian communities in warm-temperate and subtropical climates. Adapted to spring flooding after snowmelt, the riparian associations typically are in a successional stage to deciduous forests unless arrested or eliminated by impacts of upstream impoundments and/or overgrazing by livestock. A large proportion of the Southwest's "live" streams are in this climatic zone. Unlike rivers of moister zones that increase in size and volume throughout the year in a downstream direction, southwestern rivers flowing from mountains across deserts often have diminution of discharge both up and downstream from intermediate elevations.

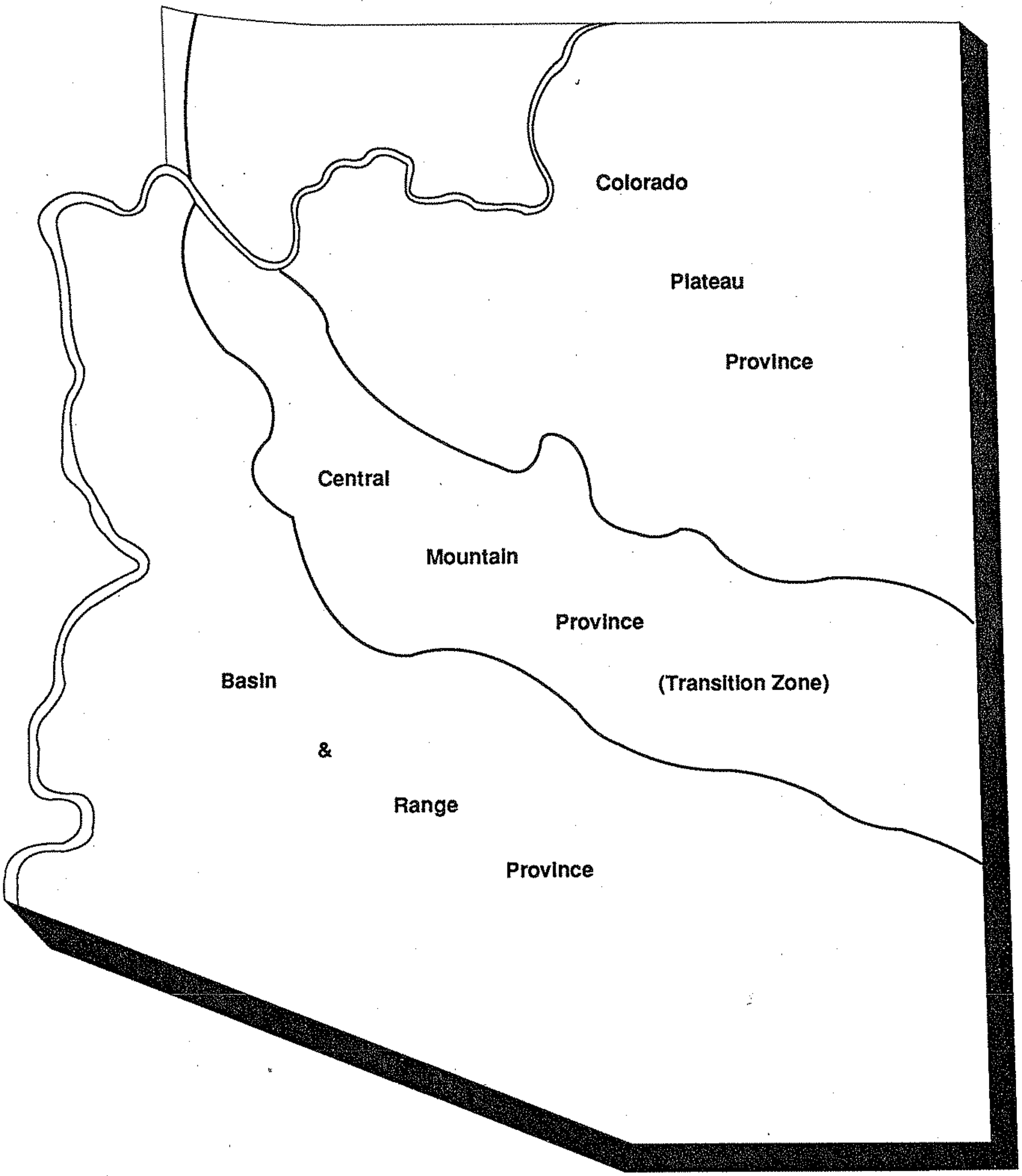


Figure 4. Physiographic Provinces

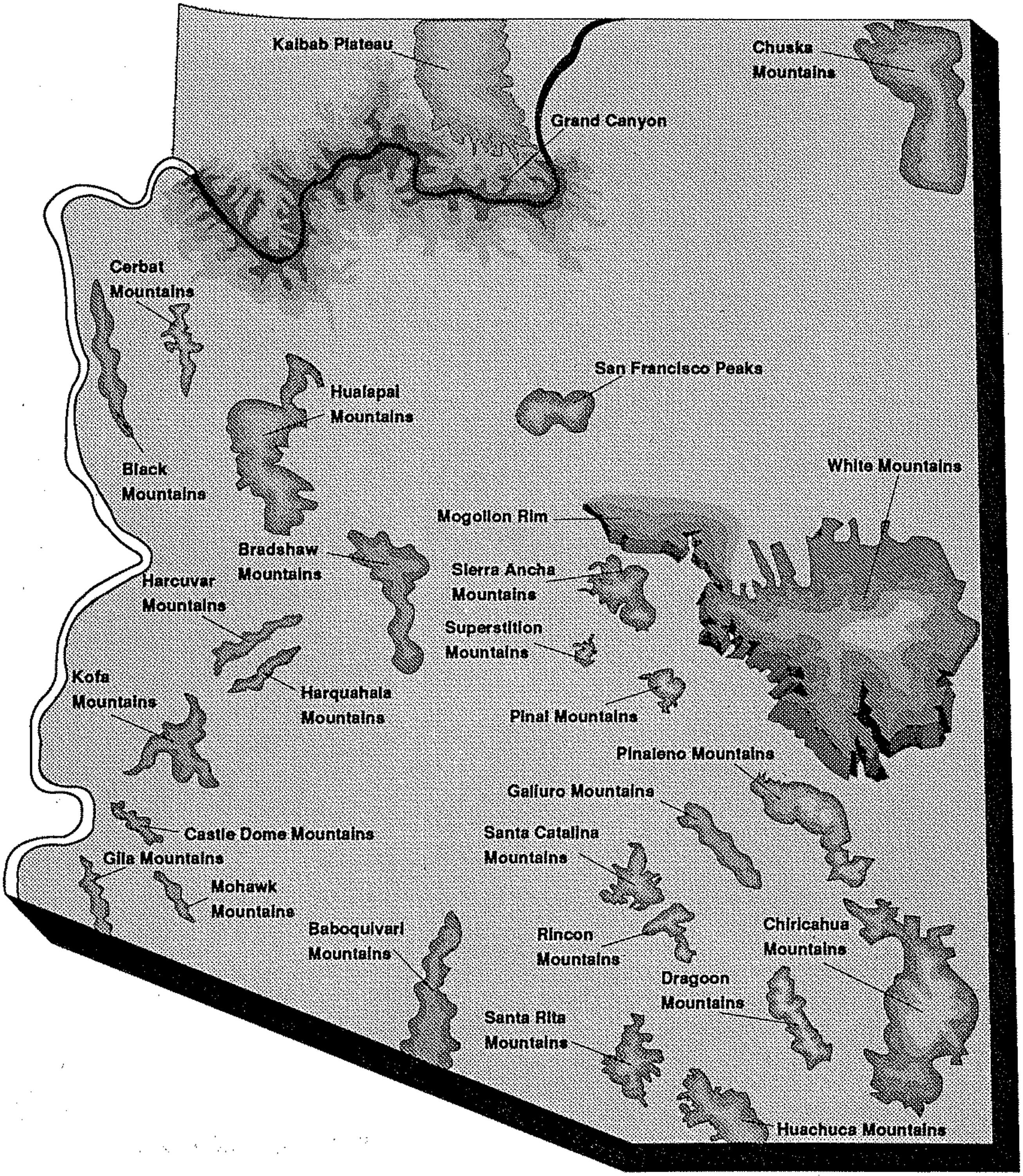


Figure 5. Major Topographic Features

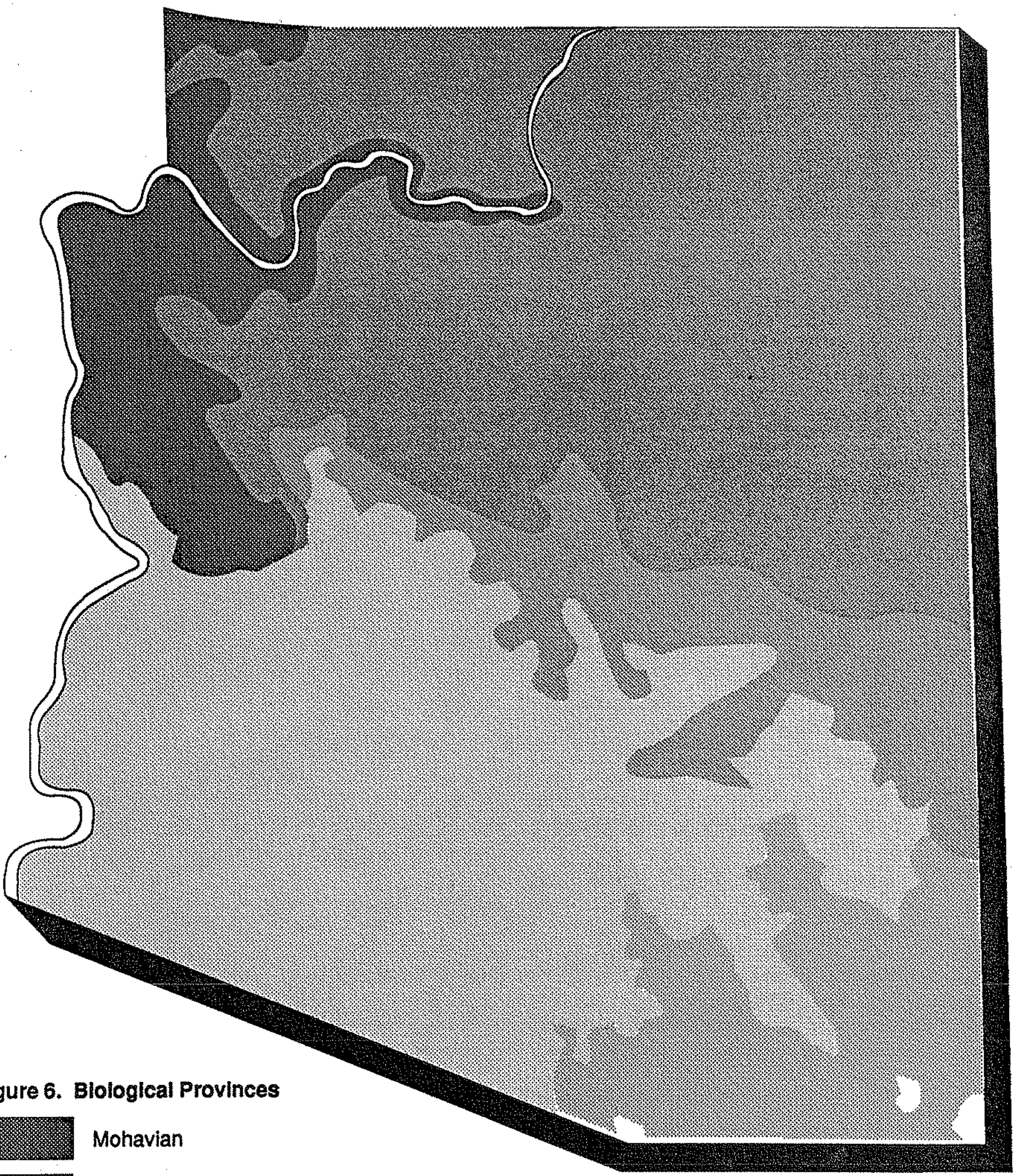


Figure 6. Biological Provinces

Mohavian
Great Basin
Interior (Arizonan)
Chihuahuan
Sonoran
Madrean

Montane Riparian Wetlands - In Arizona, these wetlands occur primarily as canyon bottom forests along perennial and near-perennial streams from 3,500-7,000 feet. The dominant aspect of many of these montane streamsides is one of scrubland. Examples of such wetlands can be found along Workman Creek in the Sierra Ancha Mountains and other canyons emanating from the Mogollon Rim and the White Mountains.

Great Basin Riparian Wetlands - Primarily limited to the northern part of Arizona, the Great Basin biotic province, comprised of disclimax riparian scrublands and strands populated by the introduced saltcedar, covers many miles of river and stream channels including ephemeral tributaries. Other exotic plants such as Russian olive and camelthorn have become naturalized and contribute increasingly to the composition of scrublands along the Colorado, Little Colorado, and Virgin Rivers and other Great Basin drainages.

Montane (Mogollon) and Great Basin Marshlands - Marshes, extremely limited in the Southwest, occupy only a small area in this climatic zone so that their wildlife values are particularly high. Some larger, natural examples include Mormon Lake and Stoneman Lake. Smaller examples are clustered in the poorly-drained portions of the Mogollon Rim and north-central Arizona (Meadow Valley Wash in Yavapai County), especially where sinkholes have developed through subsurface solution, and occasionally elsewhere within montane forests as well as in the Great Basin. The Kaibab and Colorado Plateaus support a number of small cienegas, but these are now mostly drained or pumped dry (such as Obed and Hugo Meadows south of Joseph City). Marsh vegetation is characteristically zoned along a littoral gradient. These marshlands provide feeding and watering habitat for a number of migratory and resident wildlife species.

Warm-Temperate Wetlands

Included in this climatic zone are some of the Southwest's most extensive and most endangered wetlands. Ranging from open mud flats to complex broadleaf deciduous forests with canopies more than 90 feet above the ground, these habitats provide a wide diversity to an enormous variety of aquatic and semi-aquatic inhabitants. Biotic communities represented here include several associations of riparian deciduous forest, riparian scrub, interior marshes, and strands.

Interior Riparian Deciduous Forests and Woodlands - Mixed broadleaf series of Interior riparian deciduous forests occur along rubble-bottomed perennial and near-perennial streams, such as Gap Creek in Yavapai County and the Upper Gila River and its tributaries in Graham and Greenlee Counties. These winter-deciduous communities are diverse because high altitude species penetrate downslope to occur among lowland forms. Numerous wildlife species are totally dependent on these riparian deciduous communities and many others reach their greatest densities there. Originally, they occupied many of the major as well as secondary drainages in their associated biotic provinces where they are now greatly reduced because of reductions in stream flow. These communities are maintained along perennial or seasonally intermittent streams and springs and may be divided into two major vegetation types: cottonwood-willow and mixed broadleaf.

These Interior forests are relictual communities with the present distributions reflecting a contraction of the formerly widespread mixed mesophytic forest. These riparian forests are vernally adapted to Early Tertiary climates and have retreated to pockets where the warm temperate climate persists. Where streamflows are intermittent, well-developed gallery forests can be expected only where surface flow reliably occurs during winter-spring months because the onset of the spring growing season can be expected prior to April 15. After mid-April, increased evaporation and phytotranspiration often result in only subsurface flow in all but the larger streams. The Southwest's warm-temperature riparian forests and woodlands require abundant water during March and April when most arboreal species leaf, set seed, and germinate.

Indications are that cottonwood-willow associations are maintained and depend on periodic spring floods. Evidence for the winter-spring flood adaptation of these communities are "new" forests along undammed portions of the Verde and San Pedro Rivers following spring floods in 1962 and 1967. Stabilized flows from storage reservoirs and summer flooding in today's wider channels facilitates dissemmination of saltcedar, allowing that species to replace cottonwood and willow along many miles of the Gila, Salt, and Colorado Rivers. Stabilized flows below dams seem especially to result in decadent stands of native trees in which reproduction is lacking.

Riparian Scrublands - Although riparian scrublands cover many kilometers of floodplain and stream channels in the Mohavian, Chihuahuan, and Madrean provinces, there is a tendency to ignore these communities in favor of the richer biota of more structurally diverse assemblages. These habitats may also constitute a riparian understory or prelude for the riparian forests just discussed, grade into marshlands, or in the more xeric places where salts accumulate, form alkali-loving communities.

There is ample evidence of vast increases in this formation type in the past years, largely at the expense of cottonwood forests and woodlands. Riparian scrub may range from simple disclimax consociations of introduced saltcedar to complex and diversified associations containing dozens of species. Some of the most extensive warm-temperature riparian scrublands in Arizona are along the Colorado River and its tributaries where they traverse the Mohave desert. Protected aquatic habitats such as cut-off ponds support emergent marshland plants in addition to scrub. Pondweeds and submergent aquatic plants occur intermittently, but such communities have scarcely been described. Canyon segments of large rivers in this climatic zone, now subjected to upstream controls, were too heavily scoured during flooding to support other than the most rudimentary riparian scrublands. This classically occurred within the Grand Canyon on the Colorado River prior to closure of Glen Canyon Dam, wherein most riparian vegetation was a shrubby border of mesquite above the level of most annual floods. Similar conditions may still be found in box canyons of the Salt and Gila Rivers.

Interior Marshlands - Marshlands of this climatic zone are represented by a number of Interior marsh biomes, though they are scarce in Arizona. Warm-temperate marshlands occur in old river oxbows, on poorly drained lands, at springs, and other shallow water sites in the Mohavian, Madrean, and Chihuahuan biotic provinces. Many of these represent remnants of once large aquatic systems, now scarcely perpetuated by far lower precipitation and meager outflows of groundwater, such as that found at San Simon Cienega and Willcox Playa. Many of these environments are saline, a result of evaporative concentrations of salts, and plant communities often are reminiscent of seaside marshes. These areas are now suffering invasion by saltcedar in a pattern similar to that described for riparian scrublands.

Interior Strands - Strand habitats occur in flood channels of rivers, along banks of streams below hydroelectric dams, along receding reservoirs, and around intermittent fluctuating lakes. Vegetation of these environments is made up of either short-lived successional species or plants adapted to periodic flooding, scouring or soil deposition, and in the case of playa lakes, high salinities or other special chemical conditions associated with evaporation of inland waters. Depending on substrate and frequency and type of inundation, Interior strand communities along streams may be composed of sparse, open stands of riparian scrub species, seedlings of riparian trees, or any of a number of annuals and perennials, or barren except for simple plants such as algae. Narrow strands occur at Willcox Playa, along the San Pedro River as a seasonally inundated mud-sand substratum populated by a few plants of burrobush and nightshade, and along the mainstream Colorado River within the Grand Canyon where stability is provided by upstream dams that produce an almost-tidal, daily fluctuation in water levels.

Tropical-Subtropical Wetlands

As is the case with subtropical uplands, there is a wide range of wetlands habitat types, some of which exhibit exceptional plant and animal diversity. Included are consociations of mesquite bosques and palm oases as well as associations of deciduous and evergreen riparian forests, riparian scrublands, marshlands, and strands. Human alteration of almost all of the region's rivers coupled with introductions of non-native species has resulted in major modifications and displacement of the original stream biota. The majority of tropical-subtropical wetlands in Arizona are located in the southern and south-central parts of the state.

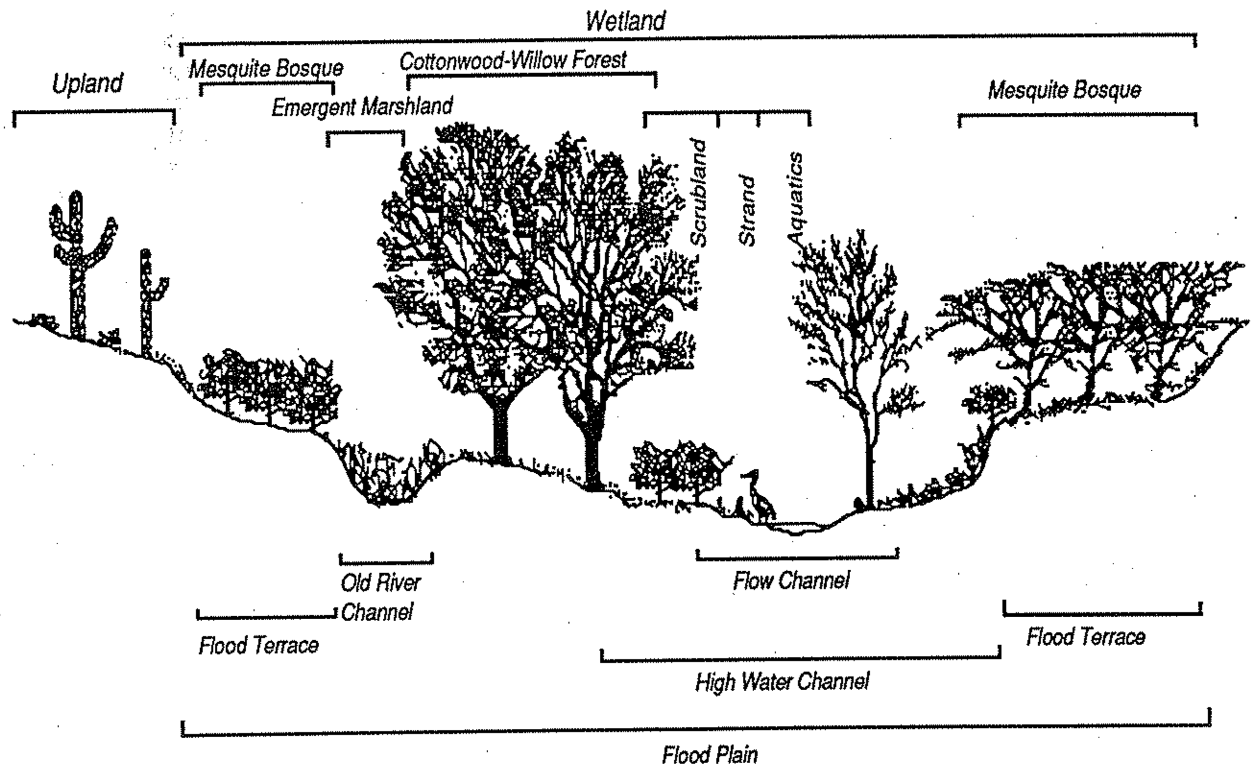
Sonoran Riparian Deciduous Forest and Woodlands - Centered in the Sonoran biotic province are streamside associations of tropic-subtropic subspecies of willow, cottonwood, and mesquite. Winter-deciduous, these biomes are nonetheless subtropical riparian where they are restricted to streams and springs below 3,500 feet in elevation in and immediately adjacent to the Sonoran Desert. While now much reduced in extent, these forests are still represented by impressive examples and may contain individual trees of great size. Willow and cottonwood forests were, and remain, largely restricted to the immediate floodplains of perennial, or at least spring-flowing streams, where they are maintained by periodic winter-spring flooding. As such, southwestern tropic-subtropic examples are largely restricted to the lower Colorado River and Arizona Upland subdivisions of the Sonoran Desert which possess watersheds of sufficient winter precipitation and hence the spring discharges necessary to support them. Mesquite bosques attain their maximum development on alluvium of old dissected floodplains, especially those laid down at the confluence of major watercourses and their larger tributaries. Consequently, these higher secondary floodplains are commonly 4-18 feet above the river channel (Figure 7).

Many of the more famous bosques referred to in the literature are today mostly of historical interest: mesquite thickets at San Xavier, Komatke, and the mesquite and cottonwood forests along the lower Gila and Colorado Rivers. Nonetheless, some excellent examples still occur as scattered remnants along the Santa Maria, Verde, middle Gila, San Pedro, and other desert river systems. These remaining bosques are all threatened by a variety of human-related causes. With some notable exceptions, willow-cottonwood forests have been reduced to small isolated groves and are now scattered along the Colorado River where they were once extensive. In many places, such areas are now vegetated by Sonoran riparian scrubland. Often, the remaining groves are open woodlands of over-mature individuals that are lacking in reproduction and may be expected soon to disappear because of stream channelization and regulation. Gallery forests of willow and cottonwood can nonetheless still be found along reaches of undammed and more natural portions of the Verde, middle Gila, Hassayampa, and San Pedro Rivers.

Sonoran Oasis Forest and Woodlands - These evergreen, Miocene and Pliocene relics, are restricted to certain isolated, permanent springs, seeps, and mountain canyons in and at the western edge of the Sonoran Desert. Natural oases are represented by groves of the California Fan Palm in the narrow canyons of the Kofa Mountains, at and near Alkali Springs near Castle Hot Springs, and possibly at Cienega Spring northeast of Parker.

Sonoran Riparian Scrubland - In and along drainages within the Sonoran Desert, such as the Verde and Salt Rivers and their tributaries, are scrublands of low to medium height, too dense to be considered desertscrub or strand. Although these scrublands usually contain plant species also found in adjacent desertscrub, the actual stream channel dominants are usually distinctive riparian species. Along the saline portions of the lower Colorado and Gila Rivers are dense and taller thickets of introduced saltcedar and the evergreen athel. These communities are in a fire succession stage and each fire occurrence increases the prevalence of root sprouting saltcedar at the expense of more valuable native vegetation. Consequently, fire disclimax consociations of saltcedar now exclusively occupy extensive areas along the lower Colorado River, its delta, tributaries, agricultural drains and sumps, and other poorly drained alkaline places.

Figure 7. Wetlands /Riparian Habitat in the Sonoran Desert



<u>Sonoran Interior Marshlands and Submergent Communities</u> - Freshwater marshes, such as Topock Marsh along the Colorado River, are rare in these biogeographic provinces because of their dependence on old oxbows of large rivers such as the Colorado. Today, many of the larger marshlands occur where rivers enter large reservoirs, such as the delta of the Bill Williams River in Lake Havasu. A very few are associated with natural springs or intersect groundwater tables. More common today are brackish marshes dependent for their existence on wastewater discharges, agricultural drains, and silt-laden reservoirs (Picacho Lake). Although these marshlands and aquatic communities are justifiably considered important wintering grounds for waterfowl, they also possess a distinctive nesting avifauna.

Sonoran Interior Strands - Stream channels, such as the Salt and lower Gila Rivers, and other Interior strands of subtropic Sonoran zones are typically occupied by open stands of scrub, shrubs, and weeds. Wetter sites have a correspondingly greater herbaceous cover and may support a dense stand of annuals. Other less-watered basins and channels, or those subject to frequent scours, may be populated only by algae or very early successional stages. As is the case with strands everywhere, the substrate may be of mud, sand, rock, or rubble. Plant-animal relationships within these linear and basin communities remain largely unstudied. Smaller desert streams often meander in aggraded, braided channels through sandy beds where change is constant. Over a period of a year, fluctuations in water levels are pronounced, so that aquatic and semi-aquatic animals may simply survive in periods of drought in greatly reduced, permanent segments and fulfill their principal biological function of reproduction in winter months of higher flow or after summer rains.

Other Wetlands Types

Rock pools, or tinajas, in arid mountain ranges have long been known as oases crucial for survival of some wildlife species, of ancient peoples, and for later desert travelers. They also support local and often distinctive populations of plants, invertebrates, and vertebrates. These small habitats, typically scoured from bedrock by boulders powered by infrequent flash floods, qualify as special wetlands within the Southwest's myriad of systems. They are so poorly known biologically that they are scarcely treated any further than a mere mention, but seepages downslope from such places may support diverse and special riparian communities, such as dense stands of cottonwood and willow or groves of palms in places like the Kofa Mountains.

Far more numerous than natural freshwater habitats are artificial reservoirs, farm ponds, and the innumerable cattle stock tanks of varying degrees of permanence that have been constructed primarily by ranchers and farmers. These, and pumped ponds, have created a scattering of aquatic communities in arid parts of the Southwest that were otherwise devoid of surface water. Such impoundments created lenthic habitats in a region formerly dominated by streams. These stock tanks provide important waterfowl resting sites, wildlife habitat and watering sources, especially in desert environments. Extensive canal systems provide linear, flowing systems across desert lands, often connecting formerly isolated bodies of water to allow dispersal of organisms across vast reaches. Lining of canals (and many natural desert streambeds) with concrete and soil cement in the past few years has drastically reduced these substitute riparian habitats by suppressing seepage and limiting vegetation growth.

Wetlands Trends in Arizona

Historic Losses

In the last one hundred years, Arizona has lost 90-95 percent of its most critical and valuable resource - **riparian ecosystems.** Once a common scene along the state's drainage-ways, now these habitats are Arizona's most rare and threatened natural communities. Man's need for water in a dependable fashion in order to establish himself in this arid environment resulted in changes and impacts on the natural environment. River impoundments, channelization, groundwater pumping, and agricultural development have reduced wetlands and riparian areas to mere vestiges of their former abundance. Cottonwood-willow gallery forests were once a dominant feature creating lush canopies along all of Arizona's major desert river systems. Now, fewer than 20 occurrences remain (The Nature Conservancy considers this habitat globally endangered, meaning that it is found in fewer than 20 places in the world) and only 5 of the 20 are extensive. Covering less than 0.001 percent of the state's land area, Fremont cottonwood-Goodding willow forests are North America's rarest forest type. Mature stands of mesquite bosques are the fourth rarest plant community of 104 types identified in the United States. From early explorer accounts, 50 separate cienega sites in Arizona have been identified. Today, only 15 remain and several of these have been greatly impacted by overgrazing and groundwater pumping. Only one is currently under permanent protection (The Nature Conservancy, 1987).

Native fish are the fastest disappearing wildlife group in the United States today. The predominant cause for the current threat to native desert fish is that man and fish are in direct competition for water. The only hope for the survival of native fish is habitat protection (riparian and wetlands habitats). Of Arizona's 35 species of native fish, 1 species is extinct and 5 are gone (extirpated) from the state; 21 of the remaining 29 species are either federally listed as threatened or endangered or are under consideration for listing; and 25 are classified by the State of Arizona as threatened (The Nature Conservancy, 1987).

Arizona has no long-term, well-documented account of its historic wetlands resources and the rates of loss of the different wetlands types. There are some historic journals and records available written by early Southwest explorers and other travelers that describe a much different environmental setting than the one that is present in Arizona today. Generally, the last one hundred years can be summarized by the following:

1) a steady decline in abundance of native grasslands
2) a marked increase in shrubs on the desert plains and foothills
3) initiation of channel-cutting on all main rivers with subsequent head-cutting through many acres of grassland
4) removal of the majority of riparian trees from all major rivers
5) significant loss of perennial instream flows in major rivers
6) substantial changes in fish and wildlife populations dependent on wetlands/riparian habitats

Historical evidence demonstrates a wider distribution of cienega and riverine marshland than is found today in southeastern Arizona. That uncised, largely perennial streams of the 1850s became today's intermittent arroyos is well documented. The cycle of erosion and arroyo cutting that left only remnants of these habitats has been thoroughly discussed by various authors, without reaching consensus as to ultimate factors of causation. Anglo-American impacts of water diversions, grazing, vegetation change, wood cutting, mining, groundwater exploitation, and artificial drainage concentration by roads, ditches, bridges, and railroads have been widely covered (Thornber, 1910; Duce, 1918; Bryan, 1922, 1925a-b, 1926, 1940; Thornwaite et al., 1942; Leopold, 1951b; Antevs, 1952; Humphrey and Mehrhoff, 1958; Hastings, 1959; Hastings and Turner, 1965; Denevan, 1967; Burkham, 1970, 1972, 1976a-b; Cooke and Reeves, 1976; Dobyns, 1978, 1981; Hendrickson and Minckley, 1985).

Prior to 1880, alluvial plains of river bottoms at lower elevations (<3,000 ft.) were wetter and less well drained than at present. Streams were commonly characterized by boggy margins, marshy sloughs, and backwaters, which were of great annoyance to early travelers and a health hazard (malaria) to personnel at nineteenth century military posts. Stream channels were typically shallow and braided, with deeper water in meanders and oxbows and where beaver activity was prevalent. The well-known but poorly understood cycle of arroyo cutting that began in the 1880s and 1890s, coupled with deliberate river channelization, streamflow impoundment and diversion, and mining of groundwater, have caused these riverine and adjacent spring-fed marshlands (cienegas) to become an almost extinct Southwestern landscape feature (Minckley and Brown, 1982).

Originally, interior riparian forests occupied most of the major drainages in the Southwest from the Mohave and Sonoran Deserts through Arizona, northeastern Sonora, southern New Mexico, northern and eastern Chihuahua to the Rio Grande, and its tributaries in southwest Texas. Today, only a few drainage systems, such as the undammed Rio Magdaleña in Sonora and small sections of the San Pedro River in Arizona, represent riparian forest development.

The Southwest's major rivers have been altered by dams for many years, their flows diverted and changed, and their once-perennial lower reaches de-watered. In fact, the Southwest's largest river, the Colorado, with the exception of a few important reaches, has been reduced to a series of impoundments connected by canals. These regulated streams have much of their former nutrient loads trapped by reservoirs, to the detriment of downflow systems. Further, discharge, temperature, and sedimentation regimes are now unsuitable for the native aquatic and semi-aquatic biota that is adapted to a seasonally turbid and variably aggrading and degrading, warm and vernal-flooded system (Minckley, 1979). Less than 10 percent of the original riparian habitat along the Colorado River remains. New riparian habitat has been created from dam construction along the river, resulting in a change in species diversity. In many places, these new areas are now vegetated by Sonoran riparian scrubland as opposed to riparian deciduous forests. The highly specialized, endemic fish faunas of Arizona, including the Colorado River squawfish, bonytail chub, and razorback sucker, have suffered population declines due to habitat alteration. They have been largely destroyed and replaced by non-native species. Some lesser rivers are as yet unregulated and these, along with many smaller streams at intermediate elevations, still support native aquatic faunas, though increasingly influenced by introduced species.

In the middle 1800s, parts of the San Pedro River were marked by channelization and "...other parts flowed slowly through grassy marshes, flush with the banks, often flooding extensively behind beaver dams" (Davis, 1973). Beaver were apparently numerous because James O. Pattie and his trapping company took over 200 beaver from the river in March 1826. As late as 1859, grizzly bears were still found in the riparian woodland along the San Pedro and large razorback suckers were caught and sold commercially for sale during Tombstone's glory days (Minckley, 1965). Early travelers made long detours around river sections to prevent wagons and livestock from sinking into the extensive cienegas. In only 25 years, 50 percent of the riparian habitat in the San Pedro Valley has been destroyed.

While there have been a number of studies conducted to map Arizona's vegetation communities, there has been a great disparity in scale, classification, and extent of areas studied. Some studies lumped all riparian habitats together, others separated each species or association, some studies centered on a specific part of the state, and others seemed to have poorly defined study boundaries. Most vegetation maps of Arizona omit riparian communities because the linear and mosaic nature of riparian vegetation often make it physically impractical to delineate riparian communities on small-scale maps. All in all, though there has been considerable research done on the state's riparian systems, they are not in a comparable format, making analysis difficult, as evidenced by the following examples.

In a 1974 report by Steve J. Sayers, it was estimated that there were 1,407,584 acres of mesquite bosques and an additional 46,697 acres of mesquite-cottonwood vegetation type occurring on private, state, and BLM land in Arizona. However, Sayers' interpretation of mesquite bosque differs from the definition used by other agencies. The most complete estimate of areal extent of phreatophytes and hydrophytes in Arizona appears in a 1965 unpublished report by T. W. Robinson. The report stated that mesquite and paloverde covered 43 percent, saltcedar 38 percent, and arrowweed and baccharis 12 percent of the 280,000 acre area surveyed. Robinson diagrammed saltcedar occurrence along streams, reservoirs, lakes, and playas on a small-scale map (1:7,500,000) of the western United States. He tabulated more than 900,000 acres of saltcedar in the western states, with more than 118,000 acres in Arizona. Much of the saltcedar occurring in Arizona was in the bottomland along the San Pedro, San Simon, and Gila Rivers.

A 1971 vegetative study, conducted by the Lower Colorado Region State-Federal Interagency Group, covering 90,328,000 acres in the lower Colorado Region, classified riparian vegetation into a single riparian type without any separation of species. The study tabulated vegetation occurring in blocks larger than 1,000 acres and the total estimate of 106,000 acres for Arizona is lower than that estimated by Robinson. The Salt, San Francisco, and Gila Rivers, as well as Tonto Creek, are centers of riparian vegetation on the Interagency Group Map (1:3,168,000).

The incomplete nature of past studies and efforts in determining the types, condition, and extent of Arizona's wetlands and riparian areas makes it difficult to determine accurate wetland acreages and the extent of losses. Based on what is known, though, it is increasingly apparent that the state's wetlands are in serious jeopardy and have sustained significant decreases in both type and acreage. The demands on the state's wetlands and riparian communities have increased in an inverse proportion to the available supply. Arizona's wetlands are being threatened by over-use, abuse, and a general reduction in quantity and quality.

Threats to Wetlands

Riparian ecosystems in Arizona can include both wetlands and upland habitats and serve as crucial fish and wildlife habitats. Riparian zones are the primary habitats for birds which find food, shelter, and nesting sites in the lush stands of cottonwood and willow. Larger mammals, such as deer, elk, and bear, regularly visit or occupy riparian zones, as do many species of smaller mammals, reptiles, amphibians, and native plants. Vital as these "ribbons of life" are to so many species, riparian zones are the most impacted land forms in the West. As important as these communities are to the natural environment, they became equally important to the people who settled here, from prehistoric times to the present. Unfortunately, wildlife and habitat considerations were frequently not an integral part of water and land decisions. Groundwater pumping, overgrazing by livestock, the construction of dams, water diversions, flood control measures, and conversion to pasture and cropland have, in the past, decimated riparian ecosystems. As much as 90 percent of the Colorado River's riparian forests in Colorado have been destroyed and stands of cottonwood along the Colorado River in Arizona have been reduced by 44 percent (NWF, 1987).

Preventing continued conversion of the remaining wetlands to crop use is made much more difficult by the fact that of the 95 million acres of wetlands left in the lower 48 states, only 13 million (14 percent) are owned or under easement by the federal government. In addition, 85 percent of the remaining palustrine wetlands, those most subject to conversion for cultivation, are privately owned.

Livestock grazing is an issue that has created one of the most heated controversies in the history of the state's management of its lands. Impacts of livestock overgrazing on riparian vegetation are magnified in arid and semi-arid regions. Typical stream habitat changes resulting from trampling of stream banks and increased erosion include: loss of streamside and instream cover, widening and shallowing of channels, increased water temperatures and velocities, silt degradation of spawning and invertebrate food producing areas, and decreased terrestrial food inputs. Most riparian systems in Arizona are grazed, which, if not managed properly, can produce aging cottonwood or hardwood galleries, with concurrent lack of reproduction of trees, vines, or shrubs; diminished wildlife and recreational values; and erosion and water quality problems. There is considerable debate over just how much of Arizona's rangeland and riparian habitat deterioration is attributable to overgrazing. However, at least one important aspect associated with direct impact of grazing on bottomland vegetation has been overlooked (Hendrickson and Minckley, 1985).

Early data on numbers of cattle in Arizona counties were based on tax assessments, which likely underestimated actual numbers. Governor F. A. Tritle in 1885 claimed that at least 50 percent could be safely added to returns of the county assessors (Wagoner, 1952). Using such a correction, Hendrickson and Minckley (1985) calculated an average of 377,474 cattle were grazing lands of Cochise, Santa Cruz, Pima, and Graham counties over the 5-year period preceeding the 1893 drought. Assuming greater accuracy of more recent reports, an average of only 180,200 cattle have grazed the same area over the period 1977 to 1981 (AZ Crop and Livestock Reporting Service, 1981). Nevertheless, there are still heavy impacts of grazing activities today, especially at watering sites (Hendrickson and Minckley, 1985). Cattle rarely travel greater than 5km from water (Valentine, 1947) and only lightly utilize range greater than 3km from water. Therefore, cattle in the 1880s must have been concentrated within a 5-km radius of natural streams. Since the innovation of stock tanks in the Arizona cattle industry did not occur until near the turn of the century, otherwise usable land would have been grazed at most seasonally. Hendrickson and Minckley (1985) hypothesize that stock tanks greatly reduce impacts on natural waters and riparian zones by providing more uniform livestock distribution. Effective cattle densities near natural waters have been greatly diminished from pre-turn-of-the-century levels.

It is commonly accepted that tremendous environmental changes occurred throughout Arizona in the late 1800s, but the cause of these changes has been hotly disputed. Although exact causes of the vegetation and landscape changes are not fully understood, three principal causes have been hypothesized: biologic, climatic, and geologic (Hastings, 1963; and Hastings and Turner, 1965). Hastings cites earlier studies which indicated there have been several erosion cycles in the Southwest, with the last one occurring about 600 years ago. Other studies interpreted geologic data differently and believe that larger streams in southeastern Arizona were stable in their main tributaries for over four millenia, broken only by brief and minor erosional episodes. From one theory, if channel cutting occurred in pre-Columbian times, factors other than livestock grazing must be responsible. Hastings and Turner introduced data which indicate that the initiation of channel cutting and the introduction of large-scale livestock grazing may not necessarily correlate. Large-scale cattle grazing began in Sonora around 1680, yet no significant vegetation changes or arroyo cutting were observed until about 1880. They also report a substantial development of ranching in parts of southeastern Arizona during the 1820s and 1830s, yet no erosional problems developed until around 1880.

Proponents of the biological explanation believe that overgrazing disrupted a delicate ecosystem by causing vegetative deterioration which altered the hydrologic cycle. Infiltration was reduced, runoff increased, and higher flood crests with greater erosive powers resulted (Phillips, Marshall, and Monson, 1964). Studies conducted in Colorado and Utah concluded that there was adequate data to link excessive livestock grazing and vegetative destruction with subsequent channel cutting, soil compaction, and meadow dessication (Duce, 1918; Cottam and Stewart, 1940).

Recently, there has been general agreement that overgrazing and climate were both important and contributing factors to channel cutting and vegetational changes in the Southwest. Hastings summarizes the "trigger-pull" theory which states that long-term erosional trends were in existence by 1880, and the "...coming of the cattle merely served as the trigger-pull that set off an already loaded weapon." Nonetheless, periods of channel cutting, with subsequent periods of lateral cutting recreating conditions of equilibrium, have always been a part of the normal history of desert streamways (Shreve and Wiggins, 1964). Studies concerning this issue will continue well into the future and are of great interest to those who must manage the state's riparian resources.

It can be generally concluded that the biggest change in the state's riparian systems have been biological, with man acting as a controlling factor. Native riparian vegetation has been removed by miners, farmers, ranchers, and other settlers for a variety of uses; "phreatophyte" clearing was the battle cry in the 1950s and 1960s; the Reclamation Act of 1902 led to dams, artificial drainages, and exposed large areas of bare, moist soil; groundwater levels were lowered as a result of large-scale pumping to supply agricultural and urban demands. In recent years, some riparian areas have been heavily impacted by intensive, uncontrolled, year round use by recreationists resulting in soil compaction, loss of vegetative diversity and regeneration, and streambank erosion.

Prehistorically and historically, man, by necessity, settled along the river drainages in the arid Southwest. These early people were attracted to the readily available water, fish and wildlife, and the abundant trees and other vegetation for use as food, shelter, and tools. Evidence of prehistoric villages and associated croplands and diversion channels along the drainages in Arizona demonstrate the importance of these limited resources to man's survival in this arid and unpredictable environment. During periods of drought, riparian areas became the focal point for nearly all prehistoric people living in the desert areas of Arizona.

As the early settlers moved into the Southwest, they too built settlements and farms along the rivers, favoring the riparian habitats for water, wood, and productive soils. Riparian trees were cleared for agricultural fields and were used to build homes and tools and to provide firewood. Canals were built to divert water to cropland and towns. Wells were drilled to provide a reliable source of water for people and livestock. The mining industry also tapped underground water supplies to process mineral ores. Many acres of marshlands and cienegas were drained and irreparably destroyed as a result of groundwater pumping.

Arizona's landscape supports limited perennial streams and riparian habitat. Of the various ecosystems in the state, riparian areas occupy the smallest land area, less than 0.75 percent (Babcock, 1968). Arizona faces the following dilemma with regard to managing the state's riparian resources: while most of the state's land base is in public ownership, the majority of the most limited, most vulnerable, and most valuable ecosystem is held within the private sector.

According to one source, federal water management projects on desert river systems are the single most potent threat to riparian habitat in Arizona (Todd, 1978). Most of Arizona's major rivers have dams constructed at various places along their lengths to control the flow of water for hydroelectric power generation, flood control protection, or for future use by downstream users (specifically agricultural uses). Hoover Dam on the lower Colorado River illustrates how the construction of a dam can alter riparian environments and affect bird populations. Prior to construction, cottonwoods and willows grew along the banks and periodic flooding created large backwater areas and silt flats which make excellent habitat for many species of birds. After construction, the river no longer overflowed, much bird habitat was lost because lagoons and silt flats were no longer created below the dam, and a large clear lake of open water was formed above the dam.

The creation of Glen Canyon Dam above the Grand Canyon wrought major changes in the Colorado River, including water conditions, fish populations, and riparian habitats. Flood control measures, especially along the lower Colorado River, have totally changed the riparian systems that once existed in the form of tremendous cottonwood-willow gallery forests and mesquite bosques. Widespread channel dredging (which drains backwaters, eliminates riparian cover, eliminates eddies and holes, increases turbidity, and increases bank erosion) and riprapping of the banks are continuing to be implemented. Mitigation to replace the cottonwood-willow forests has been minimal and largely unsuccessful.

The creation of Alamo Lake along the Santa Maria/Bill Williams River inundated miles of riparian vegetation initially, but the resulting lake provides habitat for at least three, perhaps four, pairs of bald eagles that have been nesting in the riparian habitat along the lake and stream tributaries.

Man introduced saltcedar as an ornamental early in the nineteenth century and it was established in Arizona in the early 1900s. Seed dispersal was aided by early settlers who planted it for shade and as a windbreak. Saltcedar has since replaced native riparian vegetation along substantial stretches of many streams and rivers because of its competitive ability relative to native species, and was favored by man's river and riparian system manipulations. Introduction of non-native fish species has had disastrous impacts on some species of native fishes. Many of the sport fishes are extremely competitive, edging out the less aggressive native fish, and many sport fish prey on the smaller native fishes, decimating whole populations.

Mesquite bosques, large stands of mature mesquite thickets, were commonplace when Arizona was settled in the mid to late 1800s. Mesquite forests are well adapted to living in the floodplains of large rivers and they provided important habitat for a large number of wildlife species. It was reported in early journals that in 1902, the bottomlands on either side of the Santa Cruz River near Tucson were covered, miles in extent, with a thick growth of giant mesquite trees. The fact that this bosque was on Indian land was the only reason they were still standing, since elsewhere every mesquite large enough to be used as firewood had been cut down. In 1911, the mesquite trees were described as wonders of their kind, with trunks over four feet in diameter. By 1917, the practice of deforestation had reduced the heavier timber to four-fifths of its former abundance and the cutting was removing 2,500 cords per year. This practice was repeated throughout the state, with the resultant loss of thousands of acres of old-growth mesquite forests. Woodcutting is still a major threat to the few mesquite bosques remaining today. Withdrawal of groundwater faster than plant roots can grow results in large die-offs of natural riparian growth.

Farming practices have adversely affected riparian and wetlands environments by changing water table levels, salinity levels, influencing erosional hazards, and converting thousands of acres of riparian vegetation into farmland. For example, white farmers began farming in the lower Gila River area around 1860, were irrigating by 1875, and by 1930, there were over 11,000 acres under irrigation in the Wellton-Mohawk area. In 1970, riparian vegetation was mapped along a 58-mile stretch of the lower Gila River, delineating 111,360 acres of floodplain, but finding only 16,363 acres of riparian vegetation. If one can assume that the floodplain was covered by riparian vegetation in 1860, about 85 percent of the total riparian communities have been converted to agricultural lands. Saltcedar communities accounted for more than one-half of the remaining riparian vegetation and when the total acreage of this exotic is subtracted from the total, only 5,285 acres of native riparian communities remain. This represents about 5 percent of the 1860s riparian base. The U. S. Geological Survey mapped 9,303 acres of phreatophytes in a 46-mile stretch of the upper Gila River from Thatcher to Calva in 1944. In 1959, this area was resurveyed by the Army Corps of Engineers showing that 15.9 percent of the land had been cleared for farm use. In 1967, Robinson reported only 6,600 acres remained, a 30 percent reduction in 23 years.

A complex issue of current debate facing the state concerns water transfers. Water transfer means a change in ownership of the right to use water. Such transfer of entitlements may eventually involve the physical withdrawal and transport of the actual water as well. Water farms are a relatively new threat to the state's wetlands. A water farm is defined as land purchased solely for its appurtenant water (Checchio, 1988). Since agricultural water rights in Arizona are appurtenant to the land, acquiring water rights that were originally established through applying water to crops commonly involves the purchase of irrigated farmland. The actual water may then, under certain conditions, be removed from the land to a new place and type of use. In recent years, many of the larger metropolitan cities have purchased land in rural areas to secure the water rights for future "farming" of the water for urban development in cities that are frequently many miles away.

Arizona's major water problem has been defined as the imbalance between the water consumed and the dependable supply (Kleinman, 1987). The state currently relies on groundwater for more than 60 percent of the water supply. Arizonans annually consume approximately 2.0 million acre-feet more groundwater than is replenished by nature (Kleinman, 1987). Water farming of rural areas to provide the growing demand for water in urban areas presents a potential not addressed in most reports about water transfers--that of the effect of long-term water removal on the on-site riparian habitat. When farmers and ranchers utilized the water for their agricultural operations and personal needs, there was a direct tie to the land and usually a feeling of stewardship. There is a potential of a lack of concern by distant landowners of water farms for the maintenance of the riparian values that may currently exist on the land. Environmental issues such as this should be a part of any discussion on water transfers.

Several cities have taken to dumping wastewater and effluent into river channels, changing the water quality and vegetation composition. In some cases, the discharge of effluent into the streambed is the only "flowing water" some ephemeral streams ever experience, except in extremely rainy years. It can be argued that, in some cases, this has a beneficial effect, resulting in higher concentrations of vegetation growth than would normally exist.

There is little reason, however, for long-term optimism regarding the riparian environment in many parts of Arizona. Riparian systems continue to undergo drastic changes due to both natural processes and human activities. Wetlands and riparian habitats on private lands are prime developable commodities for summer homes, resorts, and residential communities. The conversion of wetlands and riparian habitats for agriculture, residential, industrial developments, and other uses has accelerated. There is no rationale to expect a reversal in the ever-increasing population and an ever-declining water table (Lacey, Ogden, and Foster, 1975). For example, the amount of groundwater withdrawal is in excess of recharge in the Sierra Vista-Fort Huachuca area (near the San Pedro River). Water levels have declined about thirty feet in twenty-five years and a cone of depression has developed in this area.

There have been documented examples of subsidence as a result of depletion of the groundwater aquifers in Maricopa, Pinal, Pima, and Santa Cruz Counties. Subsidence is a lowering of the earth's surface caused by processes acting below the land surface. Although subsidence is a result of the interaction of natural earth forces, it can also be man-induced by the large-scale removal of underground fluids, such as petroleum or water. In 1977, in the Basin and Range country of Arizona, enough water was pumped to cover a football field with a water column over 1,000 miles in height (Peirce, 1979). The groundwater decline for areas around Phoenix and Tucson ranges from 100 feet to over 300 feet. This alone is enough to provoke the probability of subsidence. Groundwater is an integral part of the natural foundation of the earth; when it is removed in large quantities, dewatered earth materials may shrink or compact, lowering the earth's surface. With such extreme drawdowns of water occurring with increasing frequency in Arizona, the impact of groundwater pumping on wetlands has been severe.

There is no question that Arizona's wetlands and riparian areas are the most threatened communities in the state. It is estimated that 95 percent of these habitats have been lost within the last 100 years (TNC, 1987). Sheer demand for the multitude of resources associated with wetlands and riparian areas, such as water, hydro-electric power, flood control, timber, firewood, forage, fertile soils, homesites, and recreational sites, have decimated the once-abundant communities. There was a recently-held perception that riparian areas had little value unto themselves. To facilitate water salvage, the common practice of the 1950-1970s was large-scale removal of riparian vegetation, once known by the term phreatophyte eradication. The theory of water salvage through phreatophyte eradication involves removal of "non-beneficial" vegetation along a stream so less water will be used, thus more can be delivered downstream. The practicality of this theory is questionable for several reasons: 1) stream-side vegetation is the most valuable wildlife habitat in Arizona; 2) only a small percentage of the water used by plants can be delivered downstream; and 3) the costs for clearing and maintaining most projects are simply prohibitive from an economic standpoint (Bristow, 1969). There has been enough research conducted to prove the fallacy of water salvage through phreatophyte control (Culler, et al., 1970; Rowe, 1963; Muckel, 1966; Gilluly, 1971; Horton and Campbell, 1974; Hughes, 1971).

A renewable natural resource has been defined as "...a living or biotic resource that is capable of reproducing or replacing itself," and distinguishes from it the nonrenewable resources "consisting of nonliving materials which are not capable of reproducing themselves" (Dasmann, 1959). Therefore, under these conditions, it may be justifiable to regard the native riparian environment as a nonrenewable resource in many areas.

Recent Management Changes in Wetlands and Riparian Systems

The general public is becoming more aware of riparian and wetlands values and is concerned about their losses. The public is realizing that riparian habitats provide significant public benefits besides fish and wildlife habitat, especially flood protection and water quality maintenance. The aesthetic value of wetlands is extremely difficult to evaluate or place a dollar value upon. Many people simply enjoy the beauty and sounds of nature and spend their leisure time walking, picnicking, or boating in or near wetlands, observing plant and animal life. In 1980 alone, 28.8 million people (17 percent of the U.S. population) took special trips to observe, photograph, or feed wildlife. To many Arizona residents, greenery, water, and wildlife represent premium living conditions and they have demonstrated a willingness to pay inflated prices for lands in and near riparian habitats. It has been estimated that homes and cabins in and adjacent to protected riparian habitats are valued at about 35 percent above similar surrounding upland sites.

There have been attempts by local, state, and federal agencies in Arizona to protect wetlands habitats. With the full support of the community, the Pima County Flood Control District recently purchased nearly 2,000 acres along Cienega Creek in southeastern Arizona for the express purpose of protecting crucial riparian habitat to mitigate impacts of flood control projects elsewhere in the county. Other lands are being pursued for similar acquisition and protective management. In Scottsdale, the Indian Bend Wash project has received national acclaim for its successful endeavor to retain the beauty and functions of an ephemeral stream that flows through the middle of an intensively developed city. New techniques are being explored that allow for streambank protection from severe flooding while still allowing the growth of riparian vegetation.

The State of Arizona recently appropriated $2,000,000 to purchase riparian lands along the Verde River near Cottonwood in Central Arizona for the sole purpose of habitat protection. These lands are being managed as the Verde River Greenway by Arizona State Parks and the concept has been enthusiastically received by the public. To obtain protection for additional riparian acreage along the Verde River at a minimum cost, the recent innovation of utilizing conservation easements is being pursued by the state with interested landowners.

Both the USFWS and the Arizona Game & Fish Department continue to monitor and study the state's wetlands and riparian habitats and the fish and wildlife that depends on these areas. Cooperative efforts for species recovery, limiting the introduction of exotic species, and enforcing the regulations of the federal threatened and endangered species legislation all have benefitted Arizona's wetlands and riparian areas.

Four of the seven national wildlife refuges administered by the USFWS in Arizona protect critical wetlands habitats. Riparian habitats on lands administered by the U. S. Forest Service and the Bureau of Land Management will probably continue to receive more consideration in their multiple-use planning. Most federal agencies have developed specific riparian management policies to assist in the proper management of the state's riparian systems.

The Tonto National Forest has implemented a special management plan for the upper Salt River. A 40-mile stretch of the Verde River has been designated as a Wild & Scenic River. Popular recreation sites along riparian areas that have been impacted by too many people constantly using the areas are being carefully managed and periodically closed to allow the vegetation and water quality to recover. Restoration of streams and riparian habitats has been an ongoing program with the USFS and BLM.

The BLM in recent years has implemented a successful land exchange program that has brought significant tracts of crucial riparian communities into federal ownership. The Arizona State Land Department and BLM have cooperated in some of the most beneficial land exchanges in the country. The State Land Department's primary function is to administer State Trust lands in order to produce the highest revenue yields for its beneficiaries. The Department recognizes the unique resource values associated with riparian habitats and considers these values in its actions. When major conflicts have occurred between these values, the Department has attempted to exchange the environmentally sensitive lands into federal ownerships such as the BLM. Examples of this action can be found in Burro Creek and Aravaipa Canyon.

BLM's most significant private land exchange was the 1986 acquisition of 43,400 acres along the San Pedro River in southeastern Arizona. This thirty-mile riparian corridor supports some of the most significant remaining large broadleaf riparian areas and mesquite bosques in southern Arizona. The area serves as a migration corridor for pantropical wildlife species moving in and out of Mexico. In addition to providing habitat for hundreds of wildlife species, the area is home to almost 20 percent of Arizona's nesting population of the gray hawk. Legislation is pending before Congress to designate the San Pedro lands as a Riparian National Conservation Area. If the legislation is approved, the San Pedro will become BLM's first riparian conservation area. If this trend continues, riparian communities on federal lands may be maintained, but it has to include more than isolated examples.

There have been some encouraging changes in livestock and rangeland management that reflect a more coordinated/integrated management approach that considers resource values such as wildlife habitat. Much of Arizona's federal and state lands are grazed and rangeland conditions vary considerably. In some situations, fencing certain riparian habitats until the system can recover is proposed or completed on various forests throughout the state. Also, many ranchers and agencies are implementing grazing systems which allow more intensive livestock and forage management. By dividing grazing allotments into numerous pastures, cattle can be concentrated into specific areas at different times of the year, resulting in improved range and habitat conditions. By allowing creek bottoms a rest from grazing and reducing the time cattle spend in riparian zones, young tree seedlings and other riparian vegetation can be protected during the critical seedling stage. To accommodate this style of management, though, alternate water sources for livestock must be made available away from the riparian zones, which will also benefit wildlife.

There has been a very recent change in the priority for riparian research. In 1977, a search of some 24,000 research resumés in the U. S. Department of Agriculture's Current Research Information System (CRIS) revealed only 10 related to riparian habitat. CRIS information and other sources indicated 22 active studies (10 plant, 5 animal, and 7 combined) in the western United States. These figures show that riparian vegetation has not received research at a level compatible to its importance as wildlife habitat, or indeed, as an endangered habitat. A concentrated effort directed at specific problems with realistic goals is needed (Patton, 1977). Figures are not currently available, but in the Southwest, there has been a considerable increase in the number of funded studies focusing on wetlands and riparian systems, as evidenced by the number of participants and presenters at the last few southwestern riparian conferences.

Nationwide, there has been a recognition of the need for instream flow allocations for biological values. The Arizona Department of Water Resources' working definition states that Arizona's instream flow policies allow appropriation of any part of stream flow within any segment of a stream in order to protect an existing natural environment. A water right granted in support of such an appropriation is termed an instream flow water right. Arizona is still struggling with the issue of instream flow. DWR has the responsibility for determining and implementing regulations and permits for minimum instream flow rights, but the methodologies have not been finalized. Until guidelines and a permitting mechanism are in place, securing instream flow rights for recreation and fish and wildlife habitat are not a viable protection method for Arizona's streams.

People are just beginning to realize the overall importance of these ecosystems and the part they play in Arizona's economic, biotic, and social well-being. The term "riparian" is a relatively recent addition to the scientist's vocabulary and the general public is just now starting to hear the term. Strides are being made, though.

Public acknowledgement of wetlands and riparian values has increased to a point where a more comprehensive evaluation of water-related resources is applied before permitting activities, projects and developments in wetlands and riparian areas. Cooperative management efforts between various agencies, organizations, user groups, and landowners have increased awareness of wetlands and riparian issues and have resulted in diverse groups working together toward a common goal. The state's many agencies, commercial industries, and organizations are initiating programs and actions geared towards the protection of the remaining wetlands and riparian systems. The Arizona Riparian Council, an active organization, has dedicated itself to furthering the protection and proper management of the state's riparian systems. The University of Arizona Cooperative Extension Service has developed an excellent video and educational booklet on desert riparian systems and their diverse uses and management. The Arizona Nature Conservancy has begun an ambitious fund-raising campaign, "Streams of Life," to protect and acquire sensitive riparian habitats throughout the state. Documents such as this one continue to emphasize the importance of wetlands and riparian areas for all their values, not just the easily identifiable economic considerations. By placing a priority on the proper management and protection of these sites, the threats facing wetlands can be lessened.

20

PROPOSED NATURAL AREAS

SALT RIVER

BETWEEN 91ST AND 115TH AVENUES

REPORT NO. 7

Prepared by

Arizona Academy of Science

for

Planning Division
Department of Economic Planning and Development
Office of the Governor
State of Arizona

June 1973

Principal Authors

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Abstract

We recommend the establishment of a zoned natural area on the Salt River between 91st and 115th Avenues south of Tolleson, Arizona. Though grossly disturbed, the area has redeeming value as a wildlife refugium and as a site that is close to population centers and could be used by birders, students, and photographers.

SALT RIVER between 91^{st} and 115^{th} Avenues
Establishment Proposal

Location

The site of this proposed natural area on the Salt River area is $4\frac{1}{4}$ miles south of Tolleson, Maricopa County, Arizona. The proposed site includes the Salt River and Riparian habitats between 91^{st} and 115^{th} Avenues approximately 0.4 miles south of Southern Avenue (see map, Appendix B.). Elevation of the site ranges from 940 ft. to 960 ft. The Gila River-Salt River confluence is slightly less than one-half mile downstream from the proposed western boundary of this area. The area herein described is in private ownership according to the 1971 Arizona Public Land Ownership map published by DEPAD and BLM.

Description

The eastern end of the area is characterized by fairly broad flood plains on both sides of a narrow river channel. There is very little riparian vegetation along this portion of the river. Approximately 0.3 miles from the eastern boundary, the river bottom broadens considerably, the flood plain becomes narrower and riparian vegetation becomes more abundant. Areas of riparian growth are very strongly dominated by Salt Cedar (*Tamarix* sp.). Other riparian species occurring in the area include willow (*Salix* sp.) and Cottonwood (*Populus fremonti*). Desert Broom (*Baccharis* sp.) and Mesquite (*Prosopis* sp.) are also conspicuous plant species in the well-vegetated zones.

At the western end of the proposed site the Arizona Game and Fish Department has constructed several large ponds that serve as waterfowl resting areas. There is water in this portion of the Salt River year-round by virtue of sewage effluent coming from the 91^{st} avenue treatment plant. The Game and Fish ponds as well as riparian growth in the area are maintained year-round by this effluent.

Fauna

Animal species that have been observed in this area are listed in Appendix A. As is the case with many water-influenced habitat in southern Arizona, numerous uncommon (in Arizona) bird species are known to have occurred at this site. Such species include Black-bellied Tree Ducks, Glossy Ibis, Little Blue Heron, Baird's Sandpiper, Pectoral Sandpiper, Willet, Marbled Godwit, Semipalmated Plover, Parasitic Jaeger, Sabine's Gull and others. All of these are species of waterfowl and that shorebirds are known to occur in this area. In addition to aquatic bird species, many species of migrating birds are doubtless attracted to the growth of riparian vegetation where they rest and forage prior to continuing their migration.

Mammalian forms that prefer moist situations are also likely residents of the area. Muskrats have been observed at the site and it is highly probable that a number of bat species forage over the ponds and associated vegetation along the river. The water in this vicinity probably attracts Mule Deer, Coyotes, Bobcats, Javelina and other forms that will utilize open water sites as a source of drinking water.

History of Disturbance

This area has been badly disturbed by a multitude of human activities in the past and many are continuing today. The area has at least five roads running through it, there is a gravel pit operation near 107th avenue and a considerable amount of illegal refuse dumping occurs throughout the proposed natural area. The water source (sewage) could be considered a disturbance in contrast with the formerly perennial, new intermittant flow of the Salt River. The western end of the area is bordered on the north by farms and a nearby racetrack. The artificial ponds created by the Game and Fish Department represent the only attractive or beneficial "disturbance" in the area.

Natural Area Qualities

Despite rather gross disturbance to this area, there is a number of redeeming features that make this site valuable as a natural area. The vegetative community in the vicinity of the Game and Fish Department's ponds is very similar to the natural type of community that should develop in such an aquatic situation. There is a considerable amount of salt cedar in this area but cottonwood and willow trees are very common and have become established since the Salt River floods of 1965-66. This community continues upstream from the ponds in a narrow band following the course of the effluent stream. The ponds as well as the stream are bordered by cattails forming a marshy habitat.

The value of this area to migratory as well as resident wetland wildlife is obvious. The value to other wildlife forms is equally obvious and important. Perhaps of even greater scientific importance is the documentation of vegetative recovery since the floods of 1965-66.

Recommendations and Boundaries

We recommend the establishment of a zoned natural area along this stretch of the Salt River. Boundaries are indicated on the sketch map (Appendix B.) and should extend west from 91st Avenue to 115th Avenue. The proposed northern boundary is shown on the sketch map. The southern boundary would most logically be congruent with the northern edge of the Gila River Indian Reservation as shown on the sketch map.

Establishment of a zoned natural area should help maintain a small island of good riparian vegetation at this site and hopefully, add some impetus to control illegal disturbances (e.g. trash dumping).

We have alluded to the value of this site for wildlife species. From the human viewpoint, maintaining this stretch of river (even in its present state) would provide a good area for birders and waterfowl, photographers that is easy to reach and offers an excellent variety of bird species. Literally thousands of students at all educational levels could also benefit from being able to visit this area and see a number of plant and wildlife forms with which they may otherwise have little contact or appreciation.

APPENDIX A. Animal species that have been observed in the proposed Salt River Natural Area south of Tolleson, Arizona. Data provided by R. L. Todd of the Arizona Game and Fish Department and by the members of the Arizona State University Wildlife Club. Species marked with an asterisk are uncommon in Arizona and likely to be encountered only in suitable wetland habitats. It should be noted that this is only a partial listing based on a small number of visits to the site.

A. Birds

Common Name	Scientific Name
Eared Grebe	Podiceps nigricollis
White Pelican*	Pelecanus erythrorhynchos
Great Blue Heron	Ardea herodias
Green Heron	Butorides virescens
Little Blue Heron*	Florida caerula
Common Egret*	Casmerodius albus
Snowy Egret	Egretta thula
Glossy Ibis*	Plegadis chihi
Black-bellied Tree Duck*	Dendrocygna autumnalis
Mallard	Anas platyrhynchos
Gadwall	Anas strepera
Pintail	Anas acuta
Green-winged Teal	Anas crecca
American Wigeon	Anas americana
Shovelor	Anas clypeata
Lesser Scaup	Aythya affinis
Ruddy Duck	Oxyura jamaicensis
Sharp-shinned Hawk	Accipiter striatus
Red-tailed Hawk	Buteo jamaicensis
Clapper Rail**	Rallus longirostris
Virginia Rail*	Rallus limicola
Common Gallinule	Gallinula chloropus
American Coot	Fulica americana
Semipalmated Plover*	Charadrius semipalmatus
Killdeer	Charadrius vociferus
Common Snipe	Capella gallinago
Spotted Sandpiper*	Actitis macularia
Willet*	Catoptrophorus semipalmatus
Pectoral Sandpiper*	Calidris melanotos
Baird's Sandpiper*	Calidris bairdii
Least Sandpiper	Calidris minutilla
Western Sandpiper*	Calidris mauri
Long-billed Dowitcher*	Limnodromus scolopaceus
Stilt Sandpiper*	Micropalama himantopus
Marbled Godwit*	Limosa fedoa
American Avocet*	Recurvirostra americana
Black-necked Stilt*	Himantopus mexicanus
Wilson's Phalarope*	Steganopus tricolor
Parasitic Jaeger*	Stercorarius parasiticus
Franklin's Gull*	Larus pipixcan
Sabine's Gull*	Xema sabini
Forster's Tern*	Sterna forsteri

Appendix A. con't.

Black Tern*	*Chlidonias niger*
Mourning Dove	*Zenaida macroura*
White-winged Dove	*Zenaida asiatica*
Yellow-billed Cuckoo	*Coccyzus americanus*
Roadrunner	*Geococcyx californianus*
Belted Kingfisher	*Megaceryle alcyon*
Black Phoebe	*Sayornis nigricans*
Vermilion Flycatcher	*Pyrocephalus rubinus*
Tree Swallow	*Iridoprocne bicolor*
Curve-billed Thrasher	*Toxostoma curvirostre*
Starling	*Sturnus vulgaris*
Yellowthroat	*Geothlypis trichas*
Yellow-breasted Chat	*Icteria virens*
Western Meadowlark	*Sturnella neglecta*
Redwinged Blackbird	*Agelaius phoeniceus*
Brewer's Blackbird	*Euphagus cyanocephalus*
Blue Grosbeak	*Guiraca caerulea*
House Finch	*Carpodacus mexicanus*

**Listed as "endangered" by U. S. Fish and Wildlife Service

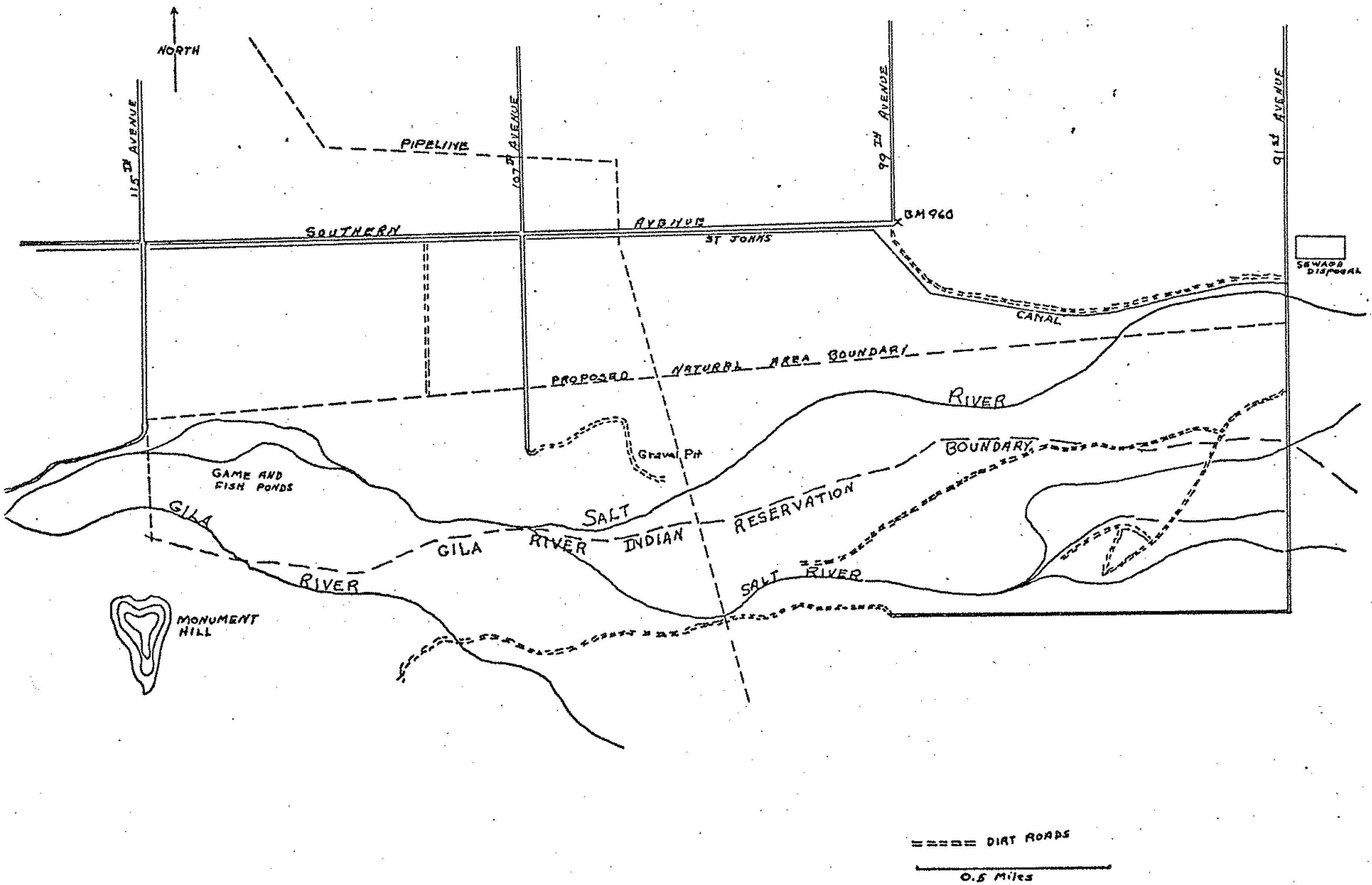
B. Mammals

Black-tailed Jackrabbit	*Lepus californicus*
Desert Cottontail	*Sylvilagus audubonii*
Muskrat	*Ondatra zibethicus*
Striped skunk	*Mephitis mephitis*
Coyote	*Canus latrans*

C. Other expected mammalian species:

Bats	several species
Round-tailed Ground Squirrel	*Spermophilus tereticaudus*
Pocket Gopher	*Thomomys umbrinus*
Pocket Mice	*Perognathus* sp.
Kangaroo Rats	*Dipodomys* sp.
Grasshopper Mouse	*Onychomys torridus*
Western Harvest Mouse	*Reithrodontomys megalotis*
Deer Mice	*Peromycus* sp.
Hispid Cotton Rat	*Sigmodon hispidus*
White-throated Wood Rat	*Neotoma albigula*
Kit Fox	*Vulpes macrotis*
Gray Fox	*Urocyon cinereoargenteus*
Ringtail	*Bassariscus astutus*
Raccoon	*Procyon lotor*
Badger	*Taxidea taxus*
Bobcat	*Lynx rufus*
Mule Deer	*Odocoileus hemionus*

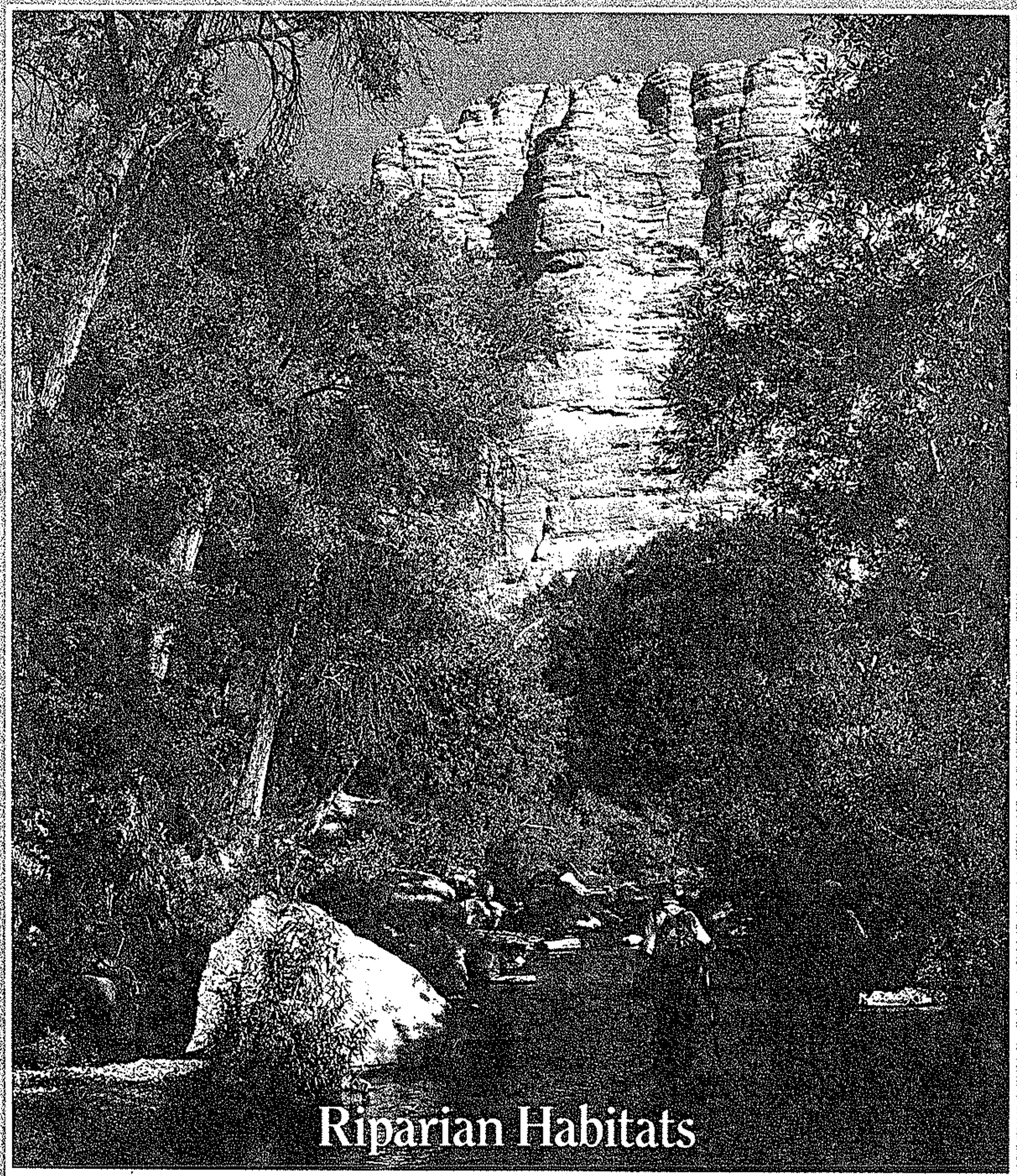
APPENDIX B. Sketch map of proposed zoned natural area on the Salt River.


NORTH
115TH AVENUE
107TH AVENUE
99TH AVENUE
91ST AVENUE
PIPELINE
SOUTHERN AVENUE
ST JOHNS
BM 960
SEWAGE DISPOSAL
CANAL
PROPOSED NATURAL AREA BOUNDARY
RIVER
BOUNDARY
Gravel Pit
GAME AND FISH PONDS
SALT
GILA
GILA RIVER INDIAN RESERVATION
RIVER
SALT RIVER
MONUMENT HILL
DIRT ROADS
0.5 Miles

21

Arizona-Sonora Desert Museum Newsletter, Summer 1988

sonorensis



sonorensis

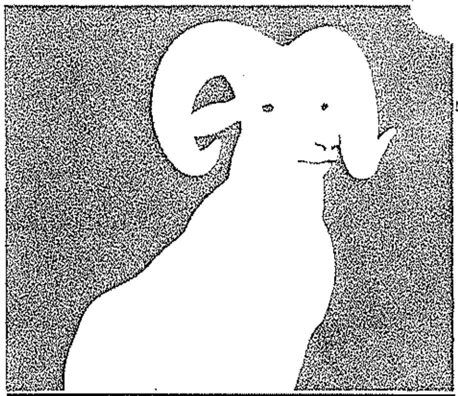
Arizona-Sonora Desert Museum
Newsletter — Vol. 9, No. 2 Summer 1988

The Arizona-Sonora Desert Museum
Co-Founded in 1952 by
Arthur N. Pack and William H. Carr

sonorensis is published by the Arizona-Sonora Desert Museum, 2021 N. Kinney Road, Tucson, Arizona 84743.

sonorensis is the Latin, scientific term indicating the species classification of many plants and animals of the Sonoran Desert region.

Cover Photo:
Aravaipa Canyon Preserve.
Photo by E. Tad Nichols



MUSEUM NEWS

Directors Club Gala Planned for October

The Directors Club of the Foundation for the Arizona-Sonora Desert Museum is planning its First Annual Elegant Affair scheduled for the evening of Saturday, October 8, 1988 at the Museum. Under the able co-chairmanship of Foundation Board member Curtis Scaife and Mrs. Francis Barrett, the $250.00 per person, black-tie dinner promises to be one of the highlights of Tucson's fall social scene. World-renowned wildlife artist Nicholas Wilson who created the Directors Club mountain lion sculpture will be the guest of honor at the dinner.

Havens elected trustee president for 1988–89

Professor William H. Havens will serve as President of the ASDM Board of Trustees during fiscal 1988–89. Other officers elected by the Board at its first meeting in May are: Margaret G. Twyman, Vice-President; Helen V. Fisher, Secretary; D. Alan Smith, Treasurer; Bernard W. Simons, Jr., M.D., Assistant Secretary; and Lloyd L. Clucas, Assistant Treasurer. Elected by Museum members to serve four-year terms on the Board of Trustees beginning this year are: Mary K. Foster, Lloyd L. Clucas, John R. Hucko, Peter L. Kresan, and William C. Scott.

Elected to serve one-year terms on the Advisory Council for 1988–89 are: Georgiana S. Boyer, M.D.; Ruben G. Fernandez; J. T. Fey; Kenneth R. Harder; Ronald G. Henry; David M. Hyatt; David O. Johnson; Daniel Lopez; Paul Madden, Docent Representative; Theodore A. Riehl; Cabot Sedgwick; Robert L. Smith, Ph.D.; Suzanne Tumblin, Ph.D.; Daniel C. Turner; Josephine R. Voevodsky; Weldon A. Washington; and Wendell E. Wilson, Ph.D.

O'Rielly to sponsor *Desert Speaks*

We welcome Tucson's O'Rielly Motor Company as the Museum's newest CORPORATE DONOR. O'Rielly has signed a contract with KOLD-TV to sponsor the Museum's weekly television program, *The Desert Speaks*, for six months beginning last June. The Museum values this new association with O'Rielly Motor Company and hopes it will be a continuing one.

Yule assumes public affairs post

Lauray Yule, Producer/Co-Host of the Arizona-Sonora Desert Museum's weekly television program, *The Desert Speaks*, was appointed ASDM Public Affairs Officer in mid-June. Yule, who joined the museum staff in August, 1986, will continue her *Desert Speaks* responsibility. Yule holds a B.A. in journalism from the University of Wisconsin with an emphasis on science communications. She has both print and broadcast experience, having served as editor of *Astronomy Magazine*, and Producer/Moderator of a public affairs program at the Public Broadcasting System affiliate in Redding, California. She has produced and co-hosted *The Desert Speaks* on KOLD-TV in Tucson for eighteen months.

Before joining the Desert Museum staff, Yule had been Director of the Schreder Planetarium in Redding, California for four years and was Special Assistant to the Director of Steward Observatory at the University of Arizona for two years.

Yule competed with 190 other applicants for the Public Affairs position at the Desert Museum.

(Continued on page 20)

Director's Report

The Desert Museum is dedicated to the idea that the more people know about the areas in which they live, the more they will appreciate their surroundings and the more they will care for them. The ASDM's regional concept of interpretation — limiting itself to the story of one area — allows its staff and docents to delve into great detail about the interrelationships of the land, plants and animals of the Sonoran Desert region. This is almost impossible at institutions which are charged with broader missions. This concept also places a greater responsibility on the ASDM, because by excluding other regions the Desert Museum is legitimately viewed as being expert on the Sonoran Desert area, and therefore, the leader in educating those who live in this beautiful region about its fragile nature. In this issue you will read about some very special habitats in our region — riparian habitats that are fast disappearing. Something must be done to stop their destruction. You will learn that many of the plants and animals you have grown to love are truly endangered. Although we are able only to acquaint you with riparian habitats in this issue, we hope you will read some of the books we list and then do what you can to help protect these invaluable resources.

The new hummingbird exhibit is under construction and will be completed soon. It will be open to visitors before the end of the year. It is our hope that the renovated Life Underground exhibit will also be open before 1989. Your 1988-89 Board of Trustees and the staff have a full agenda for this year. Your continued support is vital to complete that agenda and on behalf of the Trustees and staff I again thank you for your dedication to this museum.

Dan Davis, Director

Why a Foundation?

You may have wondered "Why a Foundation?" The answer is Stewardship.

What do I mean by Stewardship? I mean the responsible management of all the good things of the universe. The Desert Museum epitomizes one aspect of Stewardship: the protection, conservation, and preservation of the ecosystem in which we find ourselves. Stewardship not only involves present preservation but also education of future generations to continue the Stewardship. The success of the Museum in these areas has been great. The master plan for the Museum is exciting and vital to its mission. The contributions of capital to build these facilities, to annual contributions of time by docents, trustees, and others are invaluable.

However, completion of each capital project requires continuing maintenance, population with plants and animals which in turn must be cared for, fed, watered, and replaced. To the extent that the Museum depends upon admissions, there are two ways to increase revenue: increased attendance or admission fees. The Museum has had several days when the number of visitors exceeded the number which our facility can comfortably handle and provide a good learning experience. There are limits to the number of visitors which the Museum can accommodate. There is a limit to the amount which the Museum can charge for admission because after a certain point the cost of admission becomes prohibitive and exclusionary and the very public which we need to reach and educate cannot avail itself of the beautiful facilities and educational opportunities which we provide.

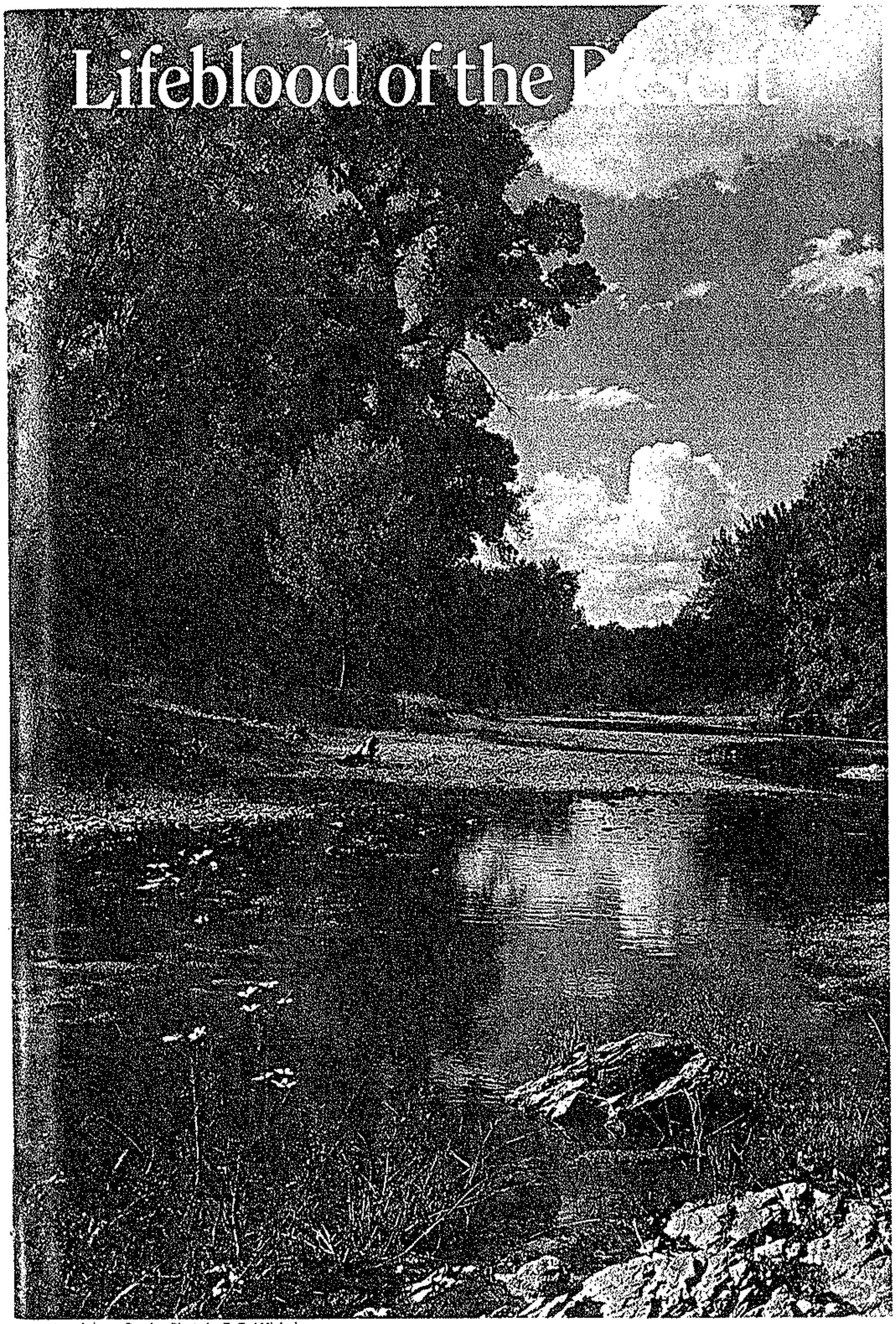
What can we do to preserve and enhance the purpose and program of our wonderful facility without overloading it or emptying it? One answer is our dream for the Foundation. Through diligent labor we can develop a program of planned giving which will combine the gifts of many of us into an endowment fund to provide a continuous income stream to augment the other income of the Museum and meet the operating income requirements of the Museum. Such an endowment income would enable the Museum to keep its admission charges to a minimum and to plow this revenue back into its facilities and programs. Such activities as the First Annual Elegant Affair of the Directors Club, to be held at the Museum on October 8, 1988, will help in creating an ongoing gift solicitation program which will provide the Museum with a group of committed volunteer fund-raisers to assist in soliciting gifts for future projects of the Museum without the necessity of invading the Board designated operating reserves which the Museum's trustees and staff have so diligently accumulated, invested, and preserved.

The answer to "Why a Foundation?" is that another important facet of our responsibility of Stewardship is the adequate funding of the ongoing programs and purposes of the Arizona-Sonora Desert Museum. The Foundation's purpose in building an endowment income for the Museum and in helping to raise the money to complete the Museum's long range master plan is good Stewardship in action.

William C. Scott, President
Foundation for the
Arizona-Sonora Desert Museum

On cloudless, hot June afternoons, Museum visitors are delighted when they discover the beaver and otter exhibit with its deep shade and silver water. Those of us working on the grounds often overhear their expressions of relief and pleasure, and sometimes, too, we hear our visitors wonder aloud why we include this watery exhibit in a *desert* museum. In reality, the streamside, or *riparian*, community represented by this exhibit is the lifeblood of the desert, the wet and lush provider of so much life in our arid land. It accounts for bald eagles and elegant trogons, red bats and river otters, leopard frogs and garter snakes, dragonflies and human beings. Our Museum visitors, standing under the cottonwood canopy, watching streams fall into pools, feel the cool truth of the expression "water is life," though they may not know much about this habitat. Their lack of familiarity is understandable, for while riparian systems are incredibly important, especially in the Southwest, they are rare and very little understood. Until recently, too, they have been little valued in themselves, and so they are vanishing. Because riparian systems are so important, and because they are in such jeopardy, we are devoting an entire *sonorensis* to an exploration of this habitat type.

Lifeblood of the



Arivaca Creek. Photo by E. Tad Nichols

Contributions to this issue were made by Curator of Education, Carol Cochran; Curator of Plants, Mark Dimmitt; Curator of Small Animals, Howard Lawler; Curator of Birds and Mammals, Peter Siminski; Curator of Earth Sciences, David Thayer; and Research Scientist, Tom Van Devender.

Riparian is an adjective, derived from the Latin *ripa* or bank, which means "of, pertaining to, or situated on, the bank of a river." A more comprehensive definition is provided by the Arizona Riparian Council:

> *The term* riparian *is intended to include vegetation, habitats, or ecosystems that are associated with bodies of water (streams or lakes) or are dependent on the existence of perennial, intermittent, or ephemeral surface or subsurface water drainage.*

Though associated with water, riparian communities differ from the aquatic system of the water itself, and we will not include a discussion of aquatic habitat in this article. Riparian systems also differ from the communities on their upland border, which are adapted to drier conditions. Riparian areas are very conspicuous: compared to surrounding areas, they have more vegetation which is also taller and denser; they are usually messier, with ground cover, debris and fallen timber; and they are generally noisier, because they contain more life.

Over much of the temperate and subtropical areas of the Southwest, the same few tree species dominate riparian habitats: Fremont cottonwood, willows, Arizona sycamore, velvet ash, and walnut. At higher elevations alder and some maples become common. Along tropical rivers the vegetation is almost wholly different: figs or Montezuma cypress share the riparian zone with a host of local forest trees. Other trees are opportunistic; they occur in riparian zones at lower elevations than they do elsewhere because of the cooler, wetter habitat. Examples are blue spruce, pines, oaks, junipers, and Arizona cypress.

The composition of riparian areas differs depending on such variables as the surrounding habitat, elevation, slope, or whether the water is a flowing river, a sluggish marsh, or a tiny spring. The riparian area may be only a few inches wide along a steep walled canyon, or it may spread out for a mile or more in a flat river valley. Examples of common riparian areas within our region are portrayed on pages 6 and 7.

Evolutionary History

Riparian plants are ancient. They grew in the Sonoran Desert region long before there were saguaros or palo verdes or even mesquites, because before it was desert, our landscape was covered by tropical rain forests, vast wetlands, and giant water courses. About 100 million years ago, the first angiosperms, or flowering plants, evolved as shrubby weeds in the disturbed areas along the streams which ran through conifer forests. As they came to drink, about 65-75 million years ago, dinosaurs trampled the ancestors of cottonwoods, willows, walnuts, and sycamores. Interestingly, many of these modern trees resemble their herbaceous ancestors in depending on wind pollination and dispersal of seeds by wind or water rather than by animals, a trait which has kept many of them ever dependent on occasional flooding. Riparian plants were old when birds and mammals began to proliferate 65 million years ago.

A period of mountain building 10-25 million years ago culminated in additional uplift of the Rockies and the Sierra Madre. This uplift permanently changed the climate and formed new vegetation types including cool montane conifer forests, grasslands, and hot desert. Wherever there was at least occasional water, riparian zones were created in each biome: older riparian plants, such as willows or alders, grew at the cooler, wetter mountain streamsides in the canyons; legumes such as mesquite and acacias could be found along desert washes; and in the lowest, driest areas typical desert plants such as the saguaro or palo verde (which probably evolved with the Sonoran Desert itself, only 5-8 million years ago) could find enough moisture only in washes. Thus a desert riparian walk from higher to lower elevation is a journey through geologic time, from the Age of Dinosaurs to the present.

Water

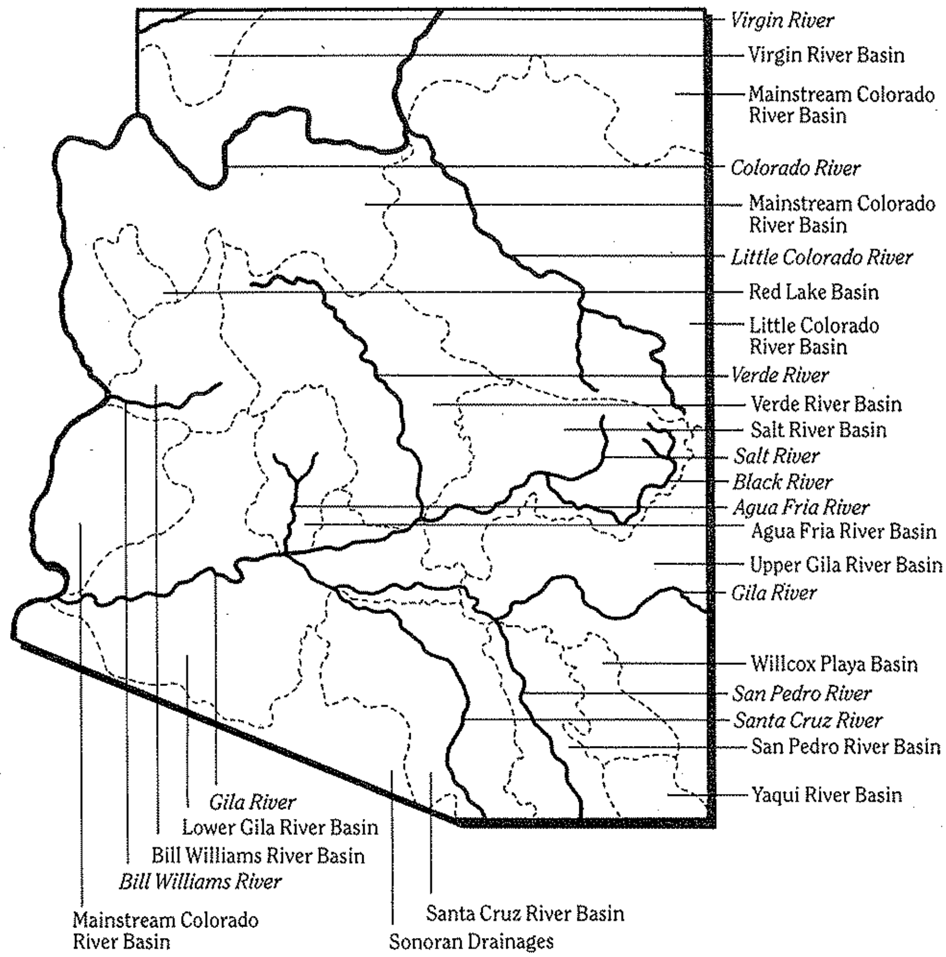
Riparian areas have been the arena for dramatic evolutionary change. This is appropriate as they are themselves dynamic systems which maintain their stability in the face of, and often because of, change. Among the most dynamic occurrences in a riparian system are floods and erosion. Riverine wetlands and their floodplains are natural courses that convey floodwaters. Those who have seen a normally dry desert wash "run" following a heavy rainstorm somewhere along its drainage know the tremendous power of a flood. Tucsonans remember the 1983 flood of the Santa Cruz River following a six-day storm. The peak flow along the Santa Cruz was over 60,000 cubic feet per second (twice the typical discharge of the Colorado River in the Grand Canyon). The flood waters destroyed buildings, power lines, sewage crossings, and caused $100 million damage to roads and bridges.

Riparian areas themselves are greatly impacted by flooding. These effects include removal of trees, floodplain scour with loss of soil and plant understory, migration of the channel, rearrangement of sand and gravel bars, introduction of silt and clay during recession of flooding, and channel scour down to bedrock. In effect, major floods "reset the clock" on development of mature (climax) riparian ecosystems, continually rejuvenating the systems by requiring them to start over.

The story of flooding should not stop with a statement of its destruction, for the issue is more complex. First, riparian areas do not merely convey floodwaters, but they can also control and reduce flooding. Structures within the floodway can block flows. Marshes or wetlands or open floodplains along a channel may store water during times of flooding and slowly release it downstream. Riparian vegetation can decrease flood peaks and can bind and stabilize soil with its root systems.

Secondly, flooding, which has always been a component of a riparian ecosystem, has benefits. A case in point is the Fremont cottonwood, perhaps the

Major Rivers and Drainage Basins



archetypal riparian tree, and certainly the most studied. It is an obligate riparian species (meaning that it can live in that habitat and nowhere else) because it requires lots of water. A mature Fremont cottonwood tree transpires 100 gallons of water a day. It grows very fast, to more than 100 feet tall, and attains a trunk diameter of up to six feet.

The seeds of cottonwoods are viable for only a few weeks following their release (between February and April depending on elevation) and can germinate only on new, wet sandbars deposited by receding spring floods. Deposition of sandbars is in turn dependent on upstream erosion; more erosion produces more deposition downstream, which provides more seed bed area for establishment of cottonwoods.

In most plants, germination occurs under the conditions most likely to ensure survival to maturity; the opposite is true of cottonwoods. The only place they can germinate is also the most likely place to be scoured by subsequent floods; survival of seedlings is thus very low. At sites more distant from the edge of the stream channel survival is more likely, but germination is low because of the usual lack of the required saturated soil. Cottonwoods are therefore rare along main stream channels, and most abundant along secondary "overflow" channels where scouring occurs less frequently.

The roots of cottonwoods must be at the surface of the water table, but cannot tolerate long inundation. Therefore, cottonwoods cannot survive in such places as reservoirs, where the water level fluctuates greatly — the trees either dry out or drown.

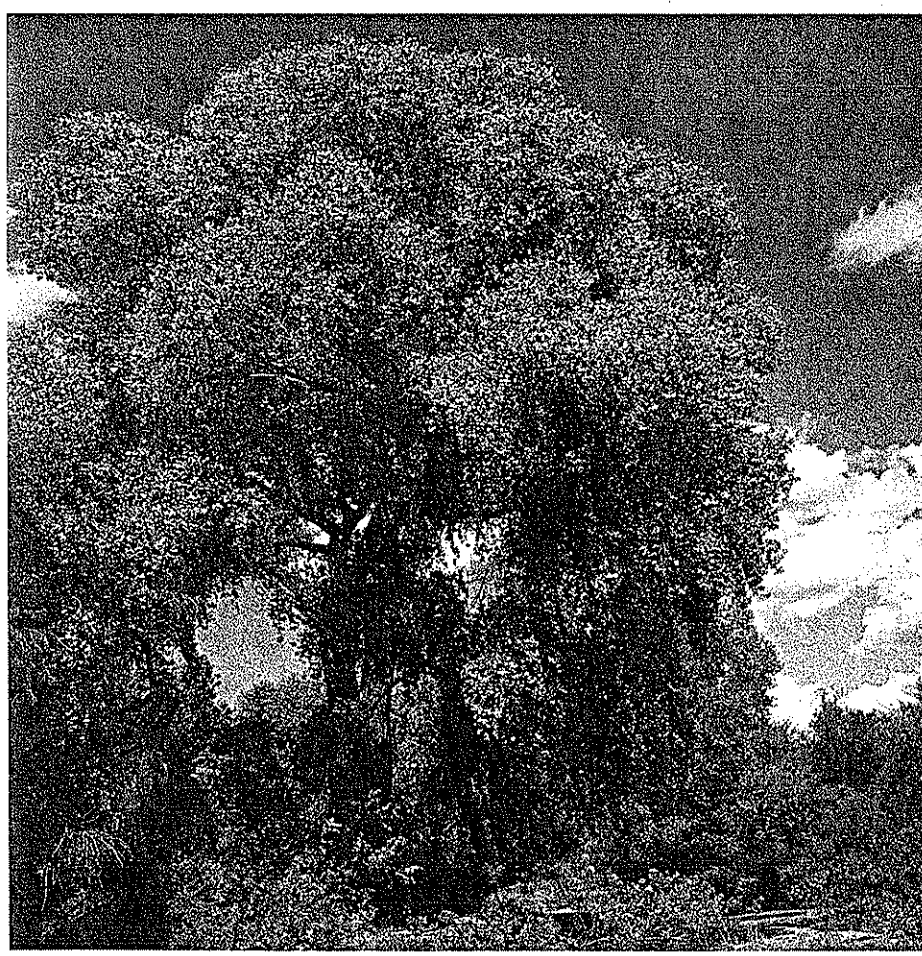
The seeds of such riparian trees as sycamore, ash, walnut, or alder need moist burial, but do not require recently deposited sandbars. However, willows, as well as cottonwoods, are dependent on flooding for seed germination. Some animals also need the sandbars produced by flooding for successful reproduction. For example, the Rio Yaqui and Rio Fuerte sliders, two aquatic turtles native to Sonora, build nests in the sandy banks created by flooding. Dams in the region have reduced flooding, and the lack of suitable nesting sites may be causing the Rio Yaqui slider to decline in some portions of its range. Flooding is just one of many interactions among the living and non-living components of a riparian system.

Riparian ecosystems could not exist without permanent sources of water. But water sources are scarce in the Southwest because of scant rainfall and a startling evapotranspiration rate. (Evapotranspiration is the total loss of water to the atmosphere, including natural evaporation and transpiration from plants.) *Potential* evapotranspiration exceeds annual precipitation by a factor of almost ten. It is obvious that little water remains in the soil under such conditions. In fact, groundwater recharge can only be accomplished by long, slow, ground-soaking rains. These are most characteristic of winter rains in the Sonoran Desert.

Since most of our rain comes bimodally during the summer and winter, there must be a mechanism for supplying a relatively steady flow to our uncommon perennial streams. This is accomplished by groundwater infiltration and relatively steady spring discharge rates which tend to smooth out the seasonal variations in precipitation.

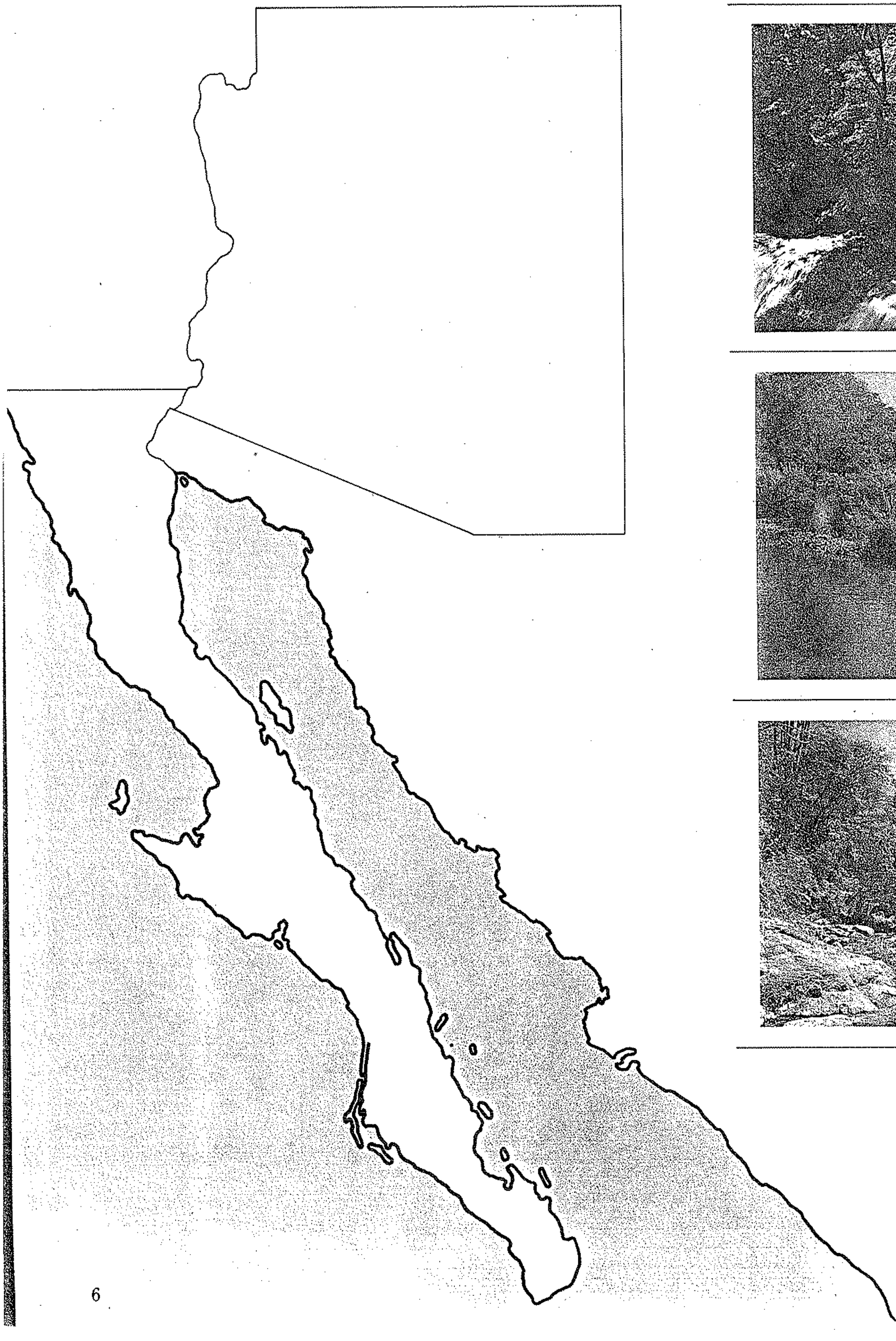
Where a water table intersects the ground surface as at springs, cienegas, and flowing artesian wells, there is a reliable water source. The groundwater can be viewed as reservoir that is recharged sporadically, yet supplies water continuously to surface runoff systems. Local geologic conditions may prevent groundwater from infiltrating to greater depths. This is usually an advantageous situation, especially in the desert. Such conditions include perched water tables, where the groundwater reservoir occurs in an aquifer (porous sediment or rock) above a non-permeable layer called an aquiclude.

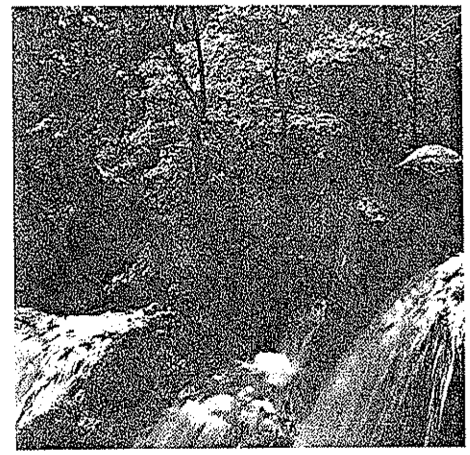
Fremont cottonwood tree



Cassandra Krause, The Nature Conservancy.

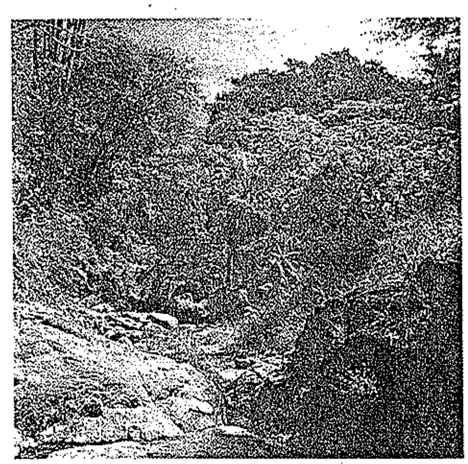
Common Riparian Types





Mark Dimmitt.

Howard Lawler



Howard Lawler

Montane Stream: Cave Creek
The montane stream is characterized by steep slopes and fast-running water, often in cascades and waterfalls. Its riparian zone is usually narrow because the stream has cut a canyon with steep sides. The surrounding habitat is usually a forest or woodland, but the riparian zone has different species of trees and is thus distinguishable even if the stream is not visible. Typical trees are willows, alders, bigtooth maples, and below 6,000 feet, cottonwoods, and sycamores.

ASDM photo

Lakes or Ponds: Quitobaquito Spring
Bodies of still water may have riparian edges. The vegetation beside lakes and ponds depends primarily on elevation and on how much the water level varies with the season. Artificial reservoirs which draw out much water during the dry season and thus have large water level changes may have very little riparian vegetation. Reservoirs with stable water levels will develop the same vegetation as natural lakes in the area.

Desert River or Stream: Salt River
The desert river or stream is typically on gently-sloping to nearly-level ground, at lower elevation than that of the mountain stream. Its riparian zone may be very narrow if the stream is cutting through a mountain range (e.g., Aravaipa Canyon), or quite broad on valley floors (e.g., the floodplain of the Colorado River). The riparian zone's lushness contrasts sharply with the adjacent desert's aridity. Typical trees are cottonwoods, sycamores, willows, and velvet ash.

Jeanne Broome

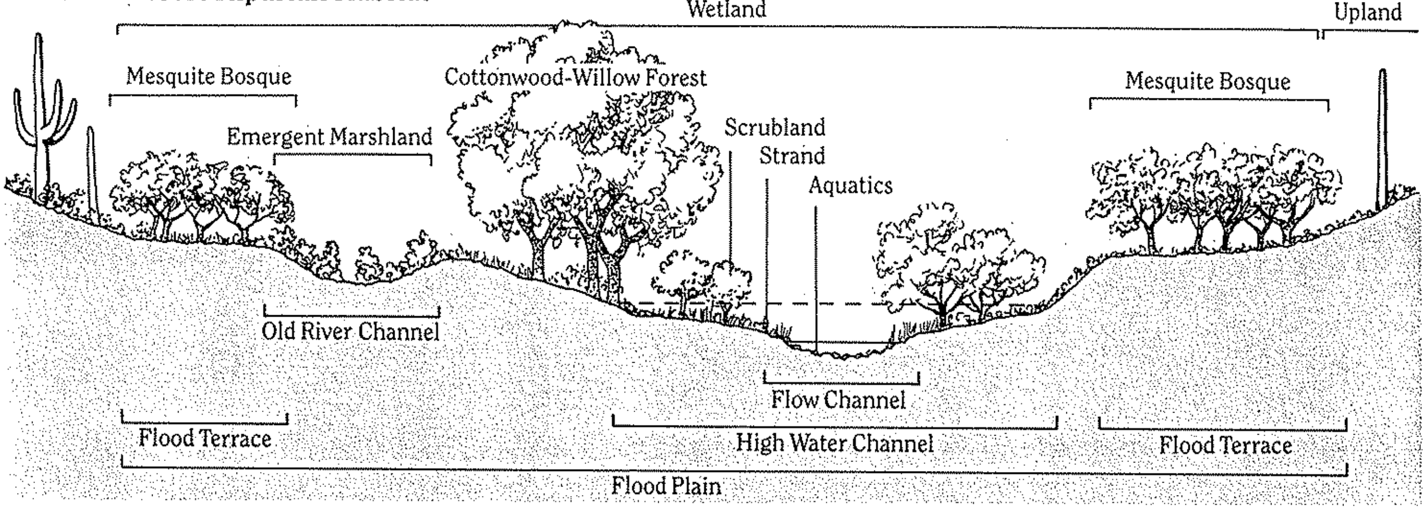
Intermittent Streams: Tanque Verde Wash
In arid places like the Southwest, the term riparian *includes not only habitats along perennial streams, but also those stretches of stream which carry water seasonally, during the period of highest rainfall or snowmelt in their headwaters. The riparian zones of intermittent streams have many of the same plants that occur along the permanently flowing stream uphill, though they are smaller and less dense.*

Tropical Stream: Rio Cuchujaqui drainage
A tropical stream may be in the mountains or lowlands; it differs from the temperate and subtropical areas in being essentially frost-free. Its vegetation is therefore tropical; its riparian areas are characterized by evergreen broadleaf species: figs, Montezuma cypress, willows, and tropical hackberry. Much of tropical riparian vegetation is the same as that on the slopes. Thus, unlike other riparian systems, tropical riparian habitats do not differ substantially in plant species from their surroundings.

Mark Dimmitt

Dry Wash: Chuckwalla Valley, CA
The dry desert wash, or arroyo, is an extreme example of riparian habitat. Although it may be dry for all but a few hours a year during flash floods, the wash collects runoff from large areas and so contains more moisture than the adjacent desert. The dominant trees in a wash are desert ironwood, blue palo verde, velvet mesquite, and desert willow. In the drier regions of the desert, these trees occur only along wash channels.

Sonoran Desert Riparian Habitat



Soil

In contrast to neighboring desert soils, Southwestern riparian soils can support luxuriant plant growth. It is easy to see why. There is abundant water to leach the salts from the soils. Compared with the surrounding desert, soils are thicker and richer in organic matter due to denser vegetation. Beneficial elements that would be leached from a tropical soil, for example, are periodically replenished here by runoff from the surrounding mineral-rich desert, and organic nutrients are transported from lusher elevations with greater rainfall. Good soils, plenty of water, and our famous southwestern sunshine combine to optimize plant growth conditions.

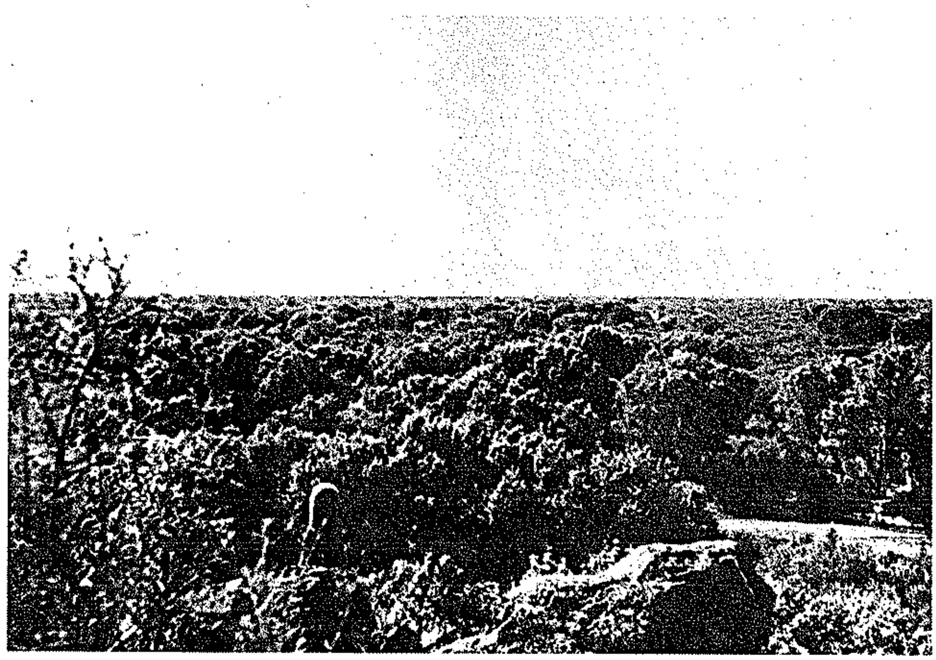
Human Impacts on Riparian Areas

Over the past 100 years, the arid Southwest has changed in many ways. Perhaps no change has been so striking or sad as the loss or degradation of its waters and their bankside communities. Recent books such as *Once a River* and *A River No More* document the death of our rivers. Studies of habitats show that only 5-10% of the Southwest's original riparian areas remain, that they are among the rarest of all North American forest types, and that they are increasingly threatened.

Those who came to the Southwest in previous centuries knew river valleys that were greener and wetter than they are today. The Hohokam of Snaketown along the Gila River decorated their pottery with pictures of waterbirds, often in the act of swallowing reptiles and fish. In 1699, Father Kino wrote of the lower Gila and its people, "All its inhabitants are fishermen, and have many nets and other tackle with which they fish all the year, sustaining themselves with the abundant fish and with their maize, beans, and calabashes." These wet and productive valleys are now mostly dry.

In 1833 a young trapper, James Ohio Pattie, pitched camp in a thick grove of timber along a river 100 yards wide. Beyond the river was a small lake noisy with ducks and geese. In the river, he trapped 200 beaver in seven days. This river, which he called Beaver River, was most likely the San Pedro. Today this same stretch of the river holds no water, timber or beaver.

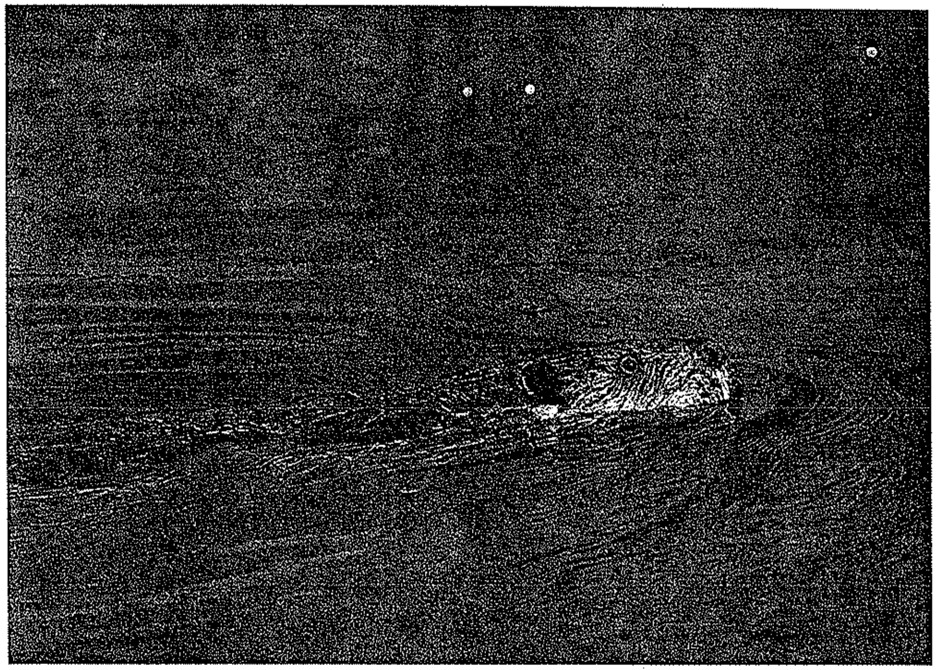
One hundred years ago, most of the streams and rivers of southern Arizona, including the San Pedro and Santa Cruz, moved slowly through very broad, unchannelled courses; they were perennial, though some, like the Santa Cruz, went underground for long stretches. Cotton-



AGFD photo.

Santa Cruz River, June 1942
This photo was taken looking south from Sahuarita Butte, now called Martinez Hill (USGS stake #937). Riparian vegetation is dominated by a cottonwood forest in the foreground and dense mesquite bosque in the background.

Beaver
Beaver played an important role in the perpetuation and modification of desert riparian habitats. They built dams, impounded water and thus reduced the rate of stream flow, raised the water table, and increased sedimentation rates. In Arizona, the beaver is still found in the Colorado River and the perennially flowing area of the Gila and Salt Rivers.



wood, brush, mesquite bosques, or marshes lined the rivers. The valleys were filled with grass, cienegas, and pools. Beaver dams were numerous, and fish abundant. Changes occurred, as they always do in a system as dynamic as a river, but beginning about 1890, truly drastic changes began. Consistent streams became intermittent, and channels went dry for most of their reach, most of the time. Once-broad water courses became steep trenches for fast-moving water; the water table dropped; marshes and cienegas dried up; vegetation disappeared; irrigation ditches could not receive water; soil eroded. In *The Changing Mile*, Rodney Hastings and Raymond Turner document these events on the Santa Cruz, using early records and photographs.

The causes of death or decline of our rivers are many and much debated. The southern rivers such as the Santa Cruz and San Pedro may have been altered by exceptionally severe floods during the last 100 years and also by drier conditions, themselves the result of a regional climatic change. Although the dynamics of weather may be a chief cause of the arroyo cutting of the Santa Cruz, most often humans are implicated in the destruction of a riparian system.

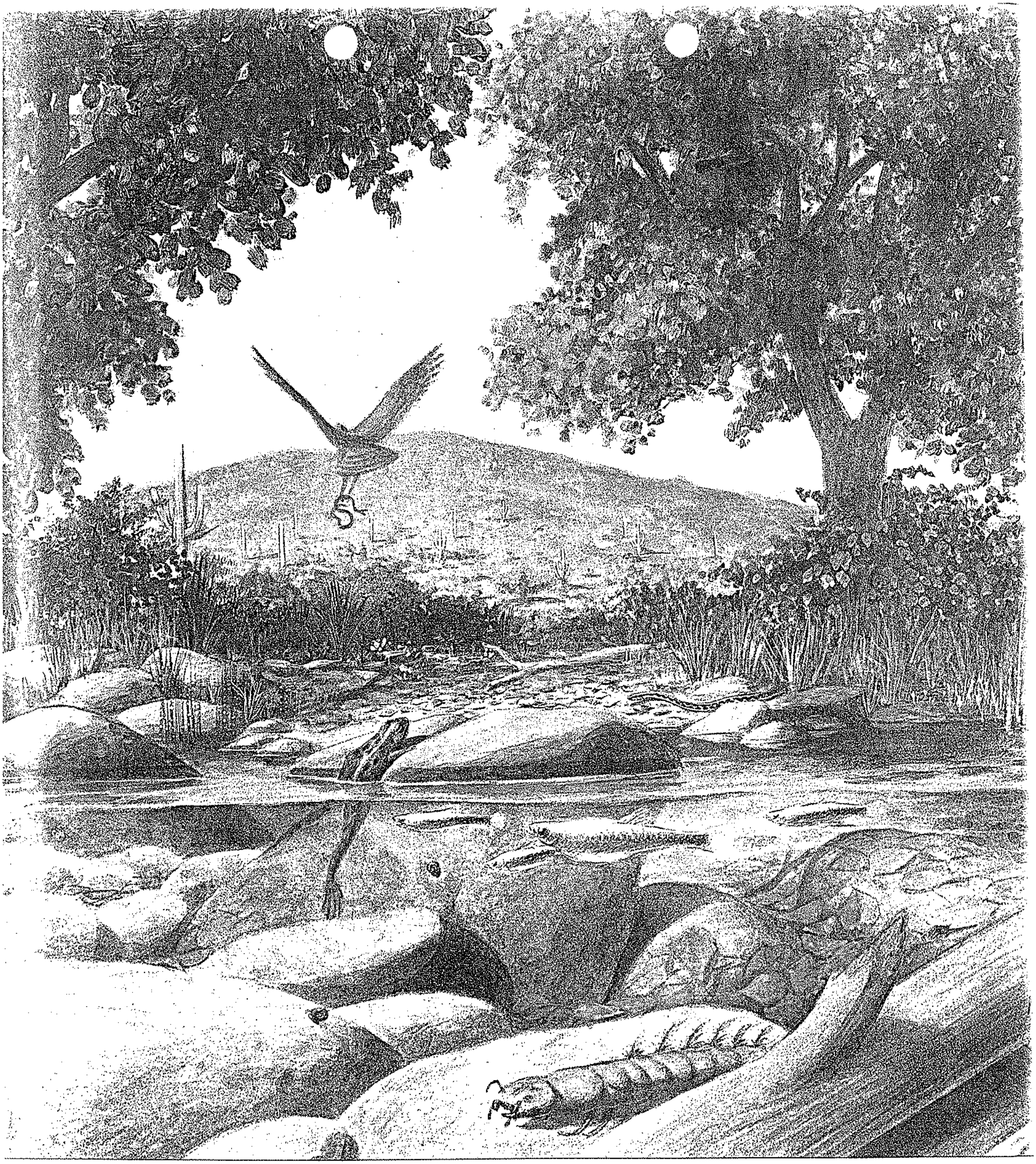
Humans have always lived along rivers, particularly in arid places where the waters are life. By the end of the last century, every running stream and permanent spring in Arizona was occupied. People have used rivers and wetlands to maintain life-styles often at variance with the land. We have lived *along* rivers, but not *with* them, and our uses have killed them.

Ever since the Spanish introduced them to the Southwest, cattle have been grazed in riparian areas, ideal providers of food, water, and shade. Because they eat seedlings, cattle can prevent the reproduction of cottonwoods and other riparian plants, resulting in woodlands of even-aged, and aging, trees. Extensive grazing can cause erosion and degradation of water quality, impacting fish and other wildlife. Riparian areas have been the source of timber for building and for fuel.

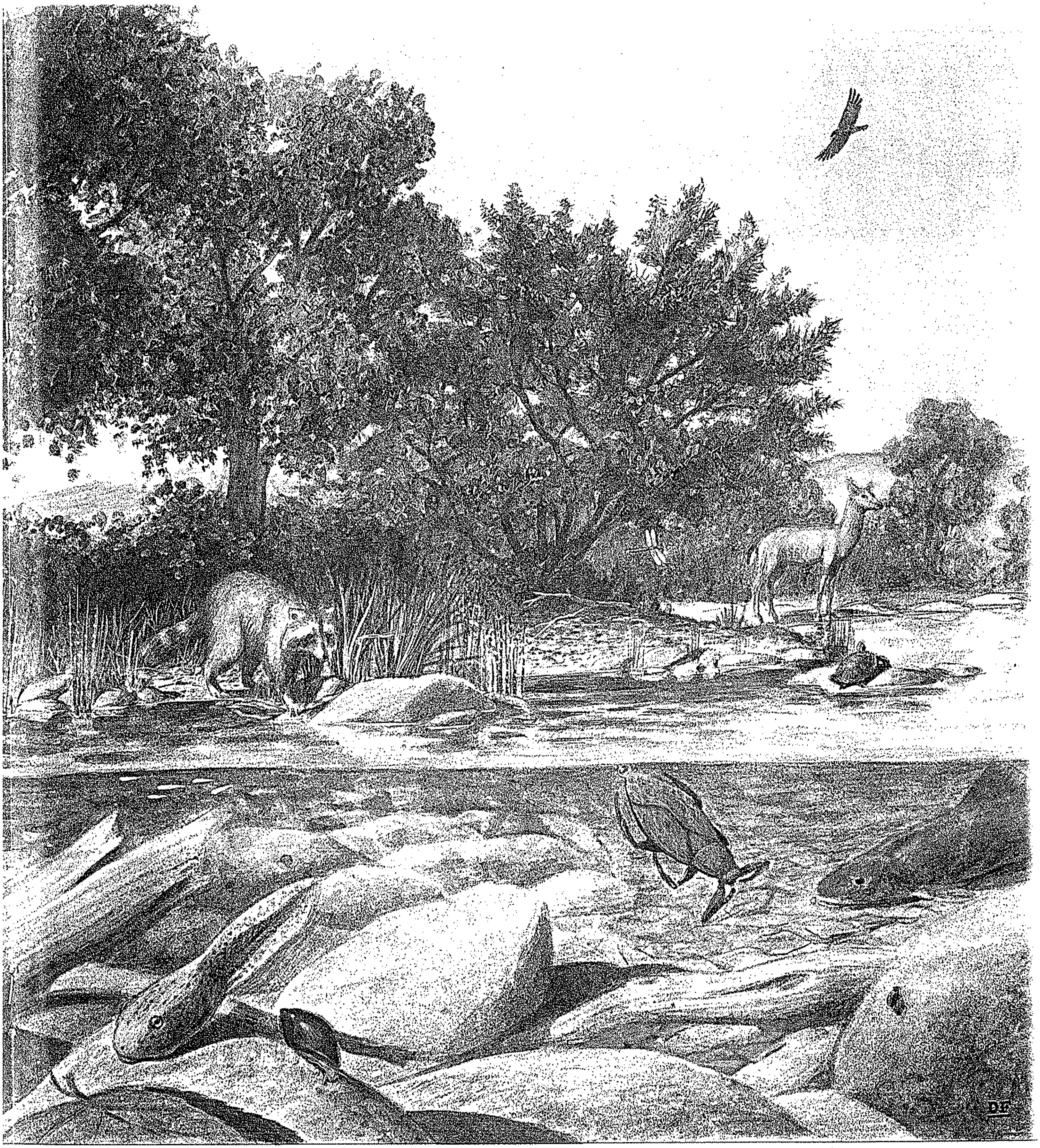
The water in rivers and streams has been "salvaged" for irrigation of farmlands, for mining and other industrial uses, and for human consumption and recreation. Dams flood riparian areas above them, trap nutrients and sediment, desiccate the wetlands below, and change the flow and temperature of the stream
(Continued on page 12)

R. M. Turner

Santa Cruz River, same view, June 1981
Note the increased width of the sandy channel, high eroded banks, absence of cottonwood trees, and scattered mesquite.



A Typical Riparian Habitat



Tent caterpillar webs *Vulure*
Raccoon *Grasses and horsetails* *Desert willow* *White-tailed deer*
Dragon fly *Sonoran mud turtle*
Leopard frog tadpole *Aquatic snail* *Giant water bug* *Razorback sucker*

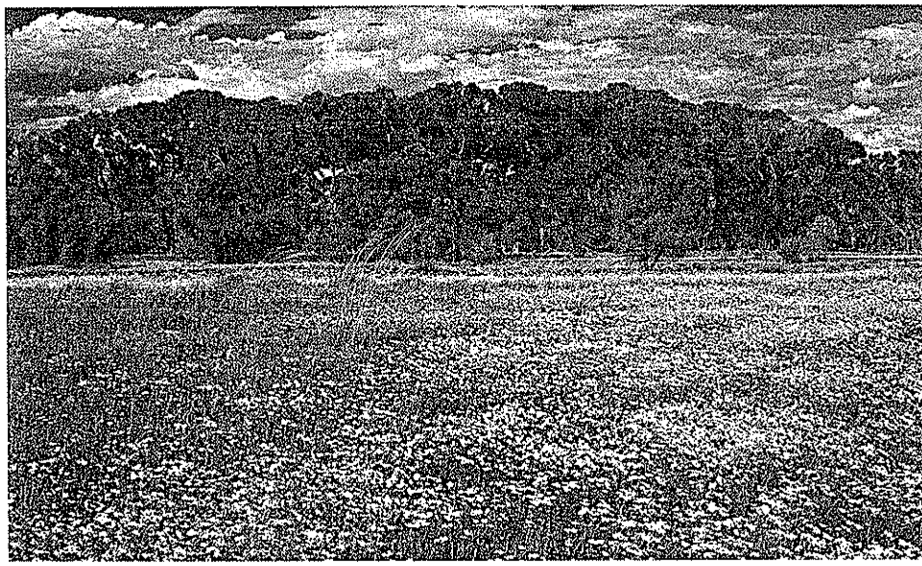
for a long way beyond. Other water salvage projects divert water from streams to channels or remove water-using streamside plants. Urban development has filled watercourses and marshes with garbage, parking lots, and buildings. Traffic moves across roads and bridges which partition woodlands with concrete barriers. Development in the floodplain is protected from flooding with dams and levees, and with channelized, dredged, straightened, paved or devegetated watercourses. When overbank flooding is prevented, plants like the cottonwood, whose ecology depends on floods, cannot

Cienegas — Vanishing Riparian Habitats

Spanish explorers of what is now the southwestern United States applied the term *cienega* to marshes found in riparian habitats. These are wet areas near springs or along streams where the water table permanently intersects the surface. Cienegas trap organic materials and nutrients and develop highly organic, reducing soils. The vegetation is often a dense mat of sedges and grasses with aquatics in open water and trees such as cottonwood and willows along the edges. Cienegas are extremely productive ecosystems that support wildlife in much greater abundance than the surrounding slopes. Fishes, amphibians, the Sonoran mud turtle, garter snakes (especially the Mexican garter snake), marsh birds, and wading birds are riparian obligates that for at least some part of their life cycle need this habitat.

Large mammals, especially grazing herbivores, often concentrate near cienegas. Overuse by cattle has been a major source of disturbance historically. Large predators such as the grizzly bear and mountain lion were often seen in them. Cienegas support dense rodent populations, especially cotton rats, and their predators.

Our cienegas typically are found in grasslands and woodlands at 3500 to 5500 feet elevation in the southeastern corner of Arizona. Today cienegas occur at San Bernardino Ranch in the Rio Yaqui drainage, Hooker Cienega in the Sulphur Springs Valley, and St. David, the Babocomori River, and O'Donnell Cienega in the San Pedro River drainage. The rare Canelo lady's tresses orchid occurs in the O'Donnell Cienega which is now protected in The Arizona Nature Conservancy's Canelo Hills Preserve. Cienegas in the Santa Cruz River drainage include several areas near its headwaters, especially Sheehy Spring, in the San Rafael Valley east of Nogales, and the Arivaca Cienega near the town of the same name. Marshy habitats were apparently found in the Tucson area along the Santa Cruz and Rillito Rivers well into this century.



Doug Koppinger

Babocomari Cienega.

People have long been attracted to cienegas. Excavations near Naco in the Sulphur Springs Valley, and at the Lehner Ranch and Murray Springs near Sierra Vista in the San Pedro River Valley yielded the elegant fluted projectile points of the Clovis Culture amongst and imbedded in the bones of the extinct Columbian mammoth. Pollen analysis of the dark, organic sediments containing the bones indicates that cienegas were more common and better developed 11,500 years ago under cooler, wetter ice age climates than today.

Indigenous peoples continued to live near cienegas in Arizona and Sonora into historic times when "rancherias" of the Apaches, Sobaipuris, Pima Altos, Opatas, and Pima Bajos were frequently encountered. From 1692 to 1697 Padre Francisco Eusebio Kino and other padres visited the Sobaipuris along the San Pedro River just east of the Clovis kill sites and estimated a population of 2000 people living in 14 villages.

Beginning in the 16th century, the Spanish and their agricultural and grazing practices increased, and gradually displaced the earlier inhabitants. As early as 1687, Pima Indians at Remedios, Sonora, were complaining that the Spanish pastured so many cattle that watering places were drying.

Anglo-American settlers in the late 1800's and especially this century had a much greater effect on cienegas than earlier peoples. Widespread arroyo cutting in response to the combined impacts of heavy grazing, increased ground water use, and unfavorable climates dried many streams and modified cienegas. Some like the Water of the Dead, a few miles above Aravaipa Canyon, have disappeared without a trace. In others like the San Bernardino Cienega east of Douglas, the area of the sedge marsh has shrunk as cottonwoods and willows declined and velvet mesquite invaded.

reproduce, and a dynamic woodland becomes a senescent grove. Deepening river channels, a plunging water table, and the drying of streams mean that even plants with long roots can no longer reach water, and forests die.

While changes in the flow regime and mineral content of streams have negatively impacted native vegetation, they have made life easy for the salt cedar or tamarisk, a species which was introduced from Eurasia and is now the dominant vegetation along many riparian systems (such as the Salt River) where it has eliminated native vegetation like cottonwood and willow, while providing little value to wildlife.

Biodiversity

In destroying Southwestern riparian communities, we are destroying areas with a biological value completely disproportionate to their size. At least 75% of all Southwestern vertebrate species depends in some capacity on streams and wetlands, yet these areas occupy less than 0.5% of the land mass. A few statistics on birds convey the amazing abundance and diversity found in an Arizona riparian system:

- Riparian areas can contain up to 10.6 times as many spring migrants per hectare as found on adjacent non-riparian habitats.
- Of 134 breeding bird species in the Sonoran Desert, 37% are totally dependent on riparian areas.

R. L. Glinski

Black hawk nestlings

- The 1,059 pairs of breeding birds found on less than 100 acres of cottonwood gallery forest along the Verde River in central Arizona is the highest breeding bird density found anywhere in the continental U.S.

Riparian communities contain so many kinds of birds and other animals because the plant community is so diverse. The crowded conditions of a good riparian forest create many microhabitats (specific local conditions): this variety allows many kinds of animals to perform their unique niches, or roles, within the ecological community.

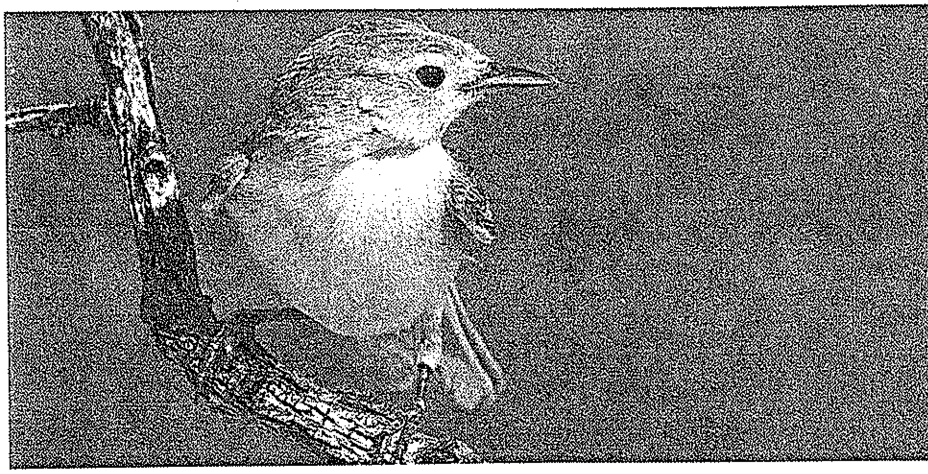
Many microhabitats can be found in the vertical layering of the tall streamside vegetation and in the horizontal gradation of vegetation as the riparian forest grades to the upland desertscrub in one direction and to the aquatic habitats in the other. A gray hawk places its nest in the tall cottonwoods of the riparian forest and then hunts the whiptail lizards that occupy the bordering desertscrub. The common black hawk also nests in the tall cottonwoods, but it hunts in the aquatic habitats for fish and frogs. Each hawk species has its own niche within the desert riparian community.

Niche separation among the insectivorous birds of the tall riparian forests is even more dramatic. Summer tanagers and yellow warblers will feed and nest

Mark Dimmitt

Sycamore trees growing along the South Fork of Cave Creek. Sycamore bark peels in a distinctive jigsaw-puzzle-like pattern.

high in the canopy of the cottonwoods. Bewick's wrens will glean insects from the trunks of these huge trees and from the rubble of fallen logs and dead brush shaded by their dense canopy. Lucy's warblers nest in the recesses of the peeling bark of a cottonwood or mesquite and then glean insects from the foliage in the bordering mesquite bosque. Yellow-billed cuckoos and yellow-breasted chats occupy the very dense borders between the riparian gallery forest and the surrounding scrub. There the cuckoo crawls through the branches searching for insects on foliage or bark. The thick-billed kingbird catches flying insects on the wing in desert riparian habitats. This flycatcher may nest on the upright limb of a tall sycamore tree. The northern beardless tyrannulet will hide its tiny nest in a clump of mistletoe or even inside the web of colonial caterpillars found in the riparian woodland. Many microhabitats and diverse niches provide for diversity of avian life in a desert riparian ecosystem.



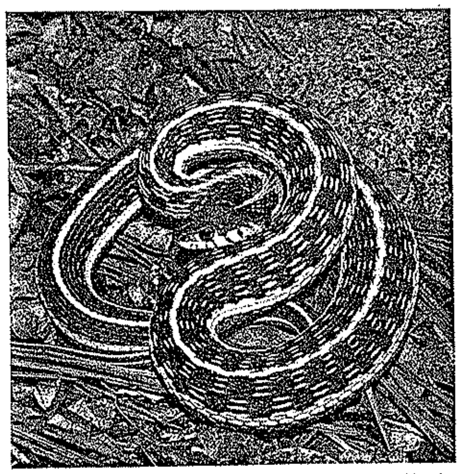
John H. Hoffman

Lucy's warbler

The abundance of birds is dependent upon the amount of food available. Or as an ecologist would say, the biomass of the consumers in a ecosystem is dependent upon the productivity of that ecosystem. For example, the greater the mass

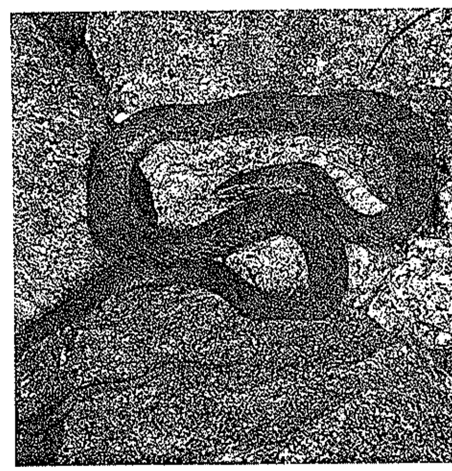
Howard Lawler

Northern Casque-headed Tree Frog
Woodcutting and overgrazing have denuded the margins of some cienegas and permanent ponds, eliminating critical cover for many reptiles and amphibians. The Great Plains narrow-mouth toad, the Sonoran green toad, and the northern casque-headed tree frog share a limited distribution in the mesquite desert-grasslands of extreme south-central Arizona. While their natural habitats may be jeopardized by these factors and groundwater pumpdown, these species adapt readily to artificial breeding sites such as roadside ditches, a versatility which may insure their survival.



Howard Lawler

Black-necked Garter Snake
Garter snakes are derived from water snakes. Although they have become more versatile than water snakes and can often leave the immediate vicinity of permanent water, in the Sonoran Desert region they are riparian obligates, and many are declining along with their habitat. Most garter snakes resemble this one, having three body stripes on a green or olive drab background.



Randy McCranie

Narrow-headed Garter Snake
In appearance and habits, this garter snake closely resembles water snakes and, in fact, has been classified as such in the past. It is highly aquatic, rarely found far from permanent water. Its strange-looking, narrow head is a specialization for catching and eating fish and amphibians. It is becoming rare in some areas, probably due to habitat modification and introduction of predatory game fishes. Healthy populations still occur along Oak Creek above Sedona, and along the Black and Blue Rivers further east.

of plants produced, the greater is the mass of insects, and consequently, the greater is the mass of insectivorous birds. The productivity of desert riparian habitats greatly exceeds that of the adjacent desertscrub.

In addition to the role desert riparian habitats play in supporting a diverse and dense breeding bird population, these habitats are also of great importance to migrating birds. In fact, as these migrants move through the Sonoran Desert, these rare riparian areas may be the only sites for them to feed or rest. Also many northern granivorous sparrows spend the winter in Sonoran Desert riparian habitats feeding on the abundant seed crop produced by the forbs and grasses of this community.

Another feature of those desert riparian habitats that extend out of the higher mountain ranges is the extension of moist and cool habitats into the desert. These extensions of mesic habitats bring some of the birds that may range more widely in the mountain forests and woodlands. The white-breasted nuthatch is such a bird. In the desert, it is only found in riparian habitats. In the high moist mountains, it is more widespread.

Much of what can be said for birds can also be said for mammals, reptiles, and amphibians. The great productivity of the desert riparian community attracts both prey species and their predators. Desert riparian communities support a large population of desert cottontails and therefore many bobcats or gray foxes.

Many snakes enter riparian zones from time to time in search of prey. The tropical vine snake reaches its northern range limit in extreme southern Arizona. Here, most records have come from riparian canyons and the nearby slopes. This slender snake is aptly named, spending much of its time in shrubs or trees where it rests motionless, waiting patiently for its prey of lizards, insects, and occasionally small birds and rodents. Its mild venom is delivered with grooved fangs located in the rear of the upper jaws.

Gray fox

Tim Fuller

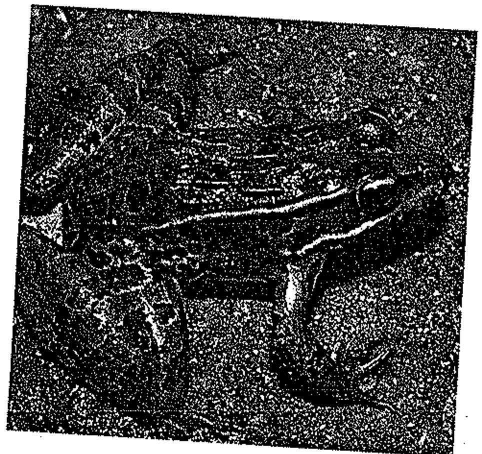
Animals which are more widespread in the mesic mountain forests or tropical woodlands but which are restricted to riparian habitats in the desert include raccoons and coatis. In the lower Colorado River valley subdivision of the Sonoran Desert, conditions became so hot and dry that typical desert creatures are concentrated in the dry washes which offer a little more moisture and vegetation than the surrounding desert. These animals include the desert spadefoot toad, red-spotted toad, Sonoran Desert toad, and side-blotched lizard.

Loss of Biodiversity

The list of animals which are riparian obligates or associates could go on and on. In terms of species diversity, productivity, and numbers of individuals, the Southwest's riparian areas are its most valuable wildlife habitat. They are fast disappearing. One wonders how many species have vanished — or are vanishing — along with them. Because riparian areas were impacted before their wildlife could be carefully censused, we have no

Porcupine
Although the porcupine is widespread at higher elevations, in the desert it is found primarily in riparian areas, where it is fairly common. In fall and winter, it feeds on the bark of trees, but switches its diet to forbs in the spring and summer.

e data against which to compare cur-t populations. However, we do know ne details which may suggest the er story. In *Once a River*, a study of middle Gila River, Amadeo Rea calcu-s that 25 bird species directly as-ated with riparian woodlands or open r have been extirpated and at least aher 25 species have conspicuously dned in numbers. Several mammal spes which were once found in Arna's riparian bosques are now gone coletely — grizzly bears, gray wolves, jags, ocelots, probably the otter — and oths, like the beaver, have declined as the habitat has dwindled. Nine species of hetozoans included in the Arizona Gam and Fish Department's Proposed List Threatened Wildlife in Arizona (198 are clearly riparian obligates and five ders are strongly associated with, and pbably dependent on, these habi-tats. gether, these comprise nearly 61% the reptiles and amphibians



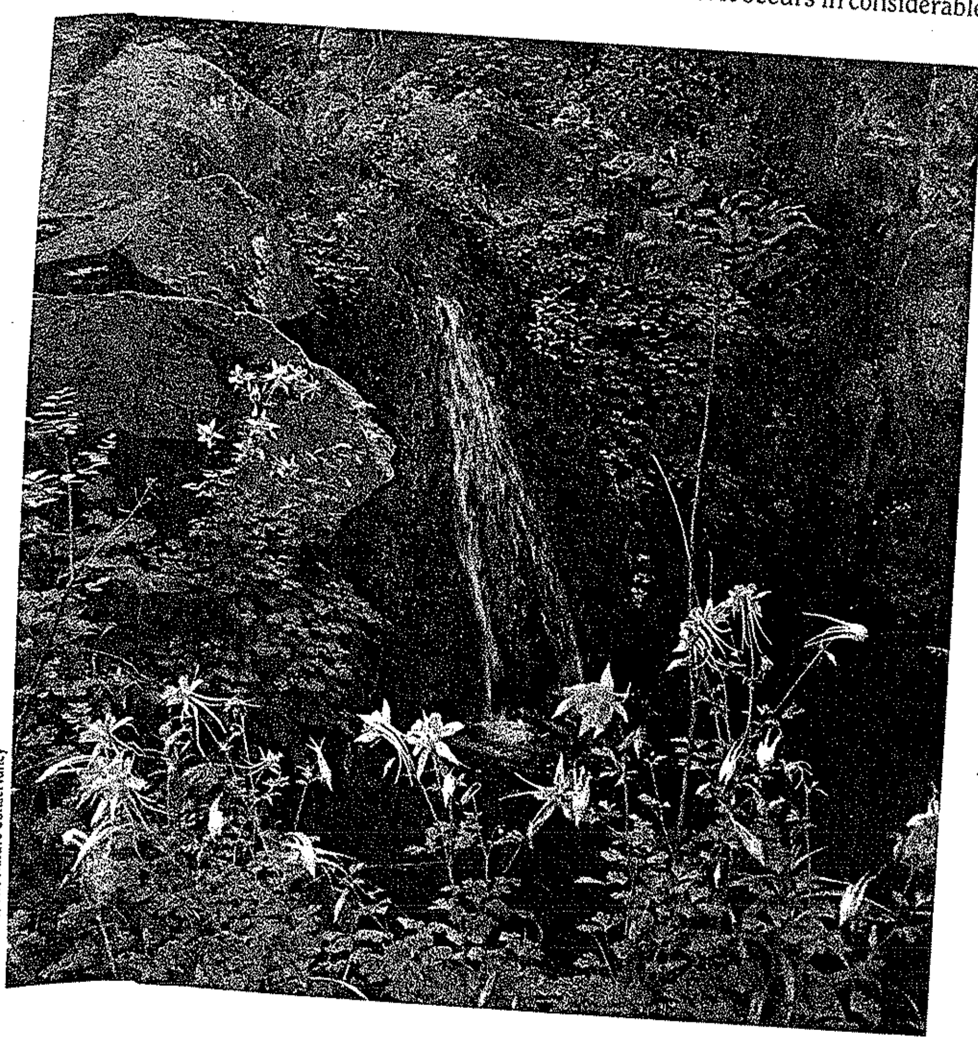
Howard Lawler

Lowland leopard frog

thought to be in need of special conservation management in Arizona. Most species are in jeopardy because of loss of habitat. A few have another story to tell as well.

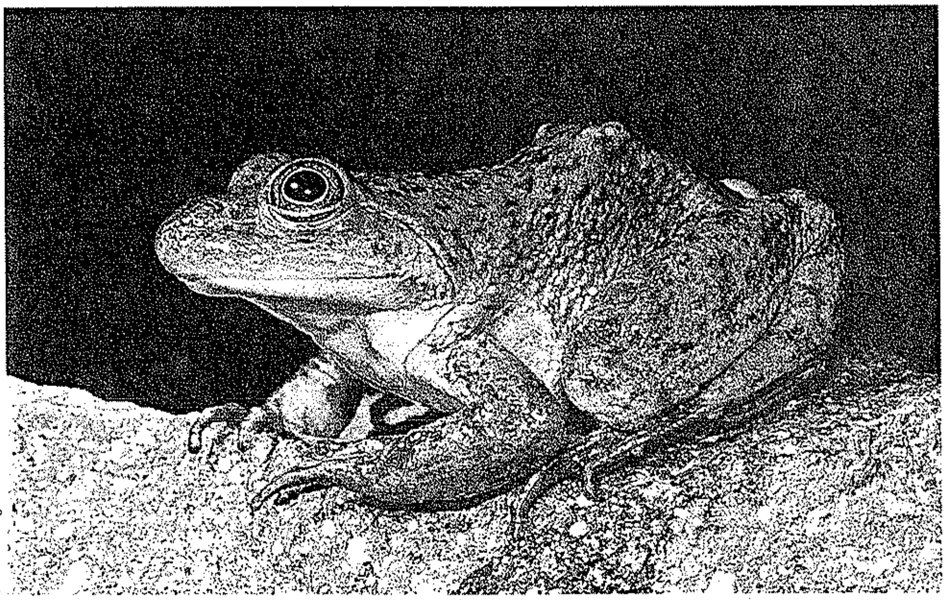
The Tarahumara frog inhabits permanent streams in mountains associated with the great Sierra Madre Occidental of western Mexico. It occurs in considerable numbers where it is undisturbed, and was once common at the six known localities in the Pajarito and Santa Rita Mountains of Santa Cruz County, Arizona. In the late 1970's a mysterious and sharp crash occurred in these populations; today the species is considered extinct in Arizona. Some populations in northern Sonora have shown similar die-offs, although Mexican populations south of the borderlands appear to be doing well. What caused this fatal decline in so short a time is still unclear, but evidence points to pollution from trace minerals or acid rain, probably originating with sulfur dioxide emissions from U.S. and Mexican copper smelters in the region. The permeable skin of this, and all frogs, makes them particularly vulnerable to water and air pollution. They may be important biological indicators of environmental quality in aquatic/riparian systems.

The leopard frogs comprise a species complex formerly considered to be a single species, but now shown to be several distinctive species, sometimes occurring together without interbreeding. Each species is specifically adapted to a particular variation of riparian habitat even though the species differ little in general appearance. Five species of leopard frogs occur in Arizona and two more in Sonora. Two, the plains leopard frog and the relict leopard frog, are considered endangered in Arizona; the latter may already be extinct in the state and is federally listed as Endangered. Accelerated loss of wetland habitats and the introduction of the non-native bullfrog have sharply reduced populations of



Tim Loomis, The Nature Conservancy

Rare lemon lilies highlight the foreground in this scene captured at Ramsey Canyon Preserve.



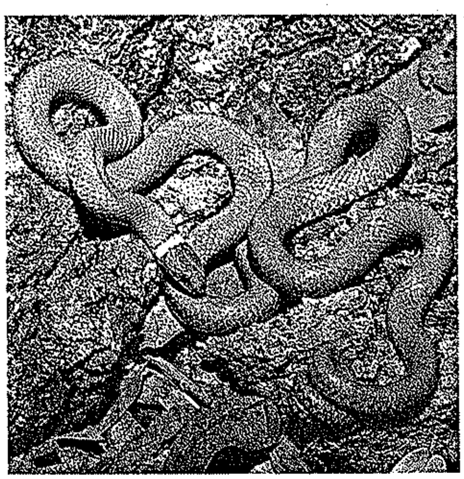
C. Allan Morgan

Tarahumara frog

these formerly common frogs. Other leopard frogs are similarly threatened but to lesser degrees.

The bullfrog, a large, highly adaptable species, with a voracious appetite for anything that moves, is well established throughout most of southern Arizona where permanent water exists. It has been implicated in the decline or disappearance of populations of native frogs and other riparian vertebrates, such as the Mexican garter snake. A high percentage of these snakes at the San Bernardino National Wildlife Refuge east of Douglas have damaged or incomplete tails. Baby and juvenile garter snakes are abnormally scarce. The bullfrog is suspected to be responsible. Due to this predation and to habitat loss or degradation, several populations of this garter snake, whose U.S. distribution is almost entirely limited to southern and central Arizona, have been extirpated, and others are in decline.

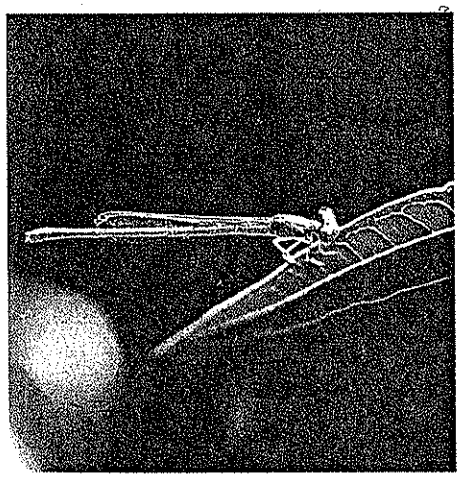
In 1987, the Arizona Game and Fish Department rescinded bag limits and eliminated seasons on the taking of bullfrogs (except in counties along the Colorado River below Lake Mead) where they compete with and prey upon native wildlife. This will allow interested individuals, agencies, and organizations to put more pressure on the bullfrog.



Kevin Black

Regal Ringneck Snake

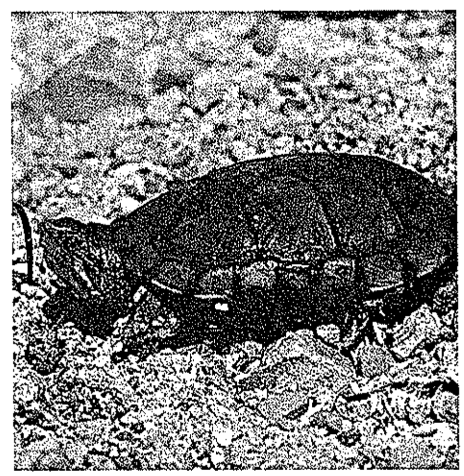
This snake enters sheltered, moist canyons to feed on other snakes, lizards, amphibians and invertebrates. It is mildly venomous, although the slightly enlarged rear teeth are not grooved. The bright reddish-orange ventral color serves a warning, or aposomatic, function. To deter a predator, the snake coils its tail like a corkscrew, waves it to attract attention, and hides its head beneath its coils.



Howard Lawler

Damselfly

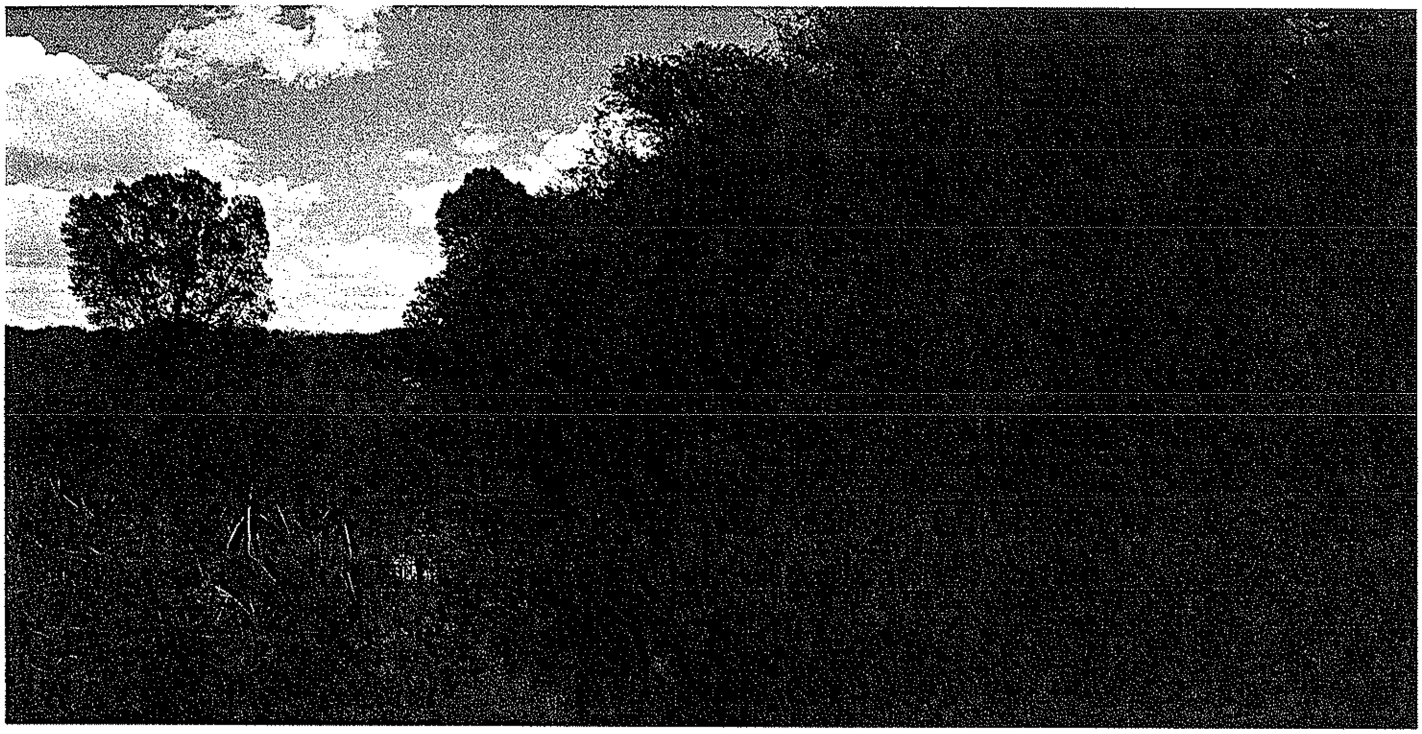
Approximately 5% of insects spend all or part of their lives in the water. The majority of insect species occurring in riparian habitats are common outside the arid Southwest. Most of them have water-based reproductive cycles with aquatic nymph (naiad) stages and winged adult stages. Examples are the dragonflies and damselflies (Order Odonata); mayflies (Order Ephemeroptera), giant water bugs, water striders and backswimmers (Order Hemiptera) and the caddisflies (Order Trichoptera).



Howard Lawler

Sonoran Mud Turtle

Although turtles are usually associated with aquatic/riparian habitats, only two of Arizona's four native species are typically found in riparian zones. These are the Sonoran mud turtle, pictured here, which usually lives in upland habitats with flowing water, and the yellow mud turtle which occupies ponds and other standing water with muddy-sandy bottoms. Both are very aquatic and feed on invertebrates, amphibians, carrion and aquatic plants.



Jeanne Broome

Recently, the Pima County Flood Control District purchased nearly 2000 acres along Cienega Creek in southeastern Arizona. The protection of this creek helps mitigate impacts of flood control projects elsewhere in the county.

Benefits of Riparian Systems

Desert riparian areas are valuable chiefly because of their biological diversity. Their plant and animal diversity can help meet the medical, agricultural, or industrial needs of human beings; thus this diversity has both actual and potential economic value. However, its primary benefit to a healthy, functioning, evolving ecosystem cannot be calculated, nor can its restorative effect on human beings, who delight in variety, vigor, and surprise.

Other benefits of a riparian area can be quantified. Hunting, fishing, and trapping, which often occur in riparian areas, bring considerable revenue, both direct and indirect, to local economies. Perhaps even more important economically are the nonconsumptive uses of riparian areas (wildlife observation and photography, camping, picnicking, hiking, etc.) which contributed $114,000,000 to Arizona in 1970. In 1978, tourists visiting just three riparian areas in southern Arizona (Ramsey Canyon, Madera Canyon, and Cave Creek) spent over $5 million, or $12,370 per acre. Water-based recreation, such as river running, is becoming a multi-million dollar industry.

Riparian vegetation helps purify air, and its waters can clean a community's effluent, a service estimated to be equivalent to between $400 and $1,500 per acre per year. By controlling erosion and stabilizing banks, riparian vegetation can help prevent flooding. In fact, according to Army Corps of Engineers analysis, riparian plants save more money controlling floods than it would cost to remove them, a practice sometimes done for flood control. Other values of riparian systems range from groundwater recharge to honey production.

The Future

E. O. Wilson begins a recent book, *Biodiversity,* this way: "The diversity of life forms, so numerous that we have yet to identify most of them, is the greatest wonder of this planet." These wonders can come in small places: in a tidepool or beneath a rock. But certain habitats are especially rich: tropical rainforests, coral reefs, and wetlands, including riparian areas. These pages have barely suggested the complexity of lives to be found in Arizona's wet places. (We have not discussed invertebrates, yet they probably constitute the majority of life forms there and are fundamentally important to the functioning of the whole.) Protection of species diversity is one of humanity's major responsibilities, but it is one we take all too lightly. We have been reckless with our riparian areas, placing value on what could be extracted from them — water, timber, food — but seeing no benefit to the intact system — the greatest wonder of our planet. If we are to save the remaining 5% of our original riparian systems, we'll have to change our values. "Arresting the loss of diversity will be extremely difficult," comments biologist Paul R. Erlich. "A quasi-religious transformation leading to the appreciation of diversity for its own sake, apart from the obvious direct benefits to humanity, may be required to save other organisms and ourselves."

Many organizations and individuals are working to effect this transformation of values and to protect remaining riparian areas from ill-conceived development and improper uses. One of these is the Arizona Riparian Council, a two-year-old organization with over 400 members which exists "to provide for the exchange and transmittal of information on the status, protection, and management of riparian systems in Arizona." Several other private organizations have helped protect the state's riparian areas by raising issues, lobbying for protection, and sometimes actually purchasing or rehabilitating riparian areas. These include the Desert Fishes Council, the Sierra Club, the Audubon Society, the Wildlife Federation, the Wilderness Society, Ducks Unlimited, Trout Unlimited, and The Arizona Nature Conservancy, which recently launched a three year campaign, "Streams of Life," to acquire or protect 19 of Arizona's remaining riparian areas. Public agencies are emphasizing the wetland and riparian habitats among their holdings. To mention only two, Arizona State Parks has identified certain natural areas and critical habitat most in need of protection; 93% of these are wetlands or riparian areas. The Bureau of Land Management has acquired some big riparian areas, including 30 miles of rare broadleaf riparian habitat on the San Pedro, and has begun to inventory all riparian areas on its lands.

Riparian systems are old. Whether they survive much longer depends on the actions of the upstart creature which has only recently cared enough about them to even name and define them. This creature, humankind, while famous for its shortsightedness, is also capable of imagination, vision and courageous action. These qualities are needed now. If we choose to use them, we may save not only Arizona's most valuable habitat, but the quality of our own lives as well. ■

Palm Oases: A Special Desert Riparian Habitat

Fifty million years ago the warm, wet climates of the early Tertiary supported tropical rainforest in what is now the Sonoran Desert. Fossil palms were found as far as 60° north in Alaska! Surprisingly, palms still occur in protected oases in this core desert even though July temperatures often rise to above 110°F and rainfall barely reaches three inches per year.

Two native palms are endemic to the Lower Colorado River Valley subdivision of the Sonoran Desert. Stands of the desert fan palm are found in over 60 springs, seeps, or desert streams from southern Nevada to western Arizona and northern Baja California. The thread palm is endemic to Baja California and a few islands in the Gulf of California. These palms are the Sonoran Desert's greatest contribution to ornamental horticulture.

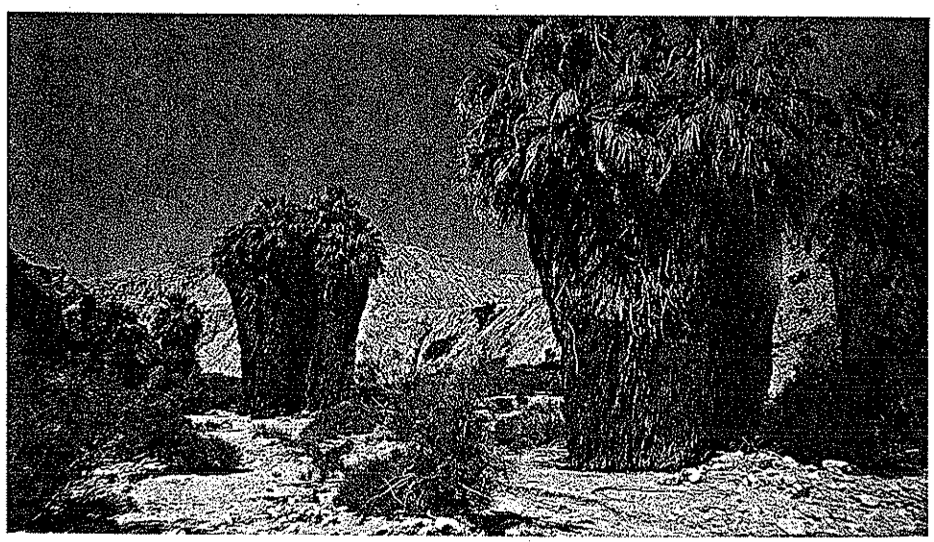
The desert fan palm is the most massive palm native to North America, reaching a height of 76 feet and 40 inches in trunk diameter. The skirts of dead leaves hanging around their trunks have led local people to call them petticoat palms. Well-developed stands greatly modify these desert riparian habitats into verdant oases.

The water and shade of palm oases attract abundant wildlife including over 80 species of migratory birds. The trees' great height — the equivalent of a six- or seven-story building — can serve as distant signs attracting birds, coyotes, and bighorn sheep. Coyotes which visit all oases are probably the most important dispersal agents of the palm's seeds. Seeds that have passed through their digestive tracts germinate more successfully than unconsumed seeds. Coyotes are known to travel up to 36 miles in three days, enough to establish most of the known fan palm sites.

Desert fan palms in more isolated springs at Mopah Spring in California's Turtle Mountains and the Kofa Mountains and Castle Creek of western Arizona may have been established by humans. Native North Americans, who often lived in the oases, had many uses for the palms and were known to carry the seeds to new areas. They used the leaves to build huts and to weave baskets. They ate the fruit fresh or dried, made a flour out of the seeds, and roasted the terminal bud or "cabbage" to eat. As a mature fan palm can produce up to a half million pea-sized dates with a sweet-tasting flesh, this was a major food resource for desert dwellers.

Unlike the many other riparian habitats, fan palm oases appear to be in good condition. The trees are tolerant of fire and not adversely affected by most casual uses of the habitat. In fact researchers at the Palm Springs Desert Museum in California have recorded a 40% increase in the population of wild fan palms since 1945, primarily due to natural increases in rainfall and clearing of debris by fires. As long as the ground water feeding the springs is protected, these desert oases can be expected to survive.

Pushawalla Canyon, California



Mark Dimmitt

Suggested Readings on Riparian Ecosystems

Arizona State Parks. March, 1988. *Arizona wetlands priority plan: an addendum to the SCORP.*

Fradkin, Philip L. 1963. *A River No More*. Tucson, AZ: University of Arizona Press.

Hastings, J. R. and Turner, R. M. 1965. *The Changing mile: an ecological study of vegetation change with time in the lower mile of an arid and semi-arid region*. Tucson, AZ: University of Arizona Press.

Lowe, C. H. 1964. *Arizona's Natural Environment*. Tucson, AZ: University of Arizona Press.

Minckley, W. L. and Brown, D. E. 1982. *Wetlands*. Part 6 of Special Issue of Desert Plants, Vol. 4, Numbers 1-4: 222-301. Tucson, AZ: University of Arizona Press.

Ohmart, R. D. and B. W. Anderson. 1986. *Riparian habitat.* Tempe, AZ: Arizona State University, Center for Environmental Studies.

Rea, Amadeo M. 1983. *Once a river: birdlife and habitat changes on the Middle Gila*. Tucson, AZ: University of Arizona Press.

(continued)

Thanks to outgoing trustees

On behalf of the Museum's 17,000 members, the staff, volunteers and former colleagues we take this opportunity to thank the following whose four-year terms on the Board of Trustees ended in May: David D. Cohn; William B. Drew, Ph.D.; Robert W. Jones; Jean Russell; Patricia H. Waterfall; and Patricia A. Young. Thanks also to the other members of the 1987–88 Board of Trustees and Advisory Council who so skillfully guided the Desert Museum through another successful year:

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ASDM receives grants totalling $90,000

The Desert Museum has been successful in two grant applications. The Institute of Museum Services, a federal agency that offers general operating support to the nation's museums, awarded the ASDM a $75,000 General Operating Support grant beginning last June to implement a new member campaign and to analyze the current ASDM membership. This was the third IMS grant, and the second in three years, the Museum has been awarded.

Also last June, the Museum was advised that the Burlington Northern Foundation approved a grant in the amount of $15,000 to assist in the "Desert Discovery" project, a new program of the Museum's Education Department which will provide learning kits to Arizona school teachers to use in classes in desert ecology on the elementary level. The Burlington Northern Foundation represents the following Burlington Northern Inc. subsidiary companies:

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This is the second grant to the ASDM from Burlington Northern in three years.

Trip to Zimbabwe, Zambia, Botswana Filling Up

A number of commitments have been made for the Museum Foundation's trip to Africa in 1989 as a result of our announcement in the last issue of *sonorensis*. Since the announcement, dates have been firmed for this fabulous 22 day, never-to-be forgotten adventure to mysterious Africa. Mark September 10 through October 2, 1989, on your calendar.

You are invited to camp with us on the banks of the Zambezi, visit the Kalahari, explore the Okavango Delta in a dugout canoe surrounded by magnificent birdlife, and stand in awe of Victoria Falls. You'll view the wildlife from safari vehicles and on foot with armed professional guides in some of the really great national parks of Africa such as Hwange (Zimbabwe), Luangwa (Zambia) and others.

This trip is limited to 15 people, so reservations should be made as soon as possible to assure yourself a slot. Contact ASDM Director Dan Davis or Administrative Secretary Jean Morgan at (602) 883-1380 for information.

Barranca del Cobre by Train and Trail

An 8-day expedition in to Mexico's Sierra Madre
Thursday–Thursday
September 29–October 6, 1988

Carved and sculpted deep into the high Sierra Madre Occidental of Mexico is a network of precipitous canyons so forbidding and remote that modern transportation has penetrated them only in recent years. This is Mexico's Barranca del Cobre or Copper Canyon, every bit as majestic as the Grand Canyon. Here, human history is telescoped, and high-tech culture reaches out and touches hands with cave-dwelling Indians. It is the land of the Tarahumara, a durable, self-sufficient people known for their ability to run for great distances at high altitudes without fatiguing.

The trip originates in Los Mochis, Sinaloa where we will spend a leisurely day at nearby Topolabampo Bay aboard a yacht, watching blue-footed boobies and possibly black skimmers. Early the next morning we begin the most incredible train ride ever engineered, carrying us from the coastal thorn scrub through tropical short-tree forest. The terrain is accented by fluffy kapok trees and strangler figs. Finally, we'll reach the Madrean oak and conifer forest reminiscent of the mountain islands we know in Southern Arizona. Accompanied by Museum naturalists, we'll take bird walks, embark on interesting plant explorations and share vistas of the fabulous volcanic geology that formed this breathtaking landscape. We will reach a new awareness of how the Sonoran Desert came to be. There will also be time to shop for unique Tarahumara basketry, musical instruments, pine bark dolls and other handcrafts.

All accommodations are in beautiful but often remote and primitive quarters. As always in Mexico, be prepared for bouncy roads, long waits, bustling boardings, and warm smiles from wonderful people.

Questions? Call Mary Erickson at 883-1380, ext. 205

Trip fee of $825 (non-members $865) includes all accommodations, all meals, first class train tickets and all transfers beginning and ending in Los Mochis. Not included is the round trip flight from Tucson to Los Mochis (currently $172). We will be happy to assist with travel arrangements.

Registration and Reservation Information: Registrations are accepted by mail or in person only and are processed in the order they are received. Please fill out the form below and mail it with your trip deposit of $100 per person. Balance of payment is due 35 days before departure.

Refunds and Cancellations: Deposit is refundable in full until time of final payment. A $100.00 per person charge will be assessed for cancellations 35 to 14 days before departure. No refunds will be made 14 days prior to departure. Cancellation insurance is available at extra charge.

*This itinerary is predicated on published airline and train schedules, but delays are always possible. Tour rates are those in effect at time of printing. Any changes in transportation, hotel or currency exchange rates will be reflected in the final tour price. Rates are per person and double occupancy.

Please list below name, address and phone number for all participants (attach list if necessary)

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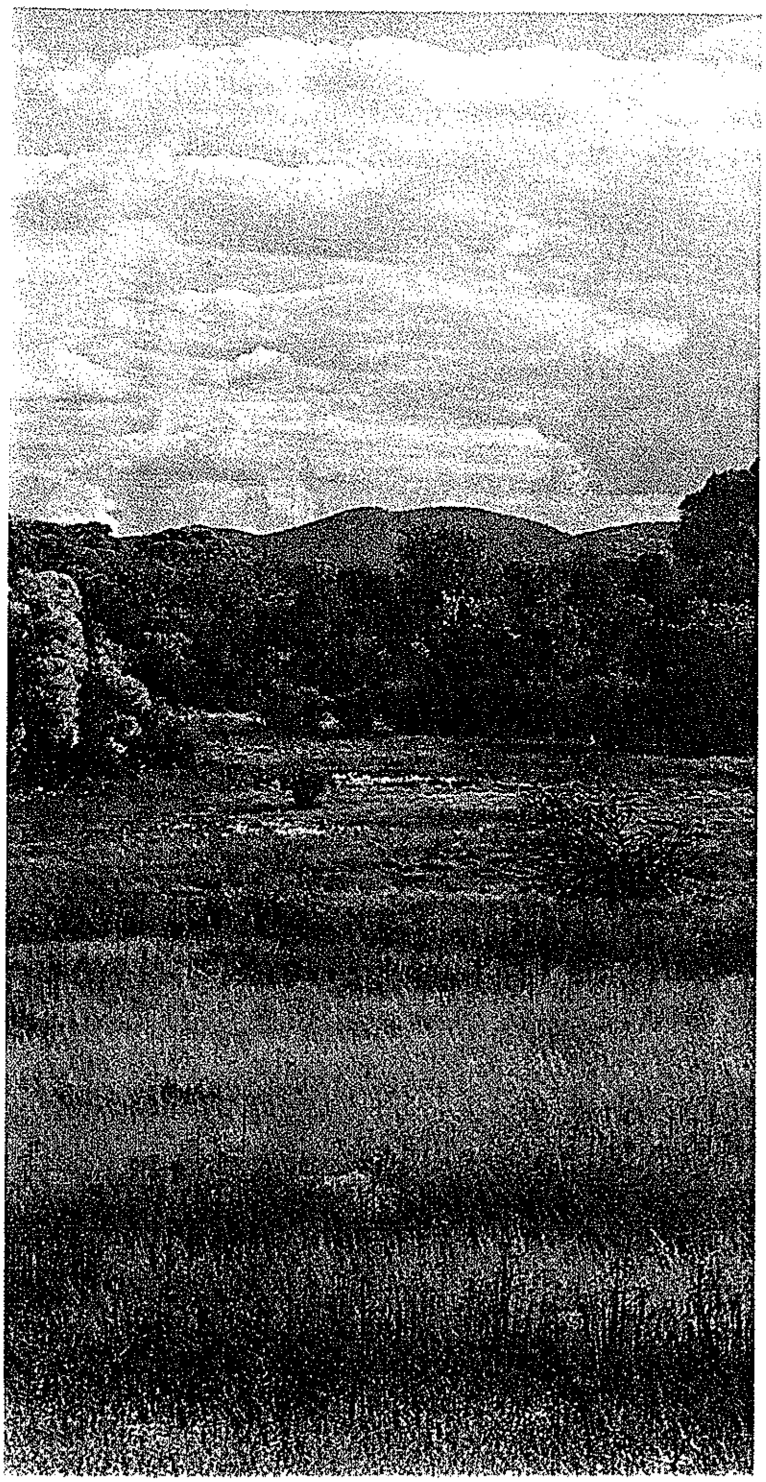
Desert Plants

Volume 6. nber 3. 1984. *(Issued early 1985)*

Published by The University of Arizona at the Boyce Thompson Southwestern Arboretum



Special Issue

Ciénegas — Vanishing Climax Communities of the American Southwest

Dean A. Hendrickson and W. L. Minckley

O'Donnell Ciénega in Arizona's upper San Pedro basin, now in the Canelo Hills Ciénega Preserve of the Nature Conservancy. Ciénegas of the American Southwest have all but vanished due to environmental changes brought about by man. Being well-watered sites surrounded by dry lands variously classified as "desert," "arid," or "semi-arid," they were of extreme importance to prehistoric and modern Homo sapiens, *animals and plants of the Desert Southwest. Photograph by Fritz Jandrey.*

Desert Plants

A quarterly journal devoted to broadening knowledge of plants indigenous or adaptable to arid and sub-arid regions, to studying the growth thereof and to encouraging an appreciation of these as valued components of the landscape.

Volume 6. Number 3. *(Issued early 1985)*
Published by The University of Arizona
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Frank S. Crosswhite, editor

University of Arizona
Boyce Thompson Southwestern Arboretum
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Editorial

The Importance of Ciénegas in History and Prehistory of the American Southwest. The history of the Desert Southwest is full of references to *"ciénegas," "ciénagas,"* and even *"chenegays"* and other corruptions. The ciénega locations were well-watered sites surrounded by dry lands variously classified as "desert," "arid," or "semi-arid." Numerous prehistoric Indians lived at or near these ciénegas, as did modern Indians, most notably those of Piman heritage such as the Sobaipuri. But then came a series of invasions, first by Athabascan-speaking nomads (the Apaches), then by Spanish-speaking people, and finally by English-speaking people.

Ciénega sites were the first to be usurped by land-hungry Hispanics and Anglos alike who developed large herds of cattle to devour the vegetation and drink the water. Overgrazing made the ciénega locations among the most mistreated sites on earth. A variety of misfortunes brought about either knowingly or unconsciously by man have resulted in drainage, arroyo cutting and general destruction of these unique habitats. Ciénegas have been a tremendous resource not only for the endemic peoples, but for the biota as well. Indeed, aside from the fascinating modern flora and fauna of such sites, there are important fossil remains of prehistoric animals now extinct. Mammoth and Mastodon have perhaps been most highly publicized.

Dean Hendrickson and W. L. Minckley describe the individual ciénegas in this issue and trace their history. The plants which grow or did once grow in the ciénega sites are listed in their Table 1. Unfortunately most of the ciénega histories revealed by Hendrickson and Minckley end with a whimper: the ciénegas being destroyed or reduced to mere shadows of their former grandeur. This sad fact has inspired the phrase "Vanishing Climax Communities of the American Southwest" in their title. There have been attempts to interest government agencies in preserving ciénegas because of their great archaeologic and biotic value. One of the most successful preservation projects, however, was mounted by a private nonprofit organization, the Nature Conservancy. Since the historic overgrazing of the 19th Century, modern ranchers are learning or have already learned to be better stewards of the land. But just as modern ranching methods improved, developers began moving in with plans for building large cities. The future of the ciénega is uncertain.

Just what is a ciénega? To grasp the meaning which has evolved for the term *ciénega* as used by scientists, anthropologists, and historians in the American Southwest, read this issue of *Desert Plants* in which the ciénega concept is clearly crystallized and in which the ciénega is demonstrated to be a unique climax ecological community.

Ciénegas — Vanishing Climax Communities of the American Southwest

Dean A. Hendrickson
Department of Zoology,
Arizona State University

and

W. L. Minckley[1]
U.S. Fish and Wildlife Service
Dexter Fish Hatchery
and Department of Zoology
Arizona State University

[1]*Minckley's affilation through the Summer of 1985 is with the U.S. Fish and Wildlife Service, Dexter National Fish Hatchery, Dexter, New Mexico 88230.*

Abstract

The term *ciénega* is here applied to mid-elevation (1,000–2,000 m) wetlands characterized by permanently saturated, highly organic, reducing soils. A depauperate flora dominated by low sedges highly adapted to such soils characterizes these habitats. Progression to ciénega is dependent on a complex association of factors most likely found in headwater areas. Once achieved, the community appears stable and persistent since paleoecological data indicate long periods of ciénega conditions, with infrequent cycles of incision. We hypothesize the ciénega to be an aquatic climax community. Ciénegas and other marshland habitats have decreased greatly in Arizona in the past century. Cultural impacts have been diverse and not well documented. While factors such as grazing and streambed modifications contributed to their destruction, the role of climate must also be considered. Ciénega conditions could be restored at historic sites by provision of constant water supply and amelioration of catastrophic flooding events.

Introduction

Written accounts and photographs of early explorers and settlers (*e.g.*, Hastings and Turner, 1965) indicate that most pre-1890 aquatic habitats in southeastern Arizona were different from what they are today. Sandy, barren streambeds (Interior Strands of Minckley and Brown, 1982) now lie entrenched between vertical walls many meters below dry valley surfaces. These same streams prior to 1880 coursed unincised across alluvial fills in shallow, braided channels, often through lush marshes. The term *ciénega*, applied to riparian marshlands by Spanish explorers, has since attained acceptance in cartographic and public vocabularies of the region.

These unique aquatic and semiaquatic habitats have been reduced in recent times from a formerly widespread distribution to small, scattered remnants (Hastings, 1959; Dobyns, 1981). Stabilization of flow by upstream dams, channelization, and desiccation by diversion and pumpage have greatly reduced natural stream communities in the desert Southwest (Brown *et al.*, 1981; Minckley and Brown, 1982). Ciénega habitats persist in headwaters, reduced in size, variously modified, or artificially maintained. In light of their continuing disappearance, cultural histories, and importance to aquatic faunas and floras, these dwindling, valuable, as yet little-understood ecosystems constitute a resource which merits further investigation. The geographic area considered is that of greatest known past and present abundance of ciénegas in the American Southwest—Arizona south of the Gila River and east of, but including, the Avra-Altar Valley (Fig. 3).

We do not claim comprehensiveness in this work. Dobyns (1981) pointed out the need for a multidisciplinary approach to the topic of environmental change in our region, and we being biologists admit many biases. We undoubtedly have overlooked archaeologic, anthropologic, geologic, and historic literature. However, we provide a review from diverse, relevant sources. Our objectives are to present an historical data base, which may motivate others to further delineate these communities and aid in

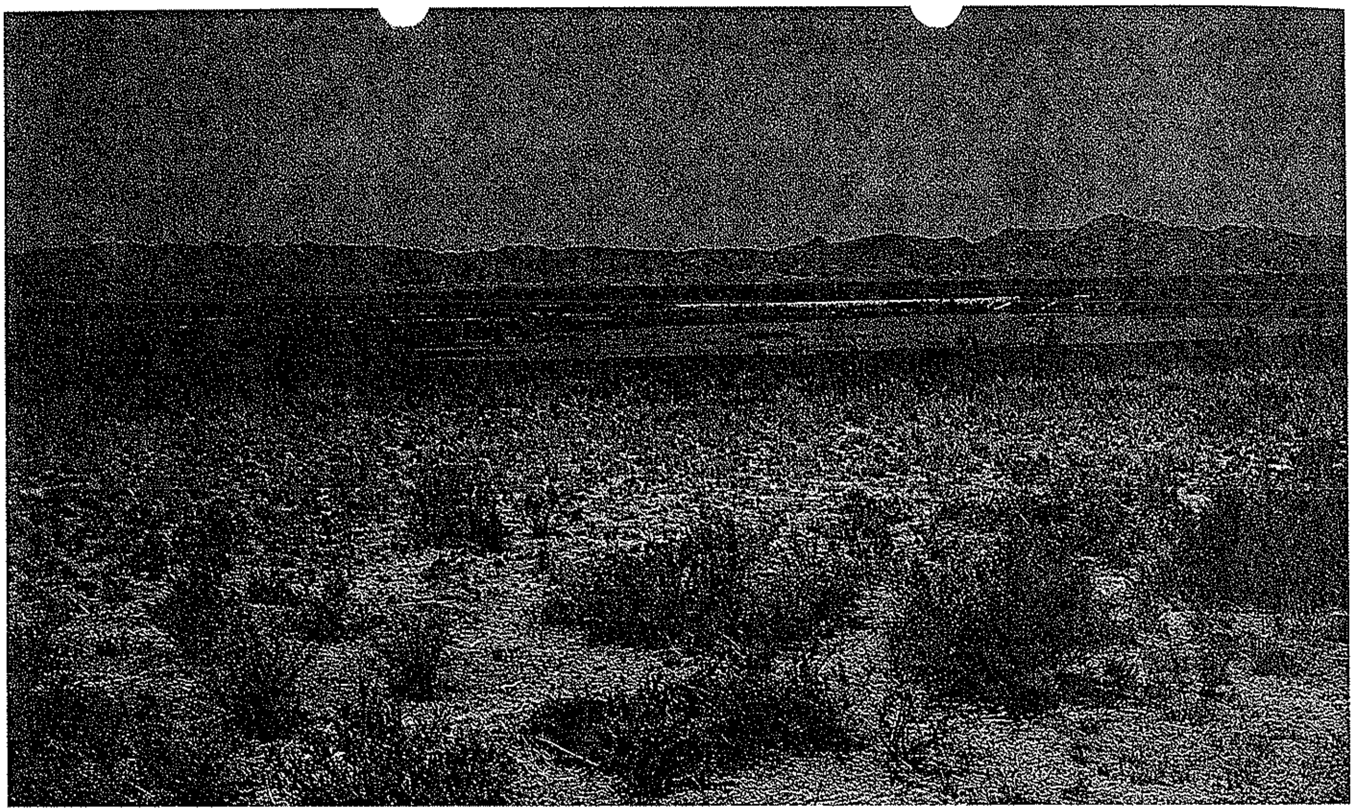


Figure 1. San Simon Ciénega, Arizona-New Mexico, after artificial protection by impoundment and deepening. Photograph 1981.

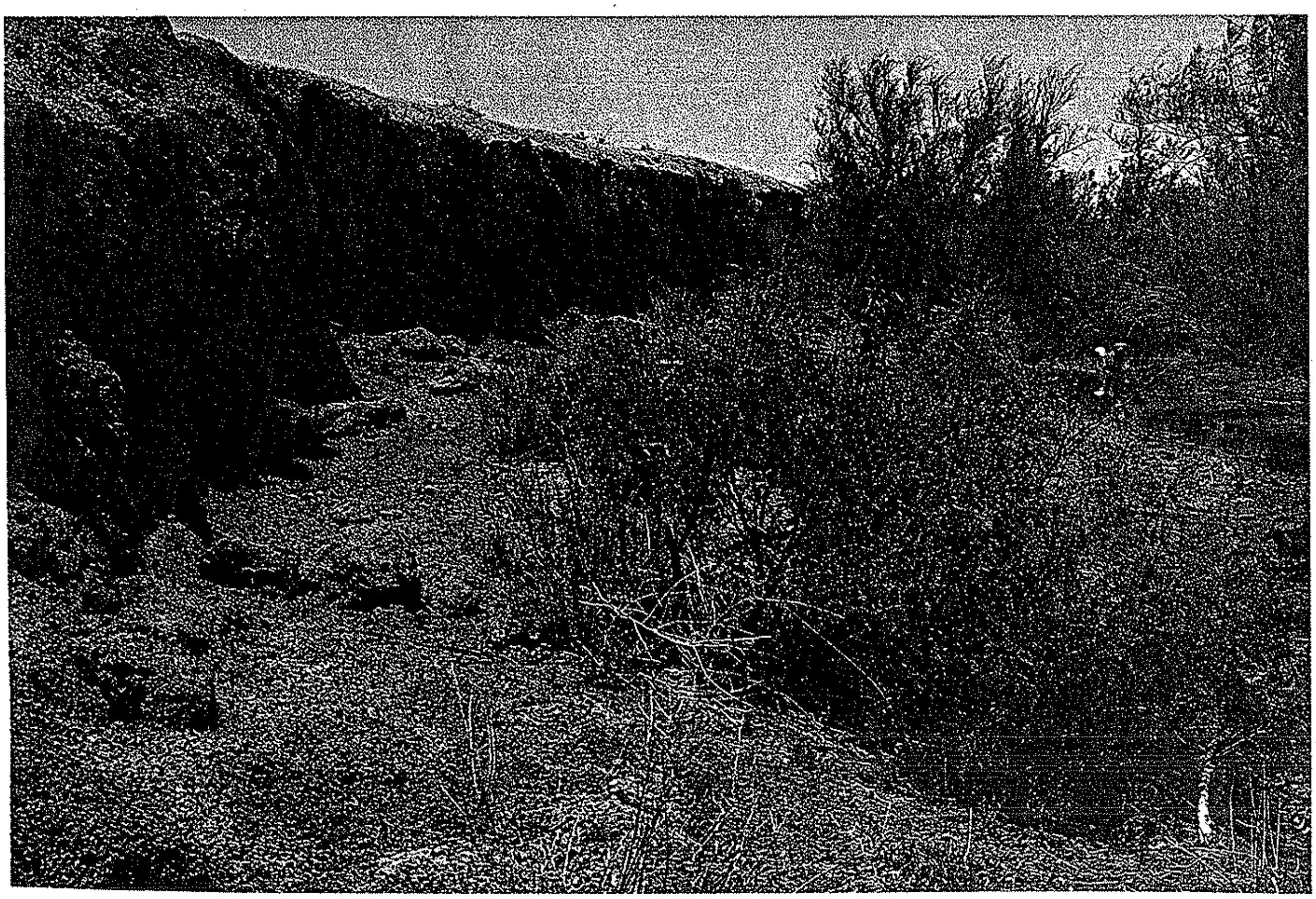


Figure 2. Arroyo walls downstream from San Simon Ciénega. Photograph 1981.

their perpetuation and management. We document cultural activities that influenced these habitats and review historical accounts of riparian conditions. We have attempted to evaluate historical statements critically by employing criteria of Forman and Russell (1983). Relationships of hydrology and succession theory to the ecology of ciénegas are discussed, and we end with a commentary on biological significance of ciénega habitats within the framework of Southwestern ecosystems.

This paper benefited from reviews and comments of a number of associates and colleagues, and we thank all of them. Included were David E. Brown, William B. Bull, James P. Collins, Stuart G. Fisher, Nancy B. Grimm, James E. Johnson, R. Roy Johnson, Dennis M. Kubly, Paul C. Marsh, Paul S. Martin, Gary K. Meffe, G. Scott Mills, Donald J. Pinkava, Frank W. Reichenbacher, John N. Rinne, George A. Ruffner, Raymond M. Turner, and Thomas R. Van Devender. Some do not fully agree with our interpretations, but all provided constructive criticisms. Any errors in fact or interpretation are solely our responsibility. Becky L. Payne and Nancy J. Meffe, Arizona State University, provided word-processing expertise in completing the manuscript. Support for this work and its publication was provided in part by the U.S. Fish and Wildlife Service, Endangered Species Office, Albuquerque, New Mexico, and by Arizona State University, Tempe, Arizona. Assistance in compilation of lists of plants comprising vegetation of ciénega habitats was provided by Gayle Marrs-Smith, Arizona State University, Laurence J. Toolin, University of Arizona, and personnel of the Arizona Natural Heritage Program, Tucson. Photographs other than those by us are acknowledged in figure captions.

Ciénega Definition

The term ciénega (or ciénaga) is applied to a diversity of aquatic habitats throughout areas of Hispanic influence. In South America the term is most commonly applied to floodplain lakes (Welcomme, 1979). These lakes often have vast expanses of open water, but are only a few meters deep and support substantial littoral emergent or floating vegetation. In North American areas with Hispanic histories, the term has been applied to a broad spectrum of marshy and swampy habitats at any elevation. In Arizona, we propose that three basic types of marshy wetlands are present.

Numerous "ciénegas" at >2,000 m elevation are marshy to bog-like Alpine and Cold Temperate meadowlands surrounded by Petran Montane (= Rocky Mountain) Conifer Forest (Patton and Judd, 1970; Judd, 1972; Brown *et al.*, 1980; Minckley and Brown, 1982). These wetlands may occur in depressions and thus be lentic, fed by seepage or precipitation, or they may be lotic habitats, bordering headwater streams. They are dominated by low, semiaquatic and terrestrial grasses (Gramineae, *e.g., Glyceria* spp.), cold-resistant rushes (Juncaceae) and sedges (Cyperaceae), and often support low woody shrubs such as Alder *(Alnus tenuifolia)*, Currant (*Ribes* spp.), and Willows *(Salix bebbiana, S. scouleriana)*. For much of the year these communities are frost-inhibited or lie beneath snow, and surface waters are subject to a succession of freezing and thawing in winter and drying in summer.

At elevations <1,000 m, subtropical marshes in oxbows, behind natural levees, and along margins of major streams comprise a different riverine community. Sharply delimited shoreward by desertlands and riverward by water depth and scouring, such marshes support stands of large reeds *(Phragmites australis* and *Arundo donax)*, Cattail *(Typha domingensis)*, Bulrush *(Scirpus californicus)*, and Three-square *(S. americanus, S. acutus)*, which thrive in fluctuating water levels and relatively well aerated hydrosoils. Goodding and Coyote Willows *(Salix gooddingii, S. exigua)*, Seep-willow *(Baccharis salicifolia)*, and Cottonwood *(Populus fremontii)* form galleries along drier alluvial terraces, and vast stands of Arrowweed *(Tessaria sericea)* and diverse Chenopodiaceae *(Atriplex lentiformis, etc.)* occupy saline areas adjacent to these swamps. All such habitats are transitory. They develop rapidly only to be removed by channel-straightening floods, or proceed toward a xeric community after drying (Grinnell, 1914; Ohmart *et al.*, 1975; Ohmart and Anderson, 1982).

At mid-elevations of 1,000 to 2,000 m in Semidesert Grassland, and more seldom in Madrean Evergreen Woodland, a third marshland community is associated with perennial springs and headwater streams. These Warm Temperate habitats were most often termed ciénegas by Hispanic and later explorers and settlers, and appear distinctive. We restrict use of the term in following text to this habitat type. Ciénegas are perpetuated by permanent, scarcely-fluctuating sources of water, yet are rarely subject to harsh winter conditions. They are near enough to headwaters that the probability of scouring from flood is minimal. The system is controlled by permanently saturated hydrosoils, within which reducing conditions preclude colonization by any but specialized organisms. Many meters of organic sediments have often been deposited. Most plant components restricted to such communities (Table 1) are monocotyledonous taxa such as low, shallow-rooted, semiaquatic sedges (Cyperaceae, such as *Eleocharis* spp.), rushes, some grasses, and only rarely cattails. Dicotyledonous taxa such as Watercress *(Rorippa nasturtium-aquaticum)* and Water-pennywort *(Hydrocotyle verticillata)* may be locally common. Dense stands of sedges and charophytes fill shallow, braided channels between pools, or deeper, narrow, vertical-walled channels may be heavily vegetated with *Rorippa nasturtium-aquaticum, Ludwigia natans*, and other macrophytes. Pools often have vertical walls of organic sediments and undercuts below root systems. Submerged macrophytes are commonly rooted in local, gravelly substrates.

Trees are scarce, limited to Goodding, Coyote, and Swamp Willow *(Salix lasiolepis)*, that can tolerate saturated soils. Immediate surroundings of ciénegas often are rendered saline through capillarity and evapotranspiration. Halophytes such as Salt Grass *(Distichlis spicata)*, Yerba-mansa *(Anemopsis californica)* and numerous species of Chenopodiaceae and Compositae thus live along salt-rich borders of these riparian marshlands. Extensive stands of Sacatón *(Sporobolis airoides)* also are common on adjacent flatlands. Upslope, and where soil aeration and salinities allow, broadleaved deciduous woodlands often develop (Minckley and Brown, 1982). Typical riparian species of the region (Seep-willow, Fremont Cottonwood, Arizona Sycamore [*Platanus wrightii*], Arizona Ash [*Fraxinus pennsylvanicus* var. *velutina*], Walnut [*Juglans major*], *etc.*) border such saturated areas, replaced in more xeric places by Mesquite *(Prosopis velutina, P. glandulosa)*.

Ciénegas act as traps for organic materials and nutrients in the aquatic ecosystem, and also must be remarkably productive. Indeed, freshwater macrophyte communities are among the most productive in the world (Westlake, 1963, 1965). The availability of water and resultant luxuriance of forage in this semi-arid region results in concentration of herbivore populations, a factor to be discussed later that may have contributed to the demise of these habitats. Vast quantities of materials are transported *via* herbivores to surrounding terrestrial habitats.

Description of the Study Region

The study region lies within the Basin and Range Geomorphic Province (King, 1977). Roughly parallel, north-south trending ranges formed by block faulting are separated by broad valleys filled with Tertiary and Quaternary sediments eroded from adjacent mountain slopes (Nations *et al.*, 1982). Faults along mountain fronts provide egress for springs, and deep valley alluvium serves as an aquifer for groundwater storage, contributing two important prerequisites for ciénega formation and maintenance.

Relevant aspects of the study area are most easily discussed by drainage sub-basins. Structural troughs from east to west are the San Simon, Sulphur Springs, San Pedro, and Santa Cruz (including Avra-Altar) valleys. With exception of the second, all drain north to the Gila River *via* rivers of the same names. The northern Sulphur Springs Valley is drained to the Río San Pedro by Aravaipa Creek through a channel that likely predates Basin and Range orogeny (Melton, 1960; Simons, 1964). Its central portion is endorheic (Pluvial Lake Cochise or Willcox Playa) while the southern regions drain south to the Río Yaqui *via* Whitewater Draw. Both divides within this basin are low. Adding the mainstream Gila River gives a total of seven hydrographic regions (Fig. 3).

Climate is characterized by a bimodal summer and winter rainfall pattern, alternating with spring and autumn drought (Sellers and Hill, 1974). Rainfall during the hottest months of July–September grades from <50% of the annual total in the northwestern corner to >70% in south and southeastern parts of the study area. A second peak in precipitation occurs in December–January. Annual precipitation varies from 13 to 48 cm, increasing along the same axis as relative importance of summer rains (Hastings and Turner, 1965).

Temperatures also show considerable variation, not necessarily correlated with elevation (Turnage and Hinckley, 1938). Cold air drainage from adjacent mountains often makes valleys colder than higher areas. Record lows at stations near ciénegas range to about −10°C, and record highs to >40°C (Sellers and Hill, 1974). Most stations have mean values of less than half a day per year during which temperature does not rise above freezing (Hastings and Turner, 1965; see however, Bowers, 1981, and Glinski and Brown, 1982).

Terrestrial vegetation was mapped and described for this region by Brown and Lowe (1980). Upland vegetation of most of the San Pedro, San Bernardino, and San Simon valleys is characterized by zones of Chihuahuan Desertscrub interdigitating with Semidesert Grasslands. In certain valleys, such as the broad upper Santa Cruz and upper Sonoita Creek, a Plains Grassland Formation lies between Semidesert Grassland and Madrean Evergreen Woodland. In most of Arizona the transition is more direct, with no development of Plains Grassland. Density of Evergreen Woodlands increases with elevation, eventually giving way to insular Petran Montane (= Rocky Mountain) Conifer Forests on high peaks. At highest extremes of the Chiricahua and Pinaleño mountains, relict stands of Subalpine Conifer Forests persist. Brown *et al.* (1980) provided photographs of these communities, and Hastings and Turner (1965) presented matched photographs of the region's Desert, Desert Grassland, and Oak Woodland, which illustrate vegetation changes between the late 19th Century and the 1960s. Lowe (1967), Gehlbach (1981), Crosswhite and Crosswhite (1982), and Brown (1982) also published plates and provided descriptions of vegetation and dominant species of these communities.

Cultural History

Four major cultural forces have influenced the Sonoran Desert Region. Least is known of early aboriginal populations who left no written records, but knowledge of subsequent cultural influences increases through time. Written documentation dates from 16th Century explorations, through nearly three centuries of Spanish occupation into early 19th Century colonization by Mexicans, and shortly thereafter the Angloamerican invasion.

Prehistoric cultures had long inhabited parts of the region when Spaniards arrived and began describing their lifestyles. Only inferences based on archaelogical data may be made about their relationships with the environment, but some populations modified or manipulated aspects of their surroundings. The Hohokam of central Arizona valleys constructed extensive canal systems for crop irrigation, which, in modified form, are still in use today (Masse, 1981). They also engineered large, complex irrigation systems in the vicinity of Casa Grande on the Gila River (Haury, 1976). These peoples mysteriously disappeared and were unknown to tribes inhabiting the region when the Spanish arrived.

By about 1600, Spanish contacts with Indians were sufficient to allow recognition of at least eight major cultures in the Sonoran Desert Region (Sauer, 1934). Spicer (1962) grouped these into economic categories, which provide a basis for discussion of their impact on the environment. Of special interest are some of his "band peoples" and "*rancheria* peoples."

The Apache, apparently unknown in Arizona prior to the 17th Century (Walker and Bufkins, 1979), were band people who came from what is now Texas. They originally inhabited montane areas north of the Gila River, but also used the Chiricahua Mountains and other southern

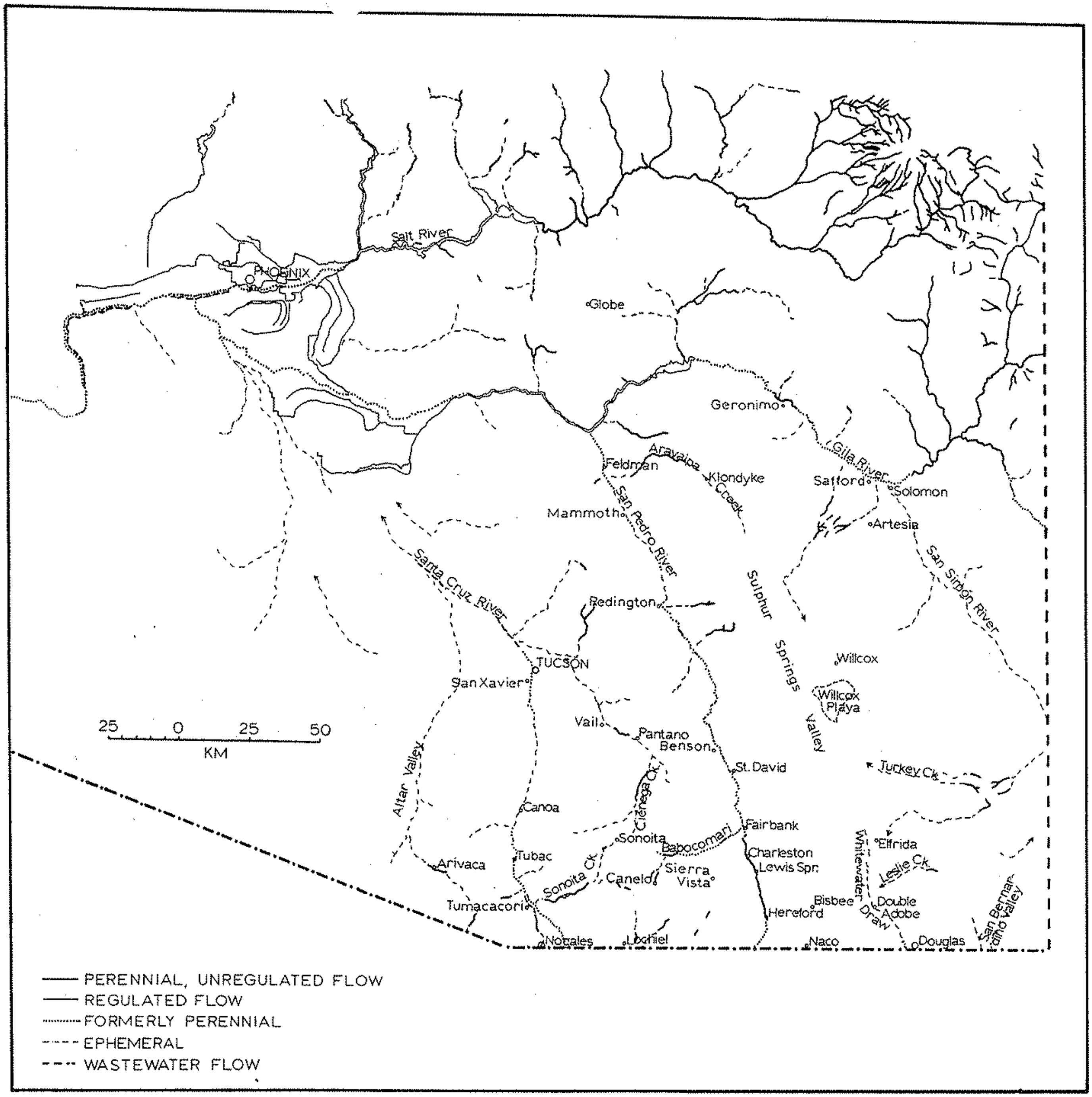


Figure 3. Sketch map of southeastern Arizona, with some place names mentioned in the text. Historical and present status of surface streamflows are indicated as adapted from Brown, Carmony, and Turner (1981).

ranges. Mostly hunters and gatherers, these groups practiced little agriculture.

Older residents were the Pimas Altos of the Santa Cruz and San Pedro valleys. These rancheria peoples lived in semi-permanent settlements wherever perennial surface water was available. They subsisted primarily by floodplain and irrigated farming (Bryan, 1929, 1941), supplemented with wild food gathering. Adjacent rancheria peoples were the Opatas who lived on northern Río Yaqui tributaries in the area of Rancho San Bernardino and the upper Río Sonora drainage in México, and the Pimas Bajos who occupied lower reaches of these same drainages. Papagos inhabited more arid deserts west of the Pimas Altos, and they were bordered on the west by Yumans of the lower Gila and Colorado rivers (Sauer 1934; Crosswhite, 1981). Size of these Indian populations 4 to 8 centuries ago was larger than the total European and Indian population of 1880 (Hastings and Turner, 1965).

Spanish colonization brought new impacts on the environment. However, descriptions of their missionary settlements are rare and provide few data for comparison with recent landscapes. A major impact of Spanish conquest on aboriginal populations predated that culture's arrival in the study region. Smallpox, introduced in 1520

Table 1. Preliminary list of macrophytic plant taxa recorded from ciénega habitats and environs in southeastern Arizona. Compiled from various literature sources and herbarium records (see Acknowledgments). Taxonomy for vascular plants follows Lehr (1978) and Lehr and Pinkava (1980, 1982). Additional detailed plant lists for some specific ciénegas are available from Arizona Natural Heritage Program, Tucson.

	Distribution		
Taxa	**Aquatic**	**Semiaquatic**	**Riparian**
Characeae, Stonewort Family (non-vascular, but important floral components)			
Chara sp.	X	–	–
C. braunii Gm.	X	–	–
Nitella clavata Bertero	X	–	–
Equisetaceae, Horsetail Family			
Equisetum laevigatum A. Br.	–	X	X
E. x. ferrisii Clute	X	X	X
Salviniaceae, Water Fern Family			
Azolla filiculoides Lam.	X	–	–
Marsileaceae, Pepperwort Family			
Marsilea vestita Hook. & Gray.	X	–	–
Polypodiaceae, Maiden-Hair Fern Family			
Adiantum capillus-veneris L.	–	–	X
Typhaceae, Cattail Family			
Typha domingensis Pers.	X	–	–
Potamogetonaceae, Pondweed Family			
Potamogeton foliosus Raf., var. *marcellus* Fern.	X	–	–
P. nodosus Poir.	X	–	–
P. pectinatus L.	X	–	–
Ruppiaceae, Widgeon Grass Family			
Ruppia maritima L.	X	–	–
Zannichelliaceae, Horned Pondweed Family			
Zannichellia palustris L.	X	–	–
Najadaceae, Naiad Family			
Najas guadalupensis Morong.	X	–	–
N. marina L.	X	–	–
Alismataceae, Water Plantain Family			
Alisma triviale Pursh	X	–	–
Sagittaria longiloba Engelm.	X	–	–
Graminae, Grass Family			
Agrostis exarata Trin.	–	X	X
A semiverticillata (Forsk) C. Chr.	–	X	X
A. stolonifera L., var. *palustris* Huds. (Farw.)	–	X	X
Arundo donax L.	–	X	–
Bouteloua gracilis (H. B. K.) Lag.	–	–	X
Bromus marginatus Nees.	–	X	X
Chloris virgata Swartz	–	–	X
Cynodon dactylon (L.) Pers.	–	X	X
Distichlis spicata (L.) Greene, var. *stricta* (Torr.) Beetle	–	–	X
Echinochloa colonum (L.) Link.	–	X	X
E. crusgalli (L.)Beauv.	–	–	X
Eragrostis cilianensis (All.) Mosher.	–	X	X
E. lutescens Scribn.	–	X	X
E. megastachya (Koel.) Link.	–	–	X
Eriochloa lemmoni Vasey & Scribn., var. *gracilis* (Fourn.) Hitchc.	–	X	X
Heteropogon contortus (L.) Beauv.	–	X	X
Muhlenbergia asperifolia (Nees & Mey) Parodi	–	X	X
Panicum obtusum H. B. K.	–	X	X
Paspalum dilatatum Poir	–	X	X
P. distichum L.	–	X	X
P. paspaloides (Michx.) Scribn.	–	X	X
Phalaris caroliniana Walt.	–	X	X
Phragmites australis (Cav.) Trin.	–	X	X
Polypogon, cf. *interruptus* H. B. K.	–	–	X
P. monspeliensis (L.) Desf.	–	X	X
Sitanion hystrix (Nutt.) J. G. Smith	–	–	X
Sorghum halapense (L.) Pers.	–	–	X
Sporobolus airoides Torr.	–	–	X
S. wrightii Munro ex Scribn.	–	–	X
Cyperaceae, Sedge Family			
Carex agrostoides Mack.	–	–	X
C. alma Bailey	–	–	X
C. bolanderi Olney	–	X	–
C. lanuginosa Michx.	–	X	–
C. praegracilis W. Boott.	–	X	X
C. senta Boott.	–	–	X
C. subfusca W. Boott.	–	–	X
C. thurberi Dewey	–	–	X
Cladium californicum (Wats.) O'Neill	–	X	X
Cyperus acuminatus Torr. & Hook	–	–	X
C. aristatus Rottb.	–	X	–
C. esculentus L.	–	–	X
C. fendlerianus Boeckl	–	–	X
C. niger R. & P.	–	X	–
C. odoratus L.	–	–	X
C. parishii Britt.	–	–	X
C. pringlei Britt.	–	–	X
C. rusbyi Britt.	–	–	X
Eleocharis acicularis (L.) R. & S.	–	X	–
E. caribaea (Rottb.) Blake	X	X	–
E. macrostachya Britt.	X	X	X
E. montevidensis Kunth.	–	X	X
E. parishii Britt.	–	X	X
Scirpus acutus Muhl.	X	X	–
S. americanus Pers.	X	X	–
S. pungens Vahl.	X	X	–
Lemnaceae, Duckweed Family			
Lemna gibba L.	X	–	–
L. minor L.	X	–	–
L. minima Phil.	X	X	–
L. valdiviana Phil.	X	–	–
L. trisulca L.	X	–	–
Pontederiaceae, Pickerel Weed Family			
Heteranthera limosa (Swartz) Willd.	X	X	–
Juncaceae, Rush Family			
Juncus balticus Willd., var. *montanus* Engelm.	–	–	X
J. ensifolius Wikstr., var. *brunnescens* (Rydb.) Crona	X	X	X
J. mexicanus Willd.	–	X	X
J. tenuis Willd.	–	X	X
J. torreyi Coville	–	X	X
Iridaceae, Iris Family			
Sisyrinchium demissum Greene	–	X	–
Orchidaceae, Orchid Family			
Spiranthes graminea Lindl.	–	X	X
Saururaceae, Lizard-Tail Family			
Anemopsis californica (Nutt.) H. & H., var. *subglabra* Kelso	–	X	X
Salicaceae, Willow Family			
Populus fremontii Wats.	–	X	X
Salix exigua Nutt.	–	X	X
S. gooddingii Ball	–	–	X
S. laevigata Bebb	–	–	X
S. lasiolepis Benth.	–	X	X
S. taxifolia H. B. K.	–	–	X
Juglandaceae, Walnut Family			
Juglans major (Torr.) Heller	–	–	X
Polygonaceae, Buckwheat Family			
Polygonum aviculare L.	–	–	X
P. coccineum Muhl.	–	X	X
P. pensylvanicum L.	–	X	X
P. persicaria L.	X	X	X
Rumex conglomeratus Murr.	–	–	X
R. crispus L.	–	X	X
R. violascens Rech. F.	–	–	X
Nyctaginaceae, Four-O'clock Family			
Mirabilis longiflora L.	–	–	X

Table 1. *(Continued)*

Taxa	Distribution		
	Aquatic	Semiaquatic	Riparian
Aizoaceae, Carpetweed Family			
Mollugo verticillata L.	–	–	X
Ranunculaceae, Crowfoot Family			
Ranunculus macranthus Scheele	–	X	X
Thalictrum fendleri Engelm.	–	–	X
Papaveraceae, Poppy Family			
Argemone pleiacantha Greene	–	–	X
Cruciferae, Mustard Family			
Rorippa nasturtium-aquaticum (L.) Shinz & Thell.	X	X	–
Saxifragaceae Saxifrage Family			
Ribes aureum Pursh.	–	–	X
Platanaceae, Plane Tree Family			
Platanus wrightii Wats.	–	–	X
Leguminosae, Pea and Bean Family			
Amorpha fruticosa L., var. *occidentalis* (Abrams) K. & P.	–	–	X
Cologania angustifolia H. B. K.	–	–	X
Medicago lupulina L.	–	–	X
Melilotus albus Desr.	–	–	X
Trifolium arizonicum Greene	–	–	X
Trifolium repens L.	–	–	X
Oxalidaceae, Wood-Sorrel Family			
Oxalis stricta L.	–	–	X
Callitrichaceae, Water-Starwort Family			
Callitriche heterophylla Pursh	X	–	–
Anacardiaceae, Sumac Family			
Rhus radicans L., var. *rydbergi* (Small) Rehder	–	–	X
R. trilobata Nutt.	–	–	X
Rhamnaceae, Buck-Thorn Family			
Sageretia wrightii Wats.	–	–	X
Vitaceae, Grape Family			
Vitis arizonica Engelm.	–	–	X
Malvaceae, Mallow Family			
Anoda cristata (L.) Schlect.	–	–	X
Sidalcea neomexicana Gray	–	X	X
Tamaricaceae, Tamarix Family			
Tamarix chinensis Loureiro	–	–	X
Elatinaceae, Water-Wort Family			
Elatine brachysperma Gray	–	X	–
Violaceae, Violet Family			
Viola nephrophylla Greene	X	X	–
Lythraceae, Loosestrife Family			
Ammannia auriculata Willd., var. *arenaria* (H.B.K.) Koehne	–	X	X
A. robusta Heer & Regel	–	X	X
Lythrum californicum T. & G.	–	X	–
Rotala ramosior (L.) Koehne	–	X	X
Onagraceae, Evening-Primrose Family			
Epilobium californicum Hausskn.	X	X	X
Gaura parviflora Dougl.	–	–	X
Ludwigia palustris (L.) Ell.	X	X	–
Ludwigia repens Forst	X	X	–
Oenothera rosea Ait.	–	X	X
Umbelliferae, Parsley Family			
Berula erecta (Huds.) Corille	X	X	X
Eryngium heterophyllum Engelm.	–	–	X
Hydrocotyle verticillata Thunb.	X	X	–
Lilaeopsis recurva A. W. Hill	X	X	–
Primulaceae, Primrose Family			
Centunculus minimus L.	–	X	X
Samolus parviflorus Raf.	–	–	X
S. vagans Greene	–	–	X
Plumbaginaceae, Plumbago Family			
Limonium limbatum Small	–	X	X
Oleaceae, Olive Family			
Fraxinus pennsylvanica Marsh, ssp. *velutina* (Torr.) G. N. Miller	–	–	X

Table 1. *(Continued)*

Taxa	Distribution		
	Aquatic	Semiaquatic	Riparian
Gentianaceae, Gentian Family			
Centaurium calycosum (Buckl.) Fern.	–	X	–
Eustoma exaltatum (L.) Griseb.	–	X	X
Apocynaceae, Dogbane Family			
Apocynum suksdorfii Greene	–	–	X
Asclepiadaceae, Milkweed Family			
Asclepias subverticillata (Gray) Vail	–	–	X
A. tuberosa L., ssp. *interior* Woods.	–	X	X
Cynanchum sinaloense Woods.	–	–	X
Labiatae, Mint Family			
Marrubium vulgare L.	–	–	X
Mentha arvensis L., var. *villosa* (Benth.) S. R. Stewart	–	X	X
M. spicata L.	–	X	–
Solanaceae, Nightshade Family			
Physalis hederaefolia Gray, var. *cordifolia* (Gray) Waterfall	–	–	X
Solanum americanum Mill	–	–	X
S. rostratum Dunal.	–	–	X
Scrophulariaceae, Figwort Family			
Bacopa rotundiflora (Michx.) Wettst.	X	–	–
Limosella aquatica L.	–	X	–
Lindernia anagallidea (Michx.) Penn.	–	X	–
Mimulus guttatus DC.	–	X	X
Bignoniaceae, Bignonia Family			
Chilopsis linearis (Cav.) Sweet	–	–	X
Lentibulariaceae, Bladderwort Family			
Utricularia vulgaris L.	X	–	–
Acanthaceae, Acanthus Family			
Anisacanthus thurberi (Torr.) Gray	–	X	X
Plantaginaceae, Plantain Family			
Plantago lanceolata L.	–	X	X
Caprifoliaceae, Honeysuckle Family			
Lonicera, cf. *arizonica* Rehd.	–	–	X
Campanulaceae, Bellflower Family			
Lobelia cardinalis L., ssp. *graminea* (Lam.) McVaugh	–	–	X
Compositae, Sunflower Family			
Ambrosia aptera DC.	–	X	X
A. confertiflora DC.	–	–	X
A. psilostachya DC.	–	X	X
Artemisia dracunculus L.	–	–	X
Aster exilis Ell.	–	–	X
A. pauciflorus Nutt.	–	X	–
A. subulatus Michx.	–	X	–
Baccharis salicifolia (R. & P.) Pers.	–	X	X
Bidens ferulaefolia (Jacq.) DC.	–	X	X
B. laevis (L.) B. S. P.	–	X	X
Centaurea rothrockii Greenm.	–	X	X
Chrysothamnus nauseosus (Pall.) Britt.	–	X	X
Conyza canadensis (L.) Cronq.	–	X	X
C. coulteri Gray	–	X	X
Cosmos parviflorus (Jacq.) Pers.	–	–	X
Erigeron canadensis L.	–	–	X
Gnaphalium chilense Spreng.	–	X	X
G. purpureum L.	–	X	–
Helianthus annuus L.	–	X	X
Heterotheca psammophila Wagenkn.	–	X	X
Pyrrhopappus multicaulis DC	–	X	X
Senecio douglasi DC., var. *longilobus* (Benth.) L. Benson	–	X	X
Sonchus asper (L.) Hill	–	X	X
Taraxacum officinale Weber	–	X	X
Xanthium strumarium L.	–	X	X
Zinnia peruviana (L.) L.	–	X	X

at Vera Cruz, México, spread through the region by 1524 with devastating Indian mortality (Crosby, 1976). This disease was followed shortly by measles (1531) and another unknown pathogen (1535) also introduced by the Spanish. These epidemics reduced aboriginal populations at the time of the first Spanish settlements to less than three-fourths of the 1519 level (Dobyns, 1981).

The 1531 epidemic was introduced to Texas by a member of a shipwrecked party led by Alvar Nuñez Cabeza de Vaca, who in 1534 escaped from Indian servitude and proceeded west, perhaps crossing the southeast corner of Arizona enroute to Culiacán. His stories of the rich "Cities of Cíbola" to the Viceroy of New Spain stimulated future expeditions through Arizona in search of wealth. Fray Marcos de Niza led the first party down the Río San Pedro and northeast into New Mexico in 1539. Francisco Vasquez de Coronado followed the same valley in 1540. Spanish explorations were few and little reported until Jesuit missionary activity began with *entradas* to Pimeria Alta by Padre Francisco Eusebio Kino from 1695 until his death in 1711. Working from missions established as much as 50 years earlier in the ríos Yaqui, Sonora, and Magdalena basins, Kino and other missionaries had profound influence on Indian cultures and their environments. As early as 1687, Pima Indians at Remedios, Sonora, were complaining that the Spanish pastured so many cattle that watering places were drying. This, and other Spanish impacts, precipitated the Pima uprising of 1751 in Arizona and Sonora (Ewing, 1941, 1945). Kino's accounts allow population estimates, evaluation of the extent of surface water, and assessment of possible impacts of Piman agricultural, food gathering, and livestock herding activities, but he was notably disinterested in natural history (Bolton, 1916, *et seq.*; Kino, 1919). Although accounts of Jesuit activities are available, it is the rare exception that provides details on the region's natural landscape.

Spanish missionary activity decreased after Kino's death. Spanish political problems in Europe coupled with Indian dissatisfaction and increasing Apache depredations ushered in an era of Spanish military control with establishment of *presidios*. By the mid-1760s a peaceful situation had been attained, but expulsion of the Jesuits by King Charles III in 1767 and their replacement by Franciscans produced deterioration of Indian-Hispanic relationships. Apache raids continued, but there were hints of general paranoia among the Spanish population and exaggeration of Apache impacts (Hastings and Turner, 1965). It is clear, however, that Spanish livestock-raising activities were maintained at high levels throughout much of the 18th Century (Bolton, 1948; Pfeffercorn, 1949; Wagoner, 1952).

By the early 19th Century, Spanish activities in Neuva España were decreased by diversion to more pressing problems in Europe. Decreased attention to her colonies eventually led to revolt, which gained México independence from Spain in 1821. Domestic problems almost immediately began in northern parts of the new country, with disagreements over state boundaries and revolt of the previously peaceful Opatas and Yaquis in Sonora. This unrest pushed the Sonoran cattle industry north into what is now southern Arizona, where Apaches were still peaceful (Bancroft, 1962). Large land grants along major drainages were made to private individuals. Expansion of the cattle industry was, however, cut short by renewed Apache depredations in 1831 (Mattison, 1946), which caused virtual abandonment by Mexican ranchers and miners. Accounts of the first large Angloamerican expeditions in 1846 and 1851 are replete with references to deteriorating haciendas and encounters with immense herds of abandoned cattle (Bartlett, 1854; Cooke, 1878, 1938; Bieber, 1937; Goetzmann, 1959). Thus ended the brief period of Mexican government in the region. The 1848 boundary treaty allotted lands north of the Gila River to the United States; the border was extended south to its present position by the Gadsden purchase of 1854.

The 1846 march of the Mormon Battalion was well chronicled by many of its participants. They provided descriptions of the land as did reports of Bartlett's surveying party and journals of numerous "49ers" enroute to gold fields in California. These were not, however, the first Angloamericans. Beaver trappers illicitly exploited the Gila River in the 1820s (Weber, 1971), and Pattie (1833) left a written chronicle of his adventures.

Basic documentation of natural conditions and cultural development is good from 1846 to present. The major impact of Angloamerican invasion was growth of the cattle industry. Suppressed first by Apaches and later the Civil War and economic depression, its expansion did not really begin until establishment of railway transportation in the 1880s (Wagoner, 1952). Herds built rapidly until overgrazing coupled with two years of drought brought disaster in 1893 with livestock mortalities reaching 50–75% (Wagoner, 1960).

Near the onset of severe overgrazing, the well-documented cycle of arroyo cutting began destroying ciénegas (Bryan, 1925b, 1926, 1928, 1940; Schumm and Hadley, 1957; Hastings, 1959; Hastings and Turner, 1965; Cooke and Reeves, 1976; Dobyns, 1981). Other forms of economic development, principally mining and irrigated agriculture, also were increasing by this time, and our general account of the region's history may end. More recent information is better detailed and our discussion becomes more specific.

Ciénegas of Individual Basins

San Simon Valley. This drainage (Fig. 4) is separated by an inconspicuous divide (1,400 m elevation) from the south-flowing Arroyo San Bernardino of the same structural trough. The valley is broad and shallow, ranging in width from 16 km in the south to 40 km at its mouth (elevation 914 m) (Schwennesen, 1917). The Peloncillo Mountains bounding the valley on the east average about 1,500 m high, with peaks to 1,800 m. The Chiricahua, Doz Cabezas, and Pinaleño mountains on the west are higher, with several peaks reaching to >2,400 m and Mt. Graham, the most northerly, exceeding 3,000 m.

Quaternary stratigraphy was described by Schwennesen (1917) as stream-gravel deposits overlain by clay-sand lake beds, which are in turn covered by younger stream gravels. The older stream deposits outcrop in only a few places. Younger stream deposits that surface two-thirds of the valley are thin near the Gila River, but thicken south-

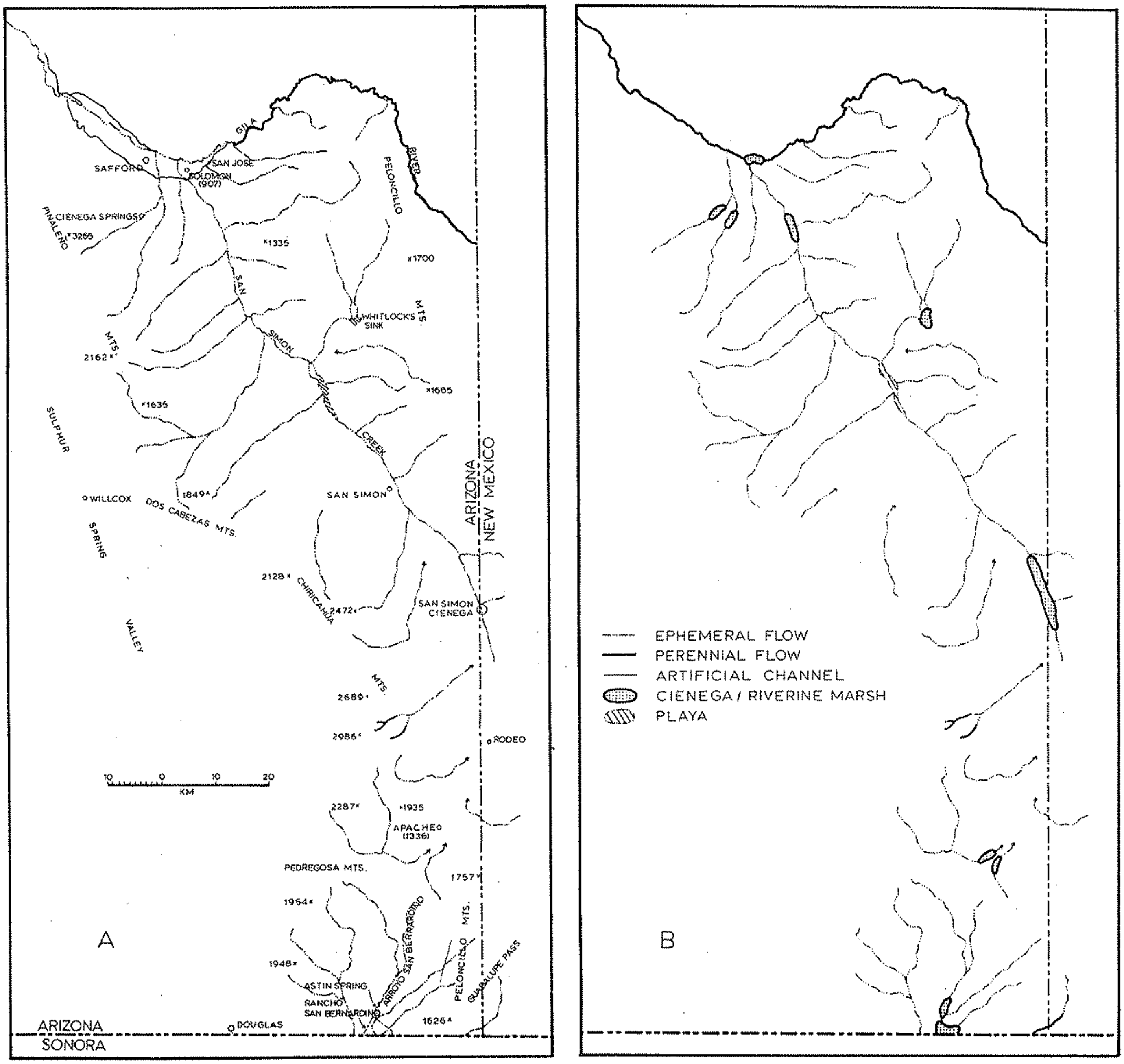


Figure 4. Sketch map of the San Simon Valley, Arizona: with place names mentioned in the text and present-day aquatic and semiaquatic habitats (excluding stock tanks) (A); and, map of San Simon Valley, with aquatic and semiaquatic habitats before 1890 as inferred from historic records (B). Elevations are in meters.

ward to 90–120 m. Lacustrine deposits >300 m thick are widely exposed in the lower valley, but are covered elsewhere by the younger stream gravels. Small, scattered lava beds are insignificant features near the San Bernardino divide. Schwennesen (1917) thoroughly surveyed wells in the valley and concluded that all groundwater resulted from infiltration of direct precipitation. Stream-gravel deposits are the water-bearing strata, the deeper one being artesian.

The San Simon Valley was inhabited by indigenous peoples who had disappeared by the time of Spanish explorations (Antevs, 1962). The valley was well known to Spaniards who christened it Río de Sauz (River of Willows), or, as Capitán Zuñiga referred to it in 1795, La Ciénega Salada (Hammond, 1931). Accounts of luxuriant vegetation prior to 1885 abound in the literature (Hinton, 1878; Barnes, 1936; Peterson, 1950). San Simon Ciénega, which lies across the present Arizona-New Mexico Border (Figs. 1, 2, 4), was a famous, well-described watering stop for pioneers, military, and surveying expeditions (Parke,

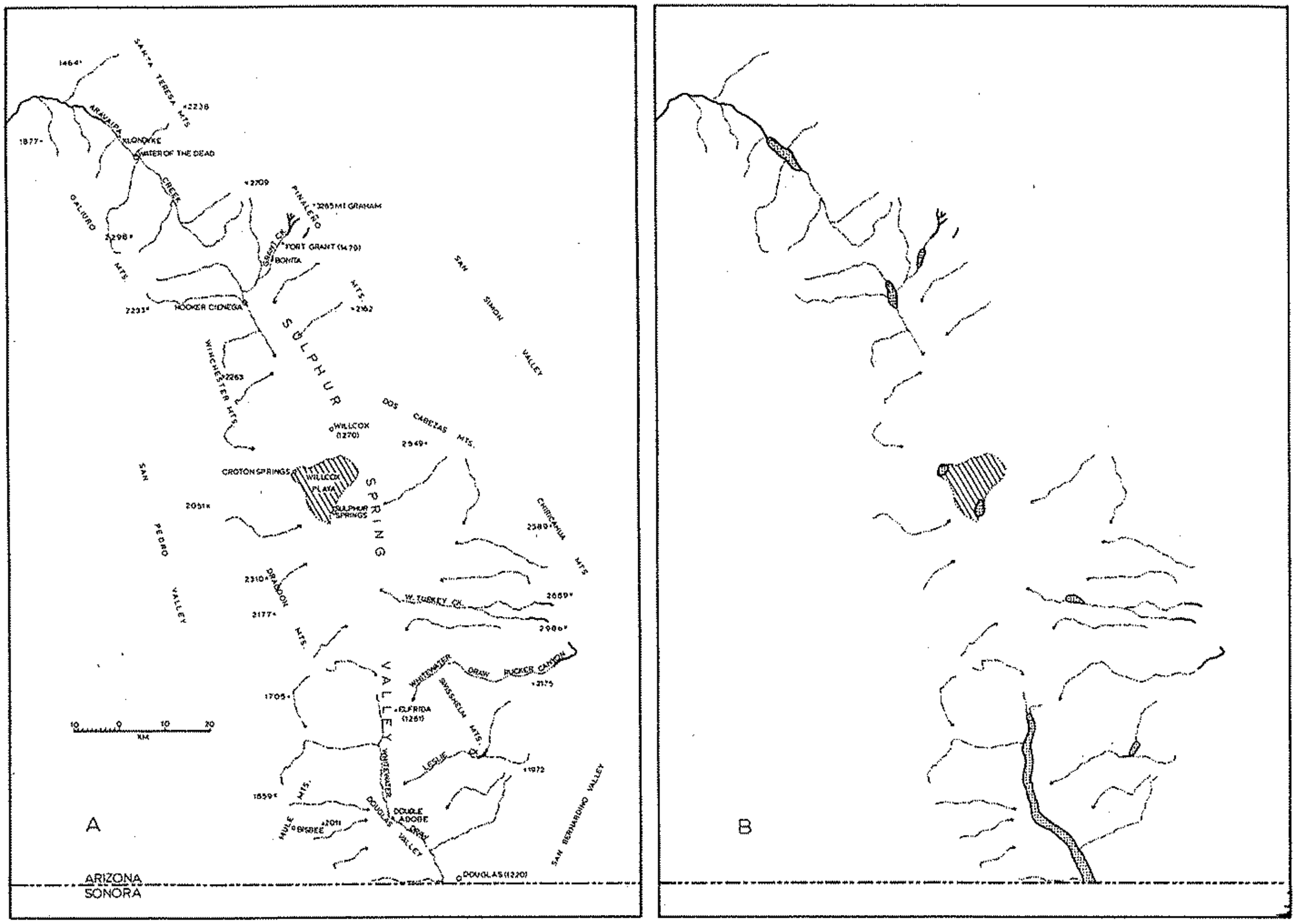


Figure 5. Sketch map of the Sulphur Spring Valley, Arizona: with some place names mentioned in the text and present-day aquatic and semiaquatic habitats (excluding stock tanks) (A); and, map of Sulphur Spring Valley, with aquatic and semiaquatic habitats before 1890 as inferred from historic records (B). Elevations are in meters. Symbols are as in Figure 4.

1857; Bell, 1869; Box, 1869; Eccleston, 1950; Peterson, 1950; Gray, 1963). The general picture was one of a grassland, with widely scattered Mesquite. The stream flowed through braided channels between low or virtually non-existent, marshy banks (Parke, 1857). Martin's (1963a) pollen data indicated that such ciénega conditions date well into prehistoric times.

The San Simon Valley changed rapidly after about 1885. Disappearance of grasses and beginning of severe erosion corresponded with heavy grazing pressure exerted by large cattle herds. Peterson (1950) proclaimed: "Today's picture of the valley... is one of devastation," and Olmstead (1919) and Barnes (1936) emotionally decried environmental destruction that had taken place.

Historical and scientific literature on arroyo cutting in this valley was reviewed by Cooke and Reeves (1976). Initiation of incision was often at points of streambed modification. A channelization project near Solomonville resulted in drastic incision during July floods of 1890. It also is clear that the present arroyo closely follows a former wagon road, which was implicated as the initiator of gullying. Cattle trails and the Gila, Globe, and Northern Railway embankments also were implicated. The result is an eroded valley with greatly improverished vegetation (see figures and descriptions in Jordan and Maynard, 1970).

San Simon Ciénega (Fig. 1), although now artificially maintained, represents the only extant ciénega in the drainage. Schwennesen (1917) reported it to cover 486 ha. In 1952 its discharge was 9.9×10^6 m^3/yr (DeCook, 1952). In 1953 a concrete retention dam was erected by the U.S. Bureau of Land Management (BLM) to prevent further incision. Immediately below the dam, remnant organic deposits remain in 3–4 m, vertical arroyo walls. Groundwater, which once intersected the surface to form the ciénega (Schwennesen, 1917), has been depressed. BLM now artificially maintains surface water by pumping, and water level is allowed to fluctuate. Expanses of open water are large and deep, creating a lentic, reservoir-like system.

Other areas in the basin formerly referred to as ciénegas are Whitlock's in Whitlock Sink (Granger, 1960), Munson's near San Jose (Hodge, 1877; Granger, 1960), Ciénega

Springs east of Cactus Flat in the lower valley (Knechtel, 1938), and unnamed ciénegas in the upper valley near the divide to the San Bernardino drainage (Riecker, 1879; Schwennesen, 1917).

Sulphur Springs Valley. This valley consists of an endorheic basin (Willcox Playa) bounded by two through-flowing drainage systems (Fig. 5). Aravaipa Creek drains the northern valley to the Río San Pedro *via* a deep canyon crossing between the Galiuro and Santa Teresa mountains, while the southern valley drains through Whitewater Draw to México. Each drainage is considered singly, although land use that affected aquatic systems was not confined by hydrographic divides.

Willcox Playa Basin.—All runoff in this middle drainage terminates in the Willcox Playa just south of the town of Willcox (Fig. 5). This barren, nearly level alkali flat covers about 130 km² and retains surface water following rainy seasons (Meinzer and Kelton, 1913). The present Willcox Playa is but a small remnant of Pleistocene Lake Cochise, which, as evidenced by remnant beach ridges, formerly covered 307 km² to depths >14 m (Meinzer and Kelton, 1913; Schreiber *et al.*, 1972).

Groundwater pumpage in the basin has increased from 2.5×10^6 m³ year^{-1} or less during the first four decades of this century, to an average of about 3.7×10^8 m³ year^{-1} for 1967 to 1975 (Mann *et al.*, 1978). Direction of groundwater movement has changed toward agricultural pumping centers. While Meinzer and Kelton (1913) reported a 320 km² area in which water was <5.0 m below the surface, Mann *et al.* (1978) mapped a similar area as having water at >30 m in 1975.

Permanent surface water is scarce throughout the approximately 3,840 km² drainage area (Mann *et al.*, 1978). Headwaters at high elevations on Mt. Graham and the Chiricahua Mountains, tributaries of Grant Creek and West Turkey Creek, respectively, collect snowmelt, rainfall, and springs to produce surface flows that rarely reach the valley floor (Brown *et al.*, 1981).

Croton Springs on the west edge of the playa and Sulphur Springs to the south both formerly produced surface flows evidently used by Indians (Meinzer and Kelton, 1913). Each had associated ciénega habitat. Eccleston (1950) described Croton Springs in October, 1849 as "springs of fresh water [that] build up here and lose themselves in the sand." Hinton (1878) referred to Croton and Sulphur springs as being among "several springs of good water in the valley." Another was Eureka Spring in upper Aravaipa Valley. At Croton Spring, Meinzer and Kelton (1913) found water within 0.3 m of the surface of a spring mound[1], and seepage from its base. A 1946 surface photograph and a 1958 aerial photograph of Croton Spring reveal ample water (R. M. Turner, U.S. Geological Survey, pers. comm., 1982). Hastings (1959) remarked that Croton Springs "has an excellent flow still...no significant difference is apparent between conditions there in 1850 and 1959." Hevly and Martin (1961), however, found no seepage anywhere and water more than a meter below tops of the mounds after a particularly wet winter. Wells near both Croton and Sulphur springs in 1975 had water at 9 to 13 m (Mann *et al.*, 1978). No surface water was present when we visited Croton Spring in 1981. Not as much historical information was found on Sulphur Springs, but a 1932 photograph (No. 5198, Arizona Pioneer Historical Society [APHS], Tucson) depicts an unmistakable marshy area that was ditched and thus probably drained by 1941, as indicated in another APHS photograph (No. 9006).

Croton Spring sediments and a 42-m core from the Willcox Playa have provided materials for palynological studies, from which major vegetation and thus climatic changes during and since Pleistocene have been inferred (*e.g.*, Hevly and Martin, 1961; Martin, 1963b; Martin and Mosimann, 1965). These studies demonstrated a higher proportion of *Pinus* pollen during Pluvial times than in modern pollen rains. A downward displacement of pine forests of 900 to 1,200 m was indicated, thus bringing them to the shores of Lake Cochise during Wisconsin time (20,000 to 23,000 years before present [ybp]) (Martin, 1963b). Relatively short-term vegetational shifts between Pine parklands and Juniper-Oak woodlands surrounding the lake during Wisconsin time were also inferred from their data (Martin and Mosimann, 1965). Sedimentologic data (Schreiber *et al.*, 1972) indicate Pluvial conditions previous to 13,000 ybp and desiccation followed by return to Pluvial conditions from 11,500 to 10,500 ybp. Increasing aridity to present has caused drying of the lake and a shift in surrounding vegetation to Desert grassland.

The largest ciénega in the basin is Hooker Ciénega (Fig. 6) at 1,350 m on the historic Sierra Bonita Ranch settled by Henry C. Hooker in 1872 (Granger, 1960). Pattie (1833) described "...a rich, black soil, with heavily timbered groves" in the vicinity. The ciénega has been essentially dry at times within the last 20 years, but after 4 of the last 5 years having abundant winter precipitation, is presently (1982) well watered (D. E. Brown, Arizona Game and Fish Department, pers. comm., 1982). Water was less than a meter below the surface in 1975 (Mann *et al.*, 1978). At its lower end the ciénega has been impounded resulting in artificially maintained habitat with large water-level fluctuations. Yatskievych and Jenkins (1981) surveyed the diverse flora at 8 transects across the 8-km-long ciénega area. Forty-six aquatic and semiaquatic taxa were documented. They noted that plants had been collected in the Area by J. J. Thornber in the first decade of this century, but did not discuss differences or similarities between the two collections.

Other references to ciénegas in this drainage were given by Granger (1960). Robert's Ciénega about 10 km from the mouth of West Turkey Creek was the site of a temporary military camp in the 1880s. In 1878, not far away, Pat Burn gave his name to another small, spring-fed ciénega near which he settled. Present status of these is unknown. Typically dark sediments and a peripheral stand of mature cottonwoods also occur near Bonita at the point where water from Grant Creek must have formerly surfaced onto the valley floor.

[1]Spring mounds result from accumulation of organic materials, entrapment of wind-blown sand and dust, and lateral accretion of salts, and may rise to heights of >2.0 m where seeps rise to the surface in arid areas.

Aravaipa Valley.—This valley remains relatively remote and sparsely inhabited and appears to have always been so. Surface drainage from the east is from the northwest end of the Pinaleño Mountains and southern slopes of the Santa Teresa Mountains. The Galiuro Mountains form the western and southern boundaries of the basin (Fig. 5).

Permanent surface water on the valley floor presently flows only in the canyon which bisects the Galiuro range (Minckley, 1981). However, Hutton (1859) reported a large ciénega about 8.0 km above the canyon and Bell (1869) presented a lithograph illustrating such a marsh. Parke (1857) mentioned a ciénega in the same vicinity. Dobyns' (1981) mapped a marsh near the same location, calling it "Water of the Dead." Few other written historical descriptions exist and no viable remnants remain today. Hastings (1959) found reference in a government report to the use of mowing machines to cut hay for the cavalry at old Fort Grant (near the mouth of Aravaipa Creek) in the 1870s and 1880s. Cooke and Reeves (1976) pointed out that such harvesting might still be possible during wet years. An earlier reference is that provided by Dobyns' (1981) translation of the report of Capitán Don Antonio Comadurán who visited "Water of the Dead" on 27 May, 1830, but failed to describe it. The next day he observed near the head of the canyon "...that the Indians caused a large fire that had been burning for five days." Then mention of "thick pieces of wood still burning" is evidence of a mature riparian gallery forest. Such a forest, also described by Bell (1869), persists today (Minckley, 1981).

Douglas and San Bernardino Valleys.—Although San Bernardino Valley occupies the southern part of the San Simon structural trough, it is related hydrographically and geologically to the south-flowing lower Sulphur Springs or Douglas Valley. Arroyo San Bernardino receives its water from the south and east slopes of the Chiricahua Mountains and the southwest end of the Peloncillo Mountains. The Douglas Valley drains western slopes of the Chiricahua Mountains, principally *via* Rucker Canyon, which enters Whitewater Draw and flows around the north end of the Swisshelm Mountains before turning south crossing the border just west of Douglas (Fig. 5). Drainages from the Mule Mountains are tributary to Whitewater Draw from the west. South of the border the stream is known as Río de Agua Prieta (River of Dark Water), an often confusing situation in light of its name just north of the border and the presence of nearby Black Draw (also known as Arroyo San Bernardino). Tamayo (1949) attributed the Spanish name for Whitewater Draw to its severely polluted nature below the Douglas copper smelter, although use of the name long predates the smelter (Parry, 1857). The Sulphur Springs and San Bernardino valleys join in Sonora to continue south to the Río de Bavispe, which then joins the Río Yaqui.

The San Bernardino and Douglas valleys are geologically similar. Both, like other basins discussed here, are dominated by fluviatile valley fills, and include deeply buried lake beds (Meinzer and Kelton, 1913). Volcanic activity has been recent in both, but more extensive and surficially evident in the San Bernardino Valley (Sauer, 1930). Buried surface flows as well as injected lavas in Douglas Valley correlate with those of San Bernardino Valley (Meinzer and Kelton, 1913). The two are tectonically connected; both experienced extensive movements in the May, 1887 Sonoran earthquake (Dubois and Smith, 1980). In spite of many similarities, however, groundwater aquifers of these two basins are independent (Wilson, 1976; Mann and English, 1980).

Some evidence is available of prehistoric human occupation and ecological conditions in the Douglas Valley. Prehistoric ciénegas along Whitewater Draw near Double Adobe were studied palynologically by Martin *et al.* (1961) and Martin (1963a) from samples at archeological sites investigated by Sayles and Antevs (1941). These data, correlated with radiocarbon dates, show dominance of Compositae pollen indicating local ponding or ciénega habitat in a mesic environment between 800 and 4,000 ybp. During that time climate was similar to present. This period was preceeded by an "altithermal" period, 4,000 to 8,000 ybp, during which ciénegas with Ash-Willow riparian zones were along Whitewater Draw. Sayles and Antevs (1941) found evidence of arroyo cutting during this period, but thought conditions were arid (see also Antevs, 1962; Solomon and Blasing, 1982). Ciénega conditions along Whitewater Draw have nonetheless long existed.

Earliest human inhabitants of this region in historic time were Chiricahua Apaches, whose warlike nature precluded settlement by other Indians and Europeans. They occupied the Chiricahua Mountains at least as early as the first Spanish explorations (Guiteras, 1894; Kino, 1919). Springs at Rancho San Bernardino were used by Spanish travelers as early as 1697 (Bolton, 1936), and at least as late as 1795 when Don Manuel de Echeagaray spent time there writing letters after a long Apache campaign (Hammond, 1931). In 1822, Ignacio Perez received the 297 km² land grant including these springs from the Mexican government (Granger, 1960). Apache activity restricted development, and the hacienda was in ruins when members of the Mormon Batallion camped there on 2 December, 1846. Members of the batallion were aware that the ranch's owner was a Señor Elias of Arizpe: "...said to have been proprietor of above two hundred miles square extending to the Gila, and eighty thousand cattle."

Cooke's road through Guadalupe Pass to San Bernardino Valley and its springs, and continuing across Douglas Valley to the Rio San Pedro, quickly became a major cross-country route. Some descriptions of the San Bernardino Valley that shed light on ecological conditions at the time (1846–55) follow (brackets ours):

...encamped near the old houses and a remarkably fine spring fifteen paces in diameter (Bieber, 1937).

...to the small and boggy valley of San Bernardino...and here we found a splendid spring of cold and clear water (Evans, 1945).

It has the appearance of being a large town originally. A flat bottom beneath the ruins bears traces of having once been under good cultivation. Saw a large bear prowling through the ruins (Aldrich, 1950). [It may be noteworthy that Aldrich makes no mention of difficulties, such as a deeply incised arroyo, after having crossed the Rio San Bernardino downstream a total of 69 times in 2 days enroute to the spring.]

Adjoining this rancho [San Bernardino] are numerous springs, spreading out into rushy ponds, and giving issue to a small stream of running water. The valley is covered thickly with a growth of coarse grass, showing in places a saline character of soil. The timber growth is confined to a few lone cotton-wood trees scattered here and there (Parry, 1857).

About 35 km west of the ruins at San Bernardino, Cooke and the Mormon Batallion found "...a large spring, which, as usual, loses itself after running a hundred yards....It is thought that as many as five thousand cattle water at this spring" (Cooke, 1938). Bliss (1931) thought it to be 10,000 cattle, but both he and Cooke agreed that there was Walnut-Ash riparian forest. Evans (1945), a 49er, found "an abundance of water for all" at this same place. Bartlett (1854) visited a spring much like that described by Cooke in May, 1851, and in August, 1852 returned to find it "filled with a dark, muddy water, whence it derives its name" (Agua Prieta). Emory (1857) noted large herds of feral cattle in 1855, and his geologist Parry (1857) provided one of the more informative descriptions of this valley:

The descent on the opposite (western) side of the ridge to the alluvial bed of the Aqua Preito is over a long, tedious slope, the gravelly table-land giving place to extensive tracts of clay or loam, supporting a patchy growth of coarse grass. The "Black Water" valley, at its lowest depression at this point, contains no constant running stream, its course being mainly occupied with low saline flats or rain-water pools. Extensive lagoons are said to occur in this valley a short distance south of where the road crosses.

The main tributary to this valley comes from the west, and is followed to its head on the line of wagon-road. Its bed consists of a wide ravine, coursing through pebbly strata, variously marked by the washings and drift deposits, caused by the occasional strong current derived from local rains. At other times its bed is entirely dry. The timber growth along its borders consists of hackberry and walnut.

At its source there is a fine spring, issuing from ledges of stratified porphyritic rock, identical in character with that noticed at the foot of the Guadalupe Pass. The stratification is inclined to the northeast, and along the line of its tilted ledges the spring issue forms frequent pools of limpid water.

During the second U.S. and Mexican Boundary Survey in 1892, E. A. Mearns collected data for his "Mammals of the Mexican Boundary..." in which he (1907) wrote:

The San Bernardino River...is wooded with willow, cottonwood, boxelder, ash and mesquite; a few red junipers grow on adjacent hills; and the creosote bush, mesquite, acacia and ocotillo occupy the stony mesas and arroyos which constitute the major portion of that region. The broad meadows below the San Bernardino Springs are now covered by grazing herds; but at the time of Emory's survey they were occupied by a dense growth of cane which has since entirely disappeared. Waterfowl were abundant along the San Bernardino River and on the marshy meadows and pools below the springs.

Apaches led by Cochise and Geronimo prevented settlement by Angloamericans until about 1872. At that time a treaty was made with Cochise, and a Chiricahua Reservation established. Geronimo remained active, however, and continued troubles were cause for removal of the Apaches to the San Carlos Reservation in 1876 upon dissolution of the Chiricahua Reservation. Construction of the Southern Pacific Railroad through Willcox in 1880 and Geronimo's surrender in 1886 provided supplies and security (Bancroft, 1962). Cattle ranching grew with rapidity at the same time mining activities in Bisbee provided impetus for development. The railroad through Douglas from Bisbee opened in 1902, and smelters located on Whitewater Draw for its groundwater provided an economic base for rapid growth (Ransome, 1904).

On 3 May, 1887, this area was shaken by a major earthquake, the epicenter of which was not far south in the San Bernardino Valley near Batepito, Sonora (now known as Colonia Morelos) (Goodfellow, 1888; Bennett, 1977; Sumner, 1977; Dubois and Smith, 1980; Herd and McMasters, 1982). Groundwater equilibria were disturbed throughout the Río Yaqui basin and elsewhere. A widely publicized occurrence was alteration of groundwater conditions at Abbott Ranch in Douglas Valley. The following quotations extracted from Dubois and Smith (1980) (compiled from Goodfellow [1888], Bennett [1977], and newspaper accounts shortly after the event) serve to illustrate these phenomena:

In one place far up the mountainside a stream of pure water 10 inches in diameter is belching forth, and at present shows no sign of ceasing.

The stream which was 10 inches in diameter created a shallow lake a mile wide.

Water came bubbling from the hillsides, from where water has never been seen.

One and a half mi. from C. S. Abbott's house the water shot up into the air to a considerable height, about 4 or 5 ft. in width, and extended fully 100 ft. in distance. Today the flow was decreasing very fast, but for miles the plains were covered with water.

Flow in the Río Yaqui in Sonora increased greatly, but this as well as Abbott's windfall, said to be sufficient to water 100,000 cattle, returned to former conditions within a few days.

Agriculture started in the Douglas Valley in 1910 with drilling of the first wells (Coates and Cushman, 1955), and expanded rapidly to 202.5 km^2 by 1965 (White and Childers, 1967). The history of groundwater exploitation is well known, starting with a comprehensive study by Meinzer and Kelton (1913), followed by Coates and Cushman (1955), White and Childers (1967), and recently, Mann and English (1980): Groundwaters of San Bernardino Valley have not been so extensively exploited. However, wells constructed by J. H. ("Texas John") Slaughter on Rancho San Bernardino in Arizona tap a warm artesian aquifer also drained by wells in Sonora. This aquifer is distinct from that which produces natural springs on the property (Wilson, 1976).

Permanent, natural surface waters in the Río Yaqui drainage in Arizona currently consist only of springs on Rancho San Bernardino, and short reaches in Leslie Creek and upper Rucker Canyon in the Douglas Valley drainage (Hendrickson *et al.*, 1980; Brown *et al.*, 1981). A few references mention high groundwater and sometimes marshy areas along Whitewater Draw west and southwest of Elfrida (Parry, 1857; Meinzer and Kelton, 1913; Coates and Cushman, 1955; Cooke and Reeves, 1976). The lower 3.2

km of Whitewater Draw and Astin Spring on the Arroyo San Bernardino have become ephemeral only within the last few decades (Coates and Cushman, 1955; Minckley, 1973; McNatt, 1974; Hendrickson *et al.*, 1980).

Springs at Rancho San Bernardino produced extensive ciénegas, still largely intact although artificially maintained by artesian wells (Fig. 8). Vegetation and flora were detailed by Marrs-Smith (1983). As reviewed above, its historical importance to human activity was considerable. However, despite frequent mention in journals, a definitive description of its historic vegetation more detailed than "a boggy valley with scattered cottonwood trees" cannot be made. Higher ground definitely supported mesquite, but the valley bottom seemed devoid of it and dominated by grasses where not "rushy" (Cooke, 1938). Mesquite now forms dense *bosques* over a wide area along Arroyo San Bernardino (Marrs-Smith, 1983).

A Sacatón meadow persists on the site of an old ciénega above a low dam on Leslie Creek. Below the Sacatón extends a 1.0-km reach of permanent water, with dense Cottonwood-Ash-Willow riparian forest bordering a narrow stream dominated by Watercress (Fig. 7). This small reach of permanent flow was proposed as a Natural Area by Smith and Bender (1974a).

Ciénegas were apparently scarce elsewhere in the Río Yaqui drainage in Mexico. Hendrickson *et al.* (1980) reported none, but an anonymous essay translated by Guiteras (1894) mentions ciénegas during Spanish times in what is now Sonora at Cuchuta, Teuricachi, and west of Cuquiarachi.

San Pedro Valley. Flowing north from Oak-Grassland hills of the Sonoran copper mining area of Cananea (40 km south of the International Boundary), the Río San Pedro drains more than 16,635 km^2 (Cooke and Reeves, 1976). The stream enters Arizona at 1,303 m elevation and flows 200 km to enter the Gila River at Winkelman (588 m) (Fig. 9). Eastern rim of the basin is formed from south to north by the Mule, Dragoon, Winchester, and Galiuro mountains, which range to peaks >2,300 m high, separated by 1,525–1,650 m passes. The western divide is higher, with peaks to 2,885 m in the Huachuca Mountains north of the border, to 2,259, 2,641, and near 3,000 m in the Whetstone, Rincon, and Santa Catalina mountains, respectively, as one proceeds north. Passes of 1,220 to 1,650 m divide these major ranges.

Geologically, structure and composition is much like that of other valleys in the Basin and Range Province (Roeske and Werrell, 1973). Valley fill consists of two basic parts, the upper (younger) ranging from 90 to 240 m thick with greatest depth in mid-valley and consisting of clay and silty gravel beds along margins and silt and sandy silt in the center. Below these strata are older gravels, sandstones, and siltstones, thin peripherally, but exceeding 300 m thick centrally. Over valley fill at the surface along drainages is a 12- to 46-m thick floodplain alluvium of gravel, sand, and silt. Bedrock outcrops restrict the valley's width near Charleston, at "The Narrows," at Redington, and again near the Gila River (Wilson *et al.*, 1960). These restrictions, producing surface flows in places, have resulted in unequal depths of valley fill between sub-basins and increased longitudinal surface slope in each successive sub-basin (Haynes, 1968; Cooke and Reeves, 1976).

Human occupation of this valley dates to as early as 1500 as indicated by excavations of Di Peso (1951) along the lower Babocomari River. The Babocomarites, with affinities to more southern cultures in Sonora, established at least four agricultural communities along eastern foothills of the Huachuca Mountains. They may have been ancestral to the Sobaipuri Indians found along the Río San Pedro by early Spanish explorers, but evidences of relationship are ambiguous (Di Peso, 1951).

The Sobaipuris were visited by Padre Kino and other missionaries from 1692 to 1697 (Kino, 1919). They were censused at 2,000 "souls" distributed along the San Pedro in 14 villages. The most populous of these was Quiburi about 2.0 km north of Fairbank, with 500 inhabitants, and La Victoria de Ojio near the mouth of Aravaipa Creek, with 380. That the river was unincised and marshy, at least at village sites, is attested to by mention of extensive *acequias* (ditches) for irrigation of squash, bean, maize, and cotton fields, and statements that houses were constructed of poles and "reeds." The Sobaipuris were provided livestock by Kino in the late 17th Century (Kino, 1919). They pursued an agricultural lifestyle until fleeing Apache depredations in 1762 (Guiteras, 1894), leaving the valley unirrigated until Mormon settlers arrived 125 years later.

During the next 70 years, variations in intensity of Apache raids allowed sporadic development of Spanish cattle industries. Mexican land grants in 1822 deeded most riparian bottomlands to wealthy cattlemen, who heavily stocked their ranges (Mattison, 1946). By the time Angloamericans began exploring, intensified Apache hostilities from 1828 to 1843 had caused the Mexicans to abandon their operations (Haskett, 1935). Clarke (1852) mentioned evidence of Mexican irrigated farming, but all that remained were ruined haciendas and plentiful feral cattle. Cooke (1938), upon reaching the Río San Pedro in 1846, remarked that "There is not on the prairies of Clay County, Missouri, so many traces of the passage of cattle and horses as we see every day." Wild herds appeared to dwindle rather quickly, possibly due to hunting by Apaches, military expeditions, and 49ers (Browne, 1869; Bell, 1932).

American cattle ranching attempts began in the late 1860s, but problems with Apaches thwarted them until the late 1870s when J. H. Slaughter brought a herd to Hereford (Haskett, 1935). By the early 1880s herds grew rapidly, peaking just before a disasterous drought of 1891–93.

During this same time irrigated farming was developing, especially near St. David where a thriving Mormon colony established (McClintock, 1921). By 1899, 1,400 ha were being irrigated (Roeske and Werrell, 1973). Mining concurrently became important, especially near Tombstone beginning in 1878 (Hamilton, 1881; Gilluly, 1956). A rip-rap dam across the river in 1879 diverted water into a 2.4-km ditch to supply an ore mill operating at Charleston by 1881. This was short-lived, however, and the mining boom that so quickly made Tombstone a population center soon died. By 1890, Charleston was deserted, and Tombstone nearly so. Agriculture continued

Figure 6. Hooker Ciénega, Arizona, after partial impoundment. Photograph 1981.

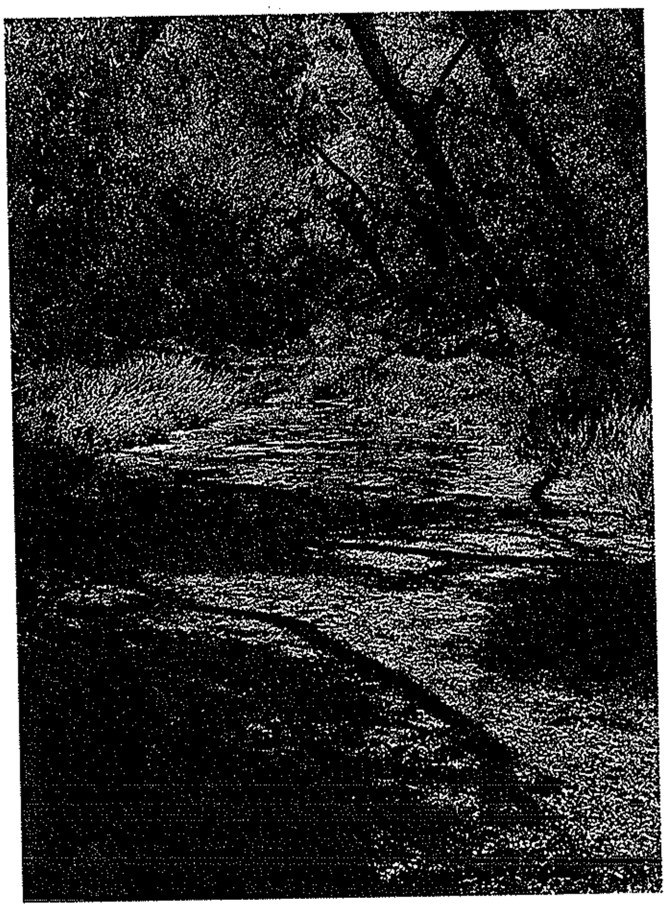


Figure 7. Leslie Creek, Arizona: narrow ciénega habitat bordered by dense riparian gallery near middle of 1.0-km, permanent reach. Photograph 1982 by G. K. Meffe.

to grow, reaching 5,000 irrigated hectares by 1966, but decreasing to 3,900 ha by 1970. Groundwater pumpage roughly paralleled changes in area irrigated (Roeske and Werrel, 1973).

As recently as a century ago the Río San Pedro was unincised and marshy along much of its length (reviewed by Hastings, 1959 and Hastings and Turner, 1965). Earliest descriptions are vague, but Padre Kino (1919) in the late 17th Century described the valley as lush, with much irrigation. The Mormon Batallion first camped in the valley "...in a marshy bottom with plenty of grass and water" (Cooke, 1938). Here and for two days travel downstream conditions remained the same. Cooke (1938) and Bliss (1931) both mention an abundance of fishes, "...salmon trout, up to three feet long" (Cooke, 1938), taken by members of the Batallion along this reach[2]. Eccleston (1950) reported such fish at Tres Alamos in 1849. Tyler (1881) described the boggy nature of the stream at "Bull Run" (presently Lewis Springs) in 1846: "A kind of cane grass grew in this region, from four to six feet high, being very profuse and luxuriant in the bottom near the stream." Cooke (1938) was impressed by the valley, and apparently referred to *Sporobolis airiodes* when he mentioned "...bottoms having very high grass and being lumpy" near Lewis Springs. The next day he wrote "the bottom grass is very tall and sometimes difficult to pass through. These bottoms average above a mile and are good land." Evans (1945), found "...our road winding through miry bottoms of a small stream which was kept alive by the water of marsh and springs" as his party crossed Río San

[2]Such fish could only have been Colorado squawfish, *Ptychocheilus lucius*, the largest native North American cyprinid, formerly abundant in the Colorado River basin, but now approaching extinction.

Figure 8. San Bernardino Ranch, Sonora: part of ciénega along west side of Rio San Bernardino maintained by flow from artesian wells. Photograph 1981 approximately 0.4 km south of the international boundary.

Pedro near the U.S.-Mexican Border before moving south of the Huachucas to the Santa Cruz Valley. Leach (1858) reported broad Sacatón "bottoms" below Tres Alamos, with Cottonwood, Ash, and Willow lining the river. Eccleston (1950), who crossed in October near the mouth of Tres Alamos Wash below Benson, disagreed with Cooke's description of a "beautiful little river." He described it as:

...extremely boggy and has to be crossed by making a brush bridge...I was obliged, in order to manage my team, to jump in beside them, and get wet above the waist... Here it is lined with a poor growth of swamp willow and other brush, so it cannot be seen till you come within a few feet of it; and then the bank is perpendicular, not affording an easy access to its water, which though not very clear, is good. The banks and bed are extremely boggy, and it is the worst place for cattle and horses we have yet been, being obliged to watch them very close.

Here reference to boggy banks is good evidence that Eccleston encountered unincised ciénega conditions and "perpendicular banks" described conditions found in extant ciénegas where flat-bottomed, vertical-walled pools a meter or more deep are common. Banks of incised arroyos are well drained, and ephemeral or intermittent streams are almost invariably shallow. Parke (1857) encountered similar difficulties in the same area above "The Narrows":

In the gorge below, and in some of the meadows, the stream approaches more nearly the surface, and often spreads itself on a wide area, producing a dense growth of cotton-wood, willows and underbrush, which forced us to ascend...

Etz (1938) remembered extensive swamps and beaver dams at many places between Benson and her ranch 35 km downstream. Davis (1982) presented other references to Beaver *(Castor canadensis)* along the full length of the valley. Hastings (1959) found evidence in 1889 court records of a marsh extending from Benson to Tres Alamos.

The Benson area and "...for miles above and below," said the Arizona Daily Star on 23 September 1879, "...might well be called the valley of the shadow of death. Malarial fevers of the most malignant type are prevalent eight months in the year" (Hastings, 1959). Malaria, indicative of swampy environments, was a major problem. Hastings (1959) also referred to an 1870 Report on Barracks from old Camp Grant at the mouth of Aravaipa Creek. By his calculations each of the 215 men housed at the camp that year was hospitalized an average of 10 times, 9 for malaria. Bell (1869) also mentioned the problem at Camp Grant, and it occurred at St. David as well (McClintock, 1916, 1921; Granger, 1960; Bennett, 1977).

The issue of extensive ciénega conditions is confused, however, by other historical references to incised, well-drained arroyos, often almost in the same areas and contemporaneous with contrasting descriptions. Bartlett (1854) and Graham (1852) reported well-drained banks cut 2 to 3 m into alluvium near St. David in 1851, which had to be leveled before wagons could be lowered by hand. Parke (1857) found the river incised nearly 4.0 m near present-day Benson. He also noted an absence of riparian vegetation. Bartlett (1854) did not think it possible to irrigate

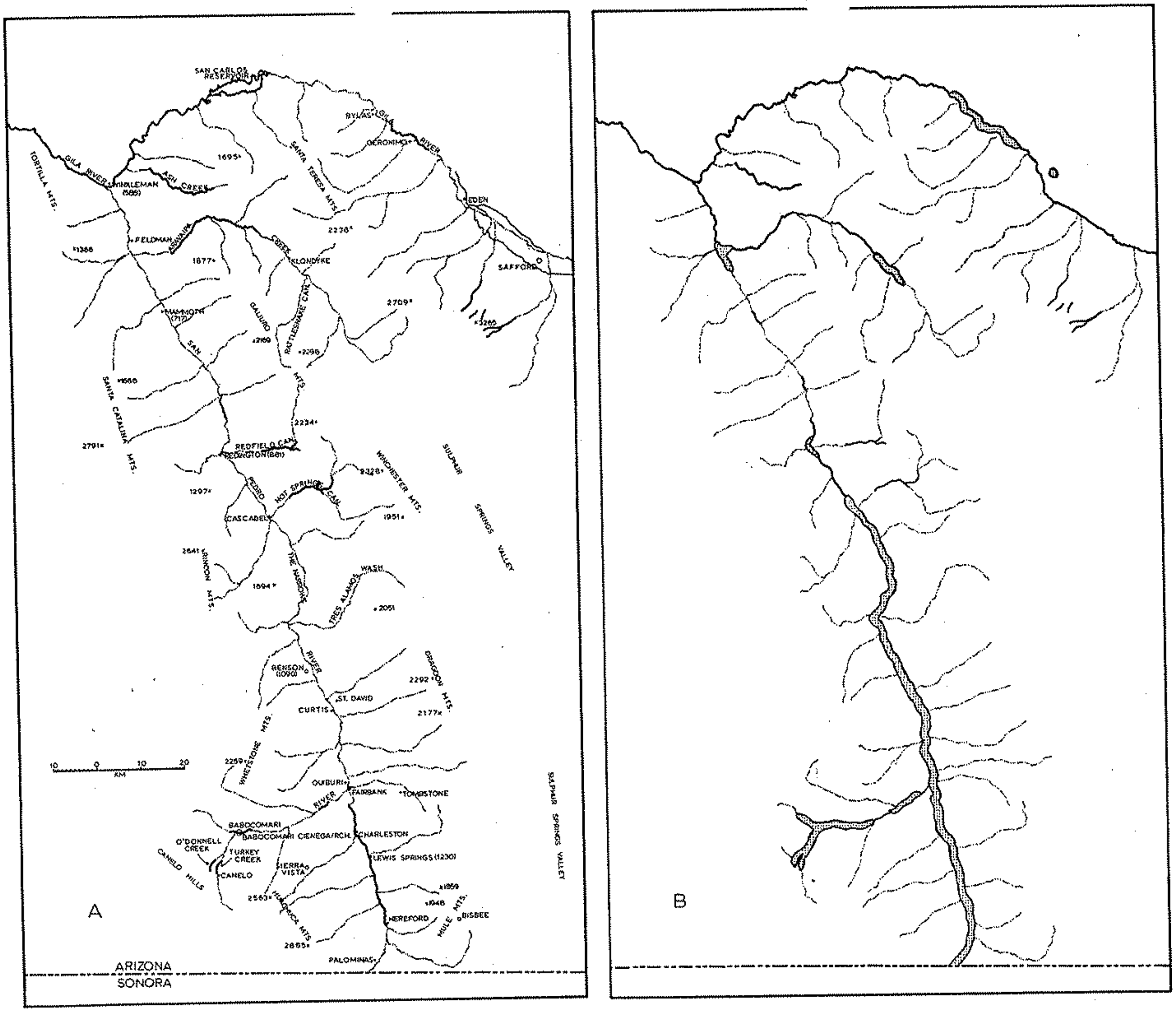


Figure 9. Sketch map of the San Pedro Valley, Arizona: with some place names mentioned in the text and present-day aquatic and semiaquatic habitats (excluding stock tanks) (A); and, map of San Pedro Valley, with aquatic and semiaquatic habitats before 1890 as inferred from historic records (B). Elevations are in meters. Symbols are as in Figure 4.

the valley because of the incised nature of the stream. Builders of the Leach Wagon Road encountered incisions just above "The Narrows," but broad, marshy conditions below (Hutton, 1859). Cooke and Reeves (1976) found surveyors' reports (1873–81) to indicate incision along some reaches, but lack of it elsewhere. It seems clear that entrenchment was local and discontinuous as early as the 1850s.

Historical accounts tend to indicate perennial surface flow in the Río San Pedro wherever it was crossed. However, Hastings and Turner (1965) found two 1850s references to intermittent flow and an ephemeral reach. Hutton (1859) and Leach (1858) mentioned an ephemeral nature below Tres Alamos. Lee (1904) described surface flow as continuous, although of small volume during dry seasons.

Surface flow has decreased since that time. Roeske and Werrell (1973) reported summer drying at Palominas, permanent surface water at Charleston, summer drying at Fairbank, ephemeral flow diversions at St. David, flow "in direct response to precipitation" at "The Narrows," and perennial flow next at Cascabel to near Redington, below which the stream was ephemeral. Basically concurring with this and the map of Brown *et al.* (1981), Konieczki (1980) claimed surface flow as permanent from just north of Hereford to Charleston, and Jones (1980) documented the only perennial surface flow in the lower basin to be a reach <3.8 km long starting 11.4 km south of Redington.

Significant permanent surface flows are present in numerous tributaries, but as is typical in the region, such streams infiltrate upon striking valley fill and have surface discharge to the mainstream only in flood. Such is the case with Babocomari River, Hot Springs Canyon, Redfield Canyon, and Aravaipa Creek (the last discussed above).

Remnant ciénegas still exist in the San Pedro basin, although greatly reduced in extent and modified from historic conditions. At least three remain in the Babocomari

Figure 10. Babocomari Ciénega, Arizona: view of the interior upstream from retention dam at Babocomari Ranch. Photograph 1982.

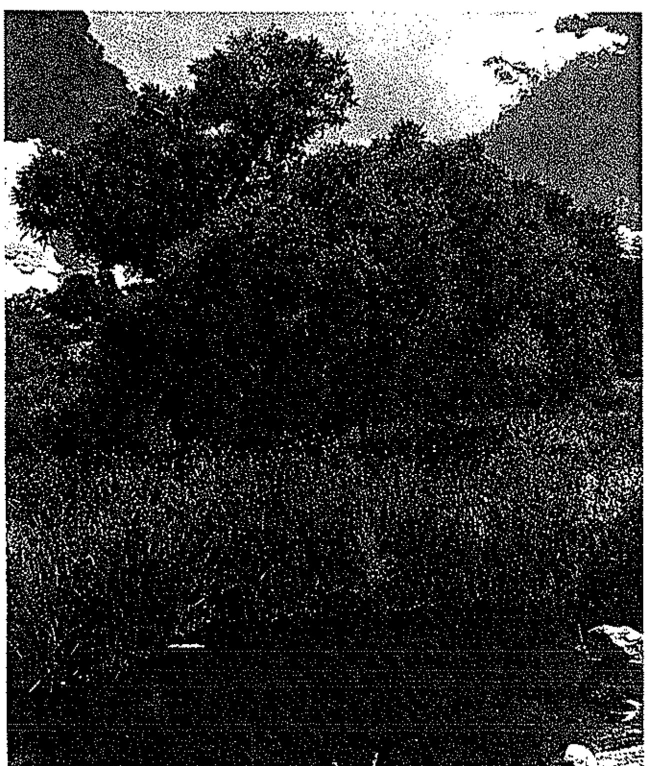


***Figure 11.** O'Donnell Ciénega, Arizona, Nature Conservancy Canelo Hills Preserve. View immediately below concrete retention dam. Photograph 1978 by Jim Anderson.*

watershed. The immediate valley of Babocomari River was described by Hinton (1878) as:

"...twenty-five miles long from its source to its junction with the San Pedro, and flows east through a fine valley, with plenty of water all the way, and in places large ciénegas."

He stated that "the stream was twenty feet wide and two feet deep" and mentioned "very productive military vegetable gardens along its banks" at old Camp Wallen. Granger (1960) translated the name "Babocomari" from Papago as "caliche hanging over in little cell-like formations." No such formations are evident today, but if a correct translation the name may refer to travertine deposits.

Prehistory of this area, based on Di Peso's (1951) study, has been previously discussed. By the late 17th Century Padre Kino had established a *visita* at the present Babocomari Ranch site, calling it Huachuca (Bolton, 1936). When surveyed in 1828 by Mexican authorities considering a land grant requested by Ignacio and Doña Eulalia Elias, the 8 *sitios*[3] included 6 with running water and 2 dry (Mattison, 1946). The grant was confirmed and sold for the equivalent of \$380.00. Bartlett (1854) happened across ruins of the hacienda in 1851 after its abandonment under Apache pressure. He claimed that its herds numbered no fewer than 40,000 cattle as well as many horses and mules when it was abandoned. Later, Camp Wallen was established and operated by the mili-

[3]A *"sitio"* is an areal measure two leagues square (17.6 km^2).

tary from the ranch buildings. Hinton (1878) mentioned that there were 7,000 sheep grazing the area, although Granger (1960) mentioned that number pastured there after the camp was closed. E. B. Perrin bought rights of the heirs in 1877 (Mattison, 1946) and the Court of Private Land Claims confirmed title to 137 km² in 1904. Meanwhile, Wagoner (1952) stated that 3,600 cattle were on the ranch by 1880, the Tevis-Perrin Land and Cattle Company was mentioned by Haskett (1935) as a large cattle holder and owner of the land grant in the early 1880s, and Granger (1960) claimed to have documented grazing by "...about 40,000 head of cattle" on the land grant before the 1891–3 drought.

A remnant of Babocomari Ciénega (Fig. 10; also see back cover) lies across the Pima-Cochise county line above a concrete dam installed in the 1930s before headward cutting reached the historic ranch headquarters (Smith and Bender, 1974c). The ciénega was proposed for preservation as a Natural Area in 1974 (Smith and Bender, 1974c). It represents a typical ciénega in near natural condition. The banks support a riparian zone of large Cottonwood trees and scattered Walnuts, with a Willow understory. Adjoining the streambed above the ranch buildings is an extensive, dense Sacatón flat. The stream is permanent over an approximate 3.8-km reach, becoming intermittent below the first abandoned railroad crossing downstream from the ranch (Brown *et al.*, 1981). Roughly the upper two thirds of the system is unincised. Di Peso (1951) mentions two other ciénegas in the Babocomari Valley, both downstream from the ranch. He noted both had been incised 3.4 to 4.0 m and invaded by Mesquite. No viable ciénegas persist in these areas.

Upstream from Babocomari Ranch, ciénegas occur along O'Donnell (Fig. 11) and Turkey creeks. The riparian plant community of the former has been studied by Barstad (1981), who attributed its original presence to a sandstone-shale obstruction in the alluvium and to faulting. It now is maintained in part by a concrete dam. Ciénega vegetation occupies waterlogged soils above two springs along the stream. The ciénega is dominated by Swamp Willow, with a *Juncus* sp., *Mimulus guttatus*, and *Eleocharis macrostachya* understory, while Goodding Willow and Cottonwood occupy less saturated soils. Along the stream grows a dense mixture of Walnut, Cottonwood, and Goodding Willow, with a thick shrub understory including False Indigo *(Amorpha fruticosa)* and Golden Currant *(Ribes aureum)*. Continually wet meadows on both sides of the stream support *Eleocharis*, *Juncus*, and *Cyperus* spp., as well as a recently discovered, rare orchid, *Spiranthes graminea*. Most of O'Donnell Ciénega is owned by The Nature Conservancy whose management objective is to maintain an undisturbed, natural community. Perpetuation of the orchid has thus involved controlled burning. The operation appears to have been successful; ciénega species composition has not been obviously altered.

Brown *et al.* (1981) mapped a former wetland on the Río San Pedro just downstream from Fairbank near the ruins of Quiburi, and Cooke and Reeves (1976) mentioned incision of a ciénega on Río San Pedro near the mouth of Babocomari River. Photographs in Hastings and Turner (1965) revealed no signs of incision about 1890. However, in an 1891 photograph a few kilometers upstream, the San Pedro appeared incised (Hastings and Turner, 1965). Today the river flows between cut banks throughout this area, and no apparent remnants of ciénega habitat remain. This site is centrally located within the 22.4-km-long and 3.2-km-wide San Juan de las Boquillas y Nogales land grant. Appraised values of $600 for each of four sitios comprising this grant indicates each had permanent surface water in about 1830 (Mattison, 1946). Today only the most upstream sitio may have perennial flow.

By 1878, springs along the west bank of Río San Pedro at St. David had been tapped for irrigation of 30.4 ha by the first Mormon settlers. The area was described as "marshy" and epidemic malaria during the first decade of settlement prompted intentional draining of parts of the surrounding marshlands (McClintock, 1921; Rodgers, 1965). Long-time residents remembered a marshy riverbed in the Curtis-St. David area within the last half-century. However, it is now incised (Cooke and Reeves, 1976). An artesian aquifer widely tapped in the St. David area (Roeske and Werrell, 1973) may be the same that supplies or formerly supplied springs in the valley. That spring flows are associated with tectonic features was demonstrated by the 1887 earthquake. That event proved a boon to St. David by drying some problem marshy areas and creating other new springs (Bennett, 1977).

Two springs, 4.8 to 6.4 km south of St. David, still flow into marshy environments 0.8 to 1.6 km west of the river. The more northern of these has been modified into farm ponds, but the southern remains undisturbed. Both are on land owned by Tenneco Corporation (D. E. Brown, pers. comm., 1982). The marsh formed by the southern spring (E1/2, S29, T18S, R2E) extends perhaps 500 m southeast from the Southern Pacific Railroad. During our visit in 1980 no open water was present in this dense, cattail-dominated marsh. Nowhere was water deeper than 10 cm, nor was surface flow observed. A broad surface intersection of the watertable results in an expanse of shallow, perennial water. *Typha domingensis* formed a nearly monospecific stand surrounded by grasses and *Anemopsis californica* on less saturated soils. A few Willows (*Salix* sp.) were at the north end, and Mesquite and Desert Grassland surrounded it on higher ground. The entire area was grazed. This marsh was proposed by Smith and Bender (1974b) as a Natural Area.

Further downstream, Brown *et al.* (1981) marked two former wetlands, one at Redington and another at Feldman near the mouth of Aravaipa Creek. Today these are known respectively as Bingham Swamp and Cook's Lake. The latter is believed to be the approximate site of Ojio, the second-largest Sobaipuri village visited by Kino in 1697 (Bolton, 1936; Granger, 1960). Camp Grant was established there in 1859, and immediately gained notoriety for epidemic malaria associated with its proximity to a swamp (Bell, 1869; Hinton, 1878; Stone, 1941; Hastings, 1959). Both are unique wetlands, but they do not fall within the realm of ciénegas as here defined. Lentic water and trees, mostly Willows, dominate. Bingham Swamp is characterized by expanses of shallow open water, broken by emergent Willows. Water Fern *(Azolla filiculoides)* mixed with some Duckweed (*Lemna* sp.) covered the surface, especially along edges and in protected areas when

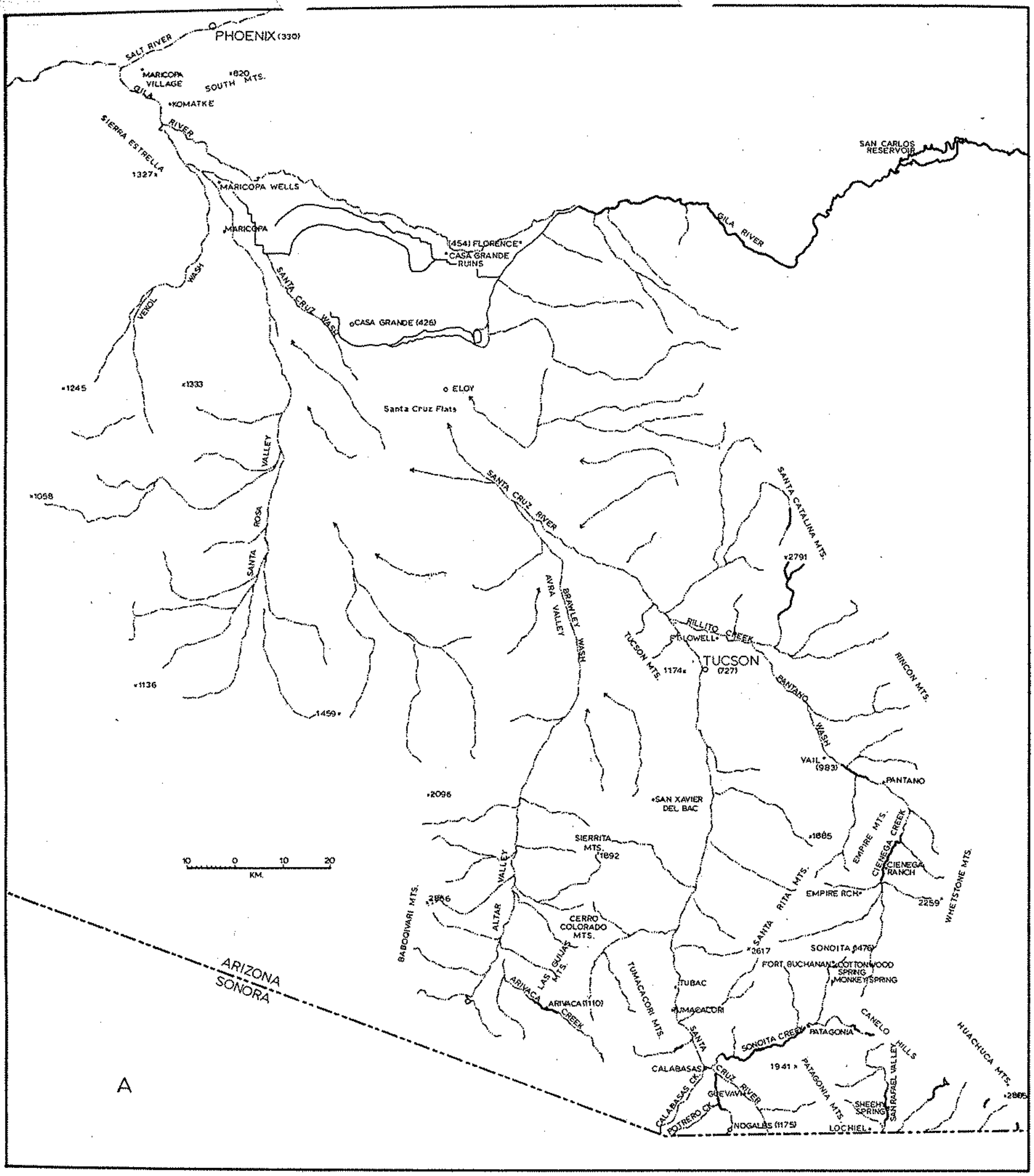


Figure 12. Sketch map of the Santa Cruz Valley, Arizona, with some place names mentioned in the text and present-day aquatic and semiaquatic habitats (excluding stock tanks). Elevations are in meters. Symbols are as in Figure 4.

we visited in 1981. Cook's lake is similarly dominated by Willows, but also has peripheral Cottonwoods. Open water is essentially absent, although present when Smith and Bender (1973a, 1974d) did their survey. In the interim between their work and ours, *Typha* sp. completely closed the open-water area. Cattail and Watercress also cover an adjacent area of tree-dominated swamp, which is drained *via* a broad, diffuse, shallow channel choked by Cattail, to a small artificial lake. Both these systems are best defined as wooded swamps, resembling such associations in the southeastern United States.

Santa Cruz Basin. Headwaters of the Río Santa Cruz (Figs. 12, 13) drain the north, west, and south slopes of the Canelo Hills, and all sides of both the Patagonia and Santa

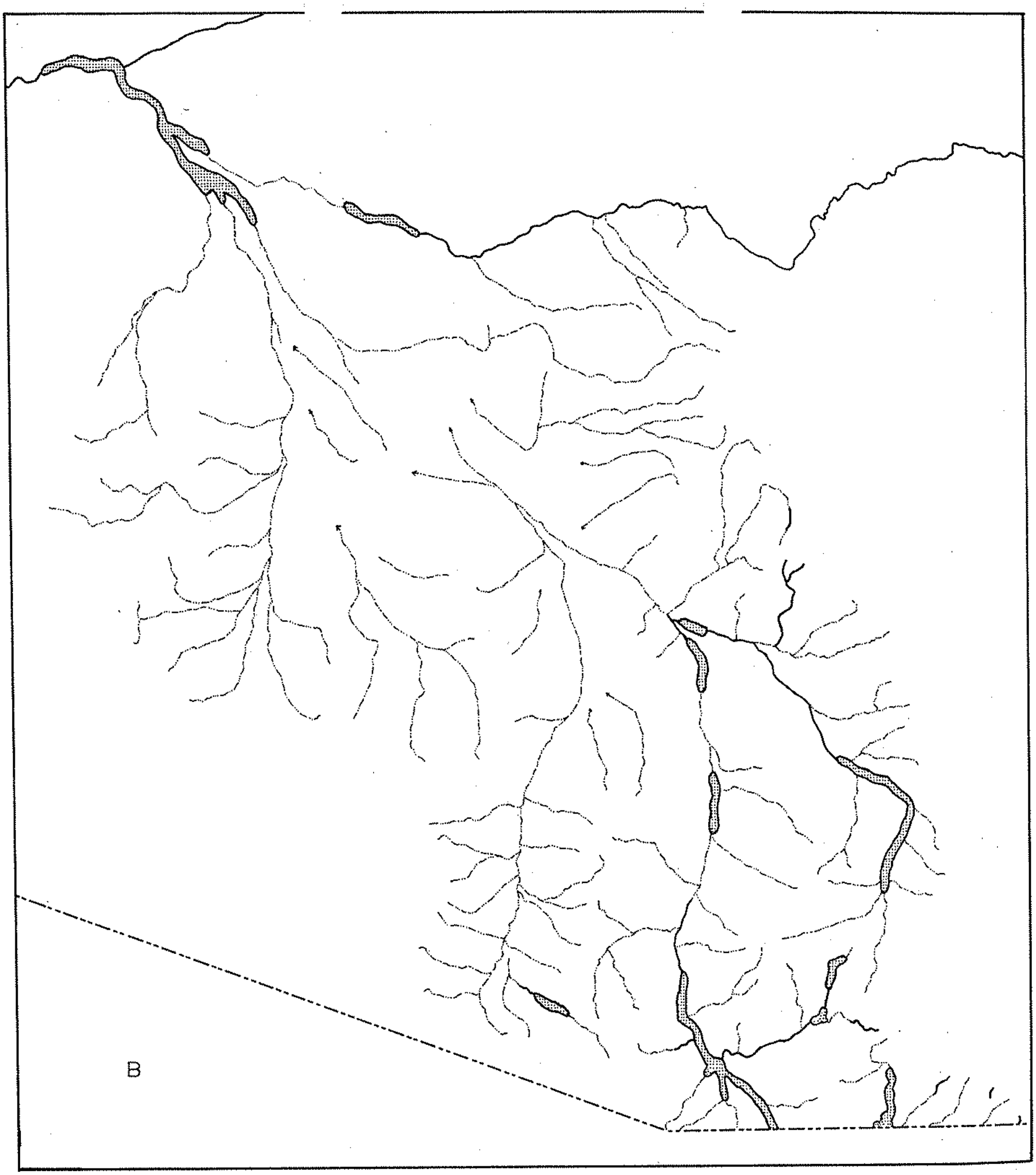


Figure 13. Sketch map of the Santa Cruz Valley, with aquatic and semiaquatic habitats before 1890 as inferred from historic records. Symbols are as in Figure 4.

Rita Mountains. Maximum elevations range from 1,900–2,600 m. The mainstream flows south through the San Rafael Valley, receiving tributaries from the Huachuca Mountains on the east. Entering Sonora it loops south of the Patagonia Mountains to flow into Arizona. It then receives discharge from the western Canelo Hills *via* Sonoita Creek, which passes between the Santa Rita and Patagonia Mountains. The valley broadens as it passes between the Santa Rita and Sierrita mountains and continues north to Tucson. North of Tucson, Rillito Creek enters from the east with drainage from the north slope of Canelo Hills *via* Cienega Creek and Pantano Wash. Further downstream the broad Avra-Altar Valley enters from the southwest, draining the area between the Baboquivari and Sierrita mountains. The Río Santa Cruz historically disappeared into its bed, except in flood, in the vicinity of

Tucson. Members of the Mormon Batallion (Cooke, 1938) expressed surprise that water existed as far as 11.2 km downstream from that presidio in 1848, and numerous other travelers attested to aridity of lands between Tucson and the Gila River. There is no evidence that the Río Santa Cruz extended as surface flow to its confluence with the Gila River in historic time. However, subsurface waters rose to the surface near the southern terminus of Sierra Estrella (Rea, 1983) producing marshlands to be discussed later along with Gila River habitats.

Beginning with a history of continuous habitation and agriculture predating the late 17th Century, this basin is distinguished from others in many ways. A consequence of continuous human habitation is not only better documentation of land use, but significant differences not seen in other valleys. Like the San Pedro, this valley was irrigated by *acequias* at least as early as Padre Kino's first visit in 1689, and surely much earlier (Bolton, 1936). Many Sobaipuri Indians who abandoned the San Pedro Valley in 1762 moved to the Río Santa Cruz near Tucson, where a continuous history of irrigation has been maintained to present.

Spanish mission activity in Arizona was centered in the upper Santa Cruz Valley, which was a principal regional thoroughfare, and nothing exceeding visita status was established outside that valley (Bolton, 1936). The extent of livestock grazing was consequently of greater intensity and duration than elsewhere (Wagoner, 1952). Padre Kino brought cattle to San Xavier del Bac in 1700 (Kino, 1919). Early floodplain alterations related to urban development in Tucson, such as infiltration galleries, mills, and mill ponds, also were unlike river modifications in other drainages (Cooke and Reeves, 1976). Early agricultural development near Tucson was substantial (Fergusson, 1862). More recently, groundwater pumpage for irrigation, especially near Eloy, has been extensive. Total annual pumpage in this hydrologic basin has often exceeded that of any other in the study region by nearly an order of magnitude (Babcock, 1980). Schwalen (1942) and Schwalen and Shaw (1957) provided rainfall, runoff, and groundwater data for the basin.

Unlike the Río San Pedro, the Santa Cruz was well documented as only locally perennial (Browne, 1869; Bourke, 1891; Bieber, 1937; Durivage, 1937; Cooke, 1938; Harris, 1960; Way, 1960). The trough through which the river passes is deeply alluviated and lacks shallow structural dikes or "narrows" which force groundwaters to the surface. Perennial flow now is absent except in short reaches above Lochiel, below Nogales in Potrero Creek, through Arivaca, and above Vail in Pantano Wash (Brown *et al.*, 1981). Longer reaches in tributaries at mid-elevations are a 10-km-flow along Ciénega Creek on the Empire and Ciénega ranches, and about 19 km in Sonoita Creek downstream from Patagonia (Brown *et al.*, 1981). Marshlands formerly occurred in present-day perennial reaches, and local remnants persist.

Private ownership of a large part of the San Rafael Valley dates to 1825 when the land grant of San Rafael de la Zanja was deeded to Ramon Romero. Valuations of the *sitios* in 1821 indicate that 3 of the 4 had permanent surface water (Mattison, 1946). Permanent surface flow is present today only in a short reach of the mainstream and in spring systems above Lochiel. Springs near the perennial reach in the mainstream connect to it *via* surface flows only during flood.

Each of two springs described by Meffe (1983) and Meffe *et al.* (1982, 1983) in the San Rafael Valley consist of similar, well-developed, but areally-restricted ciénega conditions (Figs. 17, 18). Both have long, narrow, vertical-walled pools, often exceeding a meter in depth, separated by shallow, reticulate channels flowing through sedges and other macrophytes. Sharp Spring Ciénega (Meffe, 1983; Meffe *et al.*, 1983) appears younger than Sheehy Spring Ciénega. The latter system has associated large Cottonwood trees, while younger trees predominate at the former. Sharp Spring is bounded by vertical banks often exceeding 3.0 m in height. No evidence of arroyo cutting is apparent at Sheehy Spring, where hillsides slope evenly to the valley floor ciénega. Incision of Sharp Spring has been followed by hydrologic and climatological conditions appropriate for aggradation and vegetational succession toward the present condition. Each is situated in gently rolling, Plains Grassland (Brown and Lowe, 1980). Both are grazed, sometimes heavily during drought.

Upstream, another spring persists at Bog Hole. Recently (1975) impounded by Arizona Game and Fish Department to provide Mexican Duck *(Anas platyrhynchos diazi)* nesting habitat, what surely was once a natural ciénega is now an open-water reservoir several meters deep. *Typha* sp. has invaded littoral areas and small islands, but a few remnant patches of ciénega persist.

Although not well documented, ciénegas elsewhere in this valley in Arizona and in Mexican portions of the drainage were formerly more widespread than at present. Black ciénega deposits outcrop in walls of most arroyos. Parry (1857) mentions an abundance of water near the Mexican town of Santa Cruz. Browne (1869) and his party killed enough ducks there in 1864 to last them for several days. Today the mainstream is incised along most of its course through México (Hastings, 1959).

It seems well documented that there was locally perennial surface flow in the 1800s in the upper mainstream Río Santa Cruz in Arizona from the U.S.-Mexican border to about Tubac (Brown *et al.*, 1981), and that intermittent conditions existed downstream as far as Tucson (Mowry, 1864; Browne, 1869; Bell, 1932; Bieber, 1937; Durivage, 1937). Today it is ephemeral along this reach, and virtually no marshlands exist. Historic references to marshy bottomlands near the mouths of Calabasas and Sonoita creeks, where Brown *et al.* (1981) mapped a former wetland, are in Allison (undated) and Browne (1869). Hastings (1959) reported on 1870 newspaper and government document references to problems with malaria, also mentioned by Wheeler (undated) at Calabasas. The Pete Kitchen Ranch on Potrero Creek about 9.6 km north of Nogales overlooked a ciénega (Bourke, 1891). Small remnants of ciénega associations still exist in Calabasas Creek where crossed by U.S. Highway 89, and in Potrero Creek near its mouth. Powell (1931) mentioned "...bunchy swamp grass" near Guevavi in 1849.

Although not frequently visited by early explorers, the few journal reports on Sonoita Creek are valuable. Bartlett

(1854) was impressed by the "head-high" grass and giant Cottonwoods, with an understory of dense Willows and vines, that he found in a "swamp" near headwaters of Sonoita Creek. He noted that the gallery forest and understory became dense and impossible to negotiate without axes below present-day Patagonia, where an impressive riparian gallery forest persists today (Glinski, 1977). The "large swamp" upstream, thought by Irwin (1859) to be the source of malaria at Fort Buchanan, is gone. Irwin described the marsh as follows:

This ciénega *consists of alluvial deposits and extensive beds of decaying organic matter, the result of the rank, forced vegetation of the hot season. Here several warm and cold springs pour forth their contents, which run over the surrounding level surface, forming a* peat *marsh of considerable extent, wherein there are several stagnant, filthy pools, in which vast herds of swine may be seen constantly basking in the mud or rooting up the foetid and miasmatic soil of the adjacent quagmires.*

Two small, ciénega-like remnants, Monkey and Cottonwood springs, have persisted in this area.

Cottonwood Spring, immediately downstream from ruins of Fort Buchanan, is sporadically diverted below its source. Its waters have deposited no recent travertine. The spring issues from a hillside adjoining Sonoita Creek and flows into it, unless diverted, after crossing a short reach of boggy, organic ciénega deposits dominated by low sedges.

Monkey Spring formerly deposited large amounts of travertine downstream from its source. An extensive natural lake and later an artificial pond were impounded by these deposits until its seal was broken by heavy machinery (Minckley, 1973). All that remains today is an often-dry, artificial impoundment, and the now-dry travertine (Fig. 19). Despite proximity of the area to Fort Buchanan, which thrived in the 1870s, only one account of this spring was found. Pumpelly (1870) remarked that he did a morning excursion with Lieutenant Evans "...to see some springs which were forming a heavy deposit of calcareous tufa..." Today the springhead and approximately 20 m of run are fenced against cattle. Below the fence, flow is diverted into a concrete flume leading to an impoundment, from which water is drawn for irrigation. Virtually all natural habitats outside the short spring run (Fig. 20) have been destroyed, with no documentation of their structure and composition.

The geologic map of Wilson *et al.* (1960) reveals a rhyolite-andesite intrusion into the Sonoita Creek bed in the area of Cottonwood Spring that must have forced groundwater to the surface near Fort Buchanan. Faults in this intrusion presumably help produce both the thermal Cottonwood and Monkey springs.

Marshlands along Río Santa Cruz near San Xavier del Bac and Tucson formerly occupied what is now one of the most extensive examples of arroyo cutting in the region, and consequently have long since disappeared. Progression of this incision was observed by Tucson residents during floods of 1890–92, and thoroughly discussed by Cooke and Reeves (1976). Erosion initiated at man-made structures and progressed upstream. Marshes existing around Tucson just prior to the floods were recalled by Allison (undated) and incision of those near San Xavier del Bac was documented by Olberg and Schanck (1913) and Castetter and Bell (1942).

Historical descriptions again go scarcely beyond documentation of the existence of marshes. References to lush grasslands abound. Vegetational composition is rarely mentioned except when species provided feed for livestock. Allison (undated) described what was almost certainly a stand of Common Reed *(Phragmites australis)* along the river at the next ranch below Pete Kitchen's. He and Wheeler (undated) also remembered similar marshy areas at the base of "A" Mountain in Tucson.

The history of woody riparian vegetation is confusing, although more frequently described in journals. Bartlett (1854) was impressed by dense gallery forests along Sonoita Creek and near its mouth, where he measured a Cottonwood 8.5 m in circumference 1.5 m above the ground. Browne (1869) was especially impressed with grass cover in the valley, but often mentioned abundance of cottonwood and found an abundance of "mesquit (sic), cotton-wood, willow and walnut" at Calabasas. Evans (1945) found "towering cottonwoods" along the river. Durivage (1937), another gold seeker, noted Cottonwoods marking the dry river course below Tumacacori to Tucson. Parke (1857), however, thought Cottonwood, Willow, and Mesquite scarce near Tucson, and certainly Bahre and Bradbury's (1978) rephotography of boundary survey sites document deciduous riparian galleries near Lochiel and east of Nogales where none existed in 1892.

The now dry bed of Rillito Creek passes through the northern suburbs of Tucson, past ruins of Fort Lowell where it was perennial in the 1880s (Condes de La Torre 1970), to its confluence with Río Santa Cruz northwest of the city. East of there on Pantano Wash and its tributary Ciénega Creek may have formerly been the most extensive ciénega system in the basin. Small remnants persist today. The wagon road established along this drainage by Captain Cooke and his Mormon Batallion became an important cross-country route for gold seekers. Later the Butterfield Overland Stageline connected with it over the same pass across the north end of the Whetstone Mountains, skirted the south edge of the Rincon Mountains across lower Ciénega Creek, then followed Pantano (Spanish for "swamp") Wash and Rillito Creek to Tucson (Conkling and Conkling, 1947). The Southern Pacific Railroad subsequently replaced the stageline along the same route. Marshy conditions may well have existed along all those watercourses and they were collectively known as "Ciénegas de los Pimas." This extensive system was obviously known to indigenous peoples and was used by the Zuñiga party in 1748 (Hammond, 1931), as well as Comadurán's Mexican anti-Apache campaign (Dobyns, 1981). Eccleston (1950) followed the stream 8.0 km downstream from where he first entered Ciénega de los Pimas in 1849 before it sank into its bed and marsh vegetation ended. In his words "The water was in marshes, coming from springs and a little brackish....The grass, or rather cane, was some 6 feet high..." This vegetation was accidentally ignited by Eccleston's party, who barely managed to save their teams and wagons. Way (1960), in the diary of his 1858 stagecoach trip, described the water as "...clear and beautiful, but slightly alkaline." He added

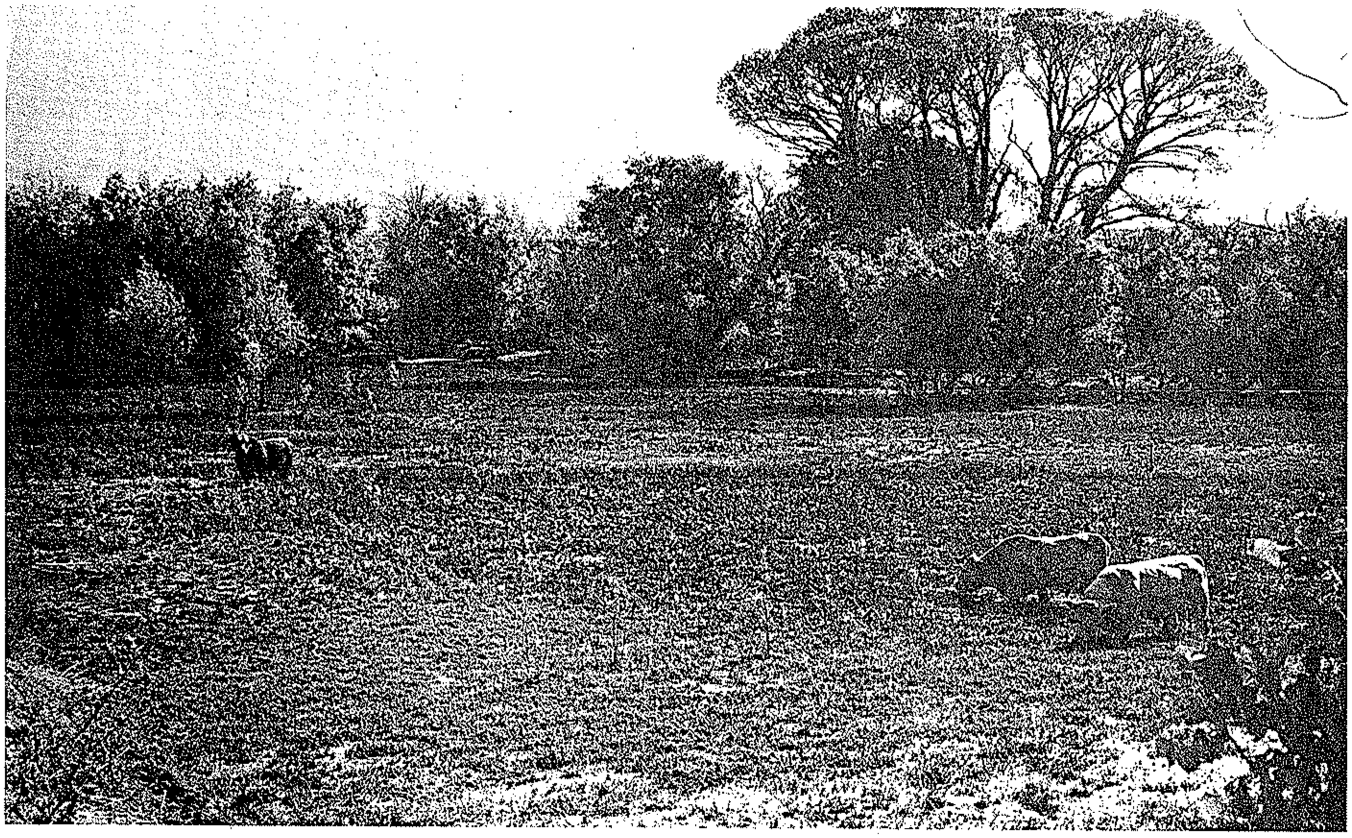


Figure 14. Ciénega Creek, Arizona: uncut, impounded ciénega adjacent to stream channel. Photograph 1980.

Figure 15. Ciénega Creek, Arizona: ciénega and riparian gallery formation on floor of incised stream. Photograph 1980.

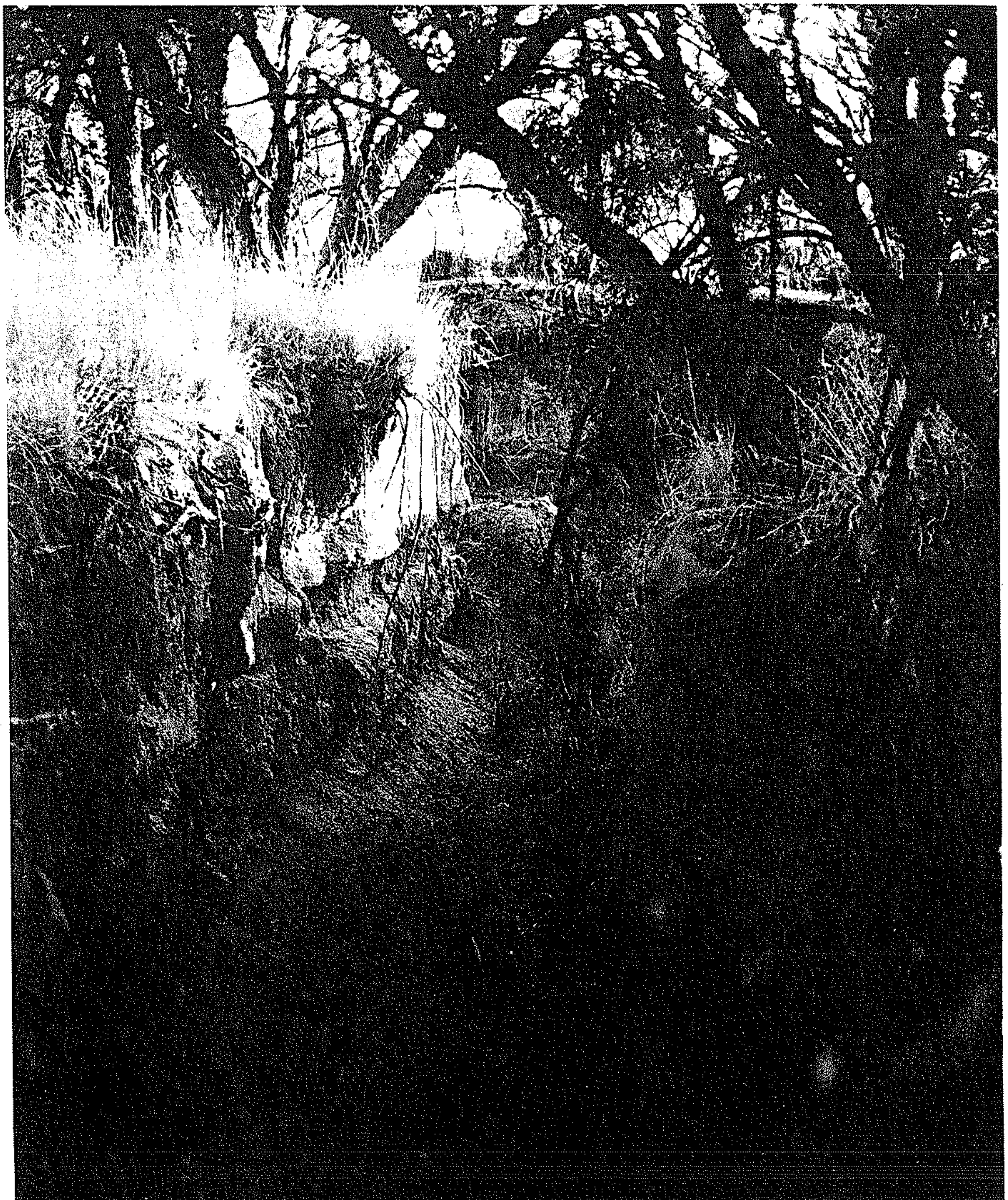


Figure 16. Ciénega Creek, Arizona: arroyo incision with subsequent Mesquite invasion. Photograph 1980.

that "The valley is a delightful looking place and its cool water, green foliage and scrubby trees look like paradise to the weary traveler over the hot and parched up plain."

Approximately a 5.0-km perennial surface flow persists today in Pantano Wash (Condes de La Torre, 1970; Brown *et al.*, 1981) above a basaltic dike (Davidson, 1973) at the railroad crossing. It infiltrates into streambed alluvium immediately below this structure, apparently near where Eccleston (1950) noted its disappearance in 1849. It thus seems likely that this same dike brought groundwater to the surface for marsh formation and maintenance. Nothing remains of the wetland today and an average annual discharge of 6.3 x 10^7 m^3 (Condes de La Torre, 1970) flows through a sandy bed, deeply incised into surrounding alluvium and bordered by mesquite.

Ciénega Creek probably took its name from Ciénega de Los Pimas. Smith (1910) referred to the entire lower Ciénega Creek Valley as:

...an unbroken forest, principally of mesquite, with a good growth of gramma and other grasses between the trees. The river course was indefinite,—a continuous grove of tall cottonwood, ash, willow and walnut trees with underbrush and sacaton and galleta grass, and it was further obstructred by beaver dams.... Such portion [of rainfall] as found its way to the river channel was retarded and controlled in its flow, and perhaps not oftener than once in a century did a master flood erode and sweep the river channel.

He described a major flood in 1881 that spread out over the valley, but later floods (1890s) which incised. The 1869 General Land Office Map of the Arizona Territory went so far as to extend "Ciénegas Las Pimas" from Tucson upstream to the town of Pantano. Granger (1960) cited another earlier map that did the same. The 1875 War Department Surgeon General's Office report on Army hygiene (U.S. Army, 1875) mentioned perennial flow ending about 1.6 km below Fort Lowell and stated that near the post Rillito received underground flow from the ciénega "...about twenty-three miles distant from this camp."

Another important marshland is still represented by remnants 16 km upstream along Ciénega Creek. While not reported as early in historical literature, inferences about prehistoric ecological conditions have been made by Schoenwetter (1960). Martin *et al.* (1961), and Martin (1963a), using palynological analyses. Their data indicate the ciénega as prehistorically more extensive, but with evidence of alternating periods of degradation and aggradation. At the northern (downstream) edge, where a deep incision now exists, a 13th Century cut may also have occurred and subsequently filled. Upstream, where ciénega habitat is actively rebuilding within an incision, evidence of the 13th Century arroyo was not detected, but later dissection was indicated during historic time. A long interval of predominately undissected ciénega conditions (dominated by ragweed pollen, *Ambrosia trifida* and *A. psilostachya*) over the last 3,500 years was, however, indicated. An absence of sediments older than 4,000 years was interpreted by Martin (1963a) as indicative of an older, extended period of erosion. It is significant that corn (*Zea* sp.) pollen was present. This, plus Eddy's (1958) study of cultural time spans contemporaneous with Martin's pollen stratigraphy, indicate the ciénega as an important resource to prehistoric cultures.

In historic time, ranches developed on upper Ciénega Creek became widely known. Hinton (1878) mentioned abundant springs, which furnished a large volume of water. It may have been here that Graham (1852) found abundant grass and a valley "quite boggy in the middle," which forced them to keep to the western side. Wagoner (1960) reported the Empire Ranch was grazing 5,000 head of cattle in the 1880s, and there were 1,000 cattle and 23,000 sheep on the adjacent Ciénega Ranch. Reminiscences of Vail (undated), one of three joint owners of the Empire Ranch in 1880, described the land as a succession of meadows thickly covered with Sacaton and Salt Grass. Mesquite grew only in gulches.

The Sacaton flats are presently invaded by Mesquite. One marshy area still exists at Ciénega Ranch, retained by an earthen dike along the edge of a drained meadow. Arroyo incision has been extreme, and vertical walls exceeding 8.0 m high are not uncommon through dense Mesquite bosques (*e.g.* Martin 1963a, plate 11).

Surface flow in the arroyo remains permanent along an approximately 12-km reach above a dike of Permian limestone, Cretaceous shale, sandstone, and conglomerate (Wilson *et al.*, 1960). Conditions have promoted streambed succession to a substantial ciénega along part of the arroyo floor (Figs. 14, 15, 16). Willows are established and the streambed is choked with Watercress (as well as *Ludwigia natans*, *Bidens* sp. and *Hydrocotyl verticillata*) growing in rich organic sediments. The channel is often ill-defined within constraints of arroyo walls, but occasional vertical-walled pools are present. Commercial developments on the Empire Ranch above the perennial reach have been planned by Gulf American Corporation Properties, who projected a maximum population of 42,000 persons within 70 years. A study of adequacy of groundwater supply (Arizona Water Commission, 1972) indicated that lowering of the water table as much as 100 m and depletion of base flows were likely, not only in Ciénega Creek, but also Sonoita Creek and Babocomari River.

One additional isolated ciénega exists in the upper Santa Cruz basin on Arivaca Creek (Fig. 21). According to Granger (1960), Kirk Bryan translated the Pima name Arivaca as "little reeds" or "little fence water." Riggs (1955), however, believed it to mean "where little people [small animals] dig holes." Whatever the origin of the name, Arivaca's water gave it an early historical importance. It was mentioned by Padre Kino as a *visita* of Guevavi, and was the site of the 1751 Pima revolt (Guiteras, 1894). Browne (1869) mentioned that it was:

...long celebrated for its rich mines and fine pastures... It contains a large amount of rich meadow land bordering on a never failing stream; it is well watered with oak, walnut, ash, cottonwood and mesquit [sic], and is capable of sustaining a population of 5 to 6,000 souls.

Hinton (1878) published a plate of the valley, which obviously depicted an expansive, unincised ciénega. Way's (1960) diary entry stated that the ranch in 1858 contained more than "...seventeen thousand acres of agricultural land, with permanent water, wood and grass." The ranch

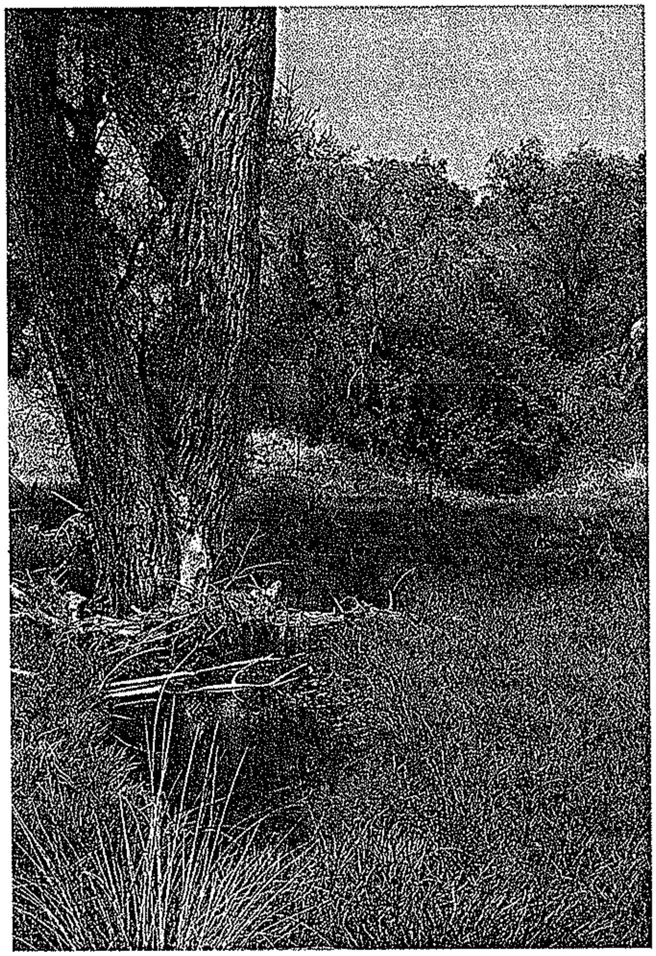


Figure 17. Upper Santa Cruz drainage, San Rafael Valley, Arizona: Sheehy Spring, a mature ciénega community partially modified by introduction of non-native plants. Photograph 1982 by G. K. Meffe.

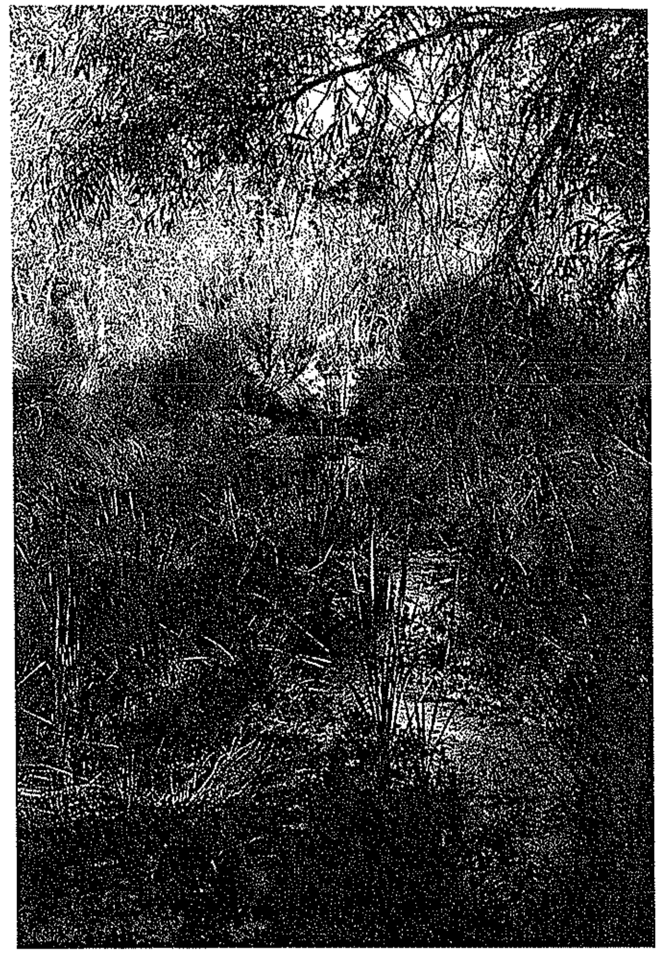


Figure 19. Monkey Spring, Arizona: headspring. Photograph 1982.

Figure 18. Upper Santa Cruz drainage, San Rafael Valley, Arizona: Sharp Spring Ciénega forming in arroyo near Sheehy Spring. Photograph 1981 by G. K. Meffe.

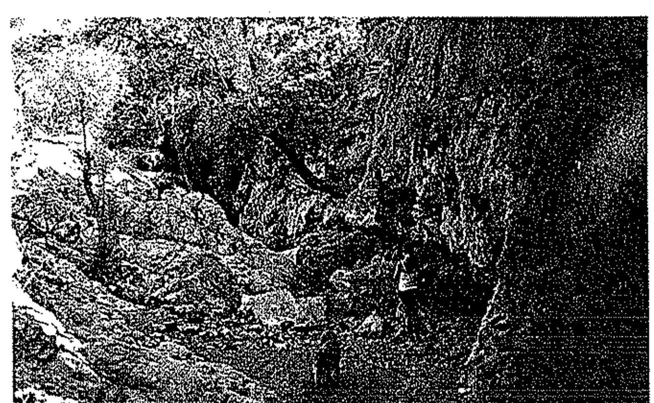


Figure 20. Monkey Spring, Arizona: inactive travertine formed by outflow of spring prior to diversion in the late Nineteenth Century. Photograph 1982.

to which he referred was the two *sitio* Land Grant issued to Tomás and Ignacio Ortiz in 1833 (Mattison, 1946). The area had long been known for its rich mines (Guiteras, 1894), and in 1856 the Sonoran Exploring and Mining Company obtained the land and established reduction works at Arivaca for the Heintzleman Mine on Cerro Colorado and other mines on the ranch (Mowry, 1864). The Mexican title was apparently lost and in 1902 the Court of Private Land Claims refused an appeal to confirm title to Arivaca Land and Cattle Company (Mattison, 1946).

A geological explanation for this ciénega is a dike of Cretaceous shales, sandstone, conglomerate, and limestone in the Las Guijas Mountains, which outcrops through Quaternary silts, sands, and gravels at Arivaca (Wilson *et al.*, 1960). These older rocks are obviously less permeable than alluvium, and force groundwaters to the surface. The short reach of perennial surface flow extends about 5.0 km through an incised channel below the road in Arivaca, and a short distance above, where ciénega habitat persists.

Just south of Arivaca is a large, mostly-dry meadow, a remnant of the formerly more extensive ciénega, edged by huge Cottonwood trees. Similar meadows extend upstream some distance, and younger Cottonwoods now line the stream course. Incision near the turn of the century extended above the present road to drain the ciénega, but construction of a concrete ford, which serves as a check dam, has resulted in aggradation and succession, now filling the arroyo. In light of its status as a significant remnant, preservation of this ciénega as a Natural Area was proposed by Smith and Bender (1973b).

Bryan (1952b) briefly recounted the little-known history of arroyo cutting in Arivaca Valley; in 1855 there were springs among the tules, a fine ciénega in 1863, and a *laguna* near the reduction works. The flood of 6 August, 1891 initiated entrenchment. As Cooke and Reeves (1976) pointed out, reasons for incision at Arivaca are unclear, although erosion lower in the drainage along Brawley Wash in Avra Valley was indisputably associated with artificial drainage concentration. Groundwater pumpage in the Avra valley is extensive and water tables have now undergone major declines (White *et al.*, 1966).

Gila River Mainstream. The vast importance of this major river to aboriginals, early explorers, travelers, and settlers is thoroughly documented (McClintock, 1921; Corle, 1951; Burkham, 1972; Dobyns, 1978, 1981; Rea, 1983) and cannot be over-emphasized. Aboriginal populations diverted its waters into elaborate and extensive irrigation systems and exploited its fishes (Kino, 1919; Bringas, 1977) as well as game in its riparian zones. Spanish explorers used it as a passage through inhospitable deserts, and in the 1820s the first American trappers found Beaver exceptionally abundant (Pattie, 1833). Reaches of its bed were heavily traveled by 49ers enroute to California. Within the next few decades agricultural communities developed on its banks.

We know from numerous journal descriptions in the mid-19th Century and before (Rea, 1983) that the Gila River also differed considerably from what we see today. Burkham's papers (1970, 1972, 1976a-b), most notably that of 1972, as well as Turner (1974), and others resulting from the U.S. Geological Survey's (USGS) Phreatophyte Project (Culler *et al.*, 1970), summarized and discussed changes which occured in the riverbed, and their hydrological implications. Summarizing results of Burkham's (1972) review of journals, surveyors' notebooks, and other sources, the Gila River in eastern Arizona:

> *...before 1875...probably was less than 150 feet [46 m] wide and 10 feet [3.05 m] deep at bankfull stage. The river meandered through a flood plain covered with willow, cottonwood and mesquite.*

The channel widened to 610 m between 1905 and 1917, and then narrowed again to 61 m by 1964. More recently the channel has again been widened by flooding, to 122 m in 1968 (Burkham, 1972), and to much more following high waters of 1978–79 (Minckley and Clark, 1984). Willow and Cottonwood are largely replaced by the exotic Saltcedar, *Tamarix chinensis* (Robinson, 1965; Culler *et al.*, 1970; Turner, 1974; Ohmart and Anderson, 1982). A similar pattern is documented in central Arizona (Eckman *et al.*, 1923), where Rea (1983) speculated that floods of 1905–17 washed out extensive marshlands that were never to return.

Apparent references to marshlands along and associated with the Gila River are found as far back as Coronado's 1540 explorations. His party is believed to have crossed the river near Geronimo (Fig. 9), where he described it as "...a deep and reedy stream" (Calvin, 1946). In 1864, Assistant Inspector-General of the U.S. Army, N. H. Davis, recommended to Captain Benjamin C. Cutler that Fort Goodwin be established on "La Ciénega Grande," in this same area (Davis, 1864). The fort was established, but had to be abandoned in 1870, largely due to malaria (Granger, 1960). This marsh has now disappeared. A high water table persists there, however, as the river is still perennial (Brown *et al.*, 1981), and an abundance of wells (24 in 7 adjacent sections on USGS [1960], Bylas 15′ topographic map) exploit it for agriculture. Downstream from old Fort Goodwin, along terraces on the north side of the Gila River, small ciénegas persist in springs and seeps near Bylas (Fig. 22). These springs flow from mounds or shallowly incised sources to spread and evaporate on the Saltcedar-dominated floodplain (Meffe, 1983; Meffe *et al.*, 1983). Marshes also persist at Indian Hot Springs near Eden (P. S. Martin, pers. comm., 1982).

Much further downstream, south of Phoenix, former wetlands mapped by Brown *et al.* (1981) are clustered up- and downstream from the mouth of the Santa Cruz River. Reaches of both the Gila and Santa Cruz rivers upstream from this area were typically dry during drought for the former and year-around for the latter. Sedelmayr (1955) described Indian settlements of the middle Gila River in 1744 as consisting of three rancherias, two near the Casa Grande (now Casa Grande National Monument), and "Still farther on the river runs entirely underground in hot weather, and where it emerges there is situated the great rancherias called Sudacsson [= Sudacson, *fide* Rea, 1983]." Russell (1908) noted that the dry reach of the Gila River was 120 km long, and perhaps resulted from upstream diversion of water for Indian irrigation. Emory (1848) noted diversions that dried segments of the river in this same reach, and Clarke (1852) commented that "Nearly the whole of the Gila is drawn off by zequias [*sic*] for irrigation..." Sweeny (1856) was told that the river was dry in this reach in summer 1851 due to its diversion by Pimas and Maricopas, and Bartlett (1854) observed this phenomenon the following summer, which again was attributed to "....water having been turned off by the Indians to irrigate their lands..."

Reasons for lack of surface water in the lower Santa Cruz, from a few kilometers north of Tucson to Sierra Estrella (Figs. 12, 13), also may include irrigation in its upper reaches. However, alluviation of the broad valley seems more of a factor. Modern topographic maps and aerial photographs clearly depict alluvial fans of the Gila forcing the Santa Cruz westward against bajadas of Sierra Estrella, producing a sediment "plug" behind (south of) which distributaries of the Santa Cruz and large, associated washes have deposited the "Santa Cruz Flats." The relatively narrow passage separating Sierra Estrella and South Mountain and inflow of Salt River just downstream from that defile also may be major factors perpetuating permanent stream flow in this region. First, bedrock must be shallower near these mountain blocks than in basins, thus forcing subsurface water to the surface. Second, proximity of mountainous terrain upstream on the erosive, high-volume Salt River should have resulted in large volumes of coarse alluvium that the lower-volume, less competent waters of the Gila could not remove, resulting in an alluvial plug and natural impoundment. Multiple channels, oxbows, "lagoons," "ciénegas," marshes, "many small creeks and seepage waters," and so on, recorded from the 17th through early 20th centuries in this area (Bartlett, 1854; Audubon, 1906; Kino, 1919; Sedelmayr, 1955; Bringas, 1977; Mathias, in Rea, 1983) all are descriptors of a complicated distributary system passing through an elevated, delta-like, alluviated area for both the lowermost Santa Cruz and middle Gila River.

Santa Teresa, later named Maricopa Wells, was an important watering place a few kilometers south of Río Gila along the Santa Cruz. Sedelmayr (1955) named the area, and described it as "...broad savannas of Reed Grass and clumps of Willow and a beautiful spring with good land for pasturage." Guiteras (1894) also noted "...a very copious spring." Bringas (1977) may have referred to the same place in the late 1700s as "...a ciénega which is to the west of the pueblos." In 1846, Turner (1966) described Maricopa Wells as "...a spot where the grass is excellent, wood sufficiently abundant, and water a short distance off." Bartlett's (1854) party camped there in 1852 and described it as follows:

...we reached some waterholes [Maricopa Wells]...It was indeed a pleasant sight to find ourselves once more surrounded by luxuriant grass. Although we had met with a little salt grass in one or two places on the march, which no animal would eat if he could get anything else, we had not seen a patch of good grass since leaving our camp at San Isabel [sic], *fifty-six miles from San Diego [California]...we turned the mules out to luxuriate on the rich pasture before them, and creeping under some mezquit* [sic] *bushes, soon fell asleep...The water here is found in several holes from four to six feet below the surface, which were dug by Colonel Cooke on his march to California. In some of these holes the water is brackish, in others very pure. The Gila passes about two miles to the north; for one half of which distance the grass extends, the other half being loose sand.*

We expect this area represented the point where water rose from the Santa Cruz aquifer in response to impervious subsurface layers, perhaps those of the Sierra Estrella-South Mountain block(s), or as part of a burgeoning subsurface aquifer fed both by the Santa Cruz and Gila rivers. Ciénega conditions were almost certainly achieved, at least locally. Along the adjacent Gila River, however, riverine marshes appear to have prevailed.

Rea (1983) summarized most literature just cited, and more, to place the middle Gila River reach in the following ecological perspective:

Aboriginally the Gila at the Pima Villages was a stream of sufficient width to support tillable islands. Throughout most of the year the depth in most places was probably not usually greater than 3 feet (1 m) and the river was readily fordable on foot. At times the entire surface flow was diverted for irrigation or sank for part of its course into the sand. Such observations were probably coincident with seasonal periods of drought in the watersheds. The river gradient was shallow and the floodplain was so level that lagoons formed in places along the main channel. At least three such marshy areas existed along the Gila on what is now the [Gila River Indian] reservation: near Sacaton, at the confluence with the Santa Cruz River and at the mouth of the Salt River. The channel was well defined, and the banks were consolidated and well vegetated. Beaver abounded. Riparian timber consisting mostly of cottonwood, willow, and ash, was well developed. There was a dense understory of arrowweed, batamote, graythorn, and cane. The bottom lands were fertile, 6 to 8 miles (9.6 to 13 km) across and a strip several miles wide was cultivated by the Pima and Maricopa. Back from the fields and riparian growth were dense mesquite bosques.

Though spotty, grasslands and pasturage were well developed on at least two areas on or near the reservation. About 8 miles (13 km) above Sacaton and below Casa Grande Ruins was a grassland many miles long....A second major grassland was west of Sacate and several miles south of the Gila, where a number of drainages (Vekol Wash, Greene's Wash, Santa Rosa Wash) running northwest converged with the Santa Cruz Wash, which once again became an above-surface stream approximately where it entered the reservation....Itinerants found abundant and luxuriant pasture for as many as a thousand pack animals and cattle. The water table was only 4 to 6 feet (1.2 to 1.8 m) below the surface. Peculiar edaphic conditions impregnated some of the lagoons and wells with so many soluble chemicals that their brackish water affected animals and man...

Indications of riverine marshes rather than ciénega conditions include frequent mention of "reed grass," "carrizo," or "cane" (= *Phragmites communis*), "willows," "wild willows," or "alders" (= *Salix* spp.), and "batemote," "water willow," or "water-mote" (= *Baccharis salicifolia*) (Russell, 1908; Gilman, 1909; Eccleston, 1950; Evans, 1945; Sedelmayr, 1955; Garcés, 1968; Mathias, in Rea, 1983). In addition, notes by Emory (1848) on lines of trees marking abandoned river channels and on the presence of "quaking ground" indicated marshland conditions. Specific references to Cattail and large Sedges are surprisingly few in number, but reference to marshes or swamps where these plants dominate typically indicated avoidance of such places by horsemen. Mathias (in Rea, 1983) recalled *Scirpus* and *Typha* as common in

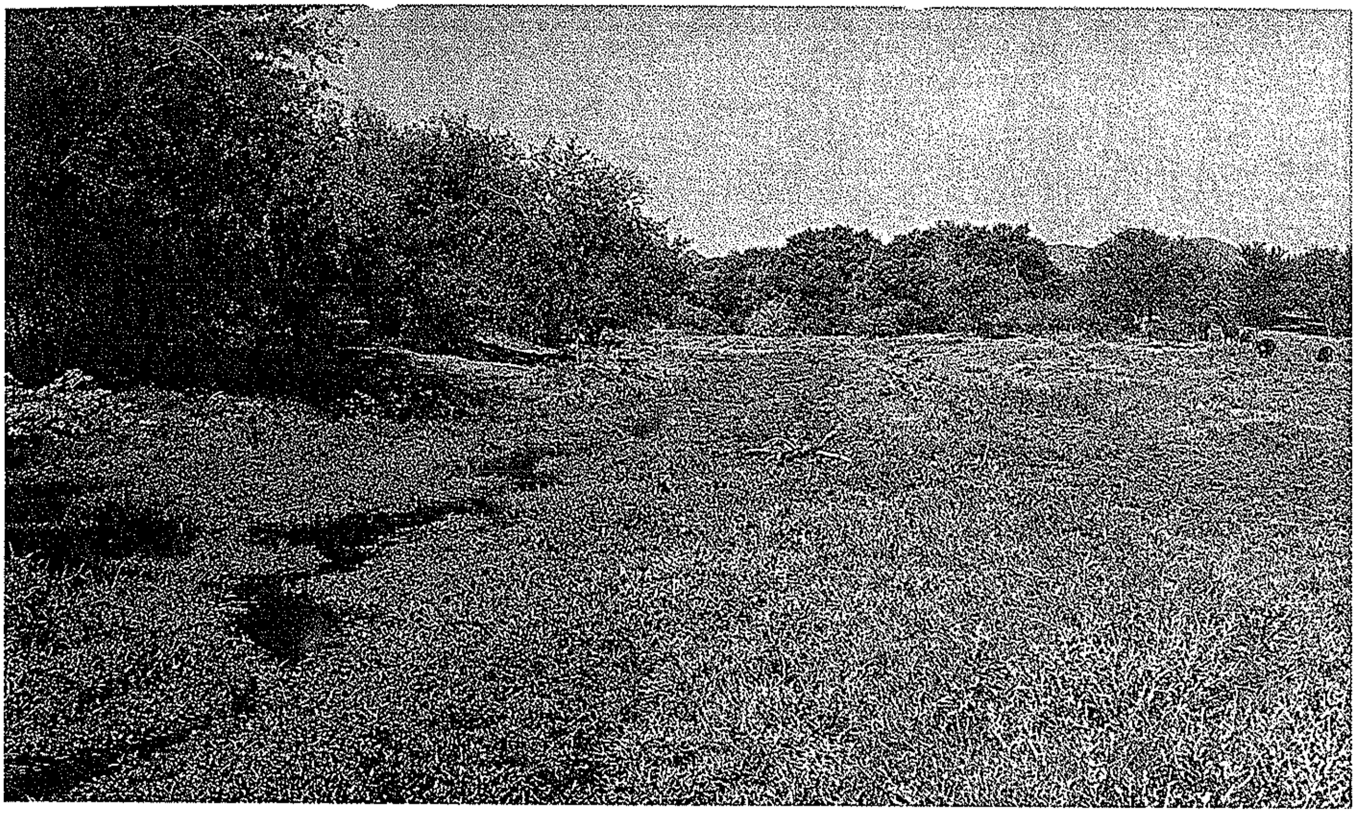


Figure 21. Arivaca Ciénega, Arizona. Photograph 1981 by Douglas G. Koppinger.

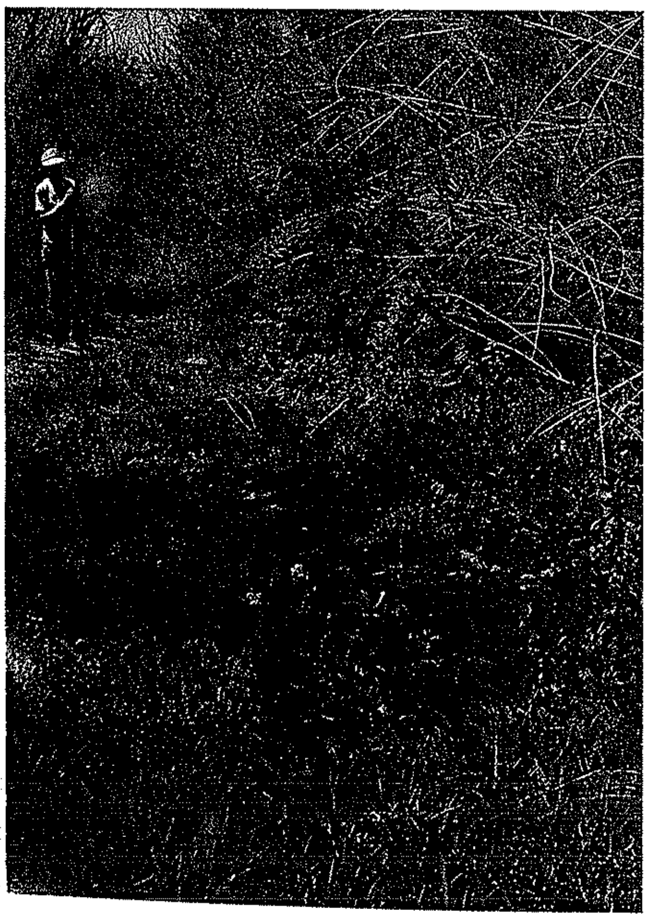


Figure 22. Bylas Springs, Arizona: Ciénega formation along one of several spring runs. Photograph 1982 by G. K. Meffe.

lagoon-like habitats of the region in the early 1900s, but Gilman (1909) mentioned a "tule marsh" only once in his description of the area. As noted before, Rea (1983) proposed that channel cutting by floods of 1905–17 (Burkham, 1972) destroyed these marshlands.

Discussion

Historical evidence demonstrates a wider distribution of ciénega and riverine marshland than is found today in Southeastern Arizona. That unincised, largely perennial streams of the 1850s became today's intermittent arroyos is well documented. The cycle of erosion and arroyo cutting that left only remnants of these habitats has been thoroughly discussed by various authors, without reaching concensus as to ultimate factors of causation.

Impacts of aboriginal man on regional ecology are variously interpreted. Hastings and Turner (1965) discussed the frequent assumption that Angloamerican culture arrived and altered a previously "natural" environment. They pointed out that a large Indian population undoubtedly was reflected in a degree of environmental change, yet did not feel that Indian activities had more than a minor influence on determination of vegetation patterns or erosion rates. They proposed that the greatest impact of Apaches on ecological history of the region may have been suppression of development of cattle and mining activities by other peoples, and thus delay of the impacts of heavy grazing.

Dobyns (1981), on the other hand, argued emphatically that influences of prehistoric man have been repeatedly under-estimated. He offered complex, multivariable hypothetical models of vegetation change and arroyo cutting based on historical and archaeological records of Indian activities. Dobyns' arguments focused on inferred broader Apache use of fire for hunting, greater impacts of aboriginal livestock herding, as well as greater affects of food and firewood gathering. He also suggested that erosion-control structures maintained by Puebloan peoples in headwaters, and flood-dispersing capabilities of diversion dams on lower mainstreams by Piman irrigation systems decreased erosion. Extreme human population crashes from epidemic disease and consequential neglect of these structures may have contributed to renewed cycles of erosion.

Impacts of 125 years of Spanish missionary, ranching, mining, and military activity, as well as a brief period of Mexican ranching, have not been widely implicated in discussions of causation of environmental change. Locally large livestock herds were maintained, although most ranching ventures were short-lived (Haskett, 1935, 1936; Wagoner, 1952, 1960).

Angloamerican impacts of grazing, vegetation change, wood cutting, mining, water diversions, groundwater exploitation, and artificial drainage concentration by roads, ditches, bridges, and railroads have been widely covered (Thornber, 1910; Duce, 1918; Bryan, 1922, 1925a–b, 1926, 1940; Thornthwaite *et al.*, 1942; Leopold, 1951b; Antevs, 1952; Humphrey and Mehrhoff, 1958; Hastings, 1959; Hastings and Turner, 1965; Denevan, 1967; Burkham, 1970, 1972, 1976a–b; Cooke and Reeves, 1976; Dobyns, 1978, 1981). In light of previous reviews, we feel no need to expand on these points. However, at least one important aspect associated with direct impact of grazing on bottomland vegetation has been overlooked.

Early data on numbers of cattle in Arizona counties were based on tax assessments, which likely underestimated actual numbers. Governor F. A. Tritle in 1885 claimed that at least 50% could safely be added to returns of the county assessors (Wagoner, 1952). Using such a correction we calculate an average of 377,474 cattle were grazing lands of Cochise, Santa Cruz, Pima, and Graham counties over the 5-year period preceeding the 1893 drought. Assuming greater accuracy of more recent reports, an average of only 180,200 cattle have grazed the same area over the period 1977 to 1981 (Arizona Crop and Livestock Reporting Service, 1981). We nevertheless see heavy impacts of grazing activities today, especially at watering sites.

Impacts of cattle on aquatic and riparian areas prior to the 1893 drought furthermore should have been even greater than double those of today. Cattle rarely travel greater than 5 km from water (Valentine, 1947; Herbel *et al.*, 1967), and only lightly utilize range greater than 3 km from water. Therefore, cattle in the 1880s must have been concentrated within a 5-km radius of natural streams. Since the innovation of stock tanks in the Arizona cattle industry did not occur until near the turn of the century, otherwise usable land would have been grazed at most seasonally. Vast areas of the region are greater than 5 km from natural surface waters (Brown *et al.*, 1981). Assuming a 5-km radius of grazing from water, we estimate that only 27 critically situated stock tanks would increase area available to cattle an amount equal to that provided by the Río San Pedro if it were perennial along its entire length. We thus hypothesize that stock tanks greatly reduce impacts on natural waters and riparian zones by providing more uniform livestock distribution. Effective cattle densities near natural waters must be greatly diminished from pre-turn-of-the-century levels. A more detailed analysis of this situation would be enlightening.

Long-term trends of climatic change were believed by Euler *et al.* (1979) to be ultimately responsible for arroyo incision, although they felt cultural activities may have advanced timing of initiation. They invoked multiple lines of evidence for prehistoric cycles of incision and climatic change. Bryan (1940) and Hall (1977) also recognized that overgrazing may have been only accessory to climate in incision causation. Considerable debate has centered over whether increased (Antevs, 1952; Martin, 1963a; Hall, 1977) or decreased (Bryan, 1940; Judson, 1952; Antevs, 1962; Euler *et al.*, 1979) rainfall, or perhaps changes in rainfall frequency and pattern (Leopold, 1951a; Hastings and Turner, 1965; Cooke and Reeves, 1976) caused initiation of incision cycles. Cooke and Reeves (1976) thoroughly discussed earlier examinations of regional climatic change as a factor in arroyo incision, as did Hastings and Turner (1965), but problems arose from lack of meteorological records prior to about 1895. They noted an apparent trend of decrease in mean annual precipitation since 1895, with greater decreases (5.0 cm) in winter rainfall than summer (3.0 cm). Temperatures increased slightly (0.56°C in winter, 1.11°C in summer). However, detailed analysis of daily rainfall data revealed no statistically significant changes in annual, annual summer, or annual non-summer precipitation totals during the century. They noted occasional droughts often followed by wet periods, and significant increases in frequency of light rains coupled with decreases in high-intensity rainfall over the same period.

Brown and Henry (1981) correlated the Palmer Drought Severity Index (PDSI), calculated from rainfall data for this century, with changes in southern Arizona deer populations. Increased incidence of drought in recent decades was evident in their analyses. This index may also serve as a useful indicator of critical moisture relationships for vegetation and its effect on stream flow regimes and erosion. Annual PDSI values might be calculated for earlier time periods using precipitation data inferred from tree rings. Dendrochronological data for the area has been widely accumulated and interpreted by workers at the Tree Ring Laboratory in Tucson (see numerous publications of Bannister, Blasing, Clark, Fritts, La Marche, Schulman, Smiley, Stockton, and their collaborators, included in the bibliography). Such valuable data have inferentially extended knowledge of past precipitation patterns and effects on hydrology and vegetation far into prehistoric times.

The argument that arroyo incision has been related to climatic shifts was countered by Patton and Schumm (1981), who presented field data indicating that geomorphological parameters are principal determinants of spatial and temporal patterns of arroyo cutting and filling, and that a close correlation between widespread climatic change and alluvial chronologies is not necessarily expected. Nevertheless, so long as massive degradation of the receiving system did not occur, headward erosion in tributaries could not physically occur. Conversely, substantial degradation of receiving streams should promote, accelerate, and perpetuate cutting in tributaries. Flooding in the 1880s was followed closely by similarly high runoff and further degradation of the Gila River in the period 1902–17 (Burkham, 1970), which may alone be adequate to explain incision throughout much of the drainage basin.

There seems little doubt that a combination of factors resulted in the geologic event of arroyo cutting. However, it also seems clear that events culminating in that catastrophe were influenced by man, and that livestock played a role in the scenario. Concentration of cattle along watercourses in southeastern Arizona in 1891–93 must have resulted in remarkable damage to riparian communities. Ciénegas, located at points of the most permanent water supplies and as a result supporting lush plant communities made up of species palatable to cattle, must have been destructively grazed and trampled. Fragmentation of the sponge-like surface deposits by cattle promotes drying of parts of present-day ciénegas, and we can visualize direct disruption of these marshlands in this way, even in the absence of arroyo formation. Ciénegas can be trampled to quagmires if organic sediments are deep, or to barren channels where substrates are relatively solid. The last condition is indicated in a photograph of Monkey Spring in 1889 (Hastings and Turner, 1965).

Southwestern Stream Hydrology. Ciénegas are plant communities which develop in southwestern streams where groundwaters perennially intersect the surface, and where stability is such that they can persist. Their development and persistence are influenced by meteorologic, biotic and hydrologic parameters, and ciénegas in turn affect stream hydrology (see Figs. 23 and 24).

The dynamic nature of stream systems has long been recognized, and the dynamic equilibrium concept of geomorphology is important to thorough understanding of ciénegas. Simply stated, the principle of this concept (Chorley, 1962) is:

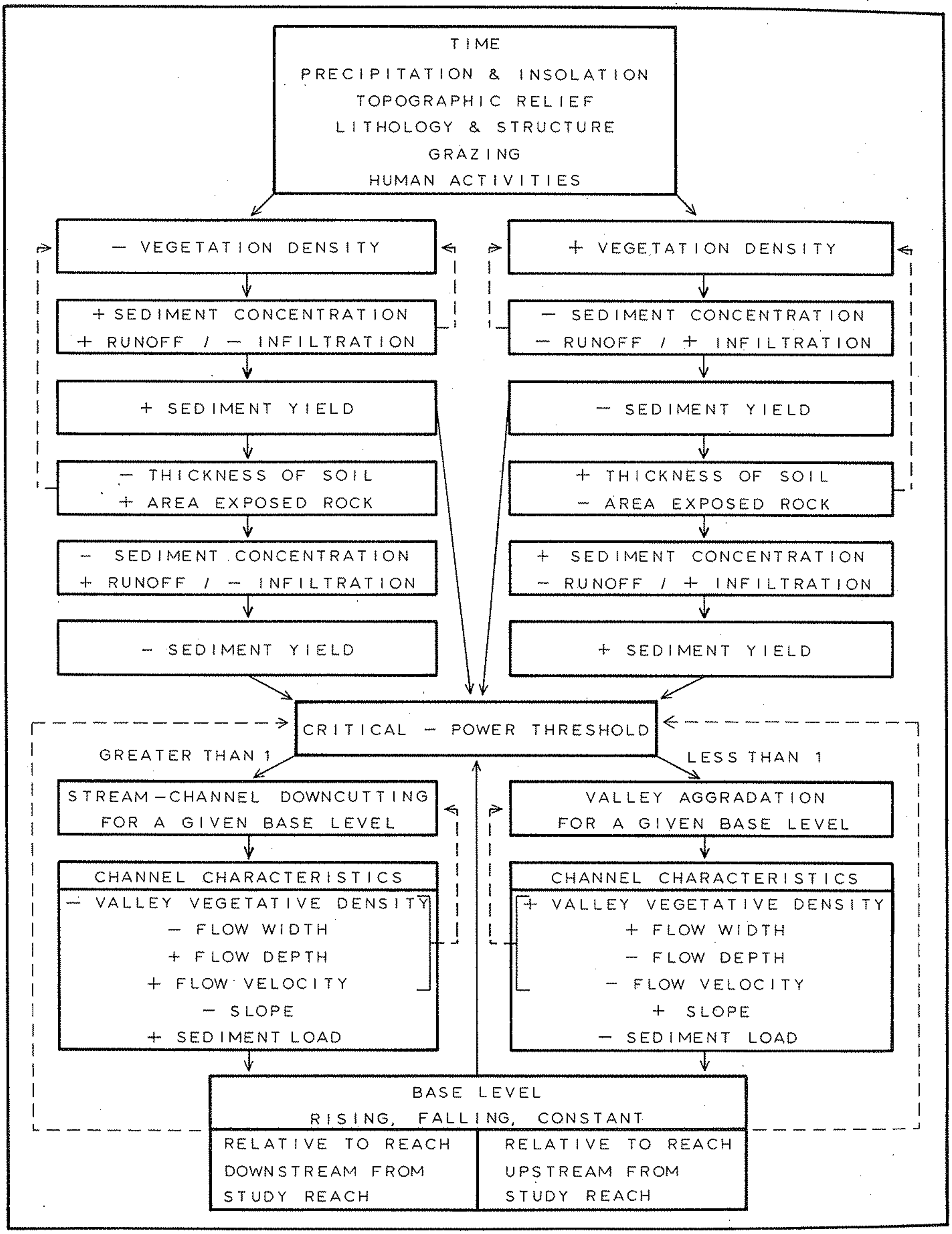
> *...that river systems proceed toward conditions of a steady-state balance, wherin the open systems balance a continuous (though not necessarily constant) supply and removal of water and sediment by adjustment of the geometry of the system itself. This steady-state open system is only rarely characterized by exact equilibrium, and generally the river and its landscape tend toward a mean form, definable only in terms of statistical means and extremes.*

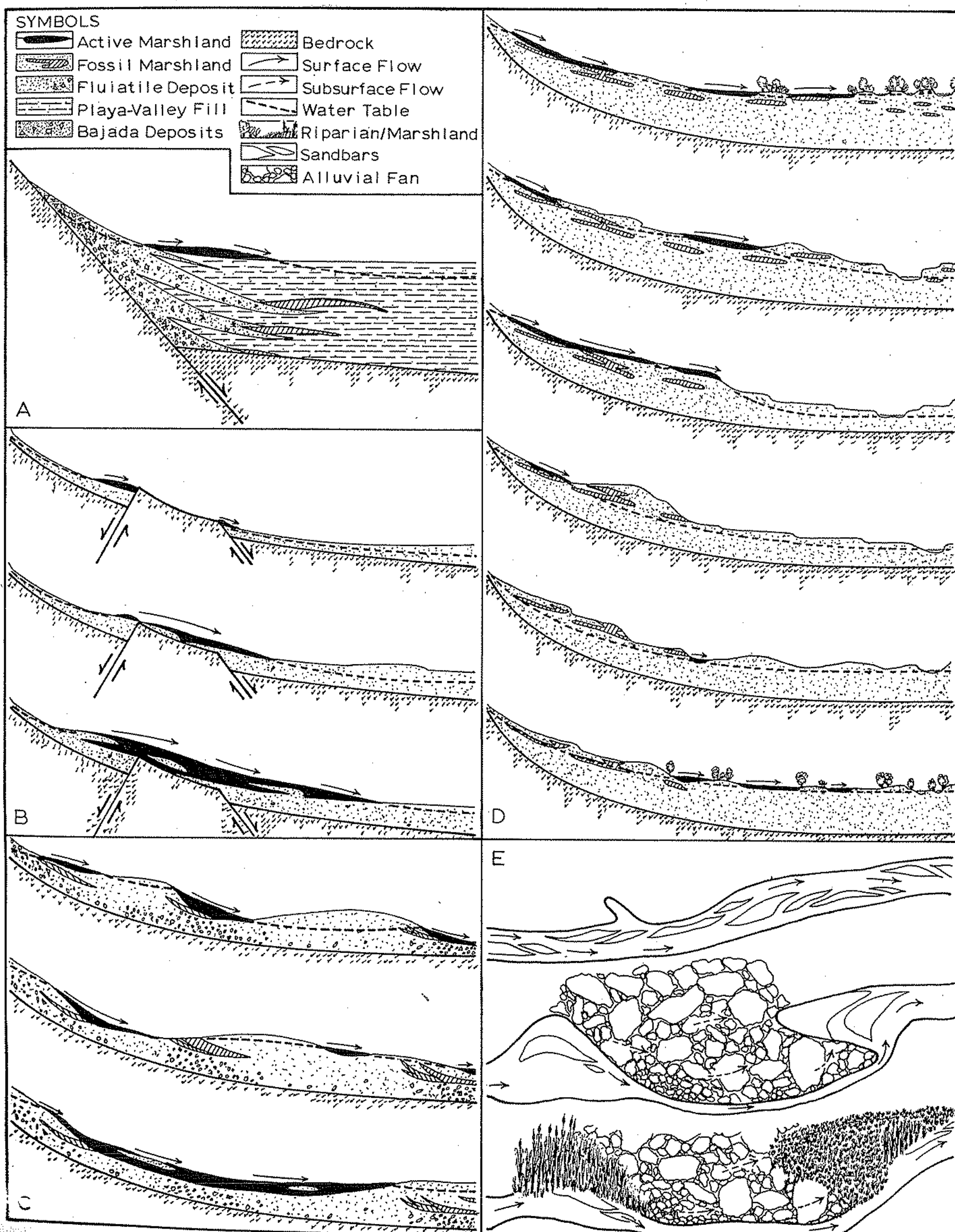
Unlike previous concepts, this "quasi-equilibrium" does not attempt to predict the ultimate form a river may take through a sum total of changes through time, but rather suggests a statistical range of immediate dynamic responses to any instantaneous change in the system. Rivers are recognized as not being static entities and not smoothly and continuously progressing toward an ultimate form. We now understand the river channel as a form representing the most efficient geometry, in terms of energy utilization, capable of accomodating the sum total of means and extremes of variability of flow that have occurred throughout its history (Curry, 1972). River channel and drainage hillslope variables thus interact, and the total system is in quasi-equilibrium, each variable reacting at different rates to compensate for changes in others (Schumm, 1977). Bull (1979, 1981) proposed use of his "critical power threshold" concept in analysis of the same basic hydrologic processes (see Fig. 23). Ciénegas are biological components of the physical stream systems. They are equally dynamic and reflect the history of watersheds in which they occur.

Our successional scheme proposed below is based on the presence of relatively stable discharge. Floods can rapidly remove accumulated organic deposits, and are of course a result of precipitation and runoff. Meteorologic and runoff conditions must therefore be examined relative to possibilities for stability sufficient to allow ciénegas to persist.

Martin (1963a) described summer anti-cyclonic monsoon rainfall patterns prevailing in the study area and their underlying meteorological bases (see also McDonald, 1956). Fogel (1981) provided statistical descriptions of spatial and temporal distributions and intensities of these precipitation events. High intensity, localized precipitation can produce destructive, sediment-scouring flash floods (*e.g.*, Ives, 1936; Jahns, 1949; Lewis, 1963; Melton, 1965; Fisher and Minckley, 1978; Collins *et al.*, 1981). Probability of a scouring flood at any headwater point is low, however, under a climatological regime with such temporal and spatial patchiness of precipitation. More geographically generalized and temporally protracted winter rainfall (distribution of which was also analyzed by Fogel, 1981) also contributes to increased

Figure 23. Simplified diagramatic interactions of hill slope and stream channel factors which influence hydrological and geomorphological phenomena. The Critical Power Threshold (C.P.T.) is defined by the formula $\frac{\text{stream power}}{\text{critical power}} = \text{C.P.T.}$*, where stream power is the ability of a stream to transport sediment, and as such is a function of discharge, velocity and sediment load as discussed in text. Critical Power (or Resisting Power) is the power required to transport the sediment load and thus varies with amount and size of sediment as well as channel roughness. Both stream power and critical power vary spatially and temporally. A stable system, or point in a system, occurs where C.P.T. = 1, with deposition found where C.P.T. < 1 and degradation where C.P.T. > 1. Dashed arrows depict self-enhancing feedback mechanisms. Given persistence of perennial surface flow and discharge stability for adequate time spans, ciénegas will develop wherever the system follows pathways to the right side of the figure. Changes in the system which result in situations depicted by the left-hand pathways produce incision. Responses will vary as a function of geological, meteorological and ecological factors including extent of alluvial fills as well as soil development and type. Form, rate and quantity of precipitation are important factors, as are extent and type of vegetation both on hillsides and in channels. Adapted from Bull (1981); copyright Institute of Ecology.*


TIME
PRECIPITATION & INSOLATION
TOPOGRAPHIC RELIEF
LITHOLOGY & STRUCTURE
GRAZING
HUMAN ACTIVITIES
− VEGETATION DENSITY
+ SEDIMENT CONCENTRATION
+ RUNOFF / − INFILTRATION
+ SEDIMENT YIELD
− THICKNESS OF SOIL
+ AREA EXPOSED ROCK
− SEDIMENT CONCENTRATION
+ RUNOFF / − INFILTRATION
− SEDIMENT YIELD
+ VEGETATION DENSITY
− SEDIMENT CONCENTRATION
− RUNOFF / + INFILTRATION
− SEDIMENT YIELD
+ THICKNESS OF SOIL
− AREA EXPOSED ROCK
+ SEDIMENT CONCENTRATION
− RUNOFF / + INFILTRATION
+ SEDIMENT YIELD
CRITICAL − POWER THRESHOLD
GREATER THAN 1
LESS THAN 1
STREAM−CHANNEL DOWNCUTTING FOR A GIVEN BASE LEVEL
CHANNEL CHARACTERISTICS
− VALLEY VEGETATIVE DENSITY
− FLOW WIDTH
+ FLOW DEPTH
+ FLOW VELOCITY
− SLOPE
+ SEDIMENT LOAD
VALLEY AGGRADATION FOR A GIVEN BASE LEVEL
CHANNEL CHARACTERISTICS
+ VALLEY VEGETATIVE DENSITY
+ FLOW WIDTH
− FLOW DEPTH
− FLOW VELOCITY
+ SLOPE
− SEDIMENT LOAD
BASE LEVEL
RISING, FALLING, CONSTANT
RELATIVE TO REACH DOWNSTREAM FROM STUDY REACH
RELATIVE TO REACH UPSTREAM FROM STUDY REACH



SYMBOLS
Active Marshland
Fossil Marshland
Fluiatile Deposit
Playa-Valley Fill
Bajada Deposits
Bedrock
Surface Flow
Subsurface Flow
Water Table
Riparian/Marshland
Sandbars
Alluvial Fan
A
B
C
D
E

probability of flood disturbance downstream as area increases. Drainage areas are again generally too small to supply adequate runoff from diffuse winter rains to produce scouring discharges near stream sources. Headwater streams are therefore the most likely places for stability to be achieved and maintained.

The capacity of soils to absorb rainfall determines amounts required to produce runoff. This is in turn a function of extent of soil development, geologic origin, structure and texture, vegetative cover, and previous moisture content. Equally intense thunderstorms on different basins may thus produce quite different types of floods. Shallow bedrock with little soil and vegetative cover will produce rapid runoff as sheet flow, and intense, short-lived ("flash") floods. Channel discharges of adequate stability to allow succession to ciénega are more likely to be found in areas of extensive soil development. Well developed, deep soils, with dense vegetation, allow greater infiltration and storage, and more precipitation is required to produce sheet flow and runoff. The net result is channel discharge dampening and attenuation by soil water storage. As a greater amount of work is done per volume of water by sheet flow than by channelized flow (Curry, 1972), more extensive sheet flow produced on barren soils carries more sediment to channels. Sediment load is, of course, also dependent on particle size, since smaller particles are more readily mobilized than larger ones. Furthermore, competence of flows to continue to mobilize sediments is inversely related to sediment load. For a given velocity of flow, less turbid waters are more competent than those already bearing heavy sediment loads. Gradient largely determines velocity, and thus also influences sediment transport, as does discharge volume that is correlated with drainage area. Channel roughness is another important factor influencing velocity. As channel roughness increases, velocity (and thus related factors) is diminished. The geographic location of ciénegas in Arizona in low-relief, rolling grasslands, or in alluvial plains bounded by relatively well-vegetated mountain fronts, is therefore not fortuitous. Slowing of runoff by dense vegetation, low gradients, and relatively deep soils undoubtedly contributes to their origins and perpetuation (Fig. 23).

Figure 24. Hypothetical diagrams depicting sequences of aggradation and degradation resulting in ciénega formation, maintenance, and destruction, with descriptions of physical biological events and features proposed to be involved in those scenarios. Scales are exaggerated. Refer to Figure 23 for definition of Critical Power Threshold (C.P.T.). (A) Ciénega development near lower edge of bajada where water table is impounded to intersect surface upon passage from coarse tributary alluvium to finer fill of receiving valley. C.P.T. < 1 in upstream portion of ciénega, producing aggradation of fine organic fills in active marshland. Downstream, as convexity increases due to upstream aggradation, increased slope and competence of flow produce C.P.T. > 1 and incision occurs. If flow stability is adequate, increased channel roughness created by vegetation can push the point where C.P.T. > 1 downstream, thus expanding ciénega. (B) Upfaulted bedrock across stream ponds alluvial groundwater producing succession to ciénega upstream. Downstream of upfaulted bedrock, increased slope and small alluvial aquifer on bedrock do not favor ciénega-forming conditions initially, but through mechanisms described for scenario A, ciénega may eventually extend downstream. (C) Fluvial deposition patterns of alternate convex and concave reaches produced by intermittent systems provide aquifers with surface seepage on steep downstream sides. If sufficiently constant, this seepage may allow ciénegas to form. Ciénegas may be removed by flooding which alters convex-concave pattern allowing succession to ciénega in new positions. (D) Ciénega evolution in tributary and receiving stream through varying cycles of change in base level of receiving stream at cross-section transect. Incision of receiving stream may lower water table causing extinction of ciénegas. Channel base level adjustments through time, along with stable water table, may eventually permit renewed localized succession to ciénega. Aggradation occurs in channels with eventual return to high water table and extensive ciénega conditions. (E) Impoundment of stream by course alluvium from landslide or deposited in receiving stream by flooding tributary. Stream power is far less than resistance of coarse bed load (i.e. C.P.T. < 1) and succession toward ciénega may ensue in new area of stability.

Ciénegas are channel phenomena, and thus are influenced by all hydrologic factors. They form at points where water permanently intersects the surface, and such points may be created in a myriad of physical ways. Coarse sediments carried by flash floods from tributaries can impound a receiving channel (*e.g.*, Cooley *et al.*, 1977) (similar to Fig. 24E), as can coarse materials dropped after flow dissipation through infiltration of high intensity, low volume floods as they pass downstream with progressive diminution of discharge (Schumm and Hadley, 1957; Patton and Schumm, 1981). Southwestern streams therefore develop an alternating convex-concave profile at a given point in time, even when passing over unconsolidated alluvium (Figs. 24C–D). Beaver dams, so common in the past (Dobyns, 1981; Davis, 1982), must also have resulted in such a profile. Steepened segments in channels with relatively high volumes of interstitial flow also may expose water, and thus stimulate ciénega formation.

Porosity of coarse bed loads results in significant underflow in southwestern streams. Relatively stable points of emergence of underflow into concavities of such channels may produce permanent reaches alternating with reaches of an ephemeral nature (Fig. 24C). Similarly coarse materials under- and overlain by lenses of impervious silts and clays may transport water across meanders. Upwelling then occurs to form a spring-like source of water. Coarse materials such as boulders can armor such outflows in an otherwise sandy floodplain, and the potential for marshland succession may be realized even in such an erosive system.

Springs rising along Basin and Range faults at valley edges may also release water and augment surface flows. Such springs have fixed-point origins. but the downstream extent of surface flow may vary with changes in artesian pressure of the aquifer and variations in available water. Constant water supplies of such systems also promote development of riparian marshlands that succeed to ciénegas.

Surface flows in streams of the region are most consistently produced above impervious dikes that intersect alluvial aquifers and force groundwaters to the surface (Figure 24b). The surfical extent of discharge will vary with seasonal and annual fluctuations of the water table, but convex-concave profiles also resulting from these structural features persist permanently in all but the geologic sense of time. Points of decreased competence of flow just upstream from dikes or other obstructions allow ciénegas to form.

Succession to Ciénega. Numerous causal mechanisms determining directions and patterns of successional sequences have been proposed, yet direct evidence in support of mechanistic models outlined by Connell and Slayter (1977) is meager and often limited in scope (Fisher, 1983). Evidence of mechanisms specifically determining progression of succession to ciénega communities is similarly lacking. In common with most studies of long-term succession, temporal limitations are such that experimental evidence has not been produced. However, the diversity of remnant ciénegas available for study, historical evidence, and observation of numerous successional sequences of varied ages developing between flood disturbances on Southwestern streams, has led us to conclude that orderly, predictable, community progression to ciénegas does occur, as does a predictable spatial distribution of communities. Inferential data supporting these conclusions are provided here. After briefly discussing the limited empirical data on stream succession in our study area, we outline temporal and spatial physical determinants of succession to ciénega climax, and propose some biotic mechanisms by which earlier communities may influence ascendency to ciénega. Experimental studies are encouraged to test our hypotheses and produce direct supporting or refuting evidence.

Development of biotic communities in southwestern streams has not been thoroughly studied. Campbell and Green (1968) and Fisher *et al.* (1982) respectively reviewed community succession on mid-elevation strands and in aquatic communities of a central Arizona stream after scouring floods. The former authors found strand vegetation consisting of *Baccharis glutinosa (= salicifolia), Salix exigua*, and *Pluchea (= Tessaria) sericea* on wetter sites, but did not address community changes through time. They felt, however, that vegetation was maintained in "perpetual succession" by periodic flood disturbance, and that abiotic factors and largely stochastic dispersal and establishment were more important in determining distribution patterns than were biotic interactions. Strand vegetation of the inland Southwest, consisting in addition to those species given by Campbell and Green (1968) of any number of characteristic annuals, biennials, or short-lived perennials (Minckley and Brown, 1982), scarcely contributes to succession toward ciénegas. Larger strand and riparian species may indeed act to increase scour by concentrating flow (Burkham, 1976b). Strands are furthermore above the level of permanently saturated soils.

Fisher *et al.* (1982) found algal succession following scour to progress through a diatom-dominated to a green-bluegreen-dominated algal community. An herbivorous invertebrate fauna rapidly invaded, followed by predators. They interpreted such algal sequences as "...often-interrupted, pioneer stages of a long-term successional sequence culminating in the desert ciénega." However, succession to ciénega in streams such as that studied by Fisher *et al.* (1982) would be improbable without increased flow stability. The longest interval between disturbance of such communities was on the order of only a few months. They only rarely recorded establishment of vascular hydrophytes, and thus did not report later community development. Algal successions described by Fisher *et al.* (1982) are characteristic of a physical environment fundamentally distinct from that necessary for succession to ciénega communities. It is likely that similar algal successions occur in more stable physical environments necessary for succession to ciénega, but a causal mechanism of succession relating the two communities is not obvious. We believe it likely that early stages of ciénega formation would establish regardless of previous presence or absence of an algal community and any modification of the environment it might have caused. These algal communities thus do not seem to represent early seral stages in the progression to ciénega, but rather an independent successional sequence (Blum, 1956; Minckley, 1963).

Fisher (1983), in a review of theory and empirical evidence of succession in streams, offered a definition of the term which we adopt here. He defined succession as a sequence of communities, resolvable in both time and space, in which "...the ascendency of each is influenced by its predecessors." We also include in our definition the requirement of Connell and Slayter (1977) that this progression of communities occur in the absence of significant trends in physical regime. Streams are thus ecoclines in both time and space, and ciénegas temporal and spatial phenomena, dependent in both dimensions on a relatively constant physical environment.

Figure 23 and the series of diagrams in Figure 24 illustrate and summarize varying scenarios of topography, geology, hydrology, and climatology in which different geomorphic events and processes relate to ciénegas. If the requirement of aggradation exceeding degradation is met and stable surface flow persists we propose that succession toward ciénega will occur. We agree with Fisher that ciénegas represent a climax community of headwater stream succession at points where perennial surface water persists, but refer to it as an aquatic community, rather than terrestrial, in light of the requirement for saturated soils. Ciénegas display apparent attributes of climax communities characterized by Odum (1969), while streams lacking ciénegas display attributes typical of younger communities. Martin's (1963a) palynological evidence of long-term persistence (>4,000 years), with rare cycles of incision and re-building, as well as Sayle's and Antev's (1941) and Antev's (1962) geological data, indicate that they are a persistent, long-lived community (see also Mehringer and Haynes, 1965; Mehringer *et al.*, 1967; and others). Deep accumulations of organic sediments deposited in ciénegas and exposed in contemporary arroyo walls provide further testimony. The community is regionally and altitudinally definable, and appears to result from intermediate stages that prepare the locale for subsequent stages through physical and chemical alterations of habitat. Ciénega systems are obviously more detritus based than are young, autotrophic stream communities as described by Fisher *et al.* (1982). Organic accumulations are large, and organisms appear to be narrow niche specialists. Furthermore, ciénegas effectively resist perturbations. We have observed flooding of a magnitude sufficient to scour systems discussed by Fisher *et al.* (1982) pass over well-developed ciénegas with little damage (in part, Collins *et al.*, 1981).

We have also observed rapid invasion of saturated streambeds in arroyos by vascular hydrophytes, and consequential initiation of organic deposition during periods of flow stability. These accumulations are sometimes removed by scouring floods, but continue to build under more stable flow regimes. Plants such as *Bidens* spp., *Typha domingensis,* and *Scirpus* spp. are early colonists on barren, flooded soils in the region. As flooded soils increase in organic content as a result of accumulation of vegetation from upstream, plus *in situ* growth, death, and decay of vascular hydrophytes, soil aeration decreases and redox (Eh) potentials drop (Teal and Kanwisher, 1961; Armstrong, 1975). Early, deeper- or larger-rooted colonists are ultimately excluded by such changes, and replaced by more tolerant, shallower-rooted species that live on the surface and have a small proportion of their biomass as roots (Barber, 1982). Anaerobic respiration by soil organisms results in reduced products, many of known phytotoxicity. Bolen (1964) and Howes *et al.* (1981) presented evidence that distributions of marshland plant species and growth forms are correlated with soil Eh. Known adaptations of emergent plants to such environments include an ability to aerate root zones (Armstrong, 1964, 1975; Teal and Kanwisher, 1966), utilize anaerobic respiratory pathways (Chirkova, 1971; Armstrong, 1975), and oxidize reduced phytotoxins (Armstrong, 1975). Armstrong (1964, 1975, 1978), Armstrong and Boatman (1967), Hook *et al.* (1972), Teskey and Hinckley (1977), and Levitt (1980) provided some reviews of waterlogged soils and plant adaptations to them.

We predict that such factors act to produce a temporal succession through marshland seral stages including *Typha* spp., tall Bulrushes such as *Scirpus acutus* and *S. californicus,* and *Salix gooddingii* or *S. lasiolepis,* to a low-sedge (*e.g., Eleocharis* spp.) dominated ciénega. As organic materials accumulate, water-levels rise accordingly through flow impedence, capillarity, and other water-holding attributes of the spongy detritus itself. Bank storage increases as water levels in the channel are further stabilized. Spates may move inorganic materials onto the marsh and interbedding of stream- and side-slope-derived sand and gravel will accrue among lenses of organic debris. Lenses of clays or other impermeable materials deposited by sheet flow over ciénegas may produce locally perched water tables.

Ciénegas become increasingly heterogeneous as a result of local equilibrium adjustments. Constraint of the channel by input of inorganic debris from side slopes (Melton, 1965) may produce locally increased gradient and flow concentration promoting surface incision. Lowered water tables accompanying incision allow germination and regrowth of less hygric species such as Goodding Willow and Fremont Cottonwood. Addition of trees presents greater heterogeneity, with roots concentrating sheet flow and inducing undercutting, and fallen logs performing similar functions. Local incisions persist as deep, slit-like pools until filled by succession back to the closed ciénega condition.

Cooke and Reeves (1976) documented increased gradient of valley floors downstream from former and extant ciénegas. As deposition occurs in ciénegas, stream gradient below, and consequently velocity of flow, increases. Competence gained in this manner is augmented by decreased suspended load as sediments are trapped by vegetation. We believe this may be another mode of formation and perpetuation of vertical-walled pools characterizing many ciénega habitats (Fig. 18). Nick points formed by local disturbances are rapidly eroded headward by highly competent water until an equilibrium is reached.

Points at which aggradation exceeds degradation are mobile in response to principles of dynamic equilibrium (Curry, 1972; Bull, 1979, 1981), so that the ciénega somewhat violates climax concepts by migrating locally as physical aggradation divorces the aquatic/semiaquatic system from its water supply. Salinized, oxidized, and drier soils that result from ciénega migration may be colonized by Saltgrass, then by Sacatón. These habitats may return to ciénega if water tables again become available, or succeed to Mesquite bosque communities if further drying occurs. Mesquite invasions occur only after water tables are lowered by local (or regional) incision that allows leaching of salts and drying of soils to a point which allows germination and growth of seedlings (Bryan, 1928). Geologically determined patterns of spatial distribution thus combine with climatologically and topographically determined temporal patterns of disturbance frequency, as well as biotic interactions, to define local community structure. The ultimate community occupying such a place is dictated by terrestrial climate if permanent water drops below root zone. Persistence of stable surface discharge, however, allows maintenance of the ciénega climax.

Ciénegas act as self-protecting, water-storage reservoirs, and as such influence stream hydrographs, and consequently spatial and temporal distribution of different seral stages in succession. Flows downstream from ciénegas are less variable and of greater permanence than flows in streams without them. The large amount of storage capacity and slow release of water, dampen and attenuate flood peaks. As such, ciénegas create downstream conditions more conducive to establishment of ciénega vegetation than were previously found, and expansion downstream might be expected. Upstream expansion of ciénega also occurs as increased channel roughness due to vegetation produces decreased competence and deposition of clays and silts, which form impervious layers (Melton, 1965; Howes *et al.*, 1981). Groundwater is further impounded, and the point of

Table 2. Attributes of various wetland habitats of the American Southwest discussed in text.

Attributes	Alpine Meadowlands	Ciénegas	Riverine Marshes
Altitude (m)	>2,000	1,000–2,000	<1,000
Drainage position	headwaters	headwaters and low-order streams	high order streams
Climatic factors	complete winter snow cover	brief hillslope snow cover only	no snow
	alternate freezing/thawing	occasional insignificant freezing (brief edge ice only)	no freezing
Basin physiography	low-relief, broad depressions	relatively narrow valley floor bounded by Basin and Range-type mountains	Broad alluvial valleys distantly bounded by mountains
Flow classification	lotic or lentic (depression)	lotic	lotic
Discharge characteristics	no scouring floods	low probability of scouring floods	higher probability of scouring floods
Channel structural control	little	relatively tight by bounding ranges	little, bounding ranges distant
Position in channel	bank to bank	along edge, leaving narrow channel or may cover channel	edge, backwaters, oxbows; substantial open water
Surface water ephemerality	perennial to briefly ephemeral	perennial	perennial
Adjoining hillslopes characteristics	extensive soil development	extensive soil development	alluvial, desert soils
	conifer forest	semi-desert or Plains/Great Basin grasslands or Madrean Evergreen woodland	Lower Colorado or Arizona Upland subdivision of Sonoran Desertscrub
	little exposed bedrock	little exposed bedrock	large amount exposed bedrock
Edaphic factors	soils saturated, may dry seasonally	soils permanently saturated	soils permanently saturated
	soils seasonally anoxic-reducing	soils perennially anoxic-reducing	lower levels soil anoxia-oxidizing
	high organic content in soils	high organic content in soils	lower organic content in soils
	low percolation rates	generally low percolation rates, but may be inter-bedding of coarser lenses	higher percolation rates
Vegetation	low, emergent sedges; grasses; riparian shrubs *(Salix, Alnus)*	low, emergent sedges; riparian trees (Salicaceae)	tall, emergent vegetation *(Typha, Phragmites)*
Grazing	naturally and by livestock	naturally and by livestock	largely ungrazed
Relative longevity	long	intermediate	short

surface-groundwater intersection moves upstream (Fig. 24C). Aggradation in ciénegas produces increased gradients downstream which stimulate incision, so that alternating ciénega and arroyo, as described by early travelers, would be predicted.

Historical information further indicates an tendency toward occurrence of low-statured, sedge-dominated, ciénegas in headwaters, and tall-sedge dominated riverine marshes along lower elevation, higher order channels with permanent flow. To some extent the pattern persists today. We propose that these two communities intergraded, interdigitated, and blended in a spatially and temporally dynamic manner along the drainage gradients in response to numerous variables.

At a yet undefined and dynamic point where stability sufficient for ciénega maintenance is lost due to increased watershed size, ciénegas give way to riverine marshes, assuming presence of perennial water. Release of channels from tight structural control of valley-bounding ranges also appears to be a factor in this transition. Riverine marshes were common in oxbows and backwaters of large rivers such as the Gila where it was perennial in the broad alluvial Phoenix and Safford valleys. Similarly, such marshes occurred along the lower Río San Pedro and were associated with the Río Santa Cruz and Ciénega Creek on the broad, alluvial Tucson formation. The distribution of ciénegas in these same systems is correlated with narrower valleys and tighter structural control found further upstream.

We propose that riverine marshes are and were maintained as transitory communities predictably removed by catastrophic flooding resulting largely from winter rainfall and runoff, or dried by channel migration across valley floors. Being short-lived, such marshes do not accumulate large amounts of organic material, and soils are less anaerobic than older organic soils. Greater discharges of higher order channels under natural conditions also tend to maintain less anaerobic soils through greater percolation rates. Hypothesized ecological and hydrological attributes of these related communities are summarized in Table 2. On larger, impounded rivers where water deliveries are constant, dams replace ciénegas as water storage reservoirs and regulators of discharge. Extensive riverine marshes persist today below such ameliorating structures (Minckley and Brown, 1982; Ohmart *et al.*, 1975; Ohmart and Anderson, 1982).

Biological Significance of Ciénegas. Within an evolutionary or geological time frame, ciénegas are transitory, and as such biotas obviously endemic to them have not evolved. However, their frequent association with springs, which commonly have associated endemics as a result of greater permanence, and their role as refugia for Tertiary and Recent species incapable of survival in the recently evolved, ephemeral arid-land systems, endow them with a level of reliction not found in other local aquatic systems. In this way ciénegas are similar to springs of Death Valley, Great Basin, Chihuahuan Desert, and elsewhere, where relicts of Pluvial lakes and streams find refuge. This is especially evident in hydrobiid molluscs. These are minute, operculate, apulmonate snails of the genera *Tryonia* and *Fontelicella*, which have living representatives in most spring-fed ciénegas discussed here (J. J. Landye, Flagstaff, AZ, pers. comm., 1982). Certain fishes also are characteristic of ciénega formations. Thick-bodied chubs of the genus *Gila* are more abundant in ciénegas than elsewhere. In our study area these include *Gila intermedia*, whose distribution in Gila River basin (Minckley, 1973; Rinne, 1976) corresponds almost exactly to that of ciénega habitat in the San Simon, San Pedro, and Santa Cruz basins. *Gila purpurea* may be the corresponding species in the Ríos Yaqui, Matape, and Sonora systems (Hendrickson *et al.*, 1980). The endangered Sonoran topminnows *(Poeciliopsis o. occidentalis, P. o. sonoriensis)* are now essentially restricted to ciénegas and springs in the United States (Meffe *et al.*, 1982, 1983). Large river fishes such as Colorado Squawfish, Razorback Sucker *(Xyrauchen texanus)*, Roundtail Chub *(Gila robusta)*, and others, were associated with riverine marshes in the San Pedro and Gila rivers when greater and more stable discharges were maintained. Aggradation in downstream parts of the San Simon and Santa Cruz rivers presumably excluded these last species.

Southwestern streams, in both past and present conditions, are unique in many ways. They differ from European and Eastern U.S. systems where most theory of stream ecology has been developed, and aspects in which they differ are critical in determining spatial and temporal attributes of succession. Surface flows in more mesic regions are continuous and increase in volume and stability downstream. In the study region, surface flows maintained by bedrock in headwaters sink into alluvial fills or disappear from evapotranspiration downstream. Perennial surface discharges on lower valley floors may be present only where impervious dikes intersect alluvial aquifers. These streams are heterogeneous systems that display temporal and spatial discontinuities of disjunct surface discharges and intervening dry reaches.

Contrary to the situation in more mesic areas, unpredictability of flow continuity precludes development of biotic communities dependent on and stabilized by import from upstream communities. Application of the River Continuum Concept outlined by Vannote *et al.* (1981) is thus largely inappropriate. Formerly, under less variable, continuous flow regimes associated with widespread ciénega-marshland communities, its principles may have been more applicable. Yet, the downstream progression from ciénega to riverine marsh communities remains based on a gradient of increasing instability, still in violation of River Continuum principles. Subterranean processes carried out largely by bacteria in streambed alluvia are certainly important in these systems and we expect will prove to be principal factors determining what products are exported downstream. Export by surface discharges may be only temporally important.

Perpetuation of ciénega habitat will require maintenance of permanent groundwater and a balance between aggradation and degradation. Permanence achieved by pumpage, with attendent fluctuations and other disruptions, will scarcely achieve the ciénega climax. Nor will check dams and other erosion control devices unless they intersect barriers to groundwater flow. Ideal structures will seal alluvial cross-sections of drainageways near headwaters, inducing bank and channel storage and causing intersection of flowing groundwaters and surface. Anaerobiosis of sediments will then occur, and the ciénega habitat should build to mound over the perennial reach. Ultimately, sediments may build to allow local "climatic" change in access by aquatic/semiaquatic species to perennial water, and Sacatón/Mesquite communities will appear. Maintenance of open waters for vertebrates such as fishes, and to provide diversity equivalent to that in historic ciénegas, may require artificial deepening or control of some vegetative components by unnatural means such as local dredging or limited livestock grazing.

The present scattered distribution of ciénegas makes them aquatic islands of unique habitat in an arid-land matrix. Among rapidly disappearing aquatic habitats of the Southwest, ciénegas have a definite potential for perpetuation, and should be given high priority as a unique remnant of our natural heritage.

Bibliography

Aldrich, L. D. 1950. *A Journal of the Overland Route to California and the Gold Mines*. Dawson's Book Shop. Los Angeles.

Allison, W. Undated. Arizona the last frontier. Unpubl. manuscript, Ariz. Hist. Soc. Tucson.

Antevs, E. 1952. Arroyo cutting and filling. *J. Geol.* 60: 375–385.

Antevs, E. 1962. Late Quaternary climates in Arizona. *Amer. Antiq.* 28: 193–198.

Arizona Crop and Livestock Reporting Service. 1981. Arizona agricultural statistics, historical summaries of county data 1965–1980. Ariz. Crop Livestock Rept. Serv. Phoenix.

Arizona Water Commission. 1972. Study of the adequacy of the water supply—proposed Empire Ranch development. Ariz. Wat. Comm. Phoenix.

Armstrong, W. 1964. Oxygen diffusion from the roots of some British bog plants. *Nature*, 204: 801–802

Armstrong, W. 1975. Waterlogged soils. Pp. 181–219. *In*, J. R. Etherington (ed.), *Environment and Plant Ecology*, John Wiley and Sons. New York.

Armstrong, W. 1978. Root aeration in the wetland condition. Pp.

269–298. *In*, D. D. Hook and R. M. M. Crawford (eds.), *Plant Life in Anaerobic Environments*. Ann Arbor Science Publishers. Ann Arbor, MI.

Armstrong, W., and D. J. Boatman. 1967. Some field observations relating the growth of bog plants to conditions of soil aeration. *J. Ecol.* 55:101–110.

Audubon, J. W. 1906. *Audubon's Western Journal: 1849–1850.* Maria R. Audubon (Ed.). Arthur H. Clark Co. Cleveland.

Babcock, H. M. 1980. Annual summary of ground-water conditions in Arizona, spring 1978 to spring 1979. U.S. Geol. Surv. Wat.-Res. Invest. Open-File Rept, 77–10. Tucson.

Bahre, C. J., and D. E. Bradbury. 1978. Vegetation change along the Arizona-Sonora boundary. *Ann. Assoc. Amer. Geogr.* 68:145–165.

Bancroft, H. H. 1962. *History of Arizona and New Mexico, 1530–1888.* Horn and Wallace. Albuquerque.

Bannister, B. 1951. Tree ring dates for the Gallina area, New Mexico. *Tree Ring Bull.* 17:21–22.

Bannister, B., J. W. Hannah, and W. J. Robinson, Jr. 1970. Tree Ring Dates from New Mexico M–N, 5, Z: Southwestern New Mexico Area. Lab. Tree Ring Res., Univ. Ariz. Tucson.

Bannister, B., and W. J. Robinson, Jr. 1971. Tree Ring Dates from Arizona U–W: Gila Salt Rivers Area. Lab. Tree Ring Res., Univ. Ariz. Tucson.

Barber, M. C. 1982. Rhizome interactions among three species of salt marsh plants: *Spartina alterniflora, Spartina patens* and *Juncus roemerianns. Bull. Ecol. Soc. Amer.* 63: 77 (Abstr.)

Barnes, W. C. 1936. Herds in San Simon Valley. *Amer. Forests* 42: 456–457, 481.

Barstad, J. F. 1981. Factors controlling plant distribution in a riparian deciduous forest in southeastern Arizona. Unpubl. M.S. Thesis. Ariz. State Univ. Tempe.

Bartlett, J. R. 1854. *Personal Narrative of Explorations and Incidents in Texas, New Mexico, California, Sonora, and Chihuahua connected with the United States and Mexican Boundary Commission during the years 1850, '51, '52,* and *'53,* Vols. I–II. D. Appleton and Co. New York and London.

Bell, J. G. 1932. A log of the Texas—California cattle trail, 1854. *Hist. Quart.* 35: 303–316.

Bell, W. A. 1869. *New Tracks in North America,* Vols. I–II. Chapman and Hall. London.

Bennett, E. F. 1977. An Afternoon of Terror: The Sonoran Earthquake of May, 1877. *Arizona and the West,* Summer 1977: 107–120.

Bieber, R. P. 1937. *Southern Trails to California in 1849.* Southwest Hist. Ser., Vol. V. Arthur H. Clark Co. Glendale, CA.

Blasing, T. J., and H. C. Fritts. 1976. Reconstructing past climatic anomalies in the North Pacific and North America from tree ring data. *Quatern. Res.* 6: 563–79.

Bliss, R. S. 1931. The Journal of Robert S. Bliss, with the Mormon Battalion. *Utah Hist. Quart.* 4:67–96.

Blum, J. L. 1956. The application of the climax concept to algal communities of streams. *Ecology* 37: 603–604.

Bolen, E. G. 1964. Plant ecology of spring-fed salt marshes in western Utah. *Ecol. Mongr.* 34: 134–166.

Bolton, H. E. (ed.) 1916. *Spanish Explorations in the Southwest (Original Narratives of Early American History), 1542–1706.* Charles Scribner's Sons. New York.

Bolton, H. E. 1932. *Padre on Horseback.* The Sonora Press. San Francisco. (Reprinted 1963, Loyola Univ. Press. Chicago.)

Bolton, H. E. 1936. *Rim of Christendom: A Biography of Eusebio Francisco Kino, Pacific Coast Pioneer.* MacMillan Co. New York.

Bourke, J. G. 1891. *On The Border with Crook.* Charles Scribner's Sons. New York. (Reprinted 1971. The Rio Grande Press. Glorieta, NM).

Bowers, J. E. 1981. Catastrophic freezes in the Sonoran Desert. *Desert Plants* 2: 232–236.

Box, M. J. 1869. *Adventures and Explorations in New and Old Mexico.* James Miller. New York.

Bringas, D. M. 1977. *Friar Bringas Reports to the King: Methods of Indoctrination on the Frontier of New Spain 1796–97.* D. S. Matson and B. L. Fontana (transl. and ed.). Univ. Ariz. Press. Tucson.

Brown, D. E. (ed.). 1982. Biotic Communities of the American Southwest: United States and Mexico. *Desert Plants* 4: 4–431.

Brown, D. E., and R. S. Henry. 1981. On relict occurrences of White-tailed deer within the Sonoran Desert in Arizona. *Southwest. Nat.* 26: 142–152.

Brown, D. E., and C. H. Lowe. 1980. Biotic communities of the southwest. *U.S. For. Serv. Gen. Tech. Rept. RM* 78: Map.

Brown, D. E., C. H. Lowe, and C. P. Pase. 1980. A digitized systematic classification for ecosystems, with an illustrated summary of the natural vegetation of North America. *U.S. For. Serv. Gen. Tech. Rept. RM* 73: 1–93.

Brown, D. E., N. B. Carmony, and R. M. Turner. 1981. Drainage map of Arizona showing perennial streams and some important wetlands. Ariz. Game Fish Dept. Phoenix. Map.

Browne, J. R. 1869. *Adventures in the Apache Country: A Tour Through Arizona and Sonora, with notes on the Silver Regions of Nevada.* Harper and Brothers. New York.

Bryan, K. 1922. Erosion and sedimentation in the Papago Country, Arizona. *U.S. Geol. Surv. Bull.* 730–B: 1–90.

Bryan, K. 1925a. The Papago Country, Arizona, a geographic, geologic, and hydrologic reconnaissance, with a guide to desert watering places: *U.S. Geol. Surv. Wat. Suppl. Pap.* 499: 1–436.

Bryan, K. 1925b. Date of channel trenching (arroyo cutting) in the arid Southwest. *Science* 62:338–344.

Bryan, K. 1926. The San Pedro Valley, Arizona, and the geographical cycle. *Bull. Geol. Soc. Amer.* 37: 169–170 (abst.).

Bryan, K. 1928. Change in plant associations by change in ground water level. *Ecology* 9:474–478.

Bryan, K. 1929. Flood water farming. *Geogr. Rev.* 19:444–456.

Bryan, K. 1940. Erosion in the valleys of the Southwest. *N. Mex. Quart.* 10: 227–232.

Bryan, K. 1941. Pre-Columbian agriculture in the Southwest as conditioned by periods of alluviation. *Ann. Assoc. Amer. Geogr.* 31: 219–242.

Bull, W. B. 1979. Threshold of critical power in streams. *Bull. Geol. Soc. Amer.* 86: 1489–1498.

Bull, W. B. 1981. Soils, geology, and hydrology of deserts. Pp. 42–58, *In*, D. E. Evans and J. L. Thames (eds.). *Water in Desert Ecosystems.* Dowden, Hutchinson and Ross, Inc. Stroudsburg, PA.

Burkham, D. E. 1970. Precipitation, streamflow, and major floods at selected sites in the Gila River drainage basin above Coolidge Dam, Arizona. *U.S. Geol. Surv. Prof. Pap.* 655–B: 1–33.

Burkham, D. E. 1972. Channel changes of the Gila River in Safford Valley, Arizona, 1846–1970. *U.S. Geol. Surv. Prof. Pap.* 655–G: 1–24.

Burkham, D. E. 1976a. Effects of changes in an alluvial channel on the timing, magnitude, and transformation of flood waves, southeastern Arizona. *U.S. Geol. Surv. Prof. Pap.* 655–K: 1–25.

Burkham, D. E. 1976b. Hydraulic effects of changes in bottomland vegetation on three major floods, Gila River in Southwestern Arizona. *U.S. Geol. Surv. Prof. Pap.* 655–J: 1–14.

Calvin, R. 1946. *River of the Sun—Stories of the Storied Gila.* Univ. N. Mex. Press. Albuquerque.

Campbell, C. J., and W. Green. 1968. Perpetual succession of stream-channel vegetation in a semiarid region. *J. Ariz. Acad. Sci.* 5: 86–99.

Castetter, E. F., and W. H. Bell. 1942. *Pima and Papago Indian*

Agriculture. Univ. N. Mex. Press. Albuquerque.
Chirkova, T. V. 1971. Role of nitrate respiration of willow roots for some woody plants under conditions of anaerobiosis. *Vestn. Leningr. Univ. Ser. Biol.* 26: 118-124.
Chorley, R. J. 1962. Geomorphology and general systems theory. *U.S. Geol. Surv. Prof. Pap.* 500-B: 1-10.
Clark, N. E., T. J . Blasing, and H. C. Fritts. 1975. Influence of interannual climatic fluctuations on biological systems. *Nature* 256: 302-305.
Clarke, A. B. 1852. *Travels in México and California*. Wright and Hasty Stream Printers. Boston.
Coates, D. R., and R. L. Cushman. 1955. Geology and ground water resources of the Douglas Basin, Arizona. *U.S. Geol. Surv. Wat.-Suppl. Pap.* 1354: 1-56.
Collins, J. P., C. Young, J. Howell, and W. L. Minckley. 1981. Impact of flooding in a Sonoran Desert stream including elimination of an endangered fish population (*Poeciliopsis o. occidentalis*, Poeciliidae). *Southwest. Nat.* 26: 415-423.
Condes de la Torre, A. 1970. Streamflow in the upper Santa Cruz River basin, Santa Cruz and Pima counties, Arizona. *U.S. Geol. Surv. Wat.-Suppl. Pap.* 1939-A: 1-26.
Conkling, R. P., and M. B. Conkling. 1947. *The Butterfield Overland Mail*, 1857-1869, Vols. I-II. Arthur H. Clark Co. Glendale, CA.
Connell, J. H., and R. O. Slayter. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. *Amer. Nat.* 111: 1119-1144.
Cooke, P. St. G. 1878. *The Conquest of New Mexico and California—an Historical and Personal Narrative*. Putnam. New York.
Cooke, P. St. G. 1938. Cooke's journal of the march of the Mormon Battalion, 1846-1847. Pp. 63-240. *In, Exploring Southwest Trails, 1846-1854*. Southwest Hist. Ser., Vol. 7. Arthur H. Clark Co. Glendale, CA.
Cooke, R. U., And R. W. Reeves. 1976. *Arroyos and Environmental Change in the American Southwest*. Oxford Univ. Press. London.
Cooley, M. E., B. N. Aldridge, and R. C. Euler. 1977. Effects of the catastrophic flood of December 1966, North Rim area, eastern Grand Canyon, Arizona. *U.S. Geol. Surv. Prof. Pap.* 980: 1-43.
Corle, E. 1951. *The Gila River of the Southwest*. Reinhart and Co. New York.
Crosby, A. W. Jr. 1976. Virgin soil epidemics as a factor in the aboriginal depopulation of America. *William and Mary Quart.* 3rd Ser. 33: 289-99.
Crosswhite. F. S. 1981. Desert plants, habitat and agriculture in relation to the major pattern of cultural differentiation in the O'odham people of the Sonoran Desert. *Desert Plants* 3: 47-76.
Crosswhite, F. S., and C. D. Crosswhite. 1982. The Sonoran Desert. Pp. 163-320. *In*, G. L. Bender (ed.). *Reference Handbook on the Deserts of North America*. Greenwood Press, Westport, CT.
Culler, R. C., D. E. Burkham, M. R. Collings, E. S. Davison, R. L. Laney, O. E. Leppanen, I. S. McQueen, N. C. Matalas, R. F. Miller, R. M. Myrick, R. M. Turner, and W. G. Weist, Jr. 1970. Objectives, methods and environment—Gila River Phreatophyte Project, Graham County, Arizona. *U.S. Geol. Surv. Prof. Pap.* 655-A: 1-25.
Curry, R. R. 1972. Rivers—a geomorphic and chemical overview. Pp. 9-31. *In*, R. T. Oglesby, C. A. Carlson, and J. A. McCann (eds.), *River Ecology and Man*. Academic Press. New York.
Davidson, E. S. 1973. Geohydrology and Water Resources of the Tucson Basin, Arizona. *U.S. Geol. Surv. Wat.-Suppl. Pap.* 1939-E: 1-81.
Davis, G. P. 1982. *Man and Wildlife in Arizona—the American Exploration Period 1824-1865*. N. B. Carmony and D. E. Brown (eds.). Ariz. Game Fish Dept. Phoenix.
Davis, N. H. 1964. Letter to Capt. Benjamin Cutler, June 5, 1864. Pp. 869-972. *In*, The War of the Rebellion, A compilation of the official records of the Union and Confederate Armies: Secretary of War, Ser. I, V. 50, pt. II.
DeCook, K. J. 1952. San Simon Basin (groundwater) Cochise County, Arizona. *U.S. Geol. Surv. Open-File Rept.* Tucson.
Denevan, W. M. 1967. Livestock numbers in ninteenth-century New Mexico, and the problem of gullying in the southwest. *Ann. Assoc. Amer. Geogr.* 57: 691-703.
Di Peso, C. C. 1951. *The Babocomari Village site on the Babocomari River, southeastern Arizona*. Amerind Found. Dragoon, AZ.
Dobyns, H. F. 1978. Who killed the Gila. *J. Ariz. Hist.*, spring 1978: 17-30.
Dobyns, H. F. 1981. *From Fire to Flood: Historic Human Destruction of Sonoran Desert Riverine Oases*. Ballena Press. Socorro, NM.
Dubois, S. M., and A. W. Smith. 1980. The 1887 earthquake in San Bernardino Valley, Sonora: Historic accounts and intensity patterns in Arizona. *Ariz. Bur. Geol. Min. Tech. Spec. Pap.* 3: 1-112.
Duce, J. T. 1918. The effect of cattle on the erosion of cañon bottoms. *Science* 47: 450-452.
Durivage, J. E. 1937. Letters and journal of John E. Durivage. *In, Southern Trails to California in 1849*. Arthur H. Clark Co. Glendale, CA.
Eccleston, R. 1950. *Overland to California on the Southwestern Trail, 1849. Diary of Robert Eccleston*. G. P. Hammond and E. H. Howes (eds.). Univ. Calif. Press. Berkeley.
Eckman, E. C., M. Baldwin, and E. J. Carpenter. 1923. Soil survey of the middle Gila Valley area, Arizona. *Field Oper. U.S. Dept. Agric. Bur. Soils* 19:2087-2119.
Eddy, F. 1958. Sequence of cultural and alluvial deposits in the Ciénega Creek basin, Southeastern Arizona. Unpubl. M.S. Thesis. Univ. Ariz. Tucson.
Emory, W. H. 1848. *Notes of a military reconnaissance from Ft. Leavenworth, in Missouri, to San Diego, in California, including parts of the Arkansas, del Norte, and Gila Rivers. By Lieut. Col. W. H. Emory, made in 1846-47, with the advanced guard of the "Army of the West."* Wendell and van Benthuysen, Printers. Washington, D.C.
Emory, W. H. 1857. *Report on the United States and Mexican Boundary Survey*, Vols. I-II. Washington, D.C. U.S. 34th Congress 1st Session, Senate Exec. Doc. 108.
Etz, D. B. 1938. Untitled, Unpubl. Manuscript. Ariz. Hist. Soc. Tucson.
Euler, R. C., G. J. Gumerman, T. N. V. Karlstrom, J. S. Dean, and R. H. Hevly. 1979. The Colorado Plateau: cultural dynamics and paleoenvironment. *Science* 205: 1089-1101.
Evans, G. W. G. 1945, *Mexican Gold Trail*. G. S. Dumke (ed.). The Huntington Library. San Marino, CA.
Ewing, R. C. 1941. Investigations into the causes of the Pima uprising of 1751. *Mid-America* 23: 138-151.
Ewing, R. C. 1945. *The Pima Uprising of 1751: A Study of Spanish-Indian Relations on the Frontier of New Spain. Greater America: Essays in Honor of Herbert Eugene Bolton*. Univ. Calif. Press. Berkeley.
Fergusson, M. D. 1862. Cultivated fields in and about Tucson. Maps, scale 1: 3600, Ariz. Hist. Soc. Tucson.
Fisher, S. G. 1983. Succession in streams. Pp. 7-27, *In*, J. R. Barnes and G. W. Minshall (eds.) *Stream Ecology: Application and Testing of General Ecological Theory*. Plenum Press. New York.
Fisher, S. G., and W. L. Minckley. 1978. Chemical characteristics of a desert stream in flash flood. *J. Arid Environ.* 1: 25-33.
Fisher, S. G., L. J. Gray, N. B. Grimm, and D. E. Busch. 1982.

Temporal succession in a desert stream ecosystem following flash flooding. *Ecol. Monogr.* 52: 93–110.

Fogel, M. M. 1981. Precipitation in the desert. Pp. 219–234, *In*, D. E. Evans and J. L. Thames (eds.) *Water in Desert Ecosystems.* Dowden, Hutchinson and Ross, Inc. Stroudsburg, PA.

Forman, R. T. T. and E. W. B. Russell. 1983. Commentary: evaluation of historical data in ecology. *Bull. Ecol. Soc. Amer.* 64: 5–7.

Fritts, H. C. 1965. Dendrochronology. Pp. 871–79. *In*, H. E. Wright, Jr., and D. G. Frey (eds.), *The Quaternary of the United States.* Princeton Univ. Press. Princeton, NJ.

Fritts, H. C. 1965. Tree ring evidence for climatic changes in western North America. *Monthly Weath. Rev.* 93: 421–443.

Fritts, H. C. 1974. Relationships of ring widths in arid site conifers to variation in monthly temperature and precipitation. *Ecol. Monogr.* 44: 411–440.

Fritts, H. C., G. R. Lofgren, and G. A. Gordon. 1979. Variations in climate since 1602 as reconstructed from tree rings, *Quatern. Res.* 12: 18–46.

Gehlbach, F. R. 1981. *Mountain Islands and Desert Seas: a Natural History of the U.S. Mexican Borderlands.* Texas A & M Univ. Press. College Station.

Gilluly, J. 1956. General geology of central Cochise County, Arizona. *U.S. Geol. Surv. Prof. Pap.* 281: 1–169.

Gilman, M. F. 1909. Among the thrashers in Arizona. *Condor* 11: 49–54.

Glinski, R. 1977. Regeneration and distribution of sycamore and cottonwood trees along Sonoita Creek, Santa Cruz County, Arizona. *In, Importance, Preservation and Management of Riparian Habitat. U.S. For. Serv. Gen. Tech. Rept. RM*-43: 116–123.

Glinski, R. L., and D. E. Brown. 1982. Mesquite *(Prosopis juliflora)* response to severe freezing in southeastern Arizona. *J. Ariz.-Nev. Acad. Sci.* 17: 15–18.

Goetzmann, W. H. 1959. *Army exploration in the American West, 1803-1863.* Yale Univ. Press. New Haven, CT.

Goodfellow, G. E. 1888. The Sonora earthquake. *Science* 11: 162–167.

Granger, B. H. 1960. *Will C. Barnes' Arizona Place Names, Revised and Enlarged.* Univ. Ariz. Press. Tucson.

Graham, J. D. 1852. *Report of Lieutenant Colonel Graham on the subject of the boundary line between the United States and Mexico.* U.S. 32nd Congress, 1st Session, Executive Docment 121: 1–250.

Gray, A. B. 1963. *The A. B. Gray Report—Survey of a Route for the Southern Pacific Railroad on the 32nd Parallel,* 2nd ed. L. R. Bailey (ed.). Westernlore Press. Los Angeles.

Grinnell, J. 1914. An account of the mammals and birds of the lower Colorado River Valley, with special reference to the distributional problems presented. *Univ. Calif. Publ. Zool.* 12: 51–294.

Guiteras, E. (transl.) 1894. Rudo Ensayo. *Rec. Amer. Cath. Hist. Soc. Phila.* 5: 109–135.

Hall, S. A. 1977. Late Quaternary sedimentation and paleoecologic history of Chaco Canyon, New Mexico. Geol. Soc. Amer. Bull. 88: 1593–1618.

Hamilton, P. 1881. *The Resources of Arizona: A Manual of Reliable Information Concerning the Territory.* Ariz. Legislature. Prescott.

Hammond, G. P. 1931. The Zuñiga Journal, Tucson to Santa Fe: The opening of a Spanish trade route, 1788–1795. *N. Mex. Hist. Rev.* 6: 40–65.

Harris, B. B. 1960. *The Texas Argonauts and the California Gold Rush.* R. H. Dillon (ed.). Univ. Okla. Press. Norman.

Haskett, B. 1935. Early history of the cattle industry in Arizona. *Ariz. Hist. Rev.* 6: 3–42.

Haskett, B. 1936. History of the sheep industry in Arizona. *Ariz. Hist. Rev.* 7: 3–49.

Hastings, J. R. 1959. Vegetation change and arroyo cutting in southeastern Arizona. *J. Ariz. Acad. Sci.* 1: 60–67.

Hastings, J. R., and R. M. Turner. 1965. *The Changing Mile: An Ecological Study of Vegetation Change with Time in the Lower Mile of an Arid and Semiarid Region.* Univ. Ariz. Press. Tucson.

Haury, E. W. 1976. *The Hohokam: Desert Farmers and Craftsman. Excavations at Snaketown, 1964-1965.* Univ. Ariz. Press. Tucson.

Haynes, V. 1968. Preliminary report on the late Quaternary geology of the San Pedro Valley, Arizona. Pp. 79–96. *In*, S. R. Titley (ed.), *Ariz. Geol. Soc., Southern Ariz. Guidebook III.*

Hendrickson, D. A., W. L. Minckley, R. R. Miller, D. S. Siebert, and P. H. Minckley. 1980. Fishes of the Río Yaqui Basin, México and United States. *J. Ariz.-Nev. Acad. Sci.* 15: 65–106.

Herbel, C. H., F. N. Ares, and A. B. Nelson. 1967. Grazing distribution patterns of Hereford and Santa Gertrudis cattle on a southern New Mexico range. *J. Range Mgmt.* 20: 296–298.

Herd, D. G., and C. R. McMasters. 1982. Surface faulting in the Sonora, México, earthquake of 1887. *Abstr. with Progr., Geol. Soc. Amer.*, 1982 meeting of Cordilleran Section. p. 172.

Hevly, R., and P. S. Martin. 1961. The geochronology of Pluvial Lake Cochise I. Pollen analysis of shore deposits. *J. Ariz. Acad. Sci.* 2:24–31.

Hinton, R. J. 1878. *The Hand-book to Arizona: Its Resources, History, Towns, Mines, Ruins, and Scenery.* American News Co. New York.

Hodge, H. C. 1877. *Arizona As It Is, or the Coming Country.* Hurd and Houghton. New York.

Hook, D. D., C. L. Brown, and R. H. Wetmore. 1972. Aeration in trees. *Bot. Gaz.* 133: 443–454.

Howes, B. L., R. W. Howarth, J. M. Teal, and I. Valiela. 1981. Oxidation-reduction potentials in a salt marsh: Spatial patterns and interactions with primary production. *Limnol. Oceanogr.* 26: 350–360.

Humphrey, R. R., and L. A. Mehrhoff. 1958. Vegetation changes on a southern Arizona grassland range. *Ecology* 39: 720–726.

Hutton, N. H. 1859. Engineers Report—El Paso and Fort Yuma wagon road. *In*, Records of the Office of the Secretary of the Interior relating to wagon roads, 1857–1881. *Nat. Arch. Film Microcopies M95:* roll 3.

Irwin, B. J. D. 1859. The military posts on Sonoita Creek. *In*, J. E. Serven. 1965. *Tucson Corral, Westerners Smoke Signal* 12: 28–33.

Ives, R. L. 1936. Desert floods in the Sonoyta Valley. *Amer. J. Sci.* 32: 349–360.

Jahns, R. H. 1949. Desert floods. *J. Eng. Sci.* 12: 10–14.

Jones, S. C. 1980. Maps showing ground-water conditions in the lower San Pedro Basin area, Pinal, Cochise, Pima, and Graham counties, Arizona—1979. *U.S. Geol. Surv. Wat. Res. Invest. Open-File Rept.* 80–954. Tucson.

Jordan, G. L., and M. L. Maynard. 1970. The San Simon watershed—historical review. *Prog. Agric. Ariz.* 22: 10–13.

Judd, B. I. 1972. Vegetation zones around a small pond in the White Mountains of Arizona. *Grt. Basin Nat.* 32: 91–96.

Judson, S. 1952. Arroyos. *Sci. Amer.* 187: 71–76.

Kino, E. F. 1919. *Kino's Historical Memoir of Pimeria Alta,* Vols. I–II. H. E. Bolton (trans. and ed.). A. H. Clark. Cleveland.

King, P. B. 1977. *The Evolution of North America.* Princeton Univ. Press. Princeton, NJ.

Knetchtel, M. M. 1938. Geology and ground-water resources of the valley of the Gila River and San Simon Creek, Graham County, Arizona: *U.S. Geol. Surv. Wat.-Suppl. Pap.* 796–F: 181–222.

Konieczki, A. D. 1980. Maps showing ground-water conditions in the upper San Pedro Basin Area, Pima, Santa Cruz, and

Cochise Counties, Arizona—1978. *U.S. Geol. Surv. Wat. Res. Invest. Open-File Rept.* 80-1192. Tucson.

LaMarche, V. C., Jr. 1966. An 800-year history of stream erosion as indicated by botanical evidence. *U.S. Geol. Surv. Prof. Pap.* 550-D: 83-86.

LaMarche, V. C., Jr. 1978. Tree ring evidence of past climatic variability. *Nature* 276: 334-338.

LaMarche, V. C., Jr., and H. C. Fritts. 1971. Anomaly patterns of climate over the western United States, 1700-1930, derived from principal component analysis of tree ring data. *Monthly Weather Rev.* 99: 138-142.

Leach, J. B. 1858. Itinerary of the El Paso and Fort Yuma wagon road expedition. National Archives Film Microcopies M95, roll 3.

Lee, W. T. 1904. The underground waters of Gila Valley, Ariz. *U.S. Geol. Surv. Wat.-Suppl. Pap.* 104: 1-71.

Lee, W. T. 1905. The underground waters of the Salt River Valley, Arizona. *U.S. Geol. Surv. Wat.-Suppl. Pap. 136: 1-196.*

Lehr, J. H. 1978. *A Catalogue of the Flora of Arizona.* Desert Botanical Garden. Phoenix.

Lehr, J. H., and D. J. Pinkava. 1980. A catalogue of the flora of Arizona Supplement I. *J. Ariz.-Nev. Acad. Sci.* 15: 17-32.

Lehr, J. H., and D. J. Pinkava. 1982. A catalogue of the flora of Arizona Supplement II. *J. Ariz.-Nev. Acad. Sci.* 17: 19-26.

Leopold, L. B. 1951a. Rainfall frequency: an aspect of climatic variation. *Trans. Amer. Geophys. Union.* 32: 347-57.

Leopold, L. B. 1951b. Vegetation of southwestern watersheds in the nineteenth century. *Geogr. Rev.* 41: 295-316.

Levitt, J. 1980. *Responses of Plants to Environmental Stresses,* Vol. II, 2nd ed. Academic Press. New York.

Lewis, D. D. 1963. Desert floods—a report on southern Arizona floods of September, 1962. *Ariz. Land Dept., Wat. Res. Rept.* 13: 1-30.

Lowe, C. H. (ed.). 1967. *The Vertebrates of Arizona.* Univ. Ariz. Press. Tucson.

Mann, L. J., C. S. English. 1980. Maps showing groundwater conditions in the Douglas Basin area, Cochise County, Arizona—1978. *U.S. Geol. Surv., Wat. Res. Invest. Open-File Rept.* 80-700. Tucson.

Mann, L. J., N. D. White, and R. P. Wilson. 1978. Maps showing ground-water conditions in the Willcox Area, Cochise and Graham counties, Arizona—1975. *U.S. Geol. Surv. Wat. Res. Invest. Open-File Rept.* 78-60. Tucson.

Marrs-Smith, G. 1983. *Vegetation and Flora of the San Bernardino Ranch, Cochise County, Arizona.* Unpubl. M.S. Thesis. Ariz. St. Univ. Tempe.

Martin, P. S. 1963a. *The Last 10,000 Years.* Univ. Ariz. Press. Tucson.

Martin, P. S. 1963b. Geochronology of Pluvial Lake Cochise, Southern Arizona. II. Pollen analysis of a 42-meter core. *Ecology* 44: 436-444.

Martin, P. S., and J. E. Mosimann. 1965. Geochronology of Pluvial Lake Cochise, Southern Arizona. III. Pollen statistics and Pleistocene metastability. *Amer. J. Sci.* 263: 313-358.

Martin, P. S., J. Schoenwetter, and B. C. Arms. 1961. *Southwestern Palynology and Prehistory: The Last 10,000 Years.* Geochron. Lab., Univ. Ariz. Tucson.

Masse, W. B. 1981. Prehistoric irrigation systems in the Salt River Valley, Arizona. *Science* 214: 408-415.

Mattison, R. H. 1946. Early Spanish and Mexican settlements in Arizona. *N. Mex. Hist. Rev.* 21: 273-327.

McClintock, J. H. 1916. *Arizona: Prehistoric; Aboriginal, Pioneer, Modern.* Vol. I-III. S. J. Clarke Publ. Chicago.

McClintock, J. H. 1921. *Mormon Settlement in Arizona.* Manufacturing Stationers. Phoenix.

McDonald, J. E. 1956. Variability of precipitation in an arid region: a survey of characteristics for Arizona. *Univ. Ariz. Inst. Atmos. Physics Tech. Rept.* 1: 1-88.

McNatt, R. M. 1974. Re-evaluation of the native fishes of the Río Yaqui in the United States. *Proc. 54th Ann. Conf. West. Assn. Game Fish Comm.* Pp. 273-279.

Mearns, E. A. 1907. Mammals of the Mexican Boundary of the United States. A Descriptive Catalog of the Species of Mammals Occurring in that Region, with a General Summary of the Natural History and List of Trees. U.S. Nat. Mus. Bul. 56(1): 1-530.

Meffe, G. K., D. A. Hendrickson, and J. N. Rinne. 1982. Description of a new topminnow population in Arizona, with observations on topminnow/mosquitofish co-occurrence. *Southwest. Nat.* 27: 226-228.

Meffe, G. K., D. A. Hendrickson, W. L. Minckley, and J. N. Rinne. 1983. Factors resulting in decline of the endangered Sonoran topminnow (Atheriniformes: Poeciliidae) in the United States. *Biol. Conserv.* 25: 135-159.

Mehringer, P. J., Jr., and C. V. Haynes, Jr. 1965. The pollen evidence for the environment of early man and extinct mammals at the Lehner mammoth site, southeastern Arizona. *Amer. Antiq.* 31: 17-23.

Mehringer, P. J., Jr., P. S. Martin, and C. V. Haynes, Jr. 1967. Murray Springs. a mid-post glacial pollen record from southern Arizona. *Amer. J. Sci.* 265: 786-797.

Meinzer, O. E., and F. C. Kelton. 1913. Geology and water resources of Sulfur Spring Valley, Arizona. *U.S. Geol. Surv. Wat.-Suppl. Pap.* 320: 1-231.

Melton, M. A. 1960. Origin of the drainage of southeastern Arizona. *Ariz. Geol. Soc. Digest* 3: 113-122.

Melton, M. A. 1965. The geomorphic and paleoclimatic significance of alluvial deposits in southern Arizona. *J. Geol.* 73: 1-38.

Minckley, W. L. 1963. The ecology of a spring stream: Doe Run, Meade County, Kentucky. *Wildl. Monogr.* 11: 1-124.

Minckley, W. L. 1973. *Fishes of Arizona,* Ariz. Game Fish Dept. Phoenix.

Minckley, W. L. 1981. Ecological studies of Aravaipa Creek, central Arizona, relative to past, present, and future uses. Final Rept., U.S. Bur. Land Mgmt. Ariz. State Univ. Tempe.

Minckley, W. L., and D. E. Brown. 1982. Wetlands. *In,* D. E. Brown (ed.). Biotic Communities of the American Southwest: United States and Mexico. *Desert Plants* 4: 222-287.

Minckley, W. L., and T. O. Clark. 1984. Formation and destruction of a Gila River mesquite bosque. *Desert Plants* 6: 23-30.

Mowry, S. 1864. *Arizona and Sonora.* Harper Bros. New York.

Nations, J. D., J. J. Landye, and R. H. Hevly. 1982. Location and chronology of Tertiary sedimentary deposits in Arizona: A review. Pp. 107-122. *In,* R. V. Ingersoll and M. O. Woodburne (eds.). *Cenozoic Nonmarine Deposits of California and Arizona.* Pacific Section, SEPM.

Odum, E. P. 1969. The strategy of ecosystem development. *Science* 164: 262-270.

Ohmart, R. D., W. O. Deason and S. J. Freeland. 1975. Dynamics of marsh land formation and succession along the lower Colorado River and their importance and management problems as related to wildlife in the arid southwest. *Trans. N. Amer. Wildl. Nat. Res. Conf., Wildlife Mgmt. Inst., Washington, D.C.* 40: 240-251.

Ohmart, R. D., and B. W. Anderson. 1982. North American desert riparian ecosystems. Pp. 433-479. *In,* G. L. Bender (ed.). *Reference Handbook on the Deserts of North America.* Greenwood Press. Westport, CT.

Olberg, C. R., and F. R. Schanck. 1913. *Special report on irrigation and flood protection, Papago Indian Reservation, Arizona.* 62nd Congress, 3rd Session, Senate Doc. 973: 1-32.

Olmstead. F. H. 1919. *Gila river flood control—a report on flood control of the Gila River in Graham County, Arizona.* U.S.

65th Congress, 3rd Session. Senate Doc. 436: 1–94.

Parke, J. G. 1857. Report of explorations for railroad routes. *In, Explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean.* U.S. 33rd Congress, 2nd Session, Senate Ex. Doc. 78, Vol. 7: 1–469.

Parry, C. C. 1857. General geological features of the country. *In,* W. H. Emory, *Report of the United States and Mexican Boundary Survey.* Vol. 1, Part II. Washington. U.S. 34th Congress, 1st Session, Senate Exec. Doc. 108: 1–23.

Pattie, J. O. 1833. *The Personal Narrative of James O. Pattie, of Kentucky.* E. H. Flint. Cincinnati. (Reprinted by Reader Microprint, 1966).

Patton, D. R., and B. I. Judd. 1970. The role of wet meadows as wildlife habitat in the Southwest. *J. Range Mgmt.* 23: 272–275.

Patton, P. C., and S. A. Schumm. 1981. Ephemeral-stream processes: implications for studies of Quaternary valley fills. *Quaternary Res.* 15: 24–43.

Peterson, H. V. 1950. The problem of gullying in western valleys. Pp. 407–434. *In,* P.D. Trask (ed.), *Applied Sedimentation.* John Wiley and Sons. New York.

Pfeffercorn, I. 1949. *Sonora, a Description of the Province.* T. E. Trentlein (transl. and ed.). Univ. N. Mex. Press. Albuquerque.

Powell, H. M. T. 1931. *Over the Santa Fe Trail to California, 1849-1852.* D. S. Watson (ed.). The Book Club of Calif. San Francisco.

Pumpelly, R. 1870. *Across America and Asia: Notes of a Five-Year Journey Around The World and of Residence in Arizona, Japan and China.* Leypoldt and Holt. New York.

Ransome, F. L. 1904. Geology and ore deposits of the Bisbee quadrangle, Arizona. *U.S. Geol. Surv. Prof. Pap.* 21: 1–168.

Rea, A. M. 1983. *Once a River: Bird Life and Habitat Changes on the Middle Gila.* Univ. Ariz. Press. Tucson.

Riecker, P. 1879. Map of Arizona Territory prepared by authority of Bvt. Major General O. B. Willcox, Commanding Dept., under the direction of 1st Lieut. Fred A. Smith. Adjutant 12th Infty., Engineer Officer D. A.

Riggs, H. D. 1955. Arivaca is old Arizona. *The Arizona Publisher,* 1 (September 1955): 6.

Rinne, J. N. 1976. Cyprinid fishes of the genus *Gila* from the lower Colorado River basin. *Wassman J. Biol.* 34: 65–107.

Robinson, T. W. 1965. Introduction, spread, and areal extent of saltcedar *(Tamarix)* in the western states. *U.S. Geol. Surv. Prof. Pap.* 491–A: 1–12.

Rodgers, W. M. 1965. Historical land occupance of the upper San Pedro Valley since 1870. Unpubl. M.A. Thesis. Univ. Ariz. Tucson.

Roeske, R. H., and W. L. Werrel. 1973. Hydrologic conditions in the San Pedro River Valley, Arizona, 1971. *Ariz. Water Comm. Bull.* 4: 1–76.

Russell, F. 1908. *The Pima Indians.* Ann. Rept. Bur. Amer. Ethnol. 26: 3–389.

Sauer, C. O. 1930. Basin and range forms in the Chiricahua Area. *Univ. Calif. Publ. Geogr.* 3: 339–414.

Sauer, C. O. 1934. *The Distribution of Aboriginal Tribes and Languages in Northwestern Mexico.* Univ. Calif. Press. Berkeley.

Sayles, E. B., and E. Antevs. 1941. The Cochise Culture. *Medallion Pap.* 29: 1–81.

Schoenwetter, J. 1960. Pollen analysis of sediments from Matty Wash. Unpubl. M.S. Thesis. Univ. Ariz. Tucson.

Schreiber, J. S., G. L. Pine, B. W. Pipkin, R. C. Robinson, and J. C. Wilt. 1972. Sedimentologic studies in the Willcox Playa area, Cochise County Arizona. Pp. 133–184. *In* C. C. Reeves, Jr. (ed.). *Playa Lake Symposium,* International Center for Arid and Semi-Arid Land Studies, Publication no. 4. Texas Tech Univ. Lubbock.

Schulman, E. 1950. Miscellaneous Ring Records. I. *Tree Ring Bull.* 16: 21.

Schulman, E. 1951. Miscellaneous Ring Records III. *Tree Ring Bull.* 17: 28–30.

Schulman, E. 1951. Tree-ring indices of rainfall, temperature, and river flow. Pp. 1024–1029. *In,* T. F. Malone (ed.), *Compendium of Meteorology.* Wanesley Press. Baltimore.

Schulman, E. 1956. *Dendroclimatic Changes in Semiarid America.* Univ. Ariz. Press. Tucson.

Schumm, S. A. 1977. *The Fluvial System.* Wiley-Interscience. New York.

Schumm, S. A., and R. F. Hadley. 1957. Arroyos and the semi-arid cycle of erosion. *Amer. J. Sci.* 255: 161–174.

Schwennesen, A. T. 1917. Ground water in San Simon Valley, Arizona and New Mexico. *U.S. Geol. Surv. Wat.-Suppl. Pap.* 425A: 1–35.

Schwalen, H. C. 1942. Rainfall and runoff in the upper Santa Cruz River drainage basin. *Univ. Ariz. Agric. Expt. Sta. Tech. Bull.* 95: 421–472.

Schwalen, H. C., and R. J. Shaw. 1957. Ground water supplies of Santa Cruz Valley. *Univ. Ariz. Agr. Expt. Sta. Tech. Bull.* 288: 1–119.

Sedelmayr, J. 1955. *Jacobo Sedelmayr, 1744-1751. Missionary, frontiersman, explorer in Arizona and Sonora.* P. M. Donne (transl. and ed.). Original manuscript narratives. Ariz. Pioneers' Hist. Soc. Tucson.

Sellers, W. D., and R. H. Hill (eds.). 1974. *Arizona Climate,* 1931–1972, 2d ed. Univ. Ariz. Press. Tucson.

Simons, F. S. 1964. Geology of the Klondyke quadrangle, Graham and Pinal counties, Arizona. *U.S. Geol. Surv. Prof. Pap.* 461: 1–173.

Smiley, T. L. 1950. Miscellaneous Ring Records II. *Tree Ring Bull.* 16: 22–23.

Smith, E. L., and G. L. Bender. 1973a. Cook's Lake. *Ariz. Dept. Econ. Plan. Devel. Proposed Natl. Area Rept.* 1: 1–10, appendix.

Smith, E. L., and G. L. Bender. 1973b. Arivaca Ciénega. *Ariz. Dept. Econ. Plan. Devel. Proposed Natl. Area Rept.* 8: 1–3, appendix.

Smith, E. L., and G. L. Bender. 1974a. Leslie Canyon. *Ariz. Dept. Econ. Plan. Devel. Proposed Natl. Area Rept.* 66: 1–6.

Smith, E. L., and G. Bender. 1974b. St. David. *Ariz. Dept. Econ. Plan. Devel. Proposed Natl. Area Rept.* 70: 1–5.

Smith, E. L., and G. L. Bender. 1974c. Babocomari Ciénega. *Ariz. Dept. Econ. Plan. Devel. Proposed Natl. Area Rept.* 72: 1–6.

Smith, E. L., and G. L. Bender. 1974d. Cook's Lake Natural Area. *Ariz. Off. Econ. Plan. Devel. Proposed Natl. Area Mgmt. Plan* Pp. 1–15.

Smith, G. E. P. 1910. Groundwater supply and irrigation in the Rillito Valley, Tucson, Arizona. *Univ. Ariz. Agric. Exp. Sta. Bull.* 64: 1–244.

Solomon, A. M., and T. J. Blasing. 1982. Modern analogues for Holocene climatic regimes in the desert southwest: a hot, dry Altithermal? *Bull. Ecol. Soc. Amer.* 63: 167 (abstr.).

Spicer, E. H. 1962. *Cycles of Conquest.* Univ. Ariz. Press. Tucson.

Stockton, C. W. 1975. Long-term Streamflow Records Reconstructed from Tree Rings. Lab. Tree Ring Res. Univ. Ariz. Tucson.

Stockton, C. W., and D. M. Meko. 1975. A long-term history of drought occurrence in western United States as inferred from tree rings. *Weatherwise* 28: 245–49.

Stockton, C. W., and H. C. Fritts. 1971. Conditional probability of occurrence for variations in climate based on width of annual tree rings. *Tree Ring Bull.* 31: 3–24.

Stone, J. 1941. History of Fort Grant. Unpubl. M.A. Thesis, Univ. Ariz. Tucson.

Sumner, J. R. 1977. The Sonora earthquake of 1887. *Bull. Seismo. Soc. Amer.* 67: 1219–1223.

Sweeny, T. W. 1956. *Journal of Lt. Thomas W. Sweeny, 1849–1853.* A. Woodward (ed.). Westernlore Press. Los Angeles.

Tamayo, J. L. 1949. *Geografía General de México.* Tomo II. México, D.F.

Teal, J. M., and J. Kanwisher. 1961. Gas exchange in a Georgia salt marsh. *Limnol. Oceanogr.* 6: 388–399.

Teal, J. M., and J. Kanwisher. 1966. Gas transport in the marsh grass. *Spartina alterniflora. J. Exp. Bot.* 17: 355–361.

Teskey, R. O., and T. M. Hinckley. 1977. *Impact of Water Level Changes on Woody Riparian and Wetland Communities,* Vol. I: *Plant and Soil Responses to Flooding.* FWS/OBS-77/58. National Stream Alteration Team, Office of Biological Services, U.S. Fish and Wildlife Service.

Thornber, J. J. 1910. The grazing ranges of Arizona. *Univ. Ariz. Agric. Expt. Sta. Tech. Bull.* 65: 241–360.

Thornthwaite, C. W., R. F. S. Sharpe, and E. F. Dosch. 1942. Climate and accelerated erosion in the arid and semiarid southwest, with special reference to Polacca Wash drainage basin, Arizona. *U.S. Dept. Agric. Tech. Bull.* 808: 1–134,

Turnage, W. V., and A. L. Hinckley. 1938. Freezing weather in relation to plant distribution in the Sonoran Desert. *Ecol. Monogr.* 8: 529–550.

Turner, H. S. 1966. *Original Journals of Henry Smith Turner, with Stephen Watts Kearney to New Mexico and California.* D. L. Clarke (ed.). Univ. Okla. Press. Norman.

Turner, R. M. 1974. Quantitative and historical evidence of vegetation changes along the upper Gila River, Arizona. *U.S. Geol. Surv. Prof. Pap.* 655-H: 1–20.

Tyler, D. S. 1881. *A Concise History of the Mormon Batallion in the Mexican War.* The Rio Grande Press. Chicago. (1964 reprint).

U.S. Army. 1875. Report on the hygiene of the U.S. Army. *U.S. Army, Surgeon General's Circ.* 8: 1–567.

Vail, E. L. Undated. Reminiscences. Unpubl. Manuscript. Ariz. Hist. Soc. Tucson.

Valentine, K. A. 1947. Distance from water as a factor in grazing capacity of rangeland. *J. Forest.* 45: 749–754.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. *Can. J. Fish. Aquat. Sci.* 37: 130–137.

Wagoner, J. J. 1952. History of the cattle industry in southern Arizona, 1540–1940. *Univ. Ariz. Soc. Sci. Bull.* 20: 1–132.

Wagoner, J. J. 1960. Overstocking of the ranges in southern Arizona during the 1870's and 1880's. *Arizoniana* 2: 23–27.

Walker, H. P., and D. Bufkins. 1979. *Historical Atlas of Arizona.* Univ. Okla. Press. Norman.

Way, P. R. 1960. Overland via Jackass Mail in 1858, the Diary of Phocian R. Way. *Arizona and the West.* 2: 35–53, 147–164, 279–292, 353–370.

Weber, D. J. 1971. *The Taos Trappers.* Univ. Okla. Press. Norman.

Welcomme, R. L. 1979. *Fisheries Ecology of Floodplain Rivers.* Longman. New York.

Westlake, D. F. 1963. Comparisons of plant productivity. *Biol. Rev.* 38: 385–425.

Westlake, D. F. 1965. Theoretical aspects of comparability of productivity data. *Mem. Ist. Ital. Idrobiol.* 18(Suppl.): 229–248.

Wheeler, C. C. Undated. History and facts concerning Warner and Silver lakes and the Santa Cruz River. Unpubl. Manuscript. Ariz. Hist. Soc. Tucson.

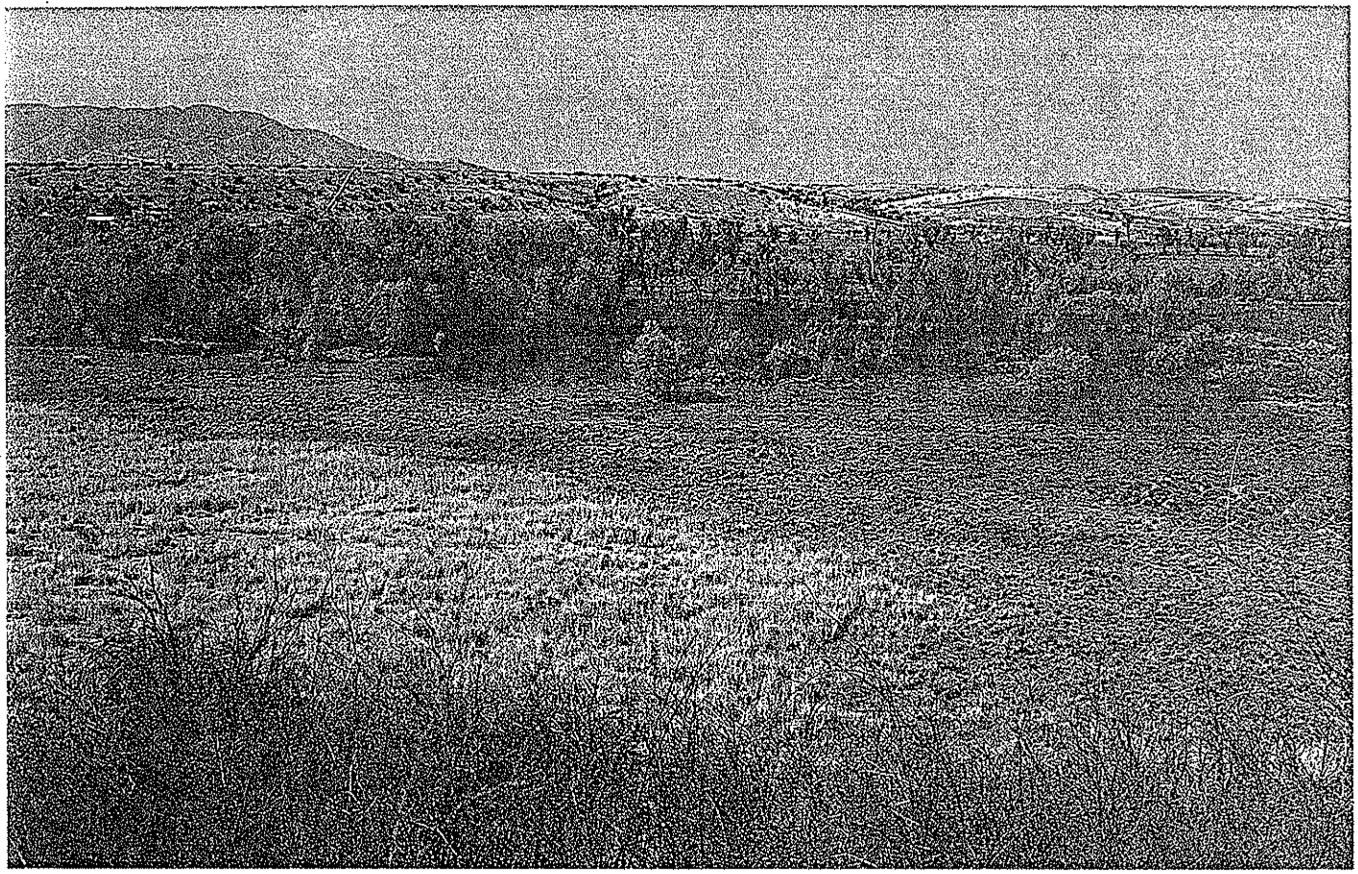
White, N. D., and D. Childers. 1967. Hydrologic conditions in the Douglas Basin, Cochise County, Arizona. *Ariz. Land Dept. Wat. Res. Rept.* 30: 1–26.

White, N. D., W. G. Matlock, and H. C. Schwalen. 1966. An appraisal of the ground-water resources of Avra and Altar valleys, Pima County, Arizona. *Ariz. Land Dept. Wat. Res. Rept.* 25: 1–66.

Wilson, E. D., R. T. Moore, and R. T. O'Haire. 1960. Geologic map of Pima and Santa Cruz counties, Arizona. Ariz. Bur. Mines. Univ. Ariz. Tucson.

Wilson, R. P. 1976. Maps showing ground-water conditions in the San Bernardino Valley area, Cochise County, Arizona, 1975. *U.S. Geol. Surv. Wat. Res. Invest.* 76–81: 2 sheets.

Yatskievych, G., and C. Jenkins. 1981. Fall vegetation and zonation of Hooker Ciénega, Graham County, Arizona. *J. Ariz.-Nev. Acad. Sci.* 16: 7–11.



Babocomari Ciénega, Arizona: overview upstream from retention dam at Babocomari Ranch. Photograph 1982.

The Ciénega Concept in the American Southwest. With this issue of *Desert Plants* Dean Hendrickson and W. L. Minckley crystallize the concept of the *ciénega* as used by scientists, anthropologists and historians in the Desert Southwest. They trace use of the term historically and geographically, presenting maps, descriptions and photographs, finally demonstrating (see their Table 2) the uniqueness of the *ciénega* and the logic with which it is set off as an ecological unit of the Desert Southwest.

Being well-watered sites in an arid setting, the *ciénegas* described in this issue have been of tremendous historic and prehistoric value to the regional biota and to man, in parallel fashion to how a dollar has greater value to the poor than to the wealthy. These *ciénegas* are special islands surrounded by land variously described as "desert," "arid," or "semi-arid."

Although *"ciénega"* has often been translated as *"marsh"* or *"swamp,"* the word has a much more specific meaning. The *ciénegas* of Hendrickson and Minckley generally owe their existence to springs in headwater situations where there is a low probability of scouring floods to cut channels which might drain them. One theory as to the derivation of the word *"ciénega"* suggested by Mitford M. Mathews in *A Dictionary of Americanisms on Historical Principles* (Univeristy of Chicago Press) ties in nicely with our present usage: *"ciénega"* is said to be a contraction or corruption of *"cien aguas,"* meaning "a hundred fountains" or a hundred springs. Indeed, in these headwater situations, water often rises to the surface in multiple sites, resulting in a unique type of well-watered flat or valley. To discover the unique aspects of the ciénega in the American Southwest, read this special issue of *Desert Plants.*

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arizona center for law in the public interest

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May 24, 1984

Terry Johnson
Arizona Game and Fish Commission
2222 W. Greenway Road
Phoenix, Arizona 85023

Dear Terry:

I would greatly appreciate any locality information that you could send me on federally or state listed threatened or endangered species in the following river segments: Santa Cruz River from City of Nogales discharge to Josephine Canyon; Santa Cruz River from Roger Road discharge (Tucson) to Baumgartner Road crossing; Gila River from the Salt River to Gillespie Dam; and Salt River from 23rd Avenue discharge to Gila River.

After our conversation, it occurred to me that some additional information about the Game and Fish Department's refuges along the Salt might also be useful.

I would be grateful if you could supply me with information on the location of these refuges, and a representative list of wildlife species that inhabit or use each.

Please send this information to me at the Tucson address shown in the letterhead. I would appreciate a response by June 7.

Sincerely,

David S. Baron

David S. Baron
Tucson Staff Attorney

DSB/kw

R12-4-109. Wildlife Areas   Amended 5/12/82

A. Wildlife Areas are described as follows:

1. Alamo Wildlife Area. The Alamo Wildlife Area shall be that area lying within the following described boundary: Beginning at the southeast abutment of the Alamo Dam; easterly on the Alamo access road to its junction with the boat dock road; northeasterly for approximately 1-3/4 miles; directly north across Bullard Wash to the Alamo Crossing road; easterly to its junction with the Brown's Crossing road; across the Bill Williams River to its junction with the Yucca road; southwesterly to the SW 1/4 of Section 22, T11N, R13W; southerly along the Reservoir Taking Line to the point of beginning.

2. Allen Severson Memorial Wildlife Area. The Allen Severson Memorial Wildlife Area shall be that area lying within the fenced and posted portion of the SE 1/4 of Section 32, and the S 1/2 SW 1/4 of Section 33, Township 11 North, Range 22 East and the N 1/2 NW 1/4 of Section 4, Township 10 North Range 22 East and the posted portion of the SW 1/4 NW 1/4 and the NW 1/4 SW 1/4 of Section 4, Township 10 North, Range 22 East, consisting of approximately 300 acres.

3. Aravaipa Canyon Wildlife Area. The Aravaipa Canyon Wildlife Area shall be that area within the boundaries of the Aravaipa Canyon Primitive Area administered by the Bureau of Land Management, consisting of approximately 4,044 acres.

4. Arlington Wildlife Area. The Arlington Wildlife Area shall be those portions of Section 9, 16 and 21 lying west on a line 100 feet west of the main channel of the Gila River, except the NW 1/4, Section 9 and the W 1/2, SW 1/4, Section 21, all in Township 2 South, Range 5 West, consisting of approximately 1,320 acres.

5. Base and Meridian Wildlife Area. The Base and Meridian Wildlife Area shall be the area within the following described legal subdivisions; Township 1 North, Range 1 East, Section 31, Lots 3, 5, 6, 7, & 8, NE 1/4 SW 1/4; Township 1 North, Range 1 West, Section 36, S 1/2 N 1/2 SE 1/4 consisting of approximately 773 acres.

6. Becker Lake Wildlife Area. The Becker Lake Wildlife Area shall be that area lying in the SE 1/4 SW 1/4 of Section 19, SW 1/4 SW 1/4 of Section 20 W 1/2 NW 1/4 SW 1/4 of Section 29, E 1/2 NE 1/4 and NE 1/4 SE 1/4 of Section 30, T9N, R29E.

7. Cibola Wildlife Area. The Cibola Wildlife Area shall be that Arizona Game and Fish Department controlled lands consisting of Section 36, Township 1 South, Range 24 West and accretions; Section 1, Township 2 South, Range 24 West and accretions; and the W 1/2 SW 1/4 Section 6, Township 2 South, Range 24 West G&SRB&M.

8. Chevelon Creek Wildlife Area. The Chevelon Creek Wildlife Area shall be that area lying in the NE 1/4 Section 26, and E 1/2 of Section 23, all in Township 18 North, Range 17 East, consisting of approximately 320 acres.

9. <u>Clarence May and C.M.H. May Memorial Wildlife Area</u>. Clarence May and C.M.H. May Memorial Wildlife Area shall be the SE 1/4 of Section 8 and N 1/2 of the NE 1/4 of Section 17, Township 17 South, Range 31 East, and the W 1/2 SE 1/4, SW 1/4 NW 1/4, SW 1/4 SW 1/4, NW 1/4 SW 1/4, SE 1/4 NW 1/4 and E 1/2 SW 1/4 of Section 9, Township 17 South, Range 31 East, G&SRB&M, containing 560 acres.

10. <u>Kaibab North Wildlife Area</u>. The Kaibab North Wildlife Area shall be that portion of the Kaibab National Forest located north of the Colorado River.

11. <u>Luna Lake Wildlife Area</u>. The Luna Lake Wildlife Area shall be that area from old Luna Lake dam then following the Arizona Game and Fish Department fence north, east, south, east and north to the point of beginning.

12. <u>Mittry Lake Wildlife Area</u>. The Mittry Lake Widlife Area shall be that area lying within the following described boundary: all lands lying west of the road paralleling the Gila Main Gravity Canal; north of the road paralleling the south shoreline of Mittry Lake; northwest on the east half of Laguna Dam; east of the California-Arizona state line; and south of the east half of the Imperial Dam.

13. <u>Painted Rock Wildlife Area</u>. The Painted Rock Wildlife Area shall be that area within the following described legal subdivisions:

T4S R6W,	Section 26 -	S 1/2, SW 1/4
	Section 27 -	S 1/2; S1/2, NW 1/4; and NW 1/4, NW 1/4
	All of Sections 28 and 29	
	Section 30 -	E 1/2; S 1/2, NW 1/4; E 1/2 SW 1/4 and NW 1/4, SW 1/4
	Section 31 -	S 1/2, SE 1/4, NE 1/4, SE 1/4; E 1/2, SW 1/4, NW 1/4, SW 1/4; SW 1/4, NW 1/4
	Section 35 -	NE 1/4, NW 1/4
T4S R7W,	Section 33 -	NE 1/4, NE 1/4, SE 1/4, NE 1/4, NW 1/4
	All of Section 34	
	Section 35 -	S 1/2; S 1/2, NE 1/4; S 1/2, NW 1/4
	All of Section 36	
T5S R7W,	Section 1 -	N 1/2, N 1/2
T5S, R6W,	Section 6 -	N 1/2, N 1/2, SE 1/4, NE 1/4

14. <u>Robbins Butte Wildlife Area</u>. The Robbins Butte Wildlife Area shall be that area lying within the fenced portion of the S 1/2, SE 1/4 of Section 21 with SW 1/4 of Section 21 lying 100 feet south of the main channel of the Gila River, the S 1/2 S 1/2, NE 1/4 SE 1/4 of Section 22, the S 1/2, S 1/2 NE 1/4 of Section 23 those portions of the SW 1/4 NW 1/4, W 1/2 SW 1/4 of Section 24 and the NW 1/4 NW 1/4 of Section 25 lying west of Hwy 80, the N 1/2 NE 1/4, SW 1/4 NE 1/4, NW 1/4 of Section 26, the N 1/2 of Section 27, the NE 1/4 of Section 28 and that area in the NW 1/4 of Section 28 lying north and east of a road extending

in a northwest direction from the center of Section 28 to the south boundary of Section 21, all in Township 1 South, Range 4 West; consisting of approximately 1,681 acres.

15. Roosevelt Lake Wildlife Area. The Roosevelt Lake Wildlife Area shall be that area lying within the following described boundary: Beginning at the junction of A-Cross Road and Hwy 188; south on 188 to junction of Hwy 88; east on 88 to Carson's Landing; northeast across Roosevelt Lake to the south tip of Bass Point; directly north to the Long Gulch Road; northeast on this road to the A-Cross Road; northwest on the A-Cross Road to the point of beginning.

16. Santa Rita Wildlife Area. The Santa Rita Wildlife Area is the posted portion of the Santa Rita Experimental Range lying west of the Madera Canyon Road (U.S. Forest Service Road 70 and north and west of those portions of U.S. Forest Service Roads 62, 85, and 505 that form the route from Madera (White House) Canyon to Helvetia.

17. Three Bar Wildlife Area. The Three Bar Wildlife Area shall be that area lying within the following described boundary: Beginning at Roosevelt Dam, northwesterly on Hwy 188 to a point approximately 7 miles from Roosevelt Dam; westerly along the boundary fence for approximately 7-1/2 miles to the boundary of Gila and Maricopa counties; southerly along this boundary through Four Peaks to Buckhorn Mountain; southerly along the barbed wire drift fence to the edge of Apache Lake; along Apache Lake to Roosevelt Dam.

18. Tucson Mountain Wildlife Area. The Tucson Mountain Wildlife Area shall be that area lying within the following described boundary: Beginning at the northwest corner of Section 33, Township 13 South, Range 11 East on the Saguaro National Monument boundary; due south approximately 1 mile to the El Paso Natural Gas Pipeline; southeast along this pipeline to its junction with the Ajo Highway; easterly along this highway to the Tucson city limits; north along the city limits to Silverbell Road; northwest along this road to Twin Peaks Road; west along this road to Sandario Road; south along this road to the Saguaro National Monument boundary; west and south along the monument boundary to the point of beginning.

19. Willcox Playa Wildlife Area. The Willcox Playa Wildlife Area shall be that area lying in the S 1/2 of Section 2, the SE 1/4 of Section 3 and all of Section 10 and 11 in T15S, R25E.

BRUCE BABBITT, *Governor*

Commissioners:
FRANCES W. WERNER, Tucson, Chairman
CURTIS A. JENNINGS, Scottsdale
W. LINN MONTGOMERY, Flagstaff
FRED S. BAKER, Elgin
LARRY D. ADAMS, Bullhead City

Director
BUD BRISTOW

Assistant Director, Services
ROGER J. GRUENEWALD

Assistant Director, Operations
DUANE L. SHROUFE

ARIZONA GAME & FISH DEPARTMENT

2222 West Greenway Road Phoenix, Arizona 85023 942-3000

June 1, 1984

RECEIVED JUN 05 1984

David S. Baron
Arizona Center for Law
in the Public Interest
32 North Tucson Blvd.
Tucson, Arizona 85716

Dear Mr. Baron:

Please find below the special category species that occur along the drainages mentioned in your letter of May 24, 1984.

Gila River

Yuma Clapper Rail (Rallus longirostris yumaensis) - at 119th Avenue and near Powers Butte
Black-crowned Night Heron (Nycticorax nycticorax hoactle) - occurs seasonally along river, nests below Painted Rock Reservoir
Desert Tortoise (Gopherus agassizi) - at Buckeye area

Santa Cruz River

Desert Hook-nosed Snake (Gyalopion quadrangularis) - near confluence with Nogales Wash
Tropical Kingbird (Tyrannus melancholicus) - near Trico Road (Marana area)

I have enclosed legal descriptions of the Department's Wildlife Areas that occur along these rivers. Unfortunately, there are no lists of plants or animals that occur in these areas. There presently are no known occurrences of any special category species on these Wildlife Areas, although Yuma Clapper Rails have been observed very near the Base and Meridian Wildlife Area and no doubt occasionally occur there. Robbins Butte & Arlington are exceptional areas for production of small game species, especially doves.

EXHIBIT A

If I can be of further assistance, please do not hesitate to contact me at 942-3000 (x 247) or the Department's main office in Phoenix,

Sincerely,

Bud Bristow, Director

Richard L. Glinski

Richard L. Glinski
Nongame Biologist

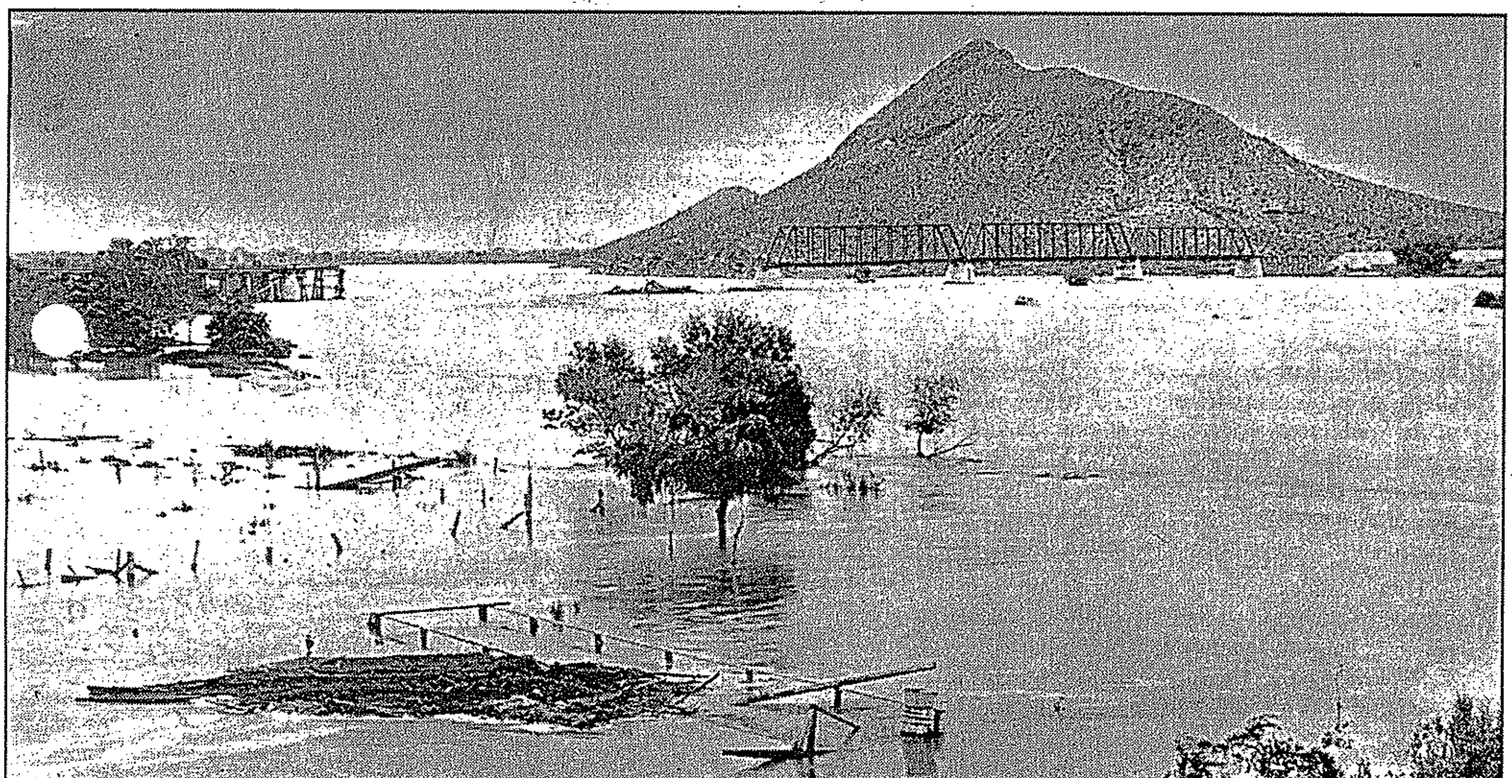
RLG:am

Encls.

OUTLOOK

RIPARIAN AREAS

Protect them, for our future



File photo

A flooded Salt River at Tempe in 1905. Flood-control and other projects have turned many Arizona rivers into washes.

By Chuck Blanchard
Special for The Arizona Republic

Arizona has seen many changes in the last century. Less than 100 years ago, the Gila, Salt and Santa Cruz rivers flowed year-round. Passage across the Salt River near Phoenix required a ferry boat.

Unfortunately, most of Arizona's desert streams and rivers are now merely washes. In many areas the Gila, Salt and Santa Cruz rivers flow intermittently, if at all. Most of the native vegetation along our rivers and streams was either removed long ago, or has been crowded out by non-native plants.

When all is said and done, fully 90 percent of Arizona's water-based habitats, known as riparian areas, has been destroyed or seriously degraded. Worse, this destruction is only part of a larger pattern in the United States and, indeed, the world. Riparian areas throughout the desert Southwest have vanished. Only a small fraction of the forests that once dominated the eastern United States still remain. Over 90 percent of the wetlands in most of the Midwestern states is gone.

It should not be surprising, therefore, that the number of species headed toward extinction has also risen dramatically in recent years. While often bitter and expensive battles are fought to save individual endangered plants and wildlife, the list of endangered species continues to grow. Efforts to save individual species often come too late, with extinction postponed but not prevented. Moreover, the most effective tool for the protection of endangered plants and wildlife — the Endangered Species Act — is under attack from a large coalition of economic interests.

'Treating the symptom'

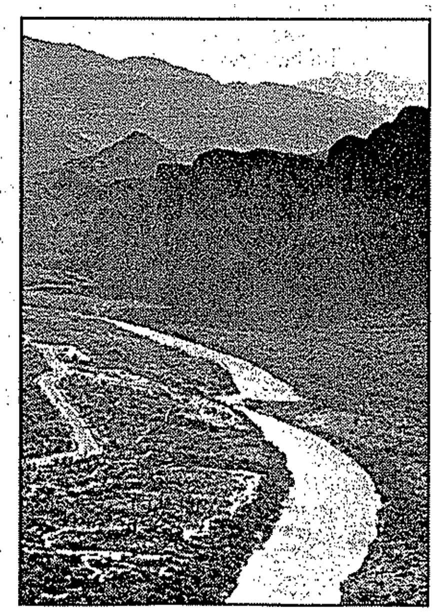
As writer Suzanne Winckler explained last year in the *Atlantic Monthly*, we are "treating the symptom and not the disease." We "have come to rely on heroic measures for saving one species at a time" because we "have failed at the alternative of saving habitat," Ms. Winckler wrote. It is time that we recognize that if we wish to preserve even a portion of our endangered wildlife, we must succeed at the alternative of saving our natural habitats.

Although riparian areas occupy less than one-half of 1 percent of the total landscape, the Arizona Game and Fish Department estimates that three-quarters or more of all the state's native wildlife species depend on these areas for at least some portion of their life cycle. Because of the large variety of plants in these areas, even small riparian communities can support a wide diversity of animal life. Desert riparian areas are capable of producing more than 100 times as much living matter as other parts of the desert.

We could wait until the Endangered Species Act forces us to take responsibility for preserving these habitats. Unfortunately, this is likely to be too little and too late, and could suddenly disrupt rural economies that are dependent on ranching, mining and agriculture. I am convinced that there is a better solution. We should follow the logic of Suzanne Winckler and work to preserve our remaining riparian areas, rather than wait until the day when we find ourselves engaged in what would probably be a futile effort at crisis management, satisfying no one.

Unfortunately, our current laws are simply inadequate for the task. The Department of Water Resources is guided by a requirement that when there are competing applications for surface water use, municipal and agricultural interests receive preference over recreation or wildlife habitat. This law no longer reflects even economic reality. It is simply no longer true that irrigating a few more acres of crops or providing water to a few more summer homes is always of greater economic benefit than recreation or habitat. State law must reflect the reality that in many instances, the most valuable use of water is for habitat preservation.

Additionally, there is no law allowing a state agency such as Game and Fish the rights to surface water in order to preserve a stream or river for natural habitat uses. In other words, the water now flowing in our streams and rivers is fair game for consumptive use.



The Arizona Republic
Riparian areas are capable of producing more than 100 times as much living matter as other parts of the desert.

Not an abstract problem

Next, outside of Active Management Areas, there is wholly inadequate regulation of groundwater pumping. Even when groundwater pumping begins to drain our streams and rivers, there is little that the Department of Water Resources can do. This is not just an abstract problem. Unless water-use patterns change, the San Pedro Riparian National Conservation Area in southern Arizona will slowly go dry.

State agencies also need to be empowered to adopt tough land-management standards that also protect riparian areas from further degradation and destruction. If good land management practices are enforced, protection of riparian areas can often be compatible with a wide variety of other land uses.

Finally, we must work toward creative solutions to the problem of saving and perhaps even restoring critical riparian areas in ways that do not threaten resource-dependent economies. The newly created Heritage Fund will provide the resources necessary for the acquisition and protection of vital riparian areas that would otherwise be destroyed by development or neglect. It can also be used to fund incentives for private-sector initiatives to restore and maintain Arizona's riparian areas. There are several exciting examples already under way in Arizona. The Nature Conservancy is working with a variety of land managers to protect the entire San Pedro River system. Others are working together to protect the Verde River system.

This year may be the year when we finally do something to protect the valuable areas. In his State of the State address, Gov. Symington made clear that such protection will be a priority this legislative session. Democrats and Republicans alike in both the House and the Senate are also in support of measures to protect these habitats.

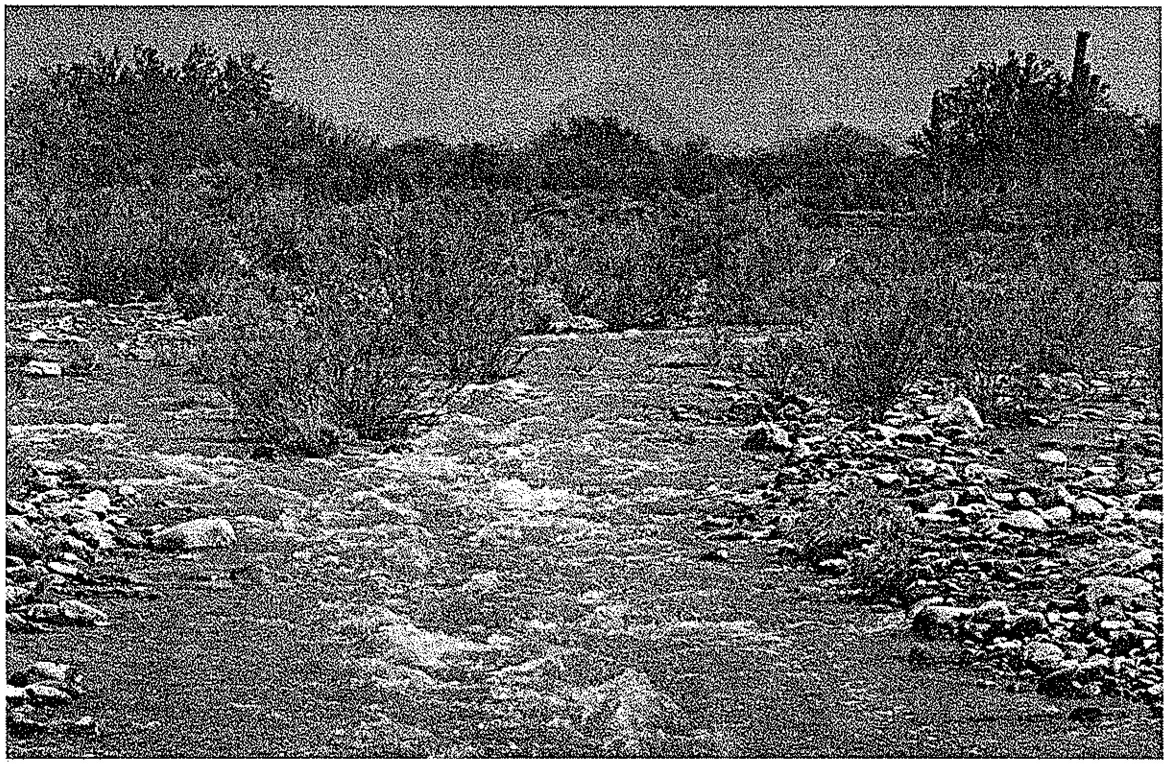
Environmental policy is always a troublesome balance between economic needs and natural preservation. In the case of riparian areas, however, the balance has been sharply tilted for too long toward economic exploitation. It is now time to right that balance.

Chuck Blanchard, Democrat of Phoenix, is vice chairman of the Arizona Senate Environment Committee.

Riparian

ARROYO

Vol. 5 No. 2 June 1991



Many washes flow from desert into urban areas. (Photo: George Andrejko, Arizona Game & Fish Dept.)

Often Neglected, Urban Washes Now Seen as Attractive Resource

Washes and arroyos cut or carve patterns into desert surfaces and are as much a natural form of the Arizona landscape as serrated mountains. Meandering over much of the desert, their crevices help make up the texture and shape of desert lands. Indeed, even in developed and urbanized desert areas, washes and arroyos often remain a conspicuous feature, a natural remnant within the urban fabric.

In the past, however, urban washes were little valued; in fact, they were often perceived to be an urban nuisance. Washes gouged land that would otherwise be suited for the accouterments of urbanization – roads, businesses and dwellings. Further, they brought floods that threatened life and property. Land adjacent to urban drainage-ways therefore was thought to have little land-use value. Such areas acted as barriers to urban growth and development.

Despite their problems, washes in urban areas served purposes that were perceived to be useful and practical, and for this they were appreciated. They acted as conduits to drain flood waters. They provided a source of sand and gravel and locations to dump unwanted materials and trash. Then, as is frequently true now, the practical benefits of preserving the natural conditions of washes were not readily recognized. An esthetics of urban washes had not evolved.

The Value of Urban Washes

"Wash" is a term that defies precise definition. Generally a wash is an ephemeral stream; i.e., a stream without a continual flow. Some rather large ephemeral streams, however, such as the Santa Cruz or the Salt, are termed rivers. Size therefore determines the river designation, although in most other respects such rivers are identical to washes. Watercourse is a more inclusive term.

Increasingly washes are being recognized as a valuable resource to benefit the urban setting. The environmental ethic that has emerged relatively recently has encouraged a perception of urban washes as a natural form to be preserved, protected, and, when necessary, restored. The occurrence of washes within an urban area provides various benefits.

An obvious benefit is that washes have the potential to provide city dwellers with a touch of nature. By offering a valued intrusion of natural habitat into urbanized areas, washes clearly contribute to the greening of the city. A natural wash in an urban setting helps demonstrate the premise that cities, especially western U.S. cities, have the resources to creatively blend natural and urban features to enrich the lives of those who live there.

As a proponent of this view, William W. Shaw of the University of Arizona's School of Renewable Natural Resources studied the occurrence of wildlife habitat within the Tucson area. He argues that wildlife is an important urban concern. In a sense, therefore, elected officials, planners, and developers are wildlife managers in metropolitan areas. Their actions affect the preservation and occurrence of wildlife within the city.

Shaw inventoried habitats remaining within the Tucson area to determine their viability to support wildlife. He indicates that the most sensitive habitats occur in association with Tucson's natural drainage system, its washes. In non-degraded areas, the network of washes provides an interconnected system of open spaces and supports native plant communities. This benefits such wildlife as quail, roadrunners, javelina, and coyotes that are able to live in close proximity to humans. Other Arizona urban areas may not share the same conditions. The main premise however is generally relevant: washes are often a preserve for desert flora and fauna within a city.

Related to the environmental benefits offered by urban washes are the recreational advantages. For example, washes form an interconnecting system of drainageways spread over an extended area. Their banks or channel beds therefore form a natural pathway for walking, jogging or hiking.

A city gains economic advantages with such environmental and recreational features. For example, studies demonstrate that property values increase in areas in proximity to recreational amenities such as hiking trails. Further, surveys have indicated that a prime factor influencing businesses to locate in Arizona is the availability of open spaces and abundant outdoor recreational opportunities. Urban washes can thus be an economic asset.

Washes can also be a natural form to guide the growth and development of a settlement or city. For example, native people who lived in this arid region often located their settlements along river banks. Here a reliable source of water was available in a pleasant environment.

Arriving well after the original inhabitants, some city planners still share their interest in washes as a focal point for development. Often prompting this interest is a dissatisfaction with the grid pattern of development common to most western cities. This development is often faulted as a synthetic overlay that ignores the natural forms and conditions abundantly, and often dramatically present in the West.

Some planners argue that the lines and patterns created by washes could be a natural form to guide city planning. As a low point of a watershed, washes reflect the land forms of an entire area and set a natural pattern for organizing urban development. The beauty and appeal of a city might well be enhanced if such projects as roads and housing were designed to be compatible with the cut and shape of area washes. The integration of washes into urban design is an intriguing but little practiced concept.

Urbanization and Washes

Previously, in areas that are now Tucson and Phoenix, virgin washes meandered through pristine desert. Various human activities, however, wrought major changes to wash areas, often despoiling their natural conditions. The land was grazed, and trees were cut. Settlements expanded into towns and cities, with desert lands converted to urban uses. Groundwater tables dropped because of increased pumping to support a growing population.

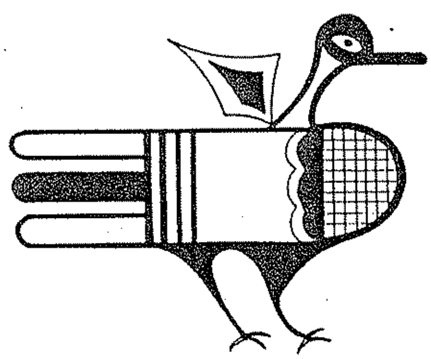
As urban conditions intensified other situations developed that further contributed to the degradation of washes. For example, urban development increased the extent of impervious surfaces. Instead of percolating into the subsurface, rain now accumulates and runs off streets, sidewalks, parking lots and buildings and flows into washes. In an urbanized area, runoff is estimated to be four times that of a comparable undeveloped desert area. The drainage from the increased runoff that concentrates in rivers and washes accelerates the quantity and velocity of the flow on downstream reaches. Channels enlarge becoming deeper and wider, and damage from erosion becomes a greater threat.

Although damaging to many washes, the increased flow from urban surfaces actually benefits others. A comparison of photographs taken during different time periods demonstrates that certain washes have recently experienced increased size and density of vegetative growth. This new growth includes palo verdes, mesquites, and acacias. Contrary to the usual state of affairs, this is an example of an urban condition benefiting a natural habitat. Still hurting, however, are stands of deciduous trees such as cottonwoods. These trees rely on the watertable which has been dropping, despite the increased flows.

Along with the volume of water that flows off urban surfaces into washes, the quality of that water is also a concern, one that will need to be increasingly reckoned with. Washes in urban areas receive water carrying varying degrees of nonpoint source (NPS) pollution. This is a type of pollution not readily identified with a particular source.

Rainfall flowing over urban surfaces—streets, parking lots, landscaped areas, industrial sites—picks up various NPS constituents. These include sediments and debris from worn and weathered pavements and buildings; heavy metals and inorganic chemicals from transportation activities and building materials; and nutrients from fertilizers used on lawns and landscape vegetation.

Concerned about the quality of urban runoff, the Environmental Protection Agency has recently proposed rules and regulations for stormwater discharge. In effect, water quality standards are to be set for runoff into urban washes. Cities of a certain size will need to obtain a National Pollutant Discharge Elimination System (NPDES) permit for stormwater discharge by 1992. Authorized under the federal Clean Water Act, the NPDES program intends to control or eliminate the discharge of stormwater runoff pollutants to waterways.



San Ildefonso bird design

The Arizona Department of Environmental Quality is presently developing the stormwater standards. Since no specific stormwater standards exist, surface water standards are expected to become the basis for the NPDES permit. This has caused concern that developed stormwater standards will be excessively strict, a burden for municipalities and industries alike. Also feared is that excessively strict standards might affect the condition of urban waterways in various ways.

For example, reduced flows into washes may result. This could happen if stormwater treatment becomes necessary to meet strict water quality standards. This is an expensive process. As a result, stormwater may be diverted from flowing into washes and contained in retention basins rather than being released. Deprived of the flow, vegetation within washes could be adversely affected.

Some officials, however, question whether the regulation of stormwater will necessarily restrict its discharge into washes. Such officials claim that, although research in the area is limtied, researchers thus far have not detected excessive amounts of pollutants that would raise concerns under proposed water quality standards.

John Brock and Doug Green from the Arizona State University's School of Agri-Business and Environmental Resources are working on a project of relevance to the NPS pollution problem within urban washes. They are studying the chemistry of soils within urban riparian areas to determine how NPS pollution is affecting such locations. Their work also involves identifying vegetation with a potential to modify some of the pollution from urban runoff.

New water quality standards are also being proposed for discharges from sewage treatment plants. Here, too, concern is expressed that excessively strict standards could adversely affect the natural conditions of streams and washes. Such discharges have benefited riparian areas. If strict standards discourage discharges, riparian habitats could be affected, even destroyed. This situation poses a quandary for some people who must now consider tradeoffs in water quality to preserve riparian areas.

Flood Control and Urban Washes

Flood control and urban wash development are complementary issues. If understood in narrowly interpreted utilitarian terms, the purpose of a wash is to carry water. If this purpose is to be solely served, then flood control efforts are best that enable a wash to more effectively carry greater amounts of water. Such strategies however are often environmentally destructive. The crux of the urban wash issue therefore is to devise a strategy to accommodate drainage needs, as well as preserve conditions essential for environmental and recreational amenities.

Different philosophies guide flood control strategies. Once thought to be a nuisance, stormwater was considered best managed and controlled if made to flow from an area expeditiously. To widen, straighten, and channelize were the preferred strategies to rid an area of floodwaters. Such methods are considered structural since they basically consist of physical modifications to adjust and change the flow of floodwaters. Structural methods include such measures as levees, floodwalls, channel improvement, and storage reservoirs.

Developers are generally strong supporters of structural flood control measures. Anxious to develop the maximum amount of land, they often advocate bank stabilization projects to control flooding and land erosion that would otherwise threaten development. With banks stabilized, more land is available to develop. For example, in planning its Rio Salado project, the city of Tempe estimates it can reclaim about 850 acres of land by creating a bank stabilized floodway channel within the Salt River. The reclaimed acreage is to be used for a multiple-use urban park.

With an increased concern about the environment, a wariness has developed about the physical changes or modifications that result from structural methods. Critics are questioning the effectiveness of structural methods to mitigate the adverse impacts of flood losses on the individual and community. For example, by directing and facilitating the flow of runoff, structural measures tend to increase the velocity of a flood. As a result, runoff is more quickly concentrated resulting in higher levels of inundation. This results in increased erosion of downstream banks and greater disruption of natural conditions.

Also flood control methods can reduce the esthetic appeal of an area and thus detract from its environmental and/or recreational uses. To most people, for example, a concrete-lined channel is much less appealing than a natural riverbed with vegetation. The latter inspires greater interest and use.

Assurances are therefore sought that whatever flood control strategies are employed will not despoil the valued natural conditions of a wash. This position has gained recognition to the extent that flood control projects are now often accompanied by mitigation efforts to reclaim degraded wash areas. In fact, federal guidelines require such actions in certain circumstances.

Actions and Policies to Preserve Urban Washes

Government agencies may take various actions that, although often primarily intending to control flooding and protect lives and property, also contribute to the preservation of urban washes. For example, a flood control district may buy up undeveloped floodplains upstream of an urban area. This helps to ensure that the area will not be developed and channelized with conventional structural flood control methods. Downstream flood peaks, therefore, are controlled. At the same time, however, the natural conditions of the wash are protected. Pima County has purchased about 5,000 acres for this purpose with flood control bond and levy money.

The issue of land acquisition also arises when washes are to be preserved or developed for recreation. Land adjacent to a wash is often needed for trails or other recreational amenities. This land is acquired in various ways. Pima County floodplain ordinance requires a fifty-foot dedication along improved major watercourses, mainly for access and maintenance purposes. The easement is also available for development as part of the Pima County linear park. When land is needed that is not part of an easement, Pima County purchases it. Also, Pima County may require developers to dedicate washes as a condition of rezoning.

A flood control district may help preserve washes by encouraging the development of master plans to guide development along watercourses. For example, the Maricopa Flood Control District is involved in developing a master plan for areas along the Salt and Gila Rivers. The plan contains several objectives to ensure the environmental quality of watercourses. For example, natural riverine habitats are to be identified for preservation. Also, a regional perspective for developing park and recreational facilities in the floodplain is to be promoted.

Conditions of rezoning can also be established to preserve the natural state of washes and are useful tools to implement the policies of an area plan. For example, a master plan might identify washes with a natural habitat to be maintained or enhanced. If the area is rezoned with such conditions, enforcement is thus prescribed. Some people are wary of rezoning, however, since it can go either way. Rezoning might also permit certain activities that are detrimental to natural conditions, such as concreting a wash.

The passing of ordinances is another strategy to protect urban washes. The city of Tucson has passed two such ordinances. One ordinance recognizes that unspoiled urban washes contribute to the health and well-being of the city's residents and describes measures to protect and maintain the natural conditions of designated urban washes. Also, Scottsdale has recently passed an Environmentally Sensitive Land Ordinance that designates much of North Scottsdale, including its mountains, foothills and alluvial fans as requiring special zoning considerations. The ordinance includes natural open space incentives which discourage development from highly visible mountains and washes.

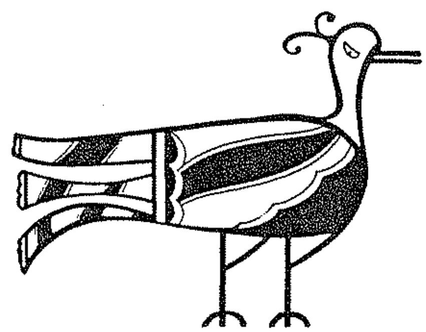
An individual property owner can protect the natural conditions of a wash by establishing a conservation easement along the watercourse. Conservation easements are restrictions landowners voluntarily place on their property or a section of it to legally bind present and future owners. It specifically prohibits certain activities – e.g, timber cutting, ditch digging, construction – to protect the habitat, flora, or fauna found on the land. A conservation easement might also provide a tax benefit to the property owner.

Different urban wash projects are in various stages of development within the state. What progress and success they demonstrate depend on a number of variables. Obviously, more than the natural forces of geology are at play. Political and social forces are also involved. A few such projects will now be described as case studies. They will demonstrate the issues involved when such work is undertaken and also convey the range and types of urban wash projects within the state.

Pima County River Park

Pima County is in the process of establishing a river park system along the banks of its major watercourses. The eventual goal is to develop up to 105 miles of linear river park along the Santa Cruz and Rillito Rivers and the Canada del Oro, Pantano, and Tanque Verde Washes. Thus far about 4 miles have been constructed.

The river park system is a component of a more grandiose trail design, the Eastern Pima County Trail System Master Plan. The latter plan intends to expand on the existing and planned river park system to connect with all major public lands in the area. Phase I of the plan designates a first priority network of 650 miles of trails, with linkages to public lands at more than 90 locations. Many of the proposed trails are to be along wash channels.



San Ildefonso bird design

Certain topographical conditions in the Tucson area favor the construction of a linear river park, along with the proposed trail extension. Tucson is surrounded by higher relief mountain ranges that are relatively unreduced by pedimentation; i.e. the development of broad platforms at the base of mountains. Higher dissected surfaces are therefore evident in which streams or washes are entrenched. Washes are generally well defined and fan out into branching patterns. The resulting system of washes forms the natural trail routes of a river park.

Not all Arizona areas have such features. Phoenix, for example, is located in an area of low, rolling topography, with fairly shallow bedrock. As a result, water flows over a broad surface in wide spread sheets. Concrete drainageways are constructed to collect the water before flowing into urban areas. As a result, Phoenix, unlike Tucson, lacks a well defined radial drainage pattern or an extensive network of washes that could be developed.

Plans call for the Tucson area park to extend along the major river banks in a 50-foot-wide corridor. This is expected to be sufficient space for vegetation and planned trails. Along certain sections, however, development has occurred close to the edge of a wash, leaving, at times, only 10 to 20 feet for parkland. The county owns some of the needed land, with other land to be purchased. Purchasing access land is a major expense of the project. Project funds are obtained from flood control tax levy money.

The river park project purports to restore the natural integrity of degraded river banks. Major rivers in the area would be revitalized to serve as appealing community attractions featuring environmental and recreational amenities. As a swath of natural life to stand in relief to urban forms and structures, the river park design has been referred to as a greenway or greenbelt.

A major feature of the river park design is the multiple use trail system. Separated from vehicular traffic, the trails are for pedestrian, bicycle, and equestrian uses. Also, the park is to provide for various activities and features: equestrian staging areas, drinking fountains and troughs, playgrounds, exercise equipment, shady rest areas, horticultural displays, interpretive features, restrooms and maintenance areas.

And, of course, the river park is to be an area with predominantly native vegetation. Where no vegetation exists because of degradation and misuse, various plants appropriate to the Sonora desert will be cultivated. Existing vegetation is to be preserved. In areas where vegetation needs to be disturbed, the mature vegetation is to be transplanted whenever possible.

The river park will be mostly in areas where urbanization has disrupted, if not destroyed, whatever wildlife habitat had existed. To help improve the setting, the wildlife types and species most likely to populate the river park are being identified. Strategies to enhance the habitats appropriate to those types and species are being developed, with the expectation that the wildlife will return to the area.

By implementing certain flood control measures Pima County became obligated to develop the river park. Under section 404 of the Clean Water Act, the Army Corps of Engineers is responsible for all tributaries to the navigable Colorado River. Since Tucson's ephemeral washes are designated U.S. waterways, Pima County applies for a 404 permit when stabilizing banks for flood control. Part of the 404 permit process requires that river parks be installed as mitigation measures to compensate for disturbed natural conditions.

Flood control is therefore the priority, a fact demonstrated by the county agencies involved in the project. Pima County Department of Transportation and Flood Control is designing and developing the river park. Later the parks will be turned over to Pima County Parks and Recreation for maintenance.

Critical comments about the river park include concern that the project, representing a mitigation strategy, is, in effect, an effort to compensate for an environmental loss that should never have occurred in the first place. Also criticized is the attempt at revegetation along the river banks. It has been described as sparse and having a tended, artificial appearance, not entirely true to natural conditions. Doubts are also expressed that linear parks can be sites of habitat restoration. At the same time, however, the river park is seen to represent an emerging appreciation of a vital natural attraction in the area.

Indian Bend Wash

Whereas Tucson claims environmental preservation as a prime purpose of its river park endeavors, the Indian Bend Wash project maximizes the recreational possibilities of a developed urban wash. The different directions taken by the Indian Bend Wash planners reflect in many ways different community preferences and interests. At the same time, however, the project demonstrates that urban washes can be developed to serve varied and creative intents and purposes.

The Indian Bend Wash runs southward through Scottsdale and a section of Tempe before flowing into the Salt River. The wash drains part of the McDowell Mountains as well as some pediment areas north of Scottsdale before cutting through the center of town. When dry, the wash was considered an eyesore, for it contrasted with the development occurring nearby. When vigorously flowing, a fairly regular occurrence, the wash was a hazard and a danger splitting the community and threatening life and property. What to do? Obviously some sort of flood control project was called for.

The Army Corps of Engineers proposed the traditional solution: a concrete lined channel. The channel would be seven miles long, about 23 feet deep and 170 feet wide. The people of Scottsdale in turn rejected this proposal. Through an organized community effort, an alternate strategy was proposed. This consisted of creating a greenbelt with varied recreational opportunities. Instead of a stark, functional concrete ditch, a community resource of multiple and varied benefits would thus be created. An innovative approach at the time, the greenbelt concept was eventually accepted as the guiding principle of the flood control project.

More than just two options to solve a flood control problem, the proposed solutions – a concrete ditch and a greenbelt – represented vastly different perspectives on urban design and development. That Scottsdale is a city with a relatively affluent and committed citizenry was no small matter in settling the affair to its satisfaction. The greenbelt was thus created.

Indian Bend Wash is a flood control project with built-in recreational facilities. Among the plethora of recreational opportunities are 300 acres of city parks, golf courses, swimming pools and fishing and boat lakes. Activities range from jogging to horseshoes to paddleboats. All facilities and equipment are designed for flood control. For example, tennis court fences break away and float with flood waters to return to normal positions when flooding subsides. Small lakes, which recharge groundwater, are designed and placed to slow rushing flood waters.

Basic to the park's development and operation were the expected economic benefits to Scottsdale. In fact, without the promise of economic gain, the project would unlikely be in its present form. And, as planned, the project has worked out to be an economic asset to the city. Because of its attractions, the Indian Bend Wash area is lined with high-cost, luxury apartments and condominiums. Also, businesses in proximity to the project greatly benefit. This growth and development are obviously to the advantage of the city's tax base.

Some critics express concern, however, that environmental uses are not adequately provided for, despite the much lauded multiple uses of the project. The natural conditions of the wash are said to be little evident, covered over by grass and recreational areas. Further, the project is criticized as a water consuming greenbelt. Some critics are thus prompted to note that a desert greenbelt is in fact a contradiction in terms. In sum, various critics believe that environmental values got slighted in the project's commitment to other priorities.

To some extent the Indian Bend Wash endeavor stands as a model for the Tempe Rio Salado project. Developers of the Tempe project claim that the Rio Salado project will do for their city what the Indian Bend Wash did for Scottsdale. There are, however, significant differences between the two projects.

Plans for the Rio Salado project, which will develop land along the Salt River in Tempe, call for certain environmental features. Native vegetation and low-water use plant species are to be used. The project also proposes to create wildlife habitats and riparian landscape areas.

Flagstaff and Prescott Begin Efforts

Smaller urban centers of Arizona are also beginning efforts to reclaim the natural conditions of their creeks and washes disturbed by development and urbanization. Two such cities are Flagstaff and Prescott. The emergence of these efforts in such areas demonstrates an important fact; i.e., the adverse effects of urbanization are not confined to major centers such as Phoenix and Tucson. Further, the concern apparent in these cities demonstrates that sensitivity to the urban wash issue and the need to take action is evident in small urban areas as well as large population centers.

Flagstaff is located along the Rio de Flag, a river fed by ephemeral streams. Because of urbanization many of Flagstaff's streams and washes are severely degraded. For example, watercourses have been filled in, and the watertable has dropped in some areas resulting in the drying up of streams.

Flagstaff citizens have recently approved the sale of bonds for a reclaimed water treatment plant. The plant is to process wastewater and produce 3 million gallons of reclaimed water per day. Uses for the reclaimed water are presently being decided, with application on cemeteries and other grasslands expected.

The Northern Arizona Riparian Council (NARC) views the eventual operations of the treatment plant as providing an opportunity to reclaim riparian areas lost because of urbanization. The council is proposing that reclaimed water be released in areas where it would revive and benefit riparian habitats.

NARC's plan of action involves identifying locations where riparian communities previously existed. Studies would then be conducted to determine what the characteristics of these communities were. Finally, how such areas would benefit from a renewed flow of water would be ascertained.

NARC recently made an initial presentation before the Flagstaff City Council. It has been invited to provide further input during city council work sessions.

Activities to protect watercourses are also beginning in Prescott, a city with fairly abundant riparian areas. As defined by an involved citizen's group, the concern in Prescott is to preserve present stream conditions from the adverse affects of grazing and urban activities. The damages to Prescott watercourses are not considered to be as severe as in other areas of the state.

The quality of stream flow through Prescott is affected by situations both outside and within the city. Located in the headwaters above town, most of the riparian areas in the Prescott National Forest are listed as either in poor or fair condition by the U.S. Forest Service. Some people believe this situation is mostly the result of over grazing. Also, concern has been expressed that zoning in Prescott is not effective for protecting natural stream conditions. A further concern is that sewer lines are laid in streambeds. This results at times in inflow that overloads the system causing flooding. Leakage into streambeds has also resulted.

A recent Prescott general management plan recognized the importance of preserving the condition and quality of stream and riparian areas in Prescott. The document however was criticized as being too general and therefore ineffective as a policy guide.

The conservation committee of the Prescott Audubon Society is working to develop a proposal advocating the protection of creeks and washes within city limits. The proposal is to be submitted to the city and provide specific recommendations, including suggested zoning changes. It is hoped that the proposal will attract general public support and provide the incentive to pass appropriate legislation.

Also, a linear trail system along Prescott creeks is being planned and developed. The intent is to create a trail to link the city with the national forest. At the same time the trails are to encourage public appreciation of the city's riparian areas.

Conclusion

The issue of preserving and reclaiming urban wash lands is not one to be resolved along an urban-vs.-nature dichotomy, with advocates lined up on each side. Instead, the urban wash issue has the potential to demonstrate that, in the best of urban environments, the developed and natural can be complementary, each contributing to an attractive, safe, and creative human setting. In a broad sense, the issue has to do with designing an urban environment that is not inhospitable to natural and environmental features.

The quest then is not to return washes to their original natural conditions. Even to identify such conditions would be difficult, since modifications resulted from Indian, Spanish and U.S. occupation and use of the land. Watercourses have experienced too much degradation and abuse, especially during the last few years, to be fully reclaimed to original conditions.

The goal, therefore, is to restore the habitat to conditions that are compatible with the situation at present. Urban washes will need to serve urban and natural needs; in other words, multiple uses. These include wildlife conservation, flood control, groundwater recharge, scenic beauty, and recreation.

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The ideas and opinions expressed in the newsletter do not necessarily reflect the views of the above people.

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Rio Salado Master Plan

Prepared for
The Rio Salado Development District
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In Association with
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January 1985

Rio Salado
DEVELOPMENT DISTRICT

141 EAST PALM LANE, #202
PHOENIX, ARIZONA 85004

Physical Image

This plan assumes that the additional upstream flood control will be in place within ten years, and that subsequent development will have to deal with a flood of no more than 55,000 cfs. The plan shows the eventual conversion of the floodway into a long succession of narrow, interlacing lakes, for the most part one-quarter to one mile long, linked by a continuous boating waterway. Drop structures would occur about every two miles, as shown on the plan, but in two locations, below 7th Avenue and between Mesa and the Mill Avenue Bridge, the slope of the river allows a longer length of quiet water. At each drop, the waterway would pass through rapids, which could be attractive features for those who enjoy white water boating.

Lakes and waterways pass alongside or among clusters of small planted islands, in a grassy bed, and within planted banks which are gentle or steep depending on the width of the waterway. In a new and more dramatic form, these lakes and islands recall the old braided stream. Trees border the lakes and desert plants create a new landscape in the streambed. The Rio Salado flows again, using a minimum of water and affording multiple new recreational opportunities. Most of the 17 miles of riverbed (4,085 acres) is devoted to recreation: swimming, boating, fishing, picnicking, camping, hiking, riding and field sports. A shallow, grassed low-flow channel protects lakes or sensitive plantings where necessary. It can take urban run-off and up to 15,000 cfs of water, the normal five-year flood.

Paralleling the riverbed are two curving parkways-- generally within 1,000 to 2,500 feet of the streambed on the south side and rather closer on the north--within which the District or other public agencies will have acquired most of the land, and where the new riverside development gradually unfolds. The southern parkway is continuous, from 35th Avenue to Alma School Road, while the northern road is interrupted by the airport. The southern bank is less affected by noise, has more generous space available, and can more easily be connected to a residential hinterland.

Above Country Club Drive, within the Indian community, the Rio Salado is shaped into a broad sedimentation basin in which flow velocities are sufficiently reduced that the water will drop its load of silt, sand, and gravel, and so will not damage the lakes and plantings located downstream. This basin will be an extended landscape, clothed in native desert plants, in places mined for the retained sand and gravel, but for the most part a wildlife refuge, open to camping and horseback riding.

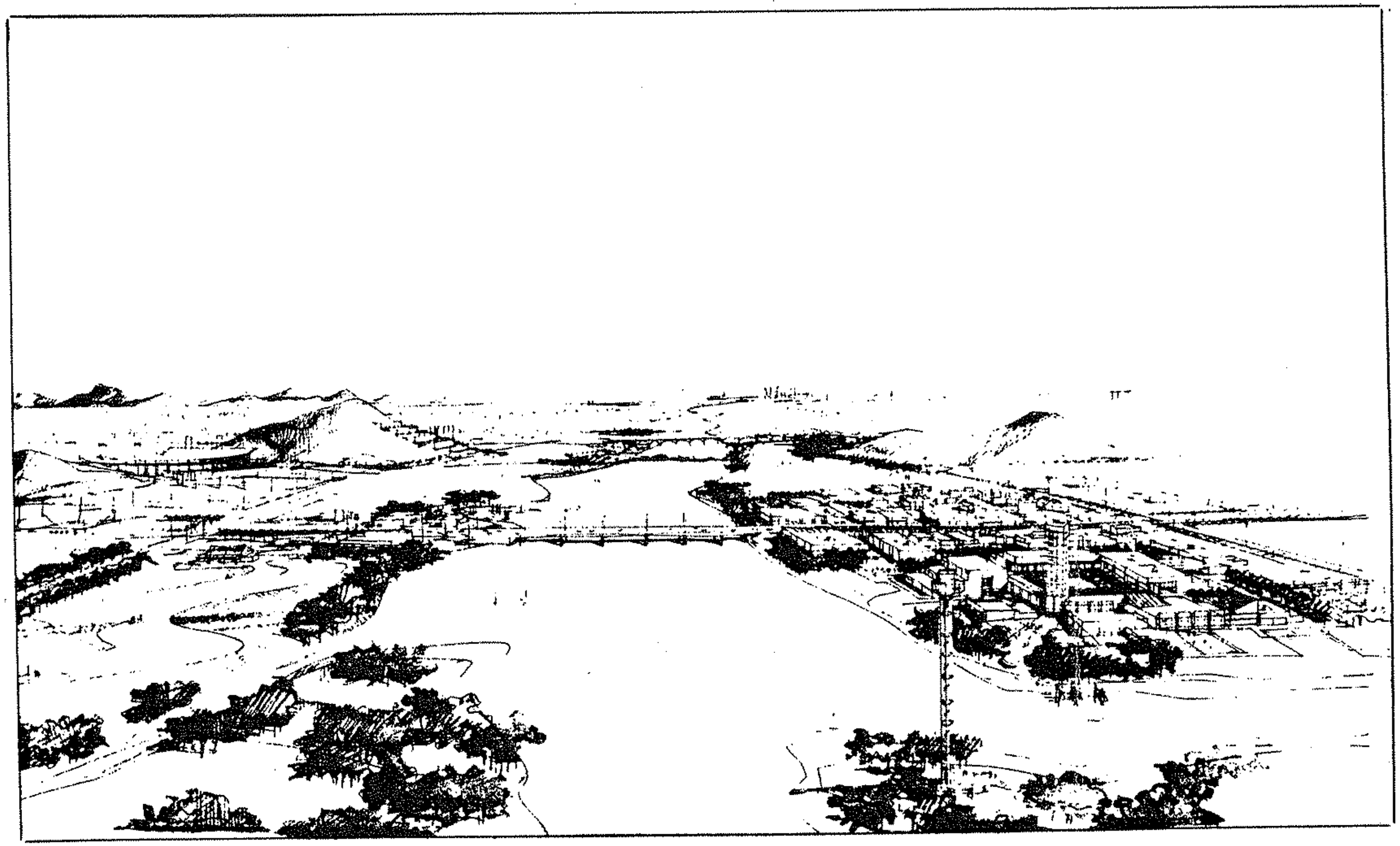
Below the wide drop structure of this retention basin, the streambed can be planted with grass. The first large lake occurs at Alma School Road. It lies wholly within the Indian Community, and is open to recreational use on a fee basis. Effluent from the expanded Dobson Road sewage plant in Mesa feeds that first lake, after undergoing tertiary treatment. South of this lake and its borders within the city of Mesa is low density residence, a resort hotel, a new Mesa public golf course, and industrial development along the Price/Pima Freeway. North of it, the land is given over to sand and gravel mining and industry, in accord with present Indian plans. The area within the City of Mesa between Country Club Drive and Granite Reef Dam will be the subject of additional planning immediately following the approval of a permanent financing vehicle for the District.

At McClintock Drive, we arrive at the historic, picturesque location where the Buttes and the Indian Bend Wash join the Rio Salado, across from Arizona State University. On the south, ASU will build its new golf course.

At the junction with Indian Bend Wash, the largest lake in the Rio Salado system provides a sheet of water a mile and a half long. It will be used for swimming, fishing, and boating. The Wash itself is completed with a stream and small lakes to its junction with the Rio Salado. This junction would be marked by a monument or observation tower set on an artificial elevation. Large rock formations cross the streambed along the course of the reef of bedrock, just below the surface. By its history and its geology, this is a unique location along the river. Development of this site will depend upon the satisfactory completion of a detailed investigation of its hydrological conditions.

Just south of Papago Park and the old Indian Bend Canal, recreational facilities and restaurants may locate along the north bank of the Rio Salado. To the east, between Scottsdale Rd. and Indian Bend Wash, on what is now an unincorporated county island,

FIGURE 3 Conference Center in Tempe



there would be a hotel with conference facilities that could serve activities related to ASU. Such a development might also include recreational features. This facility would allow the University to house visiting scholars and guests and provide room for those attending alumni events, symposiums, special courses, and conferences. Nearby offices could rent meeting rooms for their own special conferences and briefings. North of this complex, additional new townhouse developments are anticipated.

On the east bank of the Indian Bend Wash, a special mix of industry, recreation and housing would develop. It would have connections to Arizona State University, to the entertainment and resort functions along Hayden Road and further north in Scottsdale, and to the high technology industry developing around the airport.

Development at Mill Avenue in Tempe should take advantage of the elevation of the Tempe Butte. The site should be evaluated for its value to the community for its research, education, and tourist potential. Pilot Project No. 4 of the Tempe Rio Salado Plan should be evaluated for inclusion here. A downtown commercial revitalization area will include at least one major new hotel at this point. The old Tempe Bridge may be renovated to carry pedestrians to the center to look out over the lakes or to reach the north side.

Below the bridges at Mill Avenue, the river opens into a broad expanse, filled with a dense cluster of islands and interlacing lakes. Here we are under the noisy approach zone of the airport, and so this stretch will be devoted to a park and a golf course within the islands. North of this, between Mill Avenue and the airport in Phoenix, the area along Washington Street will be dominated by a mix of industry, offices and commercial ventures. This is an area already under development, and subject to high airplane noise.

Once past the Mill Avenue bridges, a continuous band of new development on the south bank begins, between the parkway and the river, which will extend to 35th Avenue and beyond. Along Priest Drive, development is devoted to industry, an equestrian center, and a clubhouse for the golf course which lies in the streambed below.

Moving westward along this southern line, the industrial and office uses begin to be mixed with housing, once I-10 is crossed and the airport noise diminishes. Described in more detail in the section on New Development, this is a blend of residence, work place, and recreation. This mix extends to the new Rio Salado Industrial Recreational Park and proposed park golf course at 12th Street, and through it, connects to the special uses at Central Avenue.

At 24th Street, the river broadens to form a large new island, occupied by offices, high density housing and one or more hotels. This will be a prestige location and principal event along the course of the river. The development is centered on a public pedestrian spine which can be expected to include retail and recreational uses. At both ends of the island are public parks.

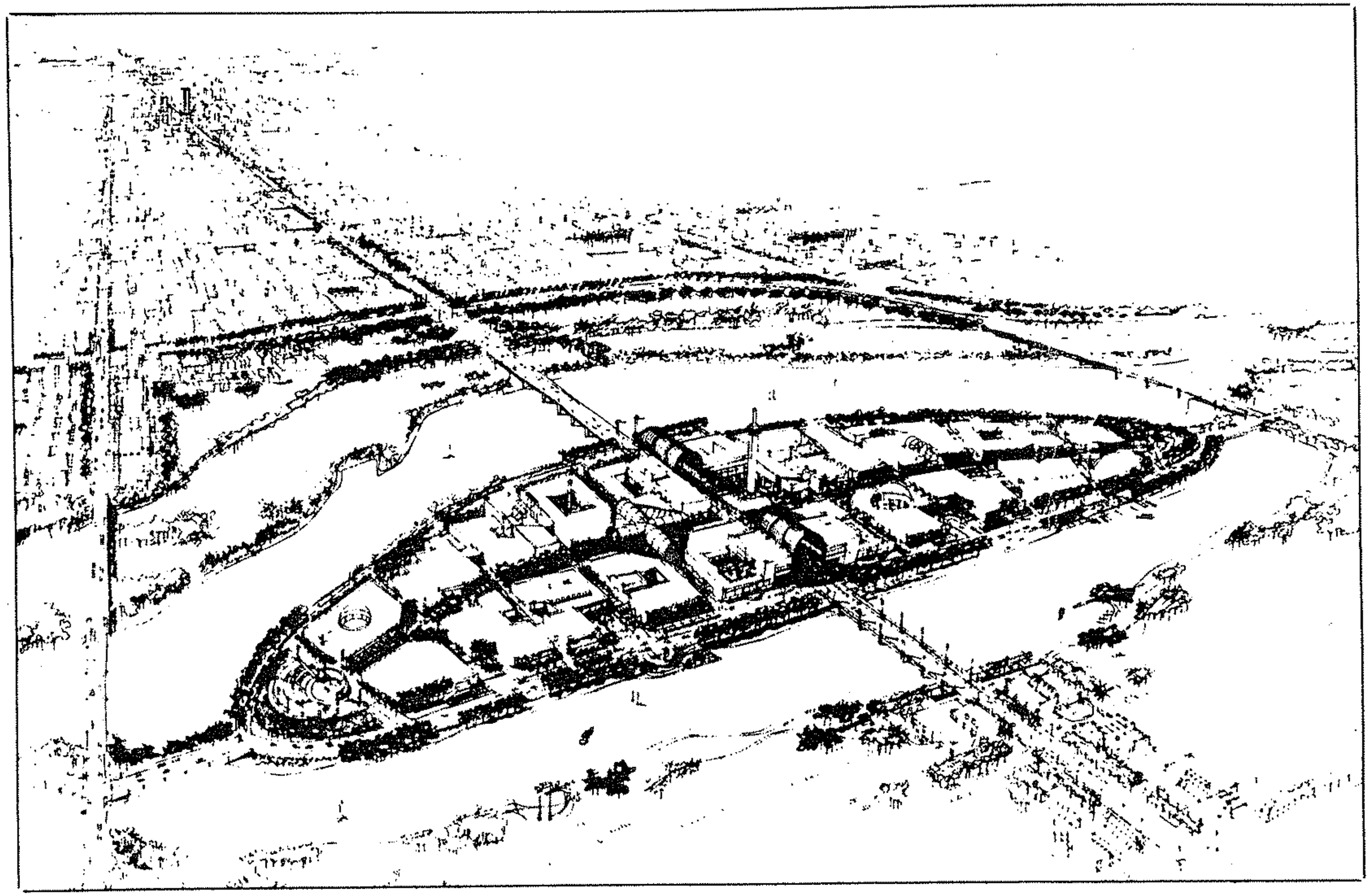
At 7th Street and Central Avenue, we approach the existing new industrial development on the north, and the river is confined between steep banks. But it still sports lakes and a waterway on a grassy bottom, all part of the continuous regional park. On the north bank, an effort will be made to strengthen and preserve the existing neighborhood between 12th and 16th Streets.

At Central Avenue, one of the key features of the plan occurs on the south bank of the Rio in the form of an island which stretches from 7th Street to 7th Avenue.

Coming from downtown Phoenix, crossing the bridge over the new lake in the riverbed, the magisterial entrance to the island is marked by high jet fountains. Shaded promenades and lookout points along the north edge of the island will provide a view of downtown and uptown Phoenix. Another, more narrow lake along the southern edge of the island creates a southern approach to this special place. Boats will shuttle between stations, connecting the southern island promenade to parking and attractions on the South Phoenix shore.

All along the central pedestrian spine of the island a series of "water events" are connected by waterways running under lath-roofed arcades. On one end, this pedestrian axis will lead to an open amphitheater for public festivities and concerts. The other tip of the island will be occupied by a discovery museum for children. A special water-garden at the junction with Central Avenue will provide freshness and shade.

FIGURE 4 Central Avenue Exposition Site



Like the "Ile de la Cite" in Paris and the "Isola Tiberina" in Rome, this island will bridge the gap between north and south Phoenix. It will attract a variety of public institutions, special industries, entertainment, shopping and recreation.

The new regional institutions here should include a Southwest Cultural Center, dedicated to the research, conservation, interpretation and communication of the southwestern heritage. There could also be a museum and research study on the world-wide role of water: its physics and chemistry, its connection with living things, and its practical use and key importance throughout the world. Here might also be located Discovery Place, a museum for young people and their elders in which they could learn about the sciences and the arts by participation. There could be computer shops, bookstores and an ethnic market of food and crafts.

This central island location will also feature an alternative school--a special technical high school open to students throughout the city, but with a particular focus on students from the Rio Salado District and from areas of high unemployment. Such a school will encourage families to settle in the district, and will stimulate investment here by technical industries interested in a recreational setting and an educational link. These industries would benefit from participation in developing a skilled work force, would be linked to advanced research and might themselves be designed to explain their functions to the public. Restaurants and other entertainments would keep this true "industrial park" open in the cool of the evening. All this will be directly connected to downtown Phoenix by means of a shuttle bus system. During Phase I, a special exposition will work as a launching platform for an exceptional concentration of public features. The opening of the exposition would be timed to coincide with the building of the upstream flood control dams.

Beyond 7th Avenue, the river opens up once more to a landscape of small hills along the north edge of the riverbed, containing a desert arboretum, displaying the life of the desert and the possibilities of desert flora. It would contain oases, dunes, mesas, and hidden "canyons", and might support a number of restaurants and other entertainment facilities. Adjacent to this, there is a lake in a park, and an equestrian center. Certain choice sections fronting on the park are given to new housing. A golf course has been built on the old landfill west of 27th Avenue. South of the arboretum, the parkway runs for a stretch along the present Broadway, then swings wide to give space to several major new resorts along the braided stream and its lakes. These resorts, along with new low density housing, replace the auto junk yards now located there. This plan does not fix the disposition of the District beyond 35th Avenue, but recommends that this ground should be preserved for a major future development. One of the strategic aims of the entire plan, implemented by the initial occupation at Central Avenue and followed by the progressive westward extension via the desert arboretum and the parkway, is to open up this empty western territory, now abandoned by the northward and eastward drive of Phoenix. New settlement might extend along this completely unexploited growth axis of the metropolis. It could be carried out according to a careful general plan, and make maximum use of the recycled water released by existing urban settlement. District strategy should be designed to unlock and to control that great opportunity. Preparation of a plan for this area will become a priority immediately following the realization of a permanent financing vehicle for the District.

The following Tables 2 and 3 outline the anticipated public and private development activities during the initial 25 year period.

TABLE 2 25 Year Development: Summary by Jurisdiction

(acres-rounded)

	Phoenix	Tempe	Mesa	Salt River Indian Community	Total
Private Development	2,895	830	400	205	4,330
Riverbed	1,695	810	270	1,310	4,085
Riverbanks (public recreation)	655	195	100	35	985
Parkways	250	125	80	15	470
Totals	5,495	1,960[1]	850	1,565	9,870

[1] This total includes 75 acres of unincorporated islands that are within the Tempe boundaries and thus now under the jurisdiction of Maricopa County.

TABLE 3 25 Year Development: Summary by Use
(acres-rounded)

	Phoenix	Tempe	Mesa	Salt River Indian Community	Total
Riverbed:					
Water	725	390	90	200	1,395
Grass	975	420	180	510	2,085
Sed. Basin	0	0	0	600	600
Riverbanks					
Water	110	15	0	0	125
Parks	425	145	0	35	605
Golf	120	35	100	0	255
Parkways	250	125	80	15	470
Private Development	2,895	830	400	205	4,330
Totals	5,495	1,960	850	1,565	9,870

PHASING

The physical development of the Rio Salado will unfold gradually over the initial 25 years. During the first 10 years (Phase I), growth is limited while funding for the upstream dams is secured and construction begun. Yet, significant development is possible and is extremely important even during this early period. The plan begins therefore at two points.

The first is at Central Avenue in Phoenix, on the south side of the river. Central Avenue is the symbolic axis of the metropolis, and a successful development at this point will tie downtown to the Rio Salado, and also leap the chasm between north and south Phoenix. Moreover, it will set the stage, not only for remaking the river eastwards toward Tempe, but also for opening up the axis for growth to the west. Its potential benefits justify a significant concentration of public and private investment. The plan suggests a unique mix of uses that might occur there, and how that apparently formless environment could be transformed, and so transform the popular image of the river. The special exposition is recommended as a launching platform. The exposition would build the southern lake and another lake initially vulnerable to a major flood on the streambed to the north, to create the new island. Furthermore, it would lay down the infrastructure for this key development, including the special waterways. Parking for the exposition will be across the southern lake, and visitors will be ferried over to the exposition grounds.

The second point for early action is at Papago Park and Indian Bend Wash in Tempe, primarily on the northern side and east of Mill Avenue. The buttes and the Wash make this the most picturesque section of the river, and it is the one most closely connected to Indian history and to the history of White settlement. It is also a significant geological break-point. The presence of A.S.U., the favorable market location, and the active plans of the city of Tempe, all reinforce the special quality of this place.

Early action would include the completion of Indian Bend Wash, and a boatway (also initially vulnerable to flooding) along the north edge of the riverbed. The conference center, new housing, a new hotel, and new commercial revitalization along Mill Avenue could be expected to appear here.

At both points, then, the potential of the river will have to be demonstrated. Only then will developers be encouraged to develop and occupy these locations. While some temporary riverbed features might be exposed to a major flood, all activities on the banks would be fully protected from flooding, as planted levees will be constructed from the start.

Between these points, other scattered development will occur before the up-stream dams are built. For the most part, this will consist of industry locating near the airport. Mixed use development, including new offices for the Salt River Project, will occur in the vicinity of the present Legend City. This development is likely to require a minimal amount of special public action.

These Phase I developments will be designed to be successfull even if additional upstream flood control is not realized. Additionally, these early improvements use only a minimal water supply. Thus, they are not dependent upon a final resolution of the water issue. The Phase II developments will be designed to be compatible with both Phase I and the then-known realities of flood control and water supply. As the details of Phase II are determined, adjustments can be made to reflect any changes in circumstances without jeopardizing the viability of Phase I.

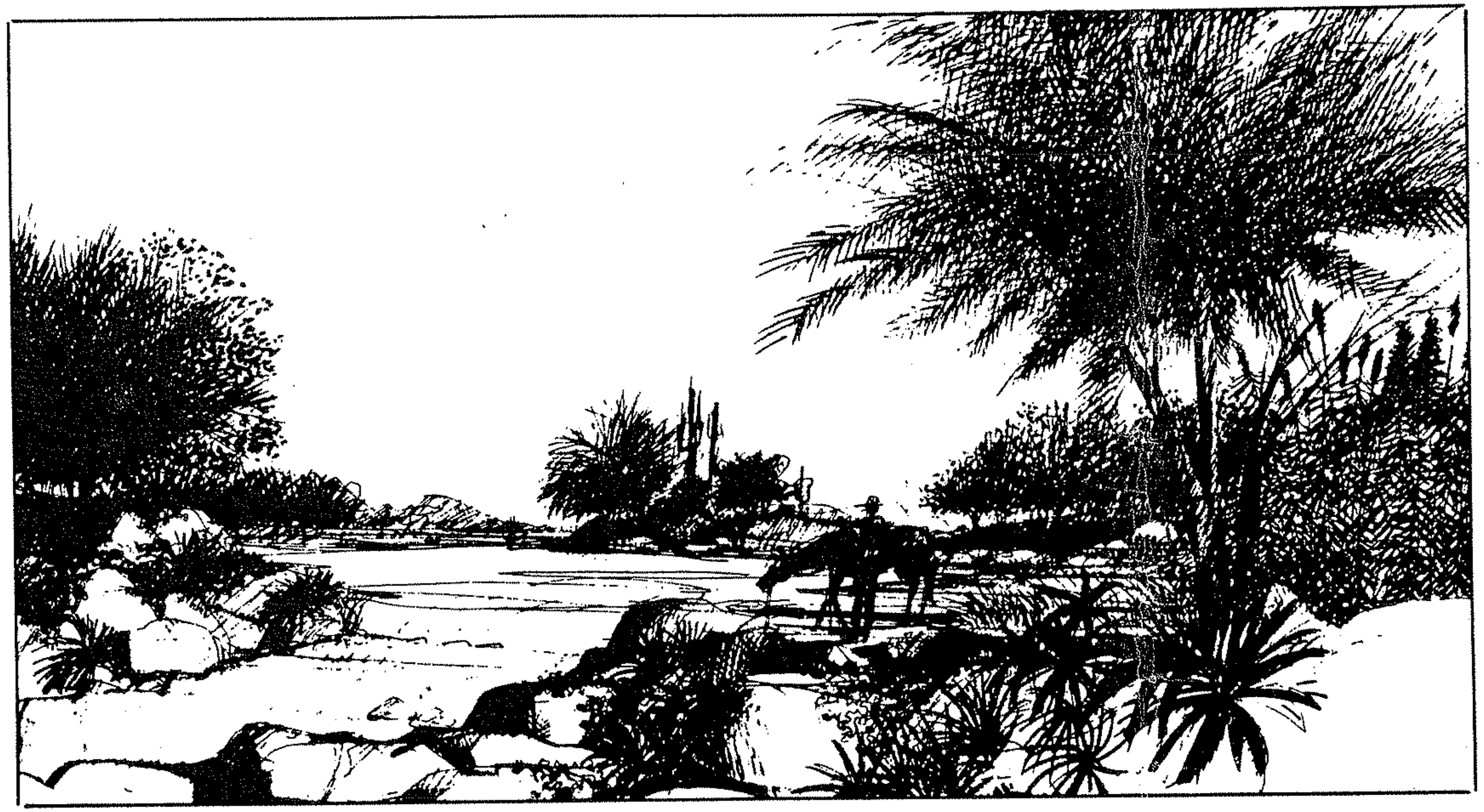
Recreation and Open Space

RECREATION

Development of the Rio Salado and its banks will create an immense new regional park. In the first 25 years of projected development, roughly 4,500 acres of parklands, water bodies, and public open space will be built as is illustrated in Fig. 9. Public access to all of these features will be maintained.

The Rio Salado will not only be five times larger than New York's Central Park, it will also be richer in its landscapes and activities. The Rio can provide 15 miles of lakes, ponds, beaches, streams, open fields, wooded groves, trails, formal playing fields, golf courses, equestrian centers, camping areas, resorts, restaurants and indoor sports facilities. Fishing, tubing, swimming, boating and other water related sports will be possible for the first time in the center of the metropolis. The park will also provide opportunities for bicycling, hiking, horseback riding,

FIGURE 7 Riverbed Park Character

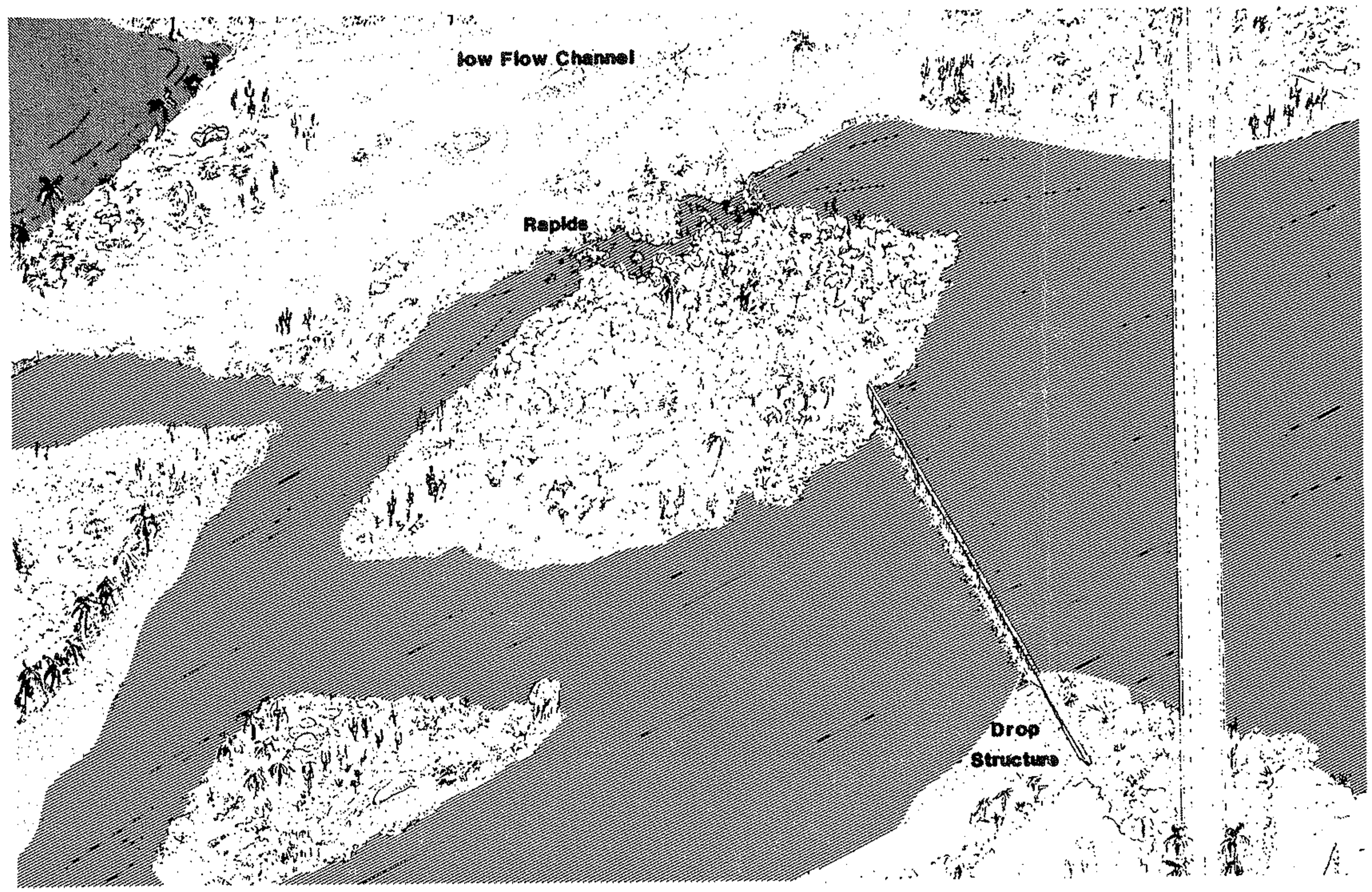


nature observation, picnicking, roller skating, jogging, soccer, baseball and a wide variety of other outdoor activities. Densely planted islands in the outer reaches of the park will make particularly interesting camping sites, a new urban resource.

Some of these activities will also be available in small parks and greenways on the banks, interspersed with housing, industry and office development. There will be continuous shaded trails along the riverbank from which walkers, joggers and bicycle riders can look over the riverbed park and watch others boating and tubing on the rapids or horseback riding.

Citizens, young and old, from near and far can come to the Rio Salado and spend an entire day taking part in several of these free or low cost activities. The Rio Salado park system will contribute greatly to meeting the significant regional recreation needs recently cited by the Statewide Comprehensive Outdoor Recreation Plan

FIGURE 8 Riverbed Park at 7th Avenue



and by various local needs assessments. Details of these assessments are in the Appendix. It will also serve as a meeting ground for citizens from the various ethnic backgrounds of the metropolitan region. It will help to heal the division between North and South Phoenix. The park will be a new focus of regional pride and also a tourist attraction.

Along the length of the Rio Salado Park will be several major recreational features, each of which will lend its special character to the adjacent development. The southwestern end of Phoenix will come alive with resort hotels and high quality residential areas, which will take advantage of the lakes, a golf course, an equestrian center, and the nearby Desert Park Arboretum. Special restaurants and night spots will spring up here as well.

The new island on the riverbank at Central Avenue in Phoenix will be the site of a one-year international exposition focused around water and its uses. Later, this island will be a prestigious location for high technology research and development. Several new institutions with recreational appeal would be built as features of the exposition and remain as permanent activities in the future. These would include a Water Museum, a Southwest Cultural Center, and Discovery Place, a hands-on museum for young people (and their elders) about science and technology. The Southwest Cultural Center will be described in greater detail in the Social section.

Adjacent to the island, on the riverbank between 7th and 16th Streets, is a new park and golf course, a special recreational resource for the residents of South Phoenix. Traveling eastward, a site has been earmarked for a new State Fairground or a domed stadium. Both of these facilities have been cited as a regional need and either would contribute significantly to the recreational offerings of the Rio. The State Fair in particular has an immediate need for larger facilities to expand its program on a year-round basis. A portion of the fairground might be used for a small theme park. Nearby, in one of the widest portions of the riverbed, there is a golf course, an equestrian center, many playfields, and a number of wooded islands for picnicking and nature observation.

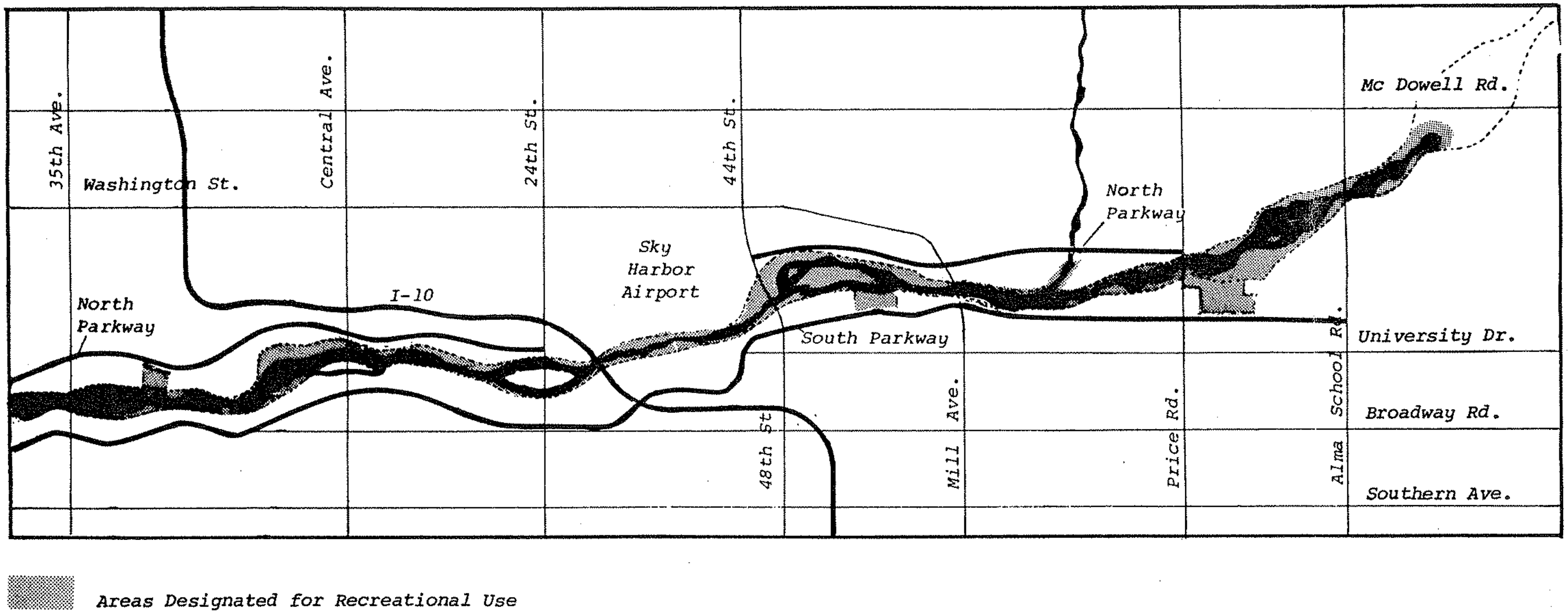
Further upstream, in the vicinity of Arizona State University, lies the largest lake in the system at the confluence of Indian Bend Wash with the Rio. This is the steepest drop along the river, which provides a special opportunity for white water boating. There will be sailing and canoeing on the lake, and swimming and tubing in the rapids. ASU students can take advantage of this opportunity.

The area between this great lake and the sedimentation basin, which lies predominantly in the Indian Community, can also become a special place. Despite continued sand and gravel mining, the riverbed can be developed as a wildlife preserve. A native landscape treatment will provide cover for birds, lizards and other desert fauna. Here too would be lakes developed particularly for fishing and operated as a concession by the Indian Community.

LANDSCAPE PLANT CHARACTER

The public spaces of the Rio Salado will form as a richly variegated landscape, which emphasizes drought-tolerant native plants requiring little care and water. Plants requiring substantial irrigation, beloved by many of the mid-westerners and easterners who have migrated to Phoenix, will also have their place, but they should be used on a limited basis at focal points. A major point of the park should be to acquaint visitors with the variety and richness of desert plantlife. The suggested treatments for the major landscape zones which follow are also illustrated in a planting plan

FIGURE 9 Public Recreation Areas



and in its composite section (Figures 10 and 11).

The Urban Edge

Many open spaces on the riverbanks would be landscaped with plants now typically found in desert cities (Area A). These relatively lush plants will line the parkways, the riverbank edge and the small greenways lacing the urban edge, where shade is most needed. These areas would be above the flood zone and safe from water damage. Such planting requires a regular irrigation program.

Open Grasslands

This area of the riverbed (Area B) would be covered by a Bermuda grass mat to control flood erosion. The scattered trees would include Olneya tesota (Ironwood), Prosopis species (Mesquite), Cercidium floridum (Blue Palo Verde), and Parkinsonia aculeate (Mexican Palo Verde). This area would be inundated by any major flood. Additional irrigation would probably not be required for the trees, since the Bermuda grass will have to have occasional supplemental water to maintain an adequate mat. The above tree species do not offer much obstruction to flood waters and, even if broken or uprooted, would not contribute any significant debris which might otherwise pile up on bridge abutments downstream. These plants normally naturalize in such areas, and will regenerate from the roots.

Recreation Water Courses

The banks of the water bodies (Area C) would be vegetated with an association of riparian trees and plants typified by Arundo donax (Giant Reed), Populus fremonti (Fremont Cottonwood), Salix goodingii (Goodings Willow), and Washingtonia filifera (Arizona native Fan Palm). This area would also be inundated by major floods. These plants require constant moisture, and would be planted immediately adjoining the water course. Should the water course be sealed, the sealed edges could be re-filled with soil for these plants.

Low Flow Channel

Some of the same plant associations used above would be repeated along the low flow channel, but only those that would lay over during high water. These species would not create any notable obstruction to the water flow or contribute debris downstream. Species included might be Arundo donax (Giant Reed), Tamarix parvifolia (Spring Flowering Salt Cedar), and Salix goodingii (Goodings Willow). Goodings Willow will probably establish itself without being planted, if the water supply is constant enough. With the exception of the willow, these plants are also quite drought tolerant and would survive with no problem the periods when the riverbed is totally dry.

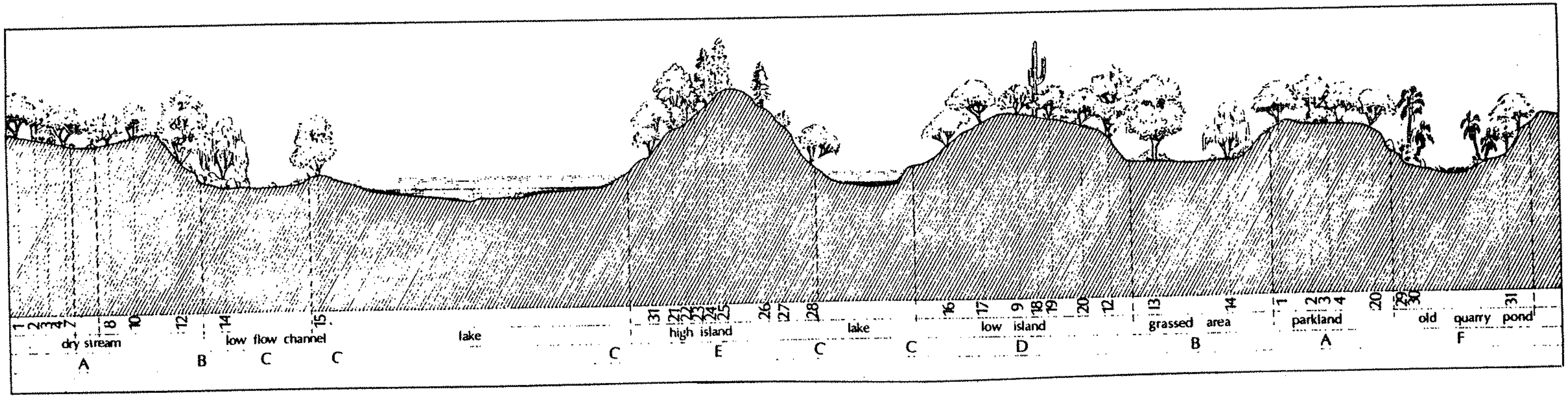
Armored Banks

Wherever riprapped banks are needed for erosion protection, they would be softened with the addition of a scattered planting of Tamarix aphylla (Athel Tree or Tamarisk). This species of tamarisk is evergreen, makes a larger tree than the others, and is very easy to establish by simply driving two inch caliper poles three feet into the ground. This could be done at the same time the bank is being riprapped. The Athel tree can tolerate an annual topping to prevent the development of too much flow-obstructing vegetative mass. Probably the topping would only need to be done every third year to prevent such a vegetative build-up, cutting back one-third of the trees each year, rotating to the next third the following year, and so on. The tree can be cut back to a basic stump just before the flood season, and the stump regrowth will rapidly green up the area the following growing season.

Intermediate Levels

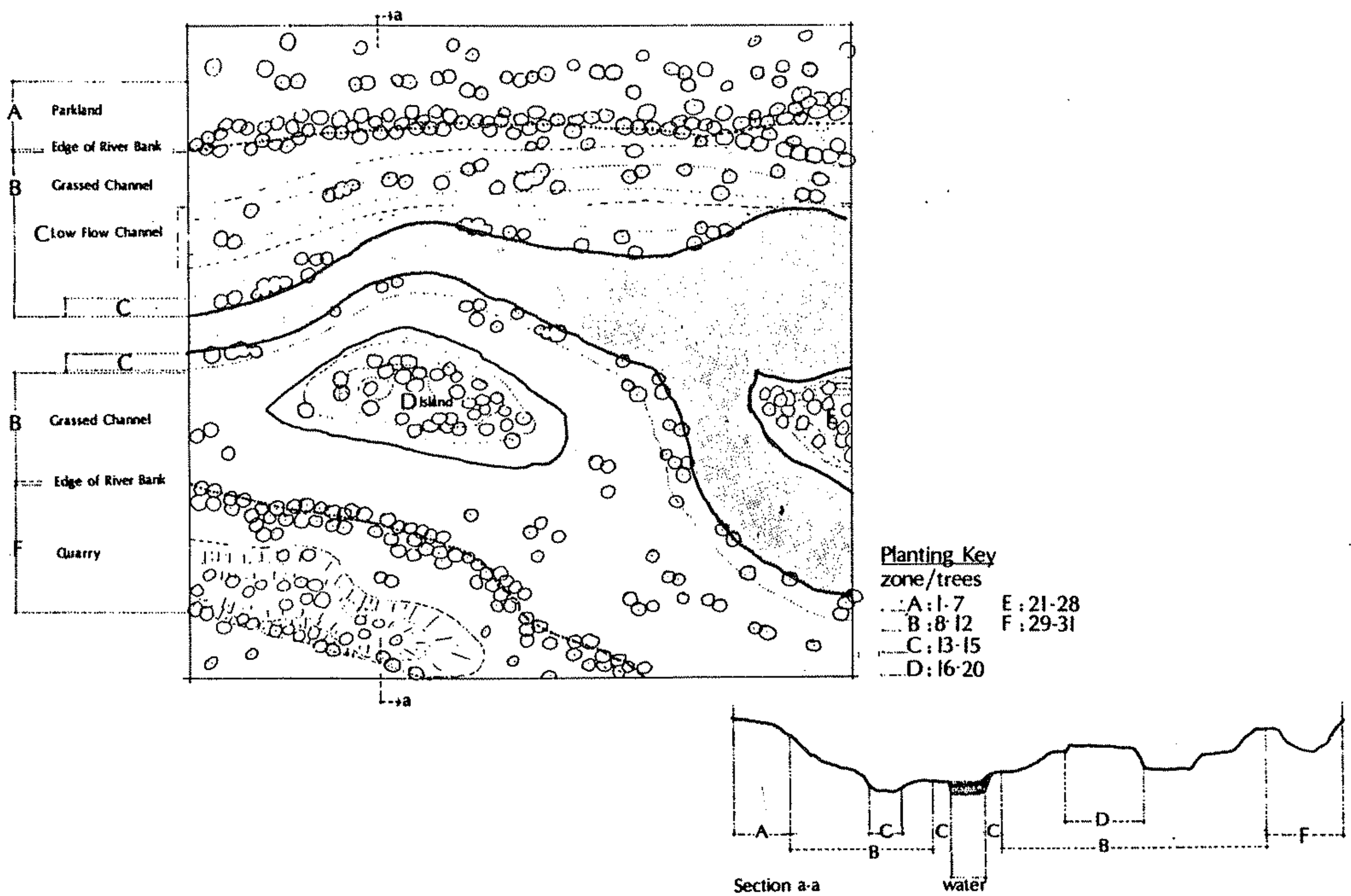
In those areas mostly above the major flood level (Area

FIGURE 10 Major Landscape Zones



1. Broadleaf Evergreen
2. Brachychiton:
   Bottle Tree
3. Ceratonia: Carob
4. Eucalyptus: Eucalyptus
5. Olea: Olive
6. Rhus Lancea:
   African Sumac
7. Schinus Molle:
   California Pepper
   Tree
8. Cercidium Floridum:
   Blue Palo Verde
9. Cercidium Microphyllum:
   Little-Leaf Palo
   Verde
10. Olneya Tesota:
    Desert Ironwood
11. Prosopis South American
    Hybrid: Mesquite
12. Platanus Arizonica:
    Sycamore
13. Populus Fremontii:
    Fremont Cottonwood
14. Salix Goodingii:
    Weeping Willow
15. Tamarix Aphylla:
    Athel Salt Cedar
16. Acacia: Evergreen
17. Prosopis Alba:
    White Poplar
18. Carnegiea Gigantea:
    Giant Cactus
19. Chilopsis Linearis:
    Desert Willow
20. Prosopis Velutina:
    Velvet Mesquite
21. Quercus Suber: Cork Oak
22. Parkinsonia Aculeata:
    Jerusalem Thorn
23. Vauquelinia Californica:
    Arizona Rosewood
24. Pinus: Pine
25. Casuarina Stricta:
    Beefwood or She Oak
26. Celtis Pallida:
    Desert Hackberry
27. Phoenix Dactylifera:
    Date Palm
28. Tamarix Parviflora:
    Salt Cedar
29. Arundo Donax:
    Giant Reed
30. Washingtonia:
    California Fan Palm
31. Acacia: Evergreen

FIGURE 11 Planting Plan



D), plants would be representative of the Sonoran Desert Uplands. The predominant species would be Cercidium microphyllum (Littleleaf or Roothill Palo Verde), Acacia minuta smallii (Western Sweet Acacia), and Prosopis velutina (Velvet Mesquite). Carnegiea gigantea (Saguaro) and other cacti could also be used above the flood line, while the other plant species could be placed somewhat down the slope below the point of the major flood high line. This planting would need some supplemental irrigation, at least to become established above the area where the Bermuda Grass mat is to be maintained.

Island Tops

These areas (Area E) would include the largest island spaces above the major flood line, and therefore could be quite thickly forested. Plant association could be built around Casuarina stricta (Coast Beefwood or Australian Pine), and in some cases true Pine species such as Pinus halepensis (Aleppo Pine) or

Pinus pinea (Italian Stone Pine). Species associated with this "key tree" might include Brachychiton populneus (Bottle Tree), Prosopis chilensis (Chilean Mesquite) and other South American species. Also, Schinus molle (California Pepper Tree) and other drought tolerant broad leafed evergreens, such as Quercus suber (Cork Oak) could be included. These upper level plant communities could grade down and blend with whatever combinations occupied the lower portion of the peak, whether a shore line plant community or open grassland.

Old Quarries and Borrow Pits

In several locations, old quarries and borrow pits should be retained for their special qualities. These old excavations often contain small lakes or ponds and present unique planting opportunities. The plant associations here would resemble those in Area C (the water edges), containing water edge or riparian plants, backed by more drought resistant species. The old quarries would probably not suffer any stress during a major flood, as there would be no strong current through these areas. The water level, however, might fluctuate, inundating shoreline plants for periods of time. Therefore, water edge plants such as Arundo donax (Giant Reed), Populus fremonti (Fremont Cottonwood), Salix goodingii (Goodings Willow) and Washingtonia filifera (Native Arizona Fan Palm) should be used. Other species of palms such as Washingtonia robusta (Mexican Fan Palm, Phoenix species) could also be used here because the plant pallette would be more isolated from the general river scene. The back-up plants on the slopes could be similar to those in Area D (the intermediate levels). These would probably require some supplemental irrigation to maintain a good appearance, while the riparian plants growing at the water's edge would not require additional water.

Desert Park Arboretum

The redevelopment of the Rio Salado presents a special opportunity to develop a site for a regional arboretum. This is particularly important at this time, with the general tightening up of water use, especially water to support landscape plantings. This arboretum can demonstrate water-miser plants as alternatives to the water demanding plants so commonly seen in the Phoenix area. The arboretum would lie above the major flood line, but could also be extended below that line wherever water side associations were displayed. These variations are illustrated in Figure 12. Although the entire Rio would be a desert park, this arboretum would be a distillation of the plant communities associated with the various landscapes described above, in a smaller area and arranged for learning. In addition, many more delicate species not able to withstand floods could be displayed here. The landscape could include miniature canyons, arroyos and dunes typical of the desert, together with seeping springs and small desert oases. This would become a major metropolitan attraction, as well as a center for learning about desert plants.

Figure 12 Arboretum