Lost, A Desert River and Its Native Fishes: A Historical Perspective of the Lower Colorado River

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Lost, A Desert River and its Native Fishes: A Historical Perspective of the Lower Colorado River

By

Gordon A. Mueller

U.S. Geological Survey
P.O. Box 25007, D-8220
Denver, CO 80225-0007

and

Paul C. Marsh

Arizona State University
Department of Biology
Box 871501
Tempe, AZ 85287-1501

Abstract. The Colorado River had one of the most unique fish communities in the world. Seventy-five percent of those species were found no where else in the world. Settlement of the lower basin brought dramatic changes to both the river and its native fish. Those changes began more than 120 years ago as settlers began stocking nonnative fishes. By 1930, nonnative fish had spread throughout the lower basin and replaced native communities. All resemblance of historic river conditions faded with the construction of Hoover Dam in 1935 and other large water development projects. Today, few remember what the Colorado River was really like.

Seven of the nine mainstream fishes are now federally protected as endangered. Federal and state agencies are attempting to recover these fish; however, progress has been frustrated due to the severity of human impact. This report presents testimony, old descriptions, and photographs describing the changes that have taken place in hopes that it will provide managers, biologists, and the interested public a better appreciation of the environment that shaped these unique fish.

Key Words: Colorado River, history, impacts, lower basin, native fish.

Introduction

The waters of the Colorado River have been used by humans for more than 11,000 years. Water was more precious than gold in the desert, and the Colorado River proved critical in the settlement, growth and economic development of the American Southwest. Today, it provides irrigation water for more than 3.7 million acres of farmland and delivers water to 30 million people in the United States and Mexico. Reservoirs blanket 675 mi^2 of the floodplain and can store five-and-a-half times the river's annual flow. Remaining portions of the lower river resemble canals and deliver reservoir water to farms and cities in Phoenix, Tucson, Los Angeles, Yuma, and Mexico.

Native fish have paid a high price for humans' unquenchable thirst and tinkering in the Colorado River Basin. Today, the river is totally diverted and only reaches the sea during major flood events. Long reaches of the Lower Salt, Gila, and Colorado Rivers and 92% of the wetlands historically found in the Colorado River Delta have dried up due to upstream water diversion and use.

Along with the obvious physical impacts of water abstraction, more than 70 nonnative fish species have been introduced. Half of these species have established and spread throughout much of the river basin and have virtually eliminated native fish. Minckley and Deacon (1991) stated: “management options may be more limited by the biological pollution of nonnative species than by the vast physical and chemical habitat changes wrought by humans.”

Today, seven of the nine freshwater fish native to the Lower Colorado River are federally listed as endangered. Wild populations of humpback chub, Sonoran topminnow, desert pupfish, woundfin, and Colorado pikeminnow are gone from the lower river, ghosts of the past. The river still contains a few bonytail and razorback sucker but the majority are stocked.

What physically and biologically remains of the ecosystem closely resembles conditions and fish communities found in the Upper Mississippi and Missouri River drainages. Today, the Lower Colorado River has the dubious distinction of being among the few major rivers of the world with an entirely introduced fish fauna.

The lower river of today no longer resembles the intimidating and harsh desert stream where the razorback sucker, bonytail, and Colorado pikeminnow evolved. Both the river and its fish have been lost in the lower basin. We hope the following old photographs and accounts help foster a better understanding and appreciation of what was lost, and the challenges faced by today’s resource managers in the conservation of these unique fish.

The Lower Colorado River

Local Indian Tribes and the Spanish had different names for the river but they all meant “Red River.” The Pima Tribe called it “Buqui Aquimuri” while the Yumas called it “Haweal.” Spanish explorers named it “Rio Colorado” meaning “reddish river,” which described its waters laden with sandstone and red silt destined for the Gulf of California (Sea of Cortez).

Discovery and Exploration (1539–1875)

Francisco De Ulloa – 1539

The Colorado River was first discovered by Europeans sailing in the Gulf of California in 1539. Hernando Cortez, Governor General of Mexico, sent Francisco De Ulloa north with three ships to explore the Pacific Coast. De Ulloa found his northward passage barred by a great river and returned. In May 1540, Francis Vasquez de Coronado launched a land expedition in search of the Seven Cities of Cibola. Hernando de Alarcon was sent north with three ships to support this expedition. He followed the coast and became the first European to enter the Colorado River basin by ship. The tidal surge at the delta nearly sank his ships but with his smaller boats he successfully sailed up the Colorado River. He reported, “...we found a very mighty river, which ran with so great fury of a stream, that we could hardly sail against it.” His journal suggests they traveled 85 leagues (288 miles) upstream, past the Gila River confluence and Chocolate Mountain range, to where Blythe, California, is today (James, 1906).

Further exploration was sporadic until the mid-1800’s. Spanish missionaries visited the delta in 1701 (Father Kino) and 1746 (Father Consag). British Lieutenant Hardy sailed his small schooner, the *Bruja*, up the delta in 1826 but missed the river’s main channel and entered the area now known as “Hardy’s Colorado” on the west end of the delta. He proceeded in a small boat through 20 miles of sloughs to reach the river. He then proceeded upstream to the confluence of the Gila River where he turned around and returned to his ship.

James O. Pattie – 1827

A group of fur trappers led by James Ohio Pattie became the first to explore the delta from the north. After trapping in the mountains of Arizona and New Mexico, they canoed down the Gila River in the autumn of 1827 to sell their furs at Spanish settlements they assumed existed further downstream. On December 9, Pattie reported:

> “...floating with the current, which bore us downward at the rate of four miles an hour... We floated about 30 miles, and in the evening encamped in the midst of signs of beavers. We set 40 traps, and in the morning of the [December] 10th caught 36 beavers, an excellent night’s hunt... The river, below its junction with the Helay [Gila], is from 200 to 300 yards wide, with high banks, that have dilapidated by falling in. Its course is west and its timber chiefly cottonwood, which in the bottoms is lofty and thick set. The bottoms are from six to ten miles wide... are subject to inundation in the flush waters of June...” [James, 1906].

Pattie’s party continued to catch beaver and had to build another canoe to haul the extra pelts. They eventually reached the tidewater where the tide and rough waters flooded their camp and they could proceed no further.

Major Heintzelman – 1851

Major Heintzelman, commander of Camp Independence [Fort Yuma] described his vision of using stern-powered steamboats to haul supplies inland. He wrote:

"The river bottom is several miles wide and covered with willow, cottonwood, and mesquite, with usual underwood and grass... The highest water is in June and July and the banks generally overflowed... The whole distance from the junction [Gila River confluence] to the mouth is about 150 miles... The junction is an important point-a military post there can be supplied by the river, either by anchoring a store ship in the mouth and running a small stern-wheel steamer, not drawing more than 2½ to 3 feet of water; or, in June and July, when a boat drawing 6 to 8 feet can ascend without difficulty [Lingenfelter, 1978]."

Lieutenant Joseph Ives – 1858

Lieutenant Joseph Ives of the U.S. Office of Explorations and Surveys led the first scientific expedition up the Colorado River. His mission was to test whether it was navigable by steamboat. A Philadelphia shipbuilding company was contracted to build a shallow-draft boat that could navigate the shallow Colorado River. The boat was built and dismantled, then transported by the schooner *Monterey* to the river's mouth where it was reassembled and christened the *Explorer* (Fig. 1). In December 1857, the adventure up the Colorado River began. Because of normal low flows during winter and a prolonged drought, progress was slowed by sandbars, snags, and frequent stops for fuel. Lieutenant Ives reported:

"On one or both sides there is usually a fringe of willow and cottonwood, or a thicket of high reeds. The channel is circuitous, but thus far there have been no very sharp bends. In few places has the depth of water been less than twelve feet. Slues branch in every direction, and many of them might mislead a person unacquainted with the localities. The current has been moderate, averaging about two-and-a-half knots an hour. At this place, which is 40 miles above Robinson's Landing, [mouth of the Colorado River] the tide raises the river two or three feet. The water is perfectly fresh, of a dark red color, and opaque from the quantity of mud held in suspension...The width of this portion of the river varies from one-eighth to half a mile. The course is exceedingly tortuous. The depth in the channel is from eight to twenty feet, but bars are frequently encountered where there are not more than two feet of water...The period of highest water is in the early part of July, when this velocity is increased to five or six miles. The average height is then ten feet greater..."

It took 11 days to reach Fort Yuma where Lieutenant Ives organized the expedition (Ives, 1861). The expeditionary team included a Prussian sketch illustrator, Balduin Möllhausen, who provided the first known illustrations of the Colorado River (Ives, 1861; Huseman, 1995).

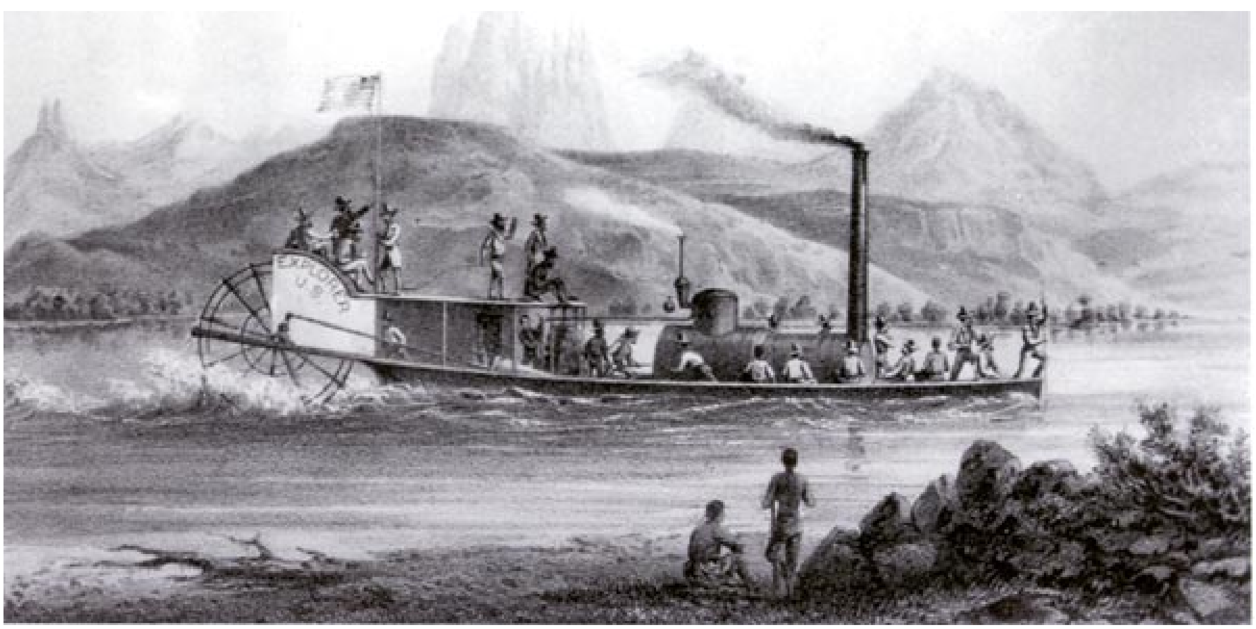

Fig. 1. Henrich Balduin Möllhausen. Steamboat *Explorer* (Chimney Peak) water color and gouache on paper, 1858, 1988.1.1. Courtesy of the Amon Carter Museum, Fort Worth, Texas.

Although the 45-foot *Explorer* was built specifically to navigate the shallow river waters, it frequently became grounded. The first grounding occurred near Fort Yuma where it took nearly a day before the crew freed the boat. Ives wrote:

> "The delay would have been less annoying if it had occurred a little higher up. We were in plain sight of the fort, and knew that this sudden check to our progress was affording an evening of great entertainment to those in and out of the garrison."

> "The shifting of the channel, the banks, the islands, the bars is so continual and so rapid that a detailed description, derived from the experiences of one trip, would be found incorrect, not only during the subsequent year, but perhaps in the course of a week, or even a day ..."

The expedition was nearly stopped at the Chemehuevie Valley (now Upper Lake Havasu) because the river was so shallow. The braided channel was nearly a mile wide. The crew dragged and pushed their boat and eventually reached deeper water. This gave Möllhausen time to sketch the upper end of the present-day site of Lake Havasu (Fig. 2).

Further upstream at Cottonwood Valley [now inundated by Lake Mohave], they encountered several Indians seining fish. Möllhausen sketched the event (Fig. 3) and Lieutenant Ives noted in his journal:

Fig. 2. Henrich Balduin Möllhausen. Distant view of the Mohave range of Needles, water color and gouache on paper, 1858, 1988.1.25. Courtesy of the Amon Carter Museum, Fort Worth, Texas.

> "...their net was made of coarse mesh pieced together from fine, but very strong, threads of inner bark fiber. The net was about four feet high and about thirty feet long. Long stakes every four feet held the net upright in the water and secured it

Fig. 3. Henrich Balduin Möllhausen. Cottonwood Valley, water color and gouache on paper, 1858, 1988.1.33. Courtesy of the Amon Carter Museum, Fort Worth, Texas.

to the ground. This was the only gear our fishermen had. Holding the net stretched taut, five or six people waded into the river and moved slowly backward with the current until they stood across from a suitable depression in the back. The two fishermen who carried the ends circled around carefully and approached the bank. Together with the others they pulled the net and its contents out of the water. Small fish easily slipped through the wide mesh, but they caught enough large ones to delight our entire party with a hearty meal [Ives, 1861]."

These Indians were probably Chemehuevie, a nomadic people who roamed southern Nevada and western Arizona. The expedition map shows a "Chemehuevis Valley" located in the area now flooded by upper Lake Havasu. Their name is derived from a Mohave word that means "people who fish." The Mohave Indians also fished and had specific names for the razorback sucker, bonytail, and Colorado pikeminnow. Ah'chee means fish, and Ah'had translates as "the best fish," which described the Colorado pikeminnow. Apparently its flesh was prized. The razorback sucker and bonytail were called Ah'chee Tcha'nop and Ah'chee Me'Kool.

Fish comprised up to one-fifth of the diet of Indians living along the river and became more important when droughts caused garden failure. Fish were caught in the river, but more were taken from lagoons where they became stranded. Seining was the most common fishing technique but Indians also used a dip net called a "suak," which was a net attached to two parallel poles. Another method was a "kwithata" or basketry scoop that was 5 feet long and about 18 inches wide. It was made of willows or reeds and used to "scoop" fish up. They also built fish traps or weirs which they baited with corn or melon seeds (Stewart, 1957).

Ives' group traveled north nearly 400 miles until they reached Black Canyon, near the future site of Hoover Dam (Fig. 4). Swift, rocky rapids prevented them from taking the *Explorer* further upstream. Using a small rowboat, they pushed upstream to the present site of Las Vegas Wash, which they mistook as the Virgin River. They considered this the highest point of navigation and returned to Yuma.

Lieutenant George Wheeler – 1871

The government launched its last river survey in 1871, commanded by Lieutenant George Wheeler (Fig. 5). Wheeler's group set off with the unprecedented challenge of boating upstream from Camp Mohave (Fort Mohave) into the Grand Canyon. The purpose of the trip is not clear since much of the area had already been floated by Ives and John Wesley Powell, or reached overland by horse and wagon. The team's upstream struggle ended at Diamond Creek, located in the southern end of the Grand Canyon where they departed the river and returned overland (Wheeler, 1876).

Fig. 4. Photograph of Black Canyon taken in 1926 before Hoover Dam was built. Courtesy of the Bureau of Reclamation, Boulder City, Nevada.

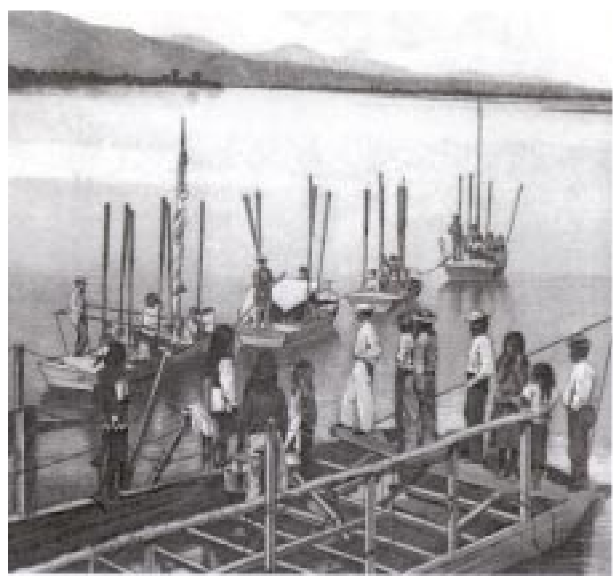

Fig. 5. Tracing of a photograph taken of the Wheeler Expedition leaving Fort Mohave in 1871. Taken from Wheeler (1876). Courtesy of the U.S. Geological Survey Library, Denver, Colorado.

Adventurers and Scientists

George W. James explored the Colorado River downstream of Yuma. He floated the New River and described the experience of floating through a mesquite forest in the delta in 1906.

> "There were some ten miles where the wild river ran through a mesquite forest, through which we should have to cut, push, force our way... Hour after hour we toiled along, up to our waist in water, chopping, cutting, pushing, pulling, and getting scratched. Mostly the latter [James, 1906]."

Kolb (1927) floated the lower river in January 1912. He reported the river would often truncate in the broader reaches forming shallow, braided channels where navigation was virtually impossible (Fig. 6). He often had to drag his boat to find deeper water. While floating through Boulder Basin, he wrote:

> "The river seemed to be growing smaller as we got out in the open country. Like all Western rivers, when unprotected by canyon, it was sinking in the sand. Sandbars impeded our progress at such places as the mouth of the [Las Vegas] Wash."

Floating through Mohave Valley, he wrote:

> "More sandbars were encountered the next day, and ranches began to appear on both sides of the river. We had difficulty on some of these bars. In places the river was a mile wide, with stagnant pools above the sand and with one deep channel between."

Kolb ended his trip at Needles but returned the following spring to finish his adventure to the Sea of Cortez. He estimated the river was a mile wide upstream of Topock Gorge and flowed 7 to 8 miles per hour. He made the 250-mile trip in just 4 days. He described the power of the flood going through Mohave Canyon (Topock Gorge) and the willow and cottonwood forest that bordered the river (Fig. 7):

> "By the time I had reached the spire-like mountainous rocks a few miles below the bridge, which gave the town of Needles its name, the sun was well up and I was beginning to learn what desert heat was, although I had little time to think of it as I was kept so busy with my boat. Here, the stream which was spread a mile wide above, had choked down to two hundred feet; small violent whirlpools at the abrupt turns in this so-called canyon and the water tore from side to side."

As he reached the Cibola Valley, he reported:

> "The river twisted back and forth in great loops with the strong current, as is usual, always on the outside of the loops close to the overhanging banks...At some such places the stream was engaged at undermining the banks which rose eight to ten feet above the water. Occasional sections, containing tons of earth and covered with tall slender willow trees would topple

Fig. 6. Broad expanses of the Lower Colorado River, exact location unknown (ca. early 1900's). Courtesy of the Bureau of Reclamation, Boulder City, Nevada.

Fig. 7. The lower river was typically bordered with cottonwood and willow trees. Courtesy of the Arizona Historical Society, Yuma.

> over...The trees, sixty feet high, resembled a field of gigantic grass or unripened grain; the river was the reaper cutting it away at the roots..."

Kolb (1927) had to portage over Laguna Dam which had been constructed in 1909 as the first manmade diversion to span the entire river. His journal continued: "In another place there were no banks, and the water had spread for three miles in broken sloughs and around half-submerged islands, the one deep channel being lost in the maze of shallow ones...Once I lost my way and spent a half hour in getting back to the right channel [Kolb, 1927]."

Joseph Grinnell, a professor of zoology from the University of California, conducted bird and mammal surveys between Needles and Yuma in 1910 (Grinnell, 1914). During his trip, he collected a few fish and made some interesting observations concerning drought. His report provided an excellent description of the river and its biota.

> "The effects of the extraordinary and continuous load of sediment of the Colorado River, together with the inconstancy of its channel, doubtless accounts directly or indirectly for many of the peculiarities of the fauna...the Needles-to-Yuma section of the river valley there are no aquatic molluscs or decapod crustaceans, or tailed amphibians..."

> "The fish fauna in the main stream is sparse in both species and individuals. Our party seined at three different points in the main stream. At two of these nothing was caught; in the third, a backwater slough on the Arizona side above Mellen, four sorts of fishes were taken, [nonnative] catfish, bonytail, humpback sucker, and [nonnative] carp. A huge minnow, called locally Colorado salmon, was caught with hook and line in backwater on the California side opposite Cibola, and was plentiful immediately below the Laguna Dam, where many were being taken by the Indians living near there."

> "...there is relatively little cyptogamic aquatic flora in the Colorado River. There is therefore little or no food-supply from this source to attract plant-eating ducks...On the other hand, herons were notably plentiful because of the supply of catfish and carp made abundant at intervals by the drying-up of overflow ponds. While fishes were not abundant in the main stream, they were plentiful in the backwater sloughs, where, too, the water was more nearly clear because the sediment had a chance to settle out."

Aldo Leopold, who many consider the father of environmental conservation, dedicated a section (Green Lagoons) of his book, *A Sand County Almanac,* to a canoe trip he took with his brother through the delta in 1922. He described the pristine area and added his unique perspectives to the value of this ecosystem.

> "It is part of the wisdom never to revisit a wilderness, for the more golden the lily, the more certain that someone has gilded it. To return not only spoils a trip, but tarnishes a memory. It is only in the mind that shining adventure remains forever bright. For this reason, I have never gone back to the Delta of the Colorado since my brother and I explored it, by canoe, in 1922... On the map the Delta was bisected by the river, but in fact the river was nowhere and everywhere, for he could not decide which of a hundred green lagoons offered the most pleasant and least speedy path to the Gulf. The still waters were of a deep emerald hue, colored by algae, I suppose, but no less green for all that. A verdant wall of mesquite and willow separated the channel from the thorny desert beyond...Camp-keeping in the Delta was

not all beer and skittles. The problem was water. The lagoons were saline; the river, where we could find it, was too muddy to drink. At each new camp we dug a new well. Most wells, however, yielded only brine from the Gulf. We learned, the hard way, where to dig for sweet water. When in doubt about a new well, we lowered the dog by his hind legs. If he drank freely, it was the signal for us to beach the canoe, kindle the fire and pitch the tent [Leopold, 1949]."

What They Found

The River

The river originates on the western slope of the Rocky Mountains and drains an area of approximately 240,000 mi^2 (Fig. 8). Its principal tributaries, the Green River and Colorado River, drain from the mountains of southwestern Wyoming and western Colorado. Moving downstream, smaller tributaries include the White, Yampa, Gunnison, Eagle, Deloris, Dirty Devil, Escalante, San Juan, Paria, Little Colorado, Virgin, Muddy, Bill Williams, and Gila Rivers. The vast majority of flow (1.9×10^{10} m^3) is produced by snowmelt in the upper basin. The lower basin is primarily desert, with annual rainfall seldom reaching 5 inches a year. Annual flow into Mexico averaged 18.5 million acre-feet (maf) (2.3×10^{10} m^3) making it the fifth largest river in the United States (McDonald and Loeltz, 1976).

The importance of the Colorado River to the future settlement of the Southwest was apparent from the beginning. With water, anything was possible in the desert. By the late 1800's, scholars commonly referred to the river as the "Nile of America." It shared striking similarities with the Nile River of Egypt. Both rivers originated in the mountains and both flowed through a hot and inhospitable desert before reaching the sea. Both were unpredictable, known and feared for their floods and droughts. Both carried massive amounts of sediment that created lush marshlands, lagoons, and river deltas that supported highly diverse wildlife communities. Most important, they provided a fertile floodplain where crops prospered. The agricultural and metropolitan centers of Arizona, Nevada, southern California, and northern Mexico were nurtured from the waters of the Colorado River.

Politically, the Lower Colorado River Basin starts at Lee's Ferry, a historic Mormon crossing located 15 miles downstream of Glen Canyon Dam and the beginning of the majestic Grand Canyon (Table 1). As the river leaves the Grand Canyon, it cuts through a number of smaller mountain ranges, forming a series of short but spectacular canyons: Iceberg Canyon, Boulder Canyon, Black Canyon, Eldorado Canyon, and Topock Gorge (Mohave Canyon), to name a few. The river cut through these narrow canyons, and deposited silt, gravel, and rock in the broader floodplain. This floodplain increased in scale and complexity as it flowed south.

The river corridor was relatively narrow upstream of Monument Canyon, but below this point it broadened to nearly 5 miles. The Great Colorado Valley started here, extending more than 100 miles to Yuma. There it was briefly squeezed by Cranebrake Canyon before reopening to the wide expanses of the delta which included the Salton and Pattie Basins.

The Lower Colorado River and its tributaries were unpredictable. Spring and summer monsoon floods could turn the river into a raging torrent, causing massive erosion and depositing millions of tons of sediment. Spring flows past Yuma averaged more than 75,000 cubic feet per second (cfs) and the maximum flow during historical times was estimated to have reached 400,000 cfs (Wheeler, 1876). Spring floods normally began in late May and peaked in late June or early July as snowmelt in the mountains subsided.

Major floods occurred nearly every decade, causing the river to overflow its banks and flood mesquite forests and wide expanses of the floodplain and desert. Wheeler (1876) reported that a Mr. Jaeger, owner of the Fort Yuma ferry, reported heavy floods in 1840, 1852, 1859, 1862, and 1867. Wheeler's (1876) survey crew mapped the river's cross-sectional profile at Stone Ferry (Virgin River confluence), Nevada; Camp (Fort) Mohave; and Fort Yuma, Arizona Territory in 1875 (Table 2; Fig. 9). The survey crew reported that the 1874 flood raised the river to overflow its banks by more than 8 feet, causing the river corridor to swell to a width of nearly 2 miles. Aerial photographs taken in 1938 show the river channel near Needles to be nearly 2 miles wide.

Summer brought the monsoon season to the desert. Storms were often intense and flash flooding was common. Some years the weather was less generous and vast areas experienced severe droughts. The river typically reached low flow in late autumn, after the monsoon. The wide and shallow expanses of the river would shrink until there was only a trickle in some reaches. The drought of the 1930's was the most severe for the 30-year pre-dam record. Mainstem flows at Yuma, Arizona dropped to 540 cfs in August 1934 (USGS, 1978).

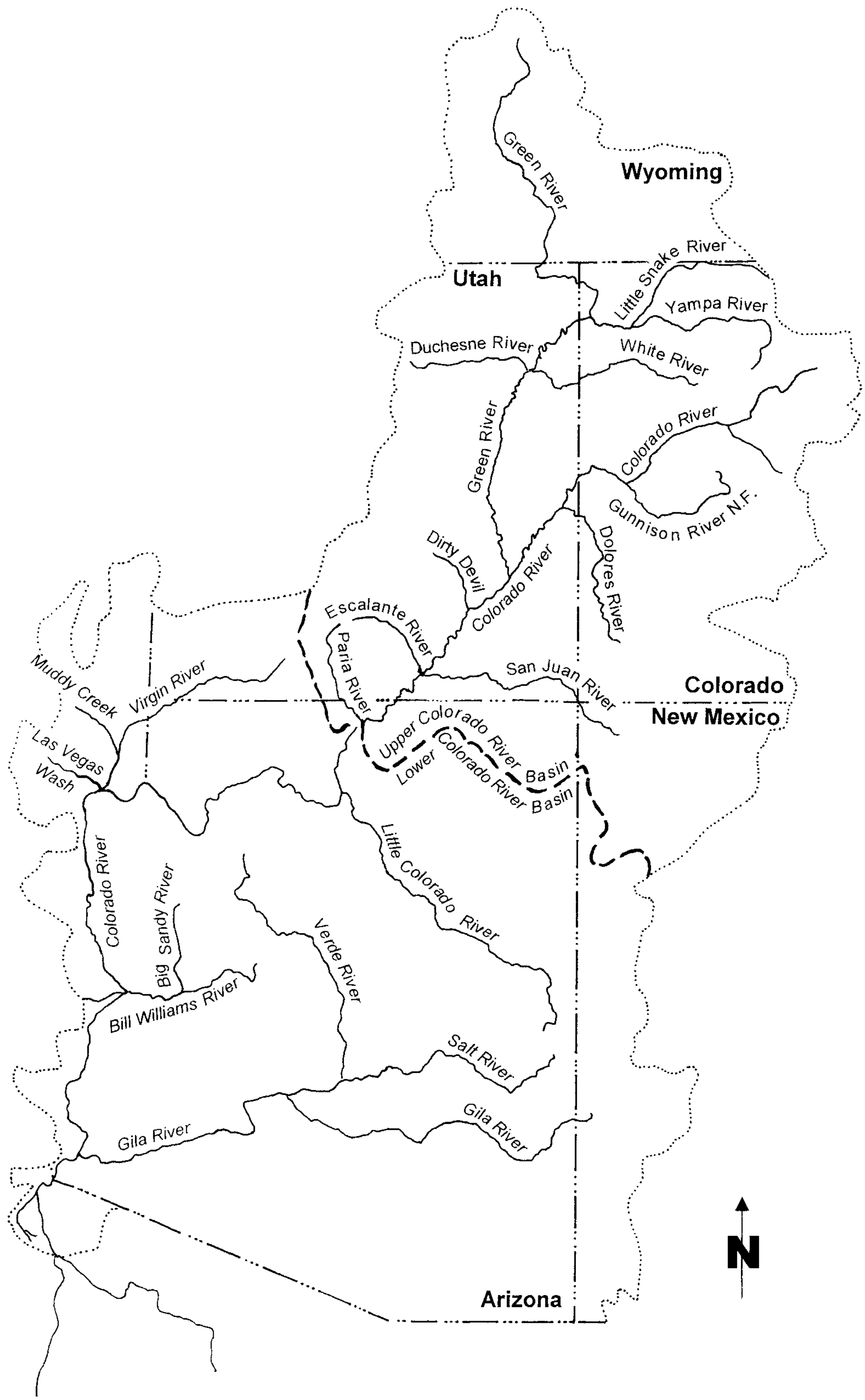

Fig. 8. Map of the undeveloped Colorado River Basin, pre-1903.

Table 1. Features of the Lower Colorado River and approximate miles from the Gulf of California, 1875.

Canyons	Features	Tributaries	Valleys	Length	River mile
Grand					510
	Grand Wash				
Iceberg				4	490
Virgin		Virgin River			465
Boulder				7	450
	Vegas Wash				440
Black				35	430
Painted				4	400
			Cottonwood	5	390
Pyramid				5	375
			Mohave	30	345
Mohave				8	335
			Chemehuevie	12	305
		Bill Williams River			290
Monument				6	290
			Great Colorado	107	175
Canebrake				10	155
	Purple Hill Pass			2	130
	Explorer Pass			1	130
		Gila River			125
	Salton Sink				125[a]
	Yuma, Arizona				125
	Volcano Lakes				60[a]
	Laguna Salada (Laguna Maquata)				60[a]
	Gulf of California				0

[a]Aerial miles.

Table 2. Physical profiles and flows of the Colorado River measured in 1875–1876 (Wheeler, 1876).

	Stone Ferry (8/12/1875)	Camp Mohave (9/2/1875)	Fort Yuma (3/20/1876)
Width (ft)	480	1,116	461
Mean depth (ft)	11.89	4.14	5.85
Average velocity (ft/sec)	3.21	2.51	2.81
Discharge (cfs)	18,410	11,611	7,659
High flood mark (ft)	+17.01	+8.0	+10.19

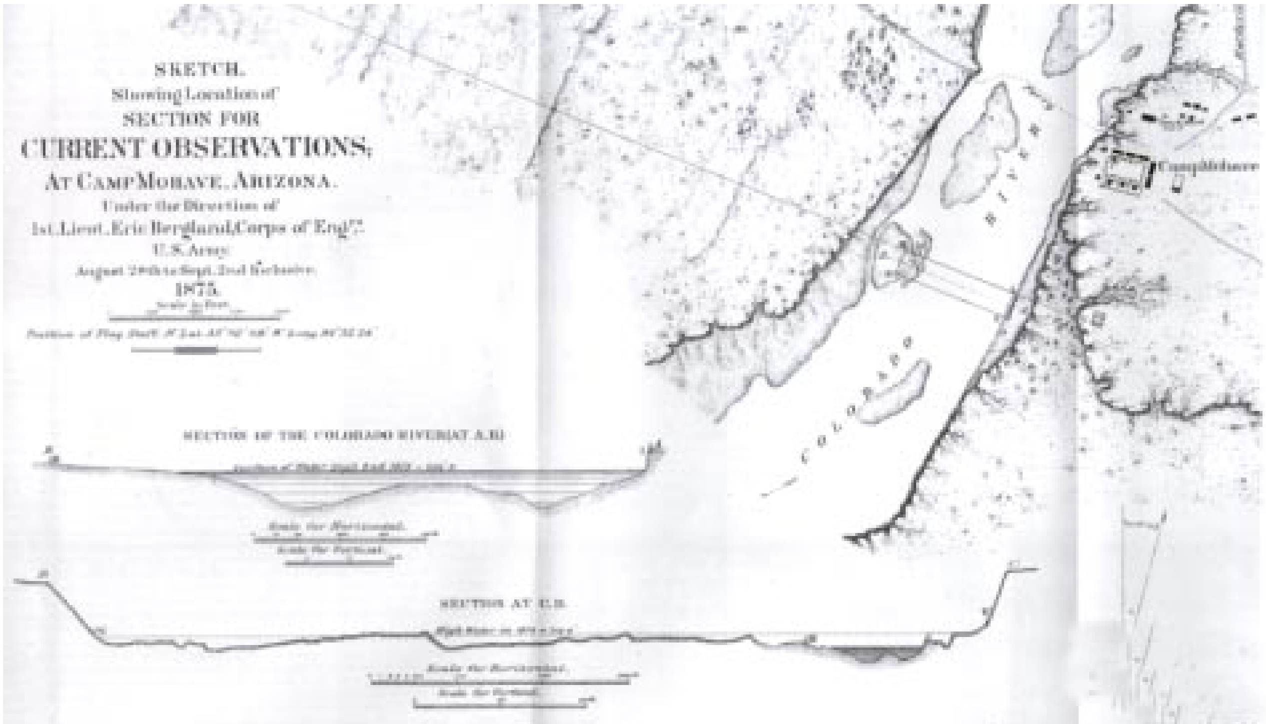

Fig. 9. Survey map of the Colorado River near Fort Mohave, Arizona Territory, drawn by First Lieutenant Eric Bergland, Corps of Engineers (Wheeler, 1876).

Colorado Delta

The most prominent feature of the lower basin was the broad floodplain of the delta. The Colorado River had the largest sediment load of any stream of its size in North America. The Grand Canyon is a testament to the amount of material that has been moved downstream. Over the millennium, the river deposited vast amounts of sediment that gradually filled the Salton Trough and isolated the Salton Sink from the Sea of Cortez.

Geographically, the river's delta starts at the confluence of the Gila River and extends downstream to cover more than 6,000 mi^2 (Fig. 10). The channel meandered through the 10- to 25-mile-wide corridor and during floods carved a complex maze of sloughs, oxbows, and wetlands. Flood waters frequently covered hundreds of square miles of the desert. Mr. Redondo, a butcher from Yuma, reported the river changed course during the 1862 flood, leaving behind a 50-mile-long slough that extended from Algodon to New River (Wheeler, 1876).

The delta contains two large basins: the Salton Sink (USA), and the Pattie Basin, which is located west of the Cucopas Mountains in Mexico. Periodically, major floods would fill these basins, forming huge, temporary lakes. Blake (1857) reported that a Cahuilla Indian legend held that in ancient times the Salton Sink filled with water, destroying lakeside villages. The legend holds that fish became plentiful as the lake slowly receded, which took a period equal to the life span of four men.

There is ample archeological evidence to support the legend. A beach mark outlines the shoreline of ancient Lake Cahuilla where archeologists found rock fish traps and charred remains of razorback sucker and bonytail bones. The traps were found some 30 feet below the high watermark and were estimated to be between 300 and 1,000 years old. High water lines suggest the basin has filled many times, creating a lake some 105 miles in length and nearly 300 feet deep (Wilke, 1980; Desert Magazine, 1981).

Colorado River waters reached the Salton Sink at least four times in recent history. Wheeler (1876) reported that a Mr. Jones stated he "saw in the basin [Salton Sea Basin] a great lake some 60 miles long and 30 miles wide" in 1862. James (1906) reported the Salton Sink was again partially flooded in 1891 when the Colorado River spilled water that covered an area 30 miles long and 10 miles wide in the Salton Sea Basin. H.W. Patton, a reporter from the Banning (California) Herald, floated by boat from Yuma to the Salton Sink during that flood.

The most notable of these events occurred in 1905 when the Colorado River broke through its levee and left

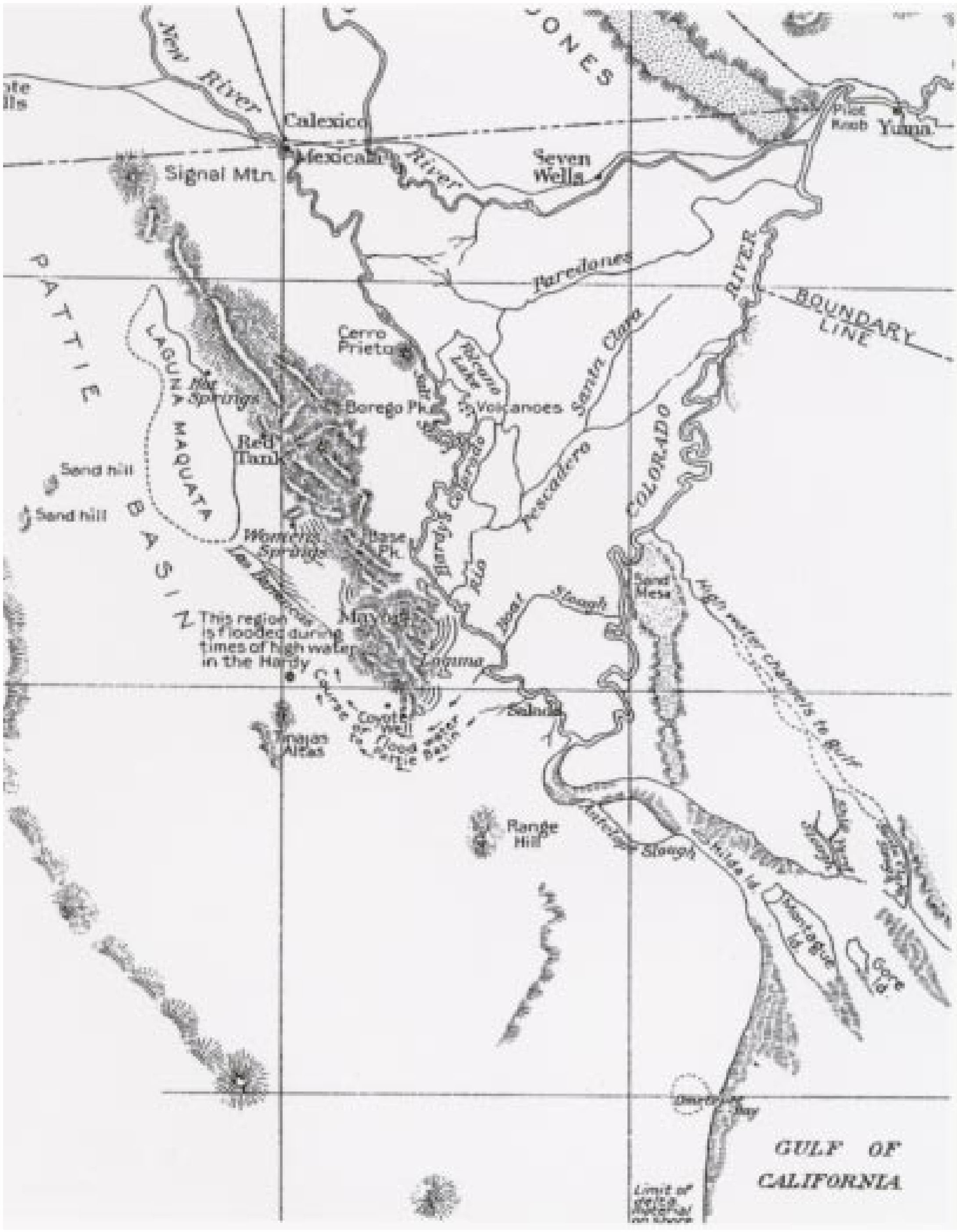

Fig. 10. Map of the Colorado River delta, pre-1910 (Sykes, 1937).

its channel and flowed uncontrolled into the Salton Sink until the levee was repaired in 1907. While the river was returned to its original channel, irrigation drainage continued to flow down these flood ways as more river water was diverted toward the Imperial and Coachella Valleys. Flood waters once again entered the Salton Sea in June 1914 when the spring flood broke through the Volcano Lakes Levee in Mexico and flowed north through the New River. Maximum flow during that short event was only 6,000 cfs.

The Pattie Basin is the second largest of the basins and is found south of the border. This basin was even more susceptible to flooding than the Salton Sink. Waters reached it by following the eastern abutment and circling behind the Cocopah Mountains. The temporary lake was originally named "Laguna Maquata" by local Indians and today is called Laguna Salada. Kiffen (1932) reported the basin flooded at least six times between 1884 and 1928. The lake often measured 20 by 40 miles in size. In 1884, it was reported that "thousands of (mullet) fish ...many...exceeding two feet in length" were trapped in Laguna Maquata. Typically, these desert lakes would evaporate between flood events, and early explorers reported seeing windrows of dead fish extending for miles. These bones are still evident in places a century later.

The main river channel meandered as much as 175 miles through the river delta cutting multiple channels until it reached the Gulf of California. The broad floodplain was covered with an estimated 1.9 million acres of sloughs, oxbows, and tidal wetlands. The upper delta was influenced by flood events and drought while the lower reach was affected by tidal fluctuations that could reach 35 feet. The tidal surges at the mouth of the Colorado were the second highest in the world.

Major Tributaries

Tributaries downstream of the Grand Canyon included the Virgin, Bill Williams, and Gila Rivers. The largest was the Gila, which flows across Arizona and drains portions of southwestern New Mexico and northern Mexico.

Miller (1961) reported that extensive cattle grazing before the 1880's changed the streamflow and started to impact fishes in central Arizona. Cattle grazing and trampling of streambanks increased soil erosion, stream headcutting, and the drainage of natural wetlands. He explained:

> "...large expanses were originally covered by a luxuriant growth of grasses and other succulent herbage which, during the rainy season, reached a height of 2 feet or more. As the dry season advanced, the vegetation died down but formed a protective mulch, and its roots were remarkably effective in binding the soil. Such a cover acts like a sponge in retaining rainfall and hence is a potent defense against erosion. Not only were valley floors covered in part by dense sacaton grass but there were extensive cienegas (wet meadows) near their centers, and elsewhere the water table was often within a few feet of the surface. Consequently, there were many more permanent streams than now, and large floods were rare."

Miller went on to suggest the subtle change in vegetation caused by grazing increased the frequency and severity of floods and droughts. Following are some descriptions of stream conditions decades after the countryside had been heavily grazed.

Wheeler (1876) described drought conditions at the confluence of the Virgin River. He reported:

> "The water of the Virgen [Virgin] was unfit for use by men or animals. It was intensely saline, its color brick-red, and surface covered with floating slime of the same color."

Evermann and Rutter (1895) reported similar basin conditions just before the turn of the century:

> "...the tributaries from Utah, Nevada, California, and Arizona are comparatively arid regions. During time of rains these streams become of considerable size and are very turbid from the easily eroded country through which they flow. They decrease in size as readily, and in some cases disappear in the sand. Such streams are of course unsuited to a large variety of fish life."

Grinnell (1914) reported: "Even the two "rivers" [Gila and Bill Williams] named often go completely dry in their lower courses following protracted drought."

Settlers around the Salt and Gila Rivers reeled from a huge flood in 1890 (Figs. 11 and 12). Blake (1915), a

Fig. 11. Photograph of the Salt River flood of 1890. Courtesy of the Bureau of Reclamation, Boulder City, Nevada.

Fig. 12. Gila River flooding around 1900. Courtesy of the Bureau of Reclamation, Boulder City, Nevada.

professor of geology from the University of Arizona, described the lower reaches of the Gila River, west of Florence, Arizona, were ordinarily dry in summer, but suggested:

> "Violent floods in the Gila and in the Salt are far more to be feared and reckoned within preparing and conducting engineering work along the Lower Colorado River than anything coming down the Colorado River proper. Relatively unimportant floods, of course, occur in the Colorado proper due to heavy rainfall over the drainage area of the Little Colorado and Virgin Rivers and from the Bill Williams Fork."

Settlement and Change

Ranching, Mining, and the Steamboat Era (1852–1900)

The Colorado River Basin was purchased from Mexico in 1848. Discovery of California gold in 1849 triggered a western migration and the search for riches. Two major trails crossed the lower Colorado River: Emigrant Trail at Yuma and Beale's (Mohave) Trail near today's Bullhead City. Both were major routes to southern California.

Immigrants brought change. Ferries became the first profitable business carrying passengers, stock, wagons, and goods across the river (Fig. 13). It was not long before travelers and settlers experienced altercations between themselves and local Indians, and the army was called in. The military built Camp Independence (later named Fort Yuma) in 1850 and Fort Mohave in 1859 to help maintain the peace. Frontier life was difficult, demanding a constant need for food and supplies. Unfortunately, hauling freight overland was not only expensive and difficult, but also dangerous. At one point, supplies and rations became so scarce, Fort Yuma had to be temporarily abandoned until emergency rations were delivered (Lingenfelter, 1978).

The demand for supplies by the military, local miners, and settlers triggered attempts to haul freight upstream from the Sea of Cortez. The schooner, *Sierra Nevada,* arrived at the mouth of the Colorado River in February 1852 with its hold full of freight. Cargo was unloaded to flatboats that were pulled 125 miles upstream to Yuma. One boat sank in the tidal surge, and the effort was so difficult it was abandoned in favor of attempting to motor upstream with a steamboat.

James Turnbull had a 45-foot side-wheel steamboat constructed in San Francisco. It was disassembled and shipped aboard the U.S. schooner *Capacity* to the mouth of the Colorado River where it was reassembled in June 1852. After being christened the *Uncle Sam,* the 20-horse-powered steamer labored 125 miles upstream to Fort Yuma. The vessel was greatly underpowered but it did make the voyage, proving steamboats could navigate at least to Yuma. Shortly later, it was replaced by the more powerful *General Jessup*, a 104-foot-long side-wheeler. On her maiden voyage in February 1854, she carried 37 tons of cargo to Fort Yuma (Lingenfelter, 1978).

The lower river was never the same after the arrival of the steamboat. Traffic increased dramatically after the Civil War as lucrative freight hauling businesses grew. Port Isabella was built at the river's mouth to transfer freight between schooners and riverboats. It also served as a port to repair and build boats (Fig. 14). The 30-foot tide cycle provided a natural dry dock.

Several steamboats and barges were built there. It was not long before other steamboats such as the *Colorado*, *Cocopah*, *Mohave*, *Gila*, *Esmeralda*, *Nina*

Fig. 13. Colorado River ferry at Yuma, April 5,1909, 115-JAJ-732. Courtesy of the National Archives, Washington, D.C.

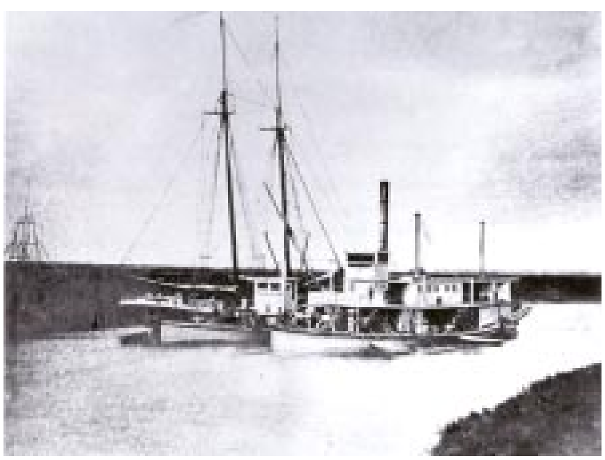

Fig. 14. Schooner and steamboat exchanging cargo near Port Isabela in the Sea of Cortez (date unknown). Courtesy of the KLVX Steamboats on the Colorado Collection, University of Nevada, Las Vegas Library.

Tilden, *Cochan*, *St. Vallier*, *Electra*, *Retta*, and *Searchlight* were hauling freight up and down the river. The steamboat landings of Port Famine, Gridiron, Ogden's Landing, Pedrick's, and Arizona City sprang up between the coast and Yuma to service and supply wood for their hungry boilers (Fig. 15). Additional landings upstream of Yuma soon appeared, including Laguna, Castle Dome City, Eureka Landing, Williamsport, Rood's Ranch, Drift Desert, Mineral City, Olivia, Ehrenberg, Parker's Landing, Mellen, Hardyville, Camp Eldorado, and Callville.

Steamboats hauled freight from the Gulf of California to Yuma year-round and by 1860 more than 1,200 tons of freight had been stockpiled in Yuma awaiting shipment further upstream. Navigation upstream of Yuma was difficult at best and most profitable during spring runoff when the river ran deep and steamboats could be fully loaded. During high water, boats could navigate as far upstream as the confluence of the Virgin River, but during low flow most river captains seldom ventured upstream of Hardyville (Bullhead City). Steamboats had to navigate around sandbars, snags, rocks, and through rapids. Swift water, especially in the canyons, made it necessary for the boats to be winched over the rapids with pulleys. Ring bolts were drilled and set in the canyon walls where block and tackle could be attached. One can still be found in Black Canyon, just downstream of Hoover Dam.

At flood stage, the river at Cottonwood (Lake Mohave), Mohave, and the Chemehuevie Valley (Lake Havasu) could swell to 2 miles wide. At low flows, these broad channels would recede into shallow braided

Fig. 15. Map showing steamboat landings on the Colorado River between 1860 and 1870. Courtesy of R.E. Lingenfelter (1978).

channels only scant inches in depth. The draft of these large boats was extremely shallow, often less than 2 feet. Captains searched for the channel where water might be a few inches deeper. Steamboats traveling between November and April had to be loaded "light" to have any chance of making it. Running aground was common and it often took hours and, at times, even days for crews to free the boats. John Mellon, a renowned Colorado River captain, once had a boat stranded for 52 days before higher water freed it (Lingenfelter, 1978).

Steamboats provided the most economical method of hauling freight into the valley for 35 years. The Santa Fe Railroad reached Yuma in 1877 and overnight the steamboat was replaced as the chief means of hauling freight into the river basin. The shipyard at Port Isabel was dismantled in 1878. However, steamboats remained the most effective method of delivering goods between the railhead at Yuma and upstream mines, ranches, and settlements (Fig. 16). Continued expansion of the railroad and a better road system replaced the steamboat by the turn of the century. The railroad reached Needles, California, in 1889. Laguna Dam, built in 1909, blocked navigation upstream of Yuma. The Bureau of Reclamation (Reclamation) bought the *Searchlight* and used it to inspect levees until it was lost during the 1916 flood. It was the last river boat to steam on the Colorado River.

Urbanization and Population Growth

The Southwest is one of the fastest growing regions in the United States. Much of that growth occurred after World War II. Phoenix remains the largest city in the area, showing a population growth from 5,544 in 1900 and more than 1.3 million in 2000 (Table 3; Fig. 17). At the beginning of the twentieth century, Yuma was the largest city on the river, having a population of 1,402 (1900). Today, it has grown to more than 77,000. The community of Searchlight has tripled during the past century, while the villages of

Fig. 16. Steamboats and barges moored at their landing at Yuma (note Southern Pacific Railroad bridge in background [1877]). Courtesy of the Arizona Historical Society, Yuma.

Fig. 17. Comparative photographs of the Phoenix area taken from Tempe Butte in 1902 and 2002. 1902 photograph courtesy of the U.S. Geological Survey Library, Denver, Colorado.

Cottonwood Island and Eldorado Canyon were displaced by Lake Mohave. Today, Las Vegas supports more than 1.2 million people, replacing the sleepy hamlet of 30 settlers found in 1900.

Table 3. Population growth for Colorado River communities between 1900 and 2000.

State, town/city	1900	2000
Arizona		
Yuma	1,402	77,515
Phoenix	5,544	1,321,045
Nevada		
Cottonwood Island	4	0
Eldorado Canyon	23	0
Las Vegas	30	478,434
Searchlight	211	730

Water Development: Diversions and Dams (1900–2001)

Agricultural Diversions

Human use of the river started modestly. Tribal societies began to garden and then developed larger farms (Fig. 18). The Anasazi farmed hundreds of acres along the Salt and Gila River Basins more than 1,000 years ago. Around Phoenix, archeologists have uncovered extensive irrigation systems that include small storage reservoirs and hundreds of miles of ancient canals. These may well represent the single largest acreage irrigated by prehistoric man in North America. This was a remarkable feat, considering canals were dug by hand using wood, bone, and stone tools.

Mysteriously, these early farmers disappeared and large-scale agriculture had to be rediscovered by the Europeans. Agriculture gradually intensified as man rediscovered methods of moving water. Simple water lifts and canals delivered water faster and easier than carrying it by hand and was sufficient for irrigating small gardens. However, larger scale irrigation similar to what the Anasazi's had used to divert water by gravity around the broader floodplains was needed.

Fig. 18. Primitive water lift believed to have been located in the Colorado River delta (date unknown). Courtesy of the Bureau of Reclamation, Yuma, Arizona.

Small-scale gravity irrigation was well established by the 1880's in the Salt River Valley and around Blythe and Yuma. Along the Salt and Gila Rivers, early canals often followed ancient routes used by the Anasazi. Initially, canals were small and shallow, often dug using horse-drawn plows and scrapers or shovels (Fig. 19). Construction and maintenance of these systems were labor-intensive and costly, and they rapidly filled with sediment or were destroyed by floods. Low summer flows often determined the number of crops that could be supplied by a stream or tributary. By 1902, ground water was being pumped to supplement streamflows in the Salt River Valley and develop new citrus groves near Blythe. Construction of Theodore Roosevelt and Granite Reef Diversion Dams in the early 1900's provided flood protection, but more importantly, provided reservoir storage. Spring floods could now be captured and used to augment summer irrigation needs which dramatically increased the acreage that could be cultivated.

Due to the unpredictable nature of the river, early irrigation companies along the Colorado River mainstem struggled. Arable land was available provided there was water for irrigation. The U.S. Geological Survey (USGS) examined potential dam sites and arable lands from the current site of Davis Dam downstream to Yuma. They reported the basin had a potential of 1 million acres of lands that could be irrigated (USGS, 1904).

The California Development Company began construction of the Alamo Canal in 1900. Water began to flow toward Imperial Valley and by 1904 nearly 8,000 farmers had converted 75,000 acres of desert to cropland. The desert literally bloomed as did the demand for more water. Huge mechanical dredges labored away digging new canals while sediment carried by diverted water gradually filled and choked the conveyance systems (Fig. 20). Canals were hastily dredged and new diversions inadequately protected from flooding as more and more water was diverted for irrigation.

The spring flood of 1905 was literally the straw that broke the camel's back. That spring the Colorado River channel broke through its levee and followed the path dug by the *Alpha* toward the Salton Sink. The river flowed unabated for 2 years until the levee break was filled and the river forced back into its channel (Fig. 21). The flood reestablished the Salton Sea, a body of water that is roughly 50 miles long and 20 miles wide.

Maintenance of the Alamo Canal continued to be difficult even after the levee was repaired. Mother nature continued to dictate the flow of the river. Floods continued to ravage local communities, damaging farms, homes, cropland, diversion structures, and canals. Operation and maintenance of the Alamo Canal were complicated because the river flowed through a portion of Mexico before entering Imperial Valley. However, by

Fig. 19. Early settlers using horse-drawn plows to help dig the first irrigation canals. Courtesy of the Arizona Historical Society, Tucson.

Fig. 20. Picture of the dredge *Delta* cutting a new canal. Courtesy of the Arizona Historical Society, Tucson.

1934 agricultural demand had totally dewatered the Colorado River. Demand had finally exceeded supply.

Further upstream, Hoover Dam was built to capture and store floods. Concurrently, Imperial Dam was being built to divert those waters, and the All-American Canal was being built to carry those waters to fields in Southern California (Fig. 22).

On September 30, 1935, the physical nature of the river dramatically changed with the dedication of Hoover Dam. From this point, society controlled the river downstream of Black Canyon. Hoover Dam started to backup the Colorado River, forming Lake Mead. It would take several years before the reservoir filled, but it would eventually store more than 2 years of the river's flow.

The magnitude and frequency of flooding declined; however, for decades, sediment continued to be a problem. Sediment originating in the upper basin was captured in Lake Mead. Levee construction, dredging, and dam construction caused the river to scour and carry sand and fine sediment downstream. Imperial Dam and Desilting Works intercepted and removed nearly 70,000 tons of silt daily that would have entered the All-American Canal.

World War II interrupted river development as resources and industry focused on the war effort. However, after the war, construction not only resumed but accelerated. Reclamation put three dredges to work to improve water conveyance and salvage water. In the late 1940's and 1950's, *The Colorado* channelized 30 miles of the river near Needles and then moved downstream to continue work in Cibola Valley during the 1960's (Fig. 23). The combination of dredging, levees, and natural river bed scour caused the river to straighten and become narrower and deeper. Reclamation estimated that channel dredging saved 60,000 acre-feet of water per year (Oliver, 1965) but the overall goal was to speed up water delivery between Lake Mead and the irrigation fields in Blythe, Yuma, Imperial, and Coachella Valleys. The lower river had become a water delivery canal.

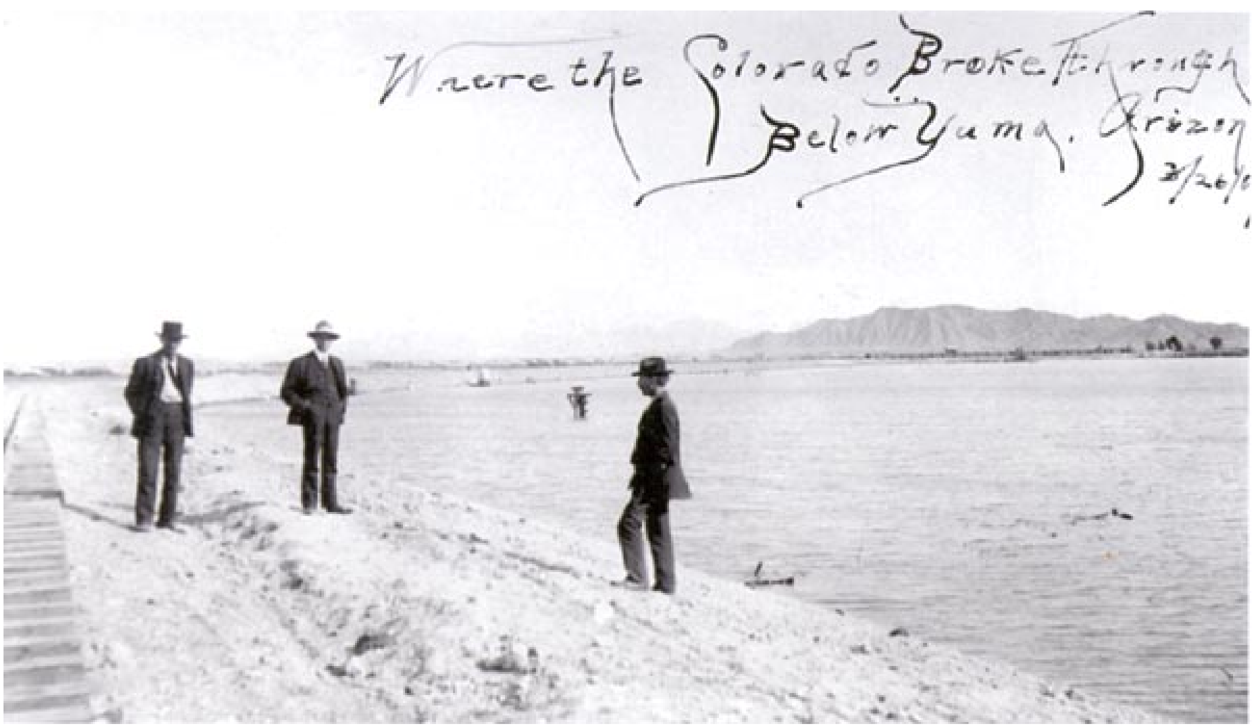

Fig. 21. The location where the Colorado River broke through its levee in 1905, AHS 62340. Courtesy of the Arizona Historical Society, Yuma.

Fig. 22. Horse and mule-drawn scrapers help dig the All-American Canal in 1935, P212-303-269A. Courtesy of the Bureau of Reclamation, Boulder City, Nevada.

Fig. 23. The dredge *Colorado* straightened 30 miles of the Colorado River near Needles, California. Here the dredge is tied at Needles in 1949, P423-3000-1808A. Courtesy of the Bureau of Reclamation, Boulder City, Nevada.

Two smaller dredges, the *Little Colorado* and *Gila*, did similar work. The *Little Colorado* dredged Topock Swamp (Marsh), a broad marshy area just east of Needles, California. The river meandered through a 4-mile-wide floodplain that had carved a series of lagoons, oxbows, and marshlands. Dredging and levees diverted the river along the western side of the valley and drained floodplains, wetlands, and lowered the water table. A large portion of Topock Swamp was dredged and enlarged through levee and headwork construction. Reclamation hydrologists estimated that dredging the marsh saved another 60,000 acre-feet of water annually. The *Gila* excavated swampy areas between Imperial and Laguna Dams. The channel "improvement" work expanded more than 240 miles of river and was accredited with saving a total 190,000 acre-feet of salvaged water per year (Oliver, 1965).

Today, dredges are being used as an environmental tool to enlarge, improve, and enhance backwater habitats along the lower river and improve access to recreational areas that have become silted in or overgrown by vegetation. Recent environmental programs include deepening waters in Mittry Lake, Beal Slough, Laughlin Lagoon, and backwaters in the Imperial Division to improve fishing. Today, dredges are building protective habitats for native fish along the lower river.

Water Law

Mark Twain once commented, "Out West, God made plenty of whiskey to drink, but only enough water to fight over." By the 1930's, demand for river water exceeded summer flows, resulting in a series of important compacts and court decisions that set water allocations and priority rights in the basin. This triggered an increased involvement by the Federal government in water projects.

The Colorado River Basin is made up of seven states. The upper basin states include Colorado, Utah, and Wyoming; the lower basin states are Arizona, California, Nevada, and New Mexico. The political boundary between the two basins is at Lee's Ferry, Arizona. Some of the more important actions are summarized below.

The Colorado River Compact – 1922

This document was signed on November 24, 1922 by the Governors of all the basin states with the exception of Arizona. It divided the basin into upper and lower basins separated at Lee's Ferry. The compact apportioned 7.5 maf to each basin with an additional 1.0 maf to the lower basin. The amount of water was determined by using hydrologic data from 1914–1923. However, these turned out to be wet years and long-term average flow was over-estimated by nearly 1 maf. The Compact recognized that Mexico might also have water rights.

Boulder Canyon Project Act – 1928

The Boulder Canyon Project Act (BCPA) authorized the construction of Hoover Dam and the All-American Canal. It also apportioned water allocated to the lower basin. California received 4.4 maf/yr, Arizona 2.8 maf/yr, and Nevada 0.3 maf/yr. Water priorities of the BCPA were: flood control, improved navigation, flow regulation, providing storage, delivery of stored water, reclamation of public lands, and hydroelectric generation.

California's Seven Party Agreement – 1931

An agreement was reached in August 1931 among the California water users in the apportionment of California's water allocation from the Colorado River. It prioritized state water rights.

Priority 1. Palo Verde Irrigation District (PVID) had irrigation rights to 104,500 acres.

Priority 2. Yuma Project, including the Reservation District, had irrigation rights to 25,000 acres.

Priority 3. Imperial Irrigation District (IID), lands served by the All-American Canal, and 16,000 acres in PVID, were provided a total of 3,850,000 acre-feet less the amount required in Priorities 1 and 2.

Priority 4. Metropolitan Water District of Southern California (MWD) and/or Los Angeles (LA) received 550,000 acre-feet

Priority 5. Another 550,000 acre-feet went to MWD and LA, and an additional 112,000 acre-feet to San Diego.

Priority 6. An additional 300,000 acre-feet of water use went to IID, Coachella Valley Water District (CVWD), and PVID.

Priority 7. All remaining water in California went toward agricultural use.

The first four priorities reached California's 4.4 maf allocation. The total of all seven priorities reached 5.36 maf, which is close to the amount of water California is currently using.

State of Arizona Contract For Delivery of Colorado River Water – 1944

This Contract obligated the Secretary of the Interior to deliver 2.8 maf/yr to Arizona. It also required Arizona to ratify the 1922 Colorado River Compact, which the legislature did on February 24, 1944.

Treaty Between the United States and Mexico – 1944

The Treaty allocated boundary waters of several rivers, including the Colorado, and expanded the responsibilities of the International Boundary Commission. Under the agreement, Mexico was entitled to 1.5 maf of water and an additional 0.2 maf in surplus years. The Treaty also required the construction of Davis Dam to regulate flows from Hoover Dam destined for Mexico.

Upper Colorado River Basin Compact – 1948

Upper basin states apportioned their 7.5 maf and created the Upper Colorado River Commission. The agreement entitled states the following amounts: Arizona 0.50 maf/yr; Colorado 3.85 maf/yr; New Mexico 0.84 maf/yr; Utah 1.71 maf/yr; and Wyoming 1.04 maf/yr.

The Colorado River Storage Project Act – 1956

This Act authorized the construction of several major storage projects in the Upper Colorado River Basin. This included the Curecanti Unit Dams on the Gunnison River, Flaming Gorge on the Green River, Navajo on the San Juan River, and Glen Canyon on the Colorado River.

The Act also authorized several land reclamation projects and established a fund generated through hydropower revenues to defray costs for operations and maintenance.

United States Supreme Court Decree in Arizona v. California – 1964

This Decree required the Secretary of the Interior to release water in accordance with the 1944 Treaty with Mexico and allocation specified in the 1922 Compact and 1928 BCPA. It also allowed use of unused water by another lower basin state. The Decree set specific water allocations for the lower basin Indian Tribes and some non-Indian Federal uses. It also set the Secretary of the Interior as water master of the Colorado River, accounting for all releases and deliveries to the lower basin and Mexico.

The Colorado River Basin Project Act – 1968

The Colorado River Basin Project Act (CRBPA) authorized the construction of the Central Arizona Project (CAP) and Navajo Generation Station in order to provide the power necessary to operate CAP. The CRBPA created a fund similar for the upper basin to pay for operational and maintenance costs. The Act also required the Secretary to develop long-term operating criteria for the Colorado River reservoir system.

Through the previously described legislation and agreements, the Colorado River was fully developed and divided. All of its waters are diverted and accounted for in a complex water storage and delivery system operated by Reclamation north of the International Border. Figure 24 summarizes where water enters the river, where it is stored, and where it leaves the basin.

Dams

Dam projects fall into three categories: (1) those belonging to the Salt River Project of central Arizona, (2) mainstem Colorado River dams, and (3) "other" smaller dams found on tributaries (Table 4). A more thorough description of these facilities is presented in Project Data: A Water Resources Technical Publication by the Water and Power Resources Service (Water and Power Resources Service, 1981).

Today, there are no less than 20 major diversion or storage reservoirs in the Lower Colorado River Basin (Fig. 25). Starting with the construction of Granite Reef Diversion Dam in 1908, five major water control structures were built on the Salt and Verde Rivers in central Arizona. Two others were built on the Gila River. Laguna Dam, built in 1909 on the lower Colorado River mainstem, sparked the construction of seven major structures on the Colorado River. Additional dams can be found on the Bill Williams, Las Vegas Wash, and Quail Creek, a major tributary of the Virgin River.

Salt and Verde River Dams

Granite Reef Diversion Dam

Granite Reef Diversion Dam and Theodore Roosevelt Dam were the first two features of the Salt River Project. The project was authorized by Congress in 1903 and water was delivered in 1907. Granite Reef is located about 20 miles east of Phoenix and 4 miles downstream of the confluence of the Verde and Salt Rivers. Construction started in 1906 and all construction features were completed in 1908. Its hydraulic height is 18 feet and the total crest length is 1,128 feet.

Theodore Roosevelt Dam

Located 75 miles northeast of Phoenix, Theodore Roosevelt (Roosevelt) Dam was the first major storage reservoir built in Arizona. Construction started in 1903 and was completed in 1911 (Fig. 26). The dam is a natural arched stone block dam that is 280 feet tall and 723 feet along its crest. Its hydroelectric facilities have been updated several times, and the dam height was increased by 77 feet in 1995. Roosevelt Lake initially had a maximum surface area of 17,315 acres. Its storage capacity of 1.3 maf was increased by a little more than 300,000 acre-feet by the 1995 construction.

Horse Mesa Dam

Located 65 miles northeast of Phoenix and just downstream of Theodore Roosevelt Dam, Horse Mesa Dam was constructed on the Salt River between 1924 and 1927. The dam is a thin-arch concrete structure which is 305 feet tall. It impounds Apache Lake and holds slightly less than 250,000 acre-feet of water. Two smaller dams are located downstream.

Mormon Flat Dam

Mormon Flat Dam is located approximately 6 miles downstream of Horse Mesa Dam. The structure is another thin-arch concrete dam that is roughly 220 feet tall. Constructed between 1923 and 1926, it impounds Canyon Lake and holds slightly more than 57,000 acre-feet of water.

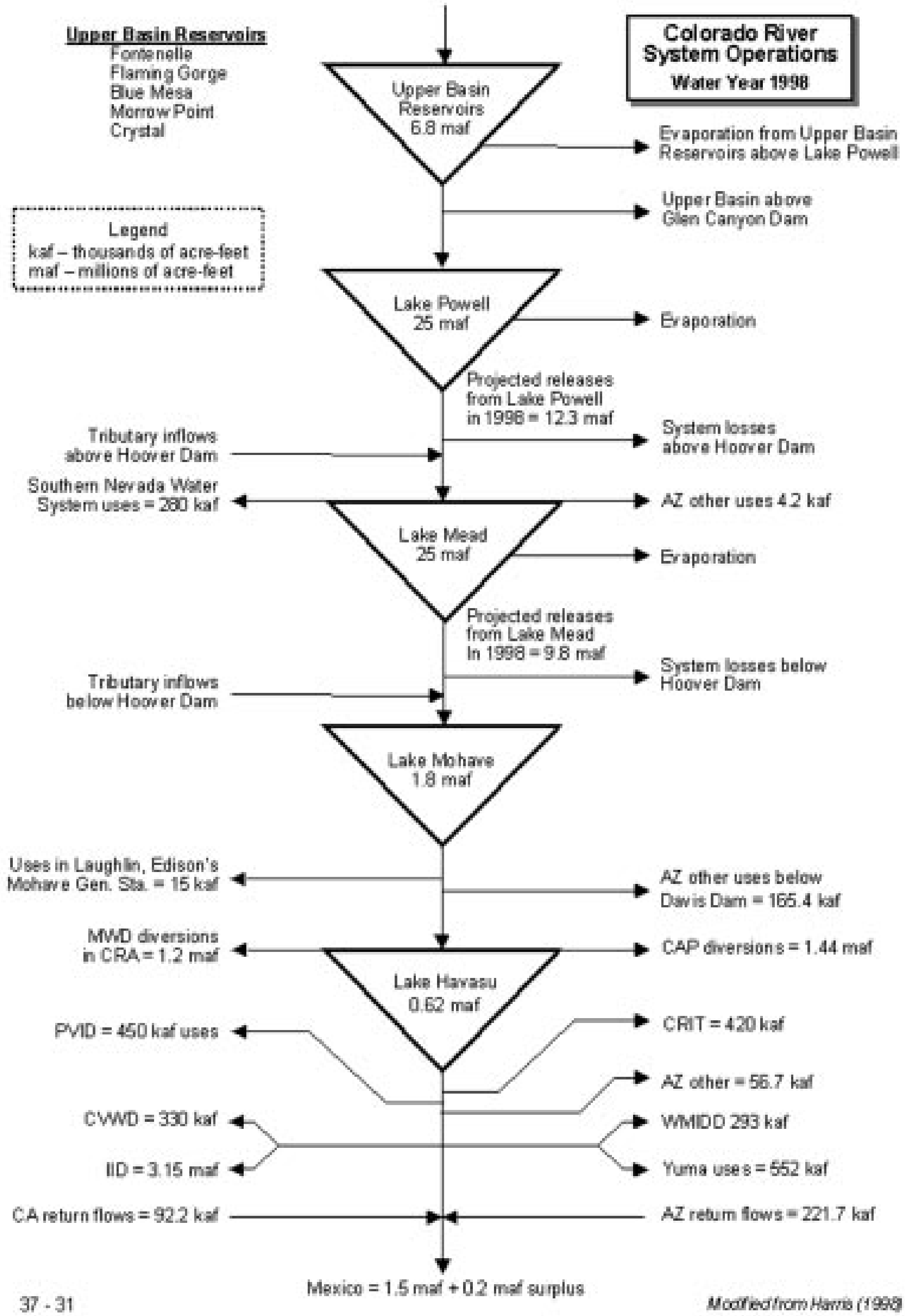

Fig. 24. A diagram of the source and fate of the Colorado River (Harris, 1998).

Table 4. Dams built in the Lower Colorado River Basin.

Site	Year completed	River
Salt and Verde River Dams		
Granite Reef Diversion	1908	Salt
Theodore Roosevelt	1911	Salt
Mormon Flat	1926	Salt
Horse Mesa	1927	Salt
Stewart Mountain	1930	Salt
Barlett	1939	Verde
Horseshoe	1946	Verde
Colorado River Dams		
Laguna	1909	Colorado
Hoover (Boulder)	1936	Colorado
Imperial	1938	Colorado
Parker	1938	Colorado
Headgate Rock Diversion	1944	Colorado
Morales (Mexico)	1950	Colorado
Davis	1953	Colorado
Palo Verde Diversion	1957	Colorado
Tributary Dams		
Coolidge	1928	Gila
Carl Pleasant (New Waddell)	1928	Agua Fria
Painted Rock	1960	Gila
Senator Wash	1966	Colorado/offsite
Alamo	1968	Bill Williams
Quail Creek	1985	Quail Creek (Virgin)
Henderson (Lake of Las Vegas)	1992	Las Vegas Wash/offsite

Stewart Mountain Dam

Stewart Mountain Dam is the last of the four-dam series on the Salt River. The dam shares similar construction features as Horse Mesa and Mormon Flats Dams. It is 207 feet tall and was built between 1928 and 1930. It impounds Saguaro Lake, which has 69,000 acre-feet of storage.

Lower Colorado River Dams

Laguna Dam

Laguna Dam has the distinction of being the first permanent dam built by Reclamation. In 1903, the newly formed Reclamation Service set up offices in the Fort Yuma Military Reservation in Arizona. The Yuma Project (1904) authorized construction of Laguna Dam, a concrete surfaced rock-filled weir to divert water to the Yuma Main Canal. Construction began in 1904 and was completed in 1909 (Fig. 27). The dam is 3.5 miles long and has a hydraulic height of only 10 feet. The dam became the first of many formidable barriers for both boats and fish. The diversion provided irrigation water for roughly 58,000 acres of farmland. In 1941, a turnout of the All-American Canal was built to divert water to the Yuma Main Canal. Imperial Dam gradually replaced the need for diversions at Laguna Dam, and in 1948 the headworks were sealed and the facility retired from service.

Hoover Dam

The Boulder Canyon Project was authorized by Congress on December 28, 1928. Construction started in 1931 and was finished in less than 5 years (Fig. 28). The dam, initially called Boulder Dam and renamed Hoover Dam, became both the highest and largest concrete dam in the world. Today, it remains the highest but now is the third largest concrete dam in this country. The structure was dedicated by President Franklin Roosevelt on September 30, 1935. Generators were added to the powerhouse to meet power demands. The first generator went online in 1936 and the last one was installed in 1961. The powerplant can produce more than 1.3 million kilowatts of power.

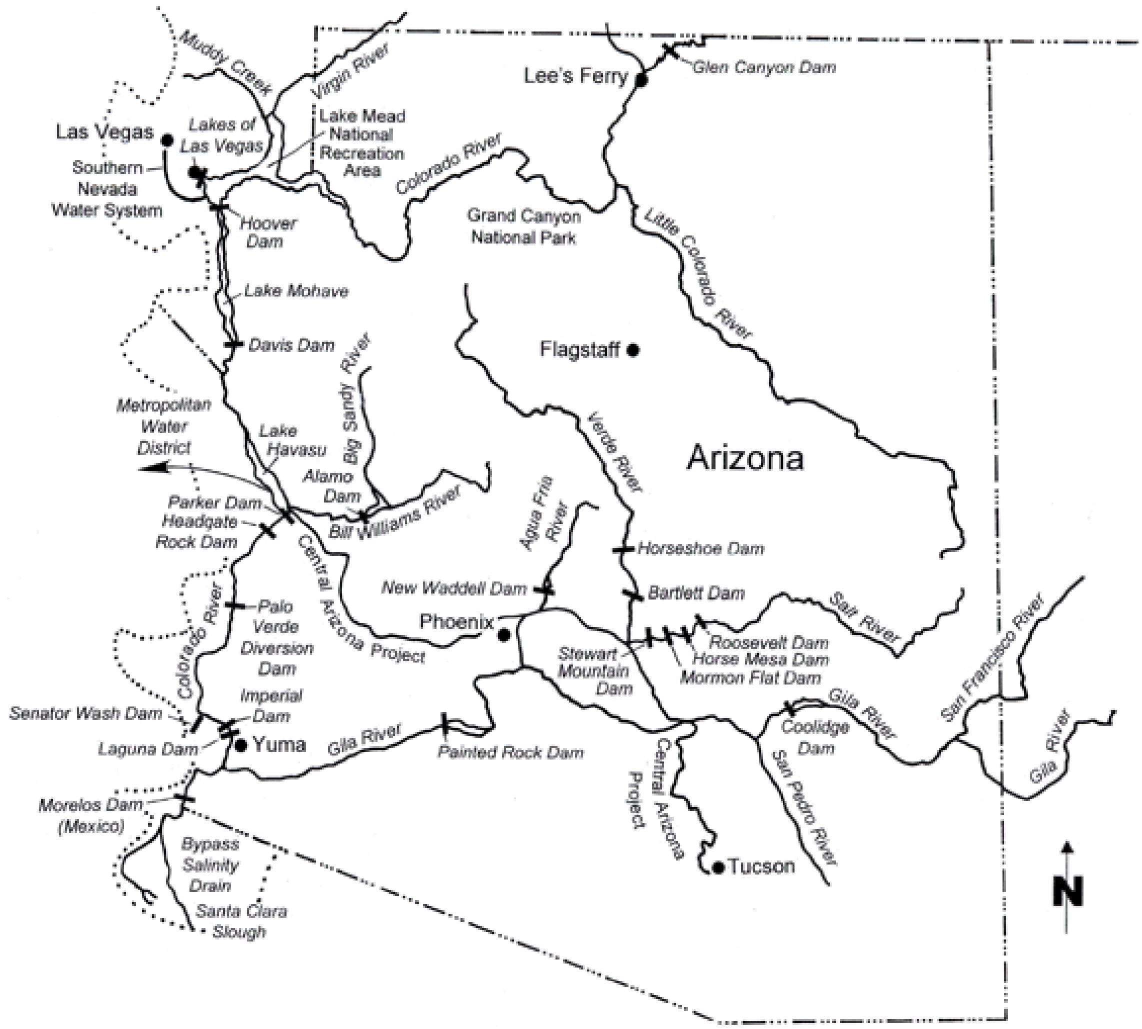

Fig. 25. Location of major dams in the Lower Colorado River Basin.

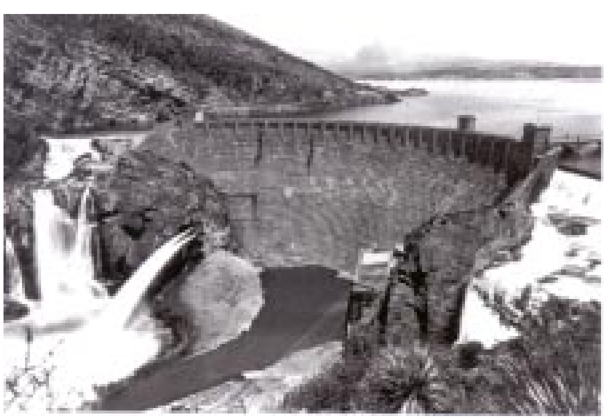

Fig. 26. Theodore Roosevelt Dam, P0025-330-011951. Courtesy of the Bureau of Reclamation, Boulder City, Nevada.

Fig. 27. Laguna Dam was built in 1909 and was the first man-made structure to span the Colorado River, P45-300-4374. Courtesy of the Bureau of Reclamation, Boulder City, Nevada.

Fig. 28. Photograph of Boulder Dam, 5119A. Courtesy of the Bureau of Reclamation, Boulder City, Nevada.

Hoover Dam impounds Lake Mead, which extends 115 miles upstream into the Grand Canyon. It has 550 miles of shoreline and is a maximum width of 8 miles. The reservoir is the largest by volume in North America and is capable of holding nearly 28 maf of water. The lake's surface area is roughly 162,700 acres with a maximum depth of 550 feet.

Parker Dam

Parker Dam is located 15 miles upstream of Parker, Arizona, and forms Lake Havasu. The Municipal Water District (MWD) of southern California advanced funding to the Federal government for construction of Parker Dam. Excavation began in 1934, and construction was finished in 1938 (Fig. 29). The powerhouse was completed in 1942. The concrete arched dam is roughly 860 feet in length and one of the deepest based dams built. It has a hydraulic height of only 75 feet, but the structure is 320 feet tall.

Lake Havasu backs up roughly 35 miles into the Topock Gorge. The reservoir has a maximum capacity of 648,000 acre-feet and a surface area of 20,400 acres. Maximum depth is 70 feet. The reservoir serves as a diversion basin where water is pumped from MWD facilities for southern California and from the Lake Havasu Pumping Plant for the Central Arizona Project. These two pumping facilities remove approximately 2.6 maf or more than a third of the rivers' average flow.

Imperial Dam

Imperial Dam and Desilting Works are located 18 miles upstream of Yuma, Arizona. The project was authorized by Congress in 1928 as part of the Boulder Canyon Project. Construction started in 1936 and was completed in 1938 (Fig. 30). Imperial Dam is short, having a hydraulic height of only 23 feet, but the structure is 3,475 feet in length. It provides the head needed to divert water to the All-American Canal located in California.

The Desilting Works consist of three basins laid off at a 60° angle from the intake channel. The basins are divided in half and measure approximately 270 x 780 feet each. Water velocity slows to less than 0.25 feet per second, thus allowing silt to settle. A series of rotating scrapers pushes the sediment into a sludge collection system that flushes sediment out of collection pipes. The system is designed to remove 70,000 tons of sediment per day.

Construction of the All-American Canal began in 1934. It started delivering water to the Imperial Valley in 1940. The delivery system was expanded with the construction of the Coachella Canal. The Coachella Valley branches

Fig. 29. Parker Dam. Courtesy of the Bureau of Reclamation, Boulder City, Nevada.

Fig. 30. Imperial Dam, P212-3000-3890-1A. Courtesy of the Bureau of Reclamation, Boulder City, Nevada.

off the All-American Canal to deliver water to the northwestern shore of the Salton Sea. Construction of the Coachella Canal started in 1936 but was interrupted by World War II. The distribution system was completed in 1954.

Headgate Rock Dam

The low-head concrete diversion dam was built in 1942 just upstream of Parker, Arizona. The structure stabilized the river channel and provided water to the Colorado River Indian Tribes. A low-head hydroelectric powerplant was added in the late 1980's.

Morales Dam

This dam is the last diversion structure on the Colorado River and was built in 1950 (Fig. 31). Located roughly 20 miles downstream of Laguna Dam, this dam diverts Mexico's 1.5 maf allocation to the Alamo Canal, which distributes irrigation water to more than 600,000 acres of farmland in Mexicali Valley.

Davis Dam

Davis Dam is located 2 miles upstream of Laughlin, Nevada. The Mexican Treaty of 1944 required the United States to construct Davis Dam for the purpose of regulating water destined for Mexico. Construction began in 1942 but was halted due to World War II. Work resumed in 1946 and the dam was completed in 1950 (Fig. 32). Work continued on the powerhouse, which was finished in 1953. The zoned earthfilled dam has a hydraulic height of 140 feet and a length of 1,600 feet.

Fig. 31. Morales Dam diverts the remaining waters of the Colorado River to Mexicali Valley (1973). Courtesy of the Bureau of Reclamation, Boulder City, Nevada.

Fig. 32. Davis Dam. Courtesy of the Bureau of Reclamation, Boulder City, Nevada.

Lake Mohave backs up 64 miles to the tailrace of Hoover Dam. Reservoir storage is roughly 1.8 maf. The reservoir has a surface area of 28,500 acres at full pool. Maximum depth is 120 feet.

Palo Verde Dam

When Hoover Dam was closed, the river channel downstream continued to scour and in some locations the streambed dropped nearly 8 feet. As the river entrenched, it reduced the volume of water that could be diverted by gravity. The cost of pumping water would have been prohibitive and threatened irrigation. This problem began in 1942 and by 1944 crops were threatened by the lack of adequate water. A temporary rock weir was built by Reclamation in 1944–1945. Congress authorized the construction of a permanent structure in 1954. Construction began in 1956 and the project was finished the following year. The dam has a hydraulic height of 46 feet and a total length of 1,300 feet. The concrete, ogee gated weir with embankment wings started to divert water to the Palo Verde Irrigation District's canal system in 1957.

"Other" Tributary Dams

There are several other tributary dams in the lower basin. In Arizona, Coolidge and Painted Rocks Dams are located on the Gila River, while Alamo Dam is found on the Bill Williams River. Quail Creek Dam is on a large tributary of the Virgin River in Utah and Senator Wash Reservoir is an offsite reservoir in California found just upstream of Imperial Dam. The newest reservoir is the Lake of Las Vegas, which is located on Las Vegas Wash, Nevada, just upstream from Lake Mead.

The Lower River Today

The Colorado River has been dramatically altered, both physically and biologically. Man has dried hundreds of miles of stream while permanently flooding other portions of the basin. Historically, water has been a scarce commodity in the basin; however, storage capacity upstream of Hoover Dam exceeds 66 maf, or roughly five-and-a-half times the annual flow of the river. Storage reservoirs flood more than 675 mi^2 of the floodplain.

There are 20 major dams found in the lower basin alone. Lakes Mead, Mohave, and Havasu flood more than 210,000 acres, or 328 mi^2. Reservoirs extend to more than 250 miles of the river corridor, or nearly half the river channel between the International Border and Grand Canyon. Broad valleys that experienced drought are now permanently flooded with water, awaiting delivery to the metropolitan and agricultural centers of southern California, southern Nevada, and central Arizona.

In contrast, hundreds of miles of stream channel have been dewatered by upstream reservoirs. Remaining portions of the river are no longer broad, shallow, or turbid. They have been straightened, dredged and squeezed by levees to a point where they more closely resemble canals than natural streams (Fig. 33). Today, the river serves man in a diminished capacity by delivering water to downstream water users. More than a third of the river's water is pumped from Lake Havasu and flows toward Phoenix, Tucson, or flows out of the basin to southern California.

Channelization brought along by levee construction, dredging, and natural processes has degraded, or deepened, the river channel as much as 8 to 10 feet. As a result, the river has become isolated from its historic floodplain. Channel degradation has also lowered adjacent ground water tables that drained floodplain and old oxbow habitats. Floodplain terraces have become dry and less susceptible to flooding, accelerating agricultural development. The historic role of floodplain habitats for native fish has disappeared. Resource managers have attempted to save some of these unique wetlands through the National Refuge System. Unfortunately, levees, water control structures, and periodic dredging are necessary to maintain these wetlands. Refuge waters provide a haven for waterfowl and game fish but they no longer function as floodplain habitats essential for native fishes.

Habitat loss has been most severe south of the International Border where oxbows, sloughs, and wetlands have disappeared. What remains of the Colorado River is diverted to crops in Mexicali Valley by Morales Dam and the Alamo Canal. Today, nearly 60 miles of the river channel downstream of the dam is usually dry. Brackish agricultural drainage from Mexicali Valley reenters the system at the Rio Hardy, but the delta's estuary only receives fresh nutrient-rich, river water during major floods when flows "escape" capture.

The Salt and Gila Rivers have shared the same fate. Storage reservoirs upstream of Phoenix have intercepted the river's flow. Municipal growth in and around Phoenix has replaced agriculture as the primary water user. Coolidge and Painted Rock Dams capture what remains in the Gila. With the exception of seepage, both rivers are generally dry downstream of Phoenix to such an extent that these reaches are no longer shown on some maps. The overall result is the Colorado River has only flowed into the Gulf of California during five flood events in the past 30 years.

Water Management

The Colorado River has become the most regulated river in the world supplying the needs of 30 million people in the United States and Mexico. The river is over-allocated, meaning there is more demand than supply. The Colorado River once flowed unobstructed, gathering in volume as it flowed to the Gulf of California. Today, its volume actually dwindles as it flows south. Main stream water diversions begin at Lake Mead and continue until the last drop of water is removed from its channel at Morales Dam. Water right holders and their lawyers ponder methods of stretching their allocations. Reclamation, as water master, has the difficult job of accommodating the needs of all the special interest groups wanting a share of this limited resource.

Water rights are based on consumptive use, or the water that is actually used (lost). Water users are credited for water returned to the river, primarily in the form of agricultural drainage or treated sewage. It is said that every drop of water used along the river will be reused at least three more times. Water managers carefully regulate reservoir storage to optimize water use and insure no excess river water is wasted to the sea. In reality, the river is operated as a complex "plumbing" system that captures and stores water and distributes it to destinations in or outside the basin (Fig. 34). Water is diverted through thousands of miles of canals and pipelines to customers. The goal of "reclamation" of the desert is complete.

Conditions on the Lower Colorado River Today

River conditions have dramatically changed since Lieutenant Ives' steam up the Colorado River in 1858. His journey began where the Colorado River was the largest, at the Gulf of California and progressed upstream to the current location of Lake Mead where the river became too difficult and shallow to navigate.

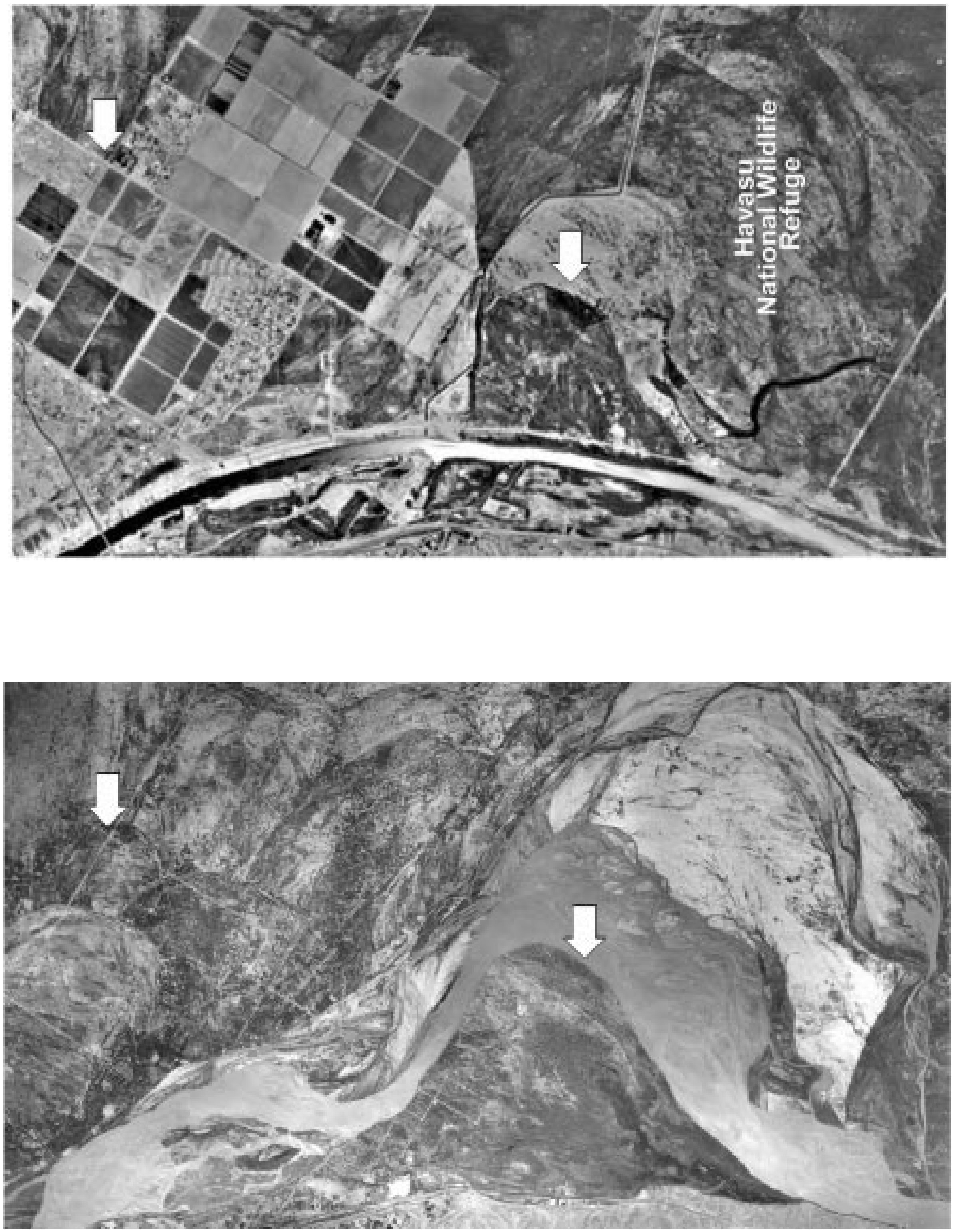

Fig. 33. Aerial photographs of the Colorado River channel just downstream of Needles, California taken in 1938 and 2000. 1938 photograph courtesy of the Bureau of Reclamation, Boulder City, Nevada.

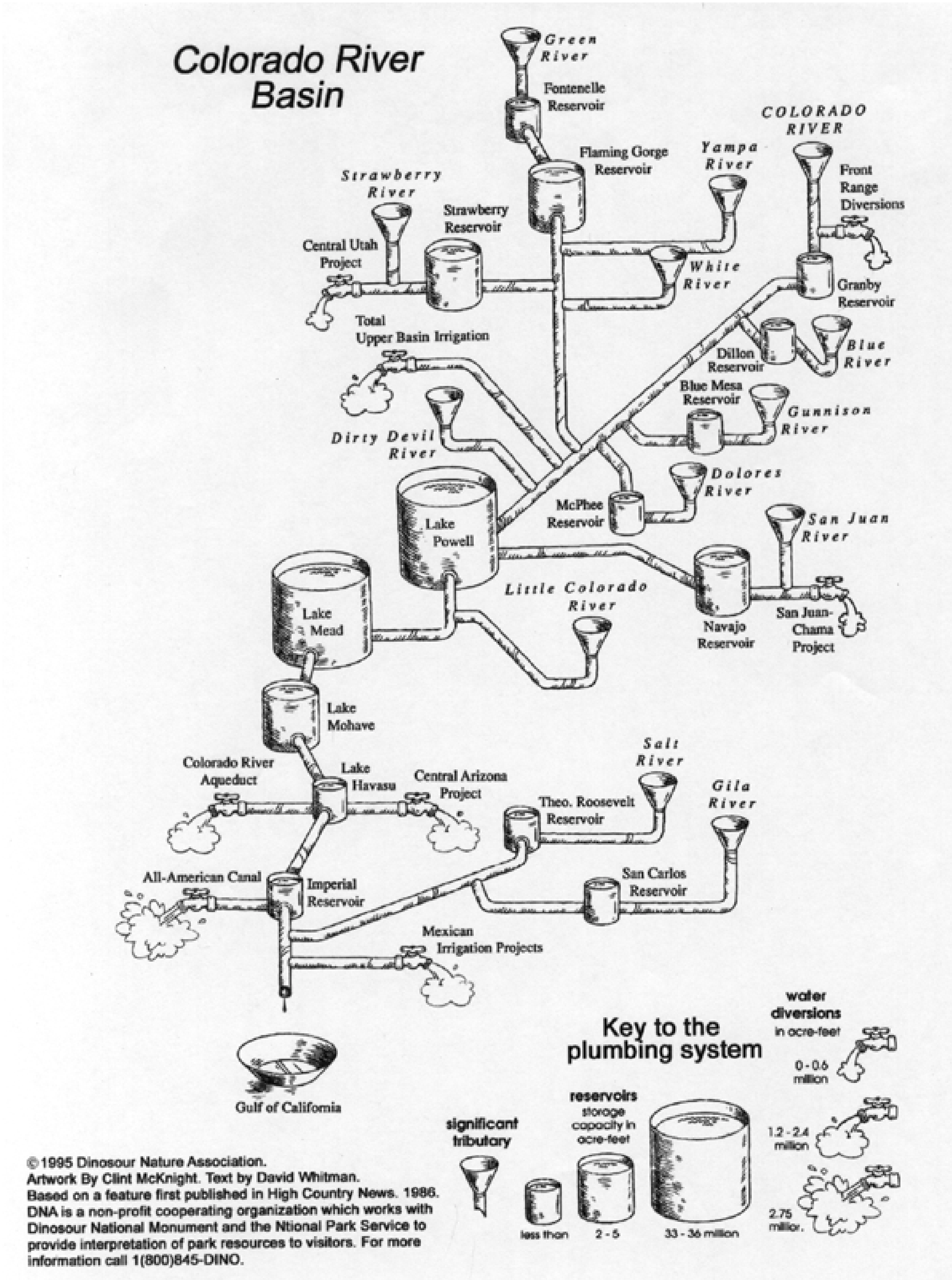

Fig. 34. The Colorado River of today is often viewed as a series of "Buckets, pipes, and faucets." Courtesy of the Dinosaur Nature Association, Vernal, Utah, and High Country News.

Today, that boat trip would have to begin at Lake Mead, where the river's flow is the greatest and proceed downstream where water diversions continuously shrink the river to a point where flow completely disappears.

Traveling Downstream from the Grand Canyon by Boat

Our boat journey would start in the lower end of the Grand Canyon. The Colorado River is still an impressive river to anyone privileged to float through the Grand Canyon. Here, evidence of man's impact is often lost to the casual observer. The river is only slightly turbid, but occasional summer storms flood side canyons and "muddy" the water. The large amounts of sediment that once flowed through the canyon are now deposited in the headwaters of Lake Powell and other upstream dams. In Lake Powell, large amounts of sediment have already filled portions of the reservoir, piling up more than 50 feet deep and growing at the inflow areas.

The Grand Canyon no longer experiences the cascading roar of unabated spring runoffs or the droughts that come with late summer. Flows are meticulously managed by Reclamation at Glen Canyon Dam to meet operational criteria that consider available flood storage, needs of river runners, a blue ribbon trout fishery, hydroelectric demands, and downstream water rights. Mother nature no longer dictates the seasonal rhythm of the river, man does.

At full pool, Lake Mead backs up into the mouth of Grand Canyon, where the river is slowed by the influence of the lake (Fig. 35). The lake extends over 100 km upstream of Hoover Dam where we no longer rely on the current to propel us downstream. River waters undergo a dramatic physical and chemical change as they journey through Lake Mead. Flow is slowed to mere inches per day, which allows suspended sediments to settle out. Waters become crystal clear and by the time they reach the center of Lake Mead, one can easily see 40 feet into the water.

Reservoir waters become thermally and chemically stratified most of the year. Summer heat warms the lake's surface where evaporation can exceed 7 feet of water per year. Evaporation concentrates salts left behind. Cold dense water sinks to the reservoir's bottom, which can exceed a depth of 450 feet near the dam while warmer and less dense waters remain near the surface. Water temperatures during the summer can range from 90° F on the surface to 48° F near the reservoir's bottom. The water temperature and density gradient (stratification) that develop results in separate layers of water column that do not mix.

LaBounty and Horn (1997) report that on rare occasions, the river can actually flow between these stratified layers to Hoover Dam. Likewise, it is possible for pollutants and treated sewage effluent to concentrate at various depths and pose potential problems for municipal water uses. If water temperature cools enough and equalizes during the winter, the entire water column can freely mix in a process called "reservoir turn over." This occurs once every few years and reduces pollution by simple dilution. Unfortunately this does not occur every year.

Reservoirs are typically more productive than rivers. Nutrients brought in by the river or sewage treatment plants mix with surface waters where the sun's warmth stimulates algal growth. Surface waters become rich with phyto- and zooplankton, which thrive in calm, warm water. Plankton in turn provide the basic food used by young fish but it can also cause water quality problems.

Both the Virgin River and Las Vegas Wash now produce more flow during the summer due to wastewater discharges. The lower Virgin River historically dried up during the summer. Today, water treatment in the Saint George, Utah, and Mesquite, Nevada areas augments summer flow. A similar condition exists in Las Vegas Wash where Las Vegas treated effluent pours into Lake Mead at a rate of more than 1,500 gallons per second. Today, Las Vegas Wash is the largest (sustained flow) tributary downstream of the Grand Canyon.

At the south end of Boulder Basin, we finally reach Hoover Dam, our first navigational barrier. Here, we have to portage around the dam.

Continuing Downstream of Hoover Dam

Water released at Hoover Dam has been totally transformed. The once turbid, high desert river now resembles a clear, cold, and slightly more saline mountain stream. Waters leaving Lake Mead discharge into Lake Mohave, which backs up to the base of Hoover Dam. The silt, mud, and sand that historically flowed through Black Canyon are now trapped in Lake Mead and Lake Powell. Fine materials were washed downstream a long time ago, causing a process known as armoring. Water releases from the dams have cut a deep channel lined with large rock. Lieutenant Ives would have marveled at the water's clarity and the ease in which we now navigate down Black Canyon.

The loss of scouring sand, crystal clear water, and rock substrate provides ideal conditions for the growth of *Cladophora*. This filamentous green algae forms dense mats of underwater vegetation that cover sections of the river's bottom. Aquatic vegetation is rich with amphipods, aquatic insects, and other fish foods. Today, the river supports a nonnative trout fishery that a century ago could have only been found high in the mountains.

River current can be detected on the surface 12 to 20 miles downstream, depending on the rate of discharge

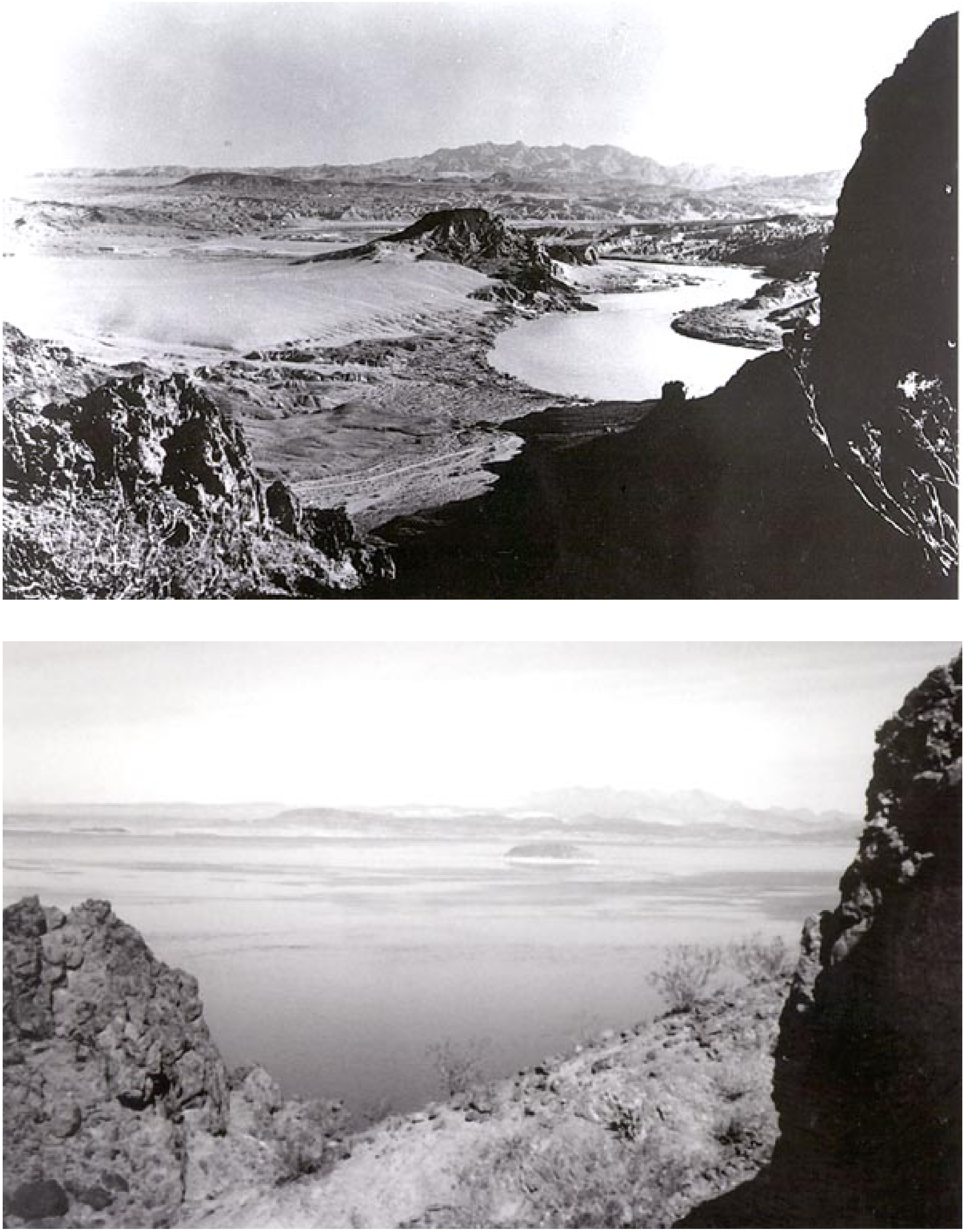

Fig. 35. Comparative photographs of the Colorado River just upstream of Boulder Canyon prior to, and after being inundated by Lake Mead (1926 and 2001). 1926 photograph courtesy of the Bureau of Reclamation, Boulder City, Nevada.

and lake elevation. Cold releases are typically denser than reservoir surface waters which cause the river to dive, or flow along the bottom of the reservoir near Eldorado Canyon. This canyon was the site of a popular gold mine and steamboat landing called Nelson's Landing. Before the turn of the twentieth century, Eldorado represented the largest population center in southern Nevada.

The river continues its journey through Lake Mohave toward Davis Dam. Forty-two miles downstream from Hoover Dam, it passes Cottonwood Marina, named for the large cottonwood galleries that once bordered the river. Approximately 10 miles further, it flows over Pyramid Canyon which historically contained a series of large river rapids which seriously challenged upstream navigation. The natural roar of the river has been replaced by the hum of generators at Davis Dam.

Water exiting the turbines at Davis Dam once again flows unobstructed past the glimmering casino lights and slot machines of Laughlin, Nevada, and Bullhead City, Arizona. The old riverboat landing and river crossing of Hardyville are long forgotten except at the Mohave County Museum. Today, tourists drive down Highway 68 which follows the old Beal Trail and cross the river by bridge or by one of the many casino tour boats.

As we float past Bullhead City, Arizona, the levee becomes crowded with expensive vacation homes that form a maze of concrete walls, piling, supporting steel, porches, and docks. Past town, we reach the Mojave Tribes land where Fort Mohave once proudly stood overlooking the river. Today, only the concrete foundation remains. Here the river channel has degraded 8 to 10 feet. Our exit from Nevada and entry into California is marked by two landmarks: one historic, the other new. Boundary Cone is a prominent column of rock set against the Black Mountains in Arizona. The landscape has not changed much since Möllhausen painted it 144 years ago. More obvious is the Avi Casino, a Fort Mojave Indian business which sits on the river bank near the Nevada and California border.

Land along the river is relatively undeveloped where it flows through the reservation except for the California bank which has a high armored levee. The cottonwoods and willows have been replaced by rip-rap (rock) and brushy salt cedar. Historically, the active river channel was nearly 2 miles wide but today the river seldom exceeds 150 yards. At quarter-mile intervals, irrigation pumps sit on high platforms along the shore. During spring and summer these pumps suck water from the river to irrigate thousands of acres of farmland.

Recreational homes and levees border both banks of the river as we pass the Reservation and approach Needles, California. Several new river homes are under construction and "For Sale" signs can be seen in front of the lots. Within a couple of miles we are again surrounded by farmland. Along the eastern shore we enter the Havasu National Wildlife Refuge. This is the huge Topock Swamp complex. Today the Fish and Wildlife Service (FWS) manages a large wetland complex that is artificially maintained through a system of levees and water control structures. The active river channel once was nearly 2 miles wide, meandering across the broad floodplain covered by side channels, sloughs, and old oxbows. Dredging during the 1950's and 1960's lowered the water table and drained much of the marsh and old oxbow lakes.

Looking at the river today, it is difficult to imagine the Colorado River being nearly 2 miles wide (Fig. 36). The wide expanses of flat, dry floodplain and irrigated farmland is a testament to the effects of human intervention. At one time steamboats ran along the Arizona shoreline to deliver freight to the mining camps around Oatman, Arizona. The old riverboat landing was nearly 4 miles east of the current river channel where 150-foot steamboats delivered thousands of tons of freight and transported ore to stamp mills. The last remnants of the wooden landing were destroyed a few years ago by a brush fire.

Once again the valley narrows, being confined by the Whale and Needle Mountains. The settlement of

Fig. 36. Comparative photographs (1908 and 2001) taken of the Colorado River at Needles, California. 1908 photograph courtesy of the Mohave County Historical Society.

Mellen, located on the Arizona shore has long since disappeared and been replaced by Interstate 40 and the Burlington Northwestern and Santa Fe railroad bridges. We quickly enter Mohave Canyon and Topock Gorge, a narrow and spectacular canyon. This area is still within the refuge and represents the most pristine and undeveloped portion of the river downstream of Davis Dam. All that is missing from Möllhausen's sketches are sandbars, snags, and trees. Within a few miles we exit the gorge and enter upper Lake Havasu. Scour from the river above had created a broad-sandy delta that is covered by lush expanses of cattails. Parker Dam backs up water nearly 30 miles to create Lake Havasu, the last major storage reservoir on the lower river. The reservoir is nearly 2.5 miles wide and shallow compared to Lake Mead.

Lake Havasu City is a popular recreation spot. The town sprawls along the lake's eastern shoreline. Here you can float under the famous "London Bridge" that spans from the city to Pittsburg Point, an island.

Lake Havasu is actually a depot for water destined for municipal centers in central Arizona and southern California. More than a third of the river is pumped from the reservoir by Arizona and California. Rows of large pipes heading over the mountains are clearly visible on the western shore where the MWD pumps water toward Los Angeles (Fig. 37). Water is lifted to Gene Wash and Copper Basin reservoirs in the Whipple Mountains before flowing west. Further downstream, between the confluence of the Bill Williams River and Parker Dam, is the Lake Havasu Pumping Plant (Fig. 38). This is the start of the Central Arizona Project (CAP) which pumps water over the Buckskin Mountains toward Phoenix and Tucson. Water flows from both facilities through thousands of miles of concrete aqueducts and distribution systems. This water is totally lost, none returns to the river.

Fig. 37. Metropolitan Water District's pumping plant on Lake Havasu.

Fig. 38. Colorado River water is lifted nearly 800 feet by the Lake Havasu Pumping Plant located on Lake Havasu near the confluence of the Bill Williams River.

Entering the Colorado Valley

Water leaving Parker Dam enters a region known as the "Parker Strip," one of the most intensely used recreational areas along the lower river. It is also the beginning of the broad Colorado Valley, which extends nearly 100 miles to Yuma. While the channel is largely constrained, this portion of the river corridor often reaches 10 miles in width and expands southward. The valley supports one of the most heavily farmed areas in the country. It is not uncommon for alfalfa farmers to harvest six to eight crops of hay per year.

About 14 miles downstream, water is diverted at Headgate Rock Dam to fields in the Colorado River Indian Tribal holdings in Arizona. Forty-four miles further downstream, water is diverted to croplands on the western bank at Palo Verde Diversion Dam. The Palo Verde Irrigation District holds the oldest, or "grandfather" water rights to the river.

The dense willow, cottonwood, and mesquite forests in this portion of the river are gone. Trees not cut for firewood, timber, or cleared for agriculture have either died because of rising waters from Laguna, Imperial, and other dams; from declining water tables caused by channelization; or from displacement through a process of fire and colonization by salt cedar. The floods that were critical for willow and cottonwood tree generation are gone. Today, river vegetation is primarily salt cedar and arrowweed.

The ground is often crusted with salt in poorly drained areas. Waters not evaporated or used for irrigation leach through the soils and carry salts and agricultural chemicals back to the river. Areas not adequately drained accumulate salts. This process increases salinity levels and water quality problems.

Floating 8 miles downstream of Palo Verde Dam we near the Interstate 10 bridge where on the eastern shore we pass the old riverboat town of Ehrenberg. Once again river front houses and recreational camps line both banks of the river as we enter Blythe, California. Downstream of town we reenter farmland. Remnants of the serpentine channel can still be seen from the air circling around Cibola National Wildlife Refuge. The floods that spilled across the valley and scoured oxbows have been gone for more than 60 years. Davis, Three Fingers, Cibola, Draper, Adobe, Ferguson, and Martinez Lakes are reminders of the course and power of the river. These lakes and marshes are gradually filling, a process that is temporarily slowed by dredging. Several old oxbows have been mechanically deepened and enlarged to improve recreational fishing.

We float on downstream through Cibola National Wildlife Refuge and enter Imperial Wildlife Refuge where we experience the influence of Imperial Dam. The majority of water remaining in the river is diverted at Imperial Dam destined for Imperial, Coachella, and Yuma Valleys. Roughly 500 cfs pass by Imperial Dam and flow through Yuma, resembling little more than a small creek (Fig. 39). This water is diverted at Morales Dam where the last of the river disappears toward cropland in Mexicali Valley.

The huge spring floods that at one time averaged more than 78,000 cfs are now captured by upstream reservoirs. Today, flows exceeding 2,000 cfs seldom pass Yuma and the river averages only a few hundred cfs, roughly one-tenth of the historic flow (Fig. 40). It is difficult to imagine the Spanish sailing upriver or that Yuma was once an important river port.

Our boat journey would end at Morales Dam as it did for Colin Fletcher. Mr. Fletcher attempted to float the Colorado River from its headwaters to the Gulf of California in 1987. After reaching Morales Dam he had his raft trucked to the Rio Hardy while he hiked the 56 miles of dry river channel to rejoin his raft. He resumed his float down the small stream, which consists of agricultural drainage. The remainder of his trip was reduced to pulling his raft through the shallows of the Rio Hardy where Lieutenant Hardy had sailed in 1826.

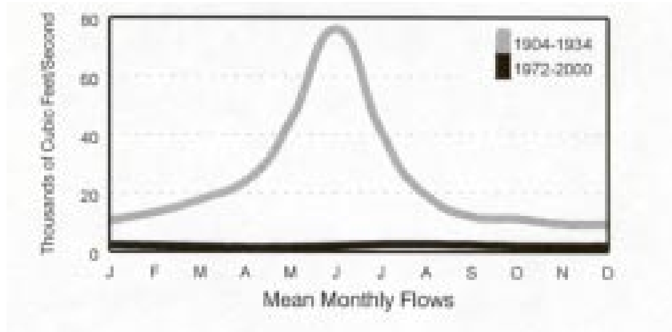

Fig. 40. Comparison of average monthly flows of the Colorado River at Yuma, Arizona prior to 1904–1934 construction of Boulder Dam and current river flows (1972–2000).

The broad expanses of cottonwood and willow forests or the "green lagoons" described by Leopold (1949) have long since been lost and replaced by cropland or claimed by the desert. The vast maze of braided river channel, cottonwood, willow and mesquite forests, old oxbows, and cattail-margined sloughs that dominated the landscape are gone. Today, only 150,000 of an estimated 1,930,000 acres of wetlands remain (7.7%) (sources: Environmental Defense Fund web site; Colorado River Water Users Association).

Just recently Reclamation and Colorado River Water Users proposed a method to prevent all "spills" to the ocean. This would change the allocation of surplus water and allow off-stream banking that would further reduce, if not totally eliminate, flood waters from ever reaching the delta. The objective of today's water management policy is to prevent any usable water from escaping to the Gulf of California.

Fig. 39. Comparative (1877 and 2001) photographs of Fort Yuma taken from the Arizona shoreline looking west (note Fort Yuma located on the top of the hill). 1877 photograph courtesy of the Arizona Historical Society, Yuma.

Tributaries

Similar changes have occurred to tributary streams. Historically, surface flow often became intermittent or totally dried up in the stream's lower reaches. Today, that condition has not only intensified but has become permanent. Upstream water storage on the Bill Williams and Gila Rivers has dried up the lower portions of these streams. On the Salt and Gila Rivers, Roosevelt, Horse Mesa, Mormon Flat, Stewart Mountain, Bartlett, Horseshoe, and Coolidge Dams capture water that historically flowed to the Colorado River and delta. The river channel through the "Valley of the Sun" is normally dry except for a few deep ponds left behind from sand and gravel mining and an incongruous, 2-mile-long artificial lake. The river corridor is leveed and highly disturbed, forming little more than a scar across the valley and state (Figs. 41 and 42). Recent maps seldom show sections of these streams, testifying to their conspicuous absence.

Fish

Fish found in the lower Colorado River were unique, having the highest proportion (75%) of endemism in the Nation. They occurred nowhere else in the world. Only nine species were native to the lower mainstem river and they evolved over millions of years in one of the harshest river environments known. They had learned how to survive floods, prolonged droughts, extreme temperatures, and salinities that few other fish could tolerate.

The majority of nonnative fish found in the river today could not have survived long in the pristine system, nor could they invade the basin on their own. Nonnative fish only gained access to the Colorado River when they were stocked by Europeans. Common carp were imported to southern Nevada and first noticed in the wild in 1881. Others soon followed. Bullhead and channel catfish were stocked in 1894 and by 1910, all had spread through the lower river and were replacing natives at a rapid pace. By 1930, the majority of native fish had already been replaced by these three species.

There is little doubt that water control projects sealed the fate of natives. Dams blocked upstream spawning migrations, irrigation reduced flows, fish were stranded in canals and fields, while critical habitat was claimed by agriculture. The wide, shallow, braided river was squeezed by levees and further deepened by dredging and the natural forces of streambed scour. Storage reservoirs captured floods, reduced sediment, supplied consistent summer flows to water users, and provided optimal conditions for recreational fisheries. Deep, cool water habitats benefitted species like channel catfish, common carp, largemouth bass, trout, and sunfish that were less tolerant of desert conditions. State and federal game agencies recognized the recreational potential of this resource and started to manage these waters to meet an ever-growing angler demand. Resource agencies sold fishing licenses to fund their programs and sport fishing generated revenue for local merchants.

What physically and biologically remains of the river more closely resembles conditions and fish communities found in the Upper Mississippi and Missouri River drainage. Today, the Lower Colorado River has the dubious distinction of being among the few major rivers of the world with an entirely introduced fish fauna. The following section describes the historical fish community, the decline of the native fishery, and the fishery that exists today.

The Native Fish Community (Pre-1880)

The river's estuary contained more than 75 marine species, but prior to 1880, only nine freshwater species were found further upstream in the main river channel (Table 5). These represented four families (cyprinids, catostomids, cyprinodontids, poeciliids) of freshwater fishes and two (mugilids, elopids) marine species that frequently invaded the lower river.

Evermann and Rutter (1895) reported that "the lower Colorado is one of the muddiest rivers in America and is unfit for any but mud-loving species." This was especially true during floods. Fish in the channel were blasted by suspended mud and sand. Abrasion to their bodies and gills must have been tremendous. Early reports suggest that fish were not plentiful in the channel and most were found in off-channel habitats where conditions were more hospitable.

Floods were unquestionably important for maintaining nursery and spawning habitat, but the size of the fish community not only depended on successful spawning during wet periods, but also the severity of droughts. It did not make any difference how many young fish were produced, if there was not enough water for them to survive. The influence that drought played in the native fish community is poorly understood and unfortunately largely ignored. Researchers and hydrologists have been fascinated with flood mechanics and stream morphology but little study has gone into understanding the long-term biological implications of droughts and how it must have shaped the fish community.

The first drought-related fishkill was reported by Father Garces in 1774–1776 (Coues, 1900). He reported observing the remains of thousands of dead fish while traveling through the delta. At the beginning of the twentieth century, MacDougal (1917) reported "a windrow of remains of fish which appeared to be carp," that "extended

Fig. 41. Aerial view of the Salt River floodplain near Phoenix, Arizona. Photograph by Michael Collier.

Fig. 42. Aerial view of the Gila River floodplain near Growler, Arizona. Photograph by Michael Collier.

Table 5. The native fish of the Lower Colorado River mainstem.[a]

Common name		Scientific name	Historical abundance	Status today
Freshwater				
Minnows (Cyprinids)				
Bonytail		*Gila elegans*	abundant	endangered-stocked
Roundtail chub		*Gila robusta*	rare	state listed-absent
Humpback chub[b]		*Gila cypha*	rare (canyons)	endangered-absent
Colorado pikeminnow		*Ptychocheilus lucius*	common	endangered-absent
Woundfin		*Plagopterus argentissimus*	common	endangered-absent
Suckers (Catostomids)				
Razorback sucker		*Xyrauchen texanus*	abundant	endangered-stocked
Flannelmouth sucker		*Catostomus latipinnis*	rare	uncommon-stocked
Pupfish (Cyprinodontids)				
Desert pupfish		*Cyprinodon macularius*	abundant (delta)	endangered-isolated in delta
Live-bearer (Poeciliids)				
Sonoran topminnows	Gila	*Poeciliopsis occidentalis occidentalis*	abundant	endangered-absent
	Yoqui	*Poeciliopsis occidentalis sonoriensis*	abundant	endangered-absent
Marine				
Mullets (Mugilids)				
Striped mullet		*Mugil cephalus*	abundant (delta)	common-present
Tenpounders (Elopids)				
Machete		*Elops affinis*	common (delta)	common-present

[a]A total of 50 families of native and introduced fish is recorded for both fresh and brackish water of the Lower Colorado River, its delta, and the estuary at the Sea of Cortez; there are 125 total species (87 native and 38 nonnative). Shown here are the species that occupied the freshwater of the lower river.

[b]Only a single record from an archaeological site is known for humpback chub below the Grand Canyon.

for about fifteen miles, and may have been double that length." Remains of those bones can still be seen today.

Major tributaries were also affected. Evermann and Rutter (1895) reported that during late summer, lower reaches dried up and "such streams are of course unsuited to a large variety of fish life." This process was common for the Virgin, Salt, and Gila Rivers. Fish communities periodically disappeared from the broader floodplains and extended portions of the tributaries. Populations that numbered in the millions could be reduced to only a few dozen fish in a single season. This was the desert Southwest.

Their Survival Strategy

Only nine fish species evolved in the harsh lower Colorado River environment. It is interesting to note that the Colorado was one of the few rivers in the country where sunfish and catfish were absent. La Rivers (1962) reported that sunfish were prehistorically found in the basin but explained their absence was probably due to their inability to cope with the harsh environmental conditions that eventually shaped the basin. Later, the mountains and deserts presented impassable barriers for sunfish, catfish, and other species that evolved outside the basin.

Conditions were even hard for the natives. W.L. Minckley speculated that severe droughts eliminated fish in the broader floodplain channels and larger tributaries, causing them to retreat to deeper, more secure canyon reaches. Predator and prey alike would retreat to these deeper sanctuaries. Small fish were eaten by terrestrial and aquatic predators and generally only a few larger fish survived. Droughts were devastating but they were undoubtedly key in the evolutionary development of these unique fish. The survival strategy of the main stream natives focused on coping with the harsh environment rather than competing among each other. Seasonal low flows, amplified by drought, was the primary factor that controlled fish numbers, it was not predation or interspecies competition which shaped fish evolution elsewhere.

For example, drought cycles could last several years but were eventually broken by spring floods. The river would swell and survivors would spawn once again. The larger females would lay thousands of eggs and within days they would hatch and young would disperse with flood waters into areas that only a few weeks earlier had been completely dry. These habitats would have been virtually predator free and survival was probably high for young fish that found permanent water. Those not finding deeper backwaters or old oxbows were either washed out to sea or stranded on the desert floor.

If conditions permitted, the fish community recovered and expanded. Both predators and prey increased in size and numbers. Fish often grew more than 12 inches their first year and early reports suggest fish occasionally became so abundant, they were commercially harvested. During these boom cycles, Colorado pikeminnow may have become abundant and actually impacted the recruitment of other species. However, we believe reoccurring periods of low flow minimized the importance of predation on the behavior of native fishes.

Our theory is speculative, but there is mounting evidence to support it. First, the basin only produced one large predator. The Colorado pikeminnow will eat almost anything, including a large variety of terrestrial animals which suggests fish prey were often scarce.

Second, studies suggest that native fish do not recognize predators nor have they developed defensive skills or behaviors that would help them avoid predation. Young have proved extremely vulnerable to predation and only survive in areas where resident predator populations have been sharply reduced or totally removed.

The last evidence, and probably the most compelling, stems from what we know about their life history. Razorback sucker, bonytail, and Colorado pikeminnow have developed unique characteristics in longevity and reproductive fecundity. All three can live nearly 50 years and produce tens of thousands of eggs each spawning season. The increased longevity allowed natives to survive through prolonged periods when spawning failed, but when favorable conditions arrived they could repopulate the river in a single season.

This is in stark contrast to the majority of other freshwater fish that live less than 10 years and can produce only a few hundred offspring each year. These species evolved in less hostile environments where they could easily reproduce every year or two. Spring and marsh fish, such as the desert pupfish, and Sonoran topminnow inhabited more stable habitats and evolved similar survival strategies. They seldom lived beyond 5 years and only produced a few dozen eggs each season.

The survival strategy of the main stream fishes served them well in the hostile Colorado River. While they developed remarkable skills to cope with floods, sediment, and droughts, they were ill prepared to compete with more aggressive species. Their inability to recognize or defend themselves against nonnative predators left them vulnerable. Within one generation (50 years), the river became home to not one predator, but several dozen that rapidly spread and colonized critical nursery and overwhelmed the native fish community.

The Mainstem Fish

Razorback Sucker (*Xyrauchen texanus* Abbott)

Fig. 43. Razorback sucker. Courtesy of the Arizona Game and Fish Department.

Common Names: Humpback Sucker, Buffalo Fish

Description

The razorback sucker (Fig. 43) is only found in the Colorado River system. It is the largest and most robust of several suckers found within the basin, reaching weights of up to 18 pounds. Suckers (Catostomids) have no sharp spines and while they are extremely strong fish, they are rather docile when handled. Its body is elongated and adults have a unique dorsal keel protruding behind the head. This feature is absent in the very young and develops with age. It was commonly called "buffalo fish" or "humpbacks" by earlier settlers because of the outgrowth from its back. It has a small, sucker-like mouth with fleshy lips and papillae (small bumps) that help the fish "feel" for food in muddy waters. The fish is multicolored having a dark back and golden-yellow colored belly. Males are normally 20% to 30% smaller than females.

Life History

The razorback sucker is the earliest and one of the most prolonged spawners in the river. Spawning typically starts in early January and continues into April. Males become sexually active at age 2, while females may take 4 to 5 years before they spawn. A large mature female can lay as many as 200,000 eggs. Suckers may have migrated long distances to spawning sites where they gathered with other spawners to form schools numbering in the hundreds (Fig. 44). Suckers can spawn over a wide range of conditions that include both river and pond habitats. Spawning always occurs over clean gravel and cobble whether in the river or reservoir. Males typically position themselves over the spawning site and are eventually visited by ripe females. Females are joined by several males that form tight spawning groups. Eggs hatch in 3–5 days and young can grow to 12 inches in their first year.

Fig. 44. Large numbers of razorback suckers congregate along the shoreline of Lake Mohave in late winter to spawn.

It has been a popular belief that the fish's dorsal hump improved stability in swift water but recent research suggests the hump may have actually been more important in preventing fish from being swallowed by predators (Portz, 1999). Adults and young actually prefer slack water or backwaters, with adults doing well in reservoirs. Adults feed on small invertebrates and plankton and are often found where food is most plentiful.

Flannelmouth Sucker (*Catostomus latipinnis* Baird and Girard)

Fig. 45. Flannelmouth sucker. Courtesy of the Arizona Game and Fish Department.

Common Names: Bigtooth Sucker

Description

The flannelmouth sucker (Fig. 45) is a large and robust fish often reaching 20 inches in length, but those found below Davis Dam often exceed 26 inches. The sucker has a large, rounded snout with a sucker-like mouth with large fleshy lips or lobes designed to help it "feel" for food. Coloration varies from a uniform grayish green to sharply bicolored with a dark olive back and upper sides and a light yellowish belly. This coloration becomes more prominent during spawning. Scales found above the lateral line are bordered in dark pigment. As with the razorback sucker, males are substantially smaller than females. The historical population was extirpated from the lower river, but later was restocked from the Paria River. A repatriated population persists today downstream of Davis Dam.

Life History

Flannelmouths feed on aquatic vegetation, diatoms, and small invertebrates. Fish spawn in May and April. Males position themselves over the spawning area where they wait for females. When a female is ready to spawn, she enters the area and is joined by one or more males who fertilize her eggs as they are deposited over the gravel. When finished, she leaves and the males resume their wait for another ripe female. Young are normally captured in submergent vegetation where they appear to hide and feed. Growth is rapid and young fish grow to 8 to 10 inches their first year. Flannelmouth suckers prefer flowing streams and can move substantial distances (>100 miles). Flannelmouths avoid reservoirs and to our knowledge only two have been captured in Lake Havasu.

Bonytail (*Gila elegans* Baird and Girard)

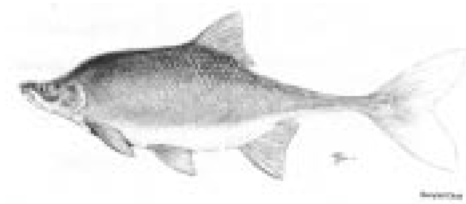

Fig. 46. Bonytail. Courtesy of the Arizona Game and Fish Department.

Common Names: Colorado Chub, Colorado Trout, Gila Trout

Description

The bonytail (Fig. 46) is only found in the Colorado River Basin and is the largest of several chubs (*Gila* spp.) found further upstream. It is the most common chub in the main stream channel. The bonytail has a streamlined body with an extremely thin or "bonytail." It has small, trout-like scales and is darkish-gray in color. It has a rather small, subterminal mouth and grows to a maximum length of about 18 inches. Large, old individuals have a prominent dorsal hump at the base of the head. When plentiful, it was often mistaken as a trout by novice anglers, but is actually a member of the minnow family (Cyprinidae).

Life History

The life history is not well known for the bonytail since wild populations became rare before scientists had enough time to study them. It is believed fish become sexually active after the second year with spawning occurring in April or May when water temperatures reach 60 to 65° F. In Lake Mohave, spawning adults prefer deeper habitats during the day and after dark congregate in schools along shore where they probably spawn over large cobble.

The streamlined body suggests the fish is adapted to swift currents; however, studies suggest they prefer eddies and pools. This might help explain their success in reservoirs. They feed on a wide variety of aquatic and terrestrial insects, worms, algae, plankton, and plant debris.

The bonytail is long lived (30+ years) which is also the case for the razorback sucker and Colorado pikeminnow. Three fish taken from Lake Mohave were estimated to be 34 to 49 years old. Scientists speculate that longevity was an adaptation for an extremely harsh and unpredictable environment.

Humpback Chub (*Gila cypha* Miller)

Fig. 47. Humpback chub. Courtesy of the Arizona Game and Fish Department.

Description

The humpback chub (Fig. 47) is a uniquely shaped and highly specialized fish. It has a streamlined, robust body similar to the bonytail, but it has an extremely pronounced dorsal hump. Its body is covered with small silvery scales, and has a small head and a slender forked-tail.

Life History

Humpback chub live exclusively in deepwater, canyon-bound river reaches where young are found near shore while adults typically occupy main channel habitats. Food use varies temporally and spatially and includes a diversity of terrestrial and aquatic invertebrates, algae and plant material, and miscellaneous items. Growth is rapid during the early years of life, then slows following maturation at age 2–3 to a maximum of about 20 inches. Longevity is unknown but thought to be decades. Spawning takes place during high spring runoff, but has never been observed. Minckley (1973) reported that humpback chub were found downstream as far as Eldorado Canyon, which is now covered by Lake Mohave.

Roundtail Chub (*Gila robusta* Baird and Girard)

Fig. 48. Roundtail chub. Courtesy of the Arizona Game and Fish Department.

Common Names: Colorado Chub, Roundtail, Verde Trout

Description

The roundtail chub (Fig. 48) is a moderately sized, streamlined fish that seldom reaches 16 inches in length. It has a moderately large terminal mouth. Its elongated body and streamlined fins make it well adapted for swift currents. Fish typically have dark olive backs, gradually lightening to cream along their sides on their belly. The sides of the body and fins often turn reddish on breeding males.

Life History

The roundtail chub is typically found in larger tributaries. The fish are difficult to age, but longevity is thought to exceed 10 years. Spawning normally occurs in May when water temperatures reach 65° F. Roundtails are stream spawners. Accompanied by two or more males, females deposit and fertilize their eggs over clean gravel. Spawning has been observed in relatively mild currents (1.5 ft/sec) and shallow depths (12 inches). Females can produce between 7,000 and 27,000 eggs.

Colorado Pikeminnow (*Ptychocheilus lucius* Girard)

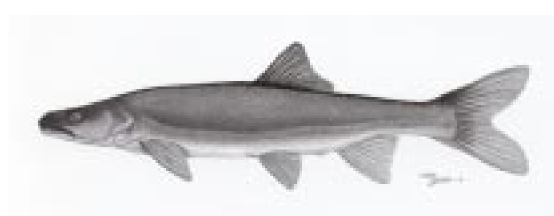

Fig. 49. Colorado pikeminnow. Courtesy of the Arizona Game and Fish Department.

Common Names: Colorado Squawfish, Colorado Salmon, Colorado Minnow, White Salmon

Description

The Colorado pikeminnow (Fig. 49) is the largest minnow in North America and is only found in the Colorado River drainage. Historically, individuals grew to 6 feet in length and weighed nearly 100 pounds (Fig. 50), but today, fish weighing more than 15 pounds are rare. Its body is "pike"-like, having an elongated and flattened shape. It has a large head and horizontal mouth adapted for grasping prey. The scales are small and adults have dark backs, lighter sides, and nearly white bellies. Young are silvery and have a black, wedge-shaped spot at the base of their tail.

Fig. 50. Mule with two large Colorado pikeminnow taken from the Salt River, Arizona. Courtesy of W.L. Minckley.

Life History

Colorado pikeminnow inhabit the main channels and larger tributaries throughout the drainage. It was historically abundant in the lower basin and delta where backwater habitat and prey were available. Adults become sexually active after their fifth year. Spawning pikeminnow migrate hundreds of miles, which is probably why they were called "salmon" by early settlers. Spawning is believed to occur upstream of backwater nursery habitats and confluences to major tributaries just after the peak of spring runoff when water temperatures reach 70° F. After hatching, the young often drift downstream to backwaters that serve as nurseries. Off-channel habitats are typically warmer and have more food than the main channel.

Adults prefer deeper stream channels or backwaters where they can move into shallower reaches to ambush prey. They are the top native predator, feeding on fish and a variety of terrestrial animals. Anglers have reported catching them using lures, mice, birds, chicken parts, and even young rabbits. Thirty-year-old fish were historically common; however, fish captured today are seldom older than 12 years.

Desert Pupfish (*Cyprinodon macularius* Baird and Girard)

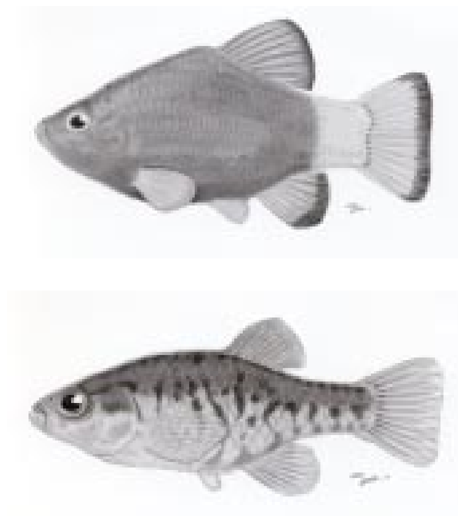

Fig. 51. Desert pupfish (male-top; female-bottom). Courtesy of the Arizona Game and Fish Department.

Common Name: Desert Minnow

Description

Desert pupfish (Fig. 51) are small, typically measuring less than 2.5 inches in length. Their bodies are robust and covered with relatively large scales. Mature males are typically larger than females and become quite colorful during the breeding season. Their bodies turn a beautiful bright blue and their tails turn a bright yellow. Females are dark brown or olive. Both sexes have five to eight vertical markings or bars along their sides.

Life History

Pupfish are truly a desert fish. They tolerate high temperatures (112° F) and salinities more than twice that of seawater (90 ppt). They thrive in habitats where few other species can survive. They occur in desert springs and shallow, sandy margins of streams where they feed on a wide variety of small invertebrates and algae.

Pupfish are short-lived, seldom living more than a year. Fish reach sexual maturity within 6 weeks. Males are territorial, aggressively protecting an area of about a square yard. Spawning occurs between April and October when water temperatures reach 68° F. Females lay up to 800 eggs which hatch in about 10 days. Larval fish measure less than a quarter of an inch.

Sonoran Topminnow [*Poeciliopsis occidentalis* (Baird and Girard)]

Fig. 52. Sonoran topminnow. Courtesy of the Arizona Game and Fish Department.

Subspecies: Gila (*P. o. occidentalis*) and Yaqui (*P. o. sonoriensis*) Topminnow

Description

Topminnows (Fig. 52) are small and have elongated bodies. They have a terminal and dorsal mouth that allows them to feed on insect larvae found near the surface. Their fins are rounded and their dorsal fin is located much closer to their tail than most fish. Topminnows have dark olive backs and their coloration lightens toward their bellies; breeding males are black. Scale margins are dark, making the scale pattern quite distinct. Males are typically less than an inch in length while females reach nearly 2 inches. They feed on a wide range of small invertebrates.

Life History

Topminnows congregate in shallow, marginal spring and stream habitats. They prefer moderate currents and areas near aquatic vegetation. They are unique, as they are the only native member of the fish family Poeciliidae in the United States. The topminnow is a live-bearer. Females are internally fertilized by males and they give live birth to their young. Spawning may occur year round, but is typically most intense in April and May. Pregnant females can hold two broods, one maturer than the other. Broods contain from 1 to 50 young.

Woundfin (*Plagopterus argentissimus* Cope)

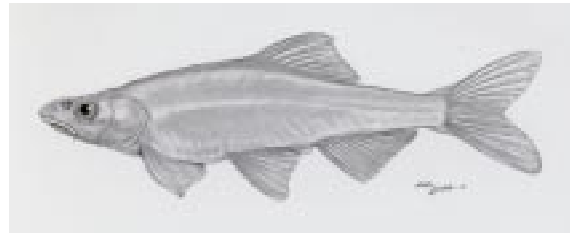

Fig. 53. Woundfin. Courtesy of the Arizona Game and Fish Department.

Description

The woundfin (Fig. 53) is a small, streamlined fish that rarely grows longer than 3 inches. Its head is flattened and tapered, which gives it a "wedged" appearance. The first two rays of its dorsal fin have prominent spines. The fin is sharply pointed, thus its common name. Woundfins have forked tails, no body scales, and have small barbels extending from the corners of the mouths. Fish are silverish in color, having darker backs and cream-colored bellies.

Life History

The woundfin is a channel-dwelling fish as its body shape suggests and prefers relatively swift and silty currents. It is normally found in streams less than 3 feet deep and is seldom found in pools. Its diet consists of a variety of aquatic and terrestrial invertebrates, plant material, and detritus.

Machete (*Elops affinis* Regan)

Fig. 54. Machete. Courtesy of the Arizona Game and Fish Department.

Common Names: Pacific Tenpounder, Tenpounder, Tarpon

Description

Machetes (Fig. 54) have an elongated body and large, wide terminal mouth. The head is not scaled and the eyes are large. They are silvery and have small scales. Large adults can exceed 3 feet but those entering the Colorado River are relatively small, seldom exceeding 16 inches.

Life History

The tenpounder is strictly marine. Its spawning and habitat requirements are in the ocean. Schools occasionally enter the lowermost Colorado River, presumably to feed on smaller fish and crustaceans.

Striped Mullet (*Mugil cephalus* Linnaeus)

Fig. 55. Striped mullet. Courtesy of the Arizona Game and Fish Department.

Common Names: Mullet, Cow-Carp

Description

The striped mullet (Fig. 55) is a moderately sized, streamlined marine fish. They have a small, terminal mouth, large eyes, and two dorsal fins; the first with four stiff spines. Their backs are dark, sides shifting to silver-gray, and they have a white belly.

Life History

Young mullet enter the Colorado River in large schools. Fish feed on detritus and eventually migrate back to sea. Spawning for this marine fish normally occurs out in the open sea, far from shore. The recent discovery of young in saline agricultural drains suggests there may be local spawning.

Early Descriptions

The recorded history of these fish is scattered through diaries, letters, published accounts, sketches, and photographs found in museum archives, family scrapbooks, and stories provided by local residents. Colorado River fish were unique and often considered bizarre by early visitors. Abbott (1861) provided one of the first descriptions of razorback sucker. The razorback was also described by Lockington (1881) and Jordan (1891) who provided the first accurate drawings of the fish (Fig. 56).

One of the earliest descriptions of bonytail and Colorado pikeminnow came from a 1864 diary entry by a W.P. Blake. Mr. Blake was a mining engineer stationed at Ehrenberg, Arizona. His diary described a fishing trip during which he caught a 1.5- to 2-pound bonytail while fishing with lettuce. He accurately sketched the fish and described its round caudal area. He also remarked that Colorado salmon (pikeminnow) weighing upward to 50 pounds were common.

Sykes (1937) and a group of friends pulled a boat up the delta to Yuma in 1894. The group ran out of provisions, and Sykes recalled taking a large pikeminnow with an axe one morning that provided breakfast for his group. Later on that trip, he reported a huge fishkill where dead fish covered the sandbars, "three to every square yard." He estimated dead fish numbered in the thousands of tons. Later he discovered that Wolfley Dam (Gila River) located at Gila Bend, Arizona, had failed. The dam was built of logs and timbers covered with layers of tar paper and pitch. Heavy rains destroyed the structure, and it was believed the tainted waters caused the kill.

Four years later, Gilbert and Scofield (1898), reported that Colorado pikeminnow and razorback suckers were abundant in the lower Colorado and Gila Rivers. They also reported that in 1890 razorback suckers were "extremely abundant at Yuma and at all points below as far as the Horseshoe Bend, and in Hardee's Colorado."

Emery and Ellsworth Kolb were explorers and adventurers of the Colorado River in the early 1900's. They were also professional photographers who not only appreciated the spectacular canyon scenery but

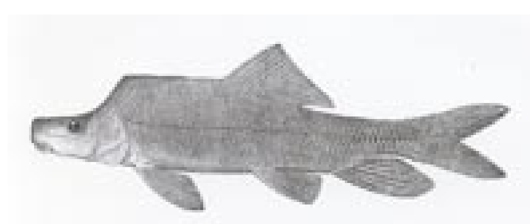

Fig. 56. Early drawing of a razorback sucker from D.S. Jordan (1891). Courtesy of the University of Washington.

recognized the uniqueness of the native fish. Many of their photographs were printed in major books and magazines featuring the canyon. They took some of the earliest known photographs of bonytail, Colorado pikeminnow, and razorback sucker (Figs. 57, 58, and 59).

Cook (1989) reported that until the mid-1950's bonytails, whose meat was bony but good to eat, were common upstream of Lake Havasu. On a boat fishing trip with his dad before 1950, he saw a large Colorado pikeminnow. The fish was reported to be nearly 6 feet long. He knew it was a Colorado pikeminnow because the Bullhead General Store and Post Office had a similar, but smaller (2–3 foot) one mounted on the back wall.

We traveled to a number of repositories along the lower Colorado River in the process of assembling the photographs and background information for this report. On the way we took every opportunity to visit with local residents and track down eyewitness accounts of the fishes and habitats of the river. Several of these recollections are provided below, recounted with great interest and attention to detail even after many intervening years, and reflecting the excitement evoked by the river and some of its finned inhabitants.

We visited with three retired gentlemen that lived in southern California but had grown up fishing the Topock Gorge area. We encountered them in a house boat in Topock Gorge. When asked if they had ever encountered native fish, they said they had seen three to four "humpbacks" while fishing the river during the early 1970's. On one fishing trip they found a large sucker moving in the shallows and easily caught it by hand. "It was a large fish, quite docile and appeared in good health. We released it and it swam away."

A 29-year employee of Park Moabi, San Bernardino County, California, reported that back in the 1970's he and friends would often float the river and shoot carp with their bows and arrows.

> "Backwaters were full of carp and they would often be on the surface sunning themselves. Beal Lake was a popular spot where we would see schools of humpback suckers on surface just like

Fig. 57. Emery and Ellsworth Kolb holding a stringer of bonytail (location unknown, 1911), 568-5739. Courtesy of the Kolb Collection, Northern Arizona University, Flagstaff.

Fig. 58. James Fagen holding a large Colorado pikeminnow taken in Lower Granite Gorge (date unknown), 568-5737. Courtesy of the Kolb Collection, Northern Arizona University, Flagstaff.

Fig. 59. Stringer of humpback chub taken from the Little Colorado River, 568-954, 568.5288. Courtesy of the Kolb Collection, Northern Arizona University, Flagstaff.

the carp. You could tell them apart because their sharp backs would be sticking out of the water."

Marvin Carter, Needles, California. "When I was a kid, back in 1962 or 1963, dad and I were boating back in the Topock Swamp. We were putting in [launching a boat] at Catfish Paradise. The water was extremely clear and we saw a big humpback. There were lots of carp, but the humpback was really different ... In the 1990's, we saw humpback suckers in Lake Mohave during a [SCUBA] diving trip at Telephone Cove. We saw two, a large fish that we got close to and a small one that was about 12 inches long ... We spent a lot of time on the river fishing and we never caught a humpback. I've never seen a bonytail or squawfish."

Don Rupe, Needles, California. "Back in the old times the river was really turbid. There were lots of backwaters and large (hydraulic) boils before they dredged the river. We'd catch thousands of soft shell turtles. The river had large cottonwoods and willows. Upstream of Needles there was a place called the Meadows or Boy Scout Camp.

There was a side channel where the carp would always spawn. This was a popular place to gig fish. We really enjoyed gigging fish. We'd get hundreds of carp but we were usually after game fish. We probably picked up 15–20 humpbacks back in the 1950's and 1960's."

> "Back when they dynamited and dredged to straighten the channel there were a lot of backwaters. When the channel was changed, a lot of these drained. We saw most of the suckers in the backwaters but we saw a few in the river. Down by Colorado Shores there was a curve in the river that was a favorite place to swim. There was a small side channel with a couple of hidden backwaters that usually had a lot of carp but I also saw half a dozen humpback. I didn't catch any bonytail, but I knew a guy who fished for trout up by Fort Mohave and caught lots of bonytail. He would bring them home and we'd bury them in our flowerbed. The fish were about 15 to 20 inches long. The river was generally shallow, but along that bluff where the old fort ruins are, it was fairly deep and easy to catch bonytail. With catfish, trout, and bass around no one ate them that I know of."

John Farmer, Needles, California. "In the late 1930's, humpbacks were found everywhere in the river. Bonytail were easy to catch and we usually threw them back or fed them to the cat. We had our favorite spots to fish. Most of the fish in the backwaters were carp, catfish, and bass. My favorite spot was 3 mile lake. We usually would camp for 2–3 days. Happy Castle was the cook. We would set trot lines and catch a lot of turtles and catfish. We would catch a lot of largemouth bass, some real dandies. We had a boat and would use cane poles rigged with 6 feet of line, a Colorado spinner, and pork rind. We'd dip the spinners next to logs and we'd mostly catch bass. Lots of bass in the potholes and few in the river." When asked, he said he never saw a Colorado pikeminnow.

Kenny Baldwin, Needles, California. "There used to be thousands of soft shell turtles before they dredged the river. We ate turtle all the time. Beal Slough was the last stronghold for the turtles. Humpbacks were everywhere. The last time I saw them was in the late 80's fishing for striped bass near Willow Valley. There was a large school just below the rapids in about 5 feet of water. I haven't seen a bonytail in a long time. Before they straightened the channel (1950) we use to see them in the connecting channels over at Topock Swamp. The channels were about 50 feet wide and 3 feet deep. We'd see bonytail along with the carp and turtles."

When asked if he had ever seen a Colorado pikeminnow: "I've only seen one and it was caught by grandpa near the old Indian Village in 1945 or 1946. He was fishing for catfish. We raised chickens and he always used chicken guts for bait. The fish was big and no one knew what it was. He nailed its head on a fence post where it remained for about 10 years." "The river has really changed. Before 1950 the river was simply mud and sand, the only rocks you would see were up near Fort Mohave. With all the backwaters there were lots of ducks and geese, you simply didn't need decoys. That's all gone and I guess that's progress."

Sam Soto, Needles, California. "There were lots of humpbacks in the old days." That's when the channel was way over on the Arizona side. We'd gig humpbacks when the water got low and sometimes we actually caught them by hand. Turtles were everywhere, especially on the sandbars. There were also a lot of bonytails. They were easy to catch if you used bait and fished in the backwaters."

Loss of the Native Fish Community

Reasons leading to the loss of the native fish community continue to be strongly debated. The debate is fueled by honest concern, misconceptions, lack of good scientific data, and political agendas. Most blame the water development agencies whose actions caused the dramatic physical and hydraulic changes seen in the basin while others contend the native losses began the day nonnative fishes were stocked. In actuality, the majority of natives were lost long before Hoover Dam was built in 1935 but there is little argument that water development guaranteed their demise.

The role of drought and flooding in the evolution and survival of native fish was paramount and helped explain how they were so easily replaced by nonnative fish. Survival hinged on coping with the harsh environment. They developed sleek body forms that allowed them to move in the current and cope with extreme turbidity and abrasive silt; many could spawn over a wide range of conditions. Typically communities were sparse, only a fraction of what we have today. Fish battled the harsh conditions dealt by the river rather than competing among themselves.

Species that eventually replaced the natives evolved under very different conditions. Many evolved in the Mississippi River or other more stable drainages. Conditions were less harsh and habitats supported a larger number and variety of species. Survival strategies were more complex and based largely on interspecies interactions. Fish learned to build nests and protect their eggs and young, which reduced the amount of energy they expended during spawning. Some specialized in specific niches and feeding techniques, while many became aggressively territorial and predatory in nature. Colorado River natives had not developed these behavioral defenses and could not compete with more aggressive intruders.

The loss of the main stream native community took over a century and is best described as a period of rapid decline followed by one of gradual disappearance. The rapid decline occurred between 1890 and 1935, followed by a prolonged period when relict communities gradually disappeared.

The 1890 to 1935 Decline

The disappearance of natives was first noticed downstream of the confluence of the Colorado and Gila Rivers. According to records and local residents, by 1920, the Colorado pikeminnow had become rare while the razorback sucker and the bonytail still remained relatively common further upstream for another two or three decades. Dill (1944) reported that by 1930, natives had disappeared downstream of Blythe, California. Game wardens he interviewed described hearing stories of "Colorado salmon, bonytail, and humpback sucker," but few had actually seen one.

Human impacts were less severe upstream of Laguna Dam. Up until 1935, spring floods continued to inundate the river corridor and this portion of the river was never dewatered by diversions. Apparently, the bonytail and razorback sucker were able to produce some young, even though their numbers continued to decline. Factors that contributed to their decline included: stranding by irrigation; commercial fishing; loss of critical habitat; migration barriers; and lastly and most important, the introduction of common carp, bullhead, and channel catfish into the river.

Stranding

The irrigation season started in March and April as the desert valley began to warm. Peak diversions occurred in June and July which coincided with spring runoff and native spawning. Newly hatched fish would drift downstream toward historic nurseries and be entrained by diversions and stranded over fields. Adult spawners were also trapped as they returned from upstream spawning areas. As a result, tens of thousands of fish were stranded each year in canals and over fields. In many cases, stranded fish were so abundant they were purposely used as fertilizer. In 1961, Dr. Robert R. Miller, a noted ichthyologist who studied western fishes, reported:

> "Until about 1911, the species [Colorado pikeminnow] was so abundant in the lower Colorado that individuals got into the irrigation ditches and were pitchforked out on the banks by the hundreds for use as fertilizer. Vast numbers of salmon, bonytails, and humpback sucker perished in this fashion or died when they were unable to re-enter the river from the irrigated lands [Imperial Valley]." Walter Scott grew up on a farm near Blythe, California and recounted similar events.

> "When I was a kid, back in the late 1920's, dad and I saw a huge wake in the feeder canal. Dad knew right away what it was and ran up and shut off the water. When it drained, we had one of those huge Colorado salmon. It was 5 to 6 feet long, and we had to use a block and tackle to pull it out of the canal. It was the only one I ever saw. It fed the family a long time . . . Bonytail and humpback sucker were real common. We didn't eat them because they were bony. At times of the year there were so many bonytail stranded in the fields that the farm just stunk."

Native Fishery

Meat was often in short supply and fish provided an additional source of protein. Fish made up 15% to 20% of the diet of Native Americans. However, Europeans were more effective in harvesting fish. Fish were often stranded in canals or concentrated behind diversion dams where they were commercially harvested and used for meat, fertilizer, and hog feed until 1910 (Fig. 60). Local fishermen supplied pikeminnow meat to construction crews building the Salt River Project near Phoenix and for a time pikeminnow were also commercially canned near Yuma. Farmers and local residents were opportunists; if an irrigation canal produced a nice fish for supper, so much the better (Fig. 61). Fish supplemented diets and fishing became a popular recreational past time (Fig. 62).

Dill (1944) reported: "Residents report that it [bonytail] was once one of the commonest fish in the Needles-to-Yuma section, but agreed that it was seen only occasionally now ... It is said to have been easily caught on hook and line; some 'old timers' claim it was the easiest fish in the river to catch."

Odens (1989) described a story told by George Utley about an experience with razorback suckers in a canal near the Salton Sea in 1909. Mr. Utley reported that splashing fish caught his attention. He harvested 147 razorback suckers from a canal in an hour using a hand axe and .22-caliber rifle.

Dewatering

Droughts were common; however, water diversions intensified the scope and duration of these events, especially downstream of the Alamo Canal. When the

Fig. 60. Eight bonytail and a large Colorado pikeminnow nailed to the barn. Courtesy of Verlyn Westwood.

Fig. 61. Ditch rider with a couple of Colorado pikeminnows. Courtesy of Wanda Staley.

Fig. 62. Fishermen with stringers of roundtail chub and suckers taken around the Phoenix area in 1899. Courtesy of Herb and Dorothy McLaughlin Collection, Arizona State University Libraries.

Colorado River left its channel and flowed uncontrolled into the Salton Sink between 1905 to 1907, the portion of river that flowed through the delta went dry. Natives continued to maintain healthy populations further upstream, and it is quite possible groundwater maintained the deeper oxbow communities in the delta during that period. Nevertheless, evidence suggests that large natives remained abundant until the 1910's.

The peak of the 1930's drought hit in 1934 when riverflows at Yuma dropped to 540 cfs. Water diversions at the Alamo Canal further reduced that flow so that only 18 cfs flowed into the delta. Continuous summer diversions eventually dewatered the delta, causing a dramatic reduction in resident fish numbers. Sykes (1937) described:

> "The various varieties of river fish, which under previous conditions of ample space for development, plentiful food supply, and general optimum environment, had practically disappeared

> from the entire region between the intake of the Imperial Canal and tidewater. The river had been dry so frequently during 1930 and 1931 and so many changes had taken place in the distributing systems during the preceding years, with temporary development and subsequent desiccation of widely separated shallow lagoons and backwaters, that conditions had doubtless become intolerable for their continued existence..."

Conditions on the Salt and Gila Rivers were degrading even faster. Theodore Roosevelt Dam began capturing spring runoff in 1911, which triggered further agricultural development. More land was tilled and more water diverted until the lower portion of the river was essentially dry. The loss of this particular tributary had a devastating impact to native communities.

Loss of the Delta

The construction of Laguna Dam in 1909 created man's first physical barrier across the Colorado River. It ended steamboat navigation and effectively isolated the delta from the inland river. While the dam had no influence on flood flows (Fig. 63), it did divert summer flows which reduced flows downstream. The impact this structure had on reducing native fish recruitment in the lower basin cannot be overstated.

W.L. Minckley (oral communication) believed the bastion or sanctuary for native fish was the Colorado River Delta and that bonytail, razorback sucker, and Colorado pikeminnow emanated from the vast nursery habitats found in the delta. The delta provided fish the ultimate sanctuary.

The river corridor north of the International Border was narrow, but south of the Border the river grew to nearly 25 miles wide and supported an estimated 1.9 million acres of wetlands. The vastness of this area was described by Lieutenant Hardy (1826) who traveled an estimated 20 miles by boat through interconnected sloughs to find the Colorado River and by Aldo Leopold who characterized the area as an interconnected, lush maze of "green lagoons." As Emery Kolb's journey demonstrated in 1912, a larval fish emerging from spawning gravels in Mohave Valley could easily find itself in the delta a week later. Likewise, marine species could easily migrate upstream to feed during high water. This photograph, believed taken near Blythe, California at the turn of the century, suggests striped mullet migrated inland more than 200 miles (Fig. 64).

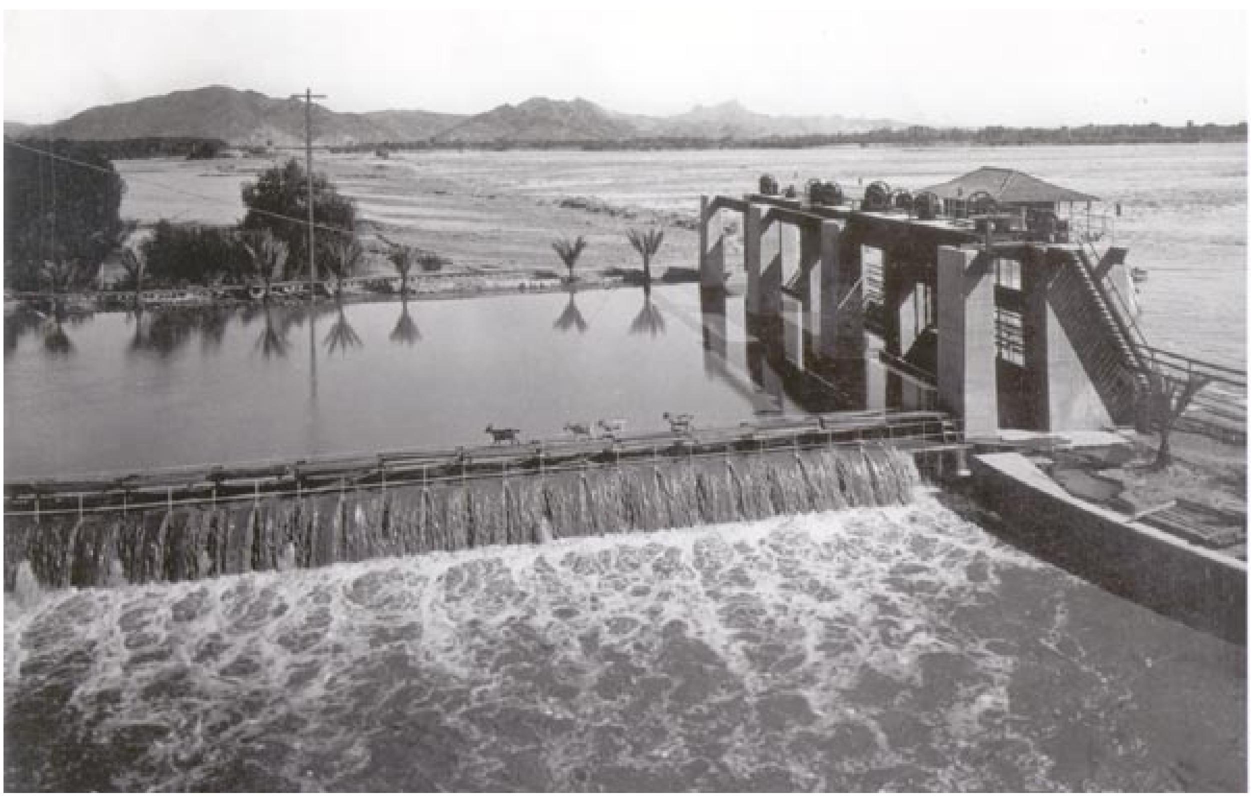

Fig. 63. The flood of 1922 breached the weir at Laguna Dam. Such floods were common until Boulder Dam was built in 1935, P45-300-4414A. Courtesy of the Bureau of Reclamation, Boulder City, Nevada.

Fig. 64. A photograph taken of a man holding a stringer of striped mullet believed taken near Blythe, California near the turn of the century. Courtesy of the Palo Verde Historical Museum Society, Blythe, California.

The delta was lost before its importance could be studied and documented. However, early reports of the massive concentrations of fish that collected below Laguna Dam and that ended up in the fields and canals in Imperial Valley provide testament to its role in the river's fishery. The dam not only prevented spawning migrations, it also concentrated fish and made them easier to harvest. Residents harvested thousands of pikeminnow, striped mullet, and other natives that concentrated against the dam's tailrace. Grinnell (1914), a biologist who surveyed terrestrial communities between Needles and Yuma in 1910, reported: "A huge minnow, called locally 'Colorado salmon'... was plentiful immediately below the Laguna Dam, where many were being taken by the Indians living near there" (Fig. 65). It is possible the dramatic decline of Colorado pikeminnow was partially due to over harvest of large adults.

Nonnative Fish Introductions

Nonnative fish played a pivotal role in the extermination of native fishes from the basin. A few scientists believe natives and nonnatives can coexist, but there is little evidence to support this claim. As the countryside was settled, nonnative fishes were introduced into local waters to provide food and recreation. Stocking began in 1881 and by 1910, common carp, bullhead, and channel catfish were common throughout the lower river. Grinnell (1914) reported they were abundant in the "over-flow ponds" found between Needles and Yuma.

As any rancher can tell you, a pasture can only support so many cattle. It is the same with fish in a river, there is only so much food and space. Common carp and channel catfish had spread to the basin by 1910. These new invaders competed with natives for available food and

Fig. 65. Native American netting fish in the Imperial Canal, August 16, 1907. National Archives Photo 115-JAJ-324 Imp. National Archives, Washington, D.C.

space and more importantly increased the predation pressure on fishes. No one noticed what was happening to the smaller species or "minnows." The initial impact here was more rapid and obvious. Miller (1961) was one of the first researchers to report on the disappearance of the Gila topminnow that was effectively eliminated within a year or two by mosquitofish. It was later discovered that mosquitofish ate the eggs and young of topminnow and effectively displaced the Gila topminnow from much of the basin. Undoubtedly, the same thing was happening to the young of the larger mainstream fish.

The reason that natives disappeared was eloquently described by Dill (1944) nearly 60 years ago. He wrote:

> "The following facts seem assured, however. (1) The native fishes of the river were once abundant. Those noted most frequently by residents were: the humpback sucker, bonytail, Colorado River squawfish. (2) Their decline was noticeable shortly before or after 1930. (3) As this decline became evident, it was also noted that there was a great increase in the numbers of exotic species, especially the channel catfish and largemouth bass. The increase of channel catfish was apparent even before 1930 but both it and the other exotic fishes increased tremendously after Boulder Dam was built. (4) At about the same time there were several periods of great drought in the river and there were some heavy floods. At such times "thousands of dead fish" (native) were observed."

His account of the factors which led to their demise is quite revealing. He went on to describe the process:

> "Extremely low water would raise the river temperature and strand fish. Such processes have, of course, been going on for many years in the unstable Colorado, and it seems probable that the native fish populations have undergone alternate periods of rise and fall. But each period of destruction was followed by a period during which the population could rehabilitate itself. Before the dams were built the native fishes were at the mercy of an adverse physical environment, but the deleterious effect of predaceous exotic fishes must have been slight. That is, the population of the latter fishes was small before the creation of Boulder Dam, and floods and droughts must have worked just as severe a hardship–and probably more–on them. Because of the unfavorable water conditions around the early thirties it seems possible that the population of native fishes sank to one of its low points, and the coincidental advent of clear water following Boulder Dam brought about a heavy production of bass and other alien fishes which preyed upon the already reduced natives. Competition as well as direct predation may have played a large part in this supposed destruction."

The 1935 to 2000 Disappearance

By 1935, all the native species (with the exception of the humpback chub) were still found in the lower basin, but their distribution and numbers were greatly reduced. Construction of Roosevelt, Hoover, Imperial, and the other dams caused remarkable physical change to the basin, which greatly benefitted nonnative fishes.

Water Development Projects

The period after 1935 brought great change to the basin. Construction of Hoover Dam in 1935 represented the beginning of the large water development projects. Imperial and Parker Dams were built in 1938. World War II interrupted construction for a short period, but after the war construction resumed in earnest. Over the next decade, the river was further segmented by Parker, Davis, Head Gate Rock, and Palo Verde Dams.

Floods were intercepted and water stored behind reservoirs was used to augment summer flows and irrigation needs. The historical role that floods and droughts had on restricting predators numbers was gone and replaced by stable conditions that disproportionately benefitted nonnative fishes. Construction of mainstem dams permanently flooded more than 40% of the historic river channel between the Grand Canyon and International Border. Soon the basin as a whole would contain 1,000 times the volume of water it did historically. This created an unprecedented amount of habitat that soon supported tens of millions of nonnative fishes. However, during the filling of several of these reservoirs, the razorback sucker and bonytail made a brief but significant resurgence.

A Brief Resurgence

Native fish became trapped in various portions of the river that were blocked by the construction of the major dams. Fish continued to spawn and as their eggs hatched, young were once again distributed in flood waters. Unlike previous years when young were lost to the various factors described in the previous section, they found themselves in the vast expanses of the swelling reservoirs. The new reservoirs flooded large portions of the floodplain, creating nursery habitats that contained few, if any, large predators. Remarkably, circumstances mimicked historical flood conditions, where large areas of new habitat contained few, if any, predators. Left unmolested, razorback suckers and bonytail survived by the hundreds and in some cases by the tens of thousands to form reservoir bound communities. The same conditions benefitted the nonnative fish community. Within a few years, predator pressure had grown to a level where all the young natives were being lost.

The relic reservoir populations remained relatively unchanged for 30 to 50 years until fish began dying of old age. In the case of Lake Mead, a few young razorback suckers did manage to survive. That population has lingered some 70 years after the gates of Hoover Dam were closed. Their numbers have dropped from hundreds of thousands to possibly 200 fish (Holden and others, 2001). These razorback suckers and bonytails could cope with the habitat conditions brought on by water control projects, but they could not sustain the losses brought upon by nonnative predators.

Development of a Recreational Fishery

The rate that new fish were being introduced after 1935 reflected the management philosophy of the time. Recreational fishing had become big business. More than 60 different fish species were introduced in the oncoming years. Most were stocked intentionally, or as contaminants in shipments of "desired" fish, or were introduced as leftover bait by anglers or well-meaning aquarium enthusiasts. Many of these fish reproduced and became established. Many spread basin wide. Table 6 lists a few of the many species that were introduced.

Dam building presented recreational opportunities for both cold and warm water fisheries. As Lake Mead was filling, it was stocked with largemouth bass and sunfish and local businesses began to promote the new fishery. It is ironic that the first promotional photographs show anglers catching Colorado pikeminnow. The photographs were taken in front of Hoover Dam in 1935, shortly after largemouth bass were stocked in Lake Mead. Apparently, the natives were easier to catch at that time. The anglers in the photographs are using cane poles and while there was no notation regarding the type of fish being caught, it is apparent all five are juvenile Colorado pikeminnow that had already been dressed (Figs. 66 and 67).

Anglers continued to be a source of valuable information on the occurrence of native fish (Fig. 68). Russell Grater was a naturalist for the newly formed Lake Mead National Recreational Area. In an interview with McBride (1995) he recounted native fish being caught by anglers from Lake Mead in the late 1930's. He recollected:

> "They [Colorado pikeminnow] look like an overgrown salmon almost. I used to go down there when the fishermen came in... One of the commonest questions that were asked by fishermen, they'd hold up a fish and ask, "What kind of fish is this?" So big, holding it up, tail on the ground. I'd always tell them that was a minnow. And they'd laugh, and I'd tell 'em, 'Don't laugh, it is a minnow. That's a squawfish and he's a member of the minnow family."

Fig. 66. Hoover Dam photograph of fishermen catching Colorado pikeminnow. Courtesy of the Cashman Collection, University of Nevada, Las Vegas Library.

Table 6. Chronology of fish introductions or capture in the Lower Colorado River Basin to 1975.

Species	Location	Source[a]	Year
Common carp	Lower River	C	1881
American shad	Needles, California	S	1884
Channel catfish	Lower River	S	1892
Yellow bullhead	Lower River	S	1899
Cutthroat trout, Rainbow trout	Lower River	S	Pre-1900
Black bullhead	Lower River	C	1904
Brown bullhead	Topock	C	1910
Brook trout	Grand Canyon	S	1920
Mosquitofish	Nevada	C	1922
Brown trout	Grand Canyon	S	1924
White crappie	Lower River	C	1934
Black crappie, Largemouth bass	Lower River	S	1935
Bluegill, Green sunfish	Lake Mead	S	1937
Smallmouth bass	Lower River	C	1940's
Goldfish	Lower River	B	1944
Fathead minnow	Grand Canyon	B	1950's
Banded cichlid	Lake Mead	C	1950's
Guppy, Mexican tetra, Sailfin molly, Shortfin molly, Green swordtail, Southern platyfish	Lower River	C	1950
Redside shiner, Leatherside chub, Utah sucker Rio Grande chub, Rio Grande sucker	Lower River	B	1950
Dusky mountain sucker	Lake Mead	B	1950
Sacramento hitch	Lake Havasu	B	1950
Rio Grande killifish, Longjaw mudsucker	Lower River	B	1950
Mottled sculpin	Lake Mead	B	1950
Utah chub	Lake Mohave	B	1951
Redear sunfish	Lower River	C	1951
White River spinedace, Yellow perch	Lower River	B	1951
California killifish	Yuma	B	1951
Golden shiner, Red shiner	Lower River	B	1953
Threadfin shad	Lake Mead	S	1953
Warmouth	Lower River	C	1958
Striped bass	Lower River	S	1959
Blue catfish, Mozambique mouthbrooder	Lower River	S	1960's
Zilli tilapia	Lower River	C	1960's
Flathead catfish	Martinez Lake	S	1962
Sockeye salmon	Lake Mohave	S	1962
White catfish	Lower River	S	1963
White sturgeon	Lake Havasu	S	1967
Coho salmon	Lake Mead	S	1966
Rainbow trout	Lake Mead	S	1969
Walking catfish	Rodgers Spring	C	1970
Walleye	Lake Mead	C	1971
Freshwater eel	Lake Mead	C	1972
Cutthroat trout	Lake Mead	S	1972
Cuttbow trout	Lake Mead	S	1975

[a]S = stocked; C = collected; B = sold as live bait (U.S. Fish and Wildlife Service, 1980).

Fig. 67. Cowboy posed with a Colorado pikeminnow on a cane pole. Courtesy of the Arizona Collection, Arizona State University Libraries.

> "So a squawfish was a fish you could fish very much like a bass. It'd hit a plug. Fisherman would come in worried about that, something had hit a plug and it wasn't a bass. Sometimes they'd come in with a story about something hit their plug, and 'did you know the thing on the other end could pull my boat?'...
>
> "[Fishermen] would bring them in. Every time I'd go down when I thought they were coming in to see if I could get a line on what they were catching, see if they got squawfish, usually about the size of trout. But they'd get one of these big ones every so often... This guy was holding it up like this, and the tail was clear down against the ground. Looked like a whale."

Along with pikeminnow, razorback sucker and bonytail were commonly seen at several locations in the reservoir. Moffett (1943), reported: "Rather large schools of bonytails are seen repeatedly" (Lake Mead). There were reports of large schools of razorback suckers on Lake Mead but often these large fish were confused with common carp. A photograph of a commercial netting operation on Lake Mead suggests that large razorback suckers were more common in their catches than common carp (Fig. 69).

Recreational fishing became a popular past time after World War II. Anglers demanded more and better fishing opportunities and Federal and state agencies responded by building hatcheries and aggressively stocking fish. Management focused on promoting the sport fishery as native fish were viewed as rough or trash fish (Figs. 70 and 71). In some cases they were poisoned to make room for more desirable game fish, or simply thrown up on the bank to feed the coyotes.

Natives were still being reported in the Salt and Gila Rivers near Phoenix and the Mohave Valley. Although rare, they continued to be taken by anglers until the 1960's and early 1970's. Jonez and Sumner (1954, Nevada Department of Wildlife) conducted one of the first surveys of the Mohave Valley and reported:

> "Squawfish were caught more often in the river below Davis Dam than in any other portion of the

Fig. 68. National Park Service Junior Naturalist Bert Long, holding a 25 1/2 inch-long Colorado pikeminnow taken from Lake Mead on April 22, 1940. Courtesy of the National Park Service, Lake Mead National Recreation Area.

Fig. 69. Photograph entitled "Netting carp in Lake Mead." The fish are mostly large razorback suckers, NAU.PH.96.4.175.34. Courtesy of the Cline Library, Northern Arizona University, Flagstaff.

Fig. 70. A day's catch of largemouth bass from Lake Mead (1947), NAU.PH.96.4.175.32. Photograph courtesy of the Cline Library, University of Northern Arizona, Flagstaff.

Fig. 71. Promotional photograph of trout anglers. Courtesy of the Lied Library, University of Nevada, Las Vegas.

Colorado River system studied during the 1950–1954 period. Several squawfish were caught in 1950 and 1951, but the fish were not observed by the author. In May 1952, James Litchfield, Nevada resident, caught a 38-inch, 20-pound squawfish about one mile below Davis Dam... In 1950, small four- to five-inch bonytails were caught in the river with a seine. Therefore, it is assumed that they had spawned successfully in the area below Davis Dam... Humpback suckers ...were found in large numbers below Davis Dam. They do not appear to be decreasing in numbers ... Small (five-inch) humpback suckers were found in the river below Davis Dam in 1950, indicating the occurrence of spawning activities." "It is doubtful whether the fish [razorback] will become extinct in the river, unless they do not find suitable spawning sites."

This was the last time substantial numbers of juvenile bonytail or razorback suckers were reported in the lower basin.

Minckley (1979) was the last to conduct a comprehensive survey of the lower river. He reported that during the 1974–1975 survey, native fish were absent from his collections in the Mohave Valley Division but there were reports that some old natives were still being caught by fishermen. He noted:

> "A large individual (bonytail), approximately 80 cm in total length, was caught by a fisherman in 1975, a few kilometers below Davis Dam (Gary Edwards, Arizona Game and Fish Department, personal communication)... Prior to 1974, a number of mature bonytail chubs were caught each year below Davis Dam and deposited at Arizona State University by fishermen."

Replacement of natives by introduced kinds became obvious as anglers caught fewer native species and more and bigger largemouth bass, catfish, and trout. Creation of Saguaro Lake on the Salt River in central Arizona and later Lake Mohave on the lower Colorado River resulted in a short-lived boom for razorback sucker and to a lesser extent, bonytail. Hubbs and Miller (1953) reported that a commercial fisherman snagged 6 tons of razorback sucker from Saguaro Lake in 1949. A similar reservoir population occurred in Lake Mohave after its closure in 1954. Minckley (1983) described tens of thousands of fish in the 1960's. Conservative estimates placed the population at 88,000 in the 1980's.

Lake Mohave also harbored populations of bonytail and Colorado pikeminnow. Wagner (1952) reported that bonytail were frequently taken from Lake Mohave by anglers. He remarked, "bonytail occur frequently in the catch and occasionally crappie, bluegill, bullhead, and catfish are also taken." Jim Sleznick, a park ranger at Willow Beach during the early 1960's, kept a daily diary and reported anglers catching native fish (Fig. 72). He recorded the second to the last Colorado pikeminnow taken from the entire lower river.

Fig. 72. Last Colorado pikeminnow captured in Lake Mohave, November 13, 1962. Courtesy of Jim Sleznick.

> "The squawfish was caught near the National Park Service buoy at Willow Beach by a Mr. Sinclair on November 13, 1962. He was fishing for trout with a 4 pound line and caught the fish on a number 6 hook. It weighed just over 16 pounds and was brought in alive. The hatchery was new and we kept the fish in a raceway until it died on December 1." He went on to say: "Bonytails and humpback suckers were everywhere in the early 1960's. You normally caught bonytails while fishing for trout, they're a bottom feeder you know. We use to throw them up on the bank to feed the coyotes. You know they were rough fish and the fishermen were after trout." His notes suggest pikeminnow were rare, the last previous pikeminnow was captured in 1956, shortly after Davis Dam was closed.

By 1980, fishing had become a lucrative source of revenue. It was estimated that fishing-related revenues generated at Lake Mead earned local businesses nearly $56 million that year (Martin and others, 1980). Resource management agencies courted the recreational and professional angler by stocking largemouth bass, smallmouth bass, bluegill, green sunfish, redear sunfish, crappie, striped bass, and dozens of others. Virtually every bit of habitat contained resident fish predators. There was simply no place where small native fish could survive.

Bonytail and razorback sucker numbers continued to decline while there was no evidence to suggest that their young were surviving. The U.S. Fish and Wildlife Service captured 11 bonytail from Lake Mohave in 1981 and removed the fish to Dexter National Fish Hatchery to start a propagation program. There was an unconfirmed report of an angler catching several bonytails at Katherine's Landing in the late 1980's. Wild razorback suckers continued to decline and in 2001 the reservoir population was estimated to be less than 4,000 wild fish. These will die off within the next few years.

The Fish Community Today

Some biologists speculate that 95% of all fish found in the Colorado River Basin are now nonnative. Recreational species are economically important in many areas, generating millions of dollars in revenue to local businesses and tens of thousands of dollars in license sales. Tailwaters below the major dams provide put-and-take trout fisheries, while reservoirs are renowned for their black bass and striped bass fisheries. More than a million striped bass are harvested each year in the lower basin alone.

Sport Fishery

There is not much water between the International Border and Imperial Dam, but anglers take a few largemouth bass, striped bass, crappie, and flathead catfish from the area. Striped mullet are occasionally reported and appear to be spawning in the more saline agricultural drains. Backwater habitats are more prevalent further upstream of Imperial Dam where fishing improves. Surveys conducted by the Arizona Game and Fish Department found eight nonnative fish species. Bluegills were the most abundant (58%), followed by common carp (11%), largemouth bass (11%), tilapia (9%), redear sunfish (4%), black crappie (3%), threadfin shad (3%), and channel catfish (<1%).

Remnants of the old river channel and oxbows are still found in the Cibola and Palo Verde reaches of the river. In the late 1980's, biologists caught nearly five times more fish in backwaters compared to the main river channel (Hiebert and Grabowski, 1987–1988). Again bluegills were the dominant fish (34%), followed by common carp (24%), largemouth bass (14%), red shiners (13%), green sunfish (4%), smallmouth bass (3%), and channel catfish (2%).

The area between Parker and Davis Dams supports an impressive and diverse recreational fishery. Lake Havasu extends upstream 25 miles and the Colorado River continues 57 miles to Davis Dam. Lake Havasu supported more than 170,000 angler days of use in 2000. Anglers took mostly largemouth bass, sunfish, channel catfish, and striped bass. During the past decade, several agencies and volunteers embarked on the Lake Havasu Fisheries Improvement Program. More than 300 acres of habitat structures were placed throughout the reservoir to improve fishing. A recent economic report estimated the project is generating more than $18,000,000 annually to the local economy (Anderson, 2001).

The river's inflow to Lake Havasu has created a lush delta pocketed by productive backwaters that support impressive largemouth bass, sunfish, and channel catfish fisheries (Figs. 73 and 74). The range and abundance of recently introduced fishes continue to change as the overall fish community attempts to stabilize. For example, recent fish surveys show that striped bass, smallmouth bass, and redear sunfish are expanding in abundance in the Mohave Valley and Topock Gorge area. Smallmouth bass are not yet common; however, striped bass and redear sunfish are. Other species that are moving upstream include the flathead catfish and African cichlids.

Fig. 73. Channel catfish taken from Topock Gorge.

Fig. 74. Largemouth bass taken from Lake Havasu.

A cold water fishery extends downstream approximately 20 miles from Davis Dam. Resource agencies have been stocking trout here for the past 50 years. This reach is also popular with striped bass anglers, who commonly take fish weighing more than 15 pounds (Fig. 75).

Lakes Mohave and Mead were renowned for their black bass fisheries and the blue ribbon trout fishery found downstream of Hoover Dam. Striped bass were introduced into Lake Mead in the mid-1970's and eventually spread throughout both reservoirs. By 1990, striped bass replaced largemouth bass in the angler's creel. Nevada Division of Wildlife estimated angler use on Lake Mohave exceeded 183,156 angler days in 2000. Rainbow trout continues to be stocked in the cold water reach below Hoover Dam. Anglers harvested an estimated 78,200 rainbow trout, 23,900 largemouth bass, 6,800 channel catfish, and 124,000 striped bass from Lake Mohave in 2000 (Burrell, 2001).

Located next to Las Vegas, Lake Mead was visited by more than 9 million people in 2000. It is estimated the lake was used by nearly 900,000 anglers that same year. Although annual harvest estimates are no longer being calculated, resource agencies estimate more than a million striped bass were being harvested each year in the late 1980's. Striped bass continue to dominate the fishery, making up 77% of the anglers creel, followed by rainbow trout (17%), channel catfish (4.3%), and largemouth bass (1.2%). Rainbow trout is the only fish currently being stocked in the lake. More than 100,800 rainbow trout were stocked in 2001 (John Hutchins, oral communication).

Fig. 75. Angler with a striped bass taken just downstream of Davis Dam.

Native Fish Community

Razorback Sucker

This species was once widely distributed and abundant in larger streams throughout the Colorado River Basin. Today, less than 4,000 wild razorback suckers remain and most of those are old fish found in Lake Mohave and Lake Mead.

The razorback sucker was federally listed as endangered in 1991 although it had been recognized as biologically imperiled for many years. Federal protection was delayed as a compromise that allowed FWS to stock more than 12 million suckers in central Arizona streams. It was hoped stocking massive numbers of fish would reestablish populations and make Federal protection unnecessary. Unfortunately, it did not. Less than 150 fish were recaptured, suggesting survival was extremely poor. Marsh and Brooks (1989) reported entire truckloads of suckers were eaten by catfish within a few days of release.

In 1989, concerned biologists formed the Native Fish Work Group to try and save the remnant Lake Mohave population. The strategy was to intercept young before they were eaten by predators and place them in safe areas where they could grow to a size large enough to avoid predation (Fig. 76). The group began stocking larger juveniles to replace the wild adults that were dying of old age. Stocking augmentation programs have grown and

Fig. 76. A young razorback sucker taken from a rearing pond located near Lake Mohave.

spread elsewhere. Today, more than 85,000 juvenile suckers have been stocked in Lake Mohave and Lake Havasu. Some fish are surviving, but unfortunately the factors that prevent young from surviving still exist, and the prospect for recovery continues to be bleak.

Razorback suckers do survive when born or stocked in the absence of predators. Minckley and others (in press) contended these isolated communities may be the only practical method of controlling predators and maintaining the species in a semi-natural state.

Flannelmouth Sucker

Flannelmouth suckers are rare in the lower main stream river but abundant in higher gradient streams. Like the other natives, their range and number have also declined. The fish is not state or federally protected but specific populations are being monitored with concern. The lower Colorado River population is unique in that it represents the only successful reintroduction of a native fish in the Colorado River mainstem. In 1976, Arizona biologists collected 611 flannelmouth suckers from the Paria River and released them in the lower river near Bullhead City. The fish has successfully colonized a 20-mile reach downstream of Davis Dam. This armored section of river appears to provide the young suckers adequate cover, and the lack of backwaters, combined with hydropower, may limit the occurrence of some predators. Current estimates place the population at more than 3,500 fish. Unlike the razorback sucker, flannelmouth young apparently have been able to avoid predators and survive downstream of Davis Dam, but the mechanism involved has yet to be identified and studied.

Bonytail

The bonytail was once one of the most common fish in the lower basin and was found in the mainstem and larger tributaries. It was federally listed as endangered in 1980. Today, the bonytail is considered by some to be one of the most endangered vertebrates in North America. Fish born in the wild appear to be gone. The last wild bonytail captured downstream of Davis Dam was taken in the early 1970's. Until the late 1990's, a few wild fish were taken from Lake Mohave. The FWS captured wild bonytail from Lake Mohave in 1981 and transferred them to Willow Beach National Fish Hatchery for propagation (Fig. 77). Fish were successfully produced, stemming from the production of just three females which saved the fish from extinction. However, this genetic "bottle neck" may eventually have serious effects and the species as we know it may not survive.

The fishes' decline is attributed to nonnative fish predation. Water development and habitat degradation

Fig. 77. One of the last known wild bonytail taken from Lake Mohave (ca. 1980's). Courtesy of the Nevada Department of Wildlife, Las Vegas.

have accelerated their disappearance. When stocked in small ponds by themselves they do well, producing countless young; however, in mixed communities, their young quickly fall prey to nonnative predators like channel catfish, sunfish, and bass. The adults eventually die of old age without young to replace them.

State and federal agencies are stocking large bonytail in Lake Mohave, Lake Havasu, and portions of the upper basin in efforts to reestablish populations. While adults can be reintroduced and managed, the factors that led to their rapid decline continue to impact any offspring these fish produce. It's doubtful these fish will ever be recovered in the main stream river due to the predation issue. Similar introductions in isolated ponds have produced thriving communities. Biologists recently estimated that natural spawning in a 5-acre pond in Cibola National Wildlife Refuge has produced a "wild" population numbering near 15,000 fish (Fig. 78).

Humpback Chub

The humpback chub was never considered common in the lower basin. Today, humpback chubs are totally absent downstream of the Grand Canyon and only a few relict populations are found upstream of Lake Mead. The largest (several thousand) population is found in the Little Colorado River. Other small (hundreds of individuals) populations may exist upstream of Lake Powell. The species was federally listed as endangered in 1967.

Roundtail Chub

The roundtail chub remains the most common of the three chubs described in this report. It is still common in the upper basin but it has suffered reductions in both distribution and numbers. Roundtail chub are no longer

Fig. 78. Cibola High Levee Pond, located in Cibola National Refuge, Arizona-California.

found in the mainstem Colorado River, but small populations can still be found in portions of the Gila, Salt, and Verde Rivers in Arizona.

The species is under consideration for federal listing and protection in the lower basin.

Colorado Pikeminnow

Colorado pikeminnows were abundant in the lower Colorado, Gila, and Salt Rivers. Thousands were commercially harvested around the turn of the twentieth century. It was federally protected in 1976 and listed as endangered. Today, the species is only found in portions of the upper basin where small populations are found in the Colorado, Green, and Yampa Rivers (Osmundson and Burnham, 1998). A brood stock is held at Dexter National Fish Hatchery and attempts are being made to reintroduce pikeminnow into the San Juan and Salt Rivers, major tributaries of the Colorado River. Recent efforts to reintroduce pikeminnow to the lower mainstem river have met with agency objections stemming from federal protection issues. Currently, there are no plans to stock these fish.

Desert Pupfish

Desert pupfish have disappeared from most of its historic range. Its decline is a result from competition and predation from exotics and the loss of habitat. Some relict populations still exist, mostly due to their ability to survive in the most inhospitable habitats.

Desert pupfish can still be found in shallow agricultural drains near the Salton Sea, in San Felipe Creek, La Cienega de Santa Clara, Baja Mexico, and possibly other shallow wetlands in the Colorado River Delta. Several agencies have built and maintain pupfish refugiums (Fig. 79).

Sonoran Topminnow

Hubbs and Miller (1941) reported the topminnow was one of the most common fish in the Lower Colorado River drainage. The fish rapidly disappeared when the mosquitofish was introduced in the early 1920's. Mosquitofish fed on topminnow young and populations of the native disappeared within a couple of years. The Gila topminnow was federally listed as endangered in 1967. Less than a dozen natural populations exist in the United States today, all in Arizona, and a number of refugia populations have been established in small, isolated habitats. Wild populations are still found in northern Mexico.

Woundfin

The woundfin was once widely distributed from the Virgin through the Salt and Gila Rivers. Today it is only found in a small part of the Virgin River and that population is threatened by water development, urbanization, and

Fig. 79. Desert pupfish refugium located at Cibola National Wildlife Refuge, Arizona-California.

introduced species. The fish was federally listed as endangered in 1967.

Machete

Machetes were occasionally taken from the Salton Sea and in the river upstream to Imperial Dam until the mid-1940's. Tenpounders only have access to the Colorado River during major floods when the river is reconnected to the Gulf of California. Several were captured near Yuma when floodflows from the Gila River reached the sea in 1997. Those trapped in the river when flows receded soon died. There is no evidence to suggest they can reproduce in the river.

Striped Mullet

Mullets were common and frequently trapped in the Laguna Maquata (Salada) by major floods. This desert playa contained thousands of mullets in 1884. Historically, mullet numbers were reported as "sporadic" upstream of Yuma by early accounts. However, they became more common as canals and drains were built. They were often seen attempting to swim over the weir at Laguna Dam. The flood of 1905–1907 carried them and other fish into the Salton Sink. Initially, common carp dominated the fishery but as salinity increased, so did mullet numbers, until they dominated by 1940. For a period, the Salton Sea supported a commercial fishery where one company harvested more than 90 tons of mullet in 1943. Today, their numbers in the lower river have declined, but unlike the machete, there is limited production in saline, agricultural drains.

The Future of Native Fish

The future is grim for native fish in the Lower Colorado River. Remnant native communities continue to decline, except for small refugium populations. Their fate has been sealed by the dependence on the river by 30 million water users in the United States and Mexico. Societies' dependence upon water makes native fish recovery economically and politically unlikely, and perhaps impossible. Four decades of research, coupled with failed stocking programs, have shown us that larger adults can be stocked but they cannot be expected to produce young that survive. Predation is too great and we do not have the technology or willingness to remove these economically important recreational fisheries.

Anglers quite often question the value of these "sucker" fish. "They certainly are bony so what good are they?" A friend once replied: "I doubt if God ever made anything that was totally worthless. The problem with man is, he often doesn't recognize how precious something is until it's lost." That is worth thinking about.

Young native fish have fed sport fish for nearly a century. Early settlers used native young as bait for catfish and bass. The large natives being stocked today will produce young for several more decades that will continue to feed recreational species like channel catfish and largemouth bass. Natives are also extremely unique, not being found anywhere else in the world. It is also possible they may provide pharmaceutical benefits yet to be discovered. We simply do not know. One thing for sure, once they are gone, they are lost forever.

Aldo Leopold once said the art of tinkering is not to lose any pieces of the puzzle. Unfortunately they are being lost. Society acting through Congress, has mandated that government agencies preserve these unique species and ecosystems through the passage of the Endangered Species Act and other environmental legislation. Unfortunately, legislation by itself does not protect the environment, only concerned citizens and agencies do. Wild populations continue to decline, and while there are people who care, in some circles, the loss of these unique fish is viewed as the elimination of a “problem.”

Minckley and Deacon (1991) stated, “Native fishes of the American West will not remain on earth without active management...” River communities can be maintained through hatcheries and stocking large fish; however, full recovery to self-sustaining populations in the lower basin appears impossible. A smaller and more attainable goal is to establish refugium populations that will provide additional security for the species and time needed to better understand these unique fish. After four decades of research and debate, the initial steps toward the construction of these facilities is slowly starting in the lower basin; however, it will take the full commitment from the public as well as the resource agencies if these fish are going to survive.

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