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OBSERVATIONS ON RECRUITMENT AND ECOLOGY OF
RAZORBACK SUCKER: LOWER COLORADO RIVER,
ARIZONA-CALIFORNIA-NEVADA

Paul C. Marsh¹ and W. L. Minckley²

ABSTRACT.—The Colorado River system downstream from Lake Mohave yielded 42 adult, 19 juvenile, and 39 larval wild razorback suckers (*Xyrauchen texanus*) between 1962 and 1988. Forty-six additional young captured between 1984 and 1987 may have been wild or stocked, hatchery-propagated fish. Wild juveniles of this endemic, imperiled species, with one exception, have not been otherwise known from the Colorado River basin downstream from the Grand Canyon since the 1950s. A majority of adults and larvae were from the river or its mainstream impoundments, while all but one wild juvenile and all presumably stocked fish were captured from irrigation canals. The ecology of artificial canals in which young razorback suckers survive and grow is poorly understood.

The razorback sucker, *Xyrauchen texanus* (Abbott), a once abundant endemic fish of the Colorado River basin of western North America, now occurs naturally in only a few places. Populations upstream from the Grand Canyon are small in size and apparently declining (McAda and Wydoski 1980, Tyus 1987, Lanigan and Tyus, in press). Downstream, a substantial remnant population persists only above Davis Dam in Lake Mohave, Arizona-Nevada (Fig. 1, Minckley 1983). That stock is comprised of old individuals (McCarthy and Minckley 1987), which despite annual reproduction have apparently failed to recruit for nearly four decades.

In the 1950s, and before, razorback suckers commonly occurred as a reproductive population in the Colorado River downstream from Davis Dam, in Lake Havasu, and below (Jones et al. 1951, Douglas 1952, Jones and Sumner 1954, Minckley 1983). They are presently rare or sporadic in those river reaches (Minckley 1979, Loudermilk and Ulmer 1985, Marsh and Minckley 1987); only a small number of adults and a few young fish have been taken in recent years (in part, Minckley 1983, Ulmer and Anderson 1985). Programs to reintroduce the razorback suckers into historic habitats have been initiated by the states of Arizona and California (Johnson 1985, Ulmer and Anderson 1985). Substantial stockings of hatchery-produced fish into the lower Colorado River mainstream were commenced in spring 1986, although a

few experimental reintroductions were made earlier.

Occurrences of larvae or juveniles collected before the times of reintroductions, or in places inaccessible to stocked fish, represent natural production in the system. The intent of this paper is to separate records of natural occurrences from those attributable to hatchery fish. We document historic collections of small-sized razorback suckers downstream from Davis Dam, which, in light of recent age-and-growth and larval studies (McCarthy and Minckley 1987, Marsh and Papoulias, in press), provide evidence of recruitment to the population. We then report probable or known occurrences of reintroduced fish in the system; Langhorst (1988) further details short-term recaptures of hatchery-produced fish recently stocked by California. Comparisons of collection localities for juveniles before and following reintroduction efforts indicate that both wild and hatchery-propagated young of the species distribute themselves in similar ways, providing information pertinent to both the recovery program and the ecology of razorback suckers.

Acronyms used in the text for various agencies are as follows: AZGFD, Arizona Game and Fish Department; ASU, Arizona State University; CADFG, California Department of Fish and Game; NVDO, Nevada Department of Wildlife; USBR, U.S. Bureau of Reclamation; and USFWS, U.S. Fish and Wildlife Service. Funding for this work was

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RAZORBACK SUCKERS IN THE LOWER COLORADO RIVER

Natural Occurrences, 1962–88

Razorback suckers (>50 cm total length [TL]) are presently common in Lake Mohave, Arizona-Nevada, and larvae of the species (<15 mm TL) are seasonally abundant. Size-groups between the larval and adult life stages are, however, essentially absent from collections, despite intense sampling. Adults comprised an average of ~25% of total fishes caught in annual trammel net samples between 1975 and 1988 (Minckley 1983, Minckley and Marsh, unpublished data). Larvae occupy the littoral zone of Lake Mohave (Bozek et al. 1984, Marsh and Langhorst 1988), where 10–100 or more can be attracted to a strong light in a few minutes at night (Langhorst and Marsh 1986). They rarely occur in open water of the reservoir; Langhorst and Marsh (1986) captured only a single specimen in 22 tow-net hours in 1985, although larvae were at the same time common in near-shore habitats. Four juvenile specimens (three preserved, 33 to 54 mm TL; ASU 11567 and 11568), collected by AZGFD personnel in July 1987 (T. Liles, AZGFD, personal communication), are the only naturally spawned juveniles recorded from Lake Mohave since the 1950s.

In marked contrast, except for a small resident population in Senator Wash Reservoir, California (Medel-Ulmer 1980, Ulmer 1987), there are confirmed records since 1962 for only 42 adult razorback suckers from the entire lower Colorado River mainstream and associated habitats downstream from Davis Dam (Fig. 1), despite intensive fisheries surveys in that area. Sixteen adults were from Lake Havasu proper: five averaging 56.9 cm TL were caught in 1962; four >50 cm TL were observed in 1975; three averaging 65.4 cm were electrofished in 1976; one (56.9 cm) was collected from the Bill Williams Arm of the reservoir in 1979; two (unmeasured) were caught by anglers in 1984 (Ulmer and Anderson 1985); and a single fish 50.6 cm TL was

gill-netted in 1986 (M. Giusti, CADFG, personal communication). Riverine reaches yielded 23 individuals: 12, all >50 cm TL, but unmeasured, were taken by various means from Blythe, California, downstream to Imperial Reservoir from 1969 to 1985 (Ulmer and Anderson 1985); nine others, mostly >60 cm TL, were angled, electrofished, trammel-netted, or observed in the Needles-Topock Gorge reach from 1972 through 1985 (Minckley 1983, Ulmer and Anderson 1985); and two, 57.2 and 61.0 cm TL, were trammel-netted from Laughlin Lagoon, Nevada, an artificial backwater about 8 km below Davis Dam in 1986 (M. Burrell, NVDOW, personal communication). An additional three adults, ~50 cm TL, were caught from the Central Arizona Project (CAP) Granite Reef Aqueduct in October 1986 (USBR 1986), which began withdrawing water in 1983 from the Bill Williams Arm of Lake Havasu. Two of the last were 25+ years of age, as determined by otolith analysis (original data; following methodology of McCarthy and Minckley 1987), and thus originated from Lake Havasu. There are no indications that adult razorback suckers in the lowermost Colorado River are occurring less frequently in the 1980s than in the 1960s, which is likely a reflection of low adult mortality and individual longevity (to at least 44 years; McCarthy and Minckley 1987).

Larval razorback suckers are as rare as adults in the lower Colorado River downstream from Lake Mohave. None was found in shoreline surveys with bright light at night in Lake Havasu in 1988. Razorback suckers accounted for only 0.56% of 6,617 larval specimens caught in tow-net samples in Lake Havasu and upstream riverine reaches in 1985 and 1986 (Marsh and Papoulias, in press). Eight individuals were taken in 1985 and 29 in 1986. Although catch per unit effort varied between years and among stations, similar abundances were indicated in riverine and reservoir habitats, and no areas of larval concentration were evident (Marsh and Papoulias, in press). Two larval razorback suckers, ~15 mm TL, were also identified among 5,036 larval specimens from the CAP canal in 1987 (G. Mueller, USBR, personal communication).

Twenty-four juvenile razorback suckers, ~15 to 37.1 cm TL, fish of sizes not otherwise known from Lake Mohave or elsewhere in the

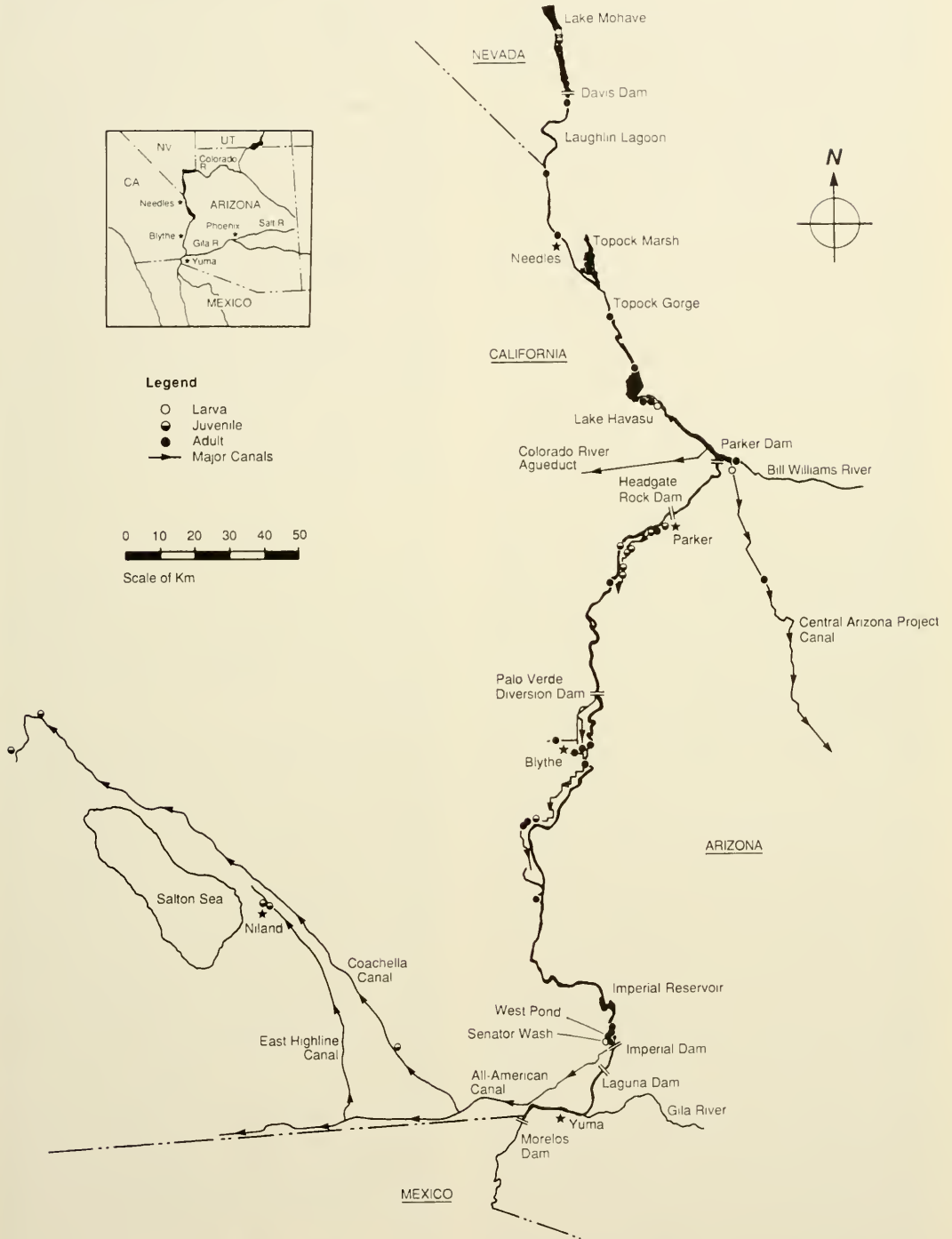


Fig. 1. Sketch map of the lower Colorado River, western North America, showing place names referred to in text and capture locations since 1962 for larval, juvenile, and adult razorback suckers.

Colorado River basin and thus the major subjects of this report, have been caught between 1974 and 1988 downstream from Lake Havasu. All but one were from the extensive system of artificial waterways that have been constructed for irrigated agriculture.

In Arizona, canals near Parker produced two fish (32.3 and 37.1 cm TL) in 1980, two specimens (each 30 cm) in 1981, and four averaging 35.2 cm in 1986 (Minckley 1983, Ulmer and Anderson 1985, S. Yess, USFWS, personal communication). Intake of water for the Parker area canal system is at Headgate Rock Dam, about 23 km downstream from Parker Dam. In California, one specimen (23.4 cm) was angled from a canal east of Palo Verde in 1983, which obtains its water from Palo Verde Diversion Dam, 21 km upstream from Blythe. Farther south, in Imperial Valley, the Coachella Canal (Fig. 1), its laterals, and its equalizing reservoirs produced three fish (average 34.8 cm TL) in 1984, and four others averaging 35.5 cm in April 1985 (Ulmer and Anderson 1985). Five young (~15 cm TL) were taken in 1973 and 1974 from the East Highline canal and adjacent ponds at Niland (St. Amant et al. 1974), a single fish measuring 22.5 cm fork length ($FL \times 1.085 \pm 0.021 = 24.4$ cm TL; unpublished data) was taken from the canal at Niland in 1974 (Ulmer and Anderson 1985), and another ~30.5 cm long was captured there from a canal-fed pond in December 1985 (E. Milstead, Niland, California, personal communication). Intake of water for the Imperial Valley is mostly through the All-American Canal, which originates near Imperial Dam (Fig. 1). The only small fish from the mainstem Colorado was a 35.1-cm individual captured 16 km downstream from Parker, Arizona, between Headgate Rock and Palo Verde Diversion dams, in summer 1987 (Langhorst 1988). That specimen was two years of age by otolith examination.

Assuming all these juvenile fish exhibited growth rates similar to those from Lake Mohave, hatchery ponds (McCarthy and Minckley 1987), and a variety of other waters where reintroduced populations have been studied (Marsh, in press, Marsh and Minckley, unpublished data), none was more than five years old. Only the eight fish captured in 1983 or later (three fish in 1984 and five others in 1985) from canals and other waters confluent with the All-American Canal (Fig. 1) could

have been derived via West Pond from artificially propagated stocks (see below); all others were wild fish.

Reintroductions, 1980–88

The first razorback sucker reintroduction to the lower Colorado River area was in 1980. It consisted of 17 hatchery-produced adults (average 32.5 cm TL; 1974 year class, Toney 1974) and 3 Lake Mohave adults (average 56.6 cm TL, ages unknown) into the isolated West Pond, Imperial County, California (Fig. 1; W. Loudermilk, CADFG, personal communication). An unknown number of progeny of Senator Wash Reservoir fish, artificially propagated and reared by CADFG personnel, also were stocked in West Pond between 1981 and 1983 (L. Ulmer, CADFG, personal communication). In November 1983, 457 razorback sucker juveniles (average 95 mm TL) from Lake Mohave broodstock also were stocked into an artificial rearing enclosure constructed in West Pond by USBR; samples of those fish averaged 115 mm ($N = 5$) in December 1983 and 156 mm ($N = 5$) in January 1984 (Ulmer, personal communication). West Pond and the enclosure were not again monitored until 1988, when no razorback suckers were encountered.

Because water from West Pond is pumped into the All-American Canal, these stocked fish could have contributed to the eight post-1983 juvenile occurrences downstream in the confluent Coachella and East Highline canals or their adjacent ponds and reservoirs. Furthermore, progeny of Senator Wash Reservoir adults, artificially propagated in spring 1983, were also reared in aquaria in Blythe, California, and later transferred for grow-out in local ponds. A total of 57 survivors (average 28.5 cm TL for 39 measured) was stocked into the Colorado River mainstem near Blythe in April 1985 (Ulmer, personal communication). A dozen others (unmeasured) from the same group were stocked into an isolated pond on federal lands in February 1986 (Ulmer, personal communication). These last two stockings could not have contributed to subsequent captures from the areas of Parker, Arizona, or Palo Verde, California, because they were downstream from barriers created by Headgate Rock and Palo Verde Diversion dams (Fig. 1); however, fish could have made their way downstream to Imperial Valley.

The first major reintroduction of razorback suckers in the mainstream was in March 1986, when nearly 1.4 million larvae (10–18 mm TL) were released by CADFG and USFWS at various localities along the Colorado River from Devil's Elbow and Blankship Bend (in the Topock Gorge area upstream from Lake Havasu, Fig. 1), downstream to Imperial National Wildlife Refuge near Yuma, Arizona. AZGFD and USFWS placed an additional 70,000 juveniles (~5.1 cm TL) into the Colorado River near Parker, Arizona, in May 1986, and CADFG stocked 4,163 juveniles (~20 cm TL) in the same area in October–November 1986. Since then, more than a million additional larvae and juveniles have been stocked downstream from Parker Dam (Langhorst 1988). These last stockings were all conducted later than the collections of all but one (Niland, December 1985) of the juveniles tabulated above, and of larvae reported by Marsh and Papoulias (in press).

Captures, 1987–88

Excluding the 1987 collection (Langhorst 1988) of a two-year-old individual in the Colorado River mainstream upstream from Palo Verde Diversion Dam (thus wild-hatched), a total of 41 juvenile razorback suckers was captured from canals downstream from Parker, Arizona, on the east (Arizona) side of the Colorado River in 1987 and 1988 (S. Yess, USFWS, personal communication). Thirty-eight fish caught in 1987 averaged 28.8 cm, and three taken in 1988 averaged 45.1 cm TL. Unfortunately, none from the first group was aged, but based on mean size they could have been one-year-old fish and therefore originated, at least in part, from the 1986 stockings. None could have been derived from earlier reintroductions, all of which were placed downstream from Headgate Rock Dam (Fig. 1). Fish of the second (1988) group had otolith ages of three, four, and seven years, having hatched, respectively, in spring 1981, 1984, and 1985. These were naturally produced wild fish, since dates of hatching do not correspond with those of any reintroductions in areas from which they could have moved to the collection sites.

DISCUSSION AND SUMMARY

Captures between 1974 and 1988 of at least 19 young, wild-hatched razorback suckers in

the lowermost Colorado River system downstream from Lake Mohave provide convincing evidence of potential recruitment to that population. Numbers recruited nonetheless appear insufficient to maintain a population of adults, since fish of reproductive size are exceedingly rare and scattered in distribution (42 adult individuals recorded in the period 1962–1988). Further, artificial canals where most young fish were recorded may act not only as a refuge for early development but as death traps later, during annual dewatering for maintenance of the irrigation system. Because of this, potential recruits may ultimately be lost to the population.

Waterways of Colorado River irrigation systems consist of two major components, *canals* and *drains* (or *wasteways*). Canals vary downward from maximum flows of 400 m³/sec. Water is withdrawn by gravity at diversion structures (e.g., Headgate Rock, Palo Verde, Imperial, and Laguna diversions) or through pumps (CAP and Colorado River Aqueduct intake facilities; USBR 1980; Fig. 1). Small *laterals*, which deliver water to agricultural fields or other points of use, are the least permanent, carrying water for only a few days or hours per month. Most canal habitats from which razorback suckers have been taken are of intermediate sizes that are dewatered at least annually for cleaning and repairs. Some of the largest canals may not be dewatered for periods of years.

Periodic cleaning and repair of canals is typically in the irrigation off-season, usually December or January. Fishes are decimated by dewatering and mechanical cleaning, and few survive (Marsh and Minckley 1982). However, razorback suckers spawn early, in late January through March, and larvae are thus available (generally from February through April; Marsh and Langhorst 1988) to colonize canals as they are placed back in service. Depleted populations of potential predators enhance larval survival, and razorback sucker growth rates (to 25+ cm in six months; unpublished data) are such that they rapidly grow out of predation range of small, abundant, nonnative predators (e.g., green sunfish, *Lepomis cyanellus*) and attain capabilities sufficient to avoid larger species (largemouth bass, *Micropterus salmoides*, and ictalurid catfishes, especially flathead catfish, *Pylodictis olivaris*). Further, annual drainage of

canals makes young razorback suckers susceptible to collectors. Now that the species is known from such places, biologists are alert for their occurrence. Interest among biologists along the lower river and extensive information exchange stimulated by active reintroduction programs have contributed to and increased the probability that razorback suckers will be noted.

Drains transport excess water used for leaching of salts from agricultural lands back to the river. They are fed by over-surface flow during irrigation cycles and subsurface percolation the rest of the time, which results in slow-moving, enriched aquatic habitats that are often densely vegetated by algae and macrophytes and may be characterized by chemical and thermal extremes (Minckley 1979). Drains are far more permanent than canals. Large drains rarely dry and are only sporadically disturbed by cleaning and maintenance operations in ways, such as dredging, that do not involve dewatering. There are, however, no known records for razorback suckers from drains.

Origins of Recruits

Larvae are most likely passively entrained into canals. Currents at intakes are substantial, and larval razorback suckers tend to be near shorelines, at least in reservoirs (Langhorst and Marsh 1986) and also in the only historic collection of aggregated larvae and juveniles of the species recorded from the mainstream Colorado River in 1950 (R. R. Miller, in Sigler and Miller 1963). Drifting catostomid larvae (*Catostomus insignis*, *Pantosteus clarki*) in the Gila River, New Mexico, were concentrated by a factor of 6.5 near banks compared with samples in midstream (Bestgen et al. 1987). Reintroduced juvenile razorback suckers also show a marked proclivity to move downstream (Brooks 1985). Such behavior would obviously enhance the probability of encountering a withdrawal point.

The absence of razorback suckers in drains may result from a lack of sampling. As noted above, these habitats are far more permanent than canals. In addition, they are more complex, and thus exceedingly difficult to sample. Drains may also suffer seasonal chemical and physical extremes that are lethal to fishes. They nonetheless often support substantial populations of nonnative species (Minckley

1979, Matter et al. 1986), including centrarchids and ictalurids that are demonstrated predators on young razorback suckers (Osmondson 1987, Marsh and Brooks, in press). Drains furthermore flow into the river, and larval or juvenile razorback suckers may either not actively ascend against current or may be blocked from ascent by structures designed to prevent headward erosion.

Young razorback suckers in the lower Colorado River system may have hatched in a number of places. Downstream, the Senator Wash Reservoir population occupies a small (190 ha) pump-storage impoundment, where they behave similarly to fish in Lake Mohave. A small number of adults (estimated population 54 ± 22 individuals [95% confidence limits] in 1980–81, which averaged ~ 60 cm TL in 1973–74 [10 fish]) spawn and produce larvae each year, which then disappear before achieving juvenile size (Ulmer and Anderson 1985). Some of these could conceivably pass through penstocks of the reservoir and enter downstream intakes that lead to Imperial Valley canals. Fish appearing in the Parker, Arizona, and Blythe, California, areas could similarly originate from reproduction in Lake Havasu (Marsh and Papoulias, in press), pass through epilimnetic penstocks of Parker Dam, and then be diverted into canals at Headgate Rock Dam or Palo Verde Irrigation Diversion, respectively. Other spawning areas are unknown but certainly may exist (Loudermilk 1985).

Occurrence in the Parker, Arizona, area in 1987 of 38 juveniles of a size attributable to the 1986 reintroductions, and three in 1988 that were wild fish, underlines a number of needs and factors to consider. First, it is imperative that reintroduced fish be marked, by fin removal or with oxytetracycline, for example, so they may be certainly and readily discriminated from naturally produced individuals. Only in this way can the relative contributions of natural and reintroduction recruitment be evaluated. Second, assuming that some or all fish caught in 1987 were reintroduced, stocked and naturally produced larvae and juveniles must behave similarly, since they both appear to have passed from the river into canals. This provides information that razorback sucker larvae and/or juveniles drift or move downstream after hatching (or introduction), and likely did so in the natural state.

Last, survival to the juvenile stage in predator-poor habitat of canals further strengthens the hypothesis (Minckley 1983, Marsh and Langhorst 1988) that attributes lack of recruitment by this imperiled species to direct predation by introduced, nonnative piscivores.

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