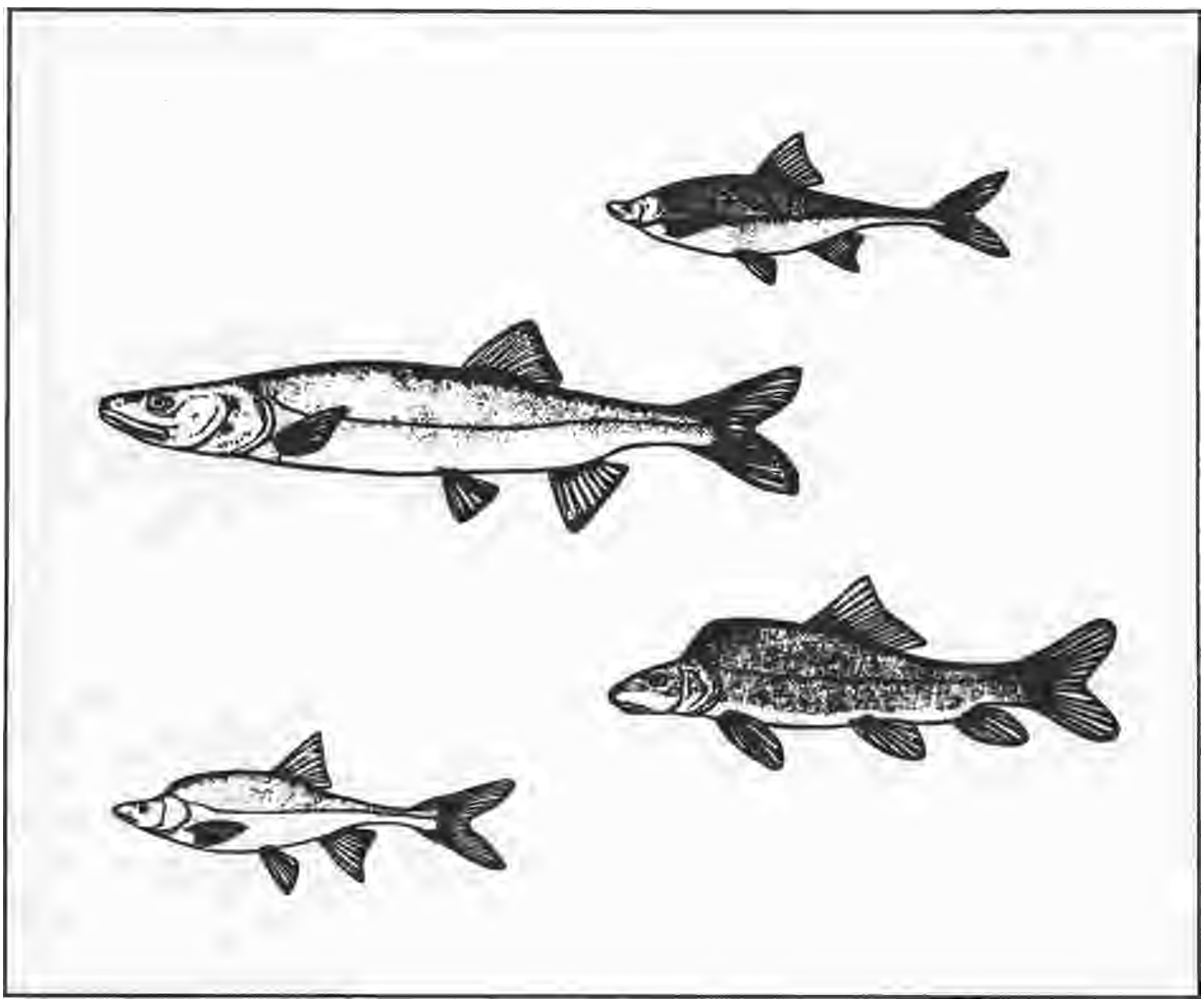
# •Colorado River Endangered Fishes Critical Habitat

## DRAFT

## BIOLOGICAL SUPPORT DOCUMENT



Department of the Interior
U.S. Fish and Wildlife Service
2060 Administration Bldg.
Salt Lake City, Utah 84104-5110

# COLORADO RIVER ENDANGERED FISHES
# CRITICAL HABITAT

# DRAFT
# BIOLOGICAL SUPPORT DOCUMENT

**by**

**Henry R. Maddux**
**Lesley A. Fitzpatrick**
**William R. Noonan**

September 3, 1993

U.S. Fish and Wildlife Service
Utah/Colorado Field Office
2060 Administration Building
1745 West 1700 South
Salt Lake City, Utah 84104-5110

# ACKNOWLEDGEMENTS

We wish to acknowledge some of those who have helped in the preparation of this document. Our greatest thanks goes to the many researchers who have spent years collecting valuable data on the fishes in the Colorado River Basin. Without these data, there would be no hope for recovery of these species. Patty Schrader helped in preparing numerous sections within this document. Her timely assistance is appreciated. Thanks to Harold Tyus and Charles Minckley for their much needed review of an earlier draft of this document. Kristen Kingery, Cheryl Breeher, and Yvonne Russell spent many hours editing and improving this document. Their efforts are greatly appreciated.

**TABLE OF CONTENTS**

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF APPENDICES

## PURPOSE

This document provides Federal, State, Tribal and local agencies, and the public with additional information about the proposed designation of critical habitat for four Colorado River endangered fishes. This document, the economic analysis, and other supporting documents provides additional information on the proposed designation. All comments received will be evaluated by the U.S. Fish and Wildlife Service (Service) for use in preparation of the final rule designating critical habitat for the four Colorado River endangered fishes.

## INTRODUCTION

The Endangered Species Act (Act) of 1973, as amended, requires the Service to designate critical habitat to the maximum extent prudent and determinable concurrent with listing a species as endangered or threatened. This proposal is for four species of fish in the Colorado River Basin (Basin) which were listed as endangered without designation of critical habitat.

The Colorado squawfish and humpback chub were listed as endangered species on March 11, 1967 (32 FR 4001). The bonytail was listed as endangered on April 23, 1980 (45 FR 27713). On May 16, 1975, the Service published a notice of its intent to determine critical habitat for the Colorado squawfish, humpback chub, and numerous other species (40 FR 21499). On September 14, 1978, the Service proposed critical habitat for the Colorado squawfish (43 FR 41060). The proposal was for 623 miles of the Colorado, Green, Gunnison, and Yampa Rivers. This proposal was later withdrawn (44 FR 12382; March 6, 1979) to comply with 1978 amendments to the Act (16 U.S.C. 1531 *et. seq.),* that required the Service to include critical habitat in the listing of most species and to complete the listing process within 2 years from the date of the proposed rule or withdraw the proposal from further consideration. The Service did not complete the listing process within the 2-year deadline. The razorback sucker was proposed for listing as a threatened species on April 24, 1978 (43 FR 17375). The proposal was withdrawn on May 27, 1980 (45 FR 35410), in accordance with 1978 amendments to the Act.

On March 15, 1989, the Service received a March 14 petition from the Sierra Club, National Audubon Society, The Wilderness Society, Colorado Environmental Coalition, Southern Utah Wilderness Alliance, and Northwest Rivers Alliance to list the razorback sucker as an endangered species. The Service made a positive finding in June 1989 and subsequently published a notice on August 15, 1989 (54 FR 33586). This notice also stated that the Service was completing a status review and was requesting that additional information be provided by December 15, 1989. A proposed rule to list the razorback sucker as an endangered species was published on May 22, 1990 (55 FR 21154), and a final rule listing the fish without critical habitat was published on October 23, 1991 (56 FR 54957). In the final rule, the Service concluded that critical habitat was not determinable at the time of listing and questioned whether it was prudent to designate critical habitat for this fish.

On October 30, 1991, the Service received a 60-day notice of intent to sue from the Sierra Club Legal Defense Fund. The notice indicated that the Service failed to designate critical habitat concurrent with listing of the razorback sucker, pursuant to Section 4(6)(c) of the Act. A second notice of intent to sue, dated January 30, 1992, was subsequently received. On December 6, 1991, the Service concluded that designation of critical habitat was prudent and determinable and, therefore, critical habitat for the razorback sucker should be designated. Because the intent of the Act is ". . . to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved . . .", the Service also decided to propose critical habitat for the Colorado squawfish, humpback chub, and bonytail. The four endangered Colorado River fishes coexist in the Basin and much of their habitats overlap.

On May 7, 1992, the Sierra Club Legal Defense Fund filed a lawsuit in the U.S. District Court (Court), Colorado, on behalf of the Colorado Wildlife Federation, Southern Utah Wilderness Alliance, Four Corners Action Coalition, Colorado Environmental Coalition, Taxpayers for the Animas River, and Sierra Club. On August 18, 1992, a motion for summary judgment was filed which requested the Court to order a final rule designating critical habitat within 90 days. In opposition to the motion, the Service explained that the complex analyses, required for designating critical habitat could not be completed until September 1993. This delay was needed to compile biological and hydrological data, and conduct an economic analysis for portions of seven western States. On October 27, 1992, the Court ruled that the Service had violated the Act in failing to designate critical habitat when the razorback sucker was listed. The Court ordered the Service to publish a proposed rule within 90 days designating critical habitat for the razorback sucker, and to publish a final rule "at the earliest time permitted and in accordance with" the Act. The Service published the proposed rule on January 29, 1993 (58 FR 6578).

In designating critical habitat, the Service followed specific provisions of the Act, which provide no alternatives on what must be designated. Critical habitat is defined in Section (3)(5)(A) of the Act to include areas occupied or not that are essential to the conservation of each species. Conservation is defined in the Act as that needed to bring about the complete recovery of the species. Therefore, the Act dictates what is included in the proposed critical habitat designation.

The process for designating critical habitat for the razorback sucker, bonytail, humpback chub, and Colorado squawfish (referred to collectively as Colorado River endangered fish in this document) consists of three major steps. The first step was to complete a biologically-based determination of potential critical habitat areas. This step provided an inventory of areas needed for the survival and recovery of the species. For the razorback sucker, the biological determination was based on the primary constituent elements and additional selection criteria determined by the Service. These constituent elements and additional selection criteria were then applied throughout the historic range of the razorback sucker. For the bonytail, humpback chub, and Colorado squawfish, the biological determination was based on the primary constituent elements and existing recovery plans for these species. The second step was to determine the potential impacts of the proposed designation. This is addressed in an analysis of economic costs and other relevant impacts. The final step is to decide which areas, if any, should be excluded based upon economic or other relevant impacts (social, cultural, etc.) and to determine costs and benefits associated with the final designation.

## BACKGROUND

### THE COLORADO RIVER BASIN

Headwaters of the Basin originate in the Rocky, Wasatch, Uinta and San Juan mountains of Colorado, Wyoming, Utah, and New Mexico. The Basin drains approximately 242,000 square miles of the United States and about 2,000 square miles of Mexico. The portion in the United States includes the states of Arizona, California, Colorado, Utah, Nevada, New Mexico, and Wyoming. To facilitate management of the water resources, the Basin was divided into Upper and Lower basins (Figure 1) by agreement between seven Basin States in the 1922 Colorado River Compact (1922 Compact). The Upper Basin begins at the headwaters and ends at Lee's Ferry, Arizona (16 miles below Glen Canyon Dam). Major drainages in the Upper Basin include the Upper Colorado, Green, Gunnison, and San Juan rivers. The Lower Basin begins at Lee's Ferry and ends at the United States/Mexico border. Major drainages in the Lower Basin include the Lower Colorado, Little Colorado, Virgin, and Gila rivers. The latter also includes the Salt and Verde river drainages.

The Colorado River Basin includes aquatic and terrestrial ecosystems. The fish fauna is composed of endemic fishes (found only in the Basin), native nonendemic fishes, and nonnative fishes that have been introduced by man.

The native fish fauna is characterized by only a few species and most of these are restricted to different subbasins or individual river systems. Carlson and Muth (1989) identified 36 native fishes (included in Table 1). Several of the species in Table 1 include one or more subspecies that are more restricted in distribution. Of the 38 fishes listed in Table 1, eight (21 percent) were found throughout the Basin, six (15 percent) in the Upper Basin, and 24 (63 percent) in the Lower Basin. The large number of species in the Lower Basin is likely reflective of climate, geologic change, and a wider variety of aquatic habitats. Because of geologic isolation, the Colorado River contains far fewer native species than other large river systems (e.g., Missouri River Basin has 150 native fish species; Hesse and Sheets 1993).

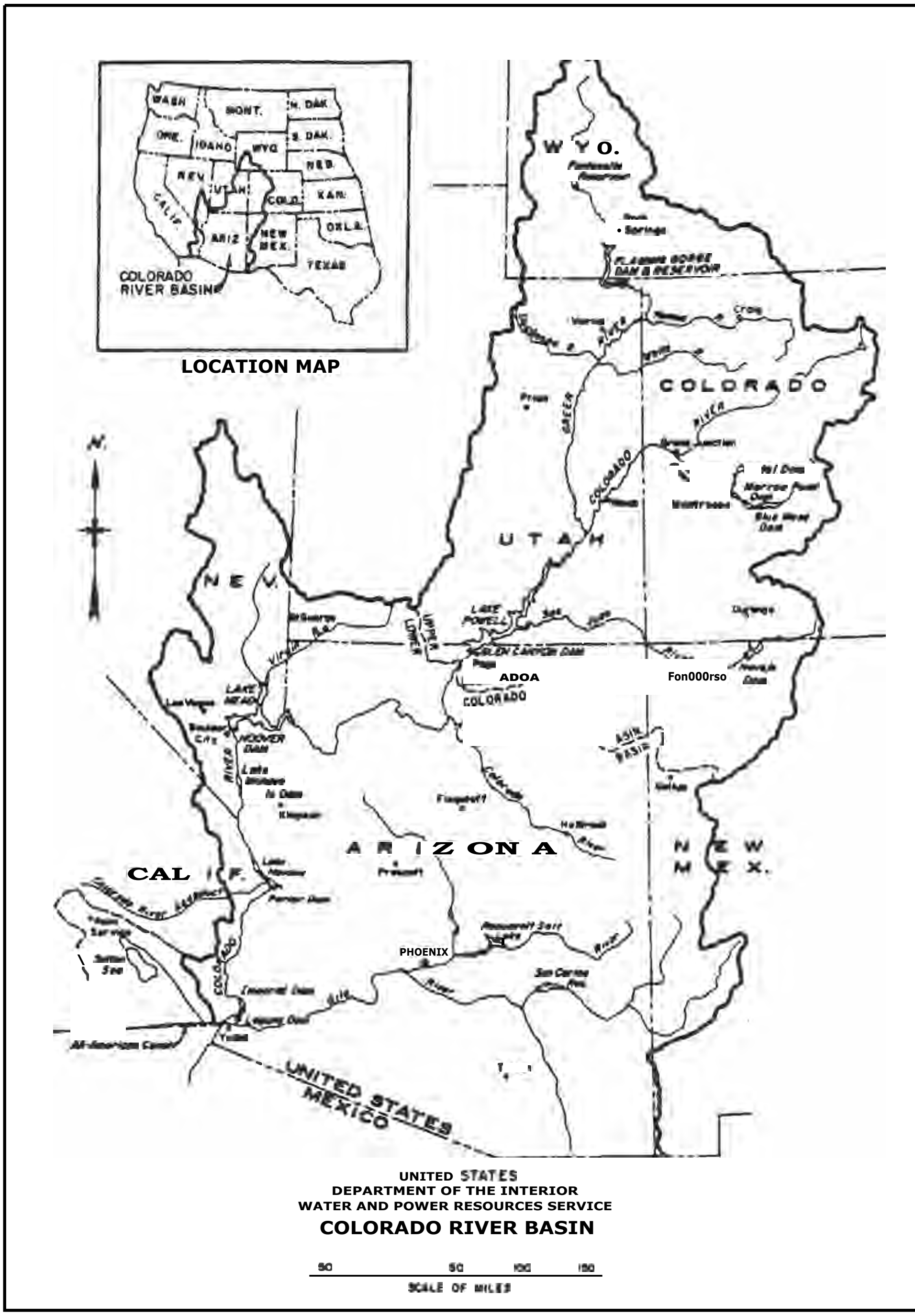



Figure 1. Map of Colorado River Basin.

Table 1. Native fish species of the Colorado River Basin.

| COMMON NAME | SCIENTIFIC NAME |
|---|---|
| Family Elopidae | |
| Machete | ***Elops affinis*** |
| Family Salmonidae | |
| Apache trout | ***Oncorhynchus apache*** |
| Colorado cutthroat trout | ***Oncorhynchus clarki pleuriticus*** |
| Gila trout | ***Oncorhynchus gilae*** |
| Rocky Mountain whitefish | ***Prosopium williamsoni*** |
| Family Cyprinidae | |
| Longfin dace | ***Agosia*** *chrysogaster* |
| Humpback chub | ***Gila cypha*** |
| Bonytail | ***Gila elegans*** |
| Gila chub | ***Gila*** *intermedia* |
| Roundtail chub | ***Gila robusta*** |
| Virgin chub | ***Gila seminuda*** |
| Virgin spinedace | ***Lepidomeda mollispinus*** |
| Little Colorado spinedace | ***Lepidomeda vittata*** |
| White River spinedace | ***Lepidomeda albivallis*** |
| Pahranagat spinedace | ***Lepidomeda altivelis*** |
| Spikedace | ***Meda fulgida*** |
| Moapa dace | ***Moapa coriacea*** |
| Woundfin | ***Plagopterus argentissimus*** |
| Colorado squawfish | *Ptychocheilus* ***lucius*** |
| Las Vegas dace | ***Rhinichthys deaconi*** |
| Speckled dace | ***Rhinichthys osculus*** |
| Loach minnow | ***Rhinichthys cobitis*** |
| Kendall Warm Springs dace | ***Rhinichthys osculus*** *thermalis* |
| Family Catostomidae | |
| Desert sucker | ***Catostomus clarki*** |
| Bluehead sucker | ***Catostomus discobolus*** |
| Sonora sucker | ***Catostomus insignis*** |
| Flannelmouth sucker | ***Catostomus latipinnis*** |
| Mountain sucker | ***Catostomus*** *platyrhynchus* |
| Little Colorado sucker | ***Catostomus sp.*** |
| Razorback sucker | ***Xyrauchen texanus*** |

**Table 1 (continued).**

| COMMON NAME | SCIENTIFIC NAME |
|---|---|
| **Family Cyprinodontidae** | |
| Moapa/White River springfish | *Crenichthys baileyi* |
| Railroad Valley springfish | *Crenichthys nevadae* |
| Desert pupfish | *Cyprinodon macularius* |
| Monkey Springs pupfish | *Cyprinodon sp.* |
| **Family Poeciliidae** | |
| Gila topminnow | *Poeciliopsis occidentalis* |
| **Family Cottidae** | |
| Mottled sculpin | *Cottus bairdi* |
| Paiute sculpin | *Cottus beldingi* |
| **Family Mugilidae** | |
| Striped mullet | *Mugil cephalus* |

Changes to the aquatic resources of the Basin has had a profound effect on the native fish fauna. Several species and subspecies are extinct, including the Las Vegas dace, Pahranagat spinedace and Monkey Springs pupfish. Of the remaining species, 44 percent are federally listed as endangered or threatened and an additional 28 percent identified as candidates to the Federal lists. Only 20 percent of the native fish fauna has not been identified as potentially in need of protection under the Act. The Basin States also have acknowledged the need to protect the native fish species. Over 70 percent of the native species are on State lists of special status species.

Historically, the native fish fauna of the mainstream Colorado River was dominated by native minnows (cyprinids) and suckers (catostomids) (Minckley et al. 1986). However, four of these, the razorback sucker, Colorado squawfish, humpback chub, and bonytail, are now federally listed as endangered species. These fishes are threatened with extinction due to the combined effects of habitat loss (including regulation of natural flow, temperature, and sediment regimes); proliferation of introduced fishes; and other man-induced disturbances (Miller 1961; Minckley 1973; Carlson and Muth 1989; Minckley and Douglas 1991).

Colorado squawfish populations only in the Upper Basin, where their numbers are relatively high only in the Green River basin of Utah and Colorado (Tyus 1991a). Razorback sucker and bonytail chub stocks consist predominately of old adult fish, and they remain only because of the longevity inherent in these species (USFWS 1990a; Minckley et al. 1991).

Humpback chub populations in the Little Colorado River and the Black Rocks area on the upper Colorado River appear relatively stable in number of fish, but declines have been apparent in other locations (USFWS 1990b).

## COLORADO RIVER FLOODPLAIN

North temperate riverine, or lotic, ecosystems are dynamic and complex. Large river systems are composed not only of the mainstream channels in which water is maintained most or all of the year, but an integral, natural part of these rivers are upland habitats that are inundated during the higher water levels that are usually associated with spring flows. These seasonally flooded habitats are major contributors to the biological productivity of the river system by providing inputs of nutrients and making terrestrial food sources available to aquatic organisms (Hesse and Sheets 1993) . The extent of flooded wetlands in the Colorado River has been reduced by the construction and operation of water resources development projects (Carlson and Muth 1989), and the remaining flooded uplands have great importance for recovery of endangered fishes.

Studies of the major floodplain rivers of the world have documented the high value of flooded bottomlands and other flooded uplands for fish production (e.g., Welcomme 1979). Because fishes are highly mobile, many species are able to take advantage of food sources made available by flooded lands. Indeed, many fishes have developed migratory strategies that allow them to utilize inundated areas as spawning, nursery, and foraging areas (Lowe-McConnell 1975; Welcomme 1979). In this context, a rich food source of terrestrial origin may enhance fish growth, fecundity, and/or survival. Use of these inundated floodplains increases the energy available for spawning and is necessary for reproductive success in some species (Finger and Stewart 1987). In many cyprinid fishes, spawning is associated with seasonal rains and flooding of rivers, and it has been found that flood-related changes in the river environment not only induce spawning for many species, but these changes comprise the ultimate factors limiting the survival of eggs, larvae, or young fish (Hontela and Stacey 1990).

Loss of inundated floodplain habitats in the Missouri River Basin has been associated with a concomitant reduction of as much as 98 percent of fish biomass (Karr and Schlosser 1978). Inundation of floodplain during spring flows also provides areas with warmer water temperatures, low velocity resting habitat, and cover from predation in flooded terrestrial vegetation. Recent studies in the Colorado River system have shown that the life histories and welfare of native riverine fishes is linked with the maintenance of a natural or historic flow regimen; i.e., a hydrological pattern of high spring and low autumn-winter flows that vary in magnitude and duration depending on annual precipitation patterns and runoff from snowmelt (Tyus and Karp 1989, 1990). This relationship is so evident to ichthyogists that it has been predicted that stream regulation that results in loss of flooding will result in extirpation of many native fish species in the Colorado River system (Minckley and Meffe 1987).

## LIFE HISTORIES OF COLORADO RIVER ENDANGERED FISHES

The Service is mandated to determine critical habitat, and to use the best scientific and commercial data available (50 CFR 424.12). Current knowledge of the life history needs of the razorback sucker was presented in the Service's final rule (56 FR 54957). The bonytail, humpback chub, and Colorado squawfish life history needs were presented in the recovery plans for each of those species (USFWS 1990a, 1990b, 1991). Biological information developed since listing the razorback sucker and preparation of recovery plans has also been used to determine habitat needs of the fishes. Also, the Service incorporated unpublished information from current research on the Colorado River endangered fishes to ensure the best and most recent scientific and commercial data were used for this determination.

These fishes evolved in the Colorado River and were adapted to the natural environment that existed prior to the beginning of large-scale water development. Thus, they were adapted to a system of fluctuating seasonal and annual flows influenced by wet, average, and dry climatic periods. Recent population declines and disappearances of endemic fish species in much of their former range have been associated with relatively rapid and widespread anthropogenic changes. These changes have altered the physical and biological characteristics of many mainstream rivers in the Basin and occurred so rapidly that the fishes have not had time to adapt to them (Carlson and Muth 1989). Dams and diversions have fragmented former fish habitat by restricting fish movement. As a result, genetic interchange (emigration and immigration of breeding individuals) between some fish populations is nonexistent. Large floods were once normal in the Basin, and provided food and nutrient exchange between river channels and shallow-water floodplain habitats. These floods are now controlled by numerous dams. As a result of these dams, major changes also have occurred in water quality, quantity, temperature, sediment and nutrient transport, and other characteristics of the aquatic environment (Carlson and Muth 1989). The altered habitats that have resulted are now more suitable for introduced, nonnative fishes, some of which have flourished (Tyus et al. 1982a; Carlson and Muth 1989; Minckley and Douglas 1991). These changes have greatly altered the river environment and little or no unaltered habitat remains in the Basin for the four Colorado River endangered fish species.

### RAZORBACK SUCKER *(Xyrauchen texanus,* Abbott 1861)

The razorback sucker is part of a unique fish fauna endemic to the Colorado River Basin (Miller 1946, 1959). This species was once one of the most abundant and widely distributed fish in the mainstream rivers of the Basin (Jordan and Evermann 1896; Minckley 1973). Historic riverine systems provided a wide variety of habitats occupied by razorback suckers including backwaters, sloughs, and oxbow lakes (Holden and Stalnaker 1975a; Minckley 1983; Tyus 1987; Tyus and Karp 1990).

## HISTORIC DISTRIBUTION AND ABUNDANCE

The razorback sucker was once abundant throughout 3,500 miles of the Basin (Figure 2), primarily in the mainstem and major tributaries in Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming; and in the States of Baja California Norte and Sonora of Mexico (Ellis 1914; Minckley 1973).

These fish were most abundant downstream of present-day Lake Mead and very abundant around Yuma, Arizona (Gilbert and Scofield 1898). There are few records of razorback suckers in Grand and Marble Canyons, perhaps due to lack of early sampling in these inaccessible canyon areas (Minckley and Carothers 1980; Minckley et al. 1991) or razorback suckers may have been historically uncommon in turbulent canyon reaches of the Lower Colorado River Basin (Bestgen 1990). Archeological remains of razorback suckers were common in the Salton Sea area (Minckley 1983; Minckley et al. 1991; Gobalet 1992), but increasing salinity made this habitat marginal for freshwater fishes after 1929 (Evermann 1916; Coleman 1929). Razorback sucker historically occurred in most warmwater reaches of the Gila River drainage (Bestgen 1990). Early reports suggest that it was common in the Gila River nearly to the New Mexico border (Kirsch 1888). Razorback suckers were abundant in the lower Salt River and in lower Tonto Creek (Hubbs and Miller 1953) and it occurred in the Verde River to Perkinsville, Arizona (Minckley 1973). Upstream distribution in the Salt River may have been limited by extensive canyon habitat (Bestgen 1990).

In the Upper Basin, razorback suckers historically occurred in the Colorado, Green, and San Juan River Basins. In the Colorado River, razorback suckers occurred from Lee's Ferry to near Rifle, Colorado. They also were found in the Gunnison River upstream to Delta, Colorado (Hubbs and Miller 1953; Wiltzius 1978; Holden 1980). No records exist for razorback sucker in the Dolores River (Holden and Stalnaker 1975b). Historic distribution of razorback suckers in the Green River was from its confluence with the Colorado River upstream to Green River, Wyoming (Jordan 1891; Evermann and Rutter 1895; Sigler and Miller 1963; Baxter and Simon 1970; Vanicek et al. 1970). Razorback sucker have been captured in the lower few miles of the Duchesne River (Tyus 1987). Sigler and Miller (1963) report them uncommon in the lower White River near Ouray, Utah. Razorback sucker occur in the lower Yampa River and are considered rare upstream to the Little Snake River, Colorado (McAda and Wydoski 1980; Lanigan and Tyus 1989). Historic status of the razorback sucker in the San Juan drainage is not well known (Bestgen 1990). There is some anecdotal evidence that razorback suckers "ran" up the Animas River (Jordan 1891). Platania (1990) reported that the first verified record of razorback sucker from the San Juan River basin/drainage was in 1976 when two adults were collected from an irrigation pond near Bluff, Utah.

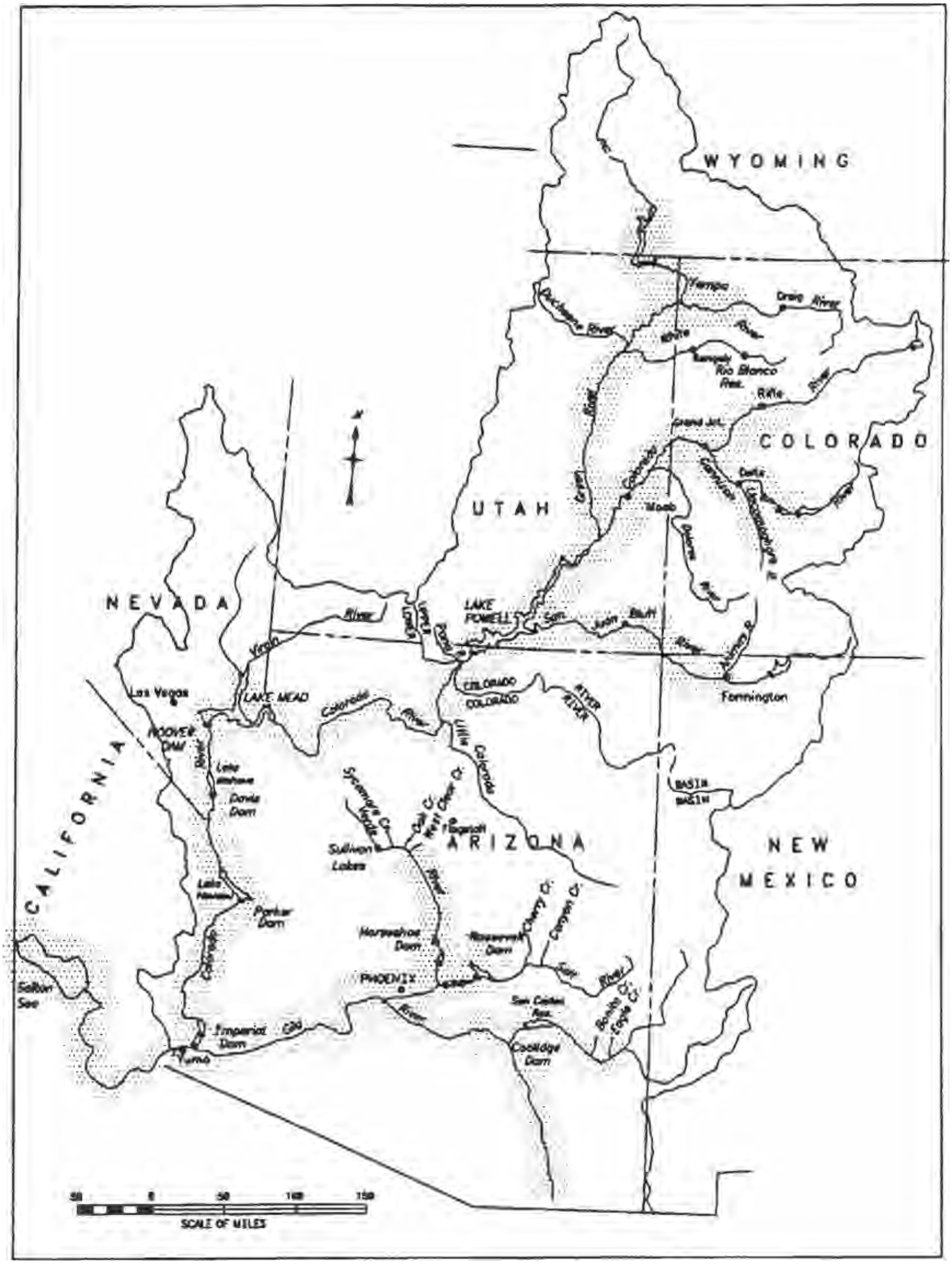



Figure 2. Historical distribution (shaded area) of the razorback sucker. (Adapted from Minckley et al. 1991).

## CURRENT DISTRIBUTION AND ABUNDANCE

Upper Basin razorback sucker distribution has been reduced to about 750 miles (Holden and Stalnaker 1975a; Ecology Consultants, Inc. 1978; McAda and Wydoski 1980). In the Upper Basin, the fish persists in the lower Yampa and Green rivers, mainstream Colorado River, and lower San Juan River (Tyus et al. 1982a; Minckley et al. 1991; Platania et al. 1991), but there is little recruitment in these remnant populations. The largest extant riverine population occurs in the upper Green River Basin, but consisted of only about 1,000 fish in 1988 (Lanigan and Tyus 1989). In the absence of conservation efforts, these wild populations will be lost as old fish die and are not replaced.

The largest concentration of razorback suckers in the Upper Basin occurs in the upper Green River from the mouth of the Duchesne River upstream to the Yampa River (Tyus 1987; Lanigan and Tyus 1989; Tyus and Karp 1991). Lanigan and Tyus (1989) estimated that 758 to 1,138 razorback suckers still inhabit the upper Green River. In the upper Colorado River subbasin, most razorback suckers occur in the Grand Valley area where the number of adult captures has declined appreciably since 1974 (Valdez et al. 1982b; Osmundson and Kaeding 1989). Recent studies on the San Juan River found razorback suckers in the San Juan arm of Lake Powell near Piute Farms, and one adult male near Bluff, Utah (Platania 1990).

In the Lower Basin, the decline of razorback suckers shortly after impoundment of Lake Mead in 1935 was noted by several researchers (Dill 1944; Miller 1946; Wallis 1951; Jonez and Sumner 1954). Now, a substantial population exists only in Lake Mohave estimated at approximately 60,000 adult razorback suckers (Minckley et al. 1991).

Small numbers of razorback suckers sporadically occur in Lake Mead and the Grand Canyon and below Lake Mohave in the mainstem and associated impoundments and canals (Marsh and Minckley 1989). Successful spawning has been documented in Lake Mohave and numerous larvae have been collected (Bozek et al. 1984; Marsh and Langhorst 1988). However, juveniles have been extremely rare in collections since the early 1950's (Minckley et al. 1991).

No significant recruitment to any populations has been documented in recent years (Tyus 1987; McCarthy and Minckley 1987; Osmundson and Kaeding 1989; Tyus and Karp 1991). The formerly large Lower Basin populations have been extirpated from most riverine environments, and recruitment is virtually nonexistent in the remnant stocks (Minckley et al. 1991).

## STATUS

The razorback sucker has been negatively affected by perturbations to its environment. These perturbations have resulted in genetic isolation, lack of recruitment, and an adult population nearing its maximum life expectancy. As these older fish die, wild populations of razorback sucker will disappear if habitat conditions favoring recruitment do not improve.

Recent research in Davis and Yuma coves on Lake Mohave sponsored by the Bureau of Reclamation (Reclamation) has shown that razorback sucker larvae can survive and grow successfully if the predator load is reduced (Burke 1992).

## HABITAT REQUIREMENTS

Although habitat use of razorback suckers has been studied for years, the habitat preferences and factors limiting their abundance in native riverine habitats are not well known because of the scarcity of extant populations (Minckley 1983; Lanigan and Tyus 1989) and the absence of younger life history stages (Minckley et al. 1991). However, based on available data taken from the Green River, Tyus and Karp (1989) considered the lack of low winter flows, high spring flows, seasonal changes in river temperatures, and inundated shorelines and bottomlands as factors that potentially limit the survival, successful reproduction, and recruitment of this species.

### Spawning Habitat

Reproduction and habitat use of razorback suckers has been studied in lower basin reservoirs, especially in Lake Mohave. Fish reproduction has been visually observed near reservoir shorelines for many years, and spawning in the reservoir usually lasts from January or February to April or May. The fish spawn over mixed substrates that range from silt to cobble, and at water temperatures ranging from 51 to 70°F (reviewed by Minckley et al. 1991).

Habitat use and spawning behavior of 307 adult razorback suckers in riverine habitats were studied by fish captures and radiotelemetry in the Green River Basin (Tyus and Karp 1990). The fish there spawned in the spring with rising water levels and increasing temperatures. The fish moved into flooded areas in early spring, and they made spawning migrations to specific locations as they became reproductively active. Spawning occurred over rocky runs and gravel bars. It has been observed that several males accompany a single female (Jonez and Sumner 1954; Ulmer 1980).

In the Upper Basin, spawning occurs from April through June 14 (Tyus 1987; Osmundson and Kaeding 1989; Tyus and Karp 1990). Water temperatures recorded in the upper Green River during spawning ranged from 48° to 63°F (Tyus and Karp 1990). McAda and Wydoski (1980) reported spawning fish in May over cobble substrates, about 3.2 feet/sec. water velocity and 3.2 feet water depth. Tyus (1987) collected ripe adults over coarse sand substrates and in the vicinity of gravel or cobble bars, but direct observation of spawning was not possible because of high turbidities prevalent during that time of year. Osmundson and Kaeding (1989) suggested that flooded bottomlands in the Grand Valley were historically the primary spawning habitats. McAda and Wydoski (1980) collected running ripe females from a gravel pit where they were probably spawning. Tyus and Karp (1990) found the average water depth of the gravel and cobble bars to be 2 feet with an average water velocity of 2.4 feet/s.

Spawning occurs in the Lower Basin from January through April (Ulmer 1980; Langhorst and Marsh 1986; Mueller 1989). Water temperatures during spawning in the Lower Basin ranged from 53° to 64°F (Douglas 1952; Ulmer 1980; Langhorst and Marsh 1986). Spawning has been extensively documented in Lower Basin reservoirs in flat or gently sloping offshore areas over gravel, cobble, or mixed substrate types (Douglas 1952; Ulmer 1980; Bozek et al. 1984; Minckley et al. 1991). Ulmer (1980) observed spawning activity in Senator Wash Reservoir in 10 to 18 feet of water. In Lake Mohave, razorback suckers were observed during spawning in water depths of <3 to 16 feet, with most fish in <7 feet of water (Bureau of Reclamation, unpublished data).

Bestgen (1990) concluded that razorback suckers may spawn in a variety of flow conditions, from rivers to impoundments. He also concluded that their longevity allows them to persist through several consecutive seasons of no or low reproduction; an adaptation to the pristine conditions of the highly fluctuating and unpredictable Colorado River system.

**Nursery Habitat**

Habitats used by young razorback suckers have not been fully evaluated because of the low number of young fish present in the river system. However, most studies agree that the larvae prefer shallow, littoral zones for a few weeks after hatching, then they disperse to deeper water areas (reviewed by Minckley et al. 1991). Laboratory studies indicated that, in a riverine environment, the larvae enter stream drift and are transported downstream (Paulin et al. 1990).

A number of investigators have collected viable fertilized eggs and larvae in the areas of known spawning activity (Ulmer 1980; Bozek et al. 1984; Tyus 1987; Marsh and Langhorst 1988), but few have collected larvae larger than 0.6 inches in the wild. This indicates little or no successful recruitment of wild razorback suckers. Several researchers have observed predation on razorback sucker eggs and larvae by carp, channel catfish, smallmouth bass, largemouth bass, bluegill, green sunfish, and redear sunfish (Jonez and Sumner 1954; Ulmer 1980; Marsh and Langhorst 1988; Langhorst 1989). Other researchers hypothesized that predation is a major cause underlying the lack of recruitment to the adult razorback sucker population throughout the basin (McAda and Wydoski 1980; Minckley 1983; Tyus 1987). Loudermilk (1985) observed that young razorback sucker larvae inhabited the upper water column for the first few days after swim-up and exhibited no defensive behavior from potential predators. Karp and Tyus (1990) observed that several fish species readily attacked razorback sucker larvae in lab experiments. Marsh and Langhorst (1988) found larval razorback suckers in Lake Mohave survived longer and grew larger in the absence of predators.

**Juvenile and Adult Habitat**

Habitat needs of young and juvenile razorback suckers in the wild are little known because they have rarely been encountered by researchers, particularly in native riverine habitats

(Tyus 1987). Taba et al. (1965) collected juveniles from backwaters in the Colorado River near Moab, and G.R. Smith (1959) caught two young fish on the Colorado River in Glen Canyon; one from a backwater and one from a creek mouth. In 1950, R.R. Miller seined 6,600 young-of-year along warm, shallow margins of the Colorado River at Cottonwood Landing, Nevada (Sigler and Miller 1963). Marsh and Langhorst (1988) observed that larval razorback suckers in Lake Mohave remained near shore after hatching but either disappeared or migrated to deep water within a few weeks. In recent years, juvenile razorback suckers have been collected from lateral canals off the Colorado River in the Lower Basin (Minckley and Marsh 1989; Charles Minckley, USFWS, pers. comm.). Two were collected in a backwater in the lower Green River (Tom Chart, UDWR, pers. comm.). Observations of young hatchery-produced fish found that they remained along shorelines, in embayments along sandbars, or in tributary mouths, eventually dispersing into channels or larger backwaters (Minckley et al. 1991).

Based on limited razorback sucker data and analogy with life history requirements of other native Colorado River fishes, it is probable that young razorback suckers require quiet, warm, shallow water for nursery habitats. These habitats are provided by backwaters and flooded bottomlands that form at various flow levels in riverine environments and by coves in reservoir environments. Backwaters have been identified as important nursery habitat for many species of native fish, providing quiet, warmwater and potential for increased food availability (Valdez and Wick 1983). During high flow periods, flooded bottomlands and tributary mouths also provide quiet water areas and Tyus and Karp (1989, 1990) implied that flooded bottomland may be important for dispersal and rearing of young. Many off-channel habitats were available prior to construction of mainstem dams and channelization (Beland 1953; Tyus and Karp 1989; Osmundson and Kaeding 1991).

Wick (1992) concluded that gravel-pit ponds that are adjacent to the river may be a substitute for bottomlands, low lying wetlands, and former oxbow channels. Recently, 97 razorback suckers were collected from waters adjacent to the Colorado River; four from Highline Lake, one from Clough Pond, near Rifle, Colorado, and 92 from a gravel-pit near DeBeque, Colorado (Pfeifer 1993). Providing nursery habitats in backwaters and flooded bottomlands under reduced predator load appears to show some hope for the survival and eventual recovery of this species.

Holden and Crist (1981) reported the capture of 56 razorback suckers in the Ashley Creek-Jensen area of the Green River from 1978 to 1980, and about 19 percent of all ripe or tuberculate razorback suckers captured by the Service from 1981 to 1989 were taken in flooded bottomlands and mouths of tributaries. Seasonal movements of some fish into these areas indicates that flooded bottomlands may provide important habitat for razorback suckers. Warmer temperatures and increased food availability offer plausible explanations, and Bulkley and Pimental (1983) reported that adult razorback suckers preferred temperatures of 71 to 77°F and avoided temperatures of 46° to 59°F. Tyus and Karp (1990) suggested that both reproduction and recruitment in razorback sucker in the Green River may be adversely affected by loss of seasonally flooded habitats due to their impoundment via dams and dikes, loss of fish access, and alteration of the duration and magnitude of spring flooding. In nonreproductive periods, adult razorback suckers tend to utilize eddies, backwaters and other types of pool habitats (Minckley et al. 1991). Adults in the upper Green and Colorado rivers use backwaters and eddies 2.0 to 11.0 feet deep with sand or silt substrates and water velocities of 0.3 to 2.0 feet per second during this time (Valdez 1982a; Tyus et al. 1982b; Tyus 1987). Radio telemetry data on razorback suckers in the Verde River indicated that deeper pools and glides with low water velocities were most often occupied (Creef et al. 1992). Other radio telemetry work on razorbacks in the Gila River indicated that flat-water areas in the main channel as well as pools and eddy habitats were used (Marsh and Minckley 1991). Adult razorback suckers survive successfully in reservoirs, although information on specific habitat use outside of the breeding season is not available. Summer riverine habitat use included deeper eddies, backwaters, holes, and midchannel sandbars (Tyus and Karp 1990; Minckley et al. 1991). Tyus and Karp (1989), based on capture and inspection of adult razorback suckers in flooded habitats, believed that flooding of bottomland during spring runoff was important to adults for feeding. The flooding of bottomlands provides access to areas for feeding and also supplies nutrient and organic input into the river.

## MOVEMENT/MIGRATION

Razorback suckers exhibited a variety of local and long-distance movements during the spring spawning period. Tyus and Karp (1990) reported that 17 radiotagged fish undertook spawning migrations of 19 to 66 miles. Osmundson and Kaeding (1989) reported movement of 7 to 12 miles within the Grand Valley. McAda and Wydoski (1980) reported movement of spaghetti tagged fish 16 to 86 miles although most individuals were recaptured close to the point of release. Similar movements were noted by Tyus (1987), and historical accounts also reported spring spawning movements of razorback suckers (Jordan 1891; Hubbs and Miller 1953; Sigler and Miller 1963).

Except for spawning migrations, razorback suckers are relatively sedentary, moving only a few miles over several months (Tyus 1987; Tyus and Karp 1990). Valdez and Masslich (1989) tracked 17 razorback suckers in the winter on the Green River, and they found that most of the fish moved less than 3 miles. The radio-telemetered razorback suckers used slow runs, slack waters, and eddies. They were found in depths of 2.0 to 4.6 feet and velocities of 0.1 to 1.1 feet per second. Osmundson and Kaeding (1989) reported that pools and slow eddies were predominantly used from November through April, runs and pools from July through October, runs and backwaters during May, and backwaters and flooded gravel pits during June. Selection of various depths changed seasonally; mean depths were 3.0 to 3.3 feet during May and June, 5.3 to 5.4 feet from August through September, and 6.6 to 7.1 feet from November through April. In Lake Mohave, mark and recapture data shows razorback suckers moved up, down, or across the lake 2.5 to 16 miles. (Marsh and Minckley 1989). Some individuals remained in the same locality, while one fish moved uplake 5 miles in less than two days.

Razorback suckers are uncommon in turbulent canyon reaches (Lanigan and Tyus 1989; Minckley et al. 1991). Although these canyons may not be suitable for spawning, nursery, or rearing areas, they provide corridors for movement and migration between more typically occupied habitat. Additionally, larger tributaries within canyons may provide suitable habitat to complete life history requirements. These canyon reaches also provide corridors for larval drift, (e.g., Whirlpool Canyon below an identified spawning site in the lower Yampa River; Tyus and Karp 1990). The ability for razorback suckers to move between spawning, adult, and nursery habitats is essential for completion of all life history requirements.

## COLORADO SQUAWFISH *(Ptychocheilus lucius,* Girard, 1856)

Colorado squawfish are adapted to rivers with seasonally variable flow, high silt loads, and turbulence. The Colorado squawfish is the largest member of the minnow family in North America, with maximum weights historically exceeding 80 lbs. The Colorado squawfish is endemic to the Basin. It is the largest of four existing species of the genus *Ptychocheilus* (Moyle 1976). Its origins predate recorded history, but fossils indicate that by the mid-Pliocene epoch (about 6 million years ago) early *Ptychocheilus* had riverine adaptations that were similar to modern forms. During the Pleistocene epoch (about 1 million years ago), an earlier wet climate was interrupted by periods of desert conditions (M. Smith 1981). It has been hypothesized that the migrations reported for Colorado squawfish are a perfect life history strategy for the survival of a large predaceous fish in the historic Colorado River environment (G. Smith 1981; Tyus 1986, 1990). During the spawning season, adult Colorado squawfish have been known to migrate up to 200 miles upstream or downstream to reach spawning areas (Tyus 1990).

### HISTORIC DISTRIBUTION AND ABUNDANCE

Historically, Colorado squawfish occurred throughout the Basin (Figure 3). In the Lower Basin, Colorado squawfish were recorded in the Colorado River mainstem from the Gulf of California in Baja California del Norte to Lee's Ferry in Arizona, the Little Colorado River, and the Gila River and its tributaries, the San Pedro, Salt, and Verde rivers. Colorado squawfish also were recorded in the Salton Sea, which was sporadically filled with water from the Colorado River (Follett 1961; Minckley 1973, 1979, 1985; Moyle 1976, Gobalet 1992). In the Upper Basin, Colorado squawfish have been captured in the lower reaches of the Gunnison, White, Yampa, Little Snake, Dolores, San Juan, Duchesne, Uncompahgre, and Animas rivers (Jordan 1891; Ellis 1914; Beckman 1952; Lemons 1954; Koster 1957, 1960; Johnson 1976; Valdez et al. 1982a; Platania 1990; Marsh et al. 1991), and Plateau Creek, a tributary of the Colorado River (Bob Burdick, USFWS, pers. comm.). The species also was common in the Colorado and Green Rivers mainstems, plus probably numerous smaller streams (Ellis 1914; Bosley 1960; LaRivers 1962; Baxter and Simon 1970; Holden 1973; Seethaler 1978; Johnson and Oberholtzer 1987).

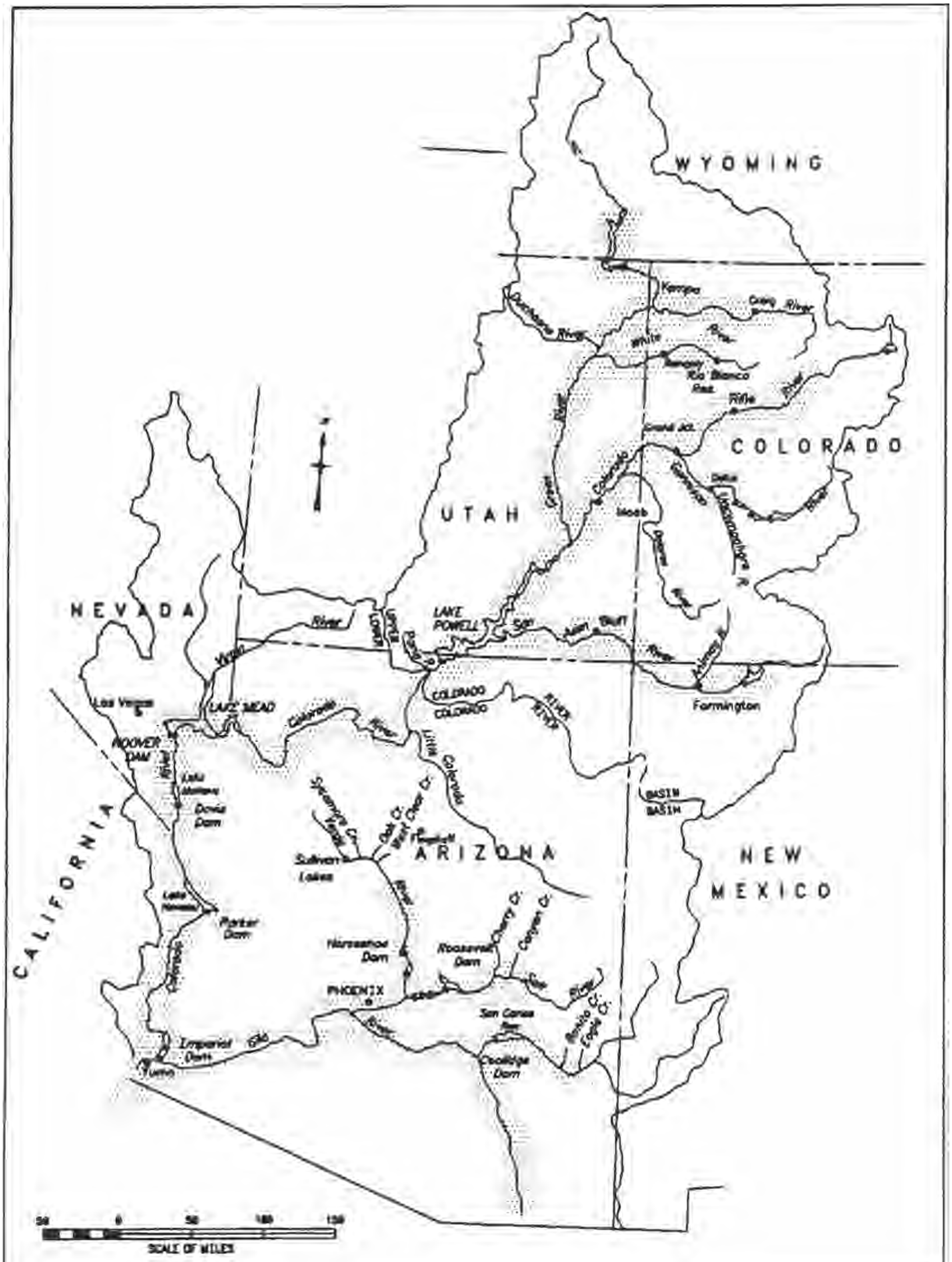



Figure 3. Historical distribution (shaded area) of the Colorado squawfish. (Map adapted from the Colorado River Recovery Plan USFWS 1991)

CURRENT DISTRIBUTION AND ABUNDANCE

Native populations of the Colorado squawfish are restricted to the Upper Basin in Wyoming, Colorado, Utah, and New Mexico. The species occurs in the Green, Yampa, White, Gunnison and Colorado rivers (Holden and Wick 1982; Miller et al. 1982b; Tyus et al. 1982b; Wick et al. 1985, 1986; Archer et al. 1985; Tyus et al. 1987; Burdick 1993; Valdez and Cowdell 1993). Colorado squawfish populations have been extirpated from the Lower Basin.

Catches of young, juvenile, and adult Colorado squawfish are higher in the Green River sub-basin of Colorado and Utah than elsewhere (Tyus 1991a). Recent investigations have found many young, juveniles, and adults in the Green River from the mouth of the Yampa River to its confluence with the Colorado (Holden 1973; Holden and Stalnaker 1975a, 1975b; Tyus et al. 1982a, 1987; Tyus and Haines 1991).

Adult Colorado squawfish have been captured in the lower 124 miles of the Yampa River and in Lodore Canyon of the Green River (Tyus et al. 1982a; Miller et al. 1982b), and larvae were identified from the lower 19 miles of the Yampa River in Dinosaur National Monument (Wick et al. 1981, 1985, 1986; Haynes et al. 1984; Tyus and Haines 1991). Two adult Colorado squawfish implanted with radio transmitters ascended the Little Snake River in 1988 (Wick and Hawkins 1989). Investigation of the Green and Little Snake rivers in Wyoming in 1986 failed to produce any Colorado squawfish, (Johnson and Oberholtzer 1987); however, an adult was found in the Little Snake River in Wyoming in 1990 (Marsh et al. 1991).

Colorado squawfish have been found in the lower 151 miles of the White River in Utah and Colorado (Prewitt et al. 1978; Wick et al. 1979, 1981; Carlson et al. 1979; Lanigan and Berry 1981; Miller et al. 1982a; Martinez 1986a). In the Duchesne River, a fisherman caught a Colorado squawfish at the mouth of the Uinta and Duchesne rivers in 1975 (Seethaler 1978) and a specimen implanted with a radio transmitter ascended the Duchesne River in 1980 (Tyus et al. 1982b).

Colorado squawfish have been collected above and below the Redlands Diversion Dam on the Gunnison River (Valdez et al. 1982a; Wick et al. 1985; Osmundson and Kaeding 1989; USFWS 1992a); adults have been captured above this diversion as recently as the spring of 1993 ( Bob Burdick per. comm.) Colorado are regularly collected in the Colorado River between the Price-Stubb Dam near Palisade, Colorado and Lake Powell (Valdez et al. 1982a; Osmundson and Kaeding 1989; Valdez and Cowdell 1993).

Adult and juvenile Colorado squawfish have been captured in Lake Powell (Minckley 1973; Wick et al. 1981; Valdez et al. 1982b; Miller et al. 1984). Adult Colorado squawfish were captured in the riverine portion of the reservoir in 1980 (Persons and Bulkley 1982). Valdez (1990) also reported both adult and juvenile Colorado squawfish in Cataract Canyon at the inlet of Lake Powell, indicating that the species is reproducing in or above that reach.

A small reproducing population of Colorado squawfish exists in the San Juan River. A single juvenile squawfish was captured in the San Juan River just below the confluence of McElmo Creek near Aneth, Utah, in 1978 (VTN Consolidated, Inc. 1978; Minckley and Carothers 1980). Platania et al. (1991) reports eight adults and 19 young-of-year were captured in New Mexico and Utah between 1987 and 1989 (two additional adults were observed but not captured). One adult was captured in the San Juan arm of Lake Powell and seven in the San Juan River between Bluff, Utah, and Shiprock, New Mexico. In 1987, 1988, and 1990, 20 young-of-year were collected from the San Juan River from Shiprock, New Mexico to the Lake Powell inflow area (Platania et al. 1991; Bill Bates, UDWR, pers. comm.). Ryden and Pfeifer (1993) captured 12 adults from 1991-1992 in a 19.2 mile reach between Cudei Diversion and the Mancos River.

In the Lower Basin, Miller and Lowe (1964), and Minckley and Deacon (1968) considered Colorado squawfish extirpated from the Gila River system, and Minckley (1973, 1979) later expanded this to include all Arizona waters except above Glen Canyon Dam. No Colorado squawfish (other than stocked fish) have been taken from the Gila River basin since 1950 (Miller 1961); a 1958 record of this species from the Salt River, Arizona (Branson et al. 1966), was based on misidentified roundtail chub (Robert Miller pers. comm. to W.L. Minckley). The last known adult Colorado squawfish from the Lower Basin was taken by a fisherman in 1975 from the mouth of Havasu Creek (Smith et al. 1979).

Although Colorado squawfish were extirpated from the Lower Basin, over 300,000 Colorado squawfish have been reintroduced in several locations. These reintroductions were classified as experimental nonessential populations as defined in the Act. More than 96,000 fingerling and 442 larger Colorado squawfish, 14-16 inch total length (TL), were introduced at six locations on the Salt and Verde Rivers, Arizona, in 1985 (Brooks 1986). Seven of the larger squawfish were captured in experimental trammel nets within 10 days after stocking, and five more fish of the larger size group were captured about 5 months after stocking. In 1987, 31,750 fingerling Colorado squawfish from Dexter National Fish Hatchery and Technology Center were stocked at two sites in the Salt River drainage (including 6,750 into Canyon Creek) and 100 Colorado squawfish were stocked into the Verde River. Arizona Game and Fish Department biologists recaptured three in Canyon Creek and one in the Salt River. In 1988, Dexter National Fish Hatchery and Technology Center personnel stocked 20,000 fingerlings into the Salt River, 18,000 into Canyon Creek, and 89,303 into the Verde River. Bubbling Ponds State Fish Hatchery personnel stocked 120,604 fingerlings into the Verde River and 1,194 into Sycamore Creek, a tributary to the Verde River. In 1988, 57 Colorado squawfish were recaptured on Verde River, and six from the Salt River. Recaptures during both years included fish which had been at large for 3 months to 1 year (Dean Hendrickson, AGFD, pers. comm., cited in USFWS 1991). Colorado squawfish stockings continue in the Salt and Verde rivers, and expansion of the program is planned. However, no reproducing population of Colorado squawfish has been confirmed in the Lower Basin as a result of these stockings.

## STATUS

Once very common throughout the Basin, Colorado squawfish populations have declined from historic levels. Its present range is restricted primarily to the Upper Basin; Colorado squawfish have been reintroduced in the Salt and Verde Rivers in Arizona. As with the other three endangered fish, the decline of Colorado squawfish populations is due to various human-initiated physical and biological changes in the Colorado River.

## HABITAT REQUIREMENTS

### Spawning Habitat

Most of the information about Colorado squawfish reproduction is known from the Yampa and Green Rivers, where the fish spawns in white water canyons. This reproduction was associated with declining flows in June, July, or August, and average water temperatures ranging from 71 to 77°F depending on annual hydrology. After spawning, adult Colorado squawfish utilized a variety of riverine habitats, including eddies, backwaters, shorelines, and others (Tyus 1990). Specific spawning sites of Colorado squawfish have not been identified outside of the Green River Basin. In the mainstream Colorado River, McAda and Kaeding (1991) suggested that Colorado squawfish spawning may have been adversely impacted by construction of mainstream dams and a 48 percent reduction in peak discharge.

Tyus (1990) reported radiotracking of 57 Colorado squawfish to spawning grounds in the Green and Yampa rivers and capture of an additional 208 ripe fish at these locations from 1980 to 1988. Numerous capture locations of ripe fish and behavior of radio-tagged fish suggested that egg deposition and fertilization were concentrated in relatively small river reaches (<12 miles) where large, deep pools, eddies and submerged bars of cobble, gravel, boulder and sand substrates were associated with the main channel. However, substrates in two spawning reaches were different. Substrates in Yampa Canyon were dominated by imbricated cobbles intermingled with gravel and sand. In the Green River, substrates were boulders, sand and silt. Although high turbidity precluded direct observation of fish or deposited sex products, the signal source of radio-tagged fish indicated that fish rested or staged in pools or eddies (average depth, six feet; average velocity, 1.0 ft/sec) for hours or days, and moved abruptly to nearby cobble or boulder bars (average depth three feet; average velocity, 1.9 ft/sec), where they remained from 30 minutes to three hours and presumably spawned before returning to their former habitats.

Colorado squawfish spawn after the peak runoff season from June to mid-August. Spawning begins when water temperature reaches 64° to 77°F, and peak spawning activity occurs between 72° to 77°F (Haynes et al. 1984; Archer et al. 1985; Tyus 1990). During the decline in water level following peak runoff, spawning adult fish move into run-riffle areas and also occupy run, eddy, and pool habitats (Tyus 1990). Spawning migrations were initiated at water temperatures of 57° to 68°F, and spawning occurred at temperatures of 72°F (range 59° to 82°F), but migrations and spawning periods varied between years.

Migrations were initiated from May 12 to June 10, associated with a mean water temperature of about 57°F, and spawning occurred at 70°F (Tyus and Karp 1989). However, Wick et al. (1985) and Tyus et al. (1987) cautioned that main channel temperatures may not accurately portray temperature preferences of Colorado squawfish because the species frequently utilized habitats outside the main river channel, such as large backwaters, gravel pits, and flooded bottomlands, which may be influenced more by ambient air temperatures and solar radiation.

Radiotelemetry studies of Colorado squawfish in the Green River basin indicate that spawning is concentrated in two major sites: (1) the lower 20 miles of Yampa River canyon; and (2) Gray Canyon of the Green River (Tyus et al. 1984; Tyus and McAda 1984; Tyus 1985; Wick et al 1985; Tyus 1990). Spawning also is suspected in Labyrinth Canyon in the Green River about 31.25 miles upstream of the Colorado River confluence (Tyus et al. 1987). This is supported by the capture of many young larval fish (protolarvae) immediately downstream of this reach (Valdez 1990). Collections made on the two known spawning grounds during 1981-88 produced 308 Colorado squawfish, of which 208 were ripe and an additional 67 fish showed secondary sex characteristics associated with breeding condition (Tyus 1990). Four fish tagged in the White River were recaptured at the Yampa and Gray Canyons spawning areas, and the recapture of five fish tagged and recaptured in the Yampa River spawning grounds after 2 or more years indicated a fidelity to that area (Tyus 1985, 1990).

The Yampa spawning population is considered historical. Holden and Stalnaker (1975b) reported increased numbers of ripe Colorado squawfish in the lower Yampa River in July 1968-70, and Seethaler (1978) reported ripe fish there in 1974-75. Successful reproduction in the lower Yampa River was substantiated when larval Colorado squawfish were collected in the lower 30 miles and below its confluence with the Green River from 1980-83 (Haynes et al. 1984; Tyus et al. 1987).

Gray Canyon of the Green River was suspected as a spawning site in 1981 when a radio-implanted Colorado squawfish from the White River was tracked to that location (Tyus et al. 1982b; Radant et al. 1983). Spawning was confirmed there by additional data collected in 1983 (Tyus 1985). Additional Colorado squawfish have been tracked to Gray Canyon, and 111 ripe fish were collected there in 1981-88 (Tyus 1990).

Two reaches of the Colorado River contain spawning areas; Black Rocks to Loma and Grand Junction to Clifton (McAda and Kaeding 1991). Additionally, the presence of larval squawfish aggregations and suitable spawning habitat in the Colorado River near Cataract Canyon, Professor Valley, and upstream from the Dolores River confluence indicate spawning is occurring in or near these areas as well (Archer et al. 1985; Valdez 1990).

## Nursery Habitat

Young-of-year (up to 2.5 inches TL), juveniles (2.5-8 inches), and subadults (8-16 inches) have been captured in shallow backwater areas over silt and sand bottoms (Holden 1973; Holden and Stalnaker 1975a, 1975b; Wick et al. 1979, 1981; Holden and Twedt 1980; Miller et al. 1982a, 1982b; Valdez et al. 1982b; Valdez and Wick 1983; Haines and Tyus 1990; Tyus and Haines 1991). Most of these backwaters were ephemeral along shore embayments with little or no water currents (Tyus and Haines 1991). A significant rearing area for Colorado squawfish occurs in the Green River (Tyus et al. 1987; Tyus and Haines 1991). Two main reaches have been documented, one from Split Mountain to Sand Wash, the other from Green River, Utah to the confluence with the Colorado River. Young-of-year Colorado squawfish have also been found in the Colorado River between Moab, Utah, and the confluence with the Green River (Valdez et al. 1982; Archer et al. 1985). Other significant nursery areas in the Colorado River have been identified: (1) in the upper Professor Valley; (2) between the confluence with the Dolores River and Westwater Canyon; (3) between Black Rocks and Loma; and (4) downstream from the confluence with the Gunnison River (Valdez et al. 1982; Archer et al. 1985; Osmundson and Kaeding 1989).

No larval Colorado squawfish have been captured in the White River (Miller et al. 1982a). Some adults that were tagged in the White River have been recaptured or radio-tracked to the Yampa and Gray Canyon spawning sites (Tyus 1990). Osmundson and Kaeding (1989) reported the capture of a single larval Colorado squawfish in the lower two miles of the Gunnison River.

The 18 young-of-year Colorado squawfish captured in the San Juan River in 1987 were collected from backwaters. Two were taken downstream of Shiprock, New Mexico; six near Bluff, Utah; and ten were taken in the lowermost 38 miles immediately upstream from Lake Powell. An additional young-of-year also was taken from this area in 1988, collected from a backwater (Platania 1990). In 1990, a young-of-year Colorado squawfish was collected from a backwater near Bluff, Utah (Bill Bates, UDWR, pers. comm.). In 1992, a young-of-year Colorado squawfish was collected below the natural waterfall on the San Juan River (I Ashmett 1993).

Larval drift is an important part of the Colorado squawfish life cycle (Tyus and Haines 1991), and laboratory studies indicate that "drift" may be active rather than a passive response to water current (Paulin et al. 1990). Larval squawfish drift downstream after hatching in the Green and Yampa rivers and rear in reaches that are removed from spawning areas (Haynes et al. 1984; Tyus and Haines 1991).

In the Green River basin, larval Colorado squawfish emerge from spawning substrates and enter the stream drift as young fry (Haynes et al. 1984). The fish are then actively or passively transported downstream for about six days, and they may travel average distances of up to 100 miles to reach nursery areas (Tyus and Haines 1991). These areas are biologically productive habitats that consist of ephemeral alongshore embayments that develop as spring flows decline. Such habitat is generally associated with lower gradient reaches.

Tyus (1991b) also found that young Colorado squawfish exhibited a diel pattern of backwater use that was positively related to backwater temperature. Most of the 1,194 young Colorado squawfish were captured in spring when water temperature in backwaters equalled or exceeded main channel temperature. Marked young were highly mobile and moved between several habitat types during a 24-hour period.

**Juvenile and Adult Habitat**

Adult Colorado squawfish are large-river fish found in a variety of depths and velocities over silt, sand, gravel, and boulder substrates (Holden 1973; Wick et al. 1979, 1981; Holden and Twedt 1980; Holden and Wick 1982; Miller et al. 1982a, 1982b; Tyus et al. 1982a, 1984; Valdez et al. 1982b). Adults and juveniles use various habitats depending upon season, streamflow, water temperature, and availability (Holden and Wick 1982; Wick et al. 1983, 1985, 1986; Tyus and McAda 1984; Tyus 1990). During peak runoff, fish move into backwater areas or flooded riparian areas where velocity is lower and water temperatures are higher than in the main channel (Wick et al. 1983). Adult Colorado squawfish exhibited little movement during winter (October-April) in the upper Green River (Valdez and Masslich 1989). Of 20 adults radio-tagged in October, 15 moved less than 3 miles by the end of the following March. The fish occupied primarily slow runs, slackwater, eddies, and backwaters.

During winter, adult Colorado squawfish in the Yampa River use backwaters, runs, and eddies, but are most common in shallow, ice-covered shoreline areas (Wick and Hawkins 1989). In spring and early summer, adult squawfish utilized shorelines and lowlands that were inundated during typical spring flooding, and this natural lowland inundation was viewed as important for their general health and reproductive conditioning (Tyus 1990). Use of these habitats may mitigate some of the effects of winter stress and aid in offsetting a large energy expenditure required for migration and spawning.

MOVEMENT/MIGRATION

Migration is an important component in the reproductive cycle of Colorado squawfish, and Tyus (1990) reported that migration clues, such as high spring flows, increasing river temperatures, and possible chemical inputs from flooded lands and springs, were important to successful reproduction. Radiotelemetry studies and collections of spawning fish have added to the knowledge of Colorado squawfish spawning activities, seasonal movements, and habitat use (Tyus et al. 1982b; Radant et al. 1983; Wick et al. 1983; Tyus and McAda 1984; Archer et al. 1985; Tyus 1990; McAda and Kaeding 1991). During the spawning season, adult Colorado squawfish migrate upstream and downstream to reach spawning areas in the Green River Basin and movements of 200 miles have been reported (Miller et al. 1983; Tyus 1985; Tyus 1990). Fidelity to spawning locations have been observed for Colorado squawfish in the Green and Yampa Rivers (Tyus 1985; Wick et al. 1986; Tyus 1990). Some authors suggest that repeated use of the same spawning areas may reflect a limited availability of spawning habitats (O'Brien 1984; Archer et al. 1985). However, Tyus (1990) reported that migrating Colorado squawfish pass through many miles of potential spawning habitat to reach specific spawning areas in Yampa Canyon. Colorado squawfish may not spawn annually, and a lack of long-distance migratory behavior has been associated with less than annual spawning and sexual immaturity (Wick et al. 1983; Tyus 1990).

One dramatic example of movement was provided by a fish radio-tagged in Gypsum Canyon of upper Lake Powell on April 5, 1982. On July 9, 1982, the fish was in lower Cataract Canyon. The next contact was made above the Black Rocks area of the Colorado River some 160 miles upstream. This was 41 days later and believed related to spawning. At the end of September, the fish was in the Colorado River near Clifton, Colorado, approximately 200 miles from its initial downstream location. Not all radio-tagged fish display such dramatic migratory behavior. Radiotelemetry studies conducted in the Grand Valley region of the Colorado River found that movement during April to October was generally limited to 25-30 miles ( Archer et al. 1985; Osmundson and Kaeding 1989; McAda and Kaeding 1991). Young Colorado squawfish also undertake movements, and Tyus (1991b) documented diel movements of age 0 and age 1 fish. The young fish moved in response to changing water temperature and water levels.

## HUMPBACK CHUB *(Gila cypha,* Miller 1946)

The humpback chub is endemic to the Colorado River Basin and is part of a native fish fauna traced to the Miocene epoch in fossil records (Miller 1955; Minckley et al. 1986). Hump-back chub remains have been dated to about 4000 B.C., but the fish was not described as a species until recent times (Miller 1946). This recent discovery has been attributed to its restricted distribution in remote, white water canyons (USFWS 1990b), and its earlier abundance and distribution is not well known.

### HISTORIC DISTRIBUTION AND ABUNDANCE

Historic distribution of the humpback chub includes portions of the mainstem Colorado River and four of its tributaries: the Green, Yampa, White, and Little Colorado rivers (Figure 4). However, its original distribution throughout the Basin is not known with certainty. Considerable manmade alteration occurred in the Colorado River before the 1940's, especially in the Lower Basin (Miller 1961), and humpback chub may have disappeared from some river reaches before their existence was documented. For example, Miller (1955) reported remains of this species from an Indian site near Hoover (Boulder) Dam. Thus, the population in this area may have been eliminated when Hoover Dam was built in the 1930's.

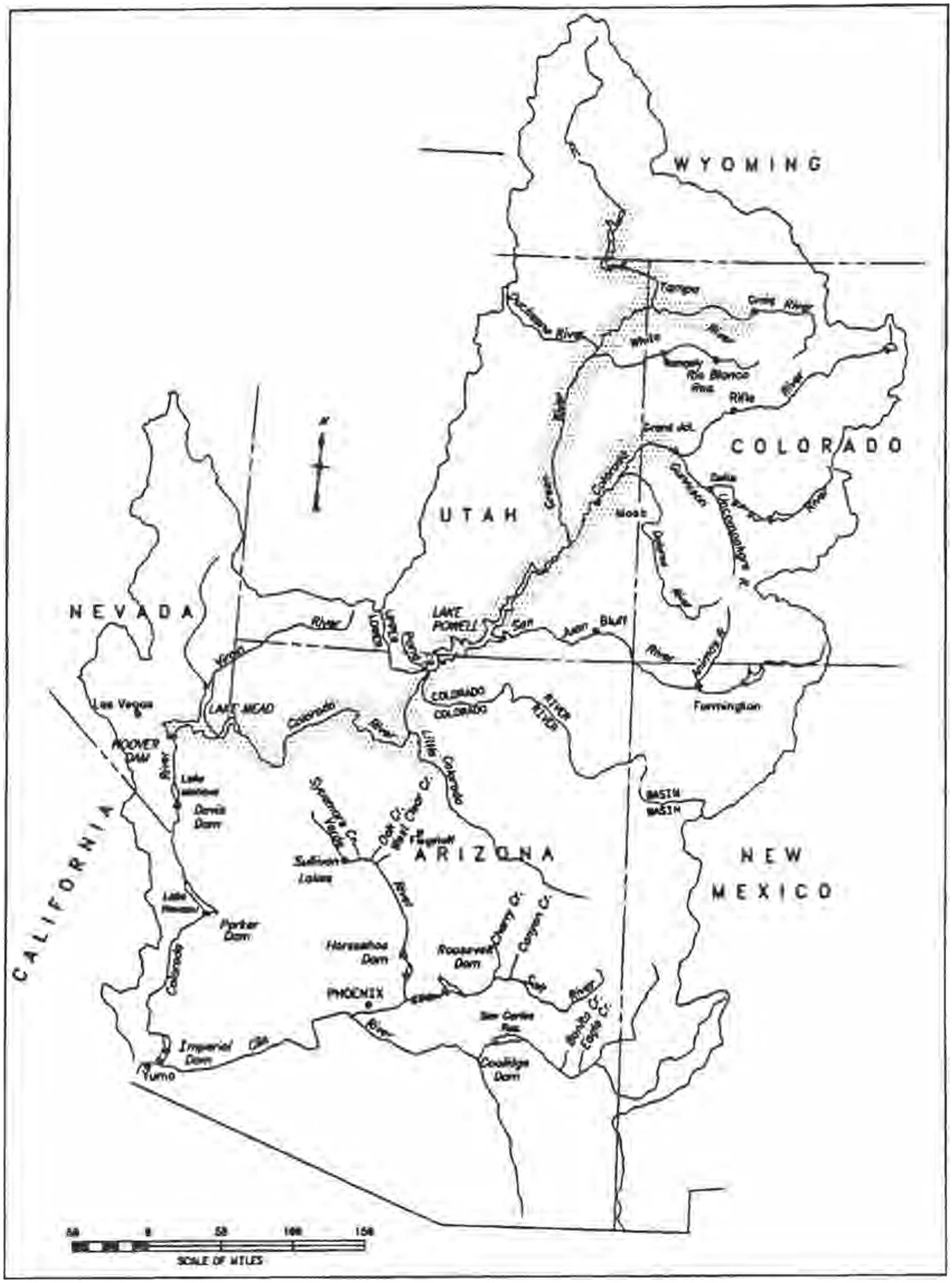



Figure 4. Historical distribution (shaded area) of the humpback chub. (Map adapted from the Humpback Chub Recovery Plan; USFWS 1990b)

Interest in Colorado River endemic fishes increased in the 1960's, primarily because of the rapid disappearance of the fishes in the Lower Basin and new concerns regarding the impacts of Colorado River Storage Project dams in the Upper Basin. Until the 1950's, the humpback chub was known only from Grand Canyon (Miller 1946), where the largest population remains. A number of surveys were made in the Upper Basin in the 1950's and 1960's, primarily in conjunction with pre- and post-impoundment studies of Flaming Gorge Reservoir. Humpback chub subsequently were found in the upper Green River (Smith 1960). Vanicek et al. (1970) reported three specimens from the upper Green River, one each from Echo Park, Island Park, and Swallow Canyon. Specimens were taken from the lower Yampa River in 1969 (Holden and Stalnaker 1975b) and one individual was reported from the White River in Utah (Sigler and Miller 1963). Specimens were collected from Desolation Canyon of the Green River in 1967 (Holden and Stalnaker 1970). One individual was reported from the Colorado River near Moab, Utah, in the 1950's (Sigler and Miller 1963) and other specimens have been collected from the Colorado River above and below Glen Canyon Dam (Holden and Stalnaker 1970, 1975a; Minckley 1973).

## CURRENT DISTRIBUTION AND ABUNDANCE

The largest populations of this species occur in the Little Colorado and Colorado Rivers in the Grand Canyon, and in the Black Rocks area of the Colorado River. Other populations have been reported in Westwater and Debeque Canyons of the Colorado River, Desolation and Gray Canyons of the Green River, and Yampa and Whirlpool Canyons in Dinosaur National Monument (USFWS 1990b).

The present distribution of humpback chub reported in the Humpback Chub Recovery Plan (USFWS 1990b) includes the lower 8 miles of the Little Colorado River, Arizona (Kaeding and Zimmerman 1983; Maddux et al. 1987), the Colorado River in Marble and Grand Canyons, Arizona (Stone and Rathbun 1969; Suttkus et al. 1976; Suttkus and Clemmer 1977; Minckley et al. 1981; Kaeding and Zimmerman 1983; Maddux et al. 1987; and USBR 1988), Cataract and Westwater Canyons in Utah (Valdez 1981, 1987, 1988; Valdez and Williams 1986), and Black Rocks Canyon in Colorado (Kidd 1977; Valdez and Clemmer 1982; Valdez et al. 1982b; Miller et al. 1982c; Archer et al. 1985). Humpback chub also occur in the Green River in Desolation and Gray Canyons, Utah (Holden and Stalnaker 1975a; Holden 1978; Tyus et al. 1982a, 1982b, 1987), and in the Yampa and Green rivers in Dinosaur National Monument, Colorado and Utah (Miller 1964; Holden and Stalnaker 1975b; Seethaler et al. 1979; Holden and Crist 1980; Douglas et al. 1989; Karp and Tyus 1990a). More recent intensive research has better defined their distribution include approximately 13 miles up the Little Colorado River up to Blue Springs (Minckley 1990). Additionally, concentrations of humpback chub have been collected in the vicinity of Pumpkin Springs in the Grand Canyon (Valdez and Hugentobler 1993).

In the Lower Basin, the Little Colorado River in Grand Canyon, contains the largest population of humpback chub and is the main area of humpback chub reproduction in the Grand Canyon region (Kaeding and Zimmerman 1983). Researchers working on the

Colorado and Little Colorado rivers in the Grand Canyon have collected over 21,000 specimens of adult and juvenile humpback chub since 1987 (Valdez 1991; Valdez et al. 1992; Douglas and Marsh 1992, 1993; Robinson and Clarkson 1992; Gorman et al. 1993; Arizona Game and Fish Department 1993). Specimens also have been collected from Shinumo, Bright Angel, Kanab and Havasu creeks (Maddux et al. 1987). Collections made in mainstem backwaters suggest that these habitats serve as important rearing areas for young-of-year humpback chub (Maddux et al. 1987). The cold tailwaters of the dam and fluctuating flows have apparently caused major reductions in both the distribution and abundance of humpback chub in Marble and Grand canyons (Minckley 1973; Holden and Stalnaker 1975a; Suttkus et al. 1976; Maddux et al. 1987). Humpback chub were collected in Lake Powell after closure of the dam in the 1960's (Holden and Stalnaker 1970; Suttkus and Clemmer 1977), but only young-of-year fish at the inflow area have been collected recently (Valdez 1987, 1988).

In the Upper Basin, the highest known concentrations of humpback chub are found in the Black Rocks and Westwater Canyon reaches of the Colorado River near the Colorado/Utah State line (Valdez 1981; Wick et al. 1981; Valdez and Clemmer 1982; and Archer et al. 1985; Kaeding et al. 1990). A population of humpback chub has been reported from Cataract Canyon on the Colorado River above the inflow area to Lake Powell. A total of 108 humpback chub, of which 22 were adult fish and 56 were juvenile, were collected during a 4-year investigation of Cataract Canyon from 1985 to 1988, by Valdez (1990). These findings and those of past studies (Valdez et al. 1982b), indicate that there is a small population of humpback chub in Cataract Canyon. Although actual spawning has not been documented, the presence of various size humpback chubs, including possible young-of-year fish, through the 12-mile reach of Cataract Canyon supports the hypotheses that spawning occurs there. Specimens also have been collected from the Colorado River in Professor Valley above Moab, in Elephant Canyon about 2 miles above the confluence with the Green River, and in the inflow area of Lake Powell (unpublished U.S. Fish and Wildlife Service data; Valdez 1987, 1988). In December 1981, the Service stocked 7,600 age-I humpback chub, marked with a coded nose-tag, (progeny from Black Rocks) into Cataract Canyon, but no recaptures have been confirmed.

Humpback chub were collected from the Desolation and Gray Canyons of the Green River in the early 1970's and 1979-81 (Holden and Stalnaker 1975a; Tyus et al. 1982b). The humpback chub also is rare in the Green and Yampa Rivers of Dinosaur National Monument (Holden and Stalnaker 1975a; Seethaler et al. 1979; Miller et al. 1982a). Tyus et al. (1987) reported that of 523 *Gila sp.* collected from the Green River basin during 1979-1986, humpback chub comprised 28 percent of those from the Green River and 12 percent of those from the Yampa River. Vanicek et al. (1970) indicated that the humpback chub was adversely affected in the Green River above the mouth of the Yampa River after Flaming Gorge Dam became operational in 1962. However, a spawning population remains in Yampa Canyon in Dinosaur National Monument near the confluence of the Green and Yampa rivers. A total of 32 fish in breeding condition were captured in Yampa Canyon from 1986-1988, including 5 ripe females, 14 ripe males, and 13 fish with breeding tubercles

(Karp and Tyus 1990a). A single humpback was collected in 1980 at Cross Mountain Canyon of the Yampa River (USFWS 1980; Wick et al. 1981), and several specimens were collected in 1988 from the Little Snake River 6.25 miles upstream from the confluence with the Yampa River (Ed Wick, NPS, pers. comm.).

STATUS

This species is most often found in relatively inaccessible canyons, so it is not surprising that the species remained undiscovered until after World War II when the use of rubber rafts allowed easier access to canyon areas for sampling and research. The few remaining populations of humpback chub are limited to remote reaches in canyon areas of the Basin. This species decline, like the other Colorado River endangered fish, is attributed to streamflow alteration, competition, increased predation, in addition to hybridization with other members of the genus *Gila* (Stalnaker and Holden 1973; Rosenfeld and Wilkinson 1989).

HABITAT REQUIREMENTS

Populations of humpback chub are found in river canyons, where they utilize a variety of habitats, including pools, riffles, and eddies. Most of the existing information on habitat preferences has been obtained from adult fish in the Little Colorado River, the Grand Canyon, and the Black Rocks of the Colorado River (Holden and Stalnaker 1975a; Kaeding and Zimmerman 1983; Kaeding et al. 1990). In these locations, the fish are found associated with boulder-strewn canyons, travertine dams, pools, and eddies. Some habitat-use data are also available from the Yampa River Canyon where the fish occupy similar habitats, but also use rocky runs, riffles, rapids, and shoreline eddies (Karp and Tyus 1990a). This diversity in habitat use suggests that the adult fish is adapted to a variety of habitats, and studies of tagged fish indicated that they move between habitats, presumably in response to seasonal habitat changes and life history needs (Kaeding and Zimmerman 1983; Karp and Tyus 1990a). Spring peak flows, availability of shoreline eddy and deep canyon habitats, and competition and predation by nonnative fishes were reported as potential factors limiting reproduction of humpback chub in the Yampa River (Tyus and Karp 1989; Karp and Tyus 1990a).

**Spawning Habitat**

**Humpback** chub in reproductive condition are usually captured in May, June, and July, depending on location. Little is known about their specific spawning requirements, other than the fish spawn soon after the highest spring flows when water temperatures approach 68°F (Kaeding et al. 1990; Karp and Tyus 1990a; USFWS 1990b). The importance of spring flows and proper temperatures for humpback chub is stressed by Kaeding and Zimmerman (1983), who implicated flow reductions and low water temperatures in the Grand Canyon as factors curtailing successful spawn of the fish and increasing its competition with other species.

Suttkus and Clemmer (1977) concluded that spawning of humpback chub probably occurs in June and July in the Grand Canyon and lower Little Colorado River. Minckley (1977, 1978, 1979, 1980) collected mature fish from the Little Colorado River in March and April (at water temperatures of 61 to 68°F) and young-of-year fish in July. Ripe humpback chubs have been collected from the mainstem Colorado River in the Grand Canyon (Kaeding and Zimmerman 1983; Charles Minckley, USFWS, pers. comm.).

The collection of ripe and spent fish indicated that spawning occurred in Black Rocks during June 2-15, 1980, at water temperatures of 53° to 61°F and flows of 21,350 to 25,900 cubic feet/second (cfs); in 1981, spawning occurred May 15-25 at water temperatures of 61° to 61.7°F and flows of 3,000 to 4,990 cfs (Valdez et al. 1982b). Humpback chub spawned in Black Rocks on the Colorado River in 1983 when flows peaked from 37,100 to 74,200 cfs and maximum daily water temperatures were 55° to 63°F (Archer et al. 1985). Archer et al. (1985) also reported that humpback chub spawned in the area in 1984 when maximum daily water temperatures were 70° to 73°F and flows were declining from 27,195 to 13,615 cfs. In the Yampa River, ripe fish were collected at water temperatures of 61°to 73°F, and an average temperature of 68°F (Karp and Tyus 1990a). These data compare favorably with laboratory studies (Marsh 1985).

Nursery Habitat

Information on depth, velocity, and substrate preferences of the humpback chub has been recorded by Valdez et al. (1982b) who summarized probability-of-use criteria for adult, juvenile, and young-of-year humpback chub from the upper Colorado River. All young-of-year were captured in water less than 10 feet deep with a silt bottom and a velocity of less than 1,060 cfs. Backwaters, eddies, and runs have been reported as common capture locations for young-of-year humpback chub (Valdez and Clemmer 1982). These data indicate that in Black Rocks and Westwater Canyon, young utilize shallow areas. Young-of-year humpback chub in the mainstem Colorado River in the Grand Canyon may use talus shorelines when other habitats are limiting (Valdez et al. 1992). Maddux et al. (1987) captured large numbers of young-of-year in backwaters immediately below the Little Colorado River.

Habitat suitability index curves developed by Valdez et al. (1990) indicate young-of-year prefer average depths of 2.1 feet with a maximum of 5.1 feet. Average velocities were reported at 0.2 feet per second.

**Juvenile and Adult Habitat**

Valdez et al. (1982b) also summarized adult habitats. Adult humpback chub (over 10 inches) were generally captured in water less than 30 feet deep over silt, sand, boulder, and bedrock substrate and with river flows usually less than 1,060 cfs. During 1985, 29 sets of habitat measurements of 10 adult humpback chub obtained by radiotelemetry indicated that the fish preferred eddies with sand substrate, a water depth mode of 5 feet (range 1 to 15 feet), and water flows between 0-525 cfs (USFWS 1986). Five humpback chub (age II-III years) were captured in water 20 to 29 feet deep. An additional age-I humpback chub was caught in water less than 10 feet deep. Humpback chub in the upper Colorado River (Valdez 1981; Valdez and Clemmer 1982) occupy deep, swift riverine areas.

Valdez et al. (1982b) and Wick et al. (1979, 1981) found humpback chub in Black Rocks and Westwater Canyons in water averaging 50 feet in depth with a maximum depth of 92 feet. In these localities, humpback chub were associated with large boulders and steep cliffs.

In the Lower Basin, humpback chub are found in the same general types of canyon habitats as in the Upper Basin (Minckley 1973). These general habitats are characterized by swift waters and rocky substrates, with the humpback chub most often utilizing shorelines, eddies and backwaters (Kaeding and Zimmerman 1983; Maddux et al. 1987; Valdez et al. 1992). In the Little Colorado River, large main channel pools, pools adjacent to eddies, and areas below travertine dams are often used by adult humpback chub (Minckley et al. 1981).

MOVEMENT/MIGRATION

Generally, humpback chub show fidelity for canyon reaches and move very little (Miller et al. 1982c; Archer et al. 1985; Burdick and Kaeding 1985; Kaeding et al. 1990). In the Grand Canyon, humpback chub move from the main channel Colorado River into the Little Colorado River to spawn (Kaeding and Zimmerman 1983). Juvenile fish have been collected about 160 miles below the Little Colorado River (Maddux et al. 1987; Valdez et al. 1992).

Movements of adult humpback chub in Black Rocks on the Colorado River were essentially restricted to a 1 mile reach. These results were based on the recapture of Carlin-tagged fish and radiotelemetry studies conducted from 1979 to 1981 (Valdez et al. 1982b) and 1983 to 1985 (Archer et al. 1985; USFWS 1986; Kaeding et al. 1990).

## BONYTAIL *(Gila elegans,* Baird and Girard 1853)

The bonytail chub is the rarest native fish in the Colorado River. Formerly reported as widespread and abundant in mainstream rivers (Jordan and Evermann 1896), its populations have been greatly reduced. The fish is presently represented in the wild by a low number of old adult fish (i.e., ages of 40 years or more) in Lake Mohave and perhaps other lower basin reservoirs (USFWS 1990a). The fish were once common in Lake Mohave and Wagner (1955) observed the fish in eddy habitats. A few individuals were reported in other locations, but concentrations of the fish have not been recently reported (Kaeding et al. 1986).

The discussion on bonytail habitat needs is presented differently than the other three endangered species in this document. The Bonytail Recovery Plan (USFWS 1990a) divides life history needs into three sections (riverine, reservoir, and hatchery). Collectively, these sections provide the only life history information available and exemplify the paucity of data.

## HISTORIC DISTRIBUTION AND ABUNDANCE

The historical range of the bonytail encompassed much of the Basin (Figure 5). The original records of bonytail were from the Colorado and Gila Rivers (Baird and Girard 1853; Jordan 1891; Jordan and Evermann 1896). However, the type locality of the bonytail was presented as the Zuni River of New Mexico. This is contested by Smith et al. (1979), who believes the type locality was from the Little Colorado River at Grand Falls. Captures in the Green River indicate bonytail were present in southern Wyoming in the area now inundated by Flaming Gorge Reservoir (Bosley 1960; Smith et al. 1979), in Dinosaur National Monument in Colorado and Utah (Binns et al. 1963; Vanicek and Kramer 1969; Vanicek et al. 1970), Desolation and Gray Canyons in Utah (Holden 1978), and the lower Green River in Utah (Jordan 1891; Holden and Stalnaker 1975a). In the Colorado River, they were collected from near Grand Junction, Colorado, downstream to the Gulf of California (Ellis 1914; Smith et al. 1979). Major tributaries of the Colorado River where bonytail were recorded included the Gila (Kirsch 1888), Salt (Evermann and Rutter 1895), and Verde rivers in Arizona (Smith et al. 1979); and the Gunnison River (Smith et al. 1979). The species also entered the Salton Sea basin in California when that area received Colorado River inflow during 1905-1907, but disappeared when salinity became intolerable (Walker et al. 1961; Gobalet 1992).

The bonytail was reported abundant in some locations of the Colorado River drainage in the late 1800's (Jordan and Evermann 1896). Jordan (1891) seined five specimens from the Green River at Green River, Utah. Kirsch (1888) cited an expedition on the Gila River at Fort Thomas, Arizona, which noted that the fish "took the hook freely." A number of other reports also indicated it was common to abundant during this period (Cope and Yarrow 1875; Gilbert and Scofield 1898; Chamberlain 1904). However, some of these and later reports may be questionable due to possible use of the term "bonytail" for other Gila species, particularly the roundtail chub.

There were few reports of bonytail for the Upper Basin in the first half of the twentieth century. The species declined in the Lower Basin during this time, disappearing from the Salt and upper Gila Rivers before 1926. Miller (1961) reported that by 1940-1942, bonytail were rare in the Colorado and Gila Rivers near Yuma, Arizona, and absent by 1950. Soon after closure of Glen Canyon Dam in 1962, bonytails were reported in Lake Powell (Dale Hepworth, UDWR, pers. comm.) and downstream of the dam to Lee's Ferry (Arizona State University museum records 1963-1965). Fishermen have reported that bonytail were caught in the upper Green River during the 1940's and 1950's (Quartarone 1993). However, the last known riverine area where bonytail were common was the Green River in Dinosaur National Monument, where Vanicek (1967) and Holden and Stalnaker (1970) collected 91 specimens during 1962-1966.

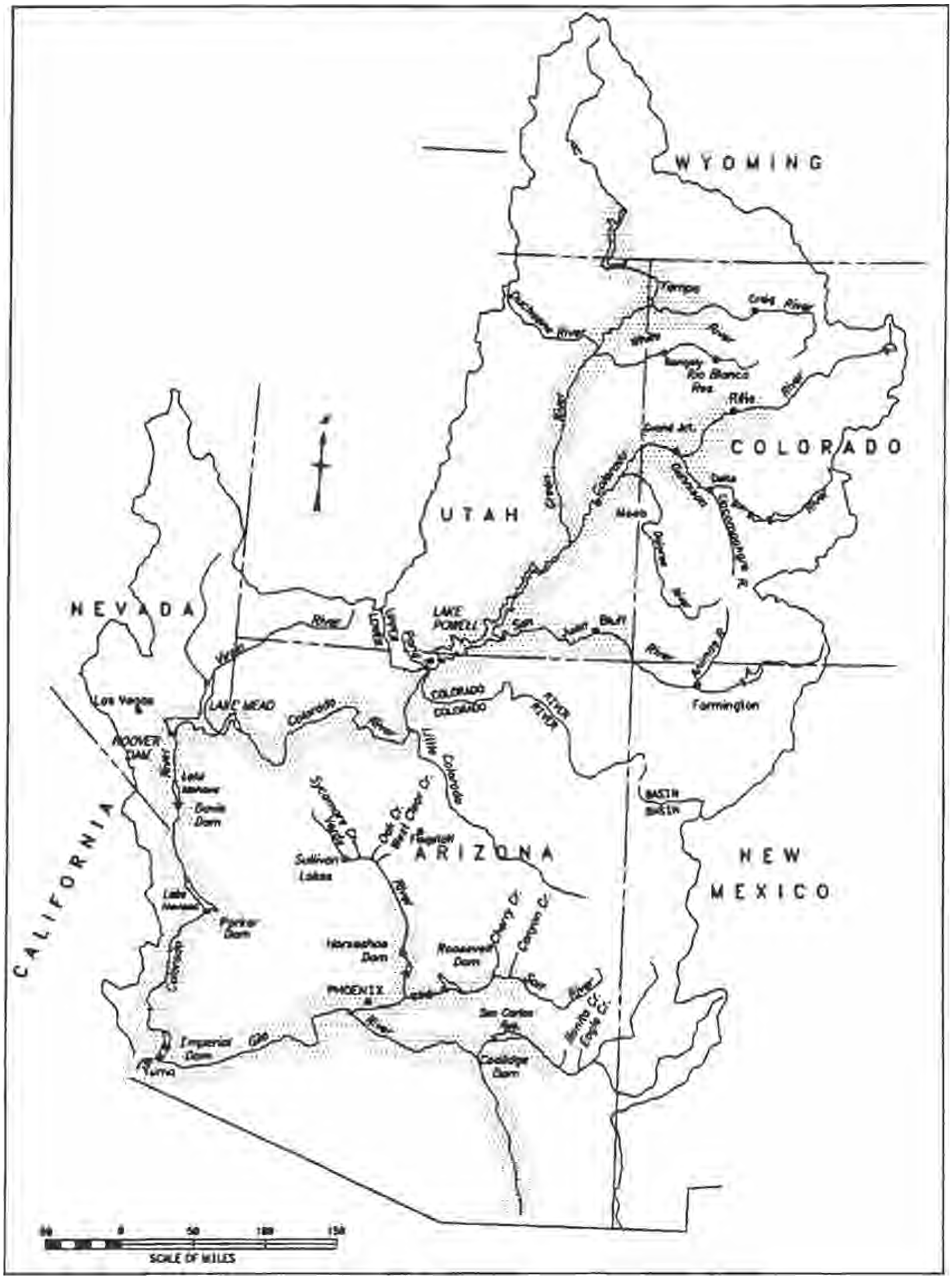



Figure 5. Historical distribution (shaded area) of the bonytail. (Map adapted from the Bonytail Chub Recovery Plan; USFWS 1990a.)

## CURRENT DISTRIBUTION AND ABUNDANCE

The bonytail now is very rare. In the Lower Basin, individual fish still are taken occasionally by fishermen in Lake Havasu (USFWS 1990a). A few large, old adults also are still found in Lake Mohave, but no successful reproduction has been documented there. A total of 32 adult specimens was collected by biologists from Lake Mohave from 1974 to 1987, and several more were reported by anglers. An additional 16 fish were collected from Lake Mohave in 1988 and 1989 (USFWS 1990a).

Recent distribution and abundance of the bonytail in the Upper Basin was described by Holden and Stalnaker (1975a), Tyus et al. (1982b, 1987), and Valdez and Clemmer (1982). Recruitment is apparently nonexistent or extremely low, with the most recent suspected juvenile bonytails originating only from the Desolation Canyon (Holden 1978) and Cataract Canyon areas (Valdez 1985). However, verifying recruitment is difficult due to the uncertainty that exists in the identification of juveniles.

The bonytail was common in the Green River below the Yampa River confluence after Flaming Gorge became operational in 1962. Vanicek and Kramer (1969) reported large year classes in 1959, 1960, and 1961 based on the collection of fish longer than 8 inches TL during those years. Holden and Stalnaker (1975a) found 36 adults during a 4-year study of the Upper Basin, 29 of which were captured in 1968, three in 1969, and four in 1970. With the exception of two fish, all were collected in the Green and Yampa Rivers within Dinosaur National Monument. No young were identified during that study. Seethaler et al. (1979) sampled the Green and Yampa Rivers of Dinosaur National Monument in 1974-1976 and found no bonytail. Holden and Crist (1981) reported one adult 11 inches TL from the lower Yampa River in 1979. However, no specimens have been reported from there since (Tyus et al. 1982b, 1986). Miller et al. (1982b) reported no adult bonytail from Dinosaur National Monument in 1981-1983, and Wick et al. (1979, 1981) caught no adults and could not distinguish among larval Gila collected there. Although roundtail chub were found in the Green and Little Snake Rivers in Wyoming during a 1986 survey, no bonytail were captured (Johnson and Oberholtzer 1987).

In other areas of the Green River, two bonytail adults were caught in Desolation Canyon in 1974 (USFWS 1990a; Paul Holden, BIO-WEST, pers. comm.). Holden (1978) caught one adult near Jensen, Utah, and one juvenile in Desolation Canyon in 1977. Several fish resembling bonytail were collected from Gray Canyon in 1980 and 1981 (Tyus et al. 1982a). During extensive sampling conducted in 1982-1985 in the Green River and a section of the Yampa River, one individual from Gray Canyon was tentatively identified as a bonytail from a total of 523 Gila specimens captured (Tyus et al. 1987).

During the period 1977 through 1983, no bonytail were collected from the Colorado or Gunnison Rivers in Colorado or Utah (Wick et al. 1979, 1981; Valdez et al. 1982b; Miller et al. 1984). However, in 1984, a single bonytail was collected from Black Rocks on the Colorado River (Kaeding et al. 1986). Several suspected bonytail also have been captured in

Cataract Canyon of the Colorado River within 20 miles upstream of the inflow to Lake Powell. This includes two in 1985 (one adult 15 inches TL and one juvenile 2 inches TL), one in 1986 (15 inches TL), and two in 1987 (one adult 11 inches TL, one juvenile 10 inches TL) (Valdez 1985, 1987, 1988). A bonytail was caught by an angler near Wahweap Marina, Lake Powell, in May 1985 (Randy Radant, Utah Division of Wildlife, pers. comm.). Also no bonytail were taken during studies of the San Juan River (VTN Consolidated, Inc. 1978; Platania 1990; Platania and Lang 1992).

STATUS

This species is very rare. Few individuals have been found in the last decade; recruitment is apparently nonexistent or very low. Like the razorback sucker, it is feared that wild populations of bonytail may soon no longer exist without recruitment of young fish. The recovery priority for the bonytail, discussed in the revised recovery plan for this species, indicates a high degree of threat with a low recovery potential under current habitat conditions.

HABITAT REOUIREMENTS

The bonytail chub always has been considered a species that is adapted to mainstream rivers, where it has been observed in pools and eddies (Vanicek 1967; Minckley 1973). In reservoirs, the fish occupies an active limnetic niche (Minckley 1973). Spawning of the fish never has been observed in nature, but Vanicek and Kramer (1969) reported that spawning occurred in June and July at water temperatures of about 64°F. Although wild bonytails are old fish, they are still capable of successful reproduction, and bonytail chubs placed in ponds have produced large numbers of young (Buddy Jensen, USFWS, pers. comm.; USFWS 1990a). Although habitats that are required for conservation of the bonytail chub are not well known, the limited data suggests that flooded, ponded, or even inundated riverine habitats may be suitable for adults, especially in the absence of competing nonnative fishes (USFWS 1990a).

**Riverine**

Bonytail is considered a big- or mainstream river species. Vanicek (1967) noted that adult bonytail occupied pools and eddies rather than areas with more current. Spawning of bonytail has not been observed in a river, but ripe fish were collected in Dinosaur National Monument during late June and early July suggesting that spawning occurred at water temperatures of about 64°F (Vanicek and Kramer 1969).

Vanicek and Kramer (1969) estimated growth rates of bonytail by back calculation of total length based on proportional growth of scales. Fish from the Green River at Dinosaur National Monument were 2 inches total length by the end of their first growing season, 4 inches their second, and 6 inches their third. The largest bonytail handled by Vanicek and Kramer (1969) was 15 inches and 7 years old.

In the Green River in Dinosaur National Monument, Vanicek and Kramer (1969) found that young bonytail and roundtail chubs primarily ate chironomid larvae and mayfly nymphs. Small fish became more dependent on floating food items as they grew larger. Larger juvenile chubs ate a more diversified diet, including terrestrial and aquatic insects. During the summer, adult bonytail fed on terrestrial insects that probably were taken from the surface. No fish remains were found in bonytail stomachs. In the Gila River, Kirsch (1888) reported that food of the bonytail consisted "almost entirely of gastropods and caddis-worms, which they crush with their powerful pharyngeals."

Reservoir

Life history data on bonytail in reservoirs have been collected by a number of biologists and summarized by Minckley (1985). Three specimens from Lake Mohave were estimated to be between 34 to 49 years old based on otolith examination (Minckley 1985). Bonytail in Lake Mohave generally occupy lacustrine habitat rather than upstream riverine habitat near Hoover Dam. W.L. Minckley (Arizona State University, pers. comm.) believes the cold hypolimnetic water from Lake Mead precludes use of the riverine habitat in Lake Mohave by bonytail. Wagner (1955) reported that the species was the most common one collected in gill nets and was usually found in areas over a clean, sandy bottom with reverse eddy current. The diet of bonytail chub in reservoirs appears to be primarily plankton and algae, although extensive food habit studies have not been carried out (Minckley 1973). Stomach analysis of specimens collected from Lake Mohave indicated they had preyed upon recently stocked rainbow trout fry less than 2.5 inches TL in size (Wagner 1955).

Spawning behavior of bonytail was observed in Lake Mohave (Jonez and Sumner 1954), but no young have been reported. Shortly after impoundment of Lake Mohave, approximately 500 bonytail congregated over a gravel bar in water up to 30 feet deep. Generally, females were escorted by three to five males and fertilized eggs were apparently deposited randomly. No effort to guard the spawning areas by either sex was observed (Jonez and Sumner 1954). Based on egg development, Wagner (1955) concluded spawning began in late spring or very early summer.

**Hatchery**

The majority of the collecting efforts in Lake Mohave since 1974 have been carried out to obtain bonytail for culture purposes, producing a total of 24 fish (Minckley 1985). Six female and five male bonytail obtained from Lake Mohave were spawned in water temperatures of 68°F at Willow Beach National Fish Hatchery (Willow Beach, Arizona), in 1981. Most eggs (90 percent) hatched 99 to 174 hours later. Only 55 percent of eggs placed in 60° to 63°F hatched between 170-269 hours) and 4 percent hatched at 54° to 55°F (between 334 and 498 hours) (Hamman 1982a). Marsh (1985) incubated bonytail eggs at 9°F intervals between 41°F and 86°F. The hatching success was 35 percent at 59°F, 32 percent at 68°F, and 0.5 percent at 77°F; no eggs survived at 41°F, 50°F or 86°F. Mean total length at hatching was 0.24-0.25 inches. Total length of normal fry at swim-up was greatest at 68°F (0.34 inches), compared with 0.32 inches at 59°and 77°F. The incidence of deformed fry was highest (4 percent) at 59°F.

Bonytail fry produced at Willow Beach in 1981 were reared at the Dexter NFHTC (Hamman 1982b). Spawning trials on 2 year-old bonytail were carried out in 1983 (Hamman 1985) when 24 females were spawned over a 4-week period using carp pituitary extract to induce ovulation. The fish ranged from 1.6-8 ounces with a mean weight of 4.5 ounces. Fecundity ranged from 1,015 to 10,384 eggs per fish with a mean of 4,677. Average number of eggs per pound of body weight varied from 5,076 to 29,935 with a mean of 17,283; egg viability averaged 67.5 percent. Eggs were hatched in Heath incubators at 70°F.

Bonytail have been placed into ponds at Arizona State University Research Park as well as earthen tanks at the Buenos Aires National Wildlife Refuge, Arizona; these stockings were made for research purposes and to produce fish for stockings elsewhere (Marsh 1988). An additional refugium was established at Hassayampa River Preserve owned by the Nature Conservancy. In 1983, 10,000 fry were shipped to the California Department of Fish and Game, and approximately 2,000 of these fish were placed into a small golf course pond. The young survived and grew with an expanding population of nonnative mosquitofish and African cichlids (USFWS 1990a). Moreover, bonytail annually produce substantial year classes through natural spawning under pond conditions at Dexter NFHTC (USFWS 1990a).

## CRITICAL HABITAT

### DEFINITION OF CRITICAL HABITAT

"Critical habitat," as defined in Section 3(5)(A) of the Act, means: (i) the specific areas within the geographical area occupied by the species at the time it is listed, on which are found those physical and biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by a species at the time it is listed upon a determination by the Secretary that such areas are essential for the conservation of the species.

The term "conservation," as defined in Section 3(3) of the Act, means: the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this Act are no longer necessary.

Therefore, in the case of critical habitat, conservation represents the areas required to recover a species to the point of delisting (i.e., the species is recovered and is removed from the list of endangered and threatened species). In this context, critical habitat preserves options for a species' eventual recovery. Section 3(5)(C) further states that the entire geographical area which can be occupied by the species shall not be included in critical habitat except in special circumstances.

## ROLE OF CRITICAL HABITAT IN SPECIES CONSERVATION

Areas considered for critical habitat designation are evaluated for their actual or potential contributions to the conservation of the species. In this regard, critical habitat serves to preserve options for a species' eventual recovery. In the definition of critical habitat, "conservation" mandates designation of areas that may be needed for a species' eventual recovery and delisting. However, when critical habitat is designated at the time a species is listed, the Service may not know recovery needs, but it must use the best scientific and commercial information available at the time in determining which areas to designate.

The designation of critical habitat will not, by itself, lead to recovery, but is one of several measures available to contribute to conservation of a species. Critical habitat helps focus conservation activities by identifying areas that contain essential habitat features (primary constituent elements) regardless of whether or not they are currently occupied by the listed species. Such designations alert Federal Agencies, States, the public, and other entities about the importance of an area for the conservation of a listed species. Critical habitat can also identify areas that may require special management or protection. Areas designated as critical habitat receive protection under Section 7 of the Act with regard to actions carried out, funded, or authorized by a Federal Agency which are likely to adversely modify or destroy critical habitat. Section 7 requires that Federal Agencies consult on their actions which may affect critical habitat and insure that their actions are not likely to destroy or adversely modify critical habitat. It also requires conferences on Federal actions which are likely to result in the modification or destruction of proposed critical habitat. Except for these added consultation (designated critical habitat) and conference (proposed critical habitat) requirements provided under Section 7, the Act does not have other requirements relating to critical habitat.

Designating critical habitat does not create a management plan for a listed species. Designation does not establish numerical population goals, prescribe specific management actions (inside or outside of critical habitat), nor does it have a direct effect on areas not designated as critical habitat. Recovery planning and critical habitat designation are different processes. Specific management recommendations for critical habitat are more appropriately addressed in recovery plans, management plans, and through Section 7 consultation.

Critical habitat identifies specific areas essential to the conservation of a species. Areas not currently containing all of the essential features, but with the capability to do so in the future, may also be essential for the long-term recovery of the species, particularly in certain portions of its range. These may be designated as critical habitat. However, not all areas containing the features of a listed species' habitat are necessarily essential to species' survival and recovery. Areas not included in critical habitat that contain one or more of the essential elements for a species may still be important to its conservation; they may be addressed under other facets of the Act, and other conservation laws and regulations. Designated areas may also be of considerable value in maintaining ecosystem integrity and supporting other species, but these values are only considered in the economic analysis and exclusion process when designating critical habitat.

## PRIMARY CONSTITUENT ELEMENTS

In determining which areas to designate as critical habitat for a species, the Service considers those physical and biological attributes that are essential to species conservation (i.e., constituent elements). In addition, the Act stipulates that the areas containing these elements may require special management considerations or protection. Such physical and biological features are stated in 50 CFR 424.12 and include, but are not limited to, the following items:

**FEATURES**

- Space for individual and population growth, and for normal behavior;
- Food, water, or other nutritional or physiological requirements;
- Cover or shelter;
- Sites for breeding, reproduction, rearing of offspring;
- Habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species.

The primary constituent elements determined necessary to the survival and recovery of the four Colorado River endangered fishes include, but are not limited to:

Water--This includes a quantity of water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminations, nutrients, turbidity, etc.) that is delivered to a specific location in accordance with a hydrologic regime that is required for the particular life stage for each species.

Physical Habitat--This includes areas of the Colorado River system that are inhabited by fish or potentially habitable for use in spawning, nursery, feeding, and rearing, or corridors between these areas. In addition to river channels, these areas also include bottomlands, side channels, secondary channels, oxbows, backwaters, and other areas in the 100-year floodplain, which when inundated provide spawning, nursery, feeding and rearing habitats, or access to these habitats.

Biological Environment--Food supply, predation, and competition are important elements of the biological environment and are considered components of this constituent element. Food supply is a function of nutrient supply, productivity, and availability to each life stage of the species. Predation, although considered a normal component of this environment, may be out of balance due to introduced fish species in some areas. This may also be true of competition, particularly from nonnative fish species.

These primary constituent elements are interrelated in the life history of the four endangered fishes. This relationship was a prime consideration in selection of proposed critical habitat for the fishes.

Critical habitat may only be seasonally occupied by the fish, but such habitat may be important for their conservation. Life history requirements of the Colorado squawfish and razorback sucker include inundated backwaters and floodplain areas which provide feeding and nursery habitat when inundated to include these areas. Proposed critical habitat for these two species includes the 100-year floodplain. Only those areas in the 100-year floodplain that contain the constituent elements will be considered part of critical habitat.

## ADDITIONAL SELECTION CRITERIA FOR THE RAZORBACK SUCKER

Because a recovery plan for the razorback sucker has not yet been prepared, additional selection criteria were developed to assist the Service in making a determination of which areas to propose as critical habitat. Previous Service findings, other published and unpublished literature sources, and discussions with individual members of the Colorado River Fishes Recovery Team were utilized to develop the constituent elements and additional selection criteria.

The razorback sucker has displayed a degree of versatility in its ability to survive and spawn in different habitats. However, razorback sucker populations continue to decline and are considered below the survival level (moving in direction of extinction). Thus, as versatile as the razorback sucker appears to be in selecting spawning habitat, there has been little recruitment of young to the adult population. Therefore, special consideration was given to habitats required for its reproduction and recruitment.

The following selection criteria were used by the Service to help determine areas necessary for survival and recovery of the razorback sucker.

1. Known or suspected wild spawning populations, although recruitment may be limited or nonexistent.

2. Areas where juvenile razorback suckers have been collected or which could provide suitable nursery habitat (backwaters, flooded bottomlands, or coves).

3. Areas presently occupied or that were historically occupied that are considered necessary for recovery and that have the potential for establishment of razorback sucker.

4. Areas and water required to maintain rangewide fish distribution, and diversity under a variety of physical, chemical, and biological conditions.

5. Areas that need special management or protection to ensure razorback survival and recovery. These areas once met the habitat needs of the razorback sucker and may be recoverable with additional protection and management.

## RESULTS OF APPLYING PRIMARY CONSTITUENT ELEMENTS AND SELECTION CRITERIA

The primary constituent elements were used to determine critical habitat throughout the historical range of the Colorado River endangered fishes. In addition, the five selection criteria described above were also used to evaluate potential razorback sucker critical habitat areas. The proposed critical habitat designations are based on the primary constituent elements, published and unpublished sources, Service reports and other findings, recovery plans (for Colorado squawfish, humpback chub, and bonytail chub), additional selection criteria, and the preliminary recovery goals being presently discussed for the razorback sucker by the Colorado River Fishes Recovery Team.

The presence of one or more primary constituent elements or additional selection criteria did not automatically result in inclusion as proposed critical habitat. Rather, the relative value of each constituent element for the survival and recovery of each fish was also evaluated for each reach. In accordance with Section 3(5)(c) of the Act, which states that: "Except in those circumstances determined by the Secretary, critical habitat shall not include the entire geographical area which can be occupied by the threatened or endangered species." Generally, the entire historical range of the fish should not be designated as critical habitat. Selection criteria number 4 was used to maximize the diversity of the selected reaches.

As discussed above under Constituent Elements-Physical Habitat, inundated floodplains (bottomland habitats) are important for razorback sucker and Colorado squawfish. These wooded bottomlands, side and secondary channels, oxbow lakes, and floodplain wetlands provide nutrients, food, cover, and other features necessary for various life stages of these fishes. In order to delineate such areas in designating critical habitat, the Service is using the 100-year flood elevation (100-year floodplain). **In no way is this meant to include all land within the 100-year floodplain as critical habitat, nor does it imply a specific frequency of flooding will be required as part of the rule. Only those areas which provide one or**

**more of the constituent elements are considered critical habitat. Areas within the 100-year floodplain which have been previously developed are not likely to provide constituent elements when flooded.** Paved areas, road and rail corridors, built-up areas within municipalities, and other previously developed or farmed areas are not considered critical habitat. Diked and leveed areas to which a connection to the river remains may continue to provide the constituent elements necessary for inclusion as critical habitat. Similarly, abandoned sand and gravel pits may provide the constituent elements of critical habitat. Sand and gravel operations which are currently extracting materials are not considered critical habitat. However, the site of such operations may later provide opportunities to recover these species. **As previously mentioned, although private land may be designated, regulation of activities only takes place when there is Federal involvement. Critical habitat designation applies only to those projects or activities which require Federal involvement (i.e.. funding, permits etc.) in order to proceed.**

Several reservoirs or portions thereof are included in the critical habitat designation. This designation is for all lands contained within the reservoir shorelines at the full-pool elevation. The full-pool elevation is defined as the water surface elevation at full capacity. The reservoirs physical features such as gravel bars, shallow depressions, washes, and areas of riparian vegetation that when covered by water, can provide spawning, nursery, feeding or other habitat components, can provide critical habitat. By establishing the upper boundary at the full pool elevation, all possible physical habitats within the reservoir are included as critical habitat regardless of the water elevation at any given time. **The critical habitat designation does not require the reservoir to be continuously maintained at the full pool elevation.** Changes in water surface elevations due to reservoir operations may have effects to the listed species or the critical habitat, however, these effects would be considered during project specific Section 7 consultations.

## RAZORBACK SUCKER

The Service is proposing 15 reaches of the Colorado River system (Figure 6 and Table 2) for designation as critical habitat for the razorback sucker. In the Upper Basin, critical habitat is being proposed in the Green, Yampa, Duchesne, White, Colorado, Gunnison, and San Juan rivers in the Lower Basin. Portions of the Colorado, Gila, Salt, and Verde rivers are being proposed.

Fifty-two percent (1,824) of the historical range of razorback sucker is proposed for designation as critical habitat. This represents reaches in each of the major basins of its historic range. Other areas that are not proposed also may be important and may contribute to the eventual recovery of razorback sucker.

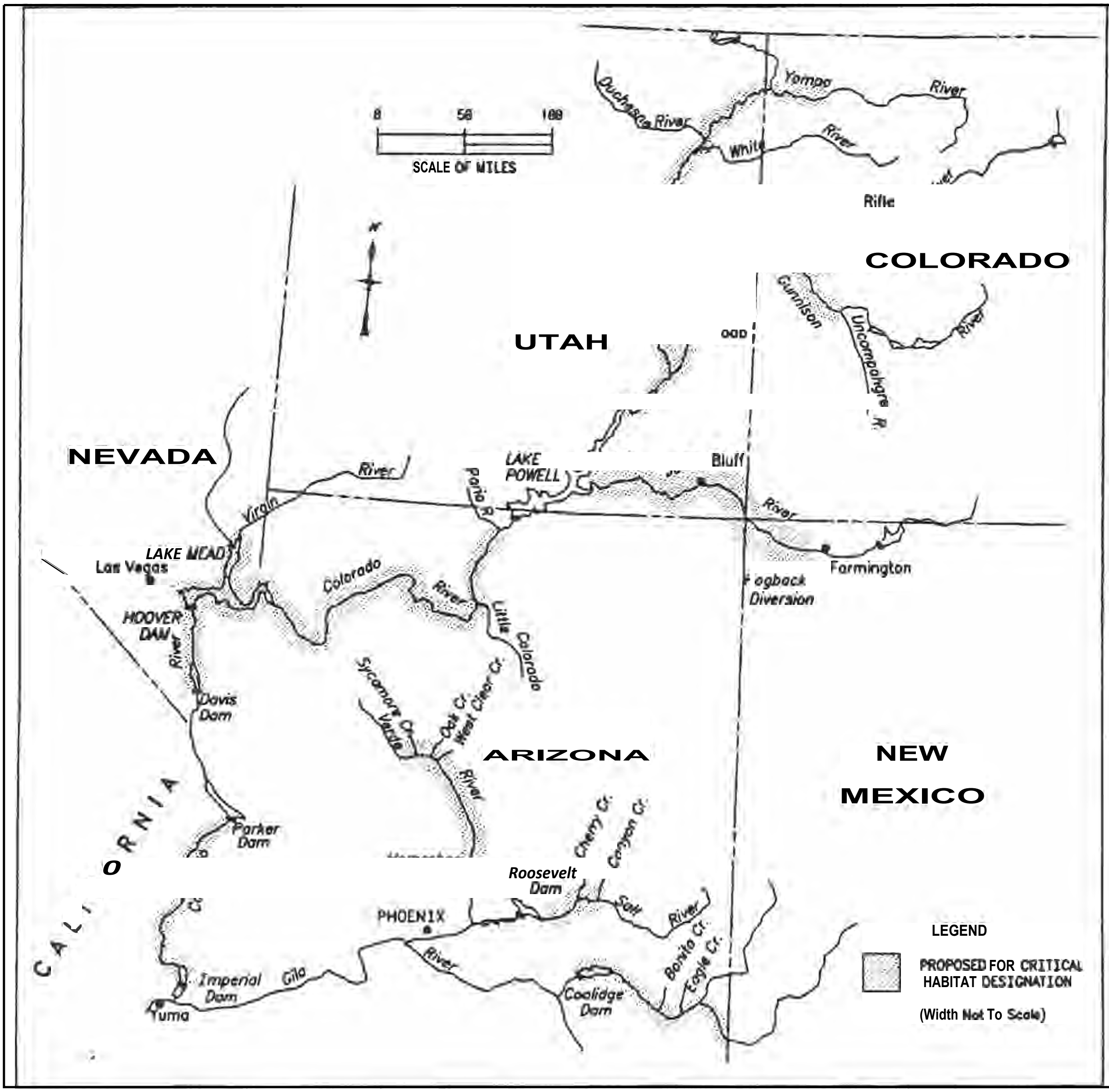



Figure 6. Map of proposed critical habitat for the razorback sucker.

**Table 2. Razorback sucker critical habitat and classifications proposed by basin and river. (Note: Potential reach classifications are based on preliminary information provided by members of the Colorado River Fishes Recovery Team and will likely change as the Razorback Sucker Recovery Plan is prepared.)**

| Upper Basin Reaches | Classification | Miles |
|---|---|---|
| Yampa River - Cross Mtn. Canyon to Green River | Downlisting | 52 |
| Green River - Yampa to Sand Wash | Downlisting | 128 |
| Green River - Sand Wash to Colorado River | Delisting | 205 |
| White River - Lower 18 Miles | Delisting | 18 |
| Duchesne River - Lower 2.5 Miles | Delisting | 2.5 |
| Gunnison River - Redlands Diversion to Uncompahgre | Delisting | 60 |
| Colorado River - Rifle to Westwater | Downlisting | 105 |
| Colorado River - Westwater to Dirty Devil | Delisting | 175 |
| San Juan River - Hogback Diversion to Neskahai Canyon | Downlisting | 198.5 |
| | Subtotal = | 944 |

| Lower Basin Reaches | Classification | Miles |
|---|---|---|
| Colorado River - Paria River to Hoover Dam | Delisting | 345 |
| Colorado River - Hoover Dam to Davis Dam | Downlisting | 65 |
| Colorado River - Parker Dam to Imperial Dam | Delisting | 134 |
| Gila River - New Mexico to San Carlos Reservoir | Delisting | 132 |
| Salt River - Apache Falls to Roosevelt Lake | Delisting | 55 |
| Verde River - Sullivan Lake to Horseshoe Lake | Delisting | 149 |
| | Subtotal = | 880 |
| | Downlisting Total | 477.5 |
| | Delisting Total | 1346.5 |
| | Grand Total | 1824 |

Razorback suckers were once more abundant and widespread in the Lower Basin. However, razorback sucker maybe more recoverable in the Upper Basin because habitat in the Upper Basin has been less altered, and current habitat conditions warrant proposing a large percentage of the Upper Basin (Figure 7). Approximately equal amounts of Upper (944) and Lower Basin (880) river miles have been proposed (Table 2).

These reaches flow through a variety of shoreline ownerships, both public and private. The National Park Service is the major manager for proposed critical habitat with 33 percent of shoreline ownership. The approximate percentages of critical habitat by shoreline ownership for the razorback sucker is presented in Figure 8.

## RAZORBACK SUCKER CRITICAL HABITAT DESIGNATION BY AREA

### Yampa River - Lily Park to Green River Confluence

**Boundary Delineation:** Colorado, Moffat County. The Yampa River and its 100-year floodplain from the mouth of Cross Mountain Canyon in T.6N., R.98W., section 23 (6th Principal Meridian) to the confluence with the Green River in T.7N., R.103W., section 28 (6th Principal Meridian).

**Shoreline Ownership:** National Park Service, 82.9 percent; Private 16.9 percent; Bureau of Land Management, 0.2 percent.

**Overlap with Proposed Critical Habitat for:** Colorado squawfish, humpback chub, bonytail.

**Occurrence:**

Historical

The historical distribution of the razorback sucker in the Yampa River is difficult to assess due to limited data from early collections (Bestgen 1990). Historical accounts indicate razorback suckers were common from the Lily Park area to the Green River (Quartarone 1993).

Recent

Recent collections indicate that the fish occur in the lower portions of the river, but rarely upstream of the confluence with the Little Snake River (McAda and Wydoski 1980; Lanigan and Tyus 1989). Concentrations of the razorback sucker were found near the Green River confluence (Holden and Stalnaker 1975a, 1975b). Carlson et al. (1979) presented data that showed the razorback sucker to be present at Lily Park. Spawning razorback suckers were found in the lower Yampa Canyon (Miller et al. 1982b; Tyus and Karp 1989, 1990).

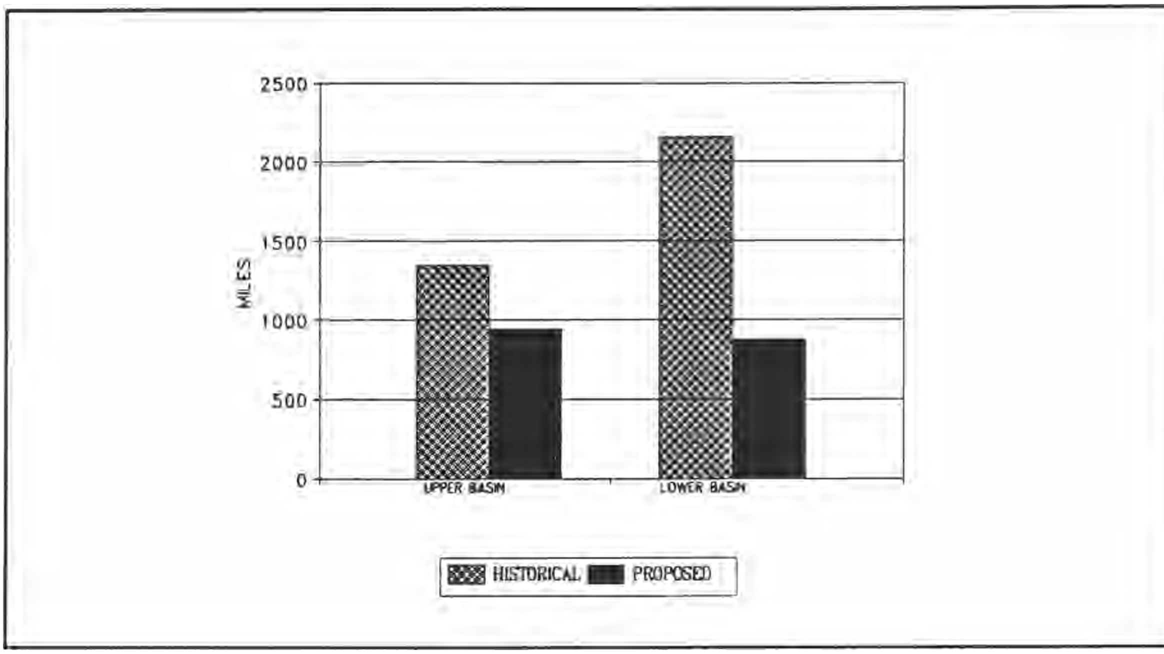



Figure 7. Relative amount of historical habitat proposed as critical habitat for the razorback sucker.

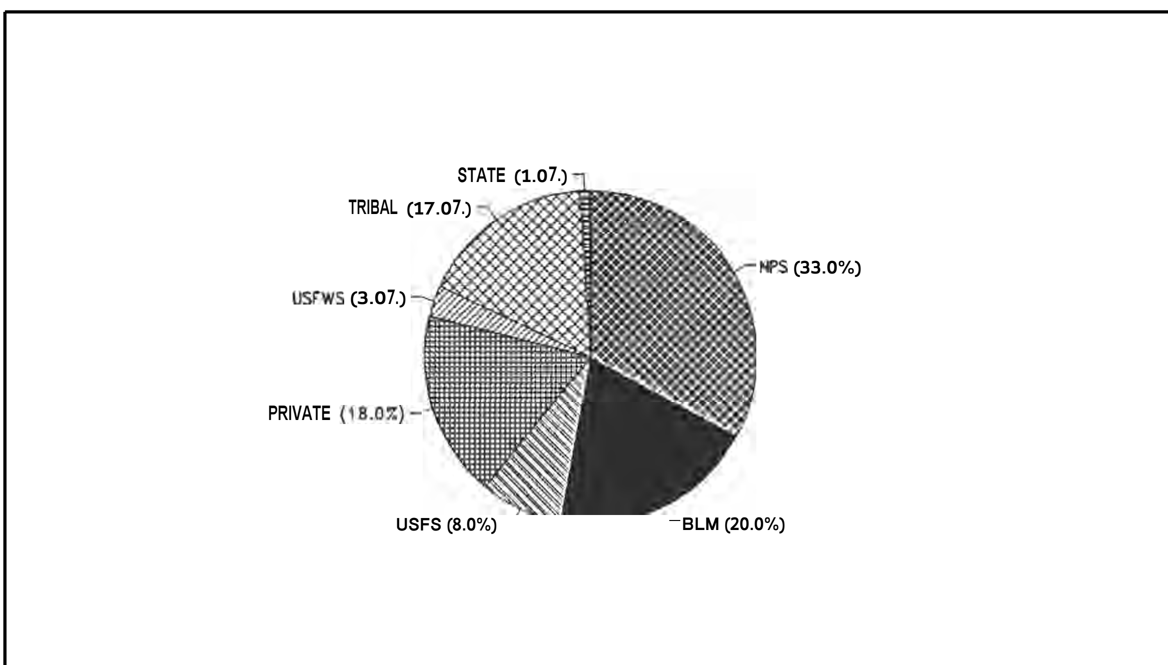



Figure 8. Shoreline ownership for proposed critical habitat for the razorback sucker.

**Description of Habitat:**

The Yampa River is the largest remaining free-flowing river in the Colorado River basin (Carlson and Muth 1989). The Yampa River flows 198 miles and drops about 7,445 feet in elevation (Tyus and Karp 1989). Only minimal physical and hydrologic changes have occurred in the mainstream Yampa River. The most significant habitat alteration may have been the introduction of nonnative fishes into the Yampa River; nonnative fishes represent 15 of 24 species reported by Tyus et al. (1982a).

From Cross Mountain Canyon to the Little Snake River, the Yampa River has boulder/cobble/gravel substrates. The river is fairly wide here, with riffles, eddies, and side channels common. Though there is at least one deep pool, the river is generally very shallow. The Yampa River receives waters from the Little Snake River near Deerlodge Park. Here, the substrate changes to sand and silt, mostly from the Little Snake River. The habitat is not varied, with few riffle, eddies, or backwaters. At RM 45, the Yampa abruptly enters Yampa Canyon. Here, steep canyon walls house the slow-moving river. Occasional boulder fields create rapids, but the predominant substrate is gravel/cobble with patches of sand. The river gradient increases in the lower portion of the canyon and the river meanders through soft sandstone cliffs. The Yampa River comes out of Yampa Canyon at Echo Park where it joins the Green River (Miller et al. 1982b).

**Relationship to Constituent Elements:**

<u>Water</u>

The Yampa River has minimal water development, thus, when it is compared to other rivers in the basin, the current hydrograph reflects flows which are representative of historical volume and timing. The Service has identified existing Yampa River flows as adequate for the needs of native fishes (Tyus and Karp 1989). Yampa River flows have also been identified as critical for maintaining native fish habitat in the Green River below their confluence (McAda and Wydoski 1980; Tyus and Karp 1989). Water quality has not been identified as a chronic problem. However, an oil spill in June of 1989 caused by a ruptured pipeline discharged approximately 10,000 gallons into the Yampa River. This spill has been implicated in the decline of Colorado squawfish larval and young-of-year abundance in the upper Green River that year (Obmasick 1989; Carlson 1991), impacts to other species may have also occurred.

<u>Physical Habitat</u>

Data collected in recent years indicate that this reach of the Yampa provides spawning and adult habitat for the razorback sucker (Tyus and Karp 1989, 1990). Analysis of this reach by the Service (Miller et al. 1982b) shows principal habitat types to be pool, riffle, eddy, and side channel. Backwaters are an important habitat component in the lower portion of this reach, and rapids occur in Dinosaur National Monument. Backwaters also are a significant habitat type in the Lily Park area. These habitats have been identified as important areas for adult razorback suckers (Tyus and Karp 1990). Collection of adult razorbacks in spawning condition in the lower 0.5 mile of the Yampa indicates the presence of spawning activity in that area (Miller et al. 1982b; Tyus and Karp 1990). Temperatures in this portion of the Yampa River have not been altered to any degree by human activities and remain suitable for native fishes. This reach historically supported razorback suckers, and they remain in low numbers. This reach of the Yampa is considered essential for the survival of this species due to the presence of constituent elements and its importance to constituent elements in downstream reaches of the Green River.

Biological Environment

Nutrient input and food sources for adult razorback suckers are present within the reach. The relatively unmodified nature of the Yampa River system likely results in food supply levels similar to predevelopment. The introduction of nonnative fishes is probably the greatest alteration to the historical Yampa system. Miller et al. (1982b) found 13 nonnative fish species within this reach. Nine native fish species were collected in the same area. The potential for competition and predation between these nonnative species and native species is high. Virtually all 13 species of nonnative fish found in this reach have the potential to prey on and/or compete with native species. Maintenance of a natural (historical) hydrograph may help limit further encroachment by nonnative fishes. The presence of nonnative fishes has not caused the extirpation of adult razorback sucker and other native species from this reach, and razorback sucker spawning continues in the lower portion.

**Relationship to Additional Selection Criteria:**

For the razorback sucker, additional selection criteria were developed to assist in the selection of proposed critical habitat designations. This reach of the Yampa River meets those criteria.

Presence of Spawning Population

The collection of adult razorback suckers in spawning condition in the lower Yampa River for several years is strong indication of spawning within this reach (Miller et al. 1982b). Tyus and Karp (1990) postulated that razorback suckers spawning in the lower Yampa River was historic, and that the fish exhibited fidelity to that spawning site as evidenced by repeated captures and recaptures of the same fish.

Nursery Habitat

There are no indications of razorback spawning in the Yampa River in the upper portion of this reach. However, backwaters and other potential nursery habitats do exist throughout the reach, particularly in the Lily Park area (Miller et al. 1982b).

Historic or Present Distribution

This reach is known historical and current razorback sucker habitat. Historical accounts (Quartarone 1993) and recent research (Lanigan and Tyus 1989) indicate little change in razorback sucker distribution in the Yampa River.

Maintenance of Rangewide Distribution

The Yampa River is or is near the northern range of occupied razorback sucker habitat. However, razorback sucker once ranged upstream in the Green River to Wyoming (Simon 1946).

Special Management

Yampa River flows are considered to be adequate for the razorbacks requirements at this time. Efforts will need to be made to maintain a relatively unmodified hydrograph in the Yampa River. The problems associated with nonnative fish predation and competition will need to be addressed.

**Green River - Confluence with the Yampa to Sand Wash**

**Boundary Delineation:** Utah, Uintah County; and Colorado, Moffat County. The Green River and its 100-year floodplain from the confluence with the Yampa River in T.7N., R.103W., section 28 (6th Principal Meridian) to Sand Wash at RM 96 in T.11S., R.18E., section 20 (6th Principal Meridian).

**Overlap with Proposed Critical Habitat for:** Colorado squawfish, humpback chub, bonytail.

**Shoreline Ownership:** Bureau of Land Management, 31.7 percent; National Park Service, 24.7 percent; Private, 27.8 percent; Fish and Wildlife Service, 8.4 percent; Tribal, 5.4 percent; State, 2.1 percent.

**Occurrence:**

Historical

Jordan (1891), reported that razorback sucker were very abundant at Green River, Utah, . Collections in the Green River just prior to and after construction of Flaming Gorge Dam confirmed the presence of razorback sucker (Binns et al. 1964; Banks 1964).

Recent

The occurrence of razorback sucker has been well documented in this reach since the 1960's (Binns 1965, 1967; Holden and Stalnaker 1975a, 1975b; Seethaler et al. 1979; McAda and Wydoski 1980). Although they have been considered rare in some portions of the Green River (Binns 1967), the upper portions of this reach supports the largest riverine population of razorback sucker remaining in the Basin, its numbers decrease below the Duchesne River (Tyus 1987; Lanigan and Tyus 1989).

**Description of Habitat:**

Historically, flows in the Green River began increasing in March, peaked in June, and remained high through July (Smith and Green 1991). The spring peak averaged about 8,000 cfs for the predam period of 1951-1962 at Greendale, Utah. Yearly and seasonal variation in this reach made flows highly variable. Mean monthly flow during spring runoff (April-July) was about 14,000 cfs.

Construction of Flaming Gorge and Fontenelle dams in the 1960's altered hydrologic conditions in the Green River. The magnitude of the spring peak has been reduced, and flows during the remainder of the year have increased. The average spring peak measured at Greendale, Utah, has decreased to about 4,000 cfs; winter baseflows have increased about 50 percent (Tyus and Karp 1991). Additionally, temperatures and sediment transport have changed since construction of the dams. The flow, temperature, and sediment from the Yampa River somewhat ameliorate the reduction in spring flows from Flaming Gorge Dam (Tyus and Karp 1989). Depletions above and within this reach have the potential to reduce the total volume of water by 32 percent (USFWS 1992b).

The Green River from its confluence with the Yampa River in Echo Park to Sand Wash includes several very different reaches. Substrate is a mixture of sand/silt with some large gravel/cobble riffles. After leaving the broad, shallow Echo Park reach, the river passes through Whirlpool Canyon, an area of steep cliffs, large pools, deep eddies, rapids, and large boulders. After exiting the canyon, the Green River flows through Island and Rainbow parks. The river in this area is shallow; backwaters, cobblebars, and side channels are common. Split Mountain Canyon contains large boulder fields, swift waters, and three large rapids. Some significant sandbars exist in the lower velocity sections of this area. The Green River, upon leaving Dinosaur National Monument at Split Mountain, enters the Uintah Basin where it becomes broad, shallow, and flat. The river is highly braided, and side channels and backwater nursery areas are prominent. Some drainage occurs due to agriculture, agricultural return flows, and urban discharge into the river. The substrate is sand underlain with rock. The Duchesne River, from the southern slope of the Uintah Mountains, enters the Green River near Ouray, Utah, RM 248. Just to the south, the White River flows into the Green River, and the river becomes deeper. However, it is still characterized by eddies, backwaters, side channels, and some pools. The substrate is predominantly sand/silt. This reach of the Green River ends near Sand Wash above Desolation Canyon.

**Relationship to Constituent Elements:**

**Water**

Flows in this reach are dominated by releases from Flaming Gorge Dam and flows from the Yampa River. During an average hydrologic year, spring peaks of about 13,000 cfs will occur at Jensen, due to an average peak flow of 8,000 cfs from the Yampa River and 4,700 cfs from Flaming Gorge Dam. Flows above about 16,000 cfs are needed to inundate bottomlands. Because of the distance between this reach and the dam and unregulated flows of the Yampa River, near-historical water temperature levels in this reach can be achieved for the fish. However, when summer and fall cold water releases exceed downstream flows, water temperatures will be depressed.

Surveys from this portion of the Green River indicate that the concentrations of boron, selenium, and zinc in the water, bottom sediments, and biological tissue are sufficiently large to be harmful to fish (Stephens et al. 1988, 1992). This study detected increasing concentrations of selenium in the water from near the detection level of 1 $\mu g/L$ at Greendale to a mean of 2 $\mu g/L$ by Green River, Utah. Large concentrations of selenium were present in water discharged from Stewart Lake (mean 6.7 $\mu g/L$) and Ashley Creek (mean 88 $\mu g/L$). Selenium concentrations in return flows to the Green River have been shown to cause direct mortality on razorback sucker larvae (Bruce Waddell, USFWS, pers. comm.).

Physical Habitat

Adult razorback suckers overwinter in the Jensen and Island and Echo Park reaches of the Green River (McAda and Wydoski 1980; Valdez and Masslich 1989). Adults are attracted to the large backwaters, tributary mouths, and flooded bottomlands within this reach in early spring prior to spawning (Tyus and Karp 1990). Spawning habitat includes cobble/gravel bars in Echo Park and from Ashley Creek to the lower boundary of Dinosaur National Monument (Tyus and Karp 1990). During high water years, adults in reproductive condition also are found in flooded bottomlands and tributary mouths within this reach (Tyus and Karp 1990). These types of areas provide warmer water temperatures, rich feeding areas, low-velocity habitat, and potential spawning and nursery habitat. This important reach contains high-quality nursery areas for the endangered fishes in the Green and Yampa Rivers. These include the mouths of backwaters, bottomlands, wetlands, and tributary streams. These same areas also are used by adult razorback sucker for feeding both pre- and post-spawning periods.

Biological Environment

Extensive bottomland habitats in this reach are sources of nutrient inputs into the Green River and provide food for razorback sucker. Additionally, historical Yampa River levels of nutrients are maintained. This portion of the Green River also contains large numbers of red shiner, channel catfish, black bullhead, green sunfish, and common carp, all of which are known to compete with and/or prey upon native fishes. Other piscivorous fish species in this reach include Colorado squawfish, northern pike, and walleye.

**Relationship to Additional Selection Criteria:**

For the razorback sucker, additional selection criteria were developed to assist in the selection of proposed critical habitat designations. This reach of the Green River meets those criteria.

Presence of Spawning Population

Adults in spawning condition have been captured at Echo Park, Old Charley Wash, lower Ashley Creek, the mouth of the Duchesne River, the Stewart Lake Drain, and areas in between (Tyus and Karp 1990).

Nursery Habitat

Echo and Island parks and the Jensen area contain numerous backwater habitats for rearing of young fish. Bottomlands at Escalante, Old Charley Wash, and elsewhere may be important nursery areas (Wick 1992).

Historic or Present Distribution

This reach contains the largest remaining riverine population of razorback sucker (Lanigan and Tyus 1989). Historically, they were much more abundant than at present. Because of lack of recruitment, the number of razorback suckers remaining in this reach continues to decline (Tim Modde, USFWS, pers. comm.).

Maintenance of Rangewide Distribution

This area is considered the most important riverine reach remaining for the razorback sucker in the Colorado River basin.

Special Management

The Bureau of Reclamation and the Service have reached an agreement on the operation of Flaming Gorge Dam to provide for some of the flow requirements of the razorback sucker in the Green River. Flow releases are increased in Spring to allow inundation of some spring habitats, especially at Old Charley Wash. However, legal protection for these flows must now be obtained to ensure the passage of this water through the reach to reach target areas. Selenium concentrations and interactions with nonnative fishes are other issues which need to addressed for recovery in this reach.

## Green River - Sand Wash to Confluence with the Colorado River

**Boundary Delineation:** Utah, Uintah, Carbon, Grand, Emery, Wayne, and San Juan Counties. The Green River and its 100-year floodplain from Sand Wash at RM 96 at T.11S., R.18E., section 20 (6th Principal Meridian) to the confluence with the Colorado River in T.30S., R.19E., section 7 (6th Principal Meridian).

**Shoreline Ownership:** Bureau of Land Management, 46.6 percent; National Park Service, 27.9 percent; Tribal, 12.6 percent; Private, 12.1 percent; State 0.8 percent.

**Overlap with Proposed Critical Habitat for:** Colorado squawfish, humpback chub, bonytail.

**Occurrence:**

Historical

Historic distribution of the razorback sucker in this reach of the river was first documented by Jordan (1891). Smith (1959) stated that razorback suckers were "common in the lower part" of the river (in Bestgen 1990). Other than these accounts, little is known about the historical occurrence of the razorback sucker in this reach of the Green River.

Recent

In more recent years, Tyus et al. (1987) reported finding only seven razorback suckers in this stretch of the river. Two of these fish were in reproductive condition when captured in Labyrinth Canyon (Tyus 1987). Razorback suckers have also been caught near the mouth of the San Rafael River (Miles Moretti, UDWR, pers. comm.).

**Description of Habitat:**

A maximum flow of 68,000 cfs was recorded at Green River, Utah in 1917 and a minimum flow of 255 cfs in 1931. Predam temperatures at Jensen, Utah, ranged from near 32°F in December and January to around 70°F during July and August (Smith and Green 1991).

Below Sand Wash, the Green River enters Desolation Canyon, a wide canyon with nearly 50 riffles and rapids. Rapids gradually increase in size as the river travels through the canyon. Habitats in this stratum include eddies, riffles, rapids, and some deep pools. Boulder cobble and sand make up the primary substrates within Desolation Canyon. This canyon is followed by Gray Canyon which contains larger and deeper pools than are found in Desolation Canyon. Other habitats within the canyon include eddies, rapids, and riffles. Side channels and backwaters also exist here. Substrate in Gray Canyon is composed mainly of boulder/rubble/sand with some gravel. In total, the river runs 159 miles through these two canyons. The Green River meets the Price River in lower Gray Canyon before that canyon ends at Book Cliffs escarpment (Tyus et al. 1987). The river then flows through the Green River Valley, near Green River, Utah. Predominant substrate in this valley varies from gravel/rubble to sand and silt. Few backwater habitats are found along this stretch of the Green, but riffles, side channels, and eddies do exist. At the southern end of the valley the San Rafael River joins the Green River before the river enters Labyrinth and Stillwater Canyons within Canyonlands National Park. This section of the river is dominated by a sand/silt substrate and is characterized by side channels and eddies. No rapids and few riffles exist within Stillwater and Labyrinth Canyons (Miller et al. 1982c). The river joins the upper Colorado River within Canyonlands National Park.

**Relationship to Constituent Elements:**

**Water**

**Because of water** depletions which occur above this reach, historic water levels are seldom if ever obtained. Because of this, flooding of bottomlands is infrequent. Research to determine actual flow needs for this reach is currently underway as part of the Upper Basin Colorado River Implementation Program. Water depletions have the potential to reduce water volumes in this reach by about 30 to 40 percent (USFWS 1992b).

Physical Habitat

This reach does not contain the large number of backwaters that are present in the Green River from Sand Wash up to the Yampa River. However, large bottomlands which were historically flooded are present throughout this reach. Eddies and other low-velocity habitats also are present. Cobble/gravel bars which can provide spawning habitat occur within this reach; but no spawning locations have been confirmed.

Biological Environment

Very little is known on the quantity or quality of the food supply in this reach. Sources of input include the river above and from washes and side channels. The flooded bottomlands along this reach were probably once sources of food into the system but are seldom flooded the way the system is presently managed. Large concentrations of nonnative fishes in this reach include common carp, channel catfish, fathead minnow, and red shiner.

**Relationship to Additional Selection Criteria:**

**For the razorback** sucker, additional selection criteria were developed to assist in the selection of proposed critical habitat designations. This reach of the Green River meets those criteria.

<u>Presence of Spawning Population</u>

No spawning population is presently known to exist within this reach, although individuals likely move to this reach after spawning. However, razorback sucker in reproductive condition have been captured in Labyrinth Canyon (Tyus 1987).

<u>Nursery Habitat</u>

This reach contains bottomlands, eddies, and other low-velocity habitats which are suitable nursery areas at certain water flows.

<u>Historic or Present Distribution</u>

Few razorback suckers remain in this reach. However, a larval razorback sucker was captured near Mineral Bottom in 1992 (Ed Wick, NPS, pers. comm.) and two young-of-year were collected in a backwater in the lower Green River (Tom Chart, UDWR, pers. comm.).

<u>Maintenance of Rangewide Distribution</u>

This reach may be very important for exchange of genetic material between the Green and Colorado Rivers. This reach also may be important for razorback sucker larvae which drift from the upper reaches of the Green River.

<u>Special Management</u>

Obtaining flows of sufficient quantity and at the appropriate time may be a priority for this reach. Nonnative fish also very abundant throughout this reach.

**<u>White River - Lower 18 Miles</u>**

**Boundary Delineation: Utah, Uintah County. The White River and** its **100-year floodplain from the boundary of the Uintah and Ouray Indian Reservation at RM 18 in T.9S., R.20E., section 21 (Salt Lake Meridian) to the confluence with the Green River in T.9S., R.20E., section 4 (Salt Lake Meridian).**

**Shoreline Ownership:** Tribal, 96.9 percent; Private, 3.1 percent.

**Overlap with Proposed Critical Habitat for:** Colorado squawfish.

**Occurrence:**

Historical

Knowledge of the historic abundance of the razorback sucker in the White River is limited. Surveys of the White River, both historic and recent, show that the razorback sucker is rare in these waters. Sigler and Miller (1963) stated that these fish are uncommon in the White River.

Recent

Recent survey efforts have resulted in few razorback sucker captures (Lanigan and Berry 1981, Miller et al. 1982a). Lanigan and Berry (1981) reported one hybrid razorback sucker collected 60 miles up the White River in 1979. In 1987, an adult razorback sucker was captured 18 miles upstream from the Green River (Steve Cranney, UDWR, pers. comm.).

**Description of Habitat:**

**The lower** 18 miles of the White River is dominated by a wide alluvial plain with a sand/silt substrate and occasional areas of exposed bedrock. There are very few riffles and no rapids or deep pools. Several side channels create eddies and backwaters (Miller et al. 1982a). Water development in the White River basin has resulted in changes to historical flows. These changes appear to be relatively minor when compared to other Basin tributaries. Taylor Draw and Rio Blanco Reservoirs are the major impoundments on the White River. These facilities act as barriers, trap sediment, and provide habitat for nonnative fishes.

**Relationship to Constituent Elements:**

Water

Although extensive water development has not occurred in the White River basin, historical flow patterns have changed. The completion of Taylor Draw Dam near Rangely, Colorado altered flow and sediment transport to downstream reaches. Flows which provide seasonal habitat requirements for razorback suckers still exist. Water quality in the White River has not been discussed as a major issue. However, the concentration of oil, natural gas, and oil shale resources in the White River basin may require future study of water-quality issues.

Physical Habitat

The habitat characteristics of the lower White River include backwaters, side channels, and secondary channels which are common (Martinez 1986a). Principal habitat types are pool, riffles, eddies, and side channels (Miller et al. 1982a). Backwaters are an important habitat component in the lower portion of this reach; small rapids occur in the upper portion. These habitats have been identified as important resting and feeding areas for adult razorback suckers (Tyus and Karp 1990). Temperatures in this portion of the White River are suitable for native fishes.

Biological Environment

Miller et al. (1982a) found 15 species of fish in the White River (8 nonnative, 7 native). These nonnatives may compete with and/or prey on razorback suckers. The establishment of nonnative sport fishes in Taylor Draw Reservoir may contribute to nonnative fish populations downstream. Food supply for larval, juvenile, and adult razorback suckers is not likely to be limiting in the White River (Bestgen 1990).

**Relationship to Additional Selection Criteria:**

For the razorback sucker, additional selection criteria were developed to assist in the selection of proposed critical habitat designations. This reach of the White River meets those criteria as discussed below.

Presence of Spawning Population

There has been no documentation of razorback sucker reproduction in the White River.

Nursery Habitat

The habitat description by Miller et al. (1982a) indicates that potential nursery habitat is present in this reach of the White River. Backwaters and other low-velocity environments occur at high water providing food and higher water temperatures than the river channel.

Historic or Present Distribution

Historic accounts of razorback suckers within the White River indicate that the species was present in the system (Quartarone 1993). Recent research efforts indicate that the razorback sucker is rare within the White River (Bestgen 1990). An adult razorback sucker was captured approximately 18 miles upstream from the Green River in 1987 (Steve Cranney, UDWR, pers. comm.).

Maintenance of Rangewide Distribution

The White River through this reach is associated with the upper Green River fish community. This reach has the potential to provide adult razorback sucker habitat for the population which exists within adjacent Green River reaches.

Special Management

Measures to insure that adequate flows continue in the White River will need to the implemented. Protection of backwater and other low water velocity environmental will be required. The problems associated with nonnative fish predation and competition will need to be addressed.

**Duchesne River - Lower 2.5 Miles**

**Boundary Delineation:** Utah, Uintah County. The Duchesne River and its 100-year floodplain from RM 2.5 in T.4S., R.3E., section 30 (Salt Lake Meridian) to the confluence with the Green River in T.5S., R.3E., section 5 (Uintah Meridian).

**Shoreline Ownership: Tribal,** 88.0 percent; Private, 12.0 percent.

**Overlap with Proposed Critical Habitat for: None.**

**Occurrence:**

Historical

No historic data on fish species abundance in the Duchesne River is available. However, razorback suckers were probably once common there. This is suggested, as Jordan (1891) indicated that razorback suckers were common throughout the Colorado River basin.

Recent

Recent collections indicate that razorback sucker are seasonally common in the mouth and lower Duchesne River (Tyus 1987).

**Description of Habitat:**

Historically, much more of the Duchesne River was accessible for use by the razorback sucker. But because of diversions and water depletions, only the lower portion is presently used by razorback sucker.

The Duchesne River enters the Green River at RM 249. The lower 2.5 miles of the Duchesne River is predominately slow runs and eddies with cobble and silt substrates. During spring runoff in the Green and Duchesne Rivers, the lower Duchesne River floods and creates large eddies and slow runs.

**Relationship to Constituent Elements:**

**Water**

**Fifty-three percent of the water from the Duchesne River is being depleted (USGS gage records). Under current flow regimes, this area attracts and is being used by razorback suckers, but additional water could increase the value of this area in meeting other life history needs of this species. Future projects associated with the Central Utah Project and proposed projects by the Soil Conservation Service will result in greater depletions. Additionally, although water quality is sufficient during most periods, this area contains numerous oil and gas wells which can cause potential water-quality problems.**

**Physical Habitat**

**During spring runoff, the mouth of the Duchesne River becomes a low velocity (eddy) habitat suitable as an adult feeding and staging area prior to spawning. Conditions also are suitable for providing nursery habitat for this species.**

**Biological Environment**

**Little has been reported on the quality or quantity of the food supply in this reach. Historically, the Duchesne River probably was a large source of nutrients into the Green River. Water diversions and depletions have likely impacted its significance as a source of nutrients. Nonnative common carp, channel catfish, red shiner, and fathead minnow are common in the lower portion of this reach.**

**Relationship to Additional Selection Criteria:**

**For the razorback sucker, additional selection criteria were developed to assist in the selection of proposed critical habitat designations. This reach of the Duchesne River meets those criteria.**

**Presence of Spawning Population**

**Razorback suckers in spawning condition have been captured in the mouth of the Duchesne River (Tyus and Karp 1990). However, it is unknown whether spawning actually occurs in this area.**

**Nursery Habitat**

**The mouth of the Duchesne River provides suitable habitat for rearing of larval and juvenile endangered fishes when flooded.**

Historic or Present Distribution

Razorback suckers are commonly collected from this area during certain times of the year (Tyus 1987; Tyus and Karp 1990).

Maintenance of Rangewide Distribution

This reach may be important in maintaining and restoring razorback suckers within the Green River.

Special Management

Water depletions within the Duchesne River drainage affect the usefulness of this area. Maintenance of flows year-round through this reach would increase its value. Flows from the Duchesne also influence the probability of bottomland flooding in the lower Green River.

**Gunnison River - Confluence with the Uncompahgre River to the Redlands Diversion Dam**

**Boundary Delineation:** Colorado, Delta and Mesa Counties. The Gunnison River and its 100-year floodplain from the confluence with the Uncompahgre River in T.15S., R.96W., section 11 (6th Principal Meridian) to Redlands Diversion Dam in T. 1S., R.1W., section 27 (Ute Meridian).

**Shoreline Ownership:** Private, 54.2 percent; Bureau of Land Management, 39.2 percent; State, 6.7 percent.

**Overlap with Proposed Critical Habitat for:** Colorado Squawfish.

**Occurrence:**

Historical

Jordan (1891) found razorback sucker in the Gunnison River near Delta. Anecdotal accounts suggest razorback suckers may have been abundant in the river at one time. Quartarone (1993) cites local Delta residents reporting razorback sucker as common in the Delta area and that they used to enter the Hartland Diversion Ditch where they would often become stranded. Chamberlain (1946) indicated they appeared to be common in the lower portion of the Gunnison River. Some razorback suckers were collected by the Colorado Division of Wildlife during the 1950's, and one was collected near Delta in 1975 (Wiltzius 1978).

Recent

Surveys conducted on the Gunnison River from the Escalante bridge to the Redlands Diversion Dam from 1979 to 1981 did not report any razorback sucker (Valdez et al. 1982a). Four adult razorback sucker were collected in 1981 in a 15-mile reach of the Gunnison River between the confluence with the Uncompahgre River and Escalante bridge crossing (Holden et al. 1981).

**Description of Habitat:**

Historically, the Gunnison River was typical of Colorado River basin tributaries with high spring turbid flows and low flows in late summer and through the winter. High spring flows create and maintain the braided channels that provide a variety of important habitats (Osmundson and Kaeding 1989; Osmundson and Kaeding 1991).

Water depletions began in the Gunnison River basin with private irrigation in the 1880's. The Redlands Diversion Dam was built on the lower Gunnison River 3 miles upstream from its confluence with the Colorado River in 1918. The Redlands Diversion can divert up to 750 cfs and can dry up the Gunnison River below the dam during extremely low-flow periods. It is considered a complete barrier to upstream fish passage. The Gunnison Tunnel was constructed by the Reclamation in 1909; it diverts water from the Gunnison River to the Uncompahgre River Valley for irrigation. Taylor Park Dam on the Taylor River in the headwaters of the Gunnison was completed in 1937 to provide water storage for the Gunnison Tunnel. The Aspinall Unit was completed in 1976 and consists of three reservoirs: Blue Mesa, Morrow Point, and Crystal. The flows on the Gunnison River are regulated by releases from Crystal Reservoir. These reservoirs store water during spring runoff and release it gradually throughout the rest of the year. Other water projects in the Gunnison basin include Crawford Dam, Paonia Dam, Fruitgrowers Reservoir, and Ridgeway Reservoir. Water development in the Gunnison River basin has changed water quantity and flow regimes in occupied habitat of the razorback sucker.

The Gunnison River near Delta (Hartland Diversion Dam, RM 59.9) to the confluence with the Colorado River flows mostly through sedimentary canyons. Floodplains occur in about 25 percent of the warmwater reach. The most extensive floodplain occurs in the delta area from Hartland Diversion Dam downstream to Roubideau Creek. This reach contains the highest degree of complex channel habitats which provide the greatest diversity of river habitats. Numerous braided channels and several large vegetated islands occur in this section with riffles, long runs, and backwaters. The flow through this area is moderately fast. Downstream from here, the river flows through canyon areas. Although not extensive, some historical floodplains are now occupied by fruit orchards in these canyon areas. Two rock irrigation diversions occur in this section but are not impediments to fish movement. Although canyon habitat containing two small rapids, the gradient is less and the flow slower than upstream section. Near Whitewater, the river widens for a short distance where gravel-pit operations in historic floodplains presently occur. From here, the river meanders again through a low-level canyon area to Redlands Diversion Dam. Some gravel-pit operations occur immediately upstream from Redlands Diversion Dam. Downstream from Whitewater, there is a mixture of riffle areas with moderate velocity, quiet shoreline, and runs; adjacent backwaters are uncommon.

**Relationship to Constituent Elements:**

**Water**

The quantity of water in the Gunnison River has been reduced by water development projects. Flow regimes also have been altered significantly. However, reoperation of the Aspinall Unit as the result of Section 7 consultation will provide a more natural hydrograph in this river reach, improving the habitat for the razorback sucker. Test flows should provide peak flows from 5,000 cfs to above 15,000 cfs during the 5-year study in river reaches historically occupied by razorback sucker. The peak will be timed to correspond with the peak flow on the Colorado River (McAda and Kaeding 1991).

Water temperatures have been reduced from historic temperatures by a maximum of 4°F in occupied habitat. This probably does not affect adult habitat, but may affect maturation of adult fish or spawning success (McAda and Kaeding 1991).

Physical Habitat

The Gunnison River provides bottomlands, side channels, secondary channels, and backwaters that when inundated could provide spawning, nursery, feeding, and rearing habitats for razorback suckers. Reoperation of the Aspinall Unit could provide high spring flows that maintain these habitats. When fish passage at the Redlands Diversion Dam is provided, these habitats would become available to razorback sucker that move upstream from the Colorado River. The combination of fish passage at the Redlands Diversion Dam, establishing a natural flow regime in the Gunnison River and enhancement of bottomlands adjacent to the river, could provide valuable habitat essential for razorback sucker recovery. Because flows released from Aspinall will be limited (i.e., 6,000 cfs), some bottomlands historically connected to the mainstem river may still not connect during present day conditions. Flows from Aspinall could be increased with installation of by-pass tubes. Consequently, habitat enhancement other than providing flows (e.g., removing dikes and levees) may be necessary to reconnect bottomlands during spring high flows.

Biological Environment

Studies conducted in 1981 and 1992 found that the Gunnison River has a high percentage of native fishes (Valdez et al. 1982a; USFWS 1992a). Electrofishing surveys conducted in 1992 from the North Fork confluence with the Gunnison River to Redlands Diversion Dam found juvenile and adult native fishes comprised 80.6 percent of the total number of all fished collected. Eight adult northern pike and only one adult channel catfish were captured upstream of Redlands Diversion Dam during this study. On the other hand, seining surveys conducted in 1992 found nonnative fishes comprised 90.4 percent of the total number of all fishes collected. Predation and competition from nonnative fishes have been identified as a contributing factor in the decline of the razorback sucker.

Relationship to Additional Selection Criteria:

For the razorback sucker, additional selection criteria were developed to assist in the selection of proposed critical habitat designations. This reach of the Gunnison River meets those criteria as discussed below.

Presence of Spawning Population

No known spawning presently occurs in the Gunnison River.

Nursery Habitat

While juvenile razorback sucker are not known to occur in the Gunnison River, it could provide suitable nursery habitat when bottomlands are inundated and backwaters maintained.

Historic or Present Distribution

The Gunnison River was historically occupied by razorback sucker and has a potential for establishment of a population with reoperation of the Aspinall Unit providing a more natural flow regime. Fish passage at the Redlands Diversion Dam also could increase potential for population establishment.

Maintenance of Rangewide Distribution

Establishment of a razorback sucker population in the Gunnison River would provide an additional river system necessary for recovery to protect against catastrophic loss that could occur in any one area or affect any one population.

Special Management

Management of flows on the Gunnison River through reoperation at the Aspinall Unit providing fish passage at the Redlands Diversion Dam and protection and enhancement of inundated bottomlands will be required to provide and improve habitat for razorback sucker. Local landowners built dikes to keep bottomlands from flooding before the dams were built that reduced spring flow levels. Some agreements, leases, easements, purchase, etc., of key lands also may be needed.

## Colorado River - Rifle, Colorado to Westwater

**Boundary Delineation:** Colorado, Mesa and Garfield Counties. The Colorado River and its 100-year floodplain from Colorado River Bridge at Exit 90 north off Interstate 70 (RM 238) in T.6S., R.93W., section 16 (6th Principal Meridian) to Westwater Canyon (RM 125) in T.20S., R.25E., section 12 (Salt Lake Meridian) including the Gunnison River and its 100-year floodplain from the Redlands Diversion Dam in T.1S., R.1W., section 27 (Ute Meridian) to the confluence with the Colorado River in T.15., R.1W., section 22 (Ute Meridian).

**Shoreline Ownership:** Private, 73.5 percent; Bureau of Land Management, 24.4 percent; State, 2.1 percent.

**Overlap with Proposed Critical Habitat for:** Colorado squawfish.

**Occurrence:**

Historical

Jordan (1891) reported razorback suckers very abundant in the river channels of the upper Colorado River.

Recent

Razorback sucker occurrence in this reach was documented by researchers (Kidd 1977; McAda and Wydoski 1980; Valdez et al. 1982b). Kidd (1977) classified them as rare from Grand Junction to Rifle and as common from Westwater to Grand Junction. Razorback sucker were collected from a variety of habitats but most were collected from gravel pit ponds adjacent to the Colorado River. Few razorback suckers have been collected in this reach in recent years (Osmundson and Kaeding 1989; Burdick 1992), although 3 adults were captured in the spring of 1993 (Doug Osmundson, USFWS, pers. comm.).

**Description of Habitat:**

Historically, the Colorado River had high spring turbid runoff with low flows in late summer and through the winter. These high spring flows inundated bottomlands, maintained side channels, and created backwaters.

This reach of river begins at Rifle, Colorado, where the river has been described as a transition zone between warm and cool water fisheries (Valdez et al. 1982b). The river meanders through open valleys and rolling sagebrush hills until it reaches Debeque Canyon. The substrate is predominately rock (gravel, rubble, boulder) with some silt and sand, shallow to moderate-depth runs and riffles, pools and eddies are numerous but backwaters are uncommon. Numerous gravel pits exist in the floodplain, where several adult razorback suckers have recently been captured. One razorback sucker was collected from a gravel-pit pond adjacent to the Colorado River 4 miles downstream of Rifle in 1991. Ninety-two juvenile and adult razorback sucker were collected from a floodplain pond near DeBeque, Colorado, from 1991-1993 (Pfeifer 1993). The river flows for 25 miles through DeBeque Canyon where the channel is paralleled by Interstate Highway 70 on one side and the Denver and Rio Grande Railroad on the other which have both constricted the channel with riprap. The flow is swift over gravel, rubble, and boulder substrate. The Government Highline Dam is located at the lower end of DeBeque Canyon and is considered a complete barrier to upstream fish passage. Several miles downstream, the Price-Stubb Dam also creates a barrier to upstream fish passage. There are plans to provide fish passage at both of these structures. From Palisade to Loma, Colorado, the river flows through the Grand Valley. The confluence with the Gunnison River is about 15 miles downstream from Palisade. The river meanders through a broad agricultural and residential valley. The channel is extensively braided around vegetated gravel islands, and many gravel pit ponds occur adjacent to the river. Predominate substrates are gravel and rubble, and the habitat consists of runs, riffles, eddies, backwaters, side channels, and gravel pit-ponds. Flows in the 15 miles between Palisade and the Gunnison River become severely reduced during late summer and autumn (August-October), due to upstream irrigation diversions. There are no diversions during winter. Extensive diking and riprap have restricted the river channel throughout much of the Grand Valley. The Colorado River from Loma to Westwater flows 29 miles through Horsethief and Ruby Canyons with high sandstone walls and open parks. The substrate is gravel and rubble with deposits of sand and silt. Habitats consist of runs, pools, and eddies, with few backwaters.

**Relationship to Constituent Elements:**

Water

Water quantity in this reach varies between different river sections because of water diversions for the Grand Valley. The section from Rifle to the Government Highline Dam is upstream of major Grand Valley water diversions; therefore, substantial quantities of water flow through this section because water must be provided to the senior water users in the Grand Valley. The 15-mile section below the Government Highline Dam and the Grand Valley Diversion, experiences alteration of its natural flow regime throughout the year and extreme low flows during August-October. These extreme low flow conditions are somewhat alleviated below the confluence with the Gunnison River and the Redlands Power canal. The Service has developed flow recommendations for the 15-mile reach (Kaeding and Osmundson 1989a; Osmundson and Kaeding 1991) and is in the process of obtaining instream flow rights for this reach from July to September. However, these summer flows for the 15-mile reach do not address the shortage of spring flows considered very important for the razorback sucker. The reoperation of the Aspinall Unit on the Gunnison River should provide a more natural flow regime on the Colorado River below the confluence of the Gunnison River. This will enhance the existing water quantity and flow regime required by the razorback sucker.

Physical Habitat

This reach provides a great variety of potential physical habitat for spawning, nursery, feeding, rearing, and corridors between areas. Predominant substrates are gravel and rubble, and the habitat consists of runs, riffles, eddies, backwaters, side channels, bottomlands, and gravel-pit ponds. These areas provide feeding, spawning and nursery habitats. When fish passage is provided at the Price-Stubb Dam and the Government Highline Dam, DeBeque Canyon would provide areas for movement and migration habitat. The reach from Rifle to DeBeque Canyon and the Grand Valley have extensive areas of floodplain habitat that, when inundated, would provide nursery and feeding habitat.

Biological Environment

The extensive bottomlands along this reach are sources of nutrient inputs into the Colorado River. Valdez et al. (1982b) found that the four most common nonnative species in the mainstem upper Colorado River (red shiner, sand shiner, channel catfish, and common carp) decreased in abundance the farther upstream they sampled. Therefore, they found relatively fewer nonnative fishes in this upper-most reach of occupied habitat.

**Relationship to Additional Selection Criteria:**

Additional selection criteria were developed to assist in the selection of proposed critical habitat designations for the razorback sucker. This reach of the Colorado River meets those criteria as discussed below.

Presence of Spawning Population

Razorback sucker spawning has not been documented in this reach. However, razorback sucker in spawning condition were captured in the 15-mile reach in 1986 (Osmundson and Kaeding 1989). Also, razorback suckers captured in a pond in the floodplain near DeBeque, Colorado were found to be 7 to 8 years old, indicating spawning occurred in this reach in 1983 or 1984.

Nursery Habitat

This reach has numerous floodplain and backwater habitats identified as important for rearing young fish.

Historic or Present Distribution

This reach contains a very small population of adult razorback suckers. Historically, they were much more abundant than at present.

Maintenance of Rangewide Distribution

This reach represents the most upstream extent of the range of razorback sucker in the Colorado River.

Special Management

Providing passage at the Price-Stubb Dam and the Government Highline Dam would enhance the recovery potential of this reach. Additional flows in the 15-mile reach and a more natural flow regime below the confluence with the Gunnison River also will increase recovery potential.

**Colorado River - Westwater to the Dirty Devil Arm of Lake Powell**

**Boundary Delineation:** Utah, Grand, San Juan, Wayne, and Garfield Counties. The Colorado River and its 100-year floodplain from Westwater Canyon (RM 125) in T.20S., R.25E., section 12 (Salt Lake Meridian) to full pool elevation, upstream of North Wash and including the Dirty Devil arm of Lake Powell in T.33S., R.14E., section 29 (Salt Lake Meridian).

**Shoreline Ownership:** National Park Service, 48.8 percent; Bureau of Land Management, 37.6 percent; Private, 12.5 percent; State (Utah), 1.1 percent.

**Overlap with Proposed Critical Habitat for:** Colorado squawfish, humpback chub, bonytail.

**Occurrence:**

Historical

Jordan (1891) reported razorback suckers very abundant in the river channels of the upper Colorado River. Taba et al. (1965) collected juveniles from backwaters in the Colorado River near Moab.

Recent

Holden and Stalnaker (1975a) reported razorback suckers in mouths of flooded washes in Canyonlands National Park. Valdez et al. (1982b) collected eight razorback suckers from this reach. Seven of the eight were collected from the lower end of this reach. In 1987, one adult razorback sucker was captured on the Colorado River 3.6 miles upstream from the confluence with the Green River (Valdez 1990). The State of Utah captured eight razorback suckers in the Dirty Devil arm of Lake Powell in 1990 and 1991.

**Description of Habitat:**

Historically, the Colorado River had high spring turbid runoff with low flows in late summer and through the winter. These high spring flows inundated bottomlands, maintained side channels, and created backwaters.

The river flows through 14 miles of Westwater Canyon which is a geologic anomaly of upthrust black metamorphic gneiss rock. It confines the river forming a narrow, deep channel with a series of rapids, strong eddies, and turbulent currents. The river is predominately deep runs, eddies and pools, with few backwaters. When the river leaves Westwater Canyon, it meanders for 25 miles through shallow canyons and rolling hills. The substrate is primarily rock and sand or rock and sand-silt. Runs and eddies are predominant with some backwaters, providing feeding and nursery habitats identified as constituent elements. From Fisher Towers to Moab, Utah, the river flows through high sandstone walls and open valleys. This area is characterized by deep, slow-flowing runs and pools over sand-rock substrate. Several small rapids are formed by rocky deltas from washes. The Colorado river from Moab, Utah to the confluence with the Green River has predominantly sand-silt substrate with sandy banks overgrown with tamarisk. Runs are predominant, but backwaters and eddies are common. Valdez et al. (1982b) found more backwaters in this reach than any other reach in the upper Colorado River. The Moab Marsh area within this reach was probably the most important rearing area for razorback sucker in the lower river. The river between the confluence and Lake Powell flows through Cataract Canyon where it cuts deeply through steep canyons and talus slopes. The river has deep, swift runs, and large eddies and pools, with a few shallow runs, riffles, and backwaters. Large angular rock and steep gradient have created large dangerous rapids through the canyon. There are approximately 13 miles of rapids before the river flows into the upper end of Lake Powell, where it becomes a large, deep, and slow-flowing through high sandstone walls.

Major habitat changes occurred in Cataract Canyon when Lake Powell was formed by the closure of Glen Canyon Dam in 1963. Prior to inundation of Lake Powell, Cataract Canyon's steep gradient and large rapids continued for 35 miles. Except for changes in water quantity and historic flow regime, the habitat in portions of Cataract Canyon above Lake Powell remains rather pristine.

**Relationship to Constituent Elements:**

Water

This reach does not have major water diversions or dams, but reduction in water quantity and changes in flow regime result from upstream developments.

Physical Habitat

Westwater and Cataract canyons provide movement and migration corridors between flat-water habitats. The section between Westwater Canyon and Moab provides numerous bottomlands that when flooded provide warmer water temperatures, rich feeding areas, low velocity habitat, and potential spawning and nursery habitat. Valdez et al. (1982b) found more backwaters from Moab to the confluence than any other reach in the upper Colorado River. These backwaters provide important nursery habitat. The Lake Powell section of this reach provides feeding and rearing habitat.

Biological Environment

Bottomlands between Westwater Canyon and Cataract Canyon are a source of nutrient inputs into the Colorado River. This portion of the Colorado River contains large numbers of non-native fishes, especially in the backwaters identified as important nursery areas.

**Relationship to Additional Selection Criteria:**

Additional selection criteria were developed to assist in the selection of proposed critical habitat designations for the razorback sucker. This reach of the Colorado River meets those criteria.

Presence of Spawning Population

No known spawning ares have been identified in this reach.

Nursery Habitat

The section between Westwater Canyon and Moab provides numerous bottomlands that, when inundated, provide rich feeding areas, low-velocity habitat, and in spring potential spawning and nursery habitat.

Historic or Present Distribution

An extremely small population of razorback sucker currently occupies this reach. Historically, the fish was much more abundant than at present.

Maintenance of Rangewide Distribution

This reach represents a major portion of the Colorado River in the Upper Basin and provides continuous habitat between Lake Powell and the upstream end of razorback sucker range on the mainstem Colorado River.

Special Management

Management of flow regime and nonnative fishes is needed for recovery. Restoration of access and tamarisk control in the Moab marsh area is important for restoring razorback sucker in this reach.

**San Juan River - Hogback Diversion to Neskahai Canyon**

**Boundary Delineation:** New Mexico, San Juan County; and Utah, San Juan County. The San Juan River and its 100-year floodplain from the Hogback Diversion in T. 29N., R.16W., section 9 (New Mexico Meridian) to the full pool elevation at the mouth of Neskahai Canyon on the San Juan arm of Lake Powell in T.41S., R.11E., section 26 (Salt Lake Meridian).

**Shoreline Ownership:** Tribal, 67.2 percent; Bureau of Land Management, 14.5 percent; National Park Service, 17.1 percent; Private, 1.2 percent.

**Overlap with Proposed Critical Habitat for:** Colorado squawfish.

**Occurrence:**

Historical

Jordan (1891) reported statements of local residents who observed razorback sucker, Colorado squawfish, and flannelmouth sucker movements in the Animas River of southwestern Colorado. There are no records or specimens of the species from the San Juan River in New Mexico (Koster 1957, 1960; Sublette 1977; Platania and Bestgen 1988; Platania and Lang 1992). However, historic surveys and collections were sporadic and did not comprehensively cover the river.

Recent

The first documentation of razorback suckers in the San Juan drainage comes from several reports of adults "stranded" in irrigation ponds and reservoirs (Behnke and Benson 1980; McAda and Wydoski 1980; Meyer and Moretti 1988). The first confirmed capture record of razorback sucker from the mainstem of the San Juan River occurred in 1988 (Roberts and Moretti 1989; Platania et al. 1991). This was a tuberculate male captured at approximately RM 91 near Bluff, Utah. Prior to the 1976 irrigation pond captures, there were no verified reports of razorback sucker in the San Juan River drainage.

Small concentrations of adult razorback suckers have been reported from the inflow area of the San Juan arm of Lake Powell (Meyer and Moretti 1988). In 1987, 12 razorbacks sucker were captured from the San Juan arm of Lake Powell near Piute Farms Marina. Of these fish, eight were ripe males and four appeared to be ripe females (Platania 1990; Platania et al. 1991). A total of ten individuals were captured in the same vicinity in 1988, five of which were in reproductive condition (Platania et al. 1991). No razorback sucker larvae or specimens of size classes other than adults have been collected in the San Juan River basin.

**Description of Habitat:**

Spring peak flows in the San Juan River above the confluence with the Animas River generally ranged form 3,000-5,000 cfs (Holden 1980). Winter flows above the Animas River confluence generally averaged from 200-300 cfs. Below the Animas confluence, San Juan River flow and habitats are increasingly influenced by inflowing tributaries. The highest flow, 70,000 cfs was recorded at Bluff, Utah, (at site below all major tributaries) on 10 September 1927 (Meyer and Moretti 1988). Summer low-flow conditions in the lower San Juan River have included zero-flow measurements at Bluff in July 1934 and August 1939 (Meyer and Moretti 1988). Many of the tributary streams that enter the San Juan River below Farmington, New Mexico introduce substantial sediment amounts. Historic sediment input by the tributaries is not well known, but influenced riverine conditions.

The geomorphology of the San Juan River is variable throughout the subject area. From the Hogback Diversion to Bluff, the floodplain is wide. The river is relatively sinuous with split channels and minor braiding common. Substrate size ranges from sand to cobble/boulder. Riffles and minor rapids are frequent. Major riverine habitat types which occur include runs, riffles, eddies, backwaters, and side channels. Between Bluff and Mexican Hat, the river flows through low hills and narrow canyon reaches.

The San Juan River channel is confined within a narrow, high-walled canyon from Mexican Hat to Neskahai Canyon,. The floodplain is significantly reduced. Overall gradient is high with substrate size ranging from sand to cobble/boulder. The channel is single thread with only occasional islands or instream bars. Minor rapids and riffles are common. The remoteness of this reach has limited human activities and impacts to the river and shoreline. Major riverine habitat types which occur include runs, riffles, eddies, and backwaters.

One significant barrier occurs in this section. A new waterfall (25-30 feet high) developed at the Lake Powell inflow area during declining reservoir levels and changing river channel alignment between Clay Hills and Piute Farms . It is considered a complete--albeit temporary--barrier to upstream fish passage. Other than this, minimal modification of physical habitat has occurred in or along the river. Hydrograph alterations related to upstream water projects constitutes major change to the natural system.

**Relationship to Constituent Elements:**

Water

Water release patterns from Navajo Dam have recently been altered by the Bureau of Reclamation to provide suitable flows for fish. Research is currently underway to determine more specific flow recommendations of the endangered fishes. Because of the extensive oil and gas development along the San Juan River and its tributaries, questions have arisen regarding water quality. Current efforts are underway to assess the water quality problems and determine the impacts to fish.

Physical Habitat

The San Juan River has two thirds fewer backwaters per mile of river than occurs on the Green River (Goettlicher and Pucherelli 1992). However, recently researchers have suggested that secondary channels on the San Juan River may be just as important for providing low-velocity habitats for fish. Too few razorback sucker have been captured to locate spawning areas, although potential spawning habitat is located within this reach. However, research of flow/habitat relationships and habitat needs of razorback sucker will identify optimum channel conditions.

Biological Environment

Surveys of main channel and low-velocity habitats in the San Juan River 1987-1989 illustrated differences in distribution and abundance patterns of fishes. Native species accounted for 70-80 percent of all specimens collected from main channel habitats. Conversely, in low-velocity habitats (secondary channels, backwaters, edges, eddies), nonnative species were most abundant, totalling 60-90 percent of all fish collected. Flannelmouth and bluehead suckers were the most abundant native species (Platania 1990). Red shiner and fathead minnow were most abundant in low-velocity habitats, and channel catfish and carp dominated mainchannel nonnative species collections. Previous benthic macroinvertebrate surveys by Holden (1980) illustrated longitudinal patterns of diversity and abundance. In general, invertebrate density declined, but diversity increased from upstream (Navajo Dam) to downstream (below Hogback Diversion) reaches.

**Relationship to Additional Selection Criteria:**

Additional selection criteria were developed to assist in the selection of proposed critical habitat designations for the razorback sucker. This reach of the San Juan River meets those criteria.

Presence of Spawning Population

No spawning locations have been documented. However, fish showing signs of being sexually mature have been captured in the upper end of the San Juan arm of Lake Powell (Platania et al. 1991).

Nursery Habitat

Analysis of videography from the Hogback Diversion to Mexican Hat, found that the total number of backwaters in that reach ranges from 68 to 216, depending on flow. This represents about two backwaters per mile of river. The number of secondary channels in this reach ranges from 91 to 170 depending on flow (Goettlicher and Pucherelli 1992).

Historic or Present Distribution

Razorback suckers occur in the San Juan River from Bluff, Utah, to Neskahai Canyon in Lake Powell. The largest concentrations are known from the San Juan arm of Lake Powell.

Maintenance of Ran gewide Distribution

Recovery of the razorback sucker in the San Juan River will contribute to the rangewide diversity of habitat occupied by the species. Recovery potential of razorback sucker in the San Juan is dependent upon preservation of all lifestage habitats.

Special Management

Future depletions to meet water needs for tribal and state lands may adversely affect this value of the reach for the razorback sucker. Oil and gas development in the San Juan Basin may also impact the razorback sucker. Development of backwater areas may be considered to provide habitat.

**Colorado River - Paria River to Hoover Dam**

**Boundary Delineation:** Arizona, Coconino and Mohave Counties; and Nevada, Clark County. The Colorado River and its 100-year floodplain from the confluence with the Paria River in T.40N., R.7E., section 24 (Gila and Salt River Meridian) to Hoover Dam in T.30N., R.23W., section 3 (Gila and Salt River Meridian) including Lake Mead to the full pool elevation.

**Shoreline Ownership:** National Park Service, 84.7 percent; Tribal, 15.5 percent.

**Overlap with Proposed Critical Habitat for:** Humpback chub.

**Occurrence:**

Historical

Razorback suckers were known from the portion of the Colorado River that now comprises Lake Mead, and they were abundant in the reservoir in the 1940's and 1950's (Moffett 1943; Wallis 1951; Jonez and Sumner 1954). There are few historical records for the species in the Grand Canyon, but fish collections in this area are sparse. A razorback sucker was taken from Bright Angel Creek in Grand Canyon in 1944 (Minckley and Carothers 1980; Minckley and Deacon 1991).

Recent

Significant declines of razorback suckers were recorded in Lake Mead the 1960's and 1970's (Minckley 1973; McCall 1980). However, in the last few years, captures of ripe adults and spawning aggregations of adults have been reported in the Echo Bay and Las Vegas Wash areas of the reservoir (Burke 1992; Heinrich and Sjoberg 1992).

Recent records for the Grand Canyon area include captures in the Paria River in 1978 and 1979, the mouth of the Little Colorado River in 1989 and 1990, and Bright Angel Creek in 1987 (Minckley and Carothers 1980; Carothers and Minckley 1981; Maddux et al. 1987; Minckley 1991).

**Description of the Habitat:**

This reach has both riverine and lacustrine portions. The river portion extends from the Paria River through Marble and Grand canyons. Lake Mead was formed by Hoover Dam and is at the lowermost end of the reach.

This riverine segment of the Colorado River is confined by steep canyon walls for virtually its entire length. The Paria and Little Colorado rivers join with the Colorado in this reach and there are smaller tributary streams that drain into the river throughout the Canyon. Kanab Creek, Bright Angel Creek, and Havasu Creek are examples.

The Colorado River through these canyon areas is characterized by high-gradient sections forming rapids separated by long runs and pools. Historically, water flows varied seasonally and annually. High silt loads were characteristic and water temperatures over the year were subject to 50°F fluctuations (Carothers and Brown 1991). Mouths of tributaries, eddies, and shallow water areas behind sand and gravel bars provided habitat out of the main channel. Substrates were largely boulder, cobble, gravel, and, in slower water areas, some sand and silt.

The riverine portion of the reach has been modified by the construction and operation of Glen Canyon Dam. The dam is located upstream of the Paria River and controls the Colorado River flows through the canyons. There has been substantial change to the natural hydrograph of the river with the operation of Glen Canyon Dam for hydropower purposes. Weekly and seasonal peaks in water flow cause erosion of sand and gravel beaches and desiccate shallow water habitats. Water velocities vary widely. The released water is cold (48°F) and carries no sediment load to replace material lost by erosion. Some sediment is added to the main flow from the Paria and the Little Colorado rivers. Changes to water temperatures from predam conditions can be observed through the Grand Canyon to Lake Mead.

The closing of Hoover Dam created Lake Mead, a large, deep reservoir. The reservoir first filled in 1941 and has a maximum depth of 590 feet, is approximately 110 miles, long and experiences seasonal water-level fluctuations. Lake Mead has an irregular shoreline with many large and small bays and coves. The Muddy and Virgin rivers are the perennial tributaries in this portion of the reach and enter the Overton Arm of the reservoir.

Water quality is good throughout the reach. Temperatures, turbidities, and other parameters are within ranges that support aquatic communities. Productivity varies between the upper and lower basins of the reservoir (Paulson et al. 1980), and the low level of nutrients may be the cause of declines in the nonnative sport fish populations in recent years. The size of the reservoir and the changes in temperature and seasonal volume of inflow from the Colorado River results in complex stratification and current patterns within the reservoir.

Populations of many nonnative game fish species are found in the reach, including largemouth bass, striped bass, channel catfish, and trout. Carp, threadfin shad, and other nongame species are common.

Recreational use of the canyon and reservoir portions of this reach is heavy. Rafting, boating, camping, and fishing are popular activities. There are facilities for boat launching, camping, and other activities around the reservoir and in locations in the canyon itself. Any future recreational developments presumably would be similar to those already present.

Releases of water from Glen Canyon Dam are currently under valuation by federal agencies. These changes could have effects on the physical habitat in the riverine canyons, and to some extent, in the reservoir portion of the reach.

**Relationship to Constituent Elements:**

Water

With the construction of Hoover Dam and the filling of Lake Mead, the natural river hydrograph in Lake Mead was converted to a reservoir. With the construction of Glen Canyon Dam, water flows into both the remaining riverine canyons and Lake Mead were entirely controlled by the releases from the dam. Fluctuations in reservoir water levels occur on seasonal and weekly cycles as inflows differ from outflows. There has always been adequate water to maintain aquatic communities.

Flows in the riverine canyons fluctuate with releases from Glen Canyon Dam, thus water depths and velocities vary considerably. The presence or extent of shallow water, backwater, or pool habitats in any part of the reach is affected by the changes in flows. The severity of change attenuates with greater distance away from the dam.

Water quality in Lake Mead is good, with a variety of temperatures available throughout the year. Productivity in the reach is adequate to sustain aquatic communities. Evaporation is high, but there have been little changes to salinity or other chemical parameters.

Water quality in the riverine canyon portion of the reach is good, although major changes in temperature and turbidity over historic conditions has occurred.

Physical Habitat

Lake Mead provides several lacustrine habitat including deep-water, shallow bay, and cove habitats. Permanent connections to the riverine habitats in the canyon exist. Adult razorbacks have been captured throughout the reach, but their movement patterns are unknown.

Razorback sucker spawning has been observed in coves and bays in Lake Mead. These coves and bays may be as important in Lake Mead as they are in Lake Mohave. Temperatures are suitable for adult maturation and for egg incubation and hatching of larvae.

Coves and bays also provide physical habitat needed for nursery habitat. These areas have little to no current, cover from aquatic plants, and food resources in the benthos and planktonic communities. These areas are likely analogs to the oxbow lakes and backwaters of the riverine system.

In the canyon portion of the reach, razorback sucker habitat may be provided by eddies, nearshore runs, midchannel sandbars, mouths of tributaries, and flat water runs. There are no complete barriers to migration in the reach. Cold water temperatures in most of the canyon may not be suitable for spawning, although this may not be true for the tributary streams. No spawning has been reported from the canyon portion of this reach.

Biological Environment

Existing nutrient resources in the reach are adequate to support populations of aquatic organisms. Plankton, benthic invertebrates, periphyton, and other potential food resources are available in both portions of the reach. Adult razorback suckers have been present in Lake Mead for almost 50 years. Although little known, there are sufficient records on the canyon population to indicate adult fish are present.

Predation on or competition with razorback suckers by nonnative fish in the reach exists. Carp, sunfish and catfish are all common or abundant in the reach and these species have been shown to prey on eggs, larvae, and juvenile razorback suckers. A lack of recruitment in the razorback population in Lake Mead may be related to this predation in addition to the changes to the physical habitat.

Relationship to Additional Selection Criteria:

Additional selection criteria for the razorback sucker were developed to assist in selecting the areas proposed for designation as critical habitat. The Colorado River: Paria River-Hoover Dam reach meets these criteria.

Presence of Spawning Population

Observations of spawning razorback suckers in Lake Mead were reported into the mid-1950's (Jonez and Sumner 1954). Because spawning aggregations were not looked for, it is not clear whether spawning populations continued to inhabit the reservoir through the 1950's to 1980's. In recent years, congregations of razorback suckers have been observed in some areas of Lake Mead (Heinrich and Sjoberg 1992).

Nursery Habitat

Coves and bays provide shallow-water habitats. These habitats are used by razorback sucker larvae in Lake Mohave and if reproduction does occur in the canyon portion, the shallow waters in tributaries or nearshore areas could provide nursery habitat.

Historic or Present Distribution

Razorback suckers were found in the Lake Mead portion of the reach in 1935 and a population currently exists in the reservoir. The collection records in the Grand Canyon date back to 1944 and adults are currently found there.

Rangewide Distribution

Although reservoirs were not a part of the historical habitat for the razorback suckers, long-term observation of several mainstem Colorado River and tributary reservoirs has shown that adult fish can survive in these habitats. The decline in numbers of razorback suckers from reservoirs results from a lack of recruitment. The reduction in or disappearance of populations in Lake Mead and Lake Havasu on the Colorado River and Roosevelt Lake on the Salt River corresponded with senescence and mortality of the 30- to 45-year old razorback suckers that made up the population.

Because adult razorback suckers have been shown to survive in reservoirs, these systems have value in recovery programs. Reservoirs are useful in the maintenance of large populations of razorback suckers to provide stock for reintroduction or augmentations of other populations. The large numbers that could be supported in Lake Mead also allow for the retention of greater genetic diversity within the population.

The connection between Lake Mead and the Colorado River in the Grand Canyon provides an opportunity for razorback suckers to use both riverine canyon and reservoir habitats. The length of the reach also provides for a variety of physical conditions to be available.

The extent of historical or present use of the Grand Canyon by the razorback sucker is not well documented. The availability of both riverine and lacustrine habitats may be of value to maintaining the population of razorback suckers in the reach.

Special Management

Natural recruitment of razorback suckers in this reach has not been documented in many years, and the present population consists of old adults. Spawning habitat exists, and spawning has been observed. Recent experiments in Lake Mohave have shown that, in the absence of predators, razorback sucker larvae can grow to juveniles in reservoirs. Opportunities to provide suitable predator-free nursery environments in Lake Mead to provide for recruitment to the population may be enhanced by designation.

Changes in the pattern of flows released from Glen Canyon Dam is currently under evaluation. The presence of critical habitat in the area affected by the dam may have effects on this process.

**Colorado River - Hoover Dam to Davis Dam (Lake Mohave)**

**Boundary Delineation:** Arizona, Mohave County; and Nevada, Clark County. The Colorado River and its 100-year floodplain from Hoover Dam in T.30N., R.23W., section 1 (Gila and Salt River Meridian) to Davis Dam in T.21N., R.21W., section 18 (Gila and Salt River Meridian) including Lake Mohave to the full pool elevation.

**Shoreline Ownership:** National Park Service, 92.3 percent; Private, 7.7 percent.

**Overlap with Proposed Critical Habitat for:** Bonytail.

**Occurrence:**

Historical

Pre-dam development records for this area are not available. Razorback suckers were recorded downstream of Hoover Dam in the 1940's (Wallis 1951). Jonez et al. (1951) reported them as very common in the river section that was flooded by the creation of Lake Mohave by Davis Dam.

Recent

The estimated 60,000 adult razorback suckers found in Lake Mohave constitute the largest population remaining in the Basin (Minckley et al. 1991). The Lake Mohave population has provided the primary brood stock for hatchery propagation of this species.

Recruitment has not been documented in recent years and the adult population is aging to senescence. Efforts are underway to provide grow-out habitats in coves and backwaters for both locally produced and hatchery produced larvae and juveniles to provide replacements for the old adults. While still experimental, these efforts have resulted in 153 fish from the 1992 year class being introduced into Lake Mohave late in 1992. Five of these released fish were recaptured in March, 1993 (Bureau of Reclamation 1993, unpublished data, Boulder City, Nevada).

**Description of the Habitat:**

Historically, this 63-mile portion of the Colorado River was a transition area between the upstream canyons and the downstream plains. Black Canyon, the uppermost portion of the reach, is the last large canyon on the lower river. Below the Black Canyon, the river valley was still incised, but was wider and more open. The Colorado River flows varied seasonally and yearly, depending upon runoff amounts. This reach does not contain any major tributaries. Runoff in the washes from seasonal storms may have provided important additions to the river flow. River waters could be quite warm in the summer and carried heavy sediment loads.

River substrates likely included boulder, cobble, gravel, and sand as well as silt in quiet water areas. Wash inflows provided inflow of sand and gravel to form bars in the channel. Backwaters and shallow areas were uncommon in the canyon sections, though the lower section of the reach may have had those habitats.

Lake Mohave is a mainstream reservoir impounded by Davis Dam and filled in the 1950's. It is a long, narrow reservoir and is generally less than 1-mile wide except at the central basin where it widens out to 5 miles.

The upper 20 miles are confined by the steep walls of the Black Canyon, and depending upon reservoir water level, can be riverine or lacustrine in character. Water depths are shallow, approximately 10 to 40 feet, depending upon the level of releases from Hoover Dam. Substrates are composed of cobble, gravel, and sand. There are few coves in this section, but shallow waters are found around the gravel bars at the inflows from washes. Flows are controlled by releases from Hoover Dam and vary on daily and seasonal schedules. The water released from deep in Lake Mead is cold and carries no sediment. Several hot springs are found in this reach and used to varying degrees by razorback sucker.

The lower 43 miles of the reservoir becomes wider as it leaves the canyon and becomes deeper, reaching about 100 feet deep near Davis Dam. Substrates include cobble and gravel near the shorelines and sands and silts in deeper water. The shoreline is complex and irregular with many coves and bays. Water levels fluctuate in response to releases from Hoover and Davis Dams. Water is normally released from Davis Dam only in response to downstream contracts. The inflow of colder water from Hoover Dam creates extensive stratification and current patterns in the reservoir. This water also contributes most of the nutrients that support the aquatic communities. Paulson et al. (1980) discusses the limnology of Lake Mohave.

Lake Mohave is in the Lake Mead National Recreation Area and recreation is managed by the National Park Service. Boating, camping and recreational fishing are popular activities.

The fishery includes rainbow trout, largemouth bass, striped bass, and channel catfish. Other nongame fish species such as threadfin shad, carp, and green sunfish are common.

Development around the reservoir is restricted by the National Park Service. There are some boat launching and marina facilities, campgrounds, and similar recreational support facilities at points around the reservoir. Any expansion of recreational facilities would be of similar types.

Plans to alter the water release schedules from Hoover Dam to enhance hydropower generation have been suggested by Reclamation. The existing generating capacity has been upgraded by a generator rewinding program completed in 1992. Construction of additional generating capacity is under consideration.

**Relationship to Constituent Elements:**

Water

The construction of Davis Dam and creation of Lake Mohave, changed the natural river hydrograph. Water flows into Lake Mohave are entirely controlled by the releases from Hoover Dam. Fluctuations in reservoir water levels occur on seasonal and weekly cycles as inflows differ from outflows from Davis Dam. In 1990, the reservoir fluctuated 15 feet over the year (Boner et al. 1991). There has always been adequate water to maintain aquatic communities, including the estimated 60,000 razorback suckers.

Water quality in the reservoir is good, and temperatures vary both seasonally and with location in the reservoir. The reservoir has a short water retention time but retains significant amounts of nutrients (Paulson et al. 1980). Evaporation is high, but there are no significant changes to salinity.

Physical Habitat

Lake Mohave provides deep water, shallow bays, coves, and riverine habitats for the razorback sucker. Razorback suckers may freely move throughout the reservoir, selecting seasonally desirable habitats.

Coves and bays have sand and gravel substrates and are used as spawning habitat for the razorback sucker in Lake Mohave. Hundreds of spawning razorback suckers can be observed each spring in the clear water of the coves. Temperatures and other conditions are suitable for adult maturation and for incubation and hatching of larvae (Douglas 1952).

Coves and bays also provide features needed for nursery habitat. These areas have little or no current, cover in the form of aquatic plants, and food resources in the benthos and planktonic communities. These areas are likely similar to the oxbow lakes and backwaters of riverine systems.

Biological Environment

Existing nutrient resources to support populations of plankton, benthic invertebrates, periphyton, and other potential food resources in Lake Mohave (Paulson et al. 1980). Adult razorback suckers have survived for over 40 years on these resources, and in controlled experiments, young-of-year razorback suckers have been successfully raised in the reservoir.

Predation on and competition with razorback suckers by nonnative fish exist in the reach. Carp, sunfish, and catfish are all common or abundant, and these species have been shown to prey on eggs, larvae, and juvenile razorback suckers. When these nonnative predators have been eliminated, young-of-year razorback suckers do survive and grow. Thus, recruitment of razorback suckers has been linked to predation more than alteration of physical habitat features in Lake Mohave.

**Relationship to Additional Selection Criteria:**

Additional selection criteria were developed for the razorback sucker to assist in selecting the areas proposed for designation as critical habitat. The Colorado River: Hoover Dam to Davis Dam (Lake Mohave) reach meets these criteria.

Presence of Spawning Population

Razorback sucker spawning has been observed in Lake Mohave from 1950's to the present back to the 1950's (Jonez and Sumner 1954). Buth et al. (1987) concluded that the Lake Mohave population had little genetic introgression from other sucker species (particularly from the flannelmouth sucker) and the genic composition of wild and hatchery bred fish was identical. This information has enabled the use of gametes, larvae and juveniles from the Lake Mohave stock for reintroductions elsewhere in the Basin.

Nursery Habitat

Larval razorback suckers have been found in coves and bays in Lake Mohave. These provide shallow water habitats that may be similar to backwaters and other shallow habitats that may be used as nursery habitat in the riverine environment.

Historic or Present Distribution

Lake Mohave contains the largest remaining razorback sucker population in the Basin. Efforts to ensure this population continues to exist are underway, sponsored by federal and state agencies.

Maintenance of Rangewide Distribution

Several mainstream Colorado River and tributary reservoirs support adult razorback suckers. these fish were present in the river before the reservoir was created. The disappearance of razorback suckers from reservoirs very likely results from a lack of recruitment to the adult population rather than habitat deficiencies. The reduction in or disappearance of populations in Lake Mead and Lake Havasu on the Colorado River and Roosevelt Lake on the Salt River corresponded with the senescence and mortality of the 30- to 45-year old razorback suckers that made up those populations.

Reservoirs are useful in the maintenance of large populations of razorback suckers to provide stock for reintroduction or augmentation of other populations. The large numbers also allow for the retention of greater genetic diversity within the population. Perpetuation of this stock will also aid in the recovery of the species in future years by sustaining those populations.

Special Management

The Lake Mohave population is important to the long-term survival and recovery of this species. The genetic quality of the population (Buth et al. 1987) has enabled a widespread reintroduction effort. The size of the population enables research into topics of age and growth (McCarthy and Minckley 1987) and parasites and disease (Valdez et al. 1982b; Minckley 1983; Minckley et al. 1991). The efforts led by Reclamation to develop isolated cove culture techniques for rearing juveniles to recruitable sizes have applicability throughout the Basin.

Habitats in Lake Mohave that support this important population be studied and evaluated. The existing spawning and nursery areas as well as adult habitats must be maintained if efforts to restore recruitment are to be successful. It is unclear how much the limnology of Lake Mohave contributes to the success of the adult population and would affect recruitment potentials. Conditions in Lake Mohave are the result of operations of Hoover Dam and downstream water releases. Designation may enable a more detailed evaluation of operations.

## Colorado River - Parker Dam to Imperial Dam

**Boundary Delineation:** Arizona, La Paz and Yuma Counties; and California, San Bernardino, Riverside, and Imperial Counties. The Colorado River and its 100-year floodplain from Parker Dam in T.11N., R. 18W., section 16 (Gila and Salt River Meridian) to Imperial Dam in T.6S., R.22W., section 25 (Gila and Salt River Meridian) including Imperial Reservoir to the full pool elevation or 100-year floodplain, whichever is greater.

**Shoreline Ownership:** Tribal, 33.9 percent; Fish and Wildlife Service, 25.8 percent; Bureau of Land Management, 18.7 percent; Private, 18.2 percent; State, 3.3 percent.

**Overlap with Proposed Critical Habitat for: None.**

**Occurrence:**

Historical

Earliest razorback sucker collection records are from the lower Colorado River (Abbott 1861; Lockington 1881; Gilbert and Scofield 1898; Snyder 1915; and others). Many of these accounts indicate the species was abundant in the lower Colorado River and its larger tributaries, such as the Gila River. In 1942, survey of the lower Colorado River from Needles, California, to Yuma, Arizona, Dill (1944) only caught razorback suckers near Parker, Arizona, in 1942. He also reported that according to local residents, the fish had previously been plentiful in the area. A decline in razorback sucker populations in the lower Colorado River below Parker Dam occurred in the last 30 years but has not been extensively documented in the literature.

Recent

During the late 1960's and through the 1970's, razorback suckers were collected occasionally in the lower portion of this reach. Fish were captured by angling and gill net operations near Blythe, Riverside County, California (Ulmer and Anderson 1985; Minckley and Deacon 1991). Survey information reported in Minckley (1979, 1983); Ulmer and Anderson (1985); Marsh and Minckley (1985, 1987); and Loudermilk and Ulmer (1985) indicates that adult razorback suckers are now rare in this reach.

Although the adult population of razorback suckers appears to be low in this reach, the river and its associated irrigation systems, especially those on the Colorado River Indian Reservation, have yielded the largest number of juvenile razorback suckers found in recent years. Between 1974 and 1988, 24 juvenile razorback suckers have been caught downstream of Parker Dam (Marsh and Minckley 1989). Of these captures, 23 were made in irrigation canals. Marsh and Minckley (1989) postulate that 16 of these specimens were wild fish and 8 were hatchery fish. Captures in these canals continue, with 10 juvenile razorbacks from 12-16 inches in length found in 1993 (Charles Minckley, USFWS, pers. comm.)

Efforts to increase the existing population of razorback sucker in this reach have included the stocking of hatchery-bred fish. The State of Arizona made several stockings of razorback sucker in the Parker area in 1986. The State of California also had a program from 1986 to 1989 to stock razorback suckers in the river. More recently, 50 three-year-old tagged razorback suckers were released into Colorado River Indian Tribe waters and others were released into Lake Havasu on the Bill Williams River National Wildlife Refuge (Charles Minckley, USFWS, pers. comm.).

**Description of the Habitat:**

This river reach flows through low-elevation Sonoran and Mohave deserts. There are no major tributary rivers or streams entering the Colorado in this reach, but numerous small washes drain into the channel along its 133 mile length. River substrates include cobble, gravel, sand, and silt. Historic records describe a river with a low gradient and scarcity of canyons and other channel-confining topography. The lack of topography allowed the lower Colorado River to meander across the desert plains. Numerous backwaters, oxbow lakes, and marshes were formed by the river as it shifted location, and extensive riparian forests flanked the channels. Seasonal variation in flows was very high, and Grinnell (1914) reported flows that varied from 4,000 to 100,000 cfs in a year. Flood and drought years significantly affected both annual flows and the creation of new channels and backwater areas. Sediment loads were very high, and contributed to forming bars and barriers and filling in shallow water areas. The extreme desert temperatures also influenced water quality, especially in shallow backwaters and lakes, because of high evaporation rates and summer water temperatures.

The reach is confined between Parker Dam on the north and Imperial Dam on the south. Imperial Dam was constructed in the 1930's to create a settling basin for water diversions to the Imperial Valley. Imperial Reservoir is shallow with many coves and backwater areas. There are other diversion dams or structures in the reach, such as Palo Verde Diversion Dam and Headgate Rock Dam, that form partial barriers to fish migration.

Flows through the reach have been controlled by Parker Dam since 1938. Releases from the reservoir are in response to downstream agricultural and municipal needs and international treaty requirements. All flows are allocated and there is no unused water. Flows may reach very low levels, but this reach is never dry. Seasonally, drainage from the washes provides some additional flows, but amounts are generally low. Overall, water velocities are generally low to moderate.

Projects to provide bank protection and stabilization, flood control, and to manage the delivery of water have considerably altered portions of the reach. This development throughout the reach is not uniform. Channels are created or maintained by dredging between riprapped levees and banks. In the lower portion of the reach, conditions are more natural, with braided channels, backwaters, and marshes. Efforts have been made to maintain some backwaters in channelized sections by providing water inflow and outflow structures in the levees to allow some water circulation into the backwaters.

Dams have changed flows and blocked streams, thus changing some water-quality parameters. Releases from Parker Dam carry little or no sediment; however, sediment load gradually increases downstream in the reach. Flushing of sediments from the upper portion of the reach leaves the substrate dominated by boulders, gravels, and sands. Backwaters and coves tend to have sand and silt dominated sediments, especially in the lower reach. The portion of the reach dominated by Imperial Reservoir has predominantly sand and silt substrates. The washes along the reach are important inflow sites for sands and gravels.

The changes to flows also has altered salinity levels, available nutrients, and temperature patterns. Continual reuse of Colorado River water concentrates salts, increasing the salinity of the water. In backwaters with limited circulation but high evaporation rates, salinities may be quite high. Blocking of upstream nutrient sources by the large reservoirs may have lowered the available nutrient levels (Paulson et al. 1980). Significant local inputs to nutrient levels may be introduced to the system in agricultural return flows through canals and drains that connect to the river channel. Nutrients also reach the system via storm runoff from the washes. It is not likely that the reach was historically very highly productive due to the sediment loads that blocked light penetration into the water. Because water released from Parker Dam is not drawn from the surface of Lake Havasu, the tailrace is cooler (70° to 77°F) than the lower portion of the reach (79° to 88°F) in summer. Winter temperatures are more uniform throughout, ranging from 54° to 69°F. Backwaters and other shallow water areas are generally from 2° to 7°F warmer or colder than the main channel, depending on the season (Ohmart et al. 1988).

There are significant populations of nonnative game fish in this reach. Sport fishing is a popular recreational pursuit, especially for catfish and sunfish species. Nongame species such as carp also are very common. Some stocking of warmwater game fish is done by state agencies in this reach, but the recreational fishery is not maintained by these activities. Efforts to provide and enhance fish habitat to increase the recreational fishery by the placement of tree bundles or artificial habitat structures in coves and backwaters have gone on for several years.

There are few new development activities in this reach. Most of the modifications deemed necessary to control the river and its flow were accomplished in the past. There are potential channelization projects in the reach, especially in the Parker Division, but these efforts are still in the planning stages.

**Relationship to Constituent Elements:**

**Water**

Flows in this reach are completely controlled by Parker Dam. Deliveries must be made to downstream users during the entire year. Lowest releases occur in the winter (November through January) when irrigation demand is lowest. September, October, and February are transition months with the highest releases in March through August (Boner et al. 1991). Canals and drains may go dry in the winter months, but retain water the rest of the year. Higher flows in the summer contribute to water exchange in backwaters, improving water quality in those areas. Although releases do not correspond with the historic hydrograph for this reach, rising water levels in the spring do provide for inundating shallow water habitats potentially used for spawning (Ulmer 1980; Bestgen 1990; Minckley et al. 1991). Higher water levels also allow better access to canals and backwaters for young fish. In this reach, young razorback suckers have been found using canals and drains (Marsh and Minckley 1989).

Water quality is generally acceptable to support aquatic communities in the reach. There have been modifications to the temperature, salinity, and nutrient loads in the reach, but these changes appear to be within the tolerance ranges for aquatic life. More information on contaminants from agricultural runoff, urban discharge, and water reuse is needed.

Physical Habitat

The lower Colorado River in this reach provides a variety of habitats for the razorback sucker. Shallow backwaters, unmodified river banks, and floodplains as well as the main channel are accessible to this species.

Temperatures in the reach are suitable for razorback sucker spawning (Douglas 1952; Ulmer 1980). Shallow gravel bars are potential spawning habitats and are found throughout the reach. The upper portion of the reach has more sand and gravel areas, but wash inflows of sand and gravel create spawning habitats even in areas more dominated by silts. In other areas of the Basin, razorback suckers can spawn successfully under a variety of flow conditions (Bestgen 1990) and it is likely that flows in this reach are not preventive of spawning.

The quiet, shallow habitats formed by backwaters are physically suitable for nursery habitat (Bland 1953; Tyus and Karp 1989; Osmundson and Kaeding 1991). Canals and drains also may serve as nursery and juvenile habitat areas. Since these are dried periodically, the populations of predatory fish is lower, perhaps allowing for better survival opportunities for young razorback sucker that use them. Most recent captures of young razorback sucker in the Lower Basin are from canals (Marsh and Minckley 1989).

Shallow backwaters and coves also are appropriate adult habitat, used seasonally for feeding and sheltering. Deeper water channel habitats in the altered portions of the reach allow access up and down the river. In the less modified portions, braided channels, backwaters, and shallows off sandbars and nearshore areas provide acceptable adult habitat.

Biological Environment

Existing nutrient resources are adequate to support populations of aquatic organisms. Plankton, benthic invertebrates, periphyton, and other potential food resources are available throughout the reach. Adult and juvenile razorback suckers have been taken in this reach.

Predation on or competition with razorback suckers by nonnative fish in the reach exists. Carp, sunfish and catfish are all common or abundant in the reach and these species have been shown to prey on eggs, larvae, and juvenile razorback suckers. A lack of recruitment in the razorback population in this reach may be related to this predation in addition to the changes to the physical habitat.

**Relationship to Additional Selection Criteria:**

Additional selection criteria for the razorback sucker, were developed to assist in selecting the areas proposed for designation as critical habitat. The Colorado River: Parker Dam to Imperial Dam reach meets these criteria.

<u>Presence of Spawning Population</u>

The population of razorback sucker in this reach, while likely small, is extant. Observation of spawning activities in this reach is limited, but the captures of presumably wild-bred juvenile razorback suckers in canals of the reach strongly implies that spawning is occurring (Marsh and Minckley 1989). Three ripe male razorback suckers were captured in Colorado River Indian Tribe waters in January 1993 (Charles Minckley, USFWS, pers. comm.).

<u>Nursery Habitat</u>

The existence of 11- to 12-inch juveniles in the irrigation canals demonstrates that acceptable nursery habitat exists, even though recruitment is limited in this reach. The backwaters, shallows, and marshes of the lower end of the reach contain acceptable nursery habitats.

<u>Historic or Present Distribution</u>

This reach is known historic habitat for the razorback sucker. Some of the earliest records for the species are from the lower Colorado River (Abbott 1861; Lockington 1881; and others). The present population is likely to be made up of older individuals and be small, but it is still present in the reach.

<u>Maintenance of Rangewide Distribution</u>

This reach is part of the lowest elevational segment of the Colorado River that still has permanent water. The only other low-elevation river with similar historic habitats is the Gila River. The Gila River is now dry throughout the low deserts except during flood releases from upstream dams and limited irrigation return drainage. The Colorado River: Parker Dam to Imperial Dam reach does maintain significant backwater and riparian areas to represent the types of habitats historically available in this portion of the species range.

<u>Special Management</u>

The population of razorback suckers in this reach is still declining. While suitable physical habitat for spawning, nursery, and adult requirements apparently exists, large populations of nonnative fish in the reach have impacted survival and recruitment of young razorback suckers. Work with other agencies and groups in managing this reach should encourage razorback sucker recovery.

**Gila River - Arizona-New Mexico Border to Coolidge Dam**

**Boundary Delineation:** Arizona, Graham, Greenlee, Gila, and Pinal Counties. The Gila River and its 100-year floodplain from the Arizona-New Mexico border in T.8S., R.32E., section 34 (Gila and Salt River Meridian) to Coolidge Dam in T.3S., R.18E., section 17 (Gila and Salt River Meridian), including San Carlos Reservoir to the full pool elevation; Bonita Creek and its 100-year floodplain from the infiltration gallery in T.6S., R.28E., section 5 (Gila and Salt River Meridian) to the confluence with the Gila River in T.6S., R.28E., section 21 (Gila and Salt River Meridian); and Eagle Creek and its 100-year floodplain from the Phelps-Dodge Pumping Plant in T.4S., R.28E., section 26 (Gila and Salt River Meridian) to the confluence with the Gila River in T.5S., R.29E., section 31 (Gila and Salt River Meridian).

**Shoreline Ownership:** Private lands, 50.0 percent; Tribal, 28.0 percent; Bureau of Land Management, 20.1 percent; State, 1.9 percent.

**Overlap with Proposed Critical Habitat for:** None.

**Occurrence:**

Historical

Early researchers reported the razorback sucker in the Gila River confluence with the Colorado River (Lockington 1881), the Gila Bend vicinity (Bartlett 1854), near Fort Thomas (Kirsch 1888), and near the Arizona-New Mexico border (Gilbert and Scofield 1898). It was extremely abundant in the Gila River from the late 1800's to the early 1900's (Ellis 1914; LaRivers 1962; Minckley 1973). Razorback sucker were caught for use as human and animal food and processed to make fertilizer (Minckley 1973).

Recent

Surveys completed through the 1970's (Minckley and Clarkson 1979) failed to locate any razorback suckers in the Gila River. As part of an interagency effort to restore the razorback sucker to its range in Arizona, stockings of hatchery-bred fry and juveniles have been made into the Gila River and some of its tributary streams since 1981. Some individuals have been recaptured (Arizona Game and Fish Department files); but Minckley (1985) did not locate any specimens in his survey of the Gila River in the mid-1980's. When the razorback sucker was listed as endangered, the final rule protected razorback suckers in the Gila River under the Act.

**Description of the Habitat:**

The Gila River rises in the mountains of west central New Mexico and flows generally south and west into Arizona. The San Carlos and San Francisco rivers are the only large tributaries to the Gila River in this reach. There are several smaller streams, most notably Bonita and Eagle creeks.

The significant tributaries to the Gila River in the reach all flow southward through higher gradient, canyon-bound channels. Floodplains are scarce and not well developed in these areas. Substrates tend to be cobble, gravel, and sand and during erosive high water events, considerable material may be moved into the main channel from the tributaries. These materials contribute to the formation of riffles, rapids, and pools in both the tributaries and the main channel.

The Gila River goes through higher gradient canyons and more open alluvial valleys in the reach. Flood plains are more developed in the valleys, the deeper alluvial soils spread flood waters over wide areas. Channel morphology often changes after high-flow events due to re-deposition of gravels and sands. In the lower portion of the reach, there were extensive riparian forests flanking the channel. Little is mentioned of backwaters or oxbow lakes in the literature (Minckley and Sommerfeld 1979).

The natural hydrograph showed both winter/spring and late summer high flows. Snowmelt and winter rains contributed to the winter/spring high flows. Summer high flows were the result of rains from thunderstorm activity. The winter/spring flows were slower to rise but were more stable over time. The summer flows rose and fell quickly. Outside of these periods, flow in the river could be very low (Minckley and Sommerfeld 1979). Large flood events were a regular part of the hydrograph.

Sediment loads varied considerably due to the lack of fine materials in the substrate. Turbidity was likely higher below the alluvial valleys and after erosive flood events. There is little data on water temperatures. Inflow to the mainstem came from colder, higher elevation streams that warmed significantly in the high summer air temperatures (typically reaching 90 to 100°F). The low flows during portions of the summer and fall allowed water to heat more readily

By the early 1900's, the Gila River had undergone significant changes. Overuse of the watershed increased runoff, raising the flood peaks. These extreme flows destroyed much of the riparian vegetation and created a wide, shallow channel across the floodplains. By the mid-1900's, smaller peak floods carrying more sediments began to aggrade the channel. Channel width was reduced, more meanders appeared, and the physical structure of the Gila River began to more closely resemble the conditions found in the previous century.

There are no major upstream dams on the Gila River or its tributaries in this 132 mile reach, although there are some diversions. As a result, the natural patterns of the hydrograph have been retained although flow levels have changed. Streambanks have not been modified except near developed areas. Salt cedar has become the dominant riparian shrub/tree species along portions of the reach. Overuse of rangelands along the reach has contributed to the loss of the natural riparian community.

Above the reach, water is diverted to irrigate 6,200 acres in New Mexico (Boner 1991). Other diversions are made in the Duncan and Safford valleys for irrigation on approximately 60,000 acres (ground water also is used on these lands) and industrial and municipal uses. Water also is diverted from Bonita and Eagle Creeks for municipal and industrial uses. Flow data recorded at gaging stations in the reach indicate the normal hydrograph has not been completely disrupted by the diversions. Seasonally, flows may be very low, especially in the lower part of the reach above San Carlos Reservoir. Portions of Bonita and Eagle Creeks may dry up in the summer due to upstream pumping.

San Carlos Reservoir was formed by Coolidge Dam in 1928. All the remaining flow of the Gila River is stored in this large (original storage capacity 1,285,000 acre-feet (af)) reservoir for use on the San Carlos Irrigation Project lands downstream. Because irrigation requirements are often higher than inflow to the reservoir, water levels in San Carlos Reservoir are not stable, showing the most decline over the summer. The reservoir has effectively gone dry or had very low water levels several times in the last 50 years.

Most streambanks in the agricultural and urban areas along the Gila River have already been modified for flood control. Outside of these areas, banks are in near natural conditions. Backwaters were never a common feature of the Gila River and remain uncommon today. Mainstream pools and eddies behind gravel or sandbars provide quieter water habitats. The predominant substrates in the reach are cobble, gravel, and sand.

Water quality has not likely changed significantly and is still suitable for aquatic communities. Water temperatures may be slightly higher or lower due to reduced flows at certain times of the year that may affect rates of water heating and cooling. Temperatures at the USGS gage near Calva ranged between 46° and 82°F in water year 1990 (Boner 1991). Turbidity levels continue to show wide variation due to flow events.

Nonnative fishes in this reach include largemouth bass, smallmouth bass, sunfish, carp, channel catfish, and flathead catfish, but populations of most nonnative fish species in the main channel of the Gila River are not high (Minckley and Sommerfeld 1979). The lack of backwater habitats and the periodic flood events do not encourage the establishment of large populations of these species. San Carlos Reservoir does have larger populations of these species, but the reservoir is susceptible to large drawdowns and these tend to limit nonnative populations.

Impacts due to urban development and mining are likely to increase in the reach, but increases in agricultural use of Gila River water is not likely. Adverse impacts to aquatic habitats in the reach, due to diversions, road crossings, overuse of rangelands, and other factors, will continue.

Relationship to Constituent Elements:

Water

Despite the large depletions of water from the Gila River in the Duncan and Safford valleys, the existing hydrograph indicates that adequate water remains in the system to support aquatic communities. Aside from summer flows in and below large diversions, the Gila River does not dry up. Pools in the main channel and the tributaries allow fish to survive over during these periods. Flow levels increase in the early spring, providing razorback suckers spawning habitat (Ulmer 1980; Bestgen 1990; Minckley et al. 1991). Water temperatures of around 55° to 69°F in the February to April period (Boner et al. 1991) are within the range needed for successful spawning (Minckley et al. 1991). Spring flood flows may contribute to providing nursery habitats in the flooded areas.

Water quality is generally acceptable within the reach. There have been changes to temperature, turbidities and salinities, but current levels are within the range of tolerance for aquatic communities. More information on contaminants in agricultural runoff and return flows, and use by mining operations and municipal users is needed to further review the water quality issues.

Physical Habitat

Aside from alterations in flow levels and limited flood control works, most of the physical habitat of the Gila River is similar to historical conditions. Substrates suitable for spawning, cobble, and gravels, (Mueller et al. 1982, 1985) are abundant in the reach. Inundation of riparian areas by floodflows may provide nursery areas for young fish. Shallow waters in the tributary streams also may be used for nursery habitat.

The Gila River reach provides adult and juvenile razorback suckers with habitats similar to historic conditions. The main channel, with its pools, runs, and riffles provides a variety of water depths and velocities on a seasonal basis. Seasonal changes in use of pools, eddies, runs, and backwaters have been reported from the Upper Basin (Osmundson and Kaeding 1989). Except for backwaters, which may be replaced by tributaries in this area, all these habitats are common in the Gila River.

Biological Environment

Nutrient levels are adequate to support aquatic communities. Physical and water-quality conditions have provided for a diverse invertebrate community (Minckley and Sommerfeld 1979).

Floods events on the Gila River and its tributaries in this reach results in the periodic removal or reduction in nonnative fish populations as they are washed downstream during these events (Minckley and Sommerfeld 1979). The native fish species have been shown to be much more able to maintain position in the stream or river in the face of heavy flows. The tolerance of native fish for the harsher summer conditions in the pools and shallow channels also is important in exploring differential survival, but pools also may enable the more reservoir species, such as largemouth bass, as well as riverine species, to remain in the system. Surveys indicate that nonnative fish populations are higher in the smaller tributaries than in the main channel (Minckley and Sommerfeld 1979).

San Carlos Reservoir provides a recreational fishery for the warmwater species found in the reach. This area also may act as a refuge for nonnatives after flood events. That the populations undergo periodic declines due to low reservoir elevations may be helpful in reducing emigration to the river.

## Relationship to Additional Selection Criteria:

Additional selection criteria for the razorback sucker were developed to assist in selecting the areas proposed for designation as critical habitat. The Gila River: Arizona-New Mexico border to Coolidge Dam reach meets these criteria.

### Presence of Spawning Population

No spawning activity for the razorback sucker has been documented in this reach in recent times. Historically, spawning is very likely to have occurred here.

### Nursery Habitat

Shallow, nearshore areas, flooded bottomlands, and the mouths of tributary streams could provide nursery habitat for razorback suckers. Bays and coves in the reservoir also may be used.

### Historic or Present Distribution

Razorback suckers were historically common in the reach, and were reintroduced during the 1980's.

### Maintenance of Rangewide Distribution

The Gila River basin historically supported large populations of the razorback sucker. The proposed reach has both canyon and open valley habitats representative of the higher elevation watersheds. It is the last large river segment in southern Arizona to maintain an approximation of the normal hydrograph and has limited development along the banks. This portion of the Gila River experiences elevational changes that affect climate conditions, water flows, and temperature that are different from the conditions in other proposed reaches.

Observation of several mainstream Colorado River and tributary reservoirs has shown that adult populations can survive very successfully in these habitats. The disappearance of razorback suckers from reservoirs results from a lack of recruitment to the adult population as the older adults die off. The reduction in or disappearance of populations in Lake Mead and Lake Havasu on the Colorado River and Roosevelt Lake on the Salt River corresponded with the senescence and mortality of the 30- to 45-year old razorback suckers that made up the population.

Reservoirs are useful in the maintenance of large populations of razorback suckers to provide stock for reintroduction or augmentations of other populations. The large numbers also allow for the retention of greater genetic diversity within the population.

Special Management

Natural recruitment of razorback suckers in this reach has not occurred in many years. Suitable spawning and nursery habitats do exist, and it is believed that stocked razorback suckers will spawn when they achieve sexual maturity. Opportunities to control the nonnative fish populations in the reach by managing for natural conditions may be an important part of the establishment of a self-sustaining population.

**Salt River - US60/SR77 Bridge to Roosevelt Diversion Dam**

**Boundary Delineation:** Arizona, Gila County. The Salt River (the river channel and the 100-year floodplain) from the old US60/SR77 highway bridge in the Salt River Canyon to Roosevelt Diversion Dam. Also included are Cherry Creek and its-100 year floodplain from the road crossing in T.4N., R.15E., section 3 to the confluence with the Salt River and Canyon Creek and its 100 year floodplain from the OW Ranch Road crossing on the Tonto National Forest in T.10 ½N., R.15E., section 22 to the confluence with the Salt River.

**Shoreline Ownership:** National Forest, 69.7 percent; Tribal, 30.3 percent.

**Overlap with Proposed Critical Habitat for: None (designated as an Experimental Non-**Essential Population for Colorado squawfish).

**Occurrence:**

Historical

The razorback sucker was first recorded from the river below this reach by Chamberlain (1904). There are no records for the species in the reach itself; however, there were no barriers between the recorded sites and the proposed reach until Roosevelt Dam and smaller diversions were constructed after 1911.

The species persisted in Roosevelt Lake until the 1930's, but could still be found in the lower Salt River Reservoirs into the 1950's (Minckley 1973). No captures or observations of the razorback sucker in the Salt River or the mainstem reservoirs were made in the period 1967-1977 (summarized by Minckley et al. 1991).

Recent

The species has been stocked into the Salt River reach since 1981 under a cooperative effort to reintroduce the species in its historic range. Twenty-two fish have been recaptured from this effort (Arizona Game and Fish Department data). The final rule listing the razorback sucker as an endangered species protected the population in the Salt River under the Act.

**Description of the Habitat:**

Except for some limited diversions above the reach for the irrigation of 3,100 acres and the construction of Roosevelt Diversion Dam and Theodore Roosevelt Dam below this reach, it is largely unmodified and retains the natural hydrograph. There are no artificial barriers in the reach, although access may be somewhat impeded by rapids and waterfalls.

This 55-mile reach of the Salt River is confined to a deep canyon above and through the reach. High gradients have resulted in many rapids. Interspersed throughout the river are slow moving runs, pools, and eddies. Substrates vary but are primarily boulders, cobble, and gravels. Few, if any, backwaters are found; and riparian communities are limited. At bends in the river, the channel can widen out and shallow, slow-moving waters, floodplains, and gravel bars form.

Flows through the reach come from the Black and White Rivers which join to form the Salt River upstream of the reach. Smaller inflows from Cibecue, Canyon, Cherry, and Pinal creeks also contribute to flows. Spring snowmelt produced the highest flows, with a second, late- summer peak resulting from thunderstorm events (Boner et al. 1991). Sediment loads were seasonally high, and water temperatures varied significantly over the year. The Salt River was named for the salt springs that drain into the river. Water quality was generally acceptable for aquatic communities.

Flows in the Salt River are not significantly different from the historic patterns or levels. Water-quality parameters have not changed, except in Pinto Creek at the bottom end of the reach. Mine tailing ponds have occasionally released polluted water into the creek and, thus, into the Salt River.

There is road access to portions of the north shore of the Salt River, and there is a highway bridge over the reach at the upstream end. Overuse of the watershed may have contributed to degradation of riparian communities and perhaps an increase in sediment loads. Other than these areas, the river channel, banks, and floodplain remain unmodified.

Nonnative fish species in this reach include smallmouth bass, green sunfish, channel catfish, flathead catfish and carp. Recreational fishing is limited due to access problems.

A new bridge over the Salt River for the US60/SR77 highway is planned. On the Tonto National Forest, the lower portion of this reach is in the Salt River Canyon Wilderness. No significant shoreline developments are anticipated in the reach. Flows through the reach may be affected in the future by water-development projects on the Fort Apache Indian Reservation.

**Relationship to Constituent Elements:**

Water

Unlike other Arizona rivers, the Salt River in this reach is little affected by upstream diversions and retains its natural hydrograph. Below the reach, four large water storage reservoirs regulate the flow of the Salt River. The limited upstream diversions from the Black and White Rivers may have some impact on flow levels, but the effect is likely slight. Some flows are diverted from Cherry Creek upstream of the reach, but there are no diversions from Canyon Creek. Flows are not limiting in this reach.

Water quality in the reach is acceptable for aquatic communities. The high turbidities sometimes seen are within historical levels and are tolerated by native fish species adapted to this environment.

Physical Habitat

The narrow canyons in this reach provide riverine habitats dominated by rapids, pools, and runs. The shallow tributaries, eddies, and nearshore shallows also provide acceptable habitat. Access through the reach may be affected by larger rapids and waterfalls, but restrictions are likely not complete.

Floodplains are rare in the reach, mostly found at bends in the river, but sand and gravel bars are not uncommon, and may provide for spawning habitat. Water temperatures in the reach are within the acceptable range for razorback sucker spawning (Douglas 1952; Ulmer 1980). Flow conditions in the reach are likely close enough to historical flows to be suitable for spawning.

Nursery habitats may be limited to areas near floodplains or behind sand or gravel bars. These sandbars are found the entire length of the reach. In wider areas of the river, these bars may divide the river flow between more than one channel and create shallow, quiet water areas at their downstream ends. These types of habitats are suitable nursery habitat for razorback suckers elsewhere (Bland 1953; Tyus and Karp 1989; Osmundson and Kaeding 1991).

Biological Environment

Without large additional nutrient inflows from development of agriculture and urban areas, current nutrient levels are likely very similar to historical levels. There may have been some increases due to livestock grazing activity on the watershed, but the amount is unknown.

Predation on and competition with razorback suckers by nonnative fish species exists. Carp, channel catfish and flathead catfish are common or abundant in the reach and have been shown to prey on eggs, larvae, and juvenile razorback suckers. With the limited habitat changes that have occurred in the reach, this predation is likely a significant restriction on expansion of the razorback population.

As on the Gila River, floods on the Salt River and its tributaries in this reach may result in the periodic removal or reduction in nonnative fish populations as they are washed downstream during these events. The native fish species have been shown to be much more able to maintain position in the stream or river in the face of heavy flows. The tolerance of native fish for the harsher summer conditions also is important in exploring differential survival. Pools also may enable the more reservoir oriented species, such as largemouth bass as well as riverine species, to remain in the system. Roosevelt Diversion Dam at the bottom of the reach restricts nonnative fish in Roosevelt Lake from coming up into the reach.

Relationship to Additional Selection Criteria:

Additional selection criteria were developed for the razorback sucker to assist in selecting the areas proposed for designation as critical habitat. The Salt River: US60/SR77 bridge to Roosevelt Diversion Dam reach meets these criteria.

Presence of Spawning Population

No razorback sucker spawning activity has been documented in this reach in recent times. Historically, spawning may have occurred here, but there are no specific records.

Nursery Habitat

Shallow nearshore areas behind sand and gravel bars and tributary streams all could provide nursery habitat for razorback suckers. Floodplains are not common in this reach.

Historic or Present Distribution

Razorback suckers were reported from river sections downstream of this reach and the species was likely present in the reach. Razorback suckers were reintroduced during the 1980's.

Maintenance of Rangewide Distribution

Historically, the Salt River supported a population of razorback sucker. The presence of the species in Roosevelt Lake immediately below the reach provides evidence for the existence of this historic population (Minckley 1973). Except for the Grand Canyon, this reach is the only major canyon habitat for the species in Arizona. The Salt River reach has the fewest changes due to human development of any proposed critical habitat reach for the razorback sucker in the Lower Basin.

Special Management

Recruitment of razorback suckers in this reach has not been documented. Suitable spawning and nursery habitats exist; and it is believed that stocked razorback suckers will spawn when they achieve sexual maturity. Opportunities for control the nonnative fish populations in the reach by managing for natural conditions may be an important part of the establishment of a self-sustaining population.

Protection of the existing flows may be more effective with the designation of critical habitat. There are agricultural programs and projects proposed for the White River upstream of the reach.

**Verde River - Dam at Sullivan Lake to Horseshoe Dam**

**Boundary Delineation:** Arizona, Yavapai County. The Verde River and its 100-year floodplain from the base of the dam forming Sullivan Lake in T.17N., R.2E., section 15 (Gila and Salt River Meridian) to Horseshoe Dam in T.7N., R.6E., section 2 (Gila and Salt River Meridian), including Horseshoe Lake to the full pool elevation; and Sycamore Creek and its 100-year floodplain from the boundary with the Sycamore Canyon Wilderness Area in T.17N., R.3E., section 8 (Gila and Salt River Meridian) to the confluence with the Verde River in T.17N., R.3E., section 7 (Gila and Salt River Meridian); Oak Creek and its floodplain from Page Springs State Fish Hatchery in T.16N., R.4E., section 23 (Gila and Salt River Meridian) to the confluence with the Verde River in T.15N., R.4E., section 20 (Gila and Salt River Meridian) and West Clear Creek and its 100-year floodplain from the boundary of the West Clear Creek Wilderness Area in T.13N., R.6E., section 15 (Gila and Salt River Meridian) to the confluence with the Verde River in T.13N., R.6E., section 21 (Gila and Salt River Meridian).

**Shoreline Ownership:** National Forest, 70.7 percent; Private, 29.0 percent; State, 0.3 percent.

**Overlap with Proposed Critical Habitat for:** Designated as an Experimental Non-Essential Population for the Colorado squawfish. A population of the federally threatened spikedace is present in the upper portion of the reach. The upper portion of the reach was proposed as critical habitat for the spikedace. That proposal has not been finalized.

**Occurrence:**

Historical

The razorback sucker was reported in the Verde River in 1898 (Gilbert and Scofield 1898) and persisted until the 1950's. The last record of razorback sucker in the Verde River was from Peck's Lake in 1954 (Minckley 1973). The species was abundant enough to be a food resource for native peoples in the area, as illustrated by the remains of a razorback sucker found in an archaeological site near Perkinsville (Minckley and Alger 1968).

Recent

Razorback suckers have been stocked into the Verde River reach since 1981 under a cooperative effort to reintroduce the species in its historic range. Of the large number of razorback suckers stocked in the Verde River, only a very low percentage have been recaptured (Arizona Game and Fish Department, unpublished data). Radiotelemetry studies are ongoing to evaluate habitat use. The final rule listing the razorback sucker as an endangered species included the population in the Verde River as fully protected under the Act.

**Description of the Habitat:**

The upper portion of the Verde River in the reach is confined between steep watersheds that limit floodplains and prevents the river from meandering. Gradients are moderate and there are many riffles and pools. Substrates in the upper portion of the reach are more likely to be boulder, cobble, and gravels, with sands and other fine materials in the wider floodplain areas, especially near the mouths of tributaries. Sycamore Creek joins the Verde River in the upper portion of the reach. Flows of surface water are augmented by springs, seeps, and other ground water contributions.

In the 1800's, the middle Verde River was a wide, low-gradient stream with a substantial floodplain. There were many backwaters and extensive riparian forests. During high flows, overbank flooding was common. Substrates are dominated by gravel and sand, with cobble and boulders locally common in the channel. Marshes and oxbow lakes were formed in the old river channels and had sand and silt substrates. Shallow riffles, pools, and runs provided habitat in the main channel. Oak and West Clear Creeks join the Verde River in this part of the reach.

Below the Verde Valley, the lower river becomes more confined, with steep mesa slopes preventing establishment of floodplains. There are places where the valley opens up wide enough to allow the river to meander, forming backwaters and marshes. Substrates tend to be cobble and sand. There are several areas of rapids in this portion of the reach, along with shallow riffles and pools. Gravel bars are common in this portion and are often above water in low-flow conditions.

There are no major dams in this 149-mile reach, but there are significant diversion dams, mostly in the portion from Clarkdale and Beasley Flats (the middle Verde River in the Verde Valley). Flows below these diversions reach very low levels during the irrigation season (Boner et al. 1991). River flows between diversions are restored by ground water accretion, irrigation return flows and inflow form tributaries. Recent USGS gage data (Boner et al. 1991) for the Verde River shows that seasonal flow changes do not appear to be as great as in other Arizona rivers. Spring runoff peaks usually are not significantly larger than base flow in other seasons, but a small summer peak also was recorded. Flow differences were greater at the bottom of the reach than at the top. Diversions to irrigate over 12,500 acres and provide municipal and industrial water may be responsible for attenuating any natural peaks (Boner et al. 1991). Oak Creek in the reach also has significant diversions and also shows little seasonal flow variation. Irrigation diversions also remove much summer flow from West Clear Creek (Boner et al. 1991).

The upper portion of the Verde River has been affected by livestock grazing, mining, and recreation use (Sullivan and Richardson 1993). Riparian resources and streambanks have been most heavily impacted and there is little modification of the stream channel itself. Through the Verde Valley, diversions, sand and gravel operations, agricultural and residential development adjacent to the channel and may have affected channel morphology, especially in restricting the Verde River from meandering. Riparian and backwater areas have been degraded. The lower portion, from Beasley Flats to Horseshoe Reservoir, is not heavily developed and is affected only by the changes in seasonal flows.

Horseshoe Dam was constructed by Phelps-Dodge Corporation between 1944 and 1946. Horseshoe Reservoir had an initial storage capacity of 131,427 af. It is subject to extreme fluctuations in water levels, sometimes reaching over 70 feet in a year and has been known to reach very low pool elevations (USBR 1990).

Water quality was affected by the changes to the river. Alterations in seasonal flows and elimination of riparian vegetation created changes in water temperatures. In the areas below diversions, summer temperatures in isolated pools may exceed tolerances for fish. Water temperatures of near 86°F are already reported in August and September. Inflows from agriculture carry salts, nutrients, and agricultural chemicals from irrigated fields into the river. Runoff from urbanized areas also enters the river and may carry contaminants. There are extensive sand and gravel operations in the Verde Valley. Turbidity may be affected by these operations.

The Verde River supports a diverse native fish community in the upper portion of the reach. At least six native species are maintaining populations, including the federally threatened spikedace (Sullivan and Richardson 1993). Nonnative fishes are present, but not dominant except in backwater areas. In the remainder the Verde River, smallmouth bass, sunfish, flathead catfish, channel catfish, and carp are common. In addition to those species, Horseshoe Reservoir has largemouth bass and black crappie.

Adequate water supplies for the communities and industries in the upper Verde River and Verde Valley portion of the reach are lacking. There are several projects under evaluation to divert more water from the Verde River or its tributaries or to pump ground water resources that may be resupplying the surface flows below diversions. Additional bank stabilization in the Verde Valley portion of the reach will likely be considered in the wake of the high flood flows of the winter of 1992-1993.

### Relationship to Constituent Elements:

Water

Flows in the Verde River and tributaries have been affected by large diversions of water, especially in the Verde Valley. Flows in the upper and lower portions have been affected, but not to the same degree. In the upper Verde River, natural flows have been maintained to the extent that the native fish community is dominant over the nonnative fish. In the lower Verde River, flows are higher and sufficient flows exist to support the aquatic community. Horseshoe Reservoir experiences severe water level fluctuations due to demands for irrigation and municipal water downstream and may go nearly dry in some years.

The existing water quality is adequate. Changes to nutrient load, salinity, turbidity, and other parameters may have occurred, but levels are within the tolerance of aquatic communities. High temperatures may be significant in isolated pools during the summer. Additional information is needed on the levels of pesticides and other contaminants in return flows.

Physical Habitat

The Verde River reach provides a diverse collection of habitats for the razorback sucker. In the upper portion, main channel riverine habitats include runs, riffles, pools, and eddies, but few backwaters. The Verde Valley has both main channel and backwater habitats and the lower portion is more riverine in character. Shallow water habitats are available in the tributaries. Horseshoe Reservoir provides either reservoir or riverine habitats depending upon water levels.

Temperatures in the reach are within the range for razorback sucker spawning (Douglas 1952; Ulmer 1980). Shallow gravel bars are available for spawning habitat throughout the reach. The alteration in flows may not preclude razorback spawning because they can spawn successfully under a variety of flow conditions (Bestgen 1990).

Backwaters and floodplains for nursery habitat are locally available in the reach. Potential spawning habitat is common and there is suitable nursery habitat nearby. Habitats for adult use include both main channel and backwater areas. Access throughout the reach may be constrained during the irrigation season, but there are no complete barriers to movement.

Biological Environment

Existing nutrient resources in the reach are adequate to support aquatic communities. Plankton, benthic invertebrates, periphyton, and other potential food resources are available throughout the reach.

Nonnative fish are common in this reach, dominating in the lower and Verde Valley portions. It appears that the nonnative species have a competitive advantage in human disrupted streams over the native fish. Predation and other forms of competition have been an issue in the reintroduction of the razorback sucker to the Verde River. As elsewhere, a factor in the elimination of the razorback sucker from the Verde River is the presence of these nonnative fish. Flood flows in the upper Verde may help to remove nonnative species by washing them downstream. Additionally, fluctuations in Horseshoe Reservoir may reduce the nonnative fish populations there and also may reduce its value as a source of nonnative species in the river.

**Relationship to Additional Selection Criteria:**

**For the** razorback sucker, additional selection criteria were developed to assist in selecting the areas proposed for designation as critical habitat. The Verde River: Dam at Sullivan Lake to Horseshoe Dam reach meets these criteria.

Presence of Spawning Population

No spawning activity for the razorback sucker has been documented in this reach in recent times. Historically, spawning is likely to have occurred here.

Nursery Habitat

Shallow nearshore areas behind sand and gravel bars, backwaters, floodplains, and tributary streams all could provide nursery habitat for razorback suckers.

Historic or Present Distribution

Razorback suckers were historically present in the reach and were reintroduced during the 1980's.

Maintenance of Rangewide Distribution

The Verde River was the last of the Gila River basin rivers to retain a population of razorback sucker, which persisted there until 1954. The Verde River reach shares some habitat characters with the Gila River reach, in elevational changes and the mix of canyon-like portions with restricted floodplains and more open valleys with meanders and backwaters. Existing patterns of flow in the two rivers are very different as is the arrangement of developed areas.

Special Management

Razorback sucker recruitment has not occurred in this reach in many years. Suitable spawning and nursery habitats exist, and it is believed stocked razorback suckers will spawn when they achieve sexual maturity. Development of isolated ponds or coves to act as grow out facilities may be appropriate to consider to assist in establishment of a breeding population in this river. Opportunities to control the nonnative fish populations in the reach by managing for natural conditions may be an important part of the establishment of a self-sustaining population.

The continued pressure for the development of water sources for municipal and agricultural purposes is a continuing concern. Maintaining the physical habitat conditions that have enabled the native fish fauna in the upper portion of the Verde River is of considerable importance.

**COLORADO SQUAWFISH**

The Service is proposing six reaches of the Colorado River system (Figure 9 and Table 3) for designation as critical habitat for the Colorado squawfish. In the Upper Basin, critical habitat is being proposed in the Green, Yampa, Colorado, White, Gunnison, and San Juan Rivers. No critical habitat for the Colorado squawfish is currently being proposed for the Salt and Verde rivers in the Lower Basin due to the presence of nonessential experimental populations in those rivers. Should that status change, these areas will need to be reviewed for possible inclusion as critical habitat.

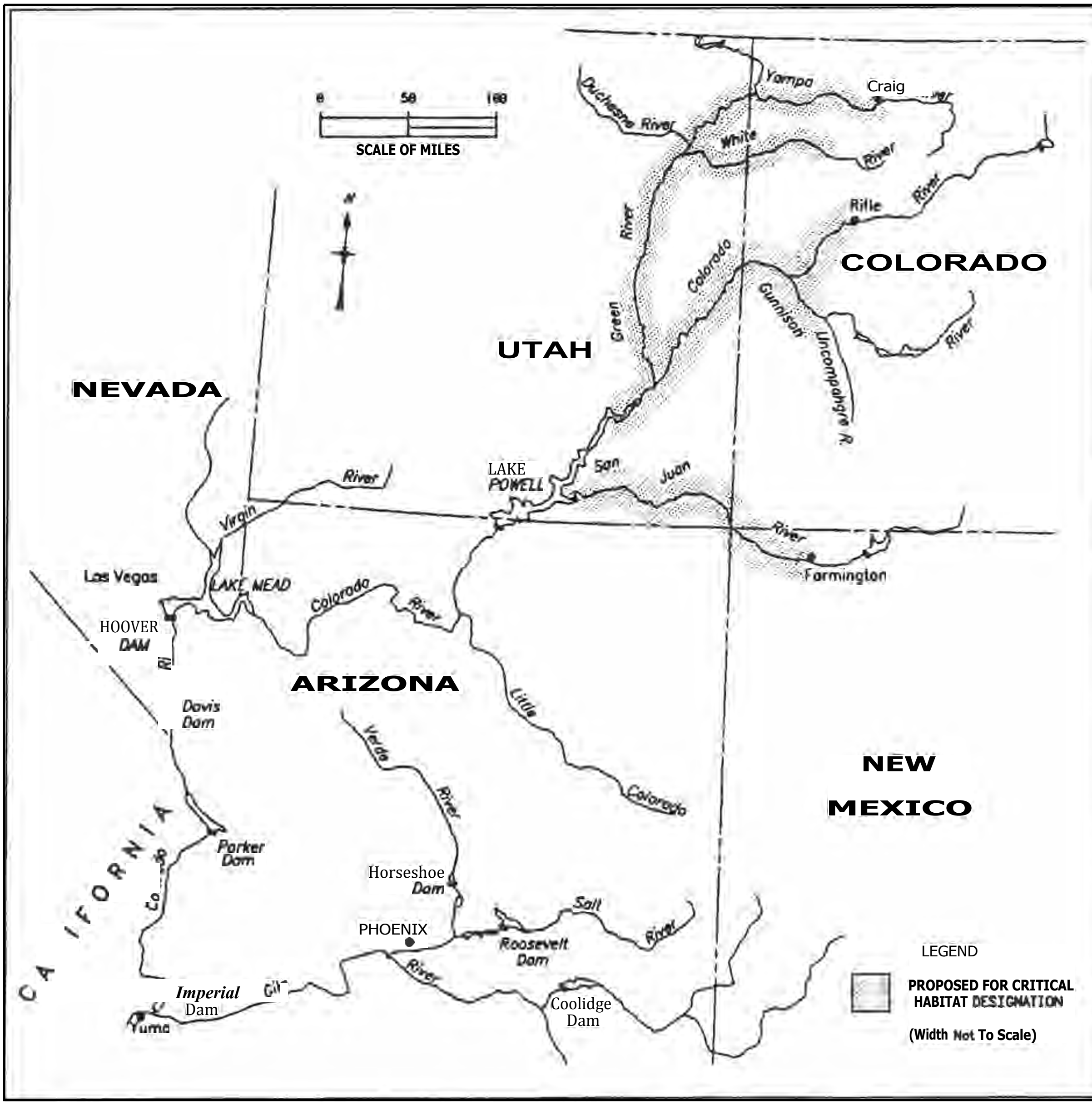



Figure 9. Map of proposed critical habitat for the Colorado squawfish.

Table 3. Colorado squawfish critical habitat proposed by basin and reach classification. Reach classifications are from downlisting and delisting criteria in the Colorado Squawfish Recovery Plan (USFWS 1991).

| Upper Basin Reaches | Classification | Miles |
|---|---|---|
| Yampa River - Craig, Colorado to Green River | Downlisting | 131 |
| Green River - Yampa to Colorado River | Downlisting | 333 |
| White River - Rio Blanco Reservoir to Green River | Downlisting | 125 |
| Gunnison River - Uncompahgre to Colorado River | Delisting | 60 |
| Colorado River - Rifle, Colorado to Price-Stubb Dam' | Delisting | 53 |
| Colorado River- Price-Stubb Dam to Dirty Devil Arm of Lake Powell[2] | Downlisting | 227 |
| San Juan River - Farmington, New Mexico to Neskahai Canyon | Downlisting | 219 |
| | Total = | 1148 |

1 For purpose of this table, the reach between Rifle, Colorado and the Dirty Devil Arm of Lake Powell was divided into two reaches.

Of the historical range of Colorado squawfish, 29 percent (1,148 miles) is proposed for designation as critical habitat (Figure 10). These represent reaches in the major tributaries of the Upper Basin. Areas in the Lower Basin not proposed are important and may contribute to the eventual recovery of Colorado squawfish. Although Colorado squawfish were once common throughout the Basin, habitat in the Upper Basin has been less altered.

These reaches flow through a variety of shoreline ownerships, both public and private. The Bureau of Land Management and the private sector are the major landowners adjacent to the proposed critical habitat. The approximate percentages of critical habitat by shoreline ownership for the Colorado squawfish is presented in Figure 11.

CRITICAL HABITAT DESIGNATION BY AREA

**Yampa River - Craig. Colorado. to Green River Confluence**

**Boundary Delineation:** Colorado, Moffat County. The Yampa River and its 100-year floodplain from the State Highway 394 bridge (RM 137.7) in T.6N., R.91W., section 1 (6th Principal Meridian) to the confluence with the Green River in T.7N., R.103W., section 28 (6th Principal Meridian).

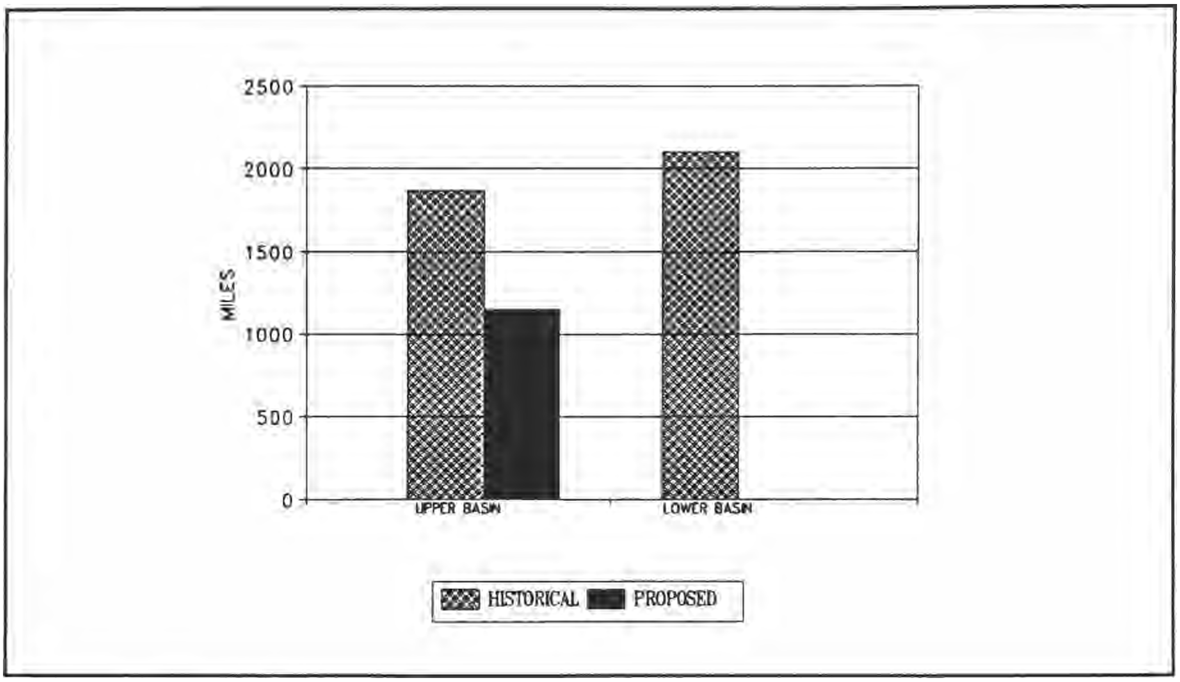



Figure 10. Relative amount of historical habitat proposed as critical habitat for the Colorado squawfish.

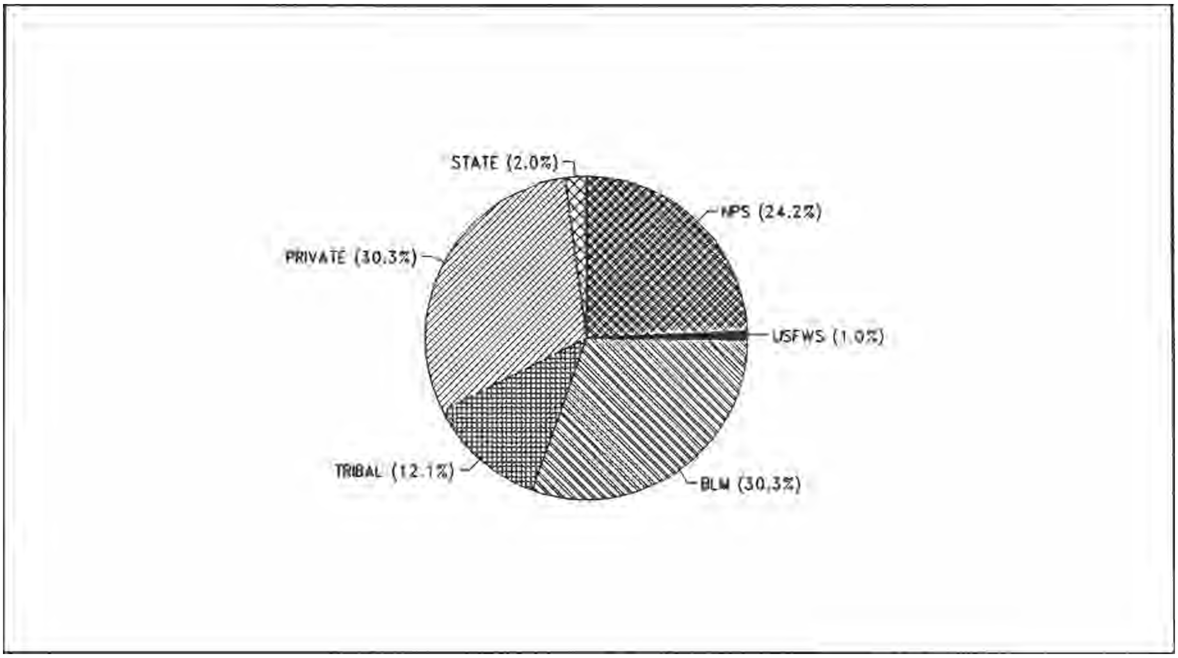



Figure 11. Shoreline ownership for proposed critical habitat for the Colorado squawfish.

**Shoreline Ownership:** Private, 44.9 percent; National Park Service, 30.9 percent; Bureau of Land Management, 19.9 percent; State, 4.3 percent.

**Overlap with Proposed Critical Habitat for:** Razorback sucker, humpback chub, bonytail.

**Occurrence:**

Historic

Colorado squawfish were historically present in the Yampa River. Ellis (1914) reported Colorado squawfish there; other early studies of native fishes in the Yampa included Beckman 1952; Banks 1964; Vanicek et al. 1970; and Holden and Stalnaker 1975b. Quartarone (1993) relates historical accounts of Colorado squawfish use as a sport and food fish in the Yampa River basin.

Recent

Colorado squawfish occur in the Yampa River from its mouth to Hayden, Colorado. Tyus and Karp (1989) placed the upper limit of Yampa River Colorado squawfish distribution near Craig, Colorado. The upper Yampa River is considered a concentration area for overwintering adults (Archer et al. 1986). A spring spawning migration of Colorado squawfish to the lower 31 miles of the Yampa River was identified by Tyus and McAda 1984 and confirmed by Wick et al. (1983) and Tyus 1990. Other recent studies of Colorado squawfish in the Yampa River include Miller et al. 1982b; Haynes and Muth 1982; Wick et al. 1985; Nesler 1986; Wick and Hawkins 1989; and Tyus 1985, 1990.

**Description of Habitat:**

In the upper portion of this reach, the Yampa River has low current velocity and meanders through low hills. Backwaters, side channels and riffles are fairly common. Sand and gravel are the primary substrate constituents. The river enters Juniper Canyon, a short (2 miles) reach of high gradient with boulder/cobble substrate at RM 91. The Yampa River between Juniper and Cross Mountain Canyons meanders through an alluvial plain. Backwaters are common and the substrate is sand/silt with gravel/cobble riffles. In Cross Mountain Canyon the substrate is boulder and bedrock, and the river drops an average of 55 feet per mile. Small rapids and riffles in this area are numerous and almost continuous. Beginning at Lily Park, the Yampa River washes over a boulder/cobble/gravel substrate from Cross Mountain Canyon downstream. The river is fairly wide here, with riffles, eddies, and side channels common. Though there is at least one deep pool, the river is generally very shallow. At the end of Lily Park, the Green River takes on the waters from the Little Snake River and enters Deerlodge Park. Here, the substrate is predominantly sand and silt, mostly from the Little Snake River. The habitat is not varied, with few riffle, eddies, or backwaters. At RM 45, the Yampa abruptly enters Yampa Canyon. Here, occasional boulder fields create rapids, but the predominant substrate is gravel/cobble with patches of

**sand. In the lower portion of the canyon, the river meanders through sandstone cliffs and it exists Yampa Canyon at Echo Park, where it meets the Green River (habitat descriptions taken from Miller et al. 1982b).**

**Relationship to Constituent Elements:**

**Water**

**The Yampa River has minimal water development; therefore, the current hydrograph reflects flows which are representative of historical volume and timing. The Service has identified existing Yampa River flows as adequate for the needs of Colorado squawfish and also has identified them as critical for maintaining native fish habitat in the Green River below their confluence (McAda and Wydoski 1980; Tyus and Karp 1989, 1991). Tyus and Karp (1989) also postulated that Yampa River flows, particularly spring runoff, may limit proliferation of introduced fishes. Water quality has not been identified as a chronic problem. However, an oil spill in June 1989 caused by a ruptured pipeline discharged approximately 10,000 gallons into the Yampa River. This spill has been implicated as resulting in low Colorado squawfish larval and young-of-year abundance in the upper Green River basin that year (Obmasick 1989; Carlson 1991).**

**Physical Habitat**

**The Yampa River primarily provides spawning, larval and adult habitat for the Colorado squawfish, although juvenile fish are caught there also. Analysis of this reach show principal habitat types to be pool, riffle, eddy, backwaters, and side channel (Miller et al. 1982b). Backwaters are an important habitat component in the upper and lower portions of this reach. Spawning of Colorado squawfish in the lower 32 miles of the Yampa on cobble substrates has been documented (Tyus and McAda 1984; Haynes and Muth 1984; Wick et al. 1983; Archer and Tyus 1984; and Tyus 1985, 1990). The upper Yampa River within this section (RM 51 to 123) has been identified as important over-wintering habitat (Archer et al. 1986; Wick and Hawkins 1989). Abundance data from Miller et al. 1982b and Wick et al. 1985, and radiotelemetry data from Tyus (1985, 1990) support this view. Wick and Hawkins (1989) identified winter habitat use by Colorado squawfish in the Yampa River finding that shallow, ice-covered shoreline areas were most commonly used followed by backwaters, runs and eddies. Larval Colorado squawfish were found drifting in the mainstream Yampa River and in shoreline habitats soon after the spawning period (Haynes and Muth 1982; Tyus and Haines 1991). This reach of the Yampa is considered essential for the survival of this species due to the presence of constituent elements and its importance to constituent elements in downstream reaches of the Green River (Tyus and Karp 1989, 1991).**

**Biological Environment**

**The relatively unmodified nature of the Yampa River system likely results in productivity that is similar to predevelopment. The introduction of nonnative fishes is probably the**

greatest alteration to the historical Yampa system. Tyus and Karp (1989) reported 18 species of nonnative fish have been introduced, while Miller et al. (1982b) found 13 nonnative and nine native fish species within this reach. However, nonnative species still dominate the fish community (Tyus and Karp 1989). The potential for competition and predation between these nonnative and native species is high. Virtually all 13 species of nonnative fish found in this reach have the potential to prey on and/or compete with native species. Maintenance of a historical hydrograph and other conditions may help limit further encroachment and further disruption of the natural system by nonnative fishes (Tyus and Karp 1989).

Green River - **Confluence with the Yampa to Confluence with the Colorado River**

**Boundary Delineation:** Utah, Uintah, Carbon, Grand, Emery, Wayne, and San Juan Counties; and Colorado, Moffat County. The Green River and its 100-year floodplain from the confluence with the Yampa River in T.7N., R.103W., section 28 (6th Principal Meridian) to the confluence with the Colorado River in T.30S., R.19E., section 7 (Salt Lake Meridian).

**Shoreline Ownership:** Bureau of Land Management, 41.1 percent; National Park Service, 26.7 percent; Private, 17.9 percent; Tribal, 9.9 percent; Fish and Wildlife Service, 3.1 percent; State, 1.3 percent.

**Overlap with Proposed Critical Habitat for:** Razorback sucker, humpback chub, bonytail.

**Occurrence:**

Historical

Colorado squawfish were reported in the Green River by Colonel Ashley during a 1825 trip near Willow Creek (Morgan 1964) and by Dellenbaugh (1908) on the second Powell expedition in 1871. They also were reported at Green River, Utah, in 1889 (Jordan 1891). Many pictures and old accounts of Colorado squawfish exist from populated areas, especially in the Jensen, Utah area (Quartarone 1993).

Recent

Colorado squawfish are more common in the Green and Yampa Rivers than at other locations (Holden 1973; Holden and Stalnaker 1975a, 1975b; Tyus 1991a; Archer et al. 1985). In the Green River, Colorado squawfish abundance peaks near Ouray, Utah, and Labyrinth Canyon (Tyus et al. 1987; Tyus and Haines 1991).

**Description of Habitat:**

Historically, flows in the Green River began increasing in March, peaked in June, and remained high through July (Smith and Green 1991). The spring peak averaged about 8,000 cfs for the predam period of 1951-1962 at Greendale, Utah. Yearly and seasonal variation in this reach made flows highly variable. Mean monthly flow during spring runoff (April-July) was about 14,000 cfs. A maximum flow of 68,000 cfs was recorded at Green River in 1917 and a minimum flow of 255 cfs in 1931. Predam temperatures at Jensen, Utah, ranged from near 32°F in December and January to around 78°F during July and August (Smith and Green 1991).

The Green River enters Echo Park at its confluence with the Yampa River. Here, the river is wide, deep, and slow moving. Substrate is a mixture of sand/silt with some large gravel/cobble riffles. After a few miles, the river passes through Whirlpool Canyon, an area of steep cliffs, large pools, deep eddies, rapids, and large boulders. The substrate in the canyon is boulder/bedrock, but large deposits of sand exist within the eddies. After leaving the canyon, the Green River flows through Island and Rainbow Parks. The river in this area is shallow, and side channels are common. At RM 327, the river enters Split Mountain Canyon. This stretch contains large boulder fields, swift waters, and major rapids. Some significant sandbars exist in the slower moving parts of this area. The Green River leaves Dinosaur National Monument and the canyon area at RM 319 and enters Uintah Basin where it becomes broad, shallow, and flat. The river is highly braided, with side channels and backwater nursery areas the predominant habitat. Some drainage occurs from agriculture return flows and discharge from nearby towns. The substrate is sand underlain with rock. The Duchesne River, from the southern slope of the Uintah mountains, meets the Green River near Ouray, Utah, at RM 248. Just to the south, the White River flows into the Green River. The river becomes deeper at this point, but is still characterized by eddies, backwaters, side channels, and some pools. The substrate is predominantly sand/silt. This reach of the Green River ends at Sand Wash above Desolation Canyon.

Below Sand Wash, the Green River enters Desolation canyon, a deep canyon with nearly 50 riffles and rapids. Rapids gradually increase in size as the river travels through the canyon. Habitats in this stratum include eddies, rapids, and riffles, with some deep pools. Boulders and sand make up the primary substrate within Desolation Canyon. This canyon is upstream of Gray Canyon which contains larger and deeper pools than are found in Desolation Canyon. Other habitats within the canyon include eddies, rapids, and riffles. Side channels and backwaters also exist here. Substrate in Gray Canyon is composed mainly of boulder/rubble with some gravel. In total, the river runs 159 miles through these two canyons. The Green River meets the Price River in lower Gray Canyon before that canyon ends at Book Cliffs escarpment (Tyus et al. 1987). The river then flows through the Green River Valley, near Green River, Utah. Here, the river habitat is dominated by drainage and runoff from agriculture and the city of Green River. Substrate in this valley varies from gravel/rubble to sand and silt. Few backwater habitats are found along this stretch of the Green, but riffles, side channels, and eddies do exist. At the southern end of the valley, the San Rafael River joins the Green River before the river enters Labyrinth and Stillwater Canyons within Canyonlands National Park. This section of the river, immediately upstream of the Colorado River, is dominated by a sand/silt substrate and is characterized by side channels and eddies. No rapids and few riffles exist within Stillwater and Labyrinth

Canyons. The Green River joins the upper Colorado River within Canyonlands National Park.

**Relationship to Constituent Elements:**

**Water**

Flows in this reach are dominated by releases from Flaming Gorge Dam and flows from the Yampa River. During an average hydrologic year, spring peaks of about 13,000 cfs will occur at Jensen due to an average peak flow of 8,000 cfs from the Yampa River and 4,000 cfs from Flaming Gorge Dam. These flows inundate natural bottomlands and provide fish habitat. Because of the distance between this reach and the dam and unregulated flows of the Yampa River, water temperatures reach near historical levels. However, when releases from the dam during summer and fall are greater than historical, then water temperatures may be lower than normal.

Because of water depletions which occur above this reach and tributary inflows, historic water levels are seldom obtained thus, flooding of bottomlands in the lower Green River is infrequent. Research to determine actual flow needs for this reach are currently underway as part of the Upper Basin Colorado River Implementation Program. Water depletions in this reach have reduced water volumes by 32 percent.

Physical Habitat

This reach contains a major Colorado squawfish spawning area in Gray Canyon of the Green River (Tyus and Karp 1989; Tyus 1985, 1990). Numerous other cobble bars exist in this reach which may be suitable for spawning. The larvae drift from the cobble bars to backwaters (Tyus and Haines 1991). The primary backwater areas are at Island Park, Echo Park, and the Jensen, Utah, area. The young Colorado squawfish move from the backwaters into the main channel of the river in response to changing environmental conditions (Tyus 1991b). During the winter, adults are found in various habitats including slow runs, slackwater areas, eddies, and backwaters (Valdez and Masslich 1989). Their occurrence in backwaters during the winter is related to feeding (Wick and Hawkins 1989). Tyus (1990) reported that adults were most often located in seasonally inundated shorelines and flooded bottomlands along the Green River during the spring and early summer. In spring, young Colorado squawfish move into backwaters as they warm during the day (Tyus 1991b).

Biological Environment

Very little is known on the quantity or quality of the food supply in this reach. Sources of input include the river upstream and from tributary washes, municipal and agriculture return flows, and perennial tributaries. The flooded bottomlands along this reach were probably once sources of food input into the system, but the area inundated has been reduced under the present flow management system.

This portion of the Green River contains large numbers of red shiner, channel catfish, and ccimmon carp (Haines and Tyus 1990), all are known to compete with and/or predate upon native fishes. Other piscivorous fish species in this reach include northern pike and walleye (Tyus and Beard 1990).

White River - Rio Blanco Reservoir to Green River

Boundary Delineation: Colorado, Rio Blanco County; and Utah, Uintah County. The White River and its 100-year floodplain from Rio Blanco Lake Dam (RM 150) in T.1N., R.96W., section 6 (6th Principal Meridian) to the confluence with the Green River in T.9S., R.20E., section 4 (Salt Lake Meridian).

**Land Ownership:** Private, 55.7 percent; Bureau of Land Management, 24.6 percent; Tribal, 13.2 percent; State, 6.5 percent.

**Occurrence:**

**Overlap with Proposed Critical Habitat for:** Razorback sucker (lower 18 miles).

Historic

There are anecdotal reports of anglers capturing Colorado squawfish from the bridge on the White River at Bonanza, Utah, in the 1940's (Seethaler 1978). Quartarone (1993) reports a historical account (no date) of a 16-pound Colorado squawfish caught just west of Meeker, Colorado.

Recent

Colorado squawfish have been found in the lower 150 miles of the White River in Utah and Colorado (Miller et al. 1982a). Colorado squawfish have been captured as far upstream as Meeker (Wick et al. 1983, 1985). They are more abundant below Taylor Draw Dam than above (Martinez 1986a). Taylor Draw Dam (completed in 1984) is a complete barrier to upstream fish passage.

**Description of Habitat:**

The White River below Rio Blanco Reservoir is characterized by clear water with predominately rubble/cobble and gravel substrate. The river then meanders through a relatively broad valley bordered by agricultural lands. In 1984, Taylor Draw Dam was constructed at RM 104.3. The dam created a complete barrier to upstream fish passage and converted riverine habitat into lacustrine habitat. The White River system is subject to extremes in discharge and carries a heavy silt load. The dam and reservoir also function as a sediment trap, reducing turbidity below the dam. Downstream of Rangely, the river flows through a deep canyon intersected with numerous side drainages with cobble/rubble and boulder substrate. Between the Ignacio bridge and the Mountain Fuel bridge, the river flows through low canyons of shale with sand/silt substrate in the low-velocity habitats and cobble/rubble and boulder substrate in the higher-velocity habitats. The lower 21 miles of the White River is dominated by a wide alluvial plain with a sand/silt substrate and occasional areas of exposed bedrock. There are very few riffles and no rapids or deep pools. Several side channels create eddies and backwaters. Habitat descriptions taken from Miller et al. (1982a).

**Relationship to Constituent Elements:**

**Water**

Although extensive water development has not occurred in the White River basin, changes to historical flow patterns have occurred. The completion of Taylor Draw Dam near Rangely, Colorado has altered flow and sediment transport to downstream reaches. However, flows which provide habitat requirements for Colorado squawfish remain. Water quality in the White River has been not been addressed. The concentration of oil, natural gas, and oil shale resources in the White River basin may require future study of water-quality issues to determine if adverse effects are occurring.

Physical Habitat

The relatively high numbers of Colorado squawfish captured by Miller et al. (1982a) provides indication of the importance of the White River to adults and juveniles. Habitat analysis by Miller et al. (1982a) showed the White River has a high degree of occurrence of types preferred by adult Colorado squawfish. Backwaters, side channels, pools, and eddies are common. Substrate ranges from silt/sand to bedrock. Taylor Draw Dam prevents upstream fish passage at RM 104.3. Although suitable cobble bars exist in the White River, no Colorado squawfish spawning has been documented there. However, Tyus (1990) reported movement of two Colorado squawfish from White River to known spawning areas in Gray Canyon and to Yampa Canyon.

Biological Environment

Food sources for adult and juvenile squawfish are present within the reach. The relatively unmodified flow regime of the White River probably maintains food and nutrient supply levels similar to predevelopment. The introduction of exotic fishes may be an important factor affecting native species. Miller et al. (1982a) found eight nonnative fish species of 15 total species within this reach. The potential for competition and predation between these nonnative and native species is high. Maintenance of a historical hydrograph may help limit further encroachment by nonnative fishes (Tyus and Karp 1989). The White River provides flow and sediment to the Green River, and aids formation of nursery habitat for Colorado squawfish. This reach also provides habitat for adult fish that migrate and spawn in the Green and Yampa Rivers.

**Gunnison River - Confluence with the Uncompahgre River to the Gunnison River Mouth**

**Boundary Delineation:** Colorado, Delta and Mesa Counties. The Gunnison River and its 100-year floodplain from the confluence with the Uncompahgre River in T.15S., R.96W., section 11 (6th Principal Meridian) to the confluence with the Colorado River in T.1S., R.1W., section 22 (Ute Meridian).

**Shoreline Ownership:** Private, 54.2 percent; Bureau of Land Management, 39.2 percent; State, 6.7 percent.

**Overlap with Proposed Critical Habitat for:** Razorback sucker.

**Occurrence:**

**Historical**

Jordan (1891) reported Colorado squawfish, known as "White Salmon," from the Gunnison River near Delta, Colorado. There also are reports of a commercial fishery on the Gunnison River near Delta from about 1925 to 1950 (Kidd 1977). Quartarone (1993) cites reports of long-time local residents that routinely captured Colorado squawfish up through the 1950's in the Delta area.

**Recent**

Valdez et al. (1982a) collected adult Colorado squawfish in 1981 from the Gunnison River both upstream and downstream of the Redlands Diversion Dam. Wick et al. (1985) reported collecting two adults upstream of Redlands Diversion Dam in 1981 and one in 1982. Osmundson and Kaeding (1989) collected one larval Colorado squawfish downstream of the Redlands Diversion Dam in 1986. Fourteen adults were captured during 1986-1988 below the Redlands Diversion Dam (Osmundson and Kaeding 1989). Two larval Colorado squawfish were collected downstream of Redlands Diversion Dam in 1992 (Nesler and Lentsch 1993). Three Colorado squawfish were captured during a fishery survey from Delta to the Redlands Diversion Dam in spring, 1993 (Bob Burdick, USFWS, pers. comm.).

**Description of Habitat:**

Historically, the Gunnison River was typical of Colorado River basin tributaries with high spring turbid flows and low flows in late summer and through the winter. High spring flows create and maintain the braided channels that provide a variety of important habitats (Osmundson and Kaeding 1989).

Water depletions began in the Gunnison River basin with private irrigation in the 1880's. The Redlands Diversion Dam was built on the lower Gunnison River 3 miles upstream from its confluence with the Colorado River in 1918. The Redlands Diversion can divert up to 750 cfs, drying up the Gunnison River below the dam during extremely low-flow periods. It is considered a complete barrier to upstream fish passage. The Gunnison Tunnel was constructed by the Reclamation in 1909; it diverts irrigation water from the Gunnison River to the Uncompahgre River Valley. Taylor Park Dam on the Taylor River, in the headwaters of the Gunnison, was completed in 1937 to provide water storage for the Gunnison Tunnel. The Aspinall Unit was completed in 1976 and consists of three reservoirs: Blue Mesa, Morrow Point, and Crystal. The flows on the Gunnison River are controlled by the largest of these reservoirs, Blue Mesa. These reservoirs store water during spring runoff and release it gradually throughout the rest of the year. Other water projects in the Gunnison basin include Crawford Dam, Paonia Dam, Fruitgrowers Reservoir, and Ridgeway Reservoir. Water development in the Gunnison River basin has changed water quantity and flow regimes in occupied habitat of the Colorado squawfish.

The Gunnison River near Delta (Hartland Diversion Dam, RM 59.9) to the confluence with the Colorado River flows mostly through sedimentary canyons. Floodplains occur in about 25 percent of the warmwater reach. The most extensive floodplain occurs in the Delta area from Hartland Diversion Dam downstream to Roubideau Creek. This reach contains the highest degree of complex channel habitats which provide the greatest diversity of river habitats. Numerous braided channels and several large vegetated islands occur in this section with riffles, long runs, and backwaters. The flow through this area is moderately fast. Downstream from here, the river flows through canyon areas. Although not extensive, some historical floodplains are now occupied by fruit orchards in these canyon areas. Two rock irrigation diversions occur in this section, but they are not impediments to fish movement. The canyon habitat has two small rapids, but the gradient is less and the flow slower than the upstream section. Near Whitewater, the river widens for a short distance where gravel-pit operations in historic floodplains presently occur. From here, the river meanders again through a low-level canyon area to Redlands Diversion Dam. Some gravel-pit operations occur immediately upstream from Redlands Diversion Dam. Downstream from Whitewater, there is a mixture of riffle areas with moderate velocity, quiet shoreline, and runs; adjacent backwaters are uncommon.

**Relationship to Constituent Elements:**

**Water**

The quantity of water in the Gunnison River has been reduced by water development projects. Flow regimes also have been altered from natural patterns. However, reoperation of the Aspinall Unit as the result of Section 7 consultation will provide a more natural hydrograph in this river reach, improving the habitat for the Colorado squawfish. Complex channel habitats (side channels, backwaters, etc.) provide a greater diversity of habitats for Colorado squawfish to use for feeding, resting, and nursery areas (Osmundson and Kaeding 1991). High spring flows are important for maintaining these habitats. High spring flows also are important to reproductive success of Colorado squawfish (Osmundson and Kaeding 1991).

Water temperatures have been reduced from historic temperatures by a maximum of 4°F in occupied habitat. This probably does not affect adult habitat, but may affect maturation of adult fish or spawning success (McAda and Kaeding 1991).

Physical Habitat

The Gunnison River provides bottomlands, side channels, secondary channels, and backwaters that, when inundated, could provide spawning, nursery, feeding, and rearing habitats for Colorado squawfish. Reoperation of the Aspinall Unit could provide high spring flows that maintain these habitats. When fish passage at the Redlands Diversion Dam is provided, these habitats would become available to Colorado squawfish that move upstream from the Colorado River. The restoration of fish passage at the Redlands Diversion Dam, provision of a natural flow regime in the Gunnison River, and enhancement of bottomlands could provide valuable habitat essential for Colorado squawfish recovery. Because flows released from Aspinall will be limited (i.e. 6,000 cfs), some bottomlands historically connected to the mainstem river may still not connect during present day conditions. Consequently, habitat enhancement other than providing flows (e.g. removing dikes and levees) may be necessary to reconnect bottomlands during spring high flows.

Biological Environment

Studies conducted in 1981 and 1992 found that the Gunnison River has a high percentage of native fishes (Valdez et al. 1982a; USFWS 1992a). Electrofishing surveys conducted in 1992 from the North Fork confluence with the Gunnison River to Redlands Diversion Dam found juvenile and adult native fishes comprised 80.6 percent of the total number of all fished collected. Eight adult northern pike and only one adult channel catfish were captured upstream of Redlands Diversion Dam during this study. On the other hand, seining surveys conducted in 1992 found nonnative fishes comprised 90.4 percent of the total number of all fishes collected. Predation and competition from nonnative fishes have been identified as a contributing factor in the decline of Colorado squawfish. Therefore, the Gunnison River appears to provide a biological environment with relatively low numbers of large-size, piscivorous, nonnative fishes.

**Colorado River - Rifle, Colorado to the Dirty Devil Ann of Lake Powell**

**Boundary Delineation:** Colorado, Mesa and Garfield Counties; and Utah, Grand, San Juan, Wayne, and Garfield Counties. The Colorado River and its 100-year floodplain from the Colorado River Bridge at exit 90 north off Interstate 70 (RM 238) in T.6S., R.93W., section 16 (6th Principal Meridian) to North Wash including the Dirty Devil arm of Lake Powell up to the full pool elevation in T.33S., R.14E., section 29 (Salt Lake Meridian).

**Shoreline Ownership:** Private, 36.1 percent; Bureau of Land Management, 32.5 percent; National Park Service, 29.9 percent; State, 1.4 percent.

**Overlap with Proposed Critical Habitat for:** Razorback sucker, humpback chub, bonytail.

**Occurrence:**

Historical

Colorado squawfish were once common in the mainstem Colorado River and probably in numerous smaller tributaries (Ellis 1914; Bosley 1960; LaRivers 1962; Baxter and Simon 1970; Holden 1973; Seethaler 1978; Johnson and Oberholtzer 1987).

Recent

Colorado squawfish occur in the Colorado River from Lake Powell to the Price Stubb dam several miles upstream of Palisade (Valdez et al. 1982b; Osmundson and Kaeding 1989; Valdez and Cowdell 1993).

**Description of Habitat:**

Historically, the Colorado River had high spring turbid runoff with low flows in late summer and through the winter. These high spring flows flooded bottomlands, maintained side channels, and created backwaters.

This reach begins at Rifle, Colorado, where it has been described as a transition zone between warm and cool water fisheries (Valdez et al. 1982b). The river meanders through open valleys and rolling sagebrush hills until it reaches DeBeque Canyon where numerous gravel pits exist in the floodplain. The substrate is predominately rock (gravel, rubble, boulder) with some silt and sand, shallow to moderate-depth runs and riffles, pools and eddies are numerous but backwaters are uncommon. It then flows for 25 miles through DeBeque Canyon where the channel is paralleled by Interstate Highway 70 on one side and the Denver and Rio Grande Railroad on the other which have both constricted the channel with riprap. The flow is swift over gravel, rubble, and boulder substrate.

The Government Highline Dam is located at the lower end of DeBeque Canyon, and is considered a complete barrier to upstream fish passage. Several miles downstream, the Price-Stubb Dam also creates a barrier to upstream fish passage. There are plans to provide fish passage at both of these structures. When this occurs, DeBeque Canyon would provide movement and migration habitat for Colorado squawfish. From Palisade to Loma, Colorado, the river flows through the Grand Valley. The confluence with the Gunnison River is about 15 miles downstream from Palisade. The river meanders through a broad agricultural and residential valley. The channel is extensively braided around vegetated gravel islands and many gravel-pit ponds occur adjacent to the river. Predominate substrates are gravel and rubble, and the habitat consists of runs, riffles, eddies, backwaters, side channels, and gravel-pit ponds. Flows in the 15 miles between Palisade and the Gunnison River become severely reduced during late summer and early spring, due to upstream irrigation diversions. The Colorado River from Loma to Westwater flows 29 miles through Horsethief and Ruby Canyons with high sandstone walls and open parks. The substrate is gravel and rubble with deposits of sand and silt. Habitats consist of runs, pools, and eddies, with few backwaters.

The river flows through 14 miles of Westwater Canyon, a geologic anomaly of upthrust black metamorphic gneiss rock. It confines the river forming a narrow deep channel with a series of rapids, strong eddies, and turbulent currents. The river is predominately deep runs, eddies, and pools, with few backwaters. When the river leaves Westwater Canyon it meanders for 25 miles through shallow canyons and rolling hills. The substrate is primarily rock and sand, or rock and sand-silt. Runs and eddies are predominant with some backwaters, providing feeding and nursery habitats. From Fisher Towers to Moab, Utah, the river flows through high sandstone walls and open valleys. This area is characterized by deep, slow-flowing runs and pools over sand-rock substrate. Several small rapids are formed by rocky deltas from washes. These areas also provide feeding and nursery habitat. Moab is the only major community in this section of river. The Colorado River from Moab to the confluence with the Green River has predominantly sand-silt substrate with sandy banks overgrown with tamarisk. Runs are predominant, but backwaters and eddies are common. The river between the confluence and Lake Powell flows through Cataract Canyon where it cuts deeply through steep canyons and talus slopes. The river has deep swift runs, large eddies and pools, with a few shallow runs, riffles, and backwaters. Large angular rock and steep gradient have created large, dangerous rapids through the canyon. There are approximately 13 miles of rapids before the river flows into the upper end of Lake Powell, where it resembles a large, deep, slow-flowing river with high sandstone walls.

**Relationship to Constituent Elements:**

Water

Water quantity in this reach varies between different river sections because of water diversions for the Grand Valley. The section from Rifle to the Government Highline Dam is upstream of major Grand Valley water diversions; therefore, substantial quantities of water flow through this section because water must be provided to the senior water users in the Grand Valley. Below Government Highline Dam and the Grand Valley Diversion, the 15-mile section above the confluence with the Gunnison experiences alteration of its natural flow regime throughout the year and extreme low flows during August-October. Below the confluence with the Gunnison River (and the Redlands Power canal), these extreme low-flow conditions are alleviated. The Service has developed flow recommendations for the "15-mile reach" (Kaeding and Osmundson 1989; Osmundson and Kaeding 1991) and is in the process of obtaining instream flow rights during the summer months for this reach. Also, the reoperation of the Aspinall Unit on the Gunnison River should provide a more natural flow regime on the Colorado River below the confluence of the Gunnison River. These two factors will enhance the existing water quantity and flow regime required by Colorado squawfish.

Physical Habitat

This reach provides a great variety of potential physical habitat for spawning, nursery, feeding, rearing, and corridors between areas. Predominant substrates are gravel and rubble, and the habitat consists of runs, riffles, eddies, backwaters, side channels, bottomlands, and gravel-pit ponds. These areas provide feeding, spawning and nursery habitats. When plans to provide fish passage at the Price-Stubb Dam and the Government Highline Dam are completed, DeBeque Canyon would provide movement and migration habitat. The reach from Rifle to DeBeque Canyon and the Grand Valley have extensive areas of floodplain habitat that when inundated would provide nursery and feeding habitat.

Westwater and Cataract canyons provide movement and migration corridors between flat water habitats. The section between Westwater Canyon and Moab provides numerous bottomlands that, when flooded can provide warm water temperatures, rich feeding areas, low velocity habitat, and nursery habitat. Valdez et al. (1982b) found more backwaters from Moab to the confluence than any other reach in the upper Colorado River. These backwaters provide important nursery habitat. The Lake Powell section of this reach provides feeding and rearing habitat.

Biological Environment

Valdez et al. (1982b) found that the four most common nonnative species in the mainstem upper Colorado River (red shiner, sand shiner, channel catfish, and common carp) decreased in abundance the farther upstream they sampled. Relatively fewer nonnative fishes were found in the uppermost reach of occupied habitat.

Bottomlands between Westwater Canyon and Cataract Canyon are a source of nutrient inputs into the Colorado River. The Palisade to Cataract Canyon portion of the Colorado River contains large numbers of nonnative fishes, especially in the backwaters identified as important nursery areas.

**San Juan River - Farmington to Neskahai Canyon**

**Boundary Delineation:** New Mexico, San Juan County; and Utah, San Juan County. The San Juan River and its 100-year floodplain from the State Route 371 Bridge in T.29N., R.13W., section 17 (New Mexico Meridian) to Neskahai Canyon in the San Juan arm of Lake Powell in T.41S., R.11E., section 26 (Salt Lake Meridian) up to the full pool elevation.

**Shoreline Ownership:** Tribal, 65.0 percent; National Park Service, 15.4 percent; Bureau of Land Management, 13.8 percent; Private, 5.5 percent; State, 0.3 percent.

**Overlap with Proposed Critical Habitat for:** Razorback sucker.

**Occurrence:**

Historical

Local residents reported Colorado squawfish ascending the Animas River to Durango in the spring (Jordan 1891). However, the first substantiated record from the San Juan River was capture of three juveniles at Alcove Canyon, Utah, in 1936. Colorado squawfish also were collected in the San Juan River near Four Corners in 1955; near Rosa, New Mexico, in 1959; and near Mexican Hat, Utah, in 1960 (Platania 1990).

Recent

A small reproducing population of Colorado squawfish exists in the San Juan River. A single juvenile squawfish was captured in the San Juan River approximately 5 miles below Aneth, Utah, in 1978 (Minckley and Carothers 1980; VTN 1978). Recent studies found eight adults and 19 young-of-year between Shiprock, New Mexico and Lake Powell (Platania et al. 1991). In 1991-1992, 12 adults were captured between Shiprock and Four Corners (Ryden and Pfeifer 1993).

**Description of Habitat:**

Spring peak flows in the San Juan River above the confluence with the Animas River generally ranged from 3,000-5,000 cfs (Holden 1980). Winter flows generally averaged from 200-300 cfs in this same area. Below the Animas confluence, San Juan River flow and habitats were increasingly influenced by inflowing tributaries. The highest recorded flow was at Bluff, Utah, below all major tributaries and measured 70,000 cfs on 10 September 1927 (Meyer and Moretti 1988). Summer low-flow conditions in the lower San Juan River included zero-flow (no-flow) at Bluff in July 1934 and August 1939 (Meyer and Moretti 1988). Many of the tributary streams entering the San Juan River below Farmington, New Mexico, introduce substantial sediment amounts. Historic sediment input by the tributaries is not well known, but influenced riverine conditions.

The San Juan River below Farmington, New Mexico, contains numerous secondary channels and other floodplain habitats. From the Hogback Diversion to Bluff, the river is wide and shallow and the primary substrate is sand and cobble. Major riverine habitat types include runs, riffles, eddies, backwaters, and side channels. Between Bluff and Mexican Hat, the river alternately flows through low hills and narrow canyon reaches where braiding is common. Substrate size ranges from sand to cobble/boulder. Riffles and minor rapids are frequent. Habitats include pools, deep runs, areas protected from current, and extensive cobble bars.

**From Mexican Hat to Neskahai Canyon, the San Juan River channel is confined within a narrow, high-walled canyon and the floodplain is significantly reduced. Overall gradient is high and substrate size ranged from sand to cobble/boulder. Through this section, the river is a single channel with only occasional islands or instream bars. Minor rapids and riffles are common. The remoteness of this reach has limited human activities and impacts to the river and shoreline. Major riverine habitat types which occur include runs, riffles, eddies, and backwaters.**

**One significant barrier occurs in this section. A water fall (25-30 feet high) developed during declining reservoir levels and river channel alignment between Clay Hills and Piute Farms at the Lake Powell inflow area. It is considered a complete--albeit temporary--barrier to upstream fish passage. Other than this, minimal modification of physical habitat has occurred in or along the river. Hydrograph alterations related to upstream water projects constitutes a major change to the natural system.**

**Relationship to Constituent Elements:**

**Water**

**Water release patterns from Navajo Dam recently have been altered to provide improved flows for fish. Research is currently underway to determine more specific flow recommendations for the endangered fishes. Because of seepage and spills associated with the extensive oil and gas development along the San Juan River and its tributaries, questions have arisen regarding water quality. Current efforts are underway to assess the water-quality problems and determine water quality impacts to fish.**

**Physical Habitat**

**The San Juan River has three times fewer backwaters per mile of river than occurs on the Green River (Goettlicher and Pucherelli 1992). However, researchers are finding that secondary channels on the San Juan River also may be important for providing low-velocity habitats for native fish including nursery habitat for Colorado squawfish. Suspected spawning locations for Colorado squawfish have been found upstream of the Mancos River in New Mexico and between Bluff, Utah, and the New Mexico border. Other spawning locations may be located as research on the San Juan River continues. Research of flow/habitat relationships, combined with biological study, will identify optimum channel conditions for native species.**

**Biological Environment**

**Surveys of main channel and low-velocity habitats in the San Juan River in 1987-1989 illustrate differences in distribution and abundance patterns of fishes. Native species accounted for 70-80 percent of all specimens collected from main channel habitats. Conversely, in low-velocity habitats (secondary channels, backwaters, edges, eddies),**

nonnative species were most abundant, totaling 60-90 percent of all fish collected. Flannelmouth and bluehead suckers were the most abundant native species (Platania 1990). Red shiner and fathead minnow were the most abundant in low-velocity habitats, and channel catfish and carp were the dominant nonnative fish species in the main channel. Surveys by Holden (1980) illustrated longitudinal patterns of diversity and abundance of benthic macroinvertebrates. In general, invertebrate density declined but diversity increased from upstream (Navajo Dam) to downstream (below Hogback Diversion) reaches.

## HUMPBACK CHUB

The Service is proposing seven reaches of the Colorado River system (Figure 12 and Table 4) for designation as critical habitat for the humpback chub. In the Upper Basin, critical habitat is being proposed in the Green, Yampa, and Colorado rivers. Portions of the Colorado and Little Colorado rivers are being proposed in the Lower Basin.

Of the historical range of humpback chub, 28 percent (379 miles) is proposed for designation as critical habitat (Figure 13). These reaches include all known major populations of humpback chubs.

Humpback chub historically occupied more habitat in the Upper Basin. Approximate equal amounts of Upper (198 miles) and Lower Basin (181 miles) habitat has been proposed for designation (Table 4).

These reaches flow through a variety of shoreline ownerships, public and private. The National Park Service is the major manager for proposed critical habitat for the humpback chub. The approximate percentages of critical habitat by shoreline ownership for the humpback chub is presented in Figure 14.

### CRITICAL HABITAT DESIGNATION BY AREA

### Yampa River - Dinosaur National Monument

**Boundary Delineation:** Colorado, Moffat County. The Yampa River within Dinosaur National Monument. From T.6N., R.99W., section 27 (6th Principal Meridian) to the confluence with the Green River in T.7N., R.103W., section 28 (6th Principal Meridian).

**Shoreline Ownership:** National Park Service, 99.0 percent; Private, 1.0 percent.

**Overlap with Proposed Critical Habitat for:** Razorback sucker, Colorado squawfish, bonytail.


Figure 12. Map of proposed critical habitat for the humpback chub.

Table 4. Humpback chub critical habitat proposed by basin and reach classification. Reach classifications are from downlisting and delisting criteria in the Humpback Chub Recovery Plan (USFWS 1990b).

| Upper Basin Reaches | Classification | Miles |
|---|---|---|
| Yampa River - Dinosaur National Monument | Downlisting | 44 |
| Green River - Dinosaur National Monument | Downlisting | 38 |
| Green River - Desolation and Gray Canyons | Downlisting | 73 |
| Colorado River - Black Rocks to Fish Ford | Downlisting | 30 |
| Colorado River - Cataract Canyon | Downlisting | 13 |
| | Subtotal = | 198 |

| Lower Basin Reaches | Classification | Miles |
|---|---|---|
| Little Colorado River - Lower 8 Miles | Downlisting | 8 |
| Colorado River - Marble and Grand Canyons | Downlisting | 173 |
| | Subtotal = | 181 |
| | Downlisting Total | 379 |
| | Delisting Total | 0 |
| | Grand Total | 379 |

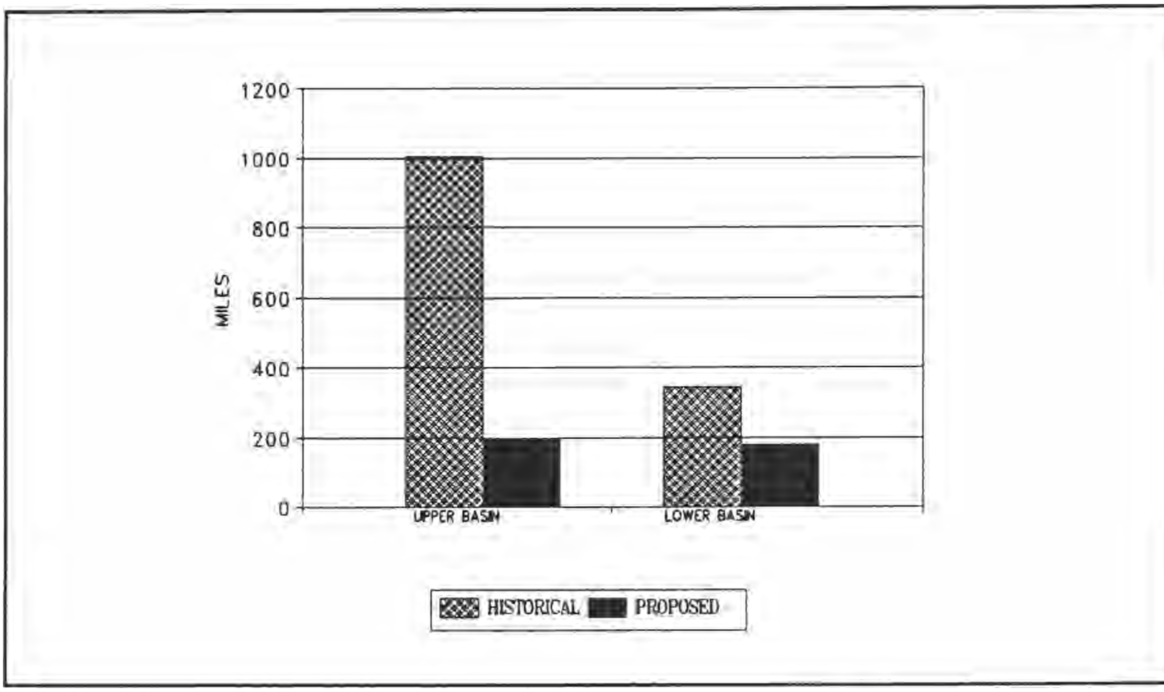



Figure 13. Relative amount of historical habitat proposed as critical habitat for the humpback chub.

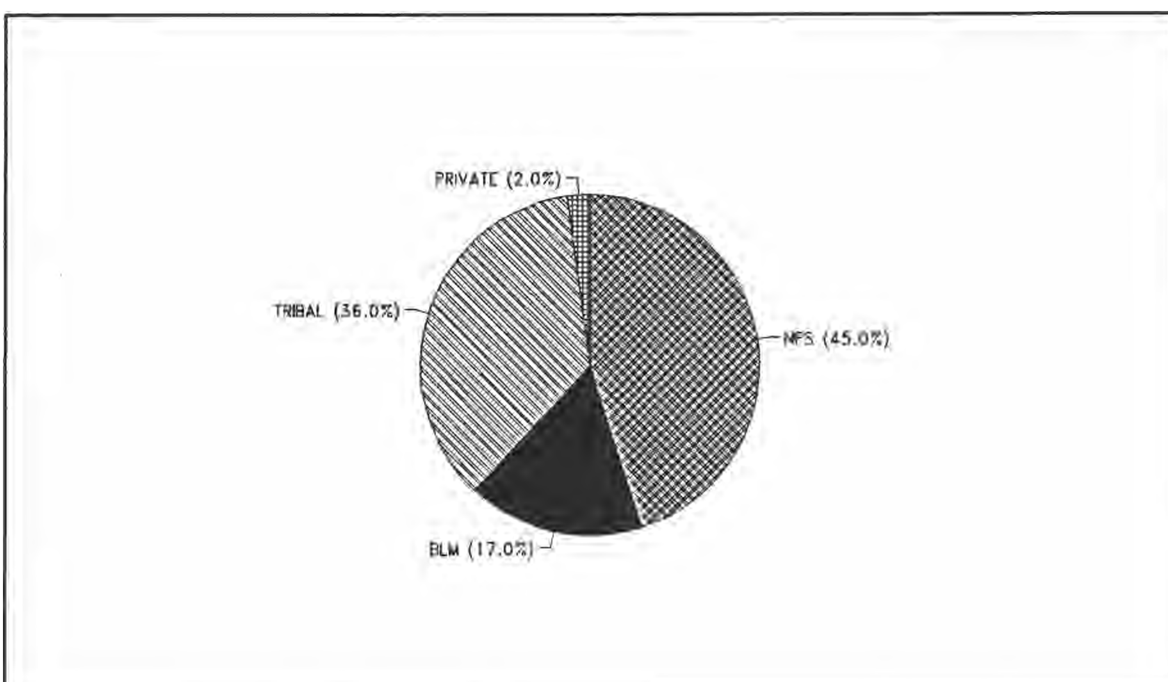



Figure 14. Shoreline ownership for proposed critical habitat for the humpback chub.

**Occurrence:**

Historical

Humpback chub was not identified as a species until 1946, thus, its historical distribution of humpback chub in the Yampa River is not well known. The Yampa River from the Green River to the site of Craig, Colorado, is considered to be historic habitat (USFWS 1990b). Holden and Stalnaker (1975b) reported several specimens were collected from the lower Yampa River in 1969. Other early reports of humpback chub from the Yampa River in Dinosaur National Monument come from Miller (1964), and Seethaler et al. (1979).

Recent

Karp and Tyus (1990a) captured 130 humpback chub in Yampa Canyon within Dinosaur National Monument; they also reported reproduction of humpback chub. Between 1986 and 1989, 39 humpback chubs in breeding condition were captured (Karp and Tyus 1990a). Within the Yampa system, humpback chub also have been collected in Cross Mountain Canyon (USFWS 1980; Wick et al. 1981), and several specimens were collected approximately 6.25 miles up the Little Snake River (USFWS 1990b).

**Description of Habitat:**

At RM 45, the Yampa abruptly enters Yampa Canyon. Here, steep canyon walls house the slow-moving river. Occasional boulder fields create rapids, but the predominant substrate is gravel/cobble with patches of sand. In the lower portion of the canyon the river meanders through soft sandstone cliffs. The Yampa River exits the canyon at Echo Park, where it meets the Green River (Miller et al. 1982b).

**Relationship to Constituent Elements:**

Water

As the Yampa River has minimal water development, when compared to other rivers in the basin, the current hydrograph reflects flows which are representative of historical volume and timing. The Service has identified existing flows as adequate for the needs of these fish (Tyus and Karp 1989). Yampa River flows also have been identified as critical for maintaining native fish habitat in the Green River below their confluence (McAda and Wydoski 1980). Water quality has not been identified as a chronic problem. However, an oil spill in June of 1989 caused by a ruptured pipeline discharged approximately 10,000 gallons of oil into the Yampa River. This spill has been implicated as resulting in low Colorado squawfish larval and young-of-year collections in the upper Green River basin that year (Obmasick 1989).

Physical Habitat

This reach of the Yampa provides spawning and adult habitat for the humpback chub (USFWS 1990b; Karp and Tyus 1990a). Yampa Canyon within Dinosaur National Monument is typical of the deep canyon habitat preferred by humpback chubs (USFWS 1990b). Present flows provide the humpback chub habitat characteristics of fast current, deep pools, shoreline eddies and runs as identified by Holden and Stalnaker (1975b); Kidd (1977); Seethaler et al. (1979); Valdez (1981); Tyus and Karp (1989); and USFWS 1990b. Temperatures in this portion of the Yampa River have not been altered to any degree by human activities and remain suitable for native fishes.

Biological Environment

Nutrient inputs and food sources for humpback chub are present within the reach. The relatively unmodified nature of the Yampa River system likely results in foods s similar to predevelopment. The introduction of nonnative fishes is probably the greatest alteration to the historical Yampa system. Miller et al. (1982b) found 13 nonnative and nine native fish species within this reach. Virtually all nonnative fish found in this reach have the potential to prey on and/or compete with native species. Tyus and Karp (1990) reported that humpback chub were captured in association with seven native and 12 nonnative fish species. The most abundant nonnative fish caught with humpback chub was channel catfish, a potential predator of humpback chub (Tyus and Karp 1990; Tyus and Nikirk 1990). Maintenance of a natural (historical) hydrograph may help limit further encroachment by nonnative fishes. However, the presence of nonnative fishes has not caused the extirpation of humpback chubs from this reach. Hybridization with other members of the *Gila* genus is an issue of concern (USFWS 1990b), but Douglas et al. (1989) did not report hybridization as a problem in this location. Rivers with natural flow patterns such as the Yampa appear to have a reduced level of hybridization (Douglas et al. 1989).

## Green River - Dinosaur National Monument

**Boundary Delineation:** Utah, Uintah County; and Colorado, Moffat County. The Green River from the confluence with the Yampa River in T.7N., R.103W., section 28 (6th Principal Meridian) to the southern boundary of Dinosaur National Monument in T.6N., R.24E., section 30 (Salt Lake Meridian).

**Land Ownership:** National Park Service, 95.5 percent; Private, 4.5 percent.

**Overlap with Proposed Critical Habitat for:** Razorback sucker, Colorado squawfish, bonytail.

**Occurrence:**

Historical

Interest in Colorado River endemic fishes increased in the 1960's, primarily because of the rapid disappearance of the fishes in the Lower Basin and new concerns regarding the impacts of Colorado River Storage Project dams in the Upper Basin. Until the 1950's, the humpback chub was known only from Grand Canyon (Miller 1946). During pre- and post-impoundment studies for Flaming Gorge Reservoir, Smith (1960) found humpback chub in the upper Green River. Vanicek et al. (1970) reported three specimens from the upper Green River, one each from Echo Park, Island Park, and Swallow Canyon.

Recent

Humpback chub are rare in this reach. Tyus et al. (1987) reported that 28 percent of the *Gila* specimens collected from in Whirlpool Canyon in Dinosaur National Monument were humpback chub. Karp and Tyus (1990a) reported the capture of two humpback chub in breeding condition in Whirlpool Canyon.

**Description of Habitat:**

Historically, flows in the Green River began increasing in March, peaked in June, and remained high through July (Smith and Green 1991). The spring peak averaged near 8,000 cfs for the predam period of 1951-1962 at Greendale, Utah. Yearly and seasonal variation in this reach made flows highly variable. Mean monthly flow during spring runoff (April-July) was about 14,000 cfs.

The Green River enters Echo Park at its confluence with the Yampa River. Here the river is wide, deep, and slow moving. Substrate is a mixture of sand/silt with some large gravel/cobble riffles. After a short distance, the river passes through Whirlpool Canyon, an area of steep cliffs, large pools, deep eddies, rapids, and large boulders. The substrate in the canyon is boulder/bedrock, but large deposits of sand exist within the eddies. After leaving the canyon, the Green River meanders through Island and Rainbow Parks. The river in this area is shallow and side channels are common. At RM 327, the river enters Split Mountain Canyon. This stretch contains large boulder fields, swift waters, and major rapids. Some significant sandbars exist in the slower moving parts of this area.

**Relationship to Constituent Elements:**

Water

Flows in this reach are primarily a product of the flows released from Flaming Gorge Dam and flows from the Yampa River. During an average hydrologic year, a spring peak of at least 13,000 cfs should occur in this reach. Because of the distance between this reach and the dam and unregulated flows of the Yampa River, water temperatures in this reach approach historical levels. However, when releases during summer and fall from the dam are greater than historical, water temperatures may be lower than under normal conditions.

Physical Habitat

In Dinosaur National Monument, humpback chub are most prevalent in high-gradient reaches containing rocky runs, riffles, and rapids (Tyus and Karp 1991). Seasonally flooded shoreline eddies in this reach appear important to adult and juvenile humpback chub.

Biological Environment

The extensive bottomlands along this reach are sources of nutrient inputs into the Green River as are inflows form the Yampa River. This portion of the Green River has large numbers of red shiner, channel catfish, and common carp, all of which are known to compete with and/or prey upon native fishes. Other piscivorous fish in this reach include Colorado squawfish, northern pike, and walleye.

Green River - Desolation and Gray Canyons. Utah

Boundary Delineation: Utah, Uintah and Grand Counties. The Green River (Desolation and Gray Canyons) from Sumners Amphitheater (RM 85) in T.12S., R.18E., section 5 (Salt Lake Meridian) to Swasey's Rapid (RM 12) in T.20S., R.16E., section 3 (Salt Lake Meridian).

Shoreline Ownership: Tribal, 50.0 percent; Bureau of Land Management, 49.0 percent; Private, 1.0 percent.

Overlap with Proposed Critical Habitat for: Razorback sucker, Colorado squawfish, bonytail.

Occurrence:

Historical

Interest in Colorado River endemic fishes increased in the 1960's, primarily because of the rapid disappearance of the fishes in the Lower Basin and new concerns regarding the impacts of Colorado River Storage Project dams in the Upper Basin. Until the 1950's, the humpback chub was known only from Grand Canyon (Miller 1946). Specimens were first collected from Desolation Canyon in 1967 (Holden and Stalnaker 1970).

Recent

Humpback chub persist in this reach although in low numbers. Fish have been captured infrequently from the early 1970's to the present time (Holden and Stalnaker 1975a; Tyus et al. 1982a).

Description of Habitat:

A maximum flow of 68,000 cfs was recorded at Green River in 1917 and a minimum flow of 255 cfs in 1931. Predam temperatures at Jensen, Utah, ranged from near 32°F in December and January to around 78°F during July and August (Smith and Green 1991).

Below Sand Wash, the Green River enters Desolation Canyon, a deep canyon with nearly 50 rapids. Rapids gradually increase in size as the river travels through the canyon. Habitats in this stratum include eddies, rapids, and riffles, with some deep pools. Boulders make up the primary substrate within Desolation Canyon. This canyon is followed by Gray Canyon which contains larger and deeper pools than are found in Desolation Canyon. Other habitats within the canyon include eddies, rapids, and riffles. Side channels and backwaters also exist here. Substrate in Gray Canyon is composed mainly of boulder/rubble with a bit of gravel. In total, the river runs 159 miles through these two canyons. The Green River meets the Price River in lower Gray Canyon before that canyon ends at Book Cliffs escarpment (Tyus et al. 1987).

**Relationship to Constituent Elements:**

Water

Because of water depletions which occur above this reach, historic water levels are seldom if ever obtained. Because of this, flooding of bottomlands is infrequent. Research to determine actual flow needs for this reach are currently underway as part of the Upper Basin Colorado River Implementation Program. Water depletions have reduced water volumes in this reach by about 30 to 40 percent.

Physical Habitat

This canyon reach contains both deep, swift riverine areas and low-velocity eddies that are associated with steep cliffs and large boulders. Spawning habitat is available based on the collection of juvenile fish, but the exact habitat needs for spawning are not well documented (USFWS 1990b).

Biological Environment

Very little is known on the quantity or quality of the food supply in this reach. Sources of input include the river above and from washes and side channels. The flooded bottomlands along this reach were probably once sources of food input into the system, but are not as extensively flooded under present water management. The nonnative fishes common in the Green River include red shiner, channel catfish, common carp, and fathead minnows (Tyus et al. 1982a).

Colorado River - Black Rocks/Westwater Canyon

Boundary Delineation: Utah, Grand County; Colorado, Mesa County. The Colorado River from Black Rocks (RM 137) in T.10S., R.104W., section 25 (6th Principal Meridian) to Fish Ford River (RM 106) in T.21S., R.24E., section 35 (Salt Lake Meridian).

Shoreline Ownership: Bureau of Land Management, 66.6 percent; Private, 33.4 percent.

Overlap with Proposed Critical Habitat for: Razorback sucker, Colorado squawfish, bonytail.

Occurrence:

Historical

No historical distribution and abundance data exist for humpback chub in the Colorado River because the species was not described until 1946. Humpback chub were well known to early river runners as a food source (Kolb 1914). Until the 1950's, the humpback chub was known only from Grand Canyon (Miller 1946). Humpback chub were first collected in the upper Colorado River in 1974 in Black Rocks (3 miles upstream of the Colorado-Utah border) (Kidd 1977). In 1979, an additional population was discovered in Westwater Canyon, approximately 11 miles downstream of Black Rocks. (Valdez et al. 1982b).

Recent

In the Upper Basin, the highest known concentrations of humpback chub are found in the Black Rocks and Westwater Canyons (Valdez 1981; Wick et al. 1981; Valdez and Clemmer 1982; and Archer et al. 1985). Sampling has been conducted since 1974 in Black Rocks and since 1979 in Westwater Canyon; numbers indicate a large population of humpback chub persist in this reach. Individual fish suspected of being hybrids (humpback chub x roundtail chub) have been found in this reach.

Description of Habitat:

Near the Colorado-Utah State line the river flows through a mile of upthrust of metamorphic gneiss called Black Rocks. In Westwater Canyon, located some five miles downstream, the river again flows through upthrust black metamorphic gneiss rock for 14 miles which confines the river, forming a narrow, deep channel with a series of rapids, strong eddies, and turbulent currents. In both areas, habitat consists of deep runs, eddies, and pools, with few backwaters. The river above and below these areas provide gravel bars, floodplains, and backwaters.

The habitat in this reach has been altered by water depletions and changes in the natural flow regime. However, Black Rocks and Westwater Canyon provide deep eddies, pools, and runs, and rapids, strong eddies, and turbulent currents. No manmade barriers occur in this reach. A railroad line built on the north side of the river through Ruby Canyon (including Black Rocks) to Westwater Canyon, has constricted the river channel in some areas.

Relationship to Constituent Elements:

Water

Geologic formations in Black Rocks and Westwater Canyon result in deep eddies and pools at all flow conditions. The quantity and quality of water in this reach are presently sufficient to support stable populations of humpback chub. Appropriate water temperatures occur in May and successful spawning occurs (Valdez et al. 1982b).

Physical Habitat

This reach provides deep pools, eddies, and runs for feeding and rearing. The intervening reach provides a movement corridor between Black Rocks and Westwater Canyon.

Biological Environment

Except for a large population of channel catfish in the Black Rocks area, relatively few introduced fishes are found in Black Rocks and Westwater Canyon (Valdez and Clemmer 1982), providing an environment with reduced predation and competition.

**Colorado River - Cataract Canyon, Utah**

**Boundary Delineation:** Utah, Garfield and San Juan Counties. The Colorado River from Brown Betty Rapid (RM 212.5) in T.30S., R.18E., section 34 (Salt Lake Meridian) to Imperial Canyon (RM 200) in T.31S., R.17E., section 28 (Salt Lake Meridian).

**Shoreline Ownership:** National Park Service, 100.0 percent.

**Overlap with Proposed Critical Habitat for:** Razorback sucker. Colorado squawfish, bonytail.

**Occurrence:**

Historical

No historical distribution and abundance data exist for humpback chub in the Colorado River because the species was not described until 1946. Until the 1950's, the humpback chub was known only from Grand Canyon (Miller 1946). Humpback chub were first collected in the upper Colorado River in 1974 in Black Rocks (just upstream of the Colorado-Utah border). In the late 1970's, an additional population was discovered in Westwater Canyon (Valdez et al. 1982b).

Recent

A population of humpback chub has been reported from the Colorado River in Cataract Canyon above the inflow area to Lake Powell. A total of 108 humpback chub, of which 22 were adult fish and 56 were juvenile, were collected during a 4-year investigation from 1985 to 1988 (Valdez 1990). Although actual spawning has not been documented, the presence of various size humpback chubs, including possible young-of-year fish, through Cataract Canyon supports spawning of humpback chubs in the canyon. Individual fish suspected of being hybrids (humpback chub x roundtail chub) have been found in this reach.

Description of Habitat:

The river between its confluence with the Green River and Lake Powell flows through Cataract Canyon, where it cuts deeply through steep canyons and talus slopes. It is characterized by deep, swift runs, large eddies and pools, with a few shallow runs, riffles, and backwaters. Large angular rock and steep gradient have created approximately 13 miles of rapids before the river flows into the upper end of Lake Powell where it resembles a large, deep, slow-flowing river with high sandstone walls.

Major habitat change occurred in Cataract Canyon when Lake Powell was formed by the closure of Glen Canyon Dam in 1963. Prior to inundation by Lake Powell, Cataract Canyon's steep gradient and large rapids comprised a 35 mile reach. Except for changes in water quantity and historic flow regime, the physical habitat in portions of Cataract Canyon above Lake Powell remains largely unmodified.

**Relation to Constituent Elements:**

Water

River flows in Cataract Canyon are greater than in other reaches in the Upper Basin because of the numerous upstream tributaries which enter the Colorado River. Recent studies found all life stages of humpback chub in this reach (Valdez 1990), indicating adequate water for successful reproduction. Hybridization with roundtail chubs may occur in this reach.

Physical Habitat

Cataract Canyon provides deep eddies and pools, with swift currents and large boulders identified as preferred habitat of humpback chub (USFWS 1990b). Valdez (1990) reported humpback chub of all age classes in Cataract Canyon, indicating a reproducing population.

Biological Environment

Cataract Canyon has many nonnative cyprinid species and channel catfish, with red shiners being the most common species. Several striped bass were captured in the canyon in 1988 and 1989 (Valdez 1990).

## Little Colorado River

**Boundary Delineation:** Arizona, Coconino County. The Little Colorado River from RM 8 in T.32N., R.6E., section 12 (Salt and Gila River Meridian) to the confluence with the Colorado River in T.32N., R.5E., section 1 (Salt and Gila River Meridian).

**Shoreline Ownership:** Tribal, 81.3 percent; National Park Service, 18.8 percent.

**Overlap with Proposed Critical Habitat for:** None.

**Occurrence:**

Historical

The humpback chub was first described in 1946 from specimens taken from Bright Angel Creek in the Grand Canyon (Miller 1946).

Recent

The lower 8 miles of the Little Colorado River contain the largest population of humpback chub in the Lower Basin (Kaeding and Zimmerman 1983). Research studies on the effects of Glen Canyon Dam on the Colorado River through the Grand Canyon have collected approximately 3,400 specimens between 1984-1987 (USFWS 1990b). Monitoring and ongoing studies that are part of the Glen Canyon Environmental Studies program have reported over 21,000 humpback chub captured in the Colorado and Little Colorado rivers between 1987-1992 (Valdez 1991; Valdez et al. 1992; Douglas and Marsh 1992, 1993; Gorman et al. 1993; Arizona Game and Fish Department 1993; Robinson and Clarkson 1992).

**Description of the Habitat:**

Perennial flows in the Little Colorado River were maintained a series of springs along the length of the river and regular or seasonal inflows from the drainage basin. Some of the springs are saline (sodium chloride) which also contribute significant amounts of calcium carbonate to the system. The precipitation of the calcium carbonate creates a channel characterized by travertine dams, reefs and ridges, forming pools, shallow runs, and races. Uncemented calcium carbonate particles form part of the stream bottom and contribute to the turbidity of the river (Kubly 1990). Large boulders, cobble, and similar substrates also occur. Sand and gravel occur in slow-moving waters and pools. Summer water temperatures can be high when water levels are low. There is no barrier to movement from the Colorado River to the Little Colorado.

The perennial flows of the Little Colorado River are maintained by a base flow of 225 cfs from springs (Kubly 1990), but some water reaches the river from its watershed, especially in late spring and summer. Water quality has not changed, except that the diluting effects of river flows from the watershed likely do not occur as often.

The physical habitat in the lower portion of the reach has been modified by the releases of water from Glen Canyon Dam. The lower ½ mile is now somewhat impounded by the high flows in the Colorado River. Temperatures are lower in this portion of the reach, reflecting the influence from the cold waters of the Colorado River. Currents are low; average depths are deeper; and more fine materials, especially sand and gravel, are found in the substrate.

Nonnative fish species, such as channel catfish, are found in the reach. They are non-selective predators that utilize shaded areas under rock ledges, the same types of habitat as the humpback chub (Kaeding and Zimmerman 1983). With the importance of the Little Colorado River as the only known humpback chub spawning area in the Grand Canyon, the presence of nonnative predators is of concern.

There are no development activities in this reach. Development plans for additional use of aquifers on the Navajo Nation will need to evaluate the potential for affects to the springs that supply the base flow to the Little Colorado River.

**Relationship to Constituent Elements:**

<u>Water</u>

Flows in the Little Colorado River maintain acceptable habitat for all sizes and age classes of humpback chub. The historic hydrograph has been altered by the reduction in flows coming into the reach from the watershed, but seasonal variations remain. Fluctuating flows in the Colorado River affect the lower portion of the reach by raising and lowering water levels and altering temperatures. These changes have not eliminated use of the area by humpback chub but there may have been some impacts associated with the changes.

Water quality has not been significantly altered by flow changes. Salinity levels may be higher during low-flow periods when there are no additional flows in the Little Colorado to dilute the inflow from the springs. Temperatures in the upper portion of the reach may have changed slightly in response to altered seasonal water levels. Temperatures in the Little Colorado River are suitable for egg maturation, spawning, and egg and larval development (Minckley 1977, 1978, 1979, 1980; Marsh 1985).

Physical Habitat

The Little Colorado River contains a variety of natural and altered habitats used by the humpback chub. The habitat preferences of the humpback chub are poorly understood, but information from the literature suggests they will successfully utilize many types of habitats.

Spawning habitats preferred by the humpback chub are unknown. Shallow water areas with gravel substrates away from the main current may be used. Humpback chubs may spawn at a variety of flows (Valdez and Clemmer 1982; Kaeding et al. 1990). Successful spawning takes place in the reach of the Little Colorado proposed for designation.

Larval to juvenile humpback chubs have been found in shallow shoreline areas, sand-bottomed runs, and silt-bottomed backwaters with low-current velocities (USFWS 1990b). Adult humpback chub in the Little Colorado River utilize shoreline areas, pools and eddies, quiet waters under rock ledges, large still pools, areas below travertine dams, and the deeper water at the confluence (Minckley et al. 1981).

Biological Environment

Information from stomach contents and other observations indicate that food resources utilized by humpback chub include bottom-dwelling invertebrates such as *Gammarus lacustris* and chironomid larvae, planktonic crustaceans, terrestrial invertebrates and algae such as *Cladophora glomerata* (Minckley 1979, 1980; Minckley et al. 1981; Valdez et al. 1992).

The extent of competition or predation by nonnative fish species on the humpback chub are not known. The habitats of the humpback chub contain potential competitors and predators such as the channel catfish and carp. Altered habitats may be more suitable to nonnative fish, thus, degree to which the habitat has been altered may affect the ability of these nonnatives to be successful in specific areas. The level of predators in the Little Colorado River is not high enough to preclude successful spawning and recruitment by the humpback chub. The Little Colorado River supports one of the few humpback chub populations left that is self-sustaining.

**Colorado River - Marble and Grand Canyons**

**Boundary Delineation:** Arizona, Coconino County. The Colorado River from Nautiloid Canyon (RM 34) in T.36N., R.5E., section 35 (Salt and Gila River Meridian) to Granite Park (RM 208) in T.30N., R.10W., section 25 (Salt and Gila River Meridian).

**Shoreline Ownership:** National Park Service, 87.8 percent; Tribal, 12.2 percent.

**Overlap with Proposed Critical Habitat for:** Razorback sucker.

**Occurrence:**

Historical

The humpback chub was first described in 1946 from specimens taken from Bright Angel Creek in the Grand Canyon (Miller 1946).

Recent

This reach connects to the Little Colorado River and is the only other population of humpback chub in the Lower Basin (Kaeding and Zimmerman 1983). Research on the effects of Glen Canyon Dam on the Colorado River in the Grand Canyon have collected approximately 600 specimens in the mainstem Colorado River from 1984-1987 (USFWS 1990b). A greater number has since been collected during ongoing research as part of the Glen Canyon Environmental Studies--Phase II. Mainstem capture locations were mostly between RM 34 and 208 (Maddux et al. 1987), although humpback chubs have been frequently collected near Pumpkin Springs (RM 213) (Valdez et al. 1992; Valdez and Hugentobler 1993).

**Description of the Habitat:**

The Colorado River in Grand Canyon has a restricted channel with limited floodplain development. Channel widths varied from 180 to 390 feet (Valdez et al. 1992). Gradients are often high, resulting in areas of rapids separated by long pools and runs. Steep, rocky shorelines, talus slopes with alluvial boulder fans and undercut ledges bordered the channel. Substrates ranged from boulders to cobbles, gravels and sand. This physical structure was influenced by the type of rock forming the channel and side slopes (Valdez et al. 1992).

Numerous small tributaries enter the Colorado River in the canyon. These are of two types: (1) Perennial tributaries such as the Little Colorado River, Bright Angel, Kanab and Havasu creeks, provide varying amounts of base flow to the river and create shallow water habitats for use by native fish. Substrates here tend to be more rocky with fewer find materials. (2) The ephemeral tributaries which provide flows during normal runoff or flood periods and contribute significant amounts of sediment to the river (Hamblin and Rigby 1968). Alluvial fans form at the mouth of these ephemeral streams, contributing to the formation of rapids (Valdez et al. 1992).

River flows vary during the year, with high flows in the spring and early summer and low flows in the fall and winter. Flows of record reached a low of 700 cfs in December 1924 and a high of 200,000 cfs in 1921 (Carothers and Brown 1991). Major floods (flows over 120,000) were not uncommon, occurring on average every 10 years.

High sediment loads, estimated at 65.4 million tons annually (USBR 1988) were carried through the canyon. As the water flow varied over the year, depositional and erosional processes occurred, creating and destroying sandbars that formed shallow habitats as well as backwaters and eddies.

Water temperatures ranged from near freezing in the winter to near 86°F in the summer (Minckley 1991). Mineral inflows from the tributaries influenced salinities and other chemical parameters.

Important physical characteristics of the Colorado River through the Grand Canyon were modified by the closure of Glen Canyon Dam in 1963. The river still consists of a series of rapids, pools and runs, but the alteration of seasonal flows has changed the dynamics of the system.

The historic hydrograph of seasonally varying flows and gradual changes over time was replaced by water releases from Glen Canyon Dam emphasizing hydropower production. Releases varied between 1,000 cfs and 31,500 cfs with no restrictions on rates of change of flows. Daily fluctuations reached 12,000 cfs 58 percent of the time (USFWS 1992b).

The dam blocks the primary sediment inflow to the river in the canyon, reducing the sediment load to the amount contributed by the tributaries (approximately 11 million tons annually, Andrews 1990). Scouring of sands and gravels from the upper reaches of the canyon has been documented (USFWS 1992b), although a dynamic equilibrium in the lower reaches of the canyon is expected to be maintained. The clarity of water that results from the decreased sediment load had increased productivity in the upper reaches since algae and associated invertebrates can become established.

Water temperatures were altered significantly from the historic pattern. Water released from Glen Canyon Dam is cold (48°F) year round. There is a warming trend the further downriver from the dam, however, the extreme fluctuations in water flow volumes carry cold waters quickly downstream and this extends the area of cold water influence.

Several nonnative fish species, most notably rainbow trout, channel catfish and carp, have become established in the river. The alterations to the historic habitat may have fostered the success of these species (Carothers and Brown 1991).

Recreation is an important use of the river and rafting, camping and fishing are popular activities. Future recreational development would presumably be similar to those already present.

Despite these changes, the Colorado River retains significant habitat for native fish species. Operations of Glen Canyon Dam are under review and changes to those operations are likely. These changes will have affects to the physical characteristics of the river.

**Relationship to Constituent Elements:**

Water

Flows in Grand and Marble canyons are controlled by releases from Glen Canyon Dam. Fluctuations are now on daily, weekly, and monthly cycles based on needs for power generation and downstream water deliveries instead of the natural seasonal extreme flows of predam years. Water depths and velocities are altered by the change in flows. The humpback chub is mostly found in backwaters, shoreline areas, and eddies (Minckley et al. 1981), both are areas of low-current velocity. These areas may expand or contract in response to changes in flows. Fish in the main channel may be forced to move to other locations more often under this type of changing flow regime (Valdez et al. 1992).

Existing water quality is adequate to support aquatic communities; however, changes in turbidity and temperature due to Glen Canyon Dam have had affects on the suitability of the mainstem for humpback chub. Effects to reproduction, predation, and foraging behavior may be the result of these changes (Valdez et al. 1992).

Physical Habitat

The Colorado River in this reach provides a variety of main channel habitats, including eddies, shorelines, and backwaters. The confluence of the Colorado and Little Colorado rivers is an important habitat area. Access to both systems provides both adult and juvenile humpback chubs with a variety of physical habitat conditions (water depth, velocity, turbidity, temperature, and substrate).

Temperatures in the river may not be suitable for humpback chub reproduction (Maddux et al. 1987); although, successful spawning may be possible in the lowest portion of the reach or in tributaries (Minckley 1993). Low temperatures also affect the use of the mainstem by young-of-year and juvenile humpback chubs. Shallow, low velocity area of silt substrates are favored by young fish are available in the reach, but these habitats are affected by temperatures and changes in flows.

**Biological Environment**

**Nutritional resources do not immediately appear to be limiting in the reach; however, research on food habitats was begun in 1992 as part of the Glen Canyon Dam Environmental Studies. There has been a change in the food resources available to the humpback chub resulting from the changes in the river due to operations of Glen Canyon Dam.**

**Predation on humpback chub by channel catfish and other nonnative fish in the reach occurs at some level (Minckley 1993; Valdez and Hugentobler 1993). There are fewer nonnative species established in the Colorado River in this reach than in other parts of the system, due in part to the harsh physical conditions present. The operation of Glen Canyon Dam may have contributed to a decline of carp and channel catfish in the mthnstem (Carothers and Brown 1991), but also may have increased use of warmer tributaries by these nonnative species.**

**BONYTAIL**

**The Service is proposing six reaches of the Colorado River system (Figure 15 and Table 5) for designation as critical habitat for the bonytail. In the Upper Basin, critical habitat is being proposed in the Green, Yampa, and Colorado rivers. A reach of the Colorado River is being proposed in the Lower Basin.**

**Of the historical range of bonytail, 15 percent (344 miles) is proposed for designation as critical habitat (Figure 16). As more life history and habitat information becomes available, other areas not proposed may be found important and contribute to the conservation of this species.**

**Bonytail are believed to have been common in the Colorado River and its large tributaries throughout the system. One hundred and ninety-eight miles in the Upper Basin, and 146 miles in the Lower Basin are proposed as critical habitat for the bonytail (Table 5).**

**These reaches flow through a variety of shoreline ownerships, both public and private. The National Park Service is the major manager for proposed critical habitat with over 60 percent of the shoreline ownership. The approximate percentages of critical habitat by shoreline ownership for the bonytail is presented in Figure 17.**

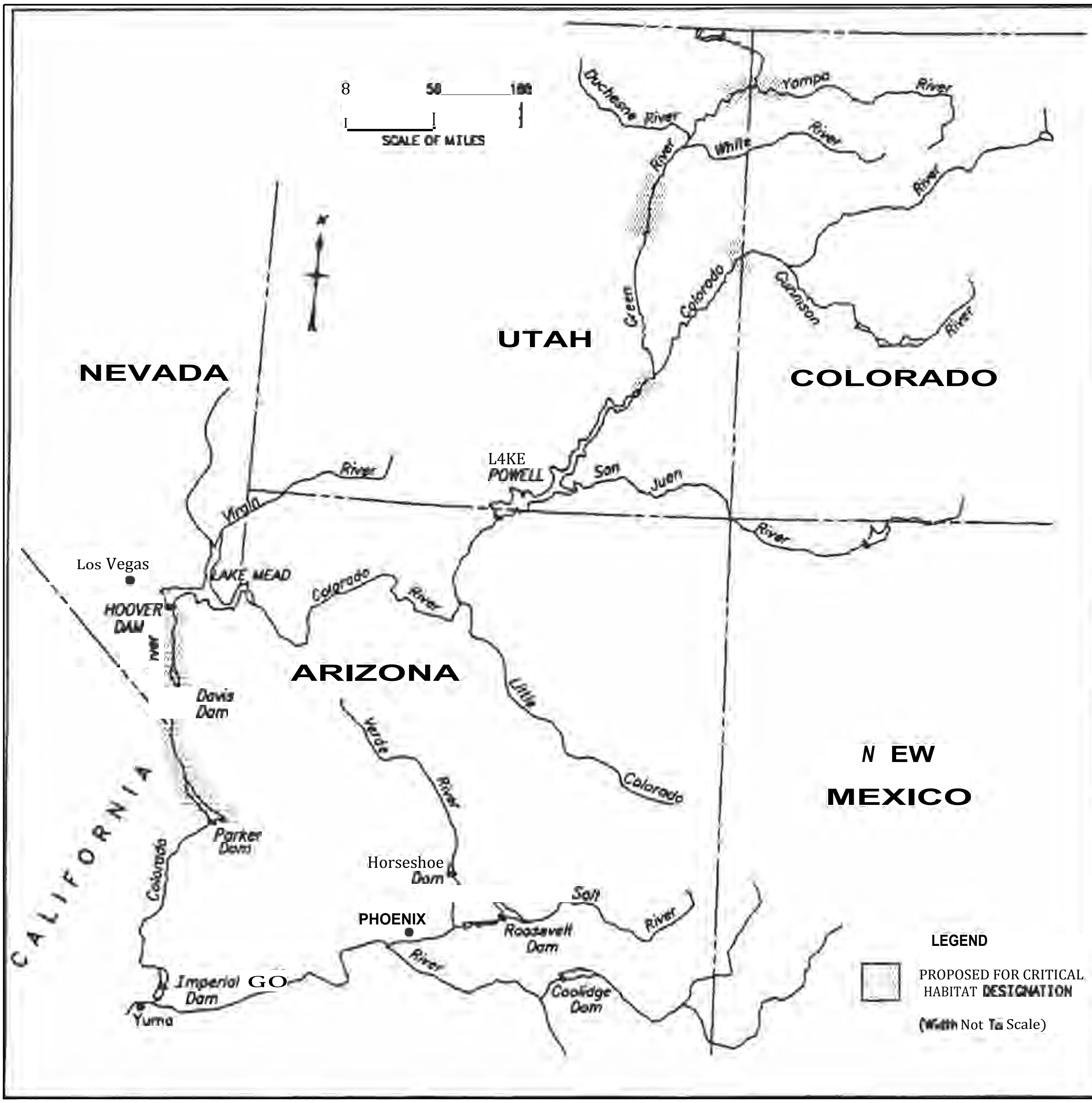



Figure 15. Map of proposed critical habitat for the bonytail.

Table 5. Bonytail critical habitat proposed by basin and reach classification. The Bonytail Chub Recovery Plan does not contain downlisting and delisting criteria (USFWS 1990a).

| Upper Basin Reaches | Classification | Miles |
|---|---|---|
| Yampa River - Dinosaur National Monument | Unknown | 44 |
| Green River - Dinosaur National Monument | Unknown | 38 |
| Green River - Desolation and Gray Canyons | Unknown | 73 |
| Colorado River - Black Rocks to Fish Ford | Unknown | 30 |
| Colorado River - Cataract Canyon | Unknown | 13 |
| | Subtotal = | 198 |

| Lower Basin Reaches | Classification | Miles |
|---|---|---|
| Colorado River - Hoover Dam to Parker Dam | Unknown | 146 |
| | Subtotal = | 146 |
| | Upper Basin | 198 |
| | Lower Basin | 146 |
| | Grand Total | 344 |

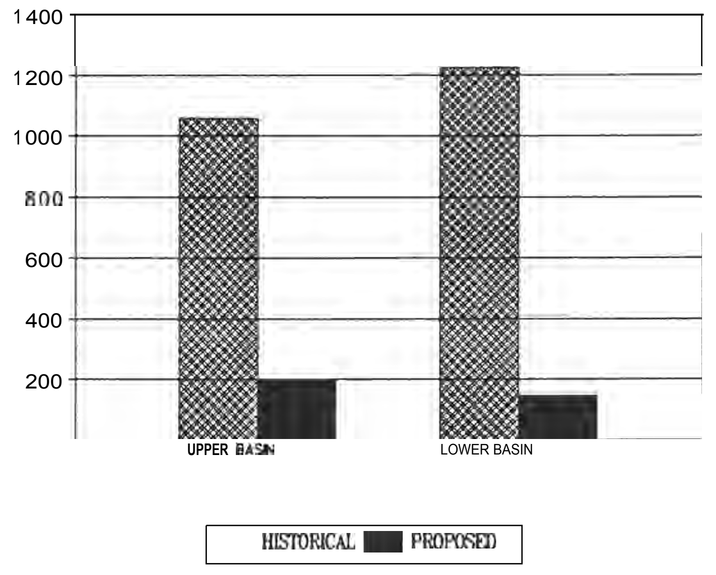



Figure 16. Relative amount of historical habitat proposed as critical habitat for the bonytail.

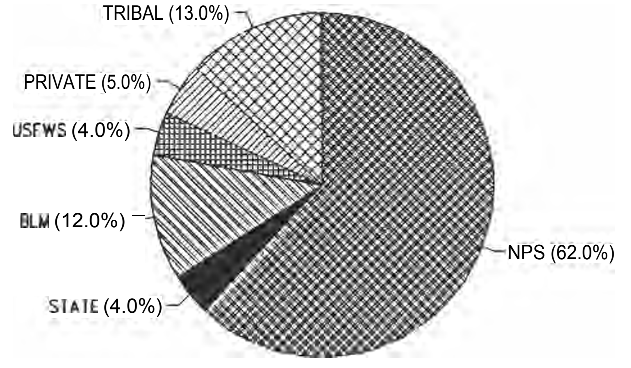



Figure 17. Shoreline ownership for proposed critical habitat for the bonytail.

CRITICAL HABITAT DESIGNATION BY AREA

**Yampa River - Dinosaur National Monument**

**Boundary Delineation:** Colorado, Moffat County. The Yampa River within Dinosaur National Monument. From T.6N., R.99W., section 27 (6th Principal Meridian) to the confluence with the Green River in T.7N., R.103W., section 28 (6th Principal Meridian).

**Shoreline Ownership:** National Park Service, 99.0 percent; Private, 1.0 percent.

**Overlap with Proposed Critical Habitat for:** Razorback sucker, Colorado squawfish, humpback chub.

**Occurrence:**

Historical

Little information on the historical presence of bonytails in the Upper Basin is available. The Green River within Dinosaur National Monument is the last known riverine reach in which the bonytail could be considered common (USFWS 1990a).

Recent

In a 4-year study of the Upper Basin, 36 adult bonytails were collected by Holden and Stalnaker (1975b); the Green and Yampa Rivers within Dinosaur National Monument yielded 29 of these specimens (Holden and Stalnaker 1975b). Holden and Crist (1981) reported the capture of one adult bonytail from the lower Yampa River.

**Description of Habitat:**

At RM 45, the Yampa enters Yampa Canyon. Here, steep canyon walls house the slow-moving river. Occasional boulder fields create rapids, but the predominant substrate is gravel/cobble with patches of sand. In the lower portion of the canyon, the river meanders through soft, sandstone cliffs. The Yampa River leaves the canyon at Echo Park, where it meets the Green River (Miller et al. 1982b).

**Relationship to Constituent Elements:**

Water

The Yampa River has minimal water development in comparison with other rivers in the basin, and the current hydrograph reflects flows which are representative of historical volume and timing. The Service has identified existing flows utilized by native fish (Tyus and Karp 1989), and Yampa River flows also have been identified as critical for maintaining native fish habitat in the Green River below their confluence (McAda and Wydoski 1980; Tyus and Karp 1989, 1991). Water quality has not been identified as a chronic problem. However, an oil spill in June 1989 caused by a ruptured pipeline discharged approximately 10,000 gallons of oil into the Yampa River. This spill has been implicated as resulting in low Colorado squawfish larval and young-of-year abundance in the upper Green River basin that year (Obmasick 1989).

Physical Habitat

Yampa River hydrology within Dinosaur National Monument has remained relatively pristine. A natural hydrograph for the Yampa has maintained instream and shoreline habitats within the monument. This reach of the Yampa River has been identified by the Service as a high priority for recovery and/or reintroduction for the bonytail (USFWS 1990a) because of historic use and habitat suitability.

Biological Environment

The presence of nonnative fishes comprises the major alteration of the historical biotic environment in this reach of the Yampa River. The introduction of nonnative fishes is probably the greatest alteration to the historical Yampa system. Miller et al. (1982b) documented 13 nonnative and nine native fish species within this reach. The potential for competition and predation between these nonnative and native species is high. Virtually all nonnative fish found in this reach have the potential to prey on and/or compete with native species. Maintenance of a historical hydrograph may help limit further encroachment by nonnative fishes. Nutrient input and food sources for bonytails are present within the reach. The relatively unmodified nature of the Yampa River system likely results in food supply levels similar to pre-development.

**Green River - Dinosaur National Monument**

**Boundary Delineation:** Utah, Uintah County; and Colorado, Moffat County. The Green River from the confluence with the Yampa River in T.7N., R.103W., section 28 (6th Principal Meridian) to the boundary of Dinosaur National Monument in T.6N. , R.24E. section 30 (Salt Lake Meridian).

**Shoreline Ownership:** National Park Service, 95.5 percent; Private, 4.5 percent.

**Overlap with Proposed Critical Habitat for:** Razorback sucker, Colorado squawfish, humpback chub.

**Occurrence:**

Historical

The last known riverine area where bonytail were common was the Green River in Dinosaur National Monument where Vanicek (1967) and Holden and Stalnaker (1970) collected 91 specimens during 1962-1966.

Recent

No bonytail have been caught in this portion of the Green River since captures 1968-1970 by Holden and Stalnaker (1975a). No bonytail were captured in this reach during surveys from 1974-1976 (Seethaler et al. 1976) or in surveys from 1981-1983 (USFWS 1990a).

**Description of Habitat:**

Historically, flows in the Green River began increasing in March, peaked in June and remained high through July (Smith and Green 1991). The spring peak averaged near 8,000 cfs for the predam period of 1951-1962 at Greendale, Utah.

Construction of Flaming Gorge and Fontenelle dams in the 1960's altered hydrologic conditions in the Green River. Generally, the magnitude of the spring peak has been reduced while flows during the remainder of the year have increased. The spring peak measured at Greendale, Utah, has decreased from 8,000 cfs to about 4,000 cfs. Winter baseflows have increased about 50 percent (Tyus and Karp 1991). Additionally, temperatures and sediment transport have changed since construction of the dams. The flow and temperature from the Yampa River somewhat ameliorates the reduction in spring flows and temperatures from Flaming Gorge Dam (Tyus and Karp 1989). Depletions from above and within this reach have reduced the total volume of water by 32 percent.

The Green River enters Echo Park at its confluence with the Yampa River. Here, the river is wide, deep, and slow moving. Substrate is a mixture of sand/silt with some large gravel/cobble riffles. After a few miles, the river passes through Whirlpool Canyon, an area of steep cliffs, large pools, deep eddies, rapids, and large boulders. The substrate in the canyon is boulder/bedrock, but large deposits of sand exist within the eddies. After leaving the canyon, the Green River flows through Island and Rainbow Parks. The river in this area is shallow and side channels are common. At RM 327, the river enters Split Mountain Canyon. This stretch contains large boulder fields, swift waters, and major rapids. Some sandbars exist in the slower moving parts of this area.

**Relationship to Constituent Elements:**

**Water**

Flows in this reach are primarily consist of the flows released from Flaming Gorge Dam and flows from the Yampa River. During an average hydrologic year, a spring peak of about 13,000 cfs occurs at Jensen, Utah. Because of the distance between this reach and the dam and unregulated flows of the Yampa River, water temperatures approach historical levels. However, when releases during summer and fall from the dam are greater than historical, then water temperatures may be lower than normal.

Physical Habitat

Little information is available on the specific habitat requirements of the bonytail (USFWS 1990a). Available information suggests that bonytail used lower velocity habitats, such as pools and eddies (Vanicek 1967). The importance that bottomlands and other flooded habitats within this reach may have in the recovery of this species is now under investigation.

Biological Environment

The extensive bottomlands along this reach are sources of nutrient inputs into the Green River. Additionally, historical levels of nutrients from the Yampa River are probably reaching this reach from the Yampa River. This portion of the Green River contains large numbers of red shiner, channel catfish, and common carp, all of which are known to compete with and/or prey upon native fishes. Other piscivorous fish species in this reach include Colorado squawfish, northern pike, and walleye.

**Green River - Desolation and Gray Canyons, Utah**

**Boundary Delineation:** Utah, Uintah and Grand Counties. The Green River (Desolation and Gray Canyons) from Sumner's Amphitheater (RM 85) in T.12S., R.18E., section 5 (Salt Lake Meridian) to Swasey's Rapid (RM 12) in T.20S., R.16E., section 3 (Salt Lake Meridian).

**Shoreline Ownership: Tribal,** 50.0 percent; Bureau of Land Management, 49.0 percent; Private, 1.0 percent.

**Overlap with Proposed Critical Habitat for:** Razorback sucker, Colorado squawfish, humpback chub.

Occurrence:

Historical

Interest in Colorado River endemic fishes increased in the Upper Basin the 1960's, primarily because of the rapid disappearance of the fishes in the Lower Basin and concerns about impacts of Colorado River Storage Project dams in the Upper Basin. Bonytail were first collected from Desolation Canyon in 1967 (Holden and Stalnaker 1970).

Recent

Two adult bonytails were caught in Desolation Canyon in 1974 (Paul Holden, BIO-WEST, pers. comm.). Holden (1978) caught one juvenile in Desolation Canyon in 1977. USFWS personnel collected one individual from Gray Canyon which was tentatively identified as a bonytail (Tyus et al. 1982a).

Description of Habitat:

Below Sand Wash, the Green River enters Desolation Canyon, a deep canyon with nearly 50 rapids. Rapids gradually increase in size as the river travels through the canyon. Habitats in this stratum include eddies, rapids, and riffles, with some deep pools. Boulders make up the primary substrate within Desolation Canyon. This canyon is followed by Gray Canyon which contains larger and deeper pools than are found in Desolation Canyon. Other habitats within the canyon include eddies, rapids, and riffles. Side channels and backwaters also exist here. Substrate in Gray Canyon is composed mainly of boulder/rubble with some gravel. In total, the river runs 193 km through these two canyons. The Green River meets the Price River in lower Gray Canyon before that canyon ends at Book Cliffs escarpment (Tyus et al. 1987). A maximum flow of 68,000 cfs was recorded at Green River in 1917 and a minimum flow of 255 cfs in 1931. Predam temperatures at Jensen, Utah, ranged from near 32°F in December and January to around 78°F during July and August (Smith and Green 1991).

**Relationship to Constituent Elements:**

**Water**

**Because of water depletions** above this reach, historic water levels are seldom, if ever obtained. Because of this, flooding of bottomlands is not as extensive as in the past. Research to determine actual flow needs for this reach are currently underway as part of the Upper Basin Colorado River Fishes Implementation Program. Water depletions have reduced water volumes in this reach by about 30 to 40 percent.

Physical Habitat

Little information is available on the specific habitat requirements of the bonytail (USFWS 1990a). The only information available suggests that bonytail use lower velocity habitats such as pools and eddies (Vanicek 1967). The importance that bottomlands and other flooded habitats may have in the recovery of this species is now under investigation.

Biological Environment

Very little is known on the quantity or quality of the food supply in this reach. Sources of input include the river above and from washes and side channels. The flooded bottomlands along this reach were probably once sources of food input into the system, but are not extensively flooded under the way the system is presently managed. The nonnative fishes common in the Green River include red shiner, channel catfish, common carp, and fathead minnows (Tyus et al. 1982a).

**Colorado River - Black Rocks/Westwater Canyon**

**Boundary Delineation:** Utah, Grand County; and Colorado, Mesa County. The Colorado River from Black Rocks (RM 137) in T.10S., R.104W., section 25 (6th Principal Meridian) to Fish Ford (RM 106) in T.21S., R.24E., section 35 (Salt Lake Meridian).

**Shoreline Ownership:** Bureau of Land Management, 66.6 percent; Private, 33.4 percent.

**Overlap with Proposed Critical Habitat for:** Razorback sucker, Colorado squawfish, humpback chub.

**Occurrence:**

Historical

The bonytail was reported abundant in some locations of the Colorado River drainage in the late 1800's (Jordan and Evermann 1896). There are few reports of bonytail for the Upper Basin in the first half of the twentieth century.

Recent

One adult bonytail was captured in Black Rocks in 1984 (Kaeding et al. 1986).

**Description of Habitat:**

Near the Colorado-Utah State line, the river flows through a mile of upthrust of metamorphic gneiss called Black Rocks. In Westwater Canyon, located five miles downstream, the river again flows through upthrust black metamorphic gneiss rock for 14 miles which confines it, forming a narrow, deep channel with a series of rapids, strong eddies, and turbulent currents. Habitat in both areas consists of deep runs, eddies, and pools, with few backwaters. The river above and below these areas provide gravel bars, floodplains, and backwaters.

The habitat in this reach has been altered by water depletions and changes in the natural flow regime. However, Black Rocks and Westwater Canyon still provide deep eddies, pools, and runs, with rapids, strong eddies and turbulent currents. No manmade barriers occur in this reach. A railroad line built on the north side of the river through Ruby Canyon (including Black Rocks) to Westwater Canyon, constricts the river channel in some areas.

Relationship to Constituent Elements:

Water

The geology of Black Rocks and Westwater Canyon provide deep eddies and pools under current flow conditions.

Physical Habitat

This reach provides deep pools, eddies, and runs for feeding and rearing. This reach provides a movement corridor between Black Rocks and Westwater Canyon.

Biological Environment

Relatively few introduced fishes are found in Black Rocks and Westwater Canyon (Valdez and Clemmer 1982), providing an environment with reduced predation and competition compared with other areas.

**Colorado River - Cataract Canyon. Utah**

**Boundary Delineation:** Utah, Garfield and San Juan Counties. The Colorado River from Brown Betty Rapid (RM 212.5) in T.30S., R.18E., section 34 (Salt Lake Meridian) to Imperial Canyon (RM 200) in T.31S., R.17E., section 28 (Salt Lake Meridian).

**Shoreline Ownership:** National Park Service, 100.0 percent.

**Overlap with Proposed Critical Habitat for:** Razorback sucker, Colorado squawfish, humpback chub.

**Occurrence:**

Historical

The bonytail was reported abundant in some locations of the Colorado River drainage in the late 1800's (Jordan and Evermann 1896). There are few reports of bonytail for the Upper Basin in the first half of the twentieth century.

Recent

Valdez (1990) tentatively identified 14 bonytail captured in Cataract Canyon between 1985 and 1988, including one young-of-year, seven juveniles, and six adults.

**Description of Habitat:**

The river between the confluence of the Green and Colorado rivers and Lake Powell flows through Cataract Canyon, where it cuts deeply through steep canyons and talus slopes. It is characterized by deep swift runs, large eddies and pools, with a few shallow runs, riffles, and backwaters. Large angular rock and steep gradient have created approximately 13 miles of rapids before the river flows into the upper end of Lake Powell, where it becomes a large, deep, slow-flowing river with high, sandstone walls.

Major habitat change occurred in Cataract Canyon when Lake Powell was formed by the closure of Glen Canyon Dam in 1963. Prior to inundation by Lake Powell, Cataract Canyon's steep gradient and large rapids continued for 35 miles. Except for changes in water quantity and historic flow regime, the habitat in portions of Cataract Canyon above Lake Powell remains rather pristine.

**Relationship to Constituent Elements:**

Water

The river through Cataract Canyon has more water than any other reach in the Upper Basin because of the numerous tributaries which enter the Colorado River upstream. Very little is known about the flow requirements of the bonytail.

Physical Habitat

Very little is known about the physical habitat requirements of the bonytail.

Biological Environment

Cataract Canyon has many nonnative cyprinids and channel catfish, with red shiners being the most common species. Several striped bass were captured in the canyon in 1988 and 1989 (Valdez 1990).

**Colorado River - Hoover Dam to Parker Dam (Lakes Mohave and Havasu)**

**Boundary Delineation:** Arizona, Mohave County; Nevada, Clark County; and California, San Bernardino County. The Colorado River from Hoover Dam in T.30N., R.23W., section 3 (Gila and Salt River Meridian) to Parker Dam in T.11N., R.18W., section 16 (Gila and Salt River Meridian) including Lakes Mohave and Havasu up to their full pool elevations.

**Shoreline Ownership:** National Park Service, 51.0 percent; Fish and Wildlife Service, 18.3 percent; Tribal, 12.5 percent; State, 9.6 percent; Bureau of Land Management, 8.6 percent.

**Overlap with Proposed Critical Habitat for:** Razorback sucker.

**Occurrence:**

Historical

The bonytail was known from the mainstem Colorado River from what is now Grand Junction, Colorado, to the mouth of the river near the Gulf of California (Ellis 1914; Smith et al. 1979).

Recent

A small population of bonytails persists in Lake Havasu. Recent records have been of angler caught specimens (USFWS 1990a). A larger population is found in Lake Mohave (Minckley 1991). A total of 32 adult specimens were collected from the reservoir between 1974 to 1987. An additional 16 fish were collected in 1988 to 1989 (Paul Marsh, ASU, pers. comm.).

**Description of the Habitat:**

This portion of the Colorado River was a transition area between the upstream canyons and the downstream plains. Black Canyon, the uppermost portion of the reach, is the last significant canyon on the lower river. Below the Black Canyon, the river valley was still incised, but was wider and more open. The Colorado River flows varied seasonally and yearly, depending upon runoff amounts. This reach did not contain major tributaries. Storm runoff from the washes may have been seasonally significant. River waters could be quite warm in the summer and carried heavy sediment loads.

Substrates likely included cobble, gravels, and sands as well as silts in quiet water areas. Wash inflows provided inflow of sand and gravel to form bars in the channel. Backwaters and shallow areas were uncommon in the canyon sections, though the lower section of the reach may have had those habitats, especially near the Topock Marsh and the mouth of the Bill Williams River.

The lower portion of the reach went through well-defined valleys with small mountain ranges flanking the river. Some floodplain development was possible in the wider valleys.

This 131-mile reach contains two water storage reservoirs and the riverine section between them. Lake Mohave is a mainstem reservoir formed by Davis Dam and filled in the 1950's. It is a long, narrow reservoir and is generally less than 1 mile wide except at the central basin where it widens out to 5 miles.

The upper 20 miles are confined by the steep walls of the Black Canyon, and depending upon reservoir water level, can be riverine or lacustrine in character. Substrates are composed of cobble, gravel, and sand and water depths are shallow, approximately 10 to 40 feet depending upon the level of releases from Hoover Dam. There are few coves in this section, but shallow waters are found around the inflows from washes. Flows in this section are controlled by releases from Hoover Dam and vary significantly on both daily and seasonal schedules. The water released is drawn from deep in Lake Mead and is cold and carries no sediment. Until recently, the upper section of this reach supported a trophy trout fishery.

The lower 43 miles of the reservoir widens out as it leaves the canyon and becomes deeper, reaching 100 feet near the dam. Substrates range from cobble and gravel near the shorelines to sands and silts in deeper water. The shoreline is complex and irregular with many coves and bays. Water levels fluctuate in response to releases from both Hoover and Davis Dams. Water is normally released from Davis Dam only in response to downstream contracts. The inflow of colder water from Hoover Dam creates extensive stratification and current patterns in the reservoir. This water also contributes most of the nutrients that support the aquatic communities. Paulson et al. (1980) discusses the limnology of Lake Mohave.

Lake Mohave is in the Lake Mead National Recreation Area administered by the National Park Service. Boating, camping, and recreational fishing are popular activities. The fishery includes rainbow trout, largemouth bass, striped bass, and channel catfish. Other nongame fish species such as threadfin shad, carp, and green sunfish are common.

Development around the reservoir is restricted by the National Park Service. There are some boat launching and marina facilities, campgrounds, and similar recreational support facilities at points around the reservoir. Any expansion of recreational facilities would be of similar types.

Plans to alter the water release schedules from Hoover Dam to enhance hydropower generation have been suggested by Reclamation. The existing generating capacity has been upgraded by a generator rewinding program completed in 1992. Construction of additional generating capacity is under consideration.

Between Davis Dam and Lake Havasu, the Colorado River is largely confined to a dredged channel. Extensive bank stabilization projects were largely completed between 1945-1960. Flows in this reach fluctuate with releases from the Davis Dam powerplant, and water is diverted for irrigation and municipal uses. Substrates are composed of larger boulders and cobble near the dam, with finer materials more prevalent nearer to Topock Marsh. Water temperatures are higher at the lower end of the riverine portion of the reach.

Sediments picked up by the released water are largely deposited in the vicinity of Topock Marsh, at the head of Lake Havasu. Topock Marsh is a large marsh protected behind the main river channel. This area has open waters, shallow backwaters, and abundant cover in the form of emergent and submerged vegetation.

Lake Havasu is a mainstem reservoir formed in 1938 by the closure of Parker Dam. It was constructed by the Metropolitan Water District as a settling basin and diversion point for water intended for southern California. The reservoir is approximately 53-miles long and is generally less than 4-miles wide with one large basin. It is a shallow reservoir with a maximum depth of 50 feet at the dam. The shoreline is very rugged with many coves and bays. Substrates in coves range from cobble and gravel to sands, silts, and clays in the marshes and backwaters. In addition to the marsh and backwater habitats at Topock Marsh, the Bill Williams River delta at the lower end of the reservoir provides another extensive area of marsh and shallow backwaters. Lake Havasu does not experience significant water level fluctuations (less than 4 feet per year) due to the need to maintain the diversions for the Metropolitan Water District and the Central Arizona Project.

Relationship to Constituent Elements:

Water

With the construction of Davis Dam and the filling of Lake Mohave, a natural flow regime was lost. Water flows into Lake Mohave are entirely controlled by the releases from Hoover Dam. Fluctuations in reservoir water levels occurs on seasonal and weekly cycles as inflows differ from outflows from Davis Dam. Lake Mohave does not go dry, nor is it drained to very low levels. There has always been adequate water to maintain aquatic communities, including the estimated 60,000 razorback suckers.

The riverine portion of the reach is dependent upon the releases from Davis Dam, diversions, and return flows from agriculture. Fluctuations occur on a daily basis as a result of

**hydropower generation, but the river does not go dry. Highest flows occur during the primary irrigation season (April to August) with the lowest flows occurring during the winter (November to February).**

**Lake Havasu receives water from Davis Dam and from the Bill Williams River. The inflow from Davis is the primary source of water for the reservoir, and water levels are maintained within a 4-foot range over the entire year.**

**Water quality in Lake Mohave is good, with a variety of temperatures available throughout the year. The reservoir has a short water retention time but retains significant amounts of nutrients (Paulson et al. 1980). Evaporation is high, but there are no significant changes to salinity. No water-quality problems are known to have affected the razorback sucker population in the reservoir.**

**Water quality in the riverine reach is acceptable. Below Davis Dam, water temperatures are between 54-61°F. Temperatures gradually increase downstream during the warmer months. Backwaters may experience significant evaporation, and summer temperatures may be very high (over 90°F).**

**Surface water temperatures in Lake Havasu reach 82°F during the summer (Ohmart et al. 1988). Shallow coves may be warmer. There are no water-quality problems known to have affected the bonytail or razorback sucker populations in the reservoir.**

**<u>Physical Habitat</u>**

**The reach provides deep water lacustrine, shallow bays, coves and riverine habitats for the bonytail. It is not clearly known how the adult bonytail population uses all these areas, but research is continuing. Adult fish may move seasonally through Lake Mohave and the riverine/Lake Havasu portions of the reach, selecting desirable habitats.**

**Coves and bays with sand and gravel substrates and gravel bars in water up to 30-feet deep may be important spawning areas for the bonytail (Jonez and Sumner 1954). Temperatures are suitable for adult maturation and for incubation and hatching of larvae.**

**Very little is known of the nursery habitat requirements for bonytail. Coves and bays may provide features needed for nursery habitat. These areas have little to no current, cover in the form of aquatic plants, and food resources in the benthos and planktonic communities. These areas are likely analogs to the oxbow lakes and backwaters of the riverine system.**

**<u>Biological Environment</u>**

**Existing nutrient resources are adequate to support populations of aquatic organisms. Plankton, benthic invertebrates, periphyton, and other potential food resources are available throughout the reach. Adult populations of bonytail have been maintained on the food**

resources of the reservoirs. The presence of possibly wild spawned young bonytail in Lake Mohave suggests that nutritional needs of most life stages of the species are met.

Significant opportunities for predation or competition on bonytail by nonnative fish in the reach exist. Carp, sunfish, and catfish are all common or abundant in the reach. These species prey on eggs, larvae, and juvenile bonytails. Cove rearing experiments in Lake Mohave show that when these nonnative predators have been eliminated, young-of-year bonytail do survive and grow successfully. Elimination of recruitment to the bonytail population is may be more likely due to predation rather than alteration of physical habitat features in this reach.

## SUMMARY OF PROPOSED CRITICAL HABITAT DESIGNATION

A map of the cumulative designation for all four fishes is presented in Figure 18. The National Park Service is the land management agency with the greatest amount of proposed critical habitat for the razorback sucker, humpback chub, and bonytail (Table 6). The Bureau of Land Management (BLM) manages the greatest portion of habitat proposed for the Colorado squawfish. Arizona and Utah contain the greatest amount of proposed critical habitat, although no area in Arizona is being proposed for the Colorado squawfish (Table 7). Tables 6 and 7 display the extensive overlap in designations for the four species. The mileages used in these tables was obtained from 1:100,000 scale BLM surface maps.

## FACTORS AFFECTING COLORADO RIVER ENDANGERED FISHES

Colorado River endemic fish populations have been declining since the turn of the century. The cumulative effects of the many perturbations to their natural environment have left these four species close to extinction. The physical and biological changes affecting these species include streamflow alteration, habitat fragmentation and modifications, contaminants, and competition with and predation by introduced, nonnative fish. Under present habitat conditions, and without a concerted management effort, extinction of natural populations of the bonytail and razorback sucker is imminent.

The conditions under which the Colorado River endangered fish thrived in the late 1800's and early 1900's no longer exist. Dams and diversions have fragmented their former habitat such that genetic interchange (emigration and immigration of individuals) between groups is limited or nonexistent. Dams also have altered water conditions. Large floods which once prevailed in the Basin, providing habitat for razorback suckers and Colorado squawfish, are now regulated. Major changes also have occurred in water quality, quantity, temperature, sediment load and nutrient transport. These altered habitats permitted introduced, nonnative fishes to flourish. No unaltered habitat remains for the endangered fish. However, as the

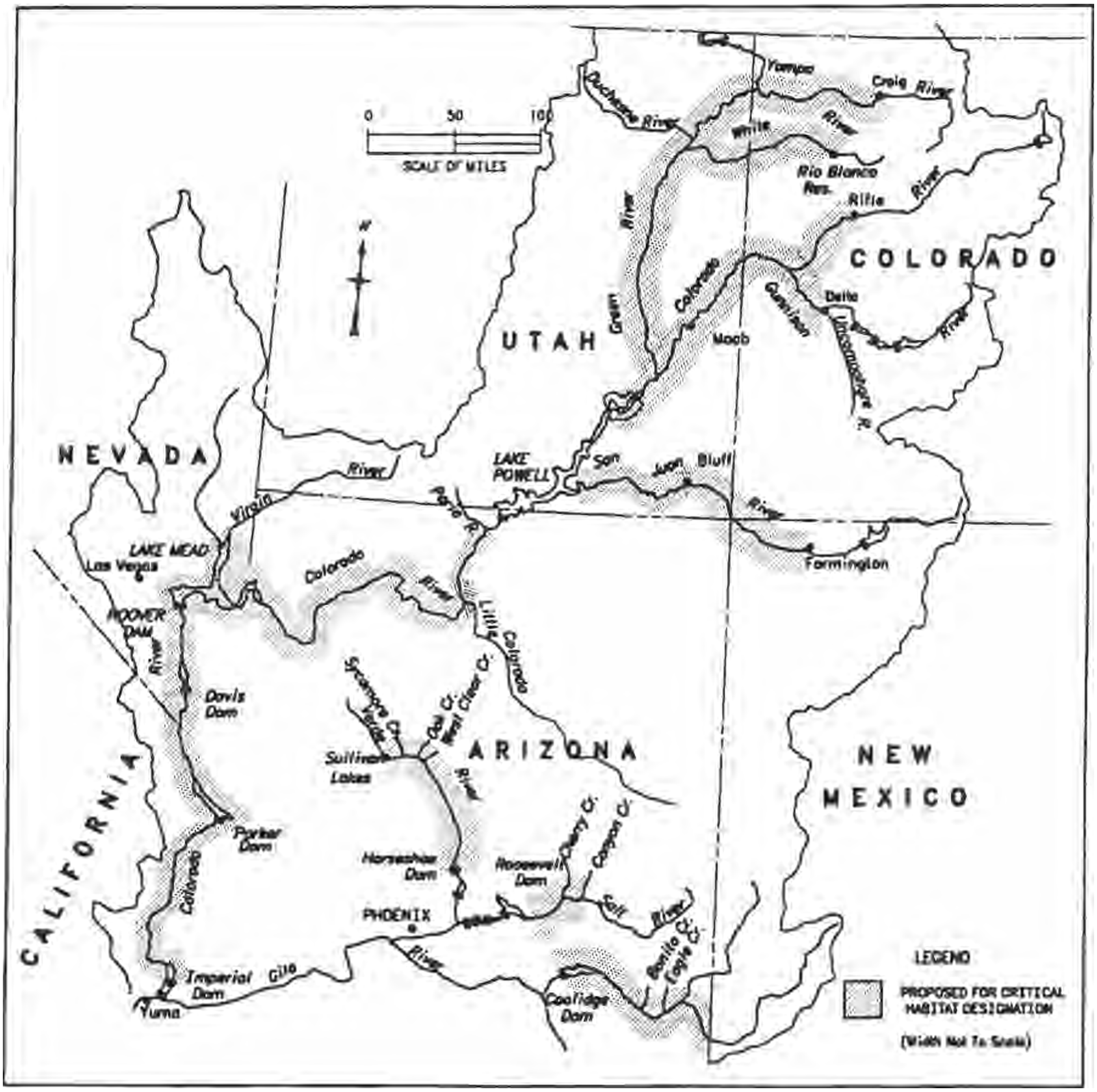



Figure 18. Overall map of proposed critical habitat for the four Colorado River endangered fishes.

Table 6. Land ownership of both shorelines for proposed critical habitat for the endangered Colorado River fishes' in miles.

| OWNERSHIP[2] | RAZORBACK SUCKER | COLORADO SQUAWFISH | HUMPBACK CHUB | BONYTAIL |
|---|---|---|---|---|
| NPS | 1215 | 559 | 338 | 426 |
| BLM | 713 | 695 | 126 | 83 |
| USFS | 286 | | | |
| USFWS | 99 | 22 | | 25 |
| TRIBAL | 620 | 280 | 276 | 86 |
| STATE LANDS | 43 | 49 | <1 | 25 |
| PRIVATE | 673 | 691 | 17 | 37 |
| TOTAL | 3,649 | 2,296 | 758 | 682 |

1 The river distances shown in this table were compiled using total shoreline miles (assuming one mile of river centerline has two miles of shoreline) for each proposed critical habitat reach. There is considerable overlap of proposed critical habitat between species, thus total miles of critical habitat for all four Colorado River endangered fish proposed to be designated cannot be obtained from this table.

2 NPS-National Park Service; BLM-Bureau of Land Management; USFS-U.S. Forest Service; USFWS-U.S. Fish and Wildlife Service.

Table 7. Critical habitat in miles by species and State.

| STATE | RAZORBACK SUCKER | COLORADO SQUAWFISH | HUMPBACK CHUB | BONYTAIL | STATE TOTALS |
|---|---|---|---|---|---|
| COLORADO | 217 | 362 | 59 | 59 | 362 |
| UTAH | 688 | 726 | 139 | 139 | 728 |
| NEW MEXICO | 39 | 60 | | | 60 |
| ARIZONA | 617 | | 181 | | 617 |
| AZ/NEVADA | 130 | | | 82 | 130 |
| AZ/CALIFORNIA | 133 | | | 64 | 197 |
| TOTAL | 1,824 | 1,148 | 379 | 344 | 2094 |

major limiting factors inhibiting recruitment of each species are addressed, recovery will be possible. Unfortunately, because the whole basin has been altered, the areas which will eventually be recoverable are difficult to determine.

## RIVER MANAGEMENT PRACTICES AND PROBLEMS

### BARRIERS

Since 1905, numerous dams have been constructed throughout the Basin (Table 8). These dams have depleted water, altered temperature and flow regimes, trapped sediments and nutrients changed water quality, fragmented habitat and provided a source of lentic nonnative fishes. Fragmentation of habitat and genetic isolation occur when dams create barriers to fish passage. In the Lower Basin, 14 dams restrict fish movement on the Colorado River and the Gila, Verde, and Salt rivers. Major barriers on the lower Colorado River include Hoover, Davis, Parker, Palo Verde Diversion, Imperial, and Laguna dams. Glen Canyon Dam forms a barrier between the Upper and Lower basins. In the Upper Basin, Burdick and Kaeding (1990) identified seven barriers above Glen Canyon Dam. Five of these structures were classified as medium- or high-head barriers that are complete barriers to fish movement, and two were classified as low-head structures that are partial or seasonal barriers to fish movement. On the San Juan River, Platania (1990) identified five diversion structures in New Mexico with the potential to impede fish movement. The most recent development on the San Juan River is a new "falls" which has developed between Clay Hills and Piute Farms where the San Juan River flows into Lake Powell. It was formed after sediment was deposited when Lake Powell was at full pool (1983-87). The sediment was stabilized with tamarisk and the old river channel altered its course so it now flows over a sandstone outcropping. The "falls" is 25-30 feet high and considered a complete barrier to upstream fish movement (Kirk Lashmett, USBR, pers. comm.).

Table 8. Major dams and diversion structures in the Colorado River Basin.

| Structure | River or Tributary | Blockage to Colorado River Fish passage | Depletes water from Colorado River Fish habitat (not including evaporation) |
|---|---|---|---|
| Fontenelle Dam | Green River Wyoming | NO | YES |
| Flaming Gorge Dam | Green River Utah | YES | YES |
| Blue Mesa Dam | Gunnison River Colorado | NO | YES |
| Morrow Point Dam | Gunnison River Colorado | NO | YES |
| Crystal Dam | Gunnison River Colorado | NO | YES |
| McPhee Dam | Dolores River Colorado | NO | YES |
| Navajo Dam | San Juan River New Mexico | YES | YES |

| Structure | River or Tributary | Blockage to Colorado River Fish passage | Depletes water from Colorado River Fish habitat (not including evaporation) |
|---|---|---|---|
| Glen Canyon Dam | Colorado River Arizona | YES | YES |
| Central Utah Project | Green River and its tributaries Utah | Possibly | YES |
| Ridgeway Dam | Gunnison River Colorado | NO | YES |
| Ruedi Dam | Colorado River Colorado | NO | YES |
| Green Mountain Reservoir | Colorado River Colorado | NO | YES |
| Williams Fork Reservoir | Colorado River Colorado | NO | YES |
| Redlands Diversion Dam | Gunnison River Colorado | YES | YES |
| Price Stubb Dam | Colorado River Colorado | YES | NO |
| Tusher Wash Diversion | Green River Utah | PARTIAL | YES |
| Taylor Draw Dam | White River Colorado | YES | YES |
| Frying Pan Arkansas Project | Colorado River Colorado | NO | YES |
| Dillion Reservoir | Colorado River Colorado | NO | YES |
| Windy Gap Project | Colorado River Colorado | NO | YES |
| Granby Reservoir | Colorado River Colorado | NO | YES |
| Shadow Mountain Dam | Colorado River Colorado | NO | YES |
| Collbran Project (19 dams) | Colorado River Colorado | NO | YES |
| Grand Valley Diversion Dam | Colorado River Colorado | YES | YES |
| Grand Valley Irrigation Company Diversion | Colorado River Colorado | YES | YES |
| Uncompahgre Project (7 dams) | Gunnison River Colorado | NO | YES |
| San Juan-Chama Project | San Juan River New Mexico | NO | YES |
| Southern Nevada Water Project | Colorado River Nevada | NO | YES |
| Hoover Dam | Colorado River Nevada/Arizona | YES | YES |
| Davis Dam | Colorado River Arizona | YES | YES |
| Colorado River Aqueduct | Colorado River California | NO | YES |
| Parker Dam | Colorado River Arizona | YES | YES |
| Central Arizona Project | Colorado River Arizona | NO | YES |
| Headgate Rock Dam | Colorado River Arizona | YES | YES |
| Palo Verde Diversion | Colorado River Arizona | YES | YES |

| Structure | River or Tributary | Blockage to Colorado River Fish passage | Depletes water from Colorado River Fish habitat (mt including evaporation) |
|---|---|---|---|
| Senator Wash Dam | Colorado River Arizona | NO | YES |
| Imperial Dam | Colorado River California | YES | YES |
| Horseshoe Dam | Verde River Arizona | YES | YES |
| Bartlett Dam | Verde River Arizona | YES | YES |
| Theodore Roosevelt Dam | Salt River Arizona | YES | YES |
| Horse Mesa Dam | Salt River Arizona | YES | YES |
| Mormon Flat Dam | Salt River Arizona | YES | YES |
| Stewart Mountain Dam | Salt River Arizona | YES | YES |
| Waddell Dam | Aqua Fria River, Arizona | NO | YES |
| Coolidge Dam | Gila River Arizona | YES | NO |
| Painted Rock Dam | Gila River Arizona | YES | NO |

Historically, the only barriers that existed were natural rapids and swift turbulent waters, which at times may have been an impediment to fish movement. Major mainstem dams completely block fish movement and create fragmented habitats. Smaller dams and diversions also may obstruct fish migration; both downstream migration, or drift of young fish, and upstream migration associated with maturity or spawning. Although little is known of exact locations of fish spawning areas prior to the construction of these facilities, it is believed that they have obstructed access to or impounded once important spawning areas. Fragmentation of habitat by barriers has been identified as a major reason for decline of native fishes in the Colorado River basin (Miller 1961; Tyus 1984; USFWS 1990a, 1990b, 1991).

## WATER MANAGEMENT

The 1922 Colorado River Compact (Compact) allocated 7.5 million acre-feet (mat) of consumptive use of water to both the Upper and Lower Basins. The Lower Basin also was given authorization to increase its consumptive use by up to 1.0 maf during any given year. The 1922 Compact requires that at least 75.0 maf be delivered to the Lower Basin over any 10-year period. In addition to the 7.5 maf for the Lower Basin, the Mexican Water Treaty of 1944 authorized an annual delivery of 1.5 maf of Basin water to Mexico. The general consensus is that the flow at Lee's Ferry was over estimated and that as water development proceeds, meeting the 1922 Compact conditions may become difficult. Other agreements and Acts which affect the delivery of water through the Colorado River have come about since the original 1922 Compact. Upper Basin water was apportioned under the Upper Colorado

River Compact of 1948. Colorado was apportioned the greatest share, 51.75 percent, followed by Utah (23.00 percent), Wyoming (14.00 percent), and New Mexico (11.25 percent). These figures are expressed as percentages because the amount of water available to the Upper Basin each year is determined by runoff and storage capacity. In 1964, a Supreme Court decision in Arizona v. California apportioned the Lower Basin water among Arizona (2.8 mat), California (4.4 mat), and Nevada (0.3 mat). The Upper Colorado River Basin Compact, the Water Treaty of 1944 with the United Mexican States, the Boulder Canyon Project Act, the Boulder Canyon Project Adjustment Act, the Colorado River Storage Project Act, and the Colorado River Basin Project Act, the Endangered Species Act, Salinity Control Act, Clean Water Act, National Environmental Policy Act, and other environmental and regulatory laws affects the States use of water in the Basin. The water developed by state as of 1985 is presented in Table 9 (USBR 1991). Many issues related to Tribal water rights have yet to be resolved and may ultimately alter water use within the Basin.

Water development in the Basin began as settlers moved to the region in the 1800's. By the late 1800's, water was being diverted from the Colorado River for agricultural purposes.
Table 9. Estimated State water use compared with allocations from the 1922 Compact and Upper Colorado River Basin Compact for the 1985 water year[1]. This table does not address Tribal water rights and claims.

| STATE | ENTITLEMENT (AF) | TOTAL USE[2] | REMAINING ENTITLEMENT |
|---|---|---|---|
| Arizona[3] | 2,800,000 | 1,032,000 | +1,768,000 |
| California | 4,400,000 | 4,710,100 | -310,100 |
| Colorado | 3,105,000 | 2,327,540 | +777,460 |
| Nevada | 300,000 | 262,000 | +38,000 |
| New Mexico | 675,000 | 473,750 | +201,250 |
| Utah | 1,380,000 | 1,027,730 | +352,270 |
| Wyoming | 840,000 | 426,690 | +413,310 |

1 Data from Bureau of Reclamation Consumptive Uses and Losses Report 1981-1985 (1991).
2 Includes evaporation; For Upper Basin mainstem reservoirs, evaporation is divided between states based on the percent compact entitlement.
3 Since 1985, the Central Arizona Project has been completed. Arizona now intends to utilize its full entitlement.
4 Nevada data was supplied by the Southern Nevada Water Authority and is for 1992.

The 1902 Reclamation Act initiated large scale construction in the Lower Basin with the construction of Laguna Dam in 1905 on the Colorado River near Yuma, Arizona. In the Upper Basin, the Gunnison River was blocked with the construction of the Redlands Power and Diversion Dam in 1907. These were the first major barriers to fish passage. Since the 1922 Compact, the Basin has been further subdivided by dams and diversions for water development projects. The primary purpose for construction of these projects was to support agriculture, municipal and industrial development consistent with the states compact entitlement. Also hydropower was major purpose for developing projects.

Developed irrigated land in the Basin exceeds 2.1 million acres. Much of the water used for irrigating these lands is diverted from the Colorado River and its tributaries. Most hydropower generation in the Basin originates from projects authorized under the Colorado River Storage Project Act for the Upper Basin and the mainstem reservoirs in the Lower Basin. These projects have a combined capacity to generate in excess of 3.6 million kilowatts annually and have a water storage capacity of 61.5 maf. This has created a complex system of water and power delivery. Management of the water resources is through the Upper and Lower Basin offices of Reclamation in consultation with the Basin States, and other government agencies and the public. The electrical energy produced by these projects is marketed and distributed by Western Area Power Administration (Western; Western 1991).

The dams in the Colorado Basin under the Colorado River Storage Project Act are operated primarily for the purposes of (1) flow regulation; (2) water storage for consumptive uses; (3) water for agriculture; (4) control floods; (5) fish and wildlife values; and (6) generating power incidental to the other purposes.

**Water Depletions and Releases**

The natural hydrograph of the Colorado River system within the historic range of the listed fishes has been altered due to human actions and needs. Water is lost to the system for agricultural, municipal and industrial uses, and reservoir evaporation throughout its length. Diversions from the system begin at or above timberline in most subbasins. In the Upper Colorado Basin, transmountain diversions to the South Platte and Arkansas River basins have been constructed in the headwaters of most major tributaries. The Green River Basin also has high elevation diversions; however, most of these are not diverted from the basin. Within Utah, the Central Utah Project is diverting water from Green River tributaries to the Great Basin. No transmountain diversions occur in the headwaters of the White River Basin. Headwater diversions in the Yampa Basin occur on the Little Snake River above Baggs, Wyoming. The Gunnison River Basin currently has no transmountain diversion, although at least two are in the planning stages. The San Juan-Chama Project diverts water out of the San Juan River Basin for use is Rio Grande Basin. At lower elevations, water is diverted from the system for irrigation and municipal and industrial use in the basin of origin.

**The Lower Basin States divert their entire Colorado River apportionments. Major reaches of the tributaries of the Gila River are controlled by dams. Water is stored in these facilities, releasing water downstream only when the need exists. Thus reaches of the Salt, Verde, and Gila Rivers are being dewatered.**

**The best information available indicates that historical natural Colorado River flows as measured at Lee's Ferry, Arizona averaged 15,328,000 af for the period 1906 to 1986 (USBR 1991). The extremes during this period were 24,511,000 af in 1984 and 5,014,000 af in 1977. Table 10 below presents the average consumption data for the Upper and Lower Colorado River Basins for 1976-1985 (USBR 1991). This report summarizes consumptive water uses by subbasin, the reporting period, and each year within the period. Water depletion in the Upper Basin has been recognized as a major source of impact to endangered fish species. Faulty assumption by restricting the ability of the Colorado River system to produce flow conditions required by various life stages of the fishes. Depletions may approach 100 percent at specific locations within the system. Water depletion in the Upper Basin has been recognized as a major source of impact to endangered fish species. Water withdrawal has changed flow conditions required by various life stages of the fishes.**

**Table 10. Estimates of average water consumption for the Colorado River 1976-1985 (taken from Bureau of Reclamation, Consumptive Uses and Losses Report, 1991).**

| MAJOR ACTIVITY | UPPER BASIN ACRE-FT (%) | LOWER BASIN ACRE-FT (%) | TOTAL ACRE-FT (%) |
|---|---|---|---|
| Irrigation | 2,146,530 (56.2) | 5,140,430 (44.83) | 7,286,960 (47.68) |
| Transbasin Exports | 697,680 (18.27) | 4,150,780 (36.20) | 4,848,460 (31.72) |
| Reservoir Evaporation | 784,690 (20.55) | 1,467,590 (12.8) | 2,252,280 (14.73) |
| Municipal Industrial | 190,080 (4.98) | 706,340 (6.16) | 896,420 (5.86) |
| Totals | 3,818,980 (24.98) | 11,465,140 (75.02) | 15,284,120 (100) |

**In addition to depletions due to consumptive uses, changes to the timing of releases due to hydropower and agriculture demands have altered the historic hydrographs. Water supply systems alters and caused impacts to listed fish. Dams and diversions have reduced peak discharges by 50 percent since 1942 and increased base flows by 21 percent in some reaches (USFWS 1992b). The listed fishes had adapted to seasonal fluctuations of the Colorado**

River system. As discussed in the life history sections, various portions of an annual hydrograph provide habitat components for reproduction and survival requirements. In general, spring peaks have been reduced by storage facilities and low autumn flows increased by irrigation returns. This can result in undesirable conditions for life history needs of the fish in a variety of ways. Flows may be too low to provide spring floodplain rearing habitat for razorback sucker or too high to provide late season rearing habitat for squawfish. The alteration of the physical habitats resulting from changes in river flows may have contributed to the successful establishment of nonnative fish species. The large historic seasonal flow fluctuations of the system have been dampened by water development projects and consumptive uses. Figure 19 presents mean monthly discharge measured at three USGS gages for the San Juan, Green, and Colorado rivers. This data displays the reduction in peak flows discussed above. Figure 20 shows similar data from USGS Topock gage data for the lower Colorado River pre- and post-major water development. Depletions along the lower Colorado River have completely altered the natural hydrograph through this area. Water depletions in major tributaries in the Gila River drainage have significantly reduced available habitat for these fish in the Lower Basin.

Power Marketing

Within the Department of Energy, Western oversees the electrical power system in the western United States. In marketing electricity generated at Federal powerplants, Western's responsibility is to sell Federal hydropower so as to encourage its widespread use at the lowest possible rates to the consumers while still staying consistent with sound business principles. They also have been given the task of encouraging the implementation of conservation and renewable energy programs, as required under the Hoover Powerplant Act (Western 1991).

Western has set up regulations which monitor and control the transfer of energy from Federal powerplants to the consumers. Marketing criteria that were developed to regulate both energy and cash flows considered the following items: (1) source of power; (2) how much power is available and when; (3) eligibility of customers; (4) resource allocation; (5) delivery of power; and (6) provisions and restrictions in the firm contracts (USBR 1988). Western controls about 16,200 miles of transmission lines, covering 1.25 million square miles. Power generated by Federal powerplants in the West is sold to 572 municipalities, rural electricity cooperatives, public utility districts, and other customers. Their sources are capable of generating 45,200 gWh annually.

Power in the Upper Basin comes from the various projects managed under the Salt Lake City Area Integrated Projects (SLCA/IP). These include the five powerplants and four reservoirs in the Colorado River Storage Project (CRSP), the Collbran Project, the Seedskadee Project, the Rio Grande Project, and the Provo River Project. Available energy is calculated by Reclamation by converting the expected annual water releases and reservoir elevation into available energy. This number is then converted into expected monthly energy and compared with anticipated energy requirements of the customers.

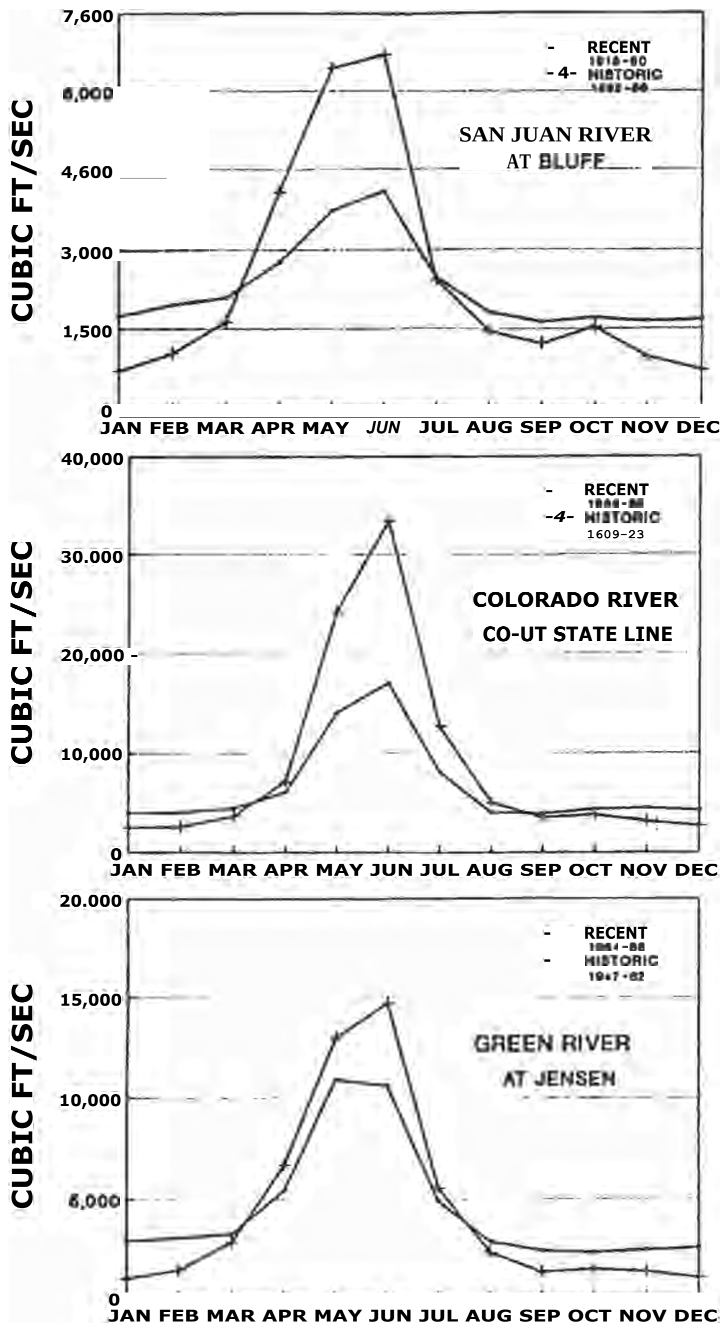



Figure 19. Mean monthly discharge at USGS gaging stations on three upper Colorado River basin rivers. Recent and historic hydrographs are from years during pre- and post-development periods for which records are available. San Juan River periods are pre- and post-Navaho Dam; Green River periods are pre- and post-Flaming Gorge Dam (from Osmundson and Kaeding 1991).

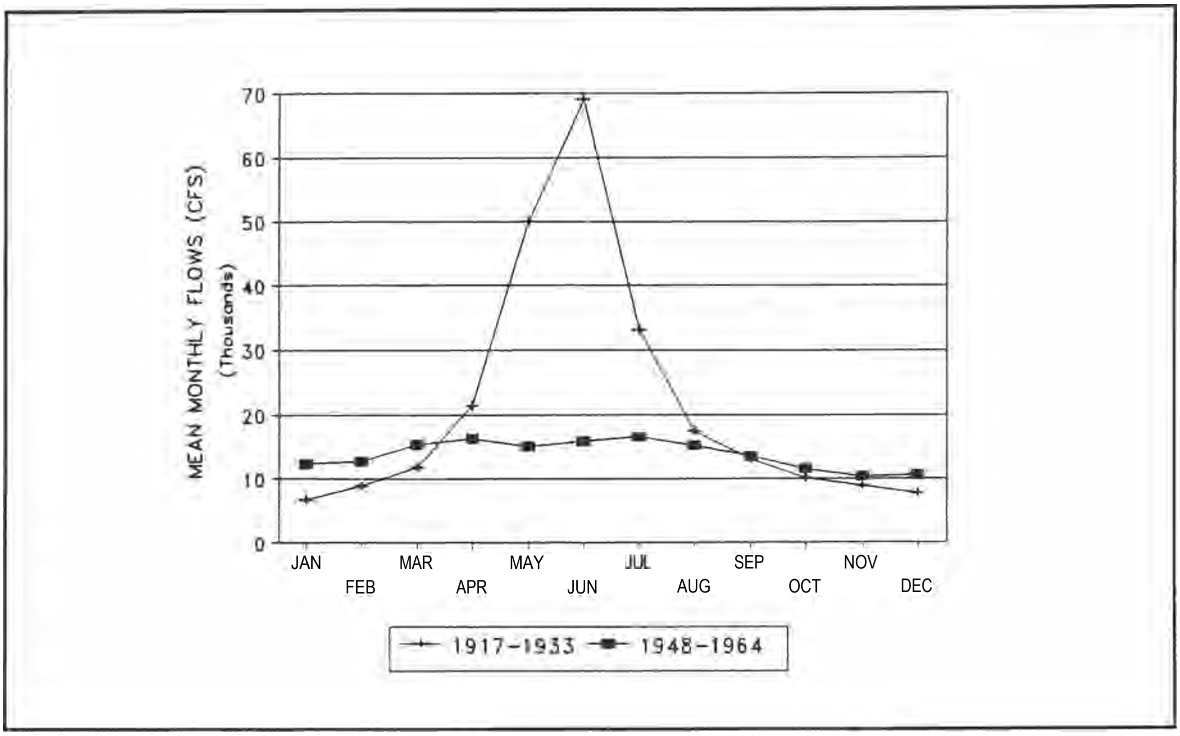



Figure 20. Mean monthly flows at Topock Marsh prior to pre-(1917-1933) and post-(1948-1964) major construction of dams and diversions on the Colorado River (USGS Topock gage data).

After the potential available energy is calculated, Western must focus on customer priority. Eligibility criteria have been established to determine customer priority. By law, priority must be given to municipalities, public corporations, and rural electric cooperatives. After that, Western can set additional requirements if needed.

After the potential customers have been decided upon, the electricity must be allocated among the various entities. Several different methods can be selected to divide the resource. All customers could receive equal portions, or resources also could be divided by taking the size of the utility into consideration. A third solution would be assigning a certain maximum percentage of a utility's resource to a customer.

Western also must look at the boundaries of service. As mentioned before, there are 16,200 miles of transmission lines. For requests outside of the system, contracts must be made with other utilities to deliver the electricity to the customer. Even when within the transmission system, contracts are important to establish the terms and conditions for using SLCA/IP electricity. The length of the contract must be established; how much electricity is needed for how long. Schedules - peak and off hours - also are necessary to maintain the proper amount of electricity at the right time. The price of electricity is a third important factor that

**should be established by contract. These contracts, no matter how long they will last, should be flexible to adjust for seasonal differences in the flow of water through the various plants.**

**The total amount of power that can be generated by SLCA/IP powerplants is 1,765 megawatts (MW). The actual capacity of the generators is higher, but flows are maintained below maximum capacity for various purposes such as safety, fish and wildlife needs, agriculture demand, and water storage. Minimum flow limits also have been established for some of the same purposes.**

**Power is marketed differently in the Lower Basin where the SLCA/IP does not manage the dams. The most striking difference in the Lower Basin is that the water users have the right to decide how much water is released from Hoover, Parker, and Davis Dams. The amount of electricity available to sell at any given time is subject to the demands of those entities (agricultural and municipal, among others) with water rights below the dams. This demand varies at different times of the year.**

**In the Lower Basin, no single organization manages all the dams and power plants. Power from Hoover Dam is managed by the Phoenix office of Western under the Hoover Powerplant Act of 1984 and is divided between Arizona, Nevada, and California. Arizona and Nevada's state governments manage the sale of their portions of hydropower coming from Hoover Dam, but the State of California did not choose to exercise this option. Instead, power earmarked for California is sent directly to various contractors, who then sell the electricity to their customers (Bob Lynch, Colorado River Energy Distribution Association, pers comm.)**

**Parker Dam and Davis Dam are managed together under Parker/Davis Power Company. Hydroelectricity from these two plants is sold along the same lines as the CRSP in the Upper Basin. Power generated from dams on the Salt River is not marketed, per se. Electricity from these powerplants goes directly to the Salt River project where it is combined with other sources of electricity (steam, nuclear, etc.) to provide power for the southern Arizona area. The relatively small amount of power generated from the Salt River is not sold to outside organizations.**

## Water Marketing

**Generally, holders of valid water rights can lease, sell or exchange water to potential users. These transactions can include direct sale of the water right, inter- and intra-basin exchanges, long- or short-term leases, and dry-year options. These types of transfers are likely to become more common as water users attempt to meet current and future needs.**

**In response to this issue, the Department of Interior (DOI) developed a set of Voluntary Water Transaction Principles in 1988. These principles were established to define the Federal role in within-State water marketing where there was a Federal interest or Federal facilities were to be used for conveyance of the transferred water. The principles were to**

provide the maximum flexibility to State, Tribal, and private entities in solving water resource problems. The legal, contractual, and regulatory concerns DOI must consider were also made clear in the principles. The DOI recognized that the lead in water allocation and management belongs to the states.

In some States within-state transfers have been going on for some time with little opposition. Between state or between Upper and Lower Basin transfers are not presently supported. There is currently opposition to an Upper Basin State marketing a portion of their share of the Colorado River to a Lower Basin State and acceptance of inter-State or Basin transfers may take many years. Water marketing from the upper to the lower basin may benefit the fish assuming the timing of delivers could be affected. Opportunities exist for governments to market portions of their water benefiting both the Tribes and endangered fishes.

Water transfers are not limited to the mainstem Colorado River. Within Arizona, water transfers between the Little Colorado River Basin, the Salt River Basin, and the Gila River Basin affect Eagle Creek and the East Verde River. Exchanges between Colorado River water carried by the Central Arizona Project aqueducts and water in the upper and middle Verde River are still under discussion.

Water marketing may have an affect on the amount and timing of water present in specific rivers and reservoirs. Marketing of water to other perhaps more distant users may alter the current Basin-wide delivery patterns. Higher or lower riverine flows, changes in reservoir storage operations, and diversion points would result. Some persons believe that there is a growing disparity between amount of water needed by some users and their Colorado River allocation under the 1922 Compact. This ensures that entities with water needs will continue efforts to obtain additional supplies and institute more efficient water management practices. Water marketing allows owners of excess water to obtain both immediate and long-term benefits from their water. More economically valuable uses of water may take precedence over less profitable ones due to free-market transfers of water.

## WATER TEMPERATURE AND SEDIMENT TRANSPORT

Water development in the Colorado River Basin has altered sediment transport and water temperature parameters from historic measurements. Large mainstem dams release of cool/cold water and altered sediment transport have changed the physical environment in which these four fish evolved.

Cooler water temperatures resulting from dam operations may have excluded the Colorado River endangered fishes from portions of their original range (Vanicek 1967; Vanicek et al. 1970). Changes in water temperature may affect the ability of adults to reach spawning areas, reach spawning conditions, influence embryo development and egg hatch rates, growth, and longevity.

Historically, the Colorado River carried approximately 103,955,000 tons of fluvial sediment annually past Lee's Ferry, Arizona (Iorns et al. 1965). Construction of dams and modification of flows has resulted in an overall reduction in sediment transport through the Basin. Water development activity in the Basin affects sediment transport two principal ways (Andrews 1986). Reservoirs act as sediment traps and are depositional. Depletion of water results in a reduction of available flow to transport sediment. Releases of clear water from reservoirs may result in streambed degradation in the reach below the dam.

The relationship between the decline of native fishes and alterations of sediment transport is poorly understood. Sediment is important in the creation and maintenance of backwaters and shallow nursery or feeding areas for squawfish and razorback suckers (Tyus and Karp 1989; Holden 1983). Adequate flows are required to maintain scoured cobble spawning areas for squawfish (Tyus and Karp 1991). Osmundson and Kaeding (1989) theorize that the combination of water clarity and the introduction of sight-feeding predator fishes may have increased the vulnerability of the Colorado River endangered fishes, especially young-of-year, to predation. Adult razorback suckers and bonytails can successfully exist in clear water reservoirs, but recruitment is limited, with predation likely playing a major role. The changes to historical sediment transport within the Basin may be impacting the four endangered fish through both alteration of physical habitat and increased vulnerability to predation.

CONTAMINANTS

The Service has studied environmental contaminants and water quality of the Colorado River Basin in an effort to protect and enhance the remaining populations of endangered fish. In addition, contaminant data has been collected by State water quality agencies, USGS, and the U.S. Environmental Protection Agency (EPA). Historical baseline data for levels of various contaminants throughout the Basin are not available. Primary concerns in the Upper Basin have been agricultural areas which contribute irrigation return flows containing high levels of selenium, impacts from active and abandoned mines some of which are on the U.S. Environmental Protection Agency's National Priority List as Superfund sites, and infiltration from oil and gas development. In the Lower Basin, studies associated with the critical habitat locations include "Environmental Contaminant Reconnaissance Investigation of Water Quality, Bottom Sediment, and Biota Associated with the upper Gila River Basin" and "Trace Element and Organochlorine Reconnaissance Investigation of Abiota and Biota at Cibola and Martinez Lake and Topock Marsh". These reports are in preparation by the Service. Contaminant concerns include, agricultural return flows with high levels of selenium, pesticides, and mine tailings.

Green River Contaminants

There has been increasing concern about the quality of irrigation drainage, surface and subsurface water draining irrigated land, and its potential effects on human health, fish, and wildlife. In 1985, the DOI initiated a program to identify the nature and extent of irrigation-induced water-quality problems that might exist in the western States. The "Task Group on Irrigation Drainage" identified several locations which required reconnaissance studies to identify potential problems caused by irrigation drainage (Stephens et al. 1988).

From 1986-1987, a reconnaissance study was conducted by inter-bureau field teams (USGS, the Service, and Bureau of Land Management) in the Middle Green River Basin, Utah. The studies were located at Browns Park and Ouray National Wildlife Refuges, the Browns Park, Stewart Lake, and Desert Lake Waterfowl Management areas, and the Pariette Wetlands. All of these wildlife areas are located in the Green River drainage area. The study focused particularly on Stewart Lake and Ouray National Wildlife Refuge. These areas are located adjacent to or drain into the Green River which provides habitat for the Colorado River endangered fish. Spawning sites for the Colorado squawfish exist north of Jensen on the Green River, and backwater areas provide nursery habitat for the squawfish. The razorback sucker also is believed to spawn upstream of the Stewart Lake Waterfowl Management Area. Historically, humpback chub and bonytail also were found in the study area.

The reconnaissance study found that the concentrations of boron, selenium, and zinc in the water, bottom sediments, and biological tissue were sufficiently large to be harmful to fish and wildlife and to adversely affect the beneficial use of water (Stephens et al. 1988). Two of the fish samples from the Stewart Lake Waterfowl Management areas contained selenium concentrations that were within the range of 25 to 45 micrograms per gram dry weight which has been associated with reproductive failures in bluegills (Gillespie and Baumann 1986). Due to the findings of the 1986-1987 reconnaissance study, analysis of the Middle Green Basin was continued from 1988-1989.

Stephens et al. (1992) detected increasing concentrations of selenium in the water from near the detection level of 1 $\mu g/L$ at Greendale to a mean of 2 $\mu g/L$ by Green River, Utah. Large concentrations of selenium were present in water discharged from Stewart Lake (mean 6.7 $\mu g/L$ ) and Ashley Creek (mean 88 $\mu g/L$). According to the report, concentrations of selenium in the biota of the Green River received limited study. Unique samples were taken of humpback chub and Colorado squawfish. One humpback chub was sampled in 1986 (site undetermined), it had 4.3, 6, and 7 $\mu g/g$ of selenium in its muscle, liver, and gonads. Moderate concentrations of mercury were found in Colorado squawfish muscle, 2.56 $\mu g/g$ (Stephens et al. 1992). Recent examinations of eggs and milt of razorback suckers from the Green River found that selenium levels may be sufficiently elevated to cause reproductive problems (Hamilton 1993).

**Upper Colorado River Basin Contaminants**

The Service has begun a study of contaminant residues in fish from the Colorado River Basin in Colorado and eastern Utah. The purpose of this study was to identify contaminants, based on residues in fish, which could be harmful to threatened or endangered fish as well as identify rivers or river reaches which were contributing these contaminants. The first phase of the study was conducted in 1987 and focused on the mainstems of the Yampa, White, Dolores, and Colorado Rivers (Krueger et al. 1991). The second phase was conducted in 1991 and focused on headwater streams and rivers including Williams Fork Creek and the Blue, Snake, Fraser, Eagle, Roaring Fork, and Colorado rivers (Archuleta et al. 1993).

Results from the first phase of the study indicated that copper and selenium concentrations exceeded established baseline concentrations (Schmitt and Brumbaugh 1990) in greater than 50 percent of the samples from all rivers sampled. Selenium occurred at concentrations which have been correlated with fish health effects, and some samples contained concentrations high enough to harm avian predators. Copper can be extremely toxic to most fish; however, the significance of copper residues as related to fish health is generally unknown. Mercury and zinc exceeded baseline concentrations in fish from all rivers with the exception of the Dolores. Arsenic exceeded baseline concentrations in fish from only the Yampa River. Organochlorine concentrations were at or below national baseline concentrations for all samples in all rivers. Overall, the Yampa River had the greatest number of samples which exceeded national baseline concentrations for arsenic, copper, mercury, selenium and zinc. One Colorado squawfish sample collected from the Green River exceeded the baseline concentrations for copper and selenium.

The second phase of the study focused on 11 sites located in Colorado headwater streams and rivers. Results indicate that cadmium and copper exceeded established baseline concentrations in greater than 50 percent of whole body samples. Fish liver samples from the Blue River indicate exposure to extremely high copper and cadmium concentrations. Selenium exceeded baseline concentrations in greater than 22 percent of the samples. Liver samples indicated highest selenium exposure in the Blue River, Roaring Fork River, and Ten Mile Creek. Zinc exceeded baseline concentrations in greater than 30 percent of the samples. Liver samples indicated highest zinc exposure in the Blue and Eagle Rivers. Arsenic and Mercury were below baseline concentrations for all samples at all sites. Overall, samples from the Blue River below the confluence with the Swan River and the Blue River below Dillon Reservoir exceeded baseline concentrations for most metals and had the highest concentrations for most metals.

**San Juan River Contaminants**

In 1990, DOI conducted a study in the San Juan River, New Mexico, to determine if irrigation drainage from five DOI sponsored irrigation projects were adversely affecting water quality and/or fish and wildlife resources. The following summary from Blanchard et al. (1993) indicates that the contaminant of major concern in the San Juan River Basin is selenium. The habitats with the largest concentrations of selenium in sampled media were "wetlands" that received subsurface return flows from irrigated fields. Six sites in four locations: the Gallegos Canyon drainage, Ojo Amarillo Canyon, West Hammond Project, and East Hogback Project had selenium concentrations in water, sediment, and/or biota that routinely exceeded established standards and criteria.

The majority of the wetland sites where elevated concentrations were found are not accessible to Colorado squawfish or razorback sucker. However, the East Hogback site is a backwater wetland that receives irrigation drainage and is connected to the San Juan River. Concentrations of selenium in four whole-body composite fish samples from this site exceeded the 12 μg/g dry weight (dwt) concentration above which reproductive failure is likely to occur. Concentrations of selenium ranged from 28.5 μg/g dwt in mosquitofish to 43 μg/g dwt in fathead minnow. Selenium concentrations in flannelmouth suckers from this site was 39 Ag/g dwt. These data indicate that there is a potential for greater risk of reproductive impairment or failure for fish that utilize backwater habitats throughout this area that receive irrigation drainage as they may be sufficiently contaminated by selenium to be a hazard to fish.

Within the San Juan River itself, selenium concentrations in biota were elevated, however, not nearly to the extent as biota from the previously identified wetlands. In 12 of the 13 adult flannelmouth sucker samples, concentrations of selenium exceeded the 85th percentile concentration of selenium in sucker species collected for the National Contaminant Biomonitoring Program (NCBP). The median selenium concentration in San Juan River suckers was approximately two times higher than the 85th percentile concentration of suckers collected for the NCBP. Although the concentrations of selenium are elevated in flannelmouth suckers when compared to the NCBP, none of flannelmouth suckers from the San Juan River had sufficient amounts of selenium to impair reproduction.

Gila River Contaminants

Various trace elements exceeding the average for western soils has been reported along the Gila River. However, at the levels reported, none seem to be a threat to fishery resources. Copper (75.0 parts/million (ppm)) in sediments above Eden, Arizona and exceeded the average concentration (21 ppm) observed in western soils as reported by Schacklette and Boerngen (1984). Copper (53.0 ppm), nickel (29.0 ppm), and zinc (155.0 ppm) concentrations observed in sediments near Bylas, Arizona exceeds the average concentrations (21, 15, and 55 ppm, respectively) in western soils. Other trace elements are reported in water and soils but are at or below the averages for western soils.

**Salt River Contaminants**

The concentration of mercury (0.6 μg/l) observed in water from the Salt River exceeded the Arizona water quality standard for the aquatic and wildlife warmwater fishery (A&Ww) chronic toxicity limit (0.01 μg/l, dissolved). However, this concentration is below the A&Ww acute toxicity limit (2.4 μg/l, dissolved) and may not pose an acute threat to fishery resources.

Arsenic, chromium, copper, lead, mercury, and zinc concentrations observed in sediments in the Salt River exceeded the average concentrations (5.5, 41, 21, 17, 0.046, and 55 ppm, respectively) in western soils. The remaining trace elements in water and soils indicate their concentrations; however, they should not pose a threat to fishery resources.

There were semivolatile and volatile organics observed in soils at the Salt River from an unknown source. However, the levels observed should not pose any threat to fishery resources.

**Verde River Contaminants**

Studies in the middle reach of the Verde River have shown higher than expected concentrations of some contaminants. Arsenic (52 ppm), copper (184 ppm), lead (108 ppm), and zinc (226 ppm) concentrations observed in river sediments near Pecks Lake exceeded the average concentrations in western soils. Arsenic (40.4 ppm), chromium (40.8 ppm), copper (183 ppm), lead (53.1 ppm), nickel (43.4 ppm), and zinc (1,100 ppm) concentrations in river sediments near Tuzigoot National Monument exceeded the average concentrations in western soils. Copper (42.4 ppm) concentrations in sediments near Cottonwood exceeded the average concentration in western soils.

In the lower Verde River, arsenic (12.9 ppm), chromium (63.6 ppm), copper (36.5 ppm), and nickel (60 ppm) concentrations reported in sediments near Childs exceeded the average concentrations in western soils. Arsenic (20.3 ppm), copper (26.1 ppm), and nickel (29.7 ppm) concentrations reported in sediments from USGS stream gage 095040 and Beasley Flat exceeded the average concentrations in western soils.

Concentrations of some volatile organics (methylene chloride, acetone, and chloroform) reported in sediments from Cottonwood and Beasley Flat are from an unknown source. However, these concentrations should not pose any threat to fishery resources.

**Lower Colorado River Contaminants**

The concentration of lead observed in water from Kanab Creek exceeded the EPA criteria established for the protection of freshwater organisms (7.7 tig/1) at a water hardness of 200 mg/l.

The concentration of mercury in water from Havasu Creek (0.34 μg/g) exceeded the Arizona water-quality standard for the A&Ww chronic toxicity limit. However, this concentration is below the A&Ww acute toxicity limit and should not pose an acute threat to fishery resources.

The selenium concentration reported in sediments from Havasu Creek exceeded the average concentration in western soils. However, this concentration is below the level of concern ( 4 μg/g, DWT) in sediments for fish and wildlife (Lemly and Smith 1987).

The concentration of mercury in water from Parker Dam (0.1 ppm) exceeded the Arizona water-quality standard for the A&Ww chronic toxicity limit. However, this concentration is below the A&Ww acute toxicity limit and should not pose an acute threat to fishery resources.

Concentrations of endosulfan alpha, p,p'DDD, and heptachlor epoxide (pesticide organics) in water from the Poston Main Drain exceeded the Arizona water-quality standard for the A&Ww chronic toxicity limit (0.06, 0.02, and 0.004 μg/l, respectively). However, these observed levels are below the A&Ww acute toxicity limits and should not pose an acute threat to fishery resources.

Concentrations of organics observed from Kanab Creek, Topock Marsh, Palo Verde Main Drain, Imperial Oasis, and Poston Main Drain are from an unknown source. However, these concentrations should not pose any threat to fishery resources.

## MINING

The Basin has been the location of three major types of mining activities during the last 150 years, i.e. hard rock, coal, and aggregate. Hard rock and coal mining are primarily located in the mountainous headwaters or small tributary systems within the Basin. Potential impacts of these two mining activities to the four endangered fish are related to the water quality and depletion issues which were discussed in previous sections. Aggregate mining, and to a lesser extent placer mining (both commercial and recreational), have the potential to alter both water quality and physical habitat for these fishes. Within the Basin, aggregate mining activities located within the floodplain or instream are concentrated along the Colorado, Yampa and White Rivers in Colorado and the Salt River in Arizona. However, small local operations can occur virtually anywhere resource availability and land ownership allows. Aggregate mining activities are most often concentrated in areas of construction activity. For this reason, floodplains near urban centers are choice locations for aggregate mining. Major highway construction projects can create a temporary local demand for aggregate.

The potential impacts of floodplain or instream aggregate mining on fish habitat are the result of physical destruction of habitat and localized water quality reduction. The magnitude of impacts is related to the location, size of the mining operation, and reclamation plan. Instream mining often requires channelization or rerouting of the stream course to facilitate mining. Floodplain operations may require diking to prevent high flows from impacting operations. Both types of operations may impact important habitat for these fish. Instream mining activities could impact spawning areas and other habitat types located within the active channel. Floodplain operations may cutoff or excavate side channel and adjacent bottomland areas which provide important feeding and nursery habitat for squawfish and razorback suckers during high flows (Tyus 1990; Karp and Tyus 1990b).

Off channel impoundments and backwater areas are important habitats for razorback suckers (Bestgen 1990). Many of the off channel impoundments where razorback suckers have been collected were abandoned gravel pits. Such pits also have been used for propagation of razorback suckers for research purposes in the Upper Basin.

## CHANNELIZATION AND LOSS OF BOTTOMLANDS

Wick (1992) identifies wetlands and bottomlands as potentially important for razorback sucker feeding, staging or spawning sites for adults, and nursery areas for young fish. These wetlands and bottomlands also are important to various life stages of the Colorado squawfish and possibly humpback chub and bonytail. Historically, the Basin provided a variety of wetlands and other shallow water habitats in river reaches outside the steep canyons. River reaches crossing the open plains were more likely to be subject to human activities and have undergone greater physical changes than the canyon bound river reaches.

Construction and operation of dams and diversions have resulted in alterations to water flow (both levels and timing) that have had significant effects on wetland, floodplain, and riparian habitats. Channel degradation and lowering of the riverbed has frequently been reported (Lyons 1989), leading to the isolation or drying up of adjacent wetlands and riparian areas. The reduction in floodflows resulting from dam construction and operation and flood-protection projects also contribute to the isolation of wetlands from main river channels and reductions in floodplain size or extent. Wetlands are most productive when they connect hydrologically with the river (Brown et al. 1979). Wetlands isolated from the river cannot provide significant habitat for endangered fish if there is no access. With the reduction of normal floodflow levels due to flood control activities at major dams and levee construction, the size of flooded areas has decreased resulting in less nursery habitat for young fish and feeding habitats for adults.

Channelization in the Basin has been extensive, especially in valleys near human population centers and agricultural areas (Bestgen 1990). In the Upper Basin, Osmundson and Kaeding (1989) reported that many of the flooded pastures or oxbow lakes in the Grand Valley area, Colorado, have been filled in or isolated by dikes from the river. On the Green River, several waterfowl management units were created by building levees along the river and filling wetlands with water pumped from the river or from ditches. Reservoirs like Flaming Gorge drowned many miles of wetland and shallow-water habitats. There are still extensive reaches of Upper Basin rivers that have not been affected by channelization activities. In the Lower Basin, many large backwaters, sloughs, and oxbow lakes historically occurred along the Lower Colorado River. Between the towns of Needles and Topock at the lower end of the Mohave Valley, the river meandered through a large marsh with many lakes and sloughs (Beland 1953). Many other oxbow lakes and backwaters existed along the river down to the delta. Today, while much of the Colorado River below Davis Dam has been converted to reservoirs or dredged into straightened channels, a 1986 survey found approximately 400 natural and artificial backwaters remaining between Davis Dam and the Mexican border (Holden et al. 1986).

Many of the riparian and wetland habitats of the middle and lower Gila River and its tributaries, the Salt and Verde Rivers, have undergone significant changes resulting from channel modification. The upper reaches of these three rivers have been less altered by modifications. The Salt River above Roosevelt Lake has not been channelized and no large-scale diversions are currently made from the headwaters. The upper Gila and Verde segments have long areas of natural banks interspersed with areas channelized to protect agricultural and urban interests. Diversions occur at intervals along both rivers.

The spread of exotic plants, specifically tamarisk, has significantly altered the river channel. Graf (1978) reports the establishment of tamarisk on islands, sand bars, and shorelines of Canyonlands National Park has caused an average reduction of channel width of 27 percent. This reduction in channel width increased water velocities in the main channel and decreased the number of low velocity backwaters (Wick 1992). Changes in flow levels and timing also have contributed to silting in of important backwaters and low-velocity shorelines, enabling vegetation to become established and eliminating these areas' potential as endangered fish habitat. Tamarisk is found throughout the Basin, often in large, dense stands that choke out the native riparian vegetation.

Natural banks, floodplains, and associated wetlands continue to be lost in the Basin. The Clean Water Act-Section 404 regulations and the River and Harbors Act-Section 10 regulations provide some protection for these resources. However, losses to streambank stabilization projects, filling and dredging shallow-water habitats, sand and gravel extraction, and other actions are allowed under permit. Conversion of floodplain or bankside lands from agriculture to suburban or urban development eliminates opportunities to restore historic wetlands and floodplains.

## FISH REMOVAL PROJECTS

**With** the construction of Flaming Gorge and Navajo dams, western game and fish agencies were faced with two new large reservoirs to manage for sportfish. In order to reduce competition and predation, the use of rotenone to poison native and other non-game fishes prior to stocking of desired sport fish species was common. This method was chosen by fisheries managers at both the Flaming Gorge and Navajo reservoir sites.

The San Juan River project was initiated on September 7, 1961, by the Service, New Mexico and Colorado game and fish departments, with a defined purpose to "eliminate the present trash fish populations in the San Juan river and tributaries upstream from the dam site" (Olson 1962a). The intended treatment area included a total of 51 miles of water. A total of 3,870 gallons of rotenone was applied over a 48 hour period for the entire project. Olson reports a nearly total kill to Fruitland, New Mexico approximately 40 miles below Navajo Dam. This resulted in a total treatment area of nearly 75 miles. Fourteen species of fish were collected from the Pine and San Juan rivers including Colorado squawfish and a species of Gila identified as robusta but referred to as bonytail chub. It is likely that these fish were Gila robusta currently commonly called roundtails and a candidate for protection under the Act (Steve Platania, UNM, pers. comm.). No razorback suckers or humpback chubs were found. No estimate of total numbers killed was attempted, however, Olson reports that flannelmouth suckers and "bonytails" accounted for about one-half of the total numbers of fish found. The project did not utilize a detoxification station to limit the downstream spread of rotenone and there did not appear to be any concern with impacts outside of inundation zone target area. Olson (1962a, 1962b) indicates that the area of concern was the future reservoir site and recommended that any future eradication project not be initiated until the reservoir began impounding water. This recommendation reinforces the point that although there was little concern for native fish, the intent of the project was not to eradicate native fishes from the entire San Juan river. Nor was it believed that the magnitude of kill would permanently eliminate native fishes from the reservoir; their re-establishment was expected (Olson 1962b).

The Green River fish removal project was initiated on September 4, 1962, and was a joint effort of the Service, Utah Division of Wildlife Resources, and Wyoming Game and Fish Department. Holden (1991) has summarized the salient points of this project, its beginnings and aftermath. With regard to the intent, scope, and effects of the project Holden reports the following information.

The project was originally planned to take place coincident with closure of the dam, holding the rotenone until it detoxified. This would limit the poisoning to the reservoir basin. The dam was not ready for closure by fall of 1962, requiring the project to proceed without the benefit of holding the poison in the reservoir until detoxification. To prevent the rotenone from reaching Dinosaur National Monument 25 miles downstream, a detoxification procedure needed to be developed. Opposition and concern with the project came from several quarters spearheaded by the National Park Service (NPS) and the American Society of Ichthyologists and Herpetologists. Concern for rare native fishes in general and the humpback chub in particular was expressed by these entities. The project went ahead as scheduled and rotenone was added to the river at 55 stations over a three day period. Detoxification began on September 8, 1962 when rotenone was first detected passing the detoxification site. Due to various problems, detoxification was incomplete and the poison reached Dinosaur National Monument. NPS personnel reported dead and dying fish within the park on 13, 14, and 15 September. The poisoning of fish within the park elevated controversy about the project to Congress and the Secretary of the Interior. Then Secretary, Stewart Udal issued a directive which expressed concern with potential impacts to "unique species" and instructed the NPS and Service to conduct follow-up studies within the park. These studies found that the fish kill within the park was fairly minor.

As with the San Juan rotenone project, the principle goal on the Green River was to eliminate non-sport fish from the future reservoir basin. Considerable effort was expended to insure that impacts below the target area were minimized. It was also recognized that the eradication effort would not result in the permanent elimination of many target species, but was intended to give stocked game fish a "head start". The long term effects to native fishes of Flaming Gorge Dam and Reservoir were also recognized as the major impacts. Post project studies for both rotenone projects showed that, while detrimental to native fish populations, recolonization by native fishes was occurring.

## NONNATIVE FISHES

The geologic isolation of Basin rivers from other watersheds gave rise to a fish fauna in which 64 percent of the native species are found only in the Basin (Miller 1959). In addition to being unique, with only 36 species of native fish found in the Basin, the fish fauna is depauperate compared with other North American river basins (Carlson and Muth 1989). The native fish were adapted to the predevelopment aquatic conditions (e.g., variable flows, high sediment levels, fluctuating temperatures) found in the Basin. Because there were only a few different native fish species within a specific habitat, interspecies competition for the resources available was likely less intense (Tyus et al. 1982a; Carlson and Muth 1989).

The changes to Basin rivers resulting from human development activities had a major impact on the native fish species. Some native fish species, adapted to the highly variable aquatic environment of the predevelopment Basin, remained successful in the altered habitats. However, the creation of these altered habitats may have contributed to the establishment of many nonnative fish species into the Basin. Aggressive competitors, the nonnative fish species soon dominated most of the altered Basin habitats. The role of habitat alteration versus nonnative fish establishment in the decline of native fish populations is unclear. In river reaches less altered, native fish apparently compete more effectively with the nonnatives.

The introduction of fish species not native to the Basin began in the late 1800's. Table 11 lists nonnative fish species that have been found in the Basin. These fishes were introduced for a variety of reasons, including establishment of game fish populations, as forage for the game species, biological control of unwanted pests, aesthetic or ornamental purposes, release of unwanted pets or bait fish, and accidental releases (Taylor et al. 1984). Some of these introductions did not result in the species becoming established. Other introductions resulted in establishing a species throughout large areas of the Basin. Some species have been repeatedly stocked as part of recreational fisheries programs. Introductions have been made by Federal and State agencies, commercial enterprises, and private citizens.

Nonnative fish species have been implicated in the population reductions or elimination of native fish species from the Basin's aquatic habitats (Dill 1944; Osmundson and Kaeding 1989; Behnke 1980; Joseph et al. 1977; Minckley and Deacon 1968; Meffe 1985; Propst and Bestgen 1991; Rinne 1991; and others). Both the larger species such as Colorado squawfish

Table 11. List of common names of nonnative fishes introduced at some time within the Colorado River Basin. * These fish continue to be stocked by Federal, State, and Tribal agencies. Information obtained from Popov and Low (1950); Minckley (1973); Tyus et al. (1982); Wiltzius (1985); Persons (1992).

Acipenseridae
White sturgeon

Anguillidae
American eel

Clupeidae
Threadfin shad

Salmonidae
Chum salmon
Coho salmon
Sockeye salmon
Bonneville cisco
Golden trout
Yellowstone cutthroat
Bonneville cutthroat
Snake River cutthroat
Rainbow trout*
Brown trout*
Brook trout*
Lake trout
Artic grayling*
Splake*
Tiger trout
Cutbow trout

Esocidae
Northern pike

Characidae
Mexican tetra

Cyprinidae
Goldfish
Grass carp*
Common carp
Utah chub
Leatherside chub
Brassy minnow
Plains minnow
Golden shiner
Creek chub
Red shiner
Sand shiner
Fathead minnow*
Longnose dace
Redside shiner*
Bonneville redside shiner

Catostomidae
Utah sucker
Longnose sucker
White sucker
Smallmouth buffalo
Bigmouth buffalo
Black buffalo

Ictaluridae
Blue catfish
Black bullhead
Yellow bullhead
Brown bullhead
Channel catfish*
Flathead catfish
Walking catfish

Cyprinodontidae
Plains killifish

Poeciliidae
Mosquitofish
Sailfin molly
Green swordtail
Southern platyfish
Variable platyfish

Percichthyidae
White bass
Yellow bass
Striped bass

Centrarchidae
Green sunfish
Pumpkinseed
Bluegill
Redear sunfish*
Smallmouth bass*
Largemouth bass*
White crappie
Black crappie*

Percidae
Iowa darter
Johnny darter
Yellow perch
Walleye*

Cichlidae
Blue tilapia
Mozambique tilapia
Zilli's tilapia

(Osmundson 1987) and razorback sucker (Jonez and Sumner 1954; Minckley 1983; Brooks 1985; Marsh and Brooks 1989; and others) and the small species such as Gila topminnow (Meffe et al. 1983) have been adversely affected by the introduction of the nonnative fish species to the Basin. The impact of nonnative fishes has had an adverse impact on the endangered fishes throughout the Basin. In many areas within the Basin, it is the primary factor for lack of recovery of these species.

Nonnative fish species compete with native fish species in several ways. Physical and biological factors in the environment regulate the capacity of a particular area to support aquatic life. Living space and food resources are the primary limiting factors. Because the amount of physical habitat available is finite, increasing the number of species present in the habitat usually equates to smaller populations of most species. The size of each species population in the system is controlled by the ability of each life stage to compete for living space and food resources. The species better adapted to the physical features of the habitat would likely be a better competitor against less well adapted species and thus have larger populations. The role of habitat alteration in nonnative fish establishment in the decline of native fish populations is unclear. In river reaches less altered, native fish appear to be able to compete more effectively with the nonnatives.

While physical habitat parameters have an influence on the ability of a species to compete against other species, the evolutionary history of both species also plays an important role. Species that developed in river basins supporting large numbers of species are usually more aggressive and successful competitors than species from depauperate basins. As discussed previously, the Basin fish fauna is a depauperate one and competition was limited. Most of the introduced nonnative fish species are from basins with larger and more varied fish faunas and evolved in very competitive environments.

Nonnative fish may physically compete with native species through direct predation, harassment, or the introduction of diseases or parasites. Predation, especially on egg, larval and juvenile stages, is a significant factor in determining population survival through the effects to recruitment. Spawning adults of the four Colorado River endangered fish can be found during the breeding seasons. Actual spawning has been documented for all species, and larvae have also been found. Yet recruitment of juveniles into the populations is very low. Predation on razorback sucker eggs and larvae by channel catfish, green sunfish, and carp has been observed (Medel-Ulmer 1983; Minckley 1983; Langhorst 1987; Marsh and Langhorst 1988). Marsh and Brooks (1989) observed predation on introduced larvae and juvenile razorback suckers by channel catfish and flathead catfish in the Gila River. Observations of spawning bonytails in the newly closed Lake Mojave included observations of carp following closely behind the spawning chubs (Jonez and Sumner 1954). Kaeding and Zimmerman (1983) and Tyus and Karp (1990) observed scars and wounds on humpback chub and attributed them to attempted predation by channel catfish. Continuing stocking of nonnative predatory fish increases the risk or level of predation on the endangered fish.

Changes to the local fish fauna from the introductions of nonnative species alters the species available to the native species as prey. Adverse effects may result from the elimination or reductions to the historic prey base for the piscivorous species such as Colorado squawfish. Native fish species that coevolved with the predatory Colorado squawfish have physical characteristics, behaviors, and patterns of habitat use that the predator is familiar with. Non-native fish, evolved with a different set of predators, likely do not exhibit the same characters as the native prey species. Difficulty in locating or utilizing the altered prey base and changes to prey abundance during critical periods (e.g., if young-of-year of a predatory native fish depended upon another species reproducing at a time that provides the predator with an abundant food resource) is the likely result of the replacement of native species by less suitable nonnatives. Even if nonnatives are available, their morphology may affect their suitability as prey. Mortality of Colorado squawfish from choking on channel catfish has been reported (McAda 1983; Pimental et al. 1985). The habit of the channel catfish to erect the dorsal and pectoral spines when threatened causes it to become lodged in the throat of the native predator. No native prey species has this type of defensive behavior.

The other potential effects to native fish from nonnative species are more difficult to quantify. Harassment of native species by nonnative fish can include territorial or other agonistic attacks that disrupt sheltering, breeding or feeding behavior or the elimination of habitat features (e.g., aquatic vegetation) utilized by the native species. Karp and Tyus (1990b) found that some small species of nonnative fishes competed with young squawfish even though they did not directly prey on them. These types of actions make it more difficult for the native fish to successfully utilize a specific habitat, thus contributing to declines in or the local extinction of the population.

The role of nonnative fish introductions in the spread of new diseases and parasites in the Basin has not been fully evaluated, but some work has been done. In the Virgin River, the Asian tapeworm contributed to recent declines in woundfin populations. The tapeworm is not native to the Virgin River and is thought to have arrived with the nonnative red shiner (Heckmann et al. 1986). The spread of the parasite Lernea sp. in the Basin is very likely the result of nonnative introductions.

The continued stocking of nonnative fish, even those already established in the Basin, continues to adversely affect the native fish species. The stocking may enable a species to maintain a higher population level than the habitat could support, increasing the effectiveness of competition against the native species. In cases where natural events such as drought or floods have reduced nonnative fish populations, stocking allows them to regain pre-event population levels faster than would occur naturally. This may suppress native fish recovery in the area. There is considerable interest in stocking different strains of nonnative sport fish to improve the recreational fishery. Some strains may be better than others at adapting to local conditions or be a more successful competitor with the native fish. Introductions of fish species not found in the Basin or in the specific area of the Basin under review is equally inappropriate for native fish management. The new species may or may not have direct effects to the native fish species; it may also affect, positively or negatively, the populations of the nonnative species already present.

## RECREATION

The rivers and reservoirs of the Basin provide a variety of recreational opportunities. Plans covering water-based recreation are included in management documents for Federal lands managed by the National Park Service, Forest Service, Bureau of Land Management, and the Service. Additional recreation planning takes place on State Park lands. Privately owned recreation sites using Basin rivers or reservoirs also are found in some areas. Private companies also may contract with a Federal or State land management agency to provide certain recreational opportunities on those lands. Water-based recreation is a component of the Basin economy that is aggressively marketed by State and local tourism agencies. Some of the Basin's opportunities are well-known nationally and internationally.

Water-based recreation includes a variety of recreational opportunities. River-running in small boats, kayaks, or rafts is popular in several areas. Rafting down the Colorado River through the Grand Canyon is perhaps the most famous river trip. River rafting is not limited to wild or undeveloped reaches. Commercial rafting operations also exist on the Colorado and Green Rivers in Utah and the Salt River in Arizona in addition to other locations in the Basin. On the reservoirs, privately owned or rented houseboats, powerboats, sailboats and jet skis support the heavy recreational use of these facilities. Swimming and waterskiing are common activities.

Wildlife observation, hunting, and fishing opportunities are an important component of the recreational resource of the Basin. State waterfowl areas and National Wildlife Refuges protect wetland habitats for migratory waterfowl and provide seasonal hunting opportunities. These areas also provide opportunities for observing wetlands dependent birds, a popular recreational pastime. In addition to the more common species, opportunities to observe endangered species such as bald eagle, peregrine falcon, Yuma clapper rail, and other listed and candidate species contributes to the quality of the experience.

The introduction of nonnative game fish to the Basin provided familiar fish species for the recreational fisherman. The trophy sport fisheries that developed at Lake Mead and below Hoover, Glen Canyon, Flaming Gorge, and the Aspinall Unit dams were/are internationally known and attracted considerable angler interest. Fishing contributes a significant portion of the recreational use of the Basin's waters. Recreational fishing occurs throughout the rivers and reservoirs of the Basin and is often a part of the boating or rafting experience. State and Federal agencies expend considerable effort to create, maintain, or enhance the recreational fishing opportunities of a reservoir or river reach. The variety of fisheries available (cold water to warmwater; trophy to casual fishing) attracts more recreationists to the Basin than a single type sport fishery might.

Designation of critical habitat for the Colorado River endangered fish may have some management implications for some types of water-based recreation in the Basin. The majority of these effects are not expected to be significant and there are likely to be both adverse and beneficial effects to recreation opportunities from the designation. Adjustment of management documents may be needed to incorporate habitat protection measures, such as seasonal human use restrictions for known spawning areas and recovery efforts the Federal agency may wish to implement. Boating, rafting, water skiing, and similar recreational activities would not likely see any adverse impacts and may receive some benefits from possible changes in reservoir operations. Waterfowl hunting and wetland associated wildlife observation also may benefit from the protection and enhancement of wetland areas in critical habitat reaches. Sport fish management may be affected by the designation of critical habitat, but it is not expected that these effects would result in the elimination of this recreational resource in the Basin. Historically, the Colorado River endangered fish were a part of the fishery. Even today, Colorado squawfish are caught by fishermen on the Yampa River, and bonytail are occasionally taken from Lake Havasu. Adjustments to management of the fishery resources of the Basin to provide opportunities for the Colorado River endangered fish to reproduce, recruit, and grow successfully while maintaining a viable sport fishery are likely to be made. Successful restoration of Colorado River endangered fish populations in the critical habitat reaches may, in the long term, enhance the recreational fishing experience, by adding fish species found nowhere else to the fishery.

Recreation may have both direct and indirect effects on the habitat for the Colorado River endangered fish. Construction of facilities (e.g., campgrounds, launch ramps, marinas, and lakes) may physically alter habitat features. Shorelines are especially affected, thus the shallow water areas in those areas become less available to the fish. Discharge of treated or untreated sewage effluent alters the nutrient load of an area, and spills of petroleum products and other contaminants results in degradation of water quality. Other physical effects include construction of levees or channelizing portions of rivers to protect facilities and dredging of shallow backwaters and side channels to provide boating access.

Indirect effects are equally important. As discussed earlier, the introduction of nonnative fish species for the recreational fishery has had significant adverse effects on the native fish populations. Management of lakes, reservoirs and riverine areas to encourage expansion of the nonnative fish populations is widespread in the Basin.

Maintaining flows for life history requirements at certain times of the year also may benefit both recreational opportunities and endangered fish populations. Providing for recreational rafting also may enable better management for the native fish if attempts to restore the natural hydrograph provide benefits for both.

Overall, recreational activities have both adverse and potentially beneficial effects to endangered fish habitats. Most recreational activities have a limited effect on the physical habitats. Effects to the biological environment are much greater.

## ONGOING RECOVERY EFFORTS

### UPPER BASIN

The Colorado River Recovery Implementation Program (RIP) is an interagency consortium of Federal, State, and private groups, whose goal is to recover endangered fish in the Upper Basin (excluding the San Juan River). The RIP was formally executed in January of 1988 by the Secretary of Interior, the Administrator of Western Power, and the Governors of Colorado, Utah, and Wyoming. Major participants in these recovery efforts are the Service, Reclamation, Western, the States of Colorado, Utah, and Wyoming, Colorado Water Congress, Utah Water Users Association, Wyoming Water Development Association, National Audubon Society, Environmental Defense Fund, Colorado Wildlife Federation, Wyoming Wildlife Federation, and the Colorado River Energy Distributors Association. Recovery elements of the RIP include: (1) habitat management; (2) habitat development and maintenance; (3) stocking of rare fish species; (4) nonnative species and sportfishing; and (5) research and monitoring. The RIP was designed to function as a reasonable and prudent alternative to offset depletion impacts of water projects.

Over the RIP's projected 15-year term, the budget is expected to total $80-$130 million. An annual operating budget of $2.5 million is contributed by the Service, Reclamation, the States of Colorado, Utah and Wyoming, and water development groups. In addition, Congressional appropriations can be requested through the RIP. Approximately $18-$50 million is projected as needed to acquire water and water rights to implement and maintain adequate instream flows for fish, and $32-$50 million is needed for capital construction projects. RIP funds are being used to identify and acquire adequate instream flows and refine operations of Reclamation dams to meet instream flow needs of fish. Flaming Gorge Reservoir is being reoperated to provide higher spring flows and lower, more stable flows in the remainder of the year. The Aspinall Unit (Gunnison River) is being reoperated to provide research flows. The RIP participants are addressing how existing Colorado law might be used to protect flows. Reclamation is evaluating opportunities for acquisition, restoration, and management of bottomlands along the Green and Colorado Rivers. Research has identified the need to open up access to historic habitats by constructing fish passageways and restoring and managing flooded bottomlands. Researchers are developing ways to identify and maintain genetic stocks of native fish and evaluating the feasibility of constructing a facility to raise and provide "refuge" for endangered fish. Refuge ponds at Horsethief State Wildlife Area, Grand Junction, Colorado, have been developed and are in operation. A genetics management and research facility currently protecting genetics stocks of razorback sucker is operating on the Ouray National Wildlife Refuge on the Green River near Vernal, Utah. Conflicts over the stocking and introduction of nonnative fishes remain unaddressed. However, a policy on stocking of nonnatives is being developed by the Service and the States. Long-term monitoring programs are established to monitor native and nonnative fish populations and to examine competition and predation between the two groups.

As a result of reasonable and prudent alternatives provided in the October 25, 1991, Biological Opinion issued by the Service on the Animas-LaPlata Project, Reclamation agreed to fund 7 years of research and develop a recovery implementation program for the San Juan River. On October 24, 1991, a Memorandum of Understanding was executed by the Service, Reclamation, Bureau of Indian Affairs, States of Colorado and New Mexico, the Ute Mountain Indian Tribe; the Southern Ute Indian Tribe; and the Jicarilla Apache Indian Tribe, to set forth certain agreements and to establish a San Juan Recovery Implementation Program (SJRIP). The SJRIP provides the basis for the recovery of the endangered fishes of the San Juan River. Activities conducted under this RIP will be closely coordinated with the ongoing Upper Basin RIP. The San Juan subbasin was not included in that program.

The 7-year research effort focuses on observing a biological response in the endangered fish population and habitat condition to the reoperation of Navajo Dam to meet the needs of Colorado squawfish and razorback sucker. The recovery elements define the major categories of activities that will be conducted to recover endangered fish species and maintain the native fish community in the San Juan Basin. Intensive studies are being conducted by the SJRIP to determine the relative abundance and distribution of endangered fishes, other natives, and nonnative fishes. Modification and loss of habitat, fish poisoning, and nonnative fishes have contributed to the decline of the Colorado squawfish and razorback sucker in the San Juan Basin. Regulating structures such as Navajo Dam can be operated to control river flow and temperatures to affect the quantity and quality of habitats in certain river reaches during periods when they are most critical to endangered fish species. After determining appropriate flow needs, the Biology Committee, with input from Reclamation, will recommend specific flow regimes to the Service. It is anticipated that the source water for habitat improvement will be derived primarily from the reoperation of Navajo Dam.

Based upon the results of the research, Reclamation has agreed that it will operate Navajo Dam to mimic a natural hydrograph, provided that research shows this type of hydrograph is beneficial to recovery of endangered species. If habitat flow needs are identified that cannot be met by reoperation of Navajo Dam, additional potential sources of water to meet those needs will be identified on a case-specific basis. The success of this RIP is contingent upon the legal protection of water released for habitat flows pursuant to Federal, State, and Tribal laws.

<u>LOWER BASIN</u>

To date, 15 years of research and $18 million have been spent in fish stocking and research on these fish in the Lower Basin. A combined research and management effort continues in the Lower Basin. This effort involves researchers from Arizona State University, Arizona Game and Fish Department, Nevada Department of Wildlife, California Fish and Game Department, Reclamation, Bureau of Land Management, and the Service. These groups are currently developing protected grow-out areas in lakes Mohave and Havasu for razorback sucker and bonytail. To date, this effort has shown great potential. Additionally, there was also a 10-year effort to restore razorback suckers and Colorado squawfish into the Gila River drainage.

An extensive research program has been initiated as part of the Glen Canyon Environmental Studies (GCES) to determine life history and ecology of the humpback chub in the Grand Canyon. The humpback chub was one of the initial species listed under the Act. In 1978, the Service issued a jeopardy Biological Opinion on the existing operation of Glen Canyon Dam, but needed further research to determine what actions are needed to benefit the listed fish. At that time, limited information existed on the distribution, abundance, life history, and habitat use for the Grand Canyon populations in the Colorado River mainstem and its associated tributaries. The inception of these studies is an outcome of the initial GCES/Phase I effort and Service conservation measures developed as part of long-term recovery effort for the species. The research program involves a coordinated effort among four principal entities (Arizona State University, Arizona Game and Fish Department, Reclamation, and the Service), each addressing specific study objectives. This program is part of the short-term experimental research for the Glen Canyon Dam Environmental Impact Statement (EIS). A commitment to a long-term research and monitoring program exists and will function as a conduit for the culmination of additional information generated through the endangered species research.

## BIODIVERSITY AND ECOSYSTEM CHANGE

One important factor to consider when designating critical habitat is the effects the added protection might have on other species within designated reaches. Species within an ecosystem affect each other directly and indirectly. The decrease in Colorado River endangered fish populations changed the composition of the Basin ecosystem affecting other species within the Basin. According to Cairns and Lackey (1992), a decrease in population and species diversity leads to a decrease in genetic diversity. This, in turn, has adverse affects on ecosystems. In addition to a loss of genetic diversity, factors which contributed to the decline of the Colorado River endangered fish also may adversely affect other native species in the Basin. The establishment of critical habitat for the Colorado River endangered fish will protect many other species in the Colorado River basin, either by direct protection of habitat or the indirect, but equally valuable, preservation of native biodiversity within the Basin.

The term biodiversity is relatively new, but the concept has been known for decades. As early as the 19th century, biologists were discussing the need to protect the diversity of life (Marsh 1964; from Cairns and Lackey 1992). Alternatively described as "the degree of nature's variety" (McNeely 1988) and "the variety of life and its processes" (Hughes and Noss 1992), biodiversity is a concept which encompasses the totality of the natural environment. Biodiversity can be recognized at four distinct levels (1) genetic biodiversity, or the size and fitness of the gene pool; (2) species biodiversity, or the number and frequency of species; (3) ecosystem biodiversity, or the variety of communities and habitats, and; (4) landscape biodiversity, or the spatial heterogeneity of ecosystems (Noss 1983; Norse et al. 1986).

Biodiversity is an important factor in any healthy ecosystem. The richer the diversity within an ecological community, the healthier the community. Diverse ecosystems are better able to adapt to a variety of disturbances. They have a larger genetic pool and are less susceptible to disease and other detrimental effects. Communities which are homogenetic or have lost genetic diversity, are much more susceptible to outside influences. Ecosystems which have lost much of their biodiversity cannot easily adapt to change. Individual species within such ecosystems are at a much higher risk of extinction.

Besides the ecological and biological reasons for protecting biodiversity, there are ethical and economic considerations as well. New crops, medicines, and commercial products are being discovered regularly. The destruction of species and genetic diversity may prevent future discoveries in the agricultural and medical fields. In addition, most biologists argue that other species have an inherent right to exist. This ethical argument is discussed by Erlich and Erlich (1981) and Taylor (1986).

The Colorado River basin was once a healthy, diverse ecosystem. An important feature of the Basin was its intrinsic variability. Due to its size, there was a wide variety of habitat and several different animal and plant communities, ranging from cool mountain headwaters to warm desert springs. Small tributaries combined to form large rivers that became constrained by deep canyons or meandered across wide floodplains. Along the rivers were lakes, marshes, and other wetlands, supporting many species of fauna and flora. The Colorado River has been described as an "aquatic island in a terrestrial sea" (Molles 1980). Many types of forest and desert communities existed within the Basin, dependent on the water from the Colorado River and its tributaries. The sheer size of the Basin, in conjunction with the variety of habitats, allowed for the evolution of a diverse number of species, many endemic to their area. Changes in the geologic structure of the Basin also contributed to the isolation of species and added to the diversity within the basin.

Until recently, the Basin supported a diverse assemblage of flora and fauna. There are (were) 36 species of fish native to the Basin (Carlson and Muth 1989). Twenty-three (64%) of these are endemic to the Basin (occur nowhere else). Only eight fish species are common to both the Upper and Lower basins. Of these, four are listed as endangered and two are candidates for listing. Historically, the Gila River drainage contained the greatest number of native fishes. The riparian and wetland areas along the Colorado and its tributaries provided habitat for invertebrates, amphibians, reptiles, birds, and mammals. These riparian areas also provided forage and resting areas for migratory waterfowl and neotropical songbirds. The canyons of the Colorado River system are home to predatory birds, including the bald eagle and peregrine falcon. All of the species in the Basin had adapted to the sometimes harsh and unpredictable environment caused by the fluctuations in the rivers and streams.

This rich diversity of habitats and native species communities have been seriously impacted by actions of humans (anthropogenic). These anthropogenic changes have resulted in a dramatic alteration of the natural structure, function, and composition of the Basin. Prior to major dam construction on the Colorado River, tamarisk (referred to as salt cedar) was introduced into the Basin (Graf 1985). Its establishment in the basin was encouraged by destruction of the riparian area resulting from overgrazing and harvest of fuel wood. The development and operation of dams, diversions, and other water-control structures fragmented the river into discrete sections, preventing the movement of migratory Colorado squawfish and other fish. These dams also altered river levels, preventing the large fluctuations in water levels which most fish species had adapted to. Changes to water temperature regimes resulting from dam operation also altered habitat. Channelization destroyed or simplified habitats. The de-watering, or conversely, the lack of flooding of low-lying areas along the waterways destroyed riparian habitat essential to many natives. Desert-dwelling species were affected by drying of small springs, cienegas and streams. Less than 1 percent of the historical flow of the Colorado River now reaches its delta in Mexico. Twelve percent of the annual flow is lost from the Basin due to evaporation, primarily from reservoirs (Graf 1985).

Recreational activities, such as fishing, camping, boating, and four-wheel driving, have further negatively impacted rivers and riparian habitat. The remaining natural habitat is seriously degraded, confined to isolated areas often without corridors between the various fragments to allow for free movement of mobile species. According to the island biogeography theory, these fragmented areas tend to contain a smaller diversity of native species than would be found in unfragmented habitat.

Introductions of nonnative fauna and flora to the Basin has profoundly altered the existing faunal assemblages. For example, the bullfrog is a known predator of small fish, tadpoles, small frogs, and snakes. Native leopard frogs are at risk, as are garter snakes. Introduced plants such as water hyacinth can choke up backwaters or spring ponds and eliminate aquatic habitats. Salt cedar replaces cottonwoods and willows in disturbed riparian zones. Unlike the native trees, the salt cedar does not provide the variety of arboreal habitats needed by resident and migratory birds. Alteration of the riparian flora also may have affected surface and shallow water flows. Studies have shown that tamarisk respires more water than the cottonwood-willow stands it has replaced, thus changing the amount of water in a particular stream or wetland.

Designation of river reaches as critical habitat for the Colorado River endangered fishes throughout the Basin will provide protection for many of these remaining natural areas. The impact would reach far beyond these four fish species, protecting habitat for other species listed under the Act (see Appendix B). For these other species, this designation may complement ongoing recovery actions and support Section 7 consultations, leading to improved conditions for all species. By protecting the habitats of candidate species, conflicts between these species and development may be lessened, reducing the urgency to list some species. The protection afforded to wetlands and riparian areas supports efforts being made for waterfowl, neotropical songbirds, and local wildlife management needs.

The richness and abundance of native plants and wildlife in the Basin depends largely on the ecosystem unity. Further fragmentation of the Basin may result in additional native species becoming threatened or endangered. Critical habitat designation for the Colorado River endangered fish also may decrease the amount of disturbances within the Basin, allowing for an increase in native species diversity. Protection of critical habitat for the Colorado River endangered fishes and the ecosystems they inhabit may prevent the listing of other species that depend on the same habitat, thereby reducing future economic costs of listing species and critical habitat designations. If these other species' habitats are adequately protected as a result of designating Colorado River endangered fish critical habitat, the need for future listings will be reduced. Thus, the designation of critical habitat for these four fish protects the diversity of species in the Basin, prevents further fragmentation of natural areas, protects unique ecosystems, and promotes the conservation of other plants and animals.

## LITERATURE CITED


Abbott, C.C. 1861. Descriptions of four new species of North American Cyprinidae. Proceedings of the Philadelphia Academy of Natural Sciences 12(1860):473-474.

Allan, R.C., and D.L. Roden. 1978. Fish of Lake Mead and Lake Mohave. Biological Bulletin No. 7. Nevada Department of Wildlife, Reno. 105 pp.

Andrews, E.D. 1986. Downstream Effects of Flaming Gorge Reservoir on the Green River, Colorado and Utah. Geological Society of America Bulletin, v. 97, pp. 1012-1023.

Andrews, E.D. 1990. Sediment transport in the Colorado River basin. Pages 54-74 in Colorado River ecology and dam management, proceedings of a symposium, May 24-25, 1990, Santa Fe, New Mexico. National Academy Press, Washington, D.C.

Archer, D.L., L.R. Kaeding, B.D. Burdick, and C.W. McAda. 1985. A study of the endangered fishes of the Upper Colorado River. Final Report - Cooperative Agreement 14-16-0006-82-959. U.S. Department of the Interior, Fish and Wildlife Service, Grand Junction, Colorado. 134 pp.

Archer, D.L., L.R. Kaeding, and H.M. Tyus. 1986. Colorado River Fishes Monitoring Project, Final Report. U.S. Fish and Wildlife Service, Lakewood, Colorado.

Archer, D.L., and H.M. Tyus. 1984. Colorado squawfish spawning study, Yampa River. U.S. Fish and Wildlife Service, Colorado River Fishery Project, Salt Lake City, Utah. 34 pp.

Archuleta, A.S., R. Krueger, L. DeWeese, and B. Osmundson. 1993. Occurrence of Inorganic Elements In the Upper Colorado River Basin and Implications For Threatened and Endangered Fish. U.S. Fish and Wildlife Service, Colorado Field Office, Environmental Contaminants Final Report (in preparation).

Arizona Game and Fish Department. 1993. Glen Canyon Environmental Studies Phase II. Annual Report to Bureau of Reclamation. Cooperative Agreement No. 9-FC-40-07940. Phoenix.

Baird, S.F., and C. Girard. 1853. Fishes. Pages 148-152 in Capt. L. Sitgraves, Editor. Report of an expedition down the Zuni and Colorado Rivers. Washington, D.C.: U.S. Senate, Executive Document 59, 33rd Congress., 2nd Session.

Banks, J.L. 1964. Fish species distribution in Dinosaur National Monument during 1961 and 1962. M.S. Thesis, Colorado State University, Fort Collins. 96 pp.

Bartlett, J.P. 1854. Personal narrative of exploration and incidents in Texas, New Mexico, California, Sonora, and Chihuahua, connected with the U.S. and Mexican Boundary Commission during the years of 1850, '51, '52, and '53, Vols. 1 and 2. New York: D. Appleton.

Baxter, G.T., and J.R. Simon. 1970. Wyoming fishes. Bulletin No. 4. Wyoming Game and Fish Department, Cheyenne.

Beckman, W.C. 1952. Guide to the Fishes of Colorado. Colorado Fish and Game Department, Denver. 110 pp.

Behnke, R.J. 1980. The impacts of habitat alterations on the endangered and threatened fishes of the upper Colorado River basin: A discussion. Pages 182-192 In W.O. Spofford, Jr., A.L. Parker, and A.V. Kneese, Editors. Energy development in the Southwest: Problems of water, fish and wildlife in the upper Colorado River basin, Vol.2. Resources for the Future, Research Paper R-18. Washington, D.C.

Behnke, R.J., and D.E. Benson. 1980. Endangered and threatened fishes of the Upper Colorado River Basin. Cooperative Extension Service, Colorado State University, Fort Collins. Bulletin 503A. 34 pp.

Beland, R.D. 1953. The effect of channelization on the fishery of the Lower Colorado River. California Fish and Game 39:137-139.

Bestgen, K.R. 1990. Status Review of the Razorback Sucker, Xyrauchen texanus. Larval Fish Laboratory Report #44. Colorado State University, Ft. Collins.

Binns, N.A. 1965. Effects of rotenone treatment on the fauna of the Green River, Wyoming. Masters thesis, Oregon State University, Corvalis, Oregon.

Binns, N.A. 1967. Effects of rotenone treatment on the fauna of the Green River, Wyoming. Wyoming Game and Fish Commission, Fisheries Technical Bulletin 1:1-114.

Binns, A., F. Eiserman, F.W. Jackson, A.F. Regenthal, and R. Stone. 1963. The planning, operation, and analysis of the Green River Fish Control Project. Utah State Department of Fish and Game and Wyoming Game and Fish Commission. 83 pp.

Binns, A., F. Eiserman, R.W. Jackson, A.F. Regenthal, and R. Stone. 1964. The planning, operation and the analysis of the Green River Fish Control Project. Utah State Department of Fish and Game and Wyoming Game and Fish Commission.

Blanchard P., R. Roy, and T. O'Brien. 1993. Reconnaissance Investigation of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the San Juan River Area, Northwest New Mexico 1990-91. U.S. Geological Survey Water-Resources Investigation Report.

Boner F.C., A.D. Koniexzki, and R.G. Davis. 1991. Water Resources Data, Arizona Water Year 1990. USGS Water Data Report AZ-90-1, Phoenix.

Bosley, C.E. 1960. Pre-impoundment study of the Flaming Gorge Reservoir. Wyoming Game and Fish Commission Technical Report 9, pp. 1-81.

Bozek, M. A., L.J. Paulson, and J.E. Deacon. 1984. Factors affecting reproductive success of bonytail chubs and razorback suckers in Lake Mohave, Final Report, 14-16-0002-81-251. Bureau of Reclamation, Boulder City, Nevada.

Branson, B.A., M.E. Sisk, and C.J. McCoy, Jr. 1966. Ptychocheilus lucius from the Salt River, Arizona. The Southwestern Naturalist 11, 301.

Brooks, J.E. 1985. Factors affecting the success of Gila topminnow (Poeciliopsis o. occidentalis) introductions on four Arizona National Forests. Annual Report to the Office of Endangered Species, U.S. Fish and Wildlife Service. Arizona Game and Fish Department, Phoenix, Arizona.

Brooks, J.E. 1986. Annual reintroduction and monitoring report for razorback sucker (Xyrauchen texanus) in the Gila River basin, Arizona, 1985. Arizona Game and Fish Department, Albuquerque, New Mexico. 22 pp.

Brown, S., M.S. Brinson, and A.E. Lugo. 1979. Structure and function of riparian wetlands. Pages 17-31 In R.R. Johnson and J.F. McCormick, technical coordinators. Strategies for protection and management of floodplain wetlands and other riparian ecosystems. Publ. GTR-WO-12 U.S. Forest Service, Washington D.C. 410 pp.

Bulkley, R.V. and R. Pimental. 1983. Temperature preference and avoidance by adult razorback suckers. Transactions of the American Fisheries Society 112:601-607.

Burdick, B.D. and L.R. Kaeding. 1985. Reproductive ecology of the humpback chub and the roundtail chub in the Upper Colorado River. Proceedings of the Annual Conference of Western Association of Game and Fish Agencies. 65:163 (abstract).

Burdick, B.D. and L.R. Kaeding. 1990. Biological Merits of Fish Passage as Part of Recovery of Colorado Squawfish in the Upper Colorado River Basin. Final Report. U.S. Fish and Wildlife Service. Grand Junction, Colorado. 23 pp.

Burdick, B.D. 1992. A plan to evaluate stocking to augment or restore razorback sucker in the upper Colorado River. USFWS, Grand Junction, Colorado. 56 pp.

Burke, T. 1992. Agency report: Bureau of Reclamation, Lower Colorado Region. Pages 12-14 in D.E. Hendrickson, editor, 1992 annual symposium, 18-21 November. Proceedings of the Desert Fishes Council XXIV.

Buth, D.G., R.W. Murphy, and L. Ulmer. 1987. Population differentiation and introgressive hyridization of the flannelmouth sucker and of hatchery and native stocks of the razorback sucker. Transactions of American Fisheries Society. 116:103-110.

Cairns, M.A. and R.T. Lackey. 1992. Biodiversity and management of natural resources: the issues. Fisheries 17(3): 6-10.

Carlson, C.A., and R.T. Muth. 1989. The Colorado River: lifeline of the American Southwest. Pages 220-239 in D.P. Dodge, Editor. Proceedings of the International Large River Symposium. Canadian Special Publication, Fisheries and Aquatic Sciences, 106.

Carlson, C.A., G.G. Prewitt, D.E. Snyder, E.J. Wick, E.L. Ames, and W.D. Frank. 1979. Fishes and macroinvertebrates of the White and Yampa Rivers, Colorado. U.S. Bureau of Land Management, Biological Science Series No. 1, Denver, Colorado. 276 pp.

Carlson, L.W. 1991. Yampa River Oil Spill Final Report. U.S. Fish and Wildlife Service letter to Amoco Pipeline Company. Grand Junction, Colorado. 5 pp.

Carothers, S.W. and B.T. Brown. 1991. The Colorado River Through Grand Canyon - Natural History and Human Change. University of Arizona Press, Tucson, Arizona. 235 pp.

Carothers, S.W. and C.O. Minckley. 1981. A survey of the fishes, aquatic invertebrates and aquatic plants of the Colorado River for selected tributaries from Lees Ferry to Separation Rapids. U.S. Bur. Reclam. contract 7-07030-00026. Museum of Northern Arizona, Flagstaff, Arizona.

Chamberlain, F.W. 1904. Unpublished field notes on file at Smithsonian Institution, Washington, D.C. 70 pp.

Chamberlain, T.K. 1946. Fishes, particularly the suckers, Catostomidae, of the Colorado River Drainage and of the Arkansas River drainage, in relation to the Gunnison-Arkansas transmountain diversion. U.S. Fish and Wildlife Service, College Station, Texas.

Coleman, G.A. 1929. A biological survey of the Salton Sea. California Fish and Game 15:218-227.

Cope, E.D. and H.C. Yarrow. 1875. Reports upon the collections of fishes made in portions of Nevada, Utah, California, Colorado, New Mexico, and Arizona during the years 1871, 1872, 1873, and 1874. Report of the Geographic and Geologic Exploration Survey W 100th Meridian (Wheeler Survey) 5 (Zoology):653-703.

Creef, E.D., R.W. Clarkson, and D.K. McGuinn-Robbins. 1992. Razorback sucker (Xyrauchen texanus) and Colorado squawfish (Ptychocheilus lucius) reintroduction and monitoring, Salt and Verde Rivers, Arizona, 1991-1992. Special report on project E5-3, Job 7, Title VI of the Endangered Species Act. Arizona Game and Fish Department, Phoenix. 22 pp.

Dellenbaugh, F.S. 1908. A canyon voyage: the narrative of the second Powell expedition down the Green and Colorado Rivers from Wyoming and the explorations on land, in the years 1871 and 1872. The Knickerbocker Press, New York. 277 pp.

Dill, W.A. 1944. The fishery of the lower Colorado River. California Fish and Game 30:109-211.

Douglas, P.A. 1952. Notes on the spawning of the razorback sucker, Xyrauchen texanus (Abbott). California Fish and Game 38:149-155.

Douglas M.E., and P.C. Marsh. 1992. Ecology and conservation biology of the humpback chub (Gila cypha) in the Little Colorado River. Progress Report to Bureau of Reclamation. Cooperative Agreement No. 1-FC-40-10490. Arizona State University, Tempe. 6 pp.

Douglas M.E., and P.C. Marsh. 1993. Ecology and conservation biology of the humpback chub (Gila cypha) in the Little Colorado River. Progress Report to Bureau of Reclamation. Cooperative Agreement No. 1-FC-40-10490. Arizona State University, Tempe. 8 pp.

Douglas, M.E., W.L. Minckley, and H.M. Tyus. 1989. Qualitative characters, identification of Colorado River chubs (Cyprinidae, genus Gila) and the "Art of Seeing Well." Copeia 1989(3): 653-661

Ecology Consultants, Inc. 1978. Capture locations of rare fish in the upper Colorado River system. Final Report FWS/OBS-78/32 U.S. Fish and Wildlife Service, Fort Collins, Colorado. 44 pp.

Ellis, M.M. 1914. Fishes of Colorado. University of Colorado Studies, Boulder. Vol 11(1). 136 pp.

Erlich, P.R. and A.H. Erlich. 1981. Extinction: the causes and consequences of the disappearance of species. Random House, New York.

Evermann, B.W. 1916. Fishes of the Salton Sea. Copeia 1916:61-63.

Evermann, B.W. and C. Rutter. 1895. The fishes of the Colorado Basin. U.S. Fish Commission Bulletin 14(1894):473-486.

Finger, T.R. and E.M. Stewart. 1987. Responses of fishes to flooding regime in lowland hardwood wetlands. Pages 86-92 in W.J. Matthews and D.C. Heins. Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press. Norman. 310 pp.

Follett, W.A. 1961. The freshwater fishes - their origins and affinities. Symposium: the biogeography of Baja California and adjacent seas. Systematic Zoology 9:212-232.

Gilbert, C.H., and N.B. Scofield. 1898. Notes on a collection of fishes from the Colorado basin in Arizona. Proceedings U.S. National Museum 20:1131.

Gillespie, R.B., and P.C. Baumann. 1986. Effects of high tissue concentrations of selenium on reproduction by bluegills: Transactions of the American Fisheries Society, 115:208-213.

Girard, C. 1856. Researches upon the cyprinoid fishes inhabiting the fresh waters of the United States of America, west of the Mississippi Valley, from specimens in he museum of the Smithsonian Institution. Proceedings of the Academy of Natural Science, Philadelphia, 8:165-213.

Gobalet, K.W. 1992. Colorado River fishes of Lake Cahuilla, Salton Basin, Southern California: A cautionary tale for zooarchaeologists. Bulletin of Southern California Academy of Sciences 91:70-83.

Goettlicher, W.P. and M.J. Pucherelli. 1992. Mapping instream habitat on the San Juan River as related to the Animas-La Plata Project using airborne videography. July 1992 Draft. Applied Sciences Branch, Research and Laboratory Services Branch, Bureau of Reclamation, Denver, Colorado. 41 pp.

Gorman, O.T., S.C. Leon, O.E. Maughan. 1993. Habitat use by humpback chub, Gila cypha, in the Little Colorado River and other tributaries of the Colorado River in the Grand Canyon. Annual Report to Bureau of Reclamation. Glen Canyon Environmental Studies Phase II. U.S. Fish and Wildlife Service, Pinetop, Arizona. 34 pp.

Graf, W.L. 1978. Fluvial adjustments to the spread of tamarisk in the Colorado Plateau region. Geological Society of America Bulletin 89:1491-1501.

Graf, W.L. 1985. The Colorado River - instability and basin management. Association of American Geographers, Washington, D.C. 86 pp.

Grinnell, J. 1914. An account of the mammals and birds of the lower Colorado Valley, with special reference to the distributional problems presented. 12:51-294 in Ohmart et al., editors. University of California Publications in Zoology. 1988.

Haines, G.B. and H.M. Tyus. 1990. Fish associations and environmental variables in Age-0 Colorado squawfish habitats, Green River, Utah. Journal of Freshwater Ecology 5:427-435

Hamilton, S.J. 1993. Significance of selenium in eggs and milt of razorback suckers in the middle Green River. U.S. Fish and Wildlife Service, National Fisheries Contaminant Research Center, Yankton, South Dakota. 22 pp.

Hamman, R.L. 1982a. Culture of endangered Colorado River fishes: induced spawning and culture of the humpback chub and bonytail chub hybrids. Pages 129-136 in W.H. Miller, J.J. Valentine, D.L. Archer, H.M. Tyus, R.A. Valdez, and L. Kaeding, eds. Colorado River Fishery Project. Final Report, Part 3. Bureau of Reclamation, Salt Lake City, Utah.

Hamman, R.L. 1982b. Spawning and culture of humpback chub. Progressive Fish-Culturist 44(4):213-216.

Hamman, R.L. 1985. Induced spawning and culture of hatchery-reared bonytail. Progressive Fish-Culturist 47(3):239-241.

Haynes, C.M., T.A. Lytle, E.J. Wick, and R.T. Muth. 1984 Larval Colorado squawfish (Ptychocheilus lucius Girard) in the Upper Colorado River Basin, Colorado, 1979-81. The Southwestern Naturalist 29:21-33.

Haynes, C.M. and R.T. Muth. 1982. Identification of habitat requirements and limiting factors for Colorado squawfish and humpback chubs. Colorado Division of Wildlife, Federal Aid Project Progress Report SE-4. 43 pp.

Haynes, C.M. and R.T. Muth. 1984. Identification of habitat requirements and limiting factors for Colorado squawfish and humpback chubs. Colorado Division of Wildlife, Federal Aid Project Progress Report, SE-3. 21 pp.

Heckman, R.A., J.E. Deacon, and P.D. Greger. 1986. Parasites of the woundfin minnow, Plagopterus argentissimus, and other endemic fishes from the Virgin River, Utah. Great Basin Naturalist 46(4): 662-675.

Heinrich, J.E., and J.C. Sjoberg. 1992. Status and evaluation of Nevada fishes. Pages 8-12 in D.E. Hendrickson, editor, 1992 annual symposium, 18-21 November. Proceedings of the Desert Fishes Council XXIV.

Hesse, L.W. and W. Sheets. 1993. The Missouri River hydrosystem. Fisheries 18(5):5-14.

Holden, P.B. 1973. Distribution, abundance and life history of the fishes of the upper Colorado River basin. Ph.D. dissertation. Utah State University, Logan. 59 pp.

Holden, P.B. 1978. A study of habitat use and movement of the rare fishes in the Green River, Utah. Transactions of the Bonneville Chapter, American Fisheries Society 1978:66-89.

Holden, P.B. 1980. The relationship between flows in the Yampa River and success of rare fish populations in the Green River system. Report PR-31-1. BIO/WEST, Inc., Logan, Utah. 39 pp.

Holden, P.B. 1983. Status and preferred habitat of the rare fishes of the Green River, Utah. Proceedings of the Desert Fishes Council 4:314 (abstract).

Holden, P.B. 1991. Ghosts of the Green River: impacts of Green River poisioning on management of natives fishes. Pages 43-54 in W.L. Minckley and J.E. Deacon, editors. Battle Against Extinction. University of Arizona Press, Tucson, Arizona.

Holden, P.B. and L.W. Crist. 1980. Documentation of changes in the macroinvertebrate and fish populations in the Green River system. Report PR 16-5. BIO/WEST, Inc., Logan, Utah. 92 pp.

Holden, P.B. and L.W. Crist. 1981. Documentation of changes in the macroinvertebrate and fish populations in the Green River due to inlet modification of Flaming Gorge Dam. Report PR-16-5. BIO/WEST, Inc., Logan, Utah. 92 pp.

Holden, P.B., R.D. Hugie, L. Crist, S.B. Chanson, and W.J. Masslich. 1986. Development of a fish and wildlife classification system for backwaters along the lower Colorado River. Prepared for Bureau of Reclamation. BIO/WEST. 260 pp.

Holden, P.B., C. Richards, L.W. Crist, and J.R. Campbell. 1981. Aquatic biology studies for proposed Colorado-Ute Electric Association power plant near Grand Junction, Colorado. PR 56-1. Submitted to Burns and McDonnell Planning and Environmental Analysis Division, Kansas City, MO. 66 pp.

Holden, P.B. and C.B. Stalnaker. 1970. Systematic studies of the cyprinid genus Gila in the Upper Colorado River Basin. Copeia 1970(3):409-420.

Holden, P.B. and C.B. Stalnaker. 1975a. Distribution and abundance of mainstream fishes of the middle and Upper Colorado River Basins, 1967-1973. Transactions of the American Fisheries Society 104:217-231.

Holden, P.B. and C.B. Stalnaker. 1975b. Distribution of fishes in the Dolores and Yampa River systems of the Upper Colorado Basin. The Southwestern Naturalist 19:403-412.

Holden, P.B. and T.M. Twedt. 1980. The development of habitat suitability curves and estimation of available habitat for Colorado squawfish in the San Juan River, New Mexico and Utah. Report PR-46-1-1. BIO/WEST, Inc., Logan, Utah.

Holden, P.B. and E.J. Wick. 1982. Life History and prospects for recovery of Colorado squawfish. Pages 98-108 in W.H. Miller, H.M. Tyus, and C.A. Carlson, editors. Proceedings of a symposium on fishes of the Upper Colorado River system: present and future. American Fisheries Society, Bethesda, Maryland. 131 pp.

Hontela and Stacey. 1990. Cyprinidae. Pages 53-78 in Monro, A.D., A.P. Scott, and T.J. Lamm. Reproductive seasonality in teleosts: Environmental influences. CRC Press, Inc., Boca Raton, Florida. 254 pp.

Hubbs, C.L., and R.R. Miller. 1953. Hybridization in nature between the fish genera Catostomus and Xyrauchen. Papers of the Michigan Academy of Science, Arts, and Letters 38:207-233.

Hughes, R.M. and R.F. Noss. 1992. Biological Diversity and Biological Integrity: current concerns for lakes and streams. Fisheries 17(3):11-19.

Iorns, W.V., C.H. Henbree, and G.L. Oakland. 1965. Water resources of the Upper Colorado River Basin - Technical Report - Introduction and Summary. Professional Paper 441-A. U.S. Department of the Interior, Geological Survey. 370 pp.

Johnson, J.E. 1976. Status of endangered and threatened fish species in Colorado. U.S. Department of the Interior, Technical Note 280. Bureau of Land Management. 28 pp.

Johnson, K. and M. Oberholtzer. 1987. Investigation into possible occurrence of Colorado squawfish (Ptychocheilus lucius) and other federally threatened or endangered fish species in the lower Green River drainage and the Little Snake River drainage of Wyoming. Administrative Report – Project Numbers 5086-13-8601 and 4486-13-8601. Wyoming Game and Fish Department, Cheyenne, Wyoming. 12 pp.

Jonez, A., J. Hemphill, R.D. Beland, G. Duncan, and R.A. Wagner. 1951. Fisheries report on the lower Colorado River. Arizona Game and Fish Commission, Phoenix, Arizona.

Jonez, A., and R.C. Sumner. 1954. Lakes Mead and Mohave investigations: a comparative study of an established reservoir as related to a newly created impoundment. Final Report Federal Aid Project F-1-R. Nevada Fish and Game Commission, Reno, Nevada.

Jordan, D. S. 1891. Report of explorations in Colorado and Utah during the summer of 1889 with an account of the fishes found in each of the river basins examined. Bulletin of the United States Fish Commission 9:24.

Jordan, D.S. and B.W. Evermann. 1896. The fishes of North and Middle America. Bulletin U.S. National Museum 47 (1):1240.

Joseph, T.W., J.A. Sinning, R.J. Behnke, and P.B. Holden. 1977. An evaluation of the status, life history and habitat requirements of endangered and threatened fishes of the Upper Colroado River System. U.S. Fish and Wildlife Service, FWS/OBS-77/2, Fort Collins, Colorado.

Kaeding, L.R., B.D. Burdick, P.A. Schrader, and C.W. McAda. 1990. Temporal and Spatial Relations between the Spawning of Humpback Chub and Roundtail Chub in the Upper Colorado River. Transactions of the American Fisheries Society. 119:135-144.

Kaeding, L.R., B.D. Burdick, P.A. Schrader, and W.R. Noonan. 1986. Recent capture of a bonytail (Gila elegans) and observations on this nearly extinct cyprinid from the Colorado River. Copeia 1986:1021-1023.

Kaeding, L.R. and D.B. Osmundson. 1989. Biologically defensible flow recommendations for the maintenance and enhancement of Colorado squawfish habitat in the '15-mile' reach of the upper Colorado River during July, August and September. U.S. Fish and Wildlife Service, Grand Junction, Colorado. 169 pp.

Kaeding, L.R. and M.A. Zimmerman. 1983. Life history and ecology of the humpback chub in the Little Colorado and Colorado Rivers of the Grand Canyon. Transactions of the American Fisheries Society 112:577-594.

Karp, C.A. and H.M. Tyus. 1990a. Humpback chub ((Iila cypha) in the Yampa and Green Rivers with observations on other sympatric fishes. Great Basin Naturalist 50:257-264.

Karp, C.A. and H.M. Tyus. 1990b. Behavior and interspecific interactions of Colorado squawfish and five other fish species. Copeia 990:25-34.

Karr, J.R. and I.J. Schlosser. 1978. Water resources and the land-water interface. Science 201:229-234.

Kidd, G. 1977. An investigation of endangered and threatened fish species in upper Colorado River as related to Bureau of Reclamation Projects. Final report, Bureau of Reclamation, Salt Lake City, Utah. 36 pp.

Kirsch, P. H. 1888. Notes on a collection of fishes obtained in the Gila River at Fort Thomas, Arizona. Proceedings of the U.S. National Museum 11:555-558.

Kolb, E., and E. Kolb. 1914. Experience in the Grand Canyon. The National Geographic Society Magazine 26(2):99-184.

Koster, W.J. 1957. Guide to the fishes of New Mexico. University of New Mexico Press, Albuquerque, New Mexico. 116 pp.

Koster, W.J. 1960. Ptychocheilus lucius (Cyprinidae) in the San Juan River, New Mexico. The Southwestern Naturalist 5(3):174-175.

Krueger, R., A. Thompson, B. Osmundson, L. DeWeese, and A. Archuleta. 1991. Big river fishes: Environmental contaminants in fish species used as surrogates for threatened and endangered fish of the Colorado River Basin. U.S. Fish and Wildlife Service, Colorado Field Office, Environmental Contaminants Interim Report, 22 pp.

Kubly, D.M. 1990. The endangered humpback chub (Gila cypha) in Arizona, a review of past studies and suggestions for future research. Draft Report U.S. Bureau of Reclamation contract. Arizona Game & Fish Department. Phoenix, Arizona. 136 pp.

Langhorst, D.R. 1987. Larval razorback sucker, (Xyrauchen texanus), in Lake Mohave, Arizona-Nevada. Proceedings of the Desert Fishes Council 17 (1985), 164-165 (abstract).

Langhorst, D.R. 1989. A monitoring study of razorback sucker (Xyrauchen texanus) reintroduced into the lower Colorado River in 1988. California Department of Fish and Game. 33 pp.

Langhorst, D.R., and P.C. Marsh. 1986. Early life history of razorback sucker in Lake Mohave. Final Report, U.S. Bureau of Reclamation. Boulder City, Nevada. 36 pp.

Lanigan, S.H. and C.R. Berry, Jr. 1981. Distribution of fishes in the White River, Utah. The Southwestern Naturalist 26:389-393.

Lanigan, S.H., and H.M. Tyus. 1989. Population size and status of the razorback sucker in the Green River basin, Utah and Colorado. North American Journal of Fisheries Management 9:1.

LaRivers, I. 1962. Fishes and fisheries of Nevada. State Game and Fish Commission, Reno. 782 pp.

Lashmett, K. 1993. Fishery survey of the lower San Juan River and the upper arm of Lake Powell (RMI 4.0- 11.0) 1991/1992. Annual Report. Bureau of Reclamation, Durango, Colorado. 29 pp.

Lemly, A.D. and G.J. Smith. 1987. Aquatic cycling of selenium: implications for fish and wildlife. U.S. Fish and Wildlife Service, Leaflet 12. 10 pp.

Lemons, D.B. 1954. A field survey of western Colorado streams and lakes. Colorado Department of Fish and Game, Denver, Colorado. 29 pp.

Lockington, W. N. 1881. Description of a new species of Catostomus (Catostomus cypho) from the Colorado River. Proceedings of the Philadelphia Academy of Natural Sciences. 32, 237-240.

Loudermilk, W.E. 1985. Aspects of razorback sucker (Xyrauchen texanus, Abbott) life history which help explain their decline. Proceedings of the Desert Fishes Council 13(1981):67-72.

Loudermilk, W.E., and L.C. Ulmer. 1985. A fishery inventory with emphasis on razorback sucker (Xyrauchen texanus) status in the lower Coloado River. Final Report for U.S. Fish and Wildlife Service Cooperative Agreement 14-16-002-80-921. California Department of Fish and Game, Blythe (also appeared as California Department of Fish and Game, Region 5 Information Bulletin 0012-9-1985, -27, 238 pp., appendix).

Lowe-McConnell, R.H. 1975. Fish communities in tropical waters. Longman, New York.

Lyons, J. 1989. Green River Channel Characteristics below Flaming Gorge. Bureau of Reclamation. Denver, Colorado.

Maddux, H.R., D.M. Kubly, J.C. deVos, Jr., W.R. Persons, R. Staedicke, and R.L. Wright. 1987. Effects of varied flow regimes on aquatic resources of Glen and Grand Canyons. Final Report - Contract 4-AG40-01810. U.S. Department of the Interior, Bureau of Reclamation, Salt Lake City, Utah. 291 pp.

Marsh, G.P. 1864. Man and nature. John Harvard Library Edition, 1985. Harvard University Press, Cambridge, Massachusetts.

Marsh, P.C. 1985. Effect of incubation temperature on survival of embryos of native Colorado River fishes. The Southwestern Naturalist 30(1): 129-140.

Marsh, P.C. 1988. Native fishes at Buenos Aires National Wildlife Refuge and Arizona State University Research Park, Arizona: Opportunities for Management, Research, and Public Education on Endangered Species. Proceedings of the Desert Fishes Council. 19(1987):67-78

Marsh, P.C., and J.E. Brooks. 1989. Predation by Ictalurid catfishes as a deterrent to re-establishment of hatchery-reared razorback suckers. The Southwestern Naturalist 34(2):188-195.

Marsh, P.C., M.E. Douglas, W.L. Minckley, and R.J. Timmons. 1991. Rediscovery of the Colorado squawfish, Ptychocheilus lucius (Cyprinidae), in Wyoming. Copeia 1991 (4): pp 1091-1092.

Marsh, P.C., and D.R. Langhorst. 1988. Feeding and fate of wild larval razorback sucker. Environmental Biology of Fishes 21:59-67.

Marsh, P.C. and W.L. Minckley. 1985. Aquatic resources of the Yuma Division, lower Colorado River. Final Report for U.S. Bureau of Reclamation, Contract 2-07-30-X0214. Arizona State University, Tempe, Arizona.

Marsh, P.C., and W.L. Minckley. 1987. Aquatic resources of the Yuma Division, lower Colorado River. Final Report for Phase II, U.S. Bureau of Reclamation, Contract 2-07-30-X0214. Arizona State University, Tempe, Arizona.

Marsh, P.C., and W.L. Minckley. 1989. Observations on recruitment and ecology of razorback sucker: lower Colorado River, Arizona-California-Nevada. Great Basin Naturalist 49:71-78.

Marsh, P.C., and W.L. Minckley. 1991. Radiotelemetry of razorback suckers in the Gila River, eastern Arizona. Proceedings of the Desert Fishes Council 21 (1989):163-171.

Martinez, P.J. 1986a. White River Taylor Draw Project: pre- and post- impoundment fish community investigations. Final Report-Contract 5281-x. Colorado Division of Wildlife, Grand Junction, Colorado. 121 pp.

Martinez, P.J. 1986b. Kenney Reservoir lake management plan. Colorado Division of Wildlife, Grand Junction, Colorado. 43 pp.

McAda, C.W. 1983. Colorado squawfish, Ptychocheilus lucius (Cyprinidae), with a channel catfish, Ictalurus punctatus (Ictaluridae), lodged in its throat. The Southwestern Naturalist 28(1):119-120.

McAda, C.W., and L.R. Kaeding. 1991. Physical Changes in the Gunnison and Colorado Rivers Resulting from Construction of the Aspinall Unit and Related Projects, with Hypotheses to Assess the Effects on the Endangered Fishes. Final Report. U.S. Fish and Wildlife Service, Grand Junction, Colorado. 60 pp.

McAda, C.W., and R.S. Wydoski. 1980. The razorback sucker, Xyrauchen texanus, in the upper Colorado River basin, 1974-76. U.S. Fish and Wildlife Service Technical Paper 99. 50 pp.

McCall T.C. 1980. Fisheries investigation of Lake Mead, Arizona-Nevada, from Separation Raids to Boulder Canyon, 1978-1979. Final Report for U.S. Water and Power Res. Serv. (U.S. Bur. Recalm). Contract 8-07-3-X0025. Arizona Game and Fish Department, Phoenix.

McCarthy, C.W., and W.L. Minckley. 1987. Age estimation for razorback sucker (Pisces: Catostomidae) from Lake Mohave, Arizona and Nevada. Journal Arizona-Nevada Academy of Science 21:87-97.

McNeely J.A. 1988. Economics and biological diversity. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland.

Medel-Ulmer, L. 1983. Movement and reproduction of the razorback sucker (Xyrauchen texanus) inhabiting Senator Wash Reservoir, Imperial County, California Proceedings of the Desert Fishes Council 12(1980):106 (abstract).

Meffe, G.K. 1985. Predation and species replacement on American southwestern fishes: a case study. The Southwestern Naturalist 30:173-187.

Meffe, G.K, D.A. Hendrickson, W.L. Minckley, and J.N. Rinne. 1983. Factors resulting in the decline of the endangered Sonoran topminnow Poeciliopsis occidentalis (Atheriniformes: Poecilidae) in the United States. Biological Conservation 25, 1983:135-159.

Meyer, C.W., and M. Moretti, 1988. Fisheries Survey of the San Juan River, Utah, 1987. Utah Division of Wildlife Resources 88-1:1-53.

Miller, R.R. 1946. Gila cypha, a remarkable new species of cyprinid fish from the Colorado River in Grand Canyon, Arizona. Journal of the Washington Academy of Science 36:409-415.

Miller, R.R. 1955. Fish remains from archaeological sites in the lower Colorado River basin, Arizona. Papers of the Michigan Academy of Sciences, Arts, Letters. 40:125-136.

Miller, R.R. 1959. Origin and affinities of the freshwater fish fauna of western North America. Pages 187-222 in C.L. Hubbs, editor. Zoogeography. American Association for the Advancement of Science, Publication 51.

Miller, R.R. 1961. Man and the changing fish fauna of the American southwest. Papers of the Michigan Academy of Science, Arts, Letters 46:365-404.

Miller, R.R. 1964. Fishes of Dinosaur. Naturalist 15:24-29.

Miller, W.H., D.L. Archer, H.M. Tyus and K.C. Harper. 1982a. White River fishes study, final report. Colorado River Fishery Project. U.S. Fish and Wildlife Service, Salt Lake City, Utah. 103 pp.

Miller, W.H., D.L. Archer, H.M. Tyus, and R.M. McNatt. 1982b. Yampa River fishes study, final report. Colorado River Fishery Project. U.S. Fish and Wildlife Service, Salt Lake City, Utah. 82 pp.

Miller, W.H., L.R. Kaeding, H.M. Tyus, C.W. McAda, and B.D. Burdick. 1984. Windy Gap Fishes Study. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Salt Lake City, Utah. 37 pp.

Miller, R.R, and C.H. Lowe. 1964. Part 2. Annotated check-list of the fishes of Arizona. Pages 133-151 in The verebrates of Arizona, C.H. Lowe, editor. University of Arizona Press, Tucson.

Miller, W.H, J.J. Valentine, D.L. Archer, H.M. Tyus, R.A. Valdez, and L. Kaeding. 1982c. Colorado River fishery project: final report. U.S. Fish and Wildlife Service and Bureau of Reclamation, Salt Lake City, Utah. 731 pp.

Miller, W.H., H.M. Tyus, and C.W. McAda. 1983. Movements, migration and habitat preference of radiotelemetered Colorado squawfish, Green, White, and Yampa Rivers, Colorado and Utah. Colorado River Fishery Project, U.S. Fish and Wildlife Service, Salt Lake City, Utah. 39 pp.

Minckley, C.O. 1977. A preliminary survey of the fish of the Little Colorado River from Blue Spring to the vicinity of Big Canyon, Coconino County, Arizona. Report to the Office of Endangered Species, Region II, U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 9 pp.

Minckley, C.O. 1978. Monitoring the population trends of the genus Gila in selected localities. In S.W. Carothers, editor. River Resource Monitoring Project. Grand Canyon National Park, Arizona.

Minckley, C.O. 1979. Additional studies on the Little Colorado River population of the humpback chub. Report to the Office of Endangered Species, Region II, U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 5 pp.

Minckley, C.O. 1980. River resource monitoring project - Gila spp. studies. 20 pp. in S.W. Carothers, editor. River Resource Monitoring Project. Grand Canyon National Park, Arizona. Part II--Final Report.

Minckley, C.O. 1990. Final report on research conducted on the Little Colorado River population of the humpback chub, during April-May 1990. Report to Non-game Branch, Arizona Game and Fish Department, Phoenix. Northern Arizona University, Flagstaff. 44 pp.

Minckley, C.O. 1993. Observations on the Little Colorado River population of humpback chub (Gila cypha). Unfinished doctoral dissertation. Northern Arizona University, Flagstaff.

Minckley, C.O. and S.W. Carothers. 1980. Recent collection of the Colorado squawfish and razorback sucker from the San Juan and Colorado Rivers in New Mexico and Arizona. The Southwestern Naturalist 24:686-687.

Minckley, C.O., S.W. Carothers, J.W. Jordan, and H.D.Usher. 1981. Observations on the humpback chub Gila cypha, within the Colorado and Little Colorado Rivers, Grand Canyon National Park, Arizona. Proceedings of the second Conference on Scientific Research in the National Parks.

Minckley, W.L. 1973. Fishes of Arizona. Arizona Game and Fish Department, Phoenix, Arizona. 293 pp.

Minckley, W.L. 1979. Aquatic habitats and fishes of the lower Colorado River, Southwestern United States. U.S. Bureau of Reclamation, Boulder City, Nevada. 477 pp.

Minckley, W.L. 1983. Status of the razorback sucker, Xyrauchen texanus (Abbott), in the lower Colorado River Basin. The Southwestern Naturalist 28:165-187.

Minckley, W.L. 1985. Memorandum (dated 16 April). Razorback sucker monitoring effort, Arizona reservoirs, March 1985. U.S. Fish and Wildlife Servvice, Dexter National Fish Hatchery and Technology Center, Dexter, New Mexico.

Minckley, W.L. 1991. Native fishes of the Grand Canyon region: an obituary? Pages 124-177 in Colorado River ecology and dam management, proceedings of a symposium, May 24-25, 1990, Santa Fe, New Mexico. National Academy Press, Washington, D.C.

Minckley, W.L. and N.T. Alger. 1968. Fish remains from an archaeological site along the Verde River, Yavapai County, Arizona. Museum of Northern Arizona, Flagstaff. Plateau 40:91-97.

Minckley, W.L. and R. Clarkson. 1979. Fishes. Pages 510-531 in W.L. Minckley and M.R. Sommerfeld, editors. Resource inventory for the Gila River complex, eastern Arizona. Final Report for U.S. Bureau of Land Management Contract YA-512-CT6-216, Arizona State University, Tempe.

Minckley, W.L., and J.E. Deacon. 1968. Southwestern fishes and the enigma of "endangered species." Science, 159:1424-1432.

Minckley, W.L., and M.E. Douglas. 1991. Discovery and extinction of western fishes: A blink of the eye in geologic time. Pages 7-17 in W.L. Minckley and J.E. Deacon, editors. Battle Against Extinction. University of Arizona Press, Tucson, Arizona.

Minckley, W.L., D.A. Hendrickson, and C.E. Bond. 1986. Geography of Western North America Freshwater Fishes: Description and Relationships to Intracontinental Tectonism. Pages 519-613 in C.H. Hocutt and E.O. Wiley, editors. The Zoogeography of North American Freshwater Fishes. Wiley-Interscience, New York, New York.

Minckley, W.L., P.C. Marsh, J.E. Brooks, J.E. Johnson, and B.L. Jensen. 1991. Management toward recovery of razorback sucker (Xyrauchen texanus). Pages 303-357 in W.L. Minckley and J.E. Deacon, editors. Battle Against Extinction. University of Arizona Press, Tucson, Arizona.

Minckley, W.L. and G.K. Meffe. 1987. Differential selection by flooding in stream fish communities in the arid American southwest. Pages 93-105 in W.J. Matthews and D.C. Heins. Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press. Norman. 310 pp.

Minckley, W.L. and M.R. Sommerfeld. 1979. Resource inventory for the Gila River complex, eastern Arizona. Final Report for U.S. Bureau of Land Management Contract YA-512-CT6-216, Arizona State University, Tempe.

Moffett J.W. 1943. A preliminary report on the fishery of Lake Mead. Transactions of the North American Wildlife Conference. 8: 179-186.

Molles, M. 1980. The impacts of habitat alterations and introduced species on the native fishes of the Upper Colorado River Basin. Pages 163-181 in W.O. Spofford, A.L. Parker, and A.V. Kneese, editors. Energy development in the Southwest - problems of water, fish and wildlife in the Upper Colorado River Basin, Vol. 2. Resources for the Future, Washington, D.C.

Morgan, D.L. (editor). 1964. The West of William H. Ashley, 1882-1838. The Old West Publishing Company, Denver, Colorado. 341 pp.

Moyle, P.B. 1976. Inland fishes of California. University of California Press, Berkeley.

Mueller, G. 1989. Observations of spawning razorback sucker (Xyrauchen texanus) utilizing riverine habitat in the lower Colorado River, Arizona-Nevada. The Southwestern Naturalist 34(1).

Mueller, G., W. Rinne, T. Burke, and M. Delamore. 1982. Habitat Selection of spawning razorback suckers observed in Arizona Bay, Lake Mohave, Arizona-Nevada. U.S. Bureau of Reclamation Lower Colorado River Region, Boulder City, Nevada.

Nesler, T.P., L. Lentsch. 1992. Aspinall Unit Studies. 1992 Annual Project Report. Colorado River Fishes Recovery Program. 7 pp.

Nesler, T.P., R.T. Muth, and A.F. Wasowicz. 1988. Evidence for basline flow spikes as spawning cues for Colorado squawfish in the Yampa River, Colorado American Fisheries Society Symposium 5:68-79.

Norse E.A., and six co-authors. 1986. Conserving biological diversity in our national forests. The Wilderness Society, Washington D.C.

Noss, R.F. 1983. A regional landscape approach to maintaining diversity. Bioscience 33:700-706.

Obmasick, M. 1989. Oil spill injures Colorado squawfish. The Denver Post, December 10, 1989, Denver, Colorado.

O'Brien, J.S. 1984. 1983 Yampa River cobble reach morphology investigation, Final Report. U.S. Fish Wildlife Service, Salt Lake City, Utah. 79 pp.

Ohmart, R.D., B.W. Anderson, and W.C. Hunter. 1988. The ecology of the lower Colorado River from Davis Dam to the Mexico-United States International Boundary: a community profile. U.S.Fish and Wildlife Service Biological Report. 85. 296 pp.

Olson, H.F. 1962a. A pre-impoundment study of Navajo Reservoir, New Mexico. Statewide Fisheries Investigations, Federal Aid Project F-22-R-3, Work Plan 1, Job No. B-1. New Mexico Department of Game and Fish. 6 pp.

Olson, H.F. 1962b. Rehabilitation of the San Juan River. State-wide Rough Fish Control, Federal Aid Project F-19-D-4. New Mexico Department of Game and Fish. 29 pp.

Osmundson, D.B. 1987. Growth and survival of Colorado squawfish (Ptychocheilus lucius) stocked in riverside ponds, with reference to largemouth bass (Micropterus salmoides) predation. Master's Thesis, Utah State University, Logan, Utah.

Osmundson, D.B. and L.R. Kaeding. 1989. Studies of Colorado squawfish and razorback sucker use of the "15-mile reach" of the Upper Colorado River as part of conservation measures for the Green Mountain and Ruedi Reservoir water sales. U.S. Fish and Wildlife Service, Final Report. Grand Junction, Colorado.

Osmundson, D.B., and L.R. Kaeding. 1991. Recommendations for flows in the 15-mile reach during October-June for maintenance and enhancement of endangered fish populations in the upper Colorado River. Final Report, U.S. Fish and Wildlife Service, Region 6, Grand Junction, Colorado. 81 pp.

Paulin, K., H. Tyus, and C. Williams. 1990. Response of young Colorado squawfish and razorback suckers to water flow and light intensity. Unpublished report. U.S. Fish and Wildlife Service, Vernal, Utah.

Paulson, L.J., J.R. Baker, and J.E. Deacon. 1980. The limnological status of Lake Mead and Lake Mohave under present and future powerplant operations of Hoover Dam. Report #1. U.S. Bureau of Reclamation Contract 14-06-300-2218. 228 pp. Boulder City, Nevada.

Pfeifer, F.K. 1993. Razorback suckers caught in ponds adjacent to the Colorado River. U.S. Fish and Wildlife Service memorandum dated May 19, 1993.

Persons, W.R. 1992. Historical stocking summary. Arizona Game and Fish Department, Phoenix. 45 pp.

Persons, W.R., and R.V. Bulkley. 1982. Feeding activity and spawning time of striped bass in the Colorado River inlet, Lake Powell, Utah. North American Journal of Fisheries Management. 4:403-408.

Pimental, R., R.V. Bulkley, and H.M. Tyus. 1985. Choking of Colorado squawfish, Ptychocheilus lucius (Cyprinidae), on channel catfish, Ictalurus punctatus (Ictaluridae), as a cause of mortality. The Southwestern Naturalist 30:154-158.

Platania, S.P. 1990. Biological summary of the 1987 to 1989 New Mexico-Utah ichthyofaunal study of the San Juan River. Unpublished report to the New Mexico Department of Game and Fish, Santa Fe, and the U.S. Bureau of Reclamation, Salt Lake City, Cooperative Agreement 7-FC-40-05060.

Platania, S.P., and K.R. Bestgen. 1988. An interim report on the fishes of the lower San Juan River, New Mexico, 1987. Report prepared for New Mexico Department of Game and Fish, Santa Fe, New Mexico. 61 pp.

Platania, S.P., and B.K. Lang. 1992. Upper San Juan River Basin endangered fish investigation. Report to New Mexico Department of Game and Fish, Santa Fe, New Mexico. 61 pp.

Platania, S.P., M.A. Moretti, D.L. Probst, and J.E. Brooks. 1991. Status of Colorado squawfish and razorback sucker in the San Juan River Colorado, New Mexico, and Utah. The Southwestern Naturalist 36:147-150.

Popov, B.H., and J.B. Low. 1950. Game, fur animal and fish: introductions into Utah. Utah State Department of Fish and Game. 84 pp.

Prewitt, C.G., W.H. Wick, D.E. Snyder, and C.A. Carlson. 1978. Baseline survey of aquatic macroinvertebrates and fishes of the White and Yampa Rivers, Colorado. Semi-annual Report, 19 Jan. 1978. Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins. 29 pp.

Propst, D.L. and K.R. Bestgen. 1991. Habitat and biology of the loach minnow, Tiaroga cobitis, in New Mexico. Copeia 1991:29-30.

Quartarone, F. 1993. Historical accounts of upper basin endangered fish. Colorado Division of Wildlife. Denver.

Radant, R.D., J.S. Cranney, R.G. Ruesink and K. Rose. 1983. Colorado squawfish investigations - White River, Utah. U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, and Utah Division of Wildlife Resources, Salt Lake City. 39 pp.

Rinne, J.N. 1991. Habitat use by spikedace, Meda fulgida (Pisces: Cyprinidae) in southwestern streams with reference to probable habitat competition by red shiner (Pisces: Cyprinidae). The Southwestern Naturalist 36:7-13.

Roberts, B., and M. Moretti. 1989. Fisheries survey of the San Juan River, Utah, 1988. Utah Division of Wildlife Resources. 89-3:1-40.

Robinson, A.T., and R.W. Clarkson. 1992. Annual spring monitoring of humpback chub (Gila cypha) in the Little Colorado River, Grand Canyon, Arizona 1987-1992. Special Report to U.S. Fish and Wildlife Service. Project E5-3, Job 3, Title VI of the Endangered Species Act. Arizona Game and Fish Department, Phoenix. 30 pp.

Rosenfeld, M.J., and J.A. Wilkinson. 1989. Biochemical genetics of the Colorado River Gila complex (Pisces: Cyprinidae). The Southwestern Naturalist 34:232-244.

Ryden, D.W., and F.K. Pfeifer. 1993. Adult Fish Collections on the San Juan River (1991-1992). Draft Annual Progress Report. U.S. Fish and Wildlife Service, Grand Junction, Colorado. 68 pp.

Schacklette, H.T. and J.G. Boerngen. 1984. Element concentrations in soils and other surficial materials of the conterminous United States. U.S. Geological Survey Professional Paper 1270. 105 pp.

Schmitt, C.J., and W.G. Brumbaugh. 1990. National Contaminants Biomonitoring Program: Concentrations of Arsenic, Cadmium, Copper, Lead, Mercury, Selenium, and Zinc in U.S. Freshwater Fish, 1976-1984. Archives of Environmental Contaminants and Toxicology. 19:731-747.

Seethaler, K.H. 1978. Life history and ecology of the Colorado squawfish (Ptychocheilus lucius) in the Upper Colorado River Basin. Masters Thesis, Utah State University, Logan, Utah. 155 pp.

Seethaler, K.H., C.W. McAda, and R.S. Wydoski. 1979. Endangered and threatened fish in the Yampa and Green Rivers of Dinosaur National Monument. Pages 605-612 in R.M. Linn, editor. Proceedings of the First Conference on Scientific Research in National Parks. U.S. Department of the Interior, National Park Service, Transactions and Proceedings Series Number 5.

Sigler, W.F. and R.R. Miller. 1963. Fishes of Utah. Utah Department of Fish and Game, Salt Lake City, Utah. 203 pp.

Smith, G.R. 1959. Annotated list of the fishes. Pages 195-199 in C.E. Dibble, editor. Ecological studies of the flora and fauna in Glen Canyon. University of Utah Anthropological Papers, Number 40, Salt Lake City, Utah.

Smith, G.R., 1981. Effects of habitat size on species richness and adult body size of desert fishes. Pages 125-169 in R.J. Naiman and D.L. Stoltz, editors. Fishes in North American deserts. John Wiley and Sons, New York.

Smith, G.R., and R. G. Green. 1991. Flaming Gorge consolidated hydrology report. Unpublished report. Division of Water Resources, U.S. Fish and Wildlife Service, Denver, Colorado. 146 pp.

Smith, G.R., R.R. Miller, and W.D. Sable. 1979. Species relationships among fishes of the genus Gila in the upper Colorado River drainage. Pages 613-623 in R.M. Linn, editor. Proceedings of the First Conference on Scientific Research in the National Parks. U.S. Department of the Interior, National Park Service. Transactions and Proceedings Series Number 5.

Smith, M.L. 1981. Late Cenozoic fishes in the warm deserts of North America: A reinterpretation of desert adaptations. Pages 11-38 In R.J. Naiman and D.L. Soltz, editors. Fishes in North American deserts. John Wiley and Sons, New York.

Smith, R., R.R. Miller, and W.D. Sable. 1979. Species relationships amoung fishes of the genus Gila of the upper Colorado River Basin. pages 613-623, in Proceedings of the First Annual Conference on Scientific Research in the National Parks. U.S. National Park Service Transactions and Proceedings Series 5.

Snyder, J.O. 1915. Notes on a collection of fishes made by Dr. Edgar A. Mearns from rivers tributary to the Gulf of California. Proceedings of the U.S. National Museum 49, 573-586.

Stalnaker, C.B., and P.B. Holden. 1973. Changes in native fish distribution in the Green River System, Utah-Colorado. Proceedings of the Utah Academy of Science 50(1):25-32.

Stephens, D.W., B. Waddell, and J.B. Miller. 1988. Reconnaissance investigation of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Middle Green River Basin, Utah, 1986-87.

Stephens, D.W., B. Waddell, L.A. Peltz, and J.B. Miller. 1992. Detailed Study of Selenium and Selected Elements in Water, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Middle Green River Basin, Utah, 1988-90. U.S. Geological Survey Water-Resources Investigation Report 92-4084. 164 pp.

Stone, J.L., and W.L. Rathbun. 1969. Tailwater fisheries investigations. Creel census and limnological study of the Colorado River below Glen Canyon Dam July 1, 1968-June 30, 1969. Arizona Game and Fish Department, Phoenix. 35 pp.

Sublette, J.E. 1977. A survey of the fishes of the San Juan River basin, with particular reference to the endangered species. Report submitted to the U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Sullivan, M.E., and M.E. Richardson. 1993. Functions and values of the Verde River riparian ecosystem and an assessment of adverse impacts to the resources. U.S. Fish and Wildlife Service, Phoenix, Arizona. 364 pp.

Suttkus, R.D., and G.H. Clemmer. 1977. The humpback chub, Gila cypha, in the Grand Canyon area of the Colorado River. Occasional Papers of the Tulane University Museum of Natural History Number 1:1-30.

Suttkus, R.D., G.H. Clemmer, C. Jones, and C.R. Shoop. 1976. Survey of fishes, mammals and herpetofauna of the Colorado River in Grand Canyon. Grand Canyon National Park, Arizona. Colorado River Research Series Contribution Number 34. 11 pp.

Taba, S.S., J.R. Murphy, and H.H. Frost. 1965. Notes on the fishes of the Colorado River near Moab, Utah. Proceedings of the Utah Academy of Sciences, Arts and Letters 42:280-283.

Taylor, J.N., W.R. Courtenay, Jr., and J.A. McCann. 1984. Known impacts of exotic fishes in the continental United States. Pages 322-373 in W.R. Courtenay, Jr., and J.R. Stauffer, Jr., editors. Distribution, biology, and management of exotic fishes. Johns Hopkins University Press. Baltimore, Maryland.

Taylor, P.W. 1986. Respect for nature. Princeton University Press, Princeton, New Jersey.

Tyus, H.M. 1984. Loss of stream passage as a factor in the decline of the endangered Colorado squawfish. Pages 138-144 in Issues and Techology in the Management of Impacted Western Wildlife. Proceedings of a national symposium. Thorne Ecological Institute Technical Publication 14. Boulder, Colorado.

Tyus, H.M. 1985. Homing behavior noted for Colorado squawfish. Copeia 1985:213-215.

Tyus, H.M. 1986. Life strategies in the evolution of the Colorado squawfish (Ptychocheilus lucius). Great Basin Naturalist 46:656-661.

Tyus, H.M. 1987. Distribution, reproduction, and habitat use of the razorback sucker in the Green River, Utah, 1979-1986. Transactions of the American Fisheries Society 116:111-116.

Tyus, H.M. 1990. Potamodromy and reproduction of Colorado squawfish (Ptyochocheilus lucius). Transactions of the American Fisheries Society 119:1,035-1,047

**Tyus, H.M. 1991a.** Management of Colorado **squawfish.** Pages **379-402** In: W. L. **Minckley** and J. E. Deacon, eds. Battle Against Extinction. University of Arizona Press, Tucson.

**Tyus, H.M. 1991b.** Movement and habitat use of young Colorado **squawfish** in the Green River, Utah. Journal of Freshwater Ecology **6:43-51.**

**Tyus, H.M.,** and **J.M.** Beard. **1990.** Nonnative fish **Esox** lucius **(Esocidae)** and Stizostedion vitreum **(Percidae)** in the Green River Basin, Colorado and Utah. Great Basin Naturalist **50:33-39.**

**Tyus, H.M., B.D.** Burdick, **C.W.** McAda. **1984.** Use of **radiotelemetry** for obtaining habitat preference data on Colorado **squawfish.** North American Journal of Fisheries Management **4:177-80.**

**Tyus, H.M., B.D.** Burdick, **R.A.** Valdez, **C.M.** Haynes, **T.A.** Lytle, and **C.R.** Berry. **1982a.** Fishes of the Upper Colorado River Basin: distribution, abundance, and status. **131** pages in W. H. Miller, H. M. **Tyus,** and C. A. Carlson, editors. Fishes of the upper Colorado River system: present and future. American Fisheries Society, Bethesda, Maryland.

**Tyus, H.M.** and **G.B.** Haines. **1991.** Distribution, habitat use, and growth of Age-0 Colorado **squawfish** in the Green River Basin, Colorado and Utah. Transactions of the American Fisheries Society **120:79-89.**

**Tyus, H.M., R.L.** Jones, and L.A. **Trinca. 1987.** Green River rare and endangered fishes study, **1982-85.** Final Report. U.S. Fish and Wildlife Service, Colorado River Fish Management Project, Vernal, Utah. **117** pp.

**Tyus, H.M.,** and C.A. Karp. **1989.** Habitat use and **streamflow** needs of rare and endangered fishes, Yampa River, Colorado. U.S. Fish and Wildlife Service, Vernal, Utah. **27** pp.

**Tyus, H.M.,** and C.A. Karp. **1990.** Spawning and movements of razorback sucker, Xyrauchen texanus, in the Green River basin of Colorado and Utah. The Southwestern Naturalist. **35:427-433.**

**Tyus, H.M.,** and C.A. Karp. **1991.** Habitat use and stream flow needs of rare and endangered fishes in the Green River, Utah. U.S. Fish and Wildlife Service, Vernal, Utah. **54** pp.

**Tyus, H.M.** and **C.W.** McAda. **1984.** Migration, movements and habitat preferences of Colorado **squawfish,** Ptychocheilus lucius, in the Green, White, and Yampa Rivers, Colorado and Utah. The Southwestern Naturalist **29:289-299.**

Tyus, H.M., C.W. McAda, and B.D. Burdick. 1982b. Green River fishery investigations: 1979-1981. Pages 1-99 in W.H. Miller, J.J. Valentine, D.L. Archer, H.M. Tyus, R.A. Valdez, and L. Kaeding, editors. Final Report-Part 1. Colorado River Fishery Project. U.S. Bureau of Reclamation, Salt Lake City, Utah.

Tyus, H.M. and N.J. Nikirk. 1990. Abundance, growth, and diet of channel catfish in the Green and Yampa Rivers, Colorado and Utah. The Southwestern Naturalist 50:33-39.

Tyus, H.M., R.A. Valdez, and R.D. Williams. 1986. Status of endangered fishes in the Upper Colorado River, 1985. Proceedings Bonneville Chapter American Fisheries Society 1986:20-30.

Ulmer, L. 1980. Preliminary results of studies on movement and reproduction of the razorback sucker inhabiting Senator Wash Reservoir, California. California Department of Fish and Game. 24 pp.

Ulmer, L., and K.R. Anderson. 1985. Management plan for the razorback sucker (Xyrauchen texanus) in California. California Department of Fish and Game,Region 5 Information Bulletin 0013-10-1985, 1-26.

USBR (U.S. Bureau of Reclamation). 1988. Glen Canyon environmental studies: final technical report. U.S. Department of the Interior, Bureau of Reclamation, Salt Lake City, Utah.

USBR (U.S. Bureau of Reclamation). 1990. Proposed safety of dams modification to Horseshoe and Bartlett Dams on the Verde River, Arizona. Final Environmental Assessment. Arizona Projects Office, Phoenix, Arizona.

USBR (U.S. Bureau of Reclamation). 1991. Colorado River system consumptive uses and losses report, 1981-1985. U.S. Department of Interior, Bureau of Reclamation. 40 pp.

USFWS (U.S. Fish and Wildlife Service). 1980. Endangered Species Technical Bulletin 5(10):3.

USFWS (U.S. Fish and Wildlife Service). 1986. Annual report to the Bureau of Reclamation: Colorado River endangered fishes investigations. U.S. Department of the Interior, Fish and Wildlife Service, Division of Endangered Species, Denver, Colorado.

USFWS (U.S. Fish and Wildlife Service). 1990a. Bonytail Chub Recovery Plan. Prepared by Colorado Fishes Recovery Team for U.S. Fish and Wildlife Service, Denver, Colorado. 35 pp.

USFWS (U.S. Fish and Wildlife Service). 1990b. Humpback Chub Recovery Plan. Prepared by Colorado Fishes Recovery Team for U.S. Fish and Wildlife Service, Denver, Colorado. 43 pp.

USFWS (U.S. Fish and Wildlife Service). 1991. Colorado Squawfish Recovery Plan. Prepared by Colorado Fishes Recovery Team for U.S. Fish and Wildlife Service, Denver, Colorado. 56 pp.

USFWS (U.S. Fish and Wildlife Service). 1992a. Aspinall Study - Ichthyofaunal survey in the Gunnison River from Delta, Colorado, to the Redlands Diversion Dam. Recovery Program Project Number: 13-1. Unpublished report Colorado River Fishery Project, Grand Junction, Colorado.

USFWS (U.S. Fish and Wildlife Service). 1992b. Final Biological Opinion for the Operation of Flaming Gorge Dam. U.S. Fish and Wildlife Service, Region 6, Denver, Colorado. 44 pp plus Appendices.

Valdez, R.A. 1981. Status of the distribution and taxonomy of Gila cypha in the upper Colorado River. Proceedings of the Desert Fishes Council 12:53-68.

Valdez, R.A. 1985. Cataract Canyon fish study. Final Report: Contract No. 5-CS-40-02820. U.S. Department of the Interior. Bureau of Reclamation, Salt Lake City, Utah. Six sections plus 4 appendices.

Valdez, R.A. 1987. Fisheries biology and rafting. Annual Summary Report--1986. Contract No. 6-CS-40-03980, conducted by BIO/WEST, Inc. U.S. Department of the Interior, Bureau of Reclamation, Salt Lake City, Utah. 43 pp. plus appendices.

Valdez, R.A. 1988. Fisheries biology and rafting. Annual Summary Report--1987. Contract No. 6-CS-40-03980, conducted by BIO/WEST, Inc., U.S. Department of the Interior, Bureau of Reclamation, Salt Lake City, Utah. 45 pp. plus appendices.

Valdez, R.A. 1990. The Endangered Fish of Cataract Canyon. Final Report prepared for the United States Department of Interior, Bureau of Reclamation, Salt Lake City, Utah. Contract No. 6-CS-40--3980, Fisheries Biology and Rafting. BIO/WEST Report No. 134-3. 94 pp. plus appendices.

Valdez, R.A. 1991. Characterization of the life history and ecology of the humpback chub in the Grand Canyon. Annual Report to the Bureau of Reclamation. Contract No. 0-CS-40-09110. Bio/West Report No. TR 250-02. Logan, Utah. 74 pp.

Valdez, R.A. and G.H. Clemmer. 1982. Life History and prospects for recovery of the humpback and bonytail chub. Pages 109-119 in W.M. Miller, H.M. Tyus and C.A. Carlson, editors. Proceedings of a Symposium on Fishes of the Upper Colorado River System: Present and Future. American Fisheries Society, Bethesda, Maryland.

Valdez, R.A., and B.R. Cowdell. 1993. Survival of age-0 Colorado squawfish in the Green and Colorado rivers. Annual Summary Report - 1992. Prepared for Utah Division of Wildlife Resources, Salt Lake City, Utah. Bio/West Report No. 345 23 pp. plus appendices.

Valdez, R.A., P.B. Holden, and T.B. Hardy. 1990. Habitat Suitability Index curves for humpback chub of the upper Colorado River Basin. Rivers 1:31-42.

Valdez, R.A., and M. Hugentobler (Editors). 1993. Characterization of the life history and ecology of the humpback chub (Gila cypha) in the Grand Canyon. Annual Report-1992 to Bureau of Reclamation. BIO/WEST Report No. TR-250-06. 168 pp. plus appendices.

Valdez, R.A., P.G. Mangan, M. McInery, and R.P. Smith. 1982a. Tributary report: fishery investigations of the Gunnison and Dolores Rivers. Pages 321-362 in W.H. Miller, J.J. Valentine, D.L. Archer, H.M. Tyus, R.A. Valdez, and L. Kaeding, editors. Part 2-Field investigations. Colorado River Fishery Project. U.S. Bureau of Reclamation, Salt Lake City, Utah.

Valdez, R.A., P.G. Mangan, R. Smith, and B. Nilson. 1982b. Upper Colorado River fisheries investigations (Rifle, Colorado, to Lake Powell, Utah). Pages 100-279 in W.H. Miller, J.J. Valentine, D.L. Archer, H.M. Tyus, R.A. Valdez, and L. Kaeding, editors. Part 2-Field investigations. Colorado River Fishery Project. U.S. Bureau of Reclamation, Salt Lake City, Utah.

Valdez, R.A., and W.J. Masslich. 1989. Winter habitat study of endangered fish-Green River. Wintertime movement and habitat of adult Colorado squawfish and razorback suckers. Prepared for the Bureau of Reclamation, Salt Lake City, Utah. BIO/WEST Report No. 136-2. 184 pp.

Valdez, R.A., W.J. Masslich, and W.C. Leibfried. 1992. Characterization of the life history and ecology of the humpback chub (Gila cypha) in the Grand Canyon. Annual Report to Bureau of Reclamation. Bio/West Report No. TR-250-04. 222 pp.

Valdez, R.A., and E.J. Wick. 1983. Natural vs. manmade backwaters as native fish habitat. Pages 519-536 in V.D. Adams and V.A. Lamarra, editors. Aquatic Resources Management of the Colorado River Ecosystem. Ann Arbor Science, Ann Arbor, Michigan.

Valdez, R.A., and R.D. Williams. 1986. Cataract Canyon fish study. Final Report Contract No. 6-CS-4-0-03980. Bureau of Reclamation, Salt Lake City, Utah. 41 pp. plus appendices.

Vanicek, C.C. 1967. Ecological studies of native Green River fishes below Flaming Gorge dam, 1964-1966. Ph.D. Dissertation. Utah State University, Logan. 124 pp.

Vanicek, C.D., and R.H. Kramer. 1969. Life history of the Colorado squawfish, Ptychocheilus lucius, and the Colorado chub, Gila robusta, in the Green River in Dinosaur National Monument, 1964-1966. Transactions of the American Fisheries Society 98(2):193-208.

Vanicek, C.D., R.H. Kramer, and D.R. Franklin. 1970. Distribution of Green River fishes in Utah and Colorado following closure of Flaming Gorge dam. Southwestern Naturalist 14:297-315.

VTN Consolidated, Inc. 1978. Fish, wildlife and habitat assessment, San Juan River, New Mexico and Utah--Gallop-Navajo Indian Water Supply Project. U.S. Bureau of Reclamation, Upper Colorado River Region, Salt Lake City, Utah. 241 pp.

Wagner, R.A. 1955. Basic survey of Lake Mohave. Completion Report, Project F-2-R-1. Wildlife Restoration Division, Arizona Game and Fish Department, Phoenix, Arizona. 16 pp.

Walker, B.W., R.R. Whitney, and G.W. Barlow. 1961. The fishes of the Salton Sea. Pages 77-91 in B.W. Walker, editor. The ecology of the Salton Sea, California, in relation to the sport fishery. California Fish and Game, Fish Bulletin 113.

Wallis, O.L. 1951. The status of the fish fauna of the Lake Mead National Recreation Area, Arizona-Nevada. Transactions of the American Fisheries Society 80:84-92.

Welcomme, R.L. 1979. Fisheries ecology of floodplain rivers. Longman, New York. 315 pp.

Western (Western Area Power Administration) 1991. Annual Report. U.S. Department of Energy, Washington, D.C. 32 pp. plus Statistical Appendix 98 pp.

Wick, E.J. 1992. River management and habitat restoration strategy: an issue paper on habitat development. Recovery Program--Endangered Fishes--Upper Colorado River. a U.S. Fish and Wildlife Service Technical Paper. IN PREP.

Wick, E.J. and J.A. Hawkins. 1989. Observations on the use of the Little Snake River in Colorado, by endangered Colorado squawfish and humpback chub, 1988. Larval fish laboratory, Colorado State University, Fort Collins. 10 pp.

Wick, E.J., J.A. Hawkins and C.A. Carlson. 1985. Colorado squawfish population and habitat monitoring 1983-1984. Final Report SE-3-7. Colorado Division of Wildlife and Colorado State University, Larval Fish Laboratory, Fort Collins, Colorado. 48 pp.

Wick, E.J., J.A. Hawkins and C.A. Carlson. 1986. Colorado squawfish population and habitat monitoring 1985. Final Report SE-3-8. Colorado Division of Wildlife and Colorado State University, Larval Fish Laboratory, Fort Collins, Colorado. 80 pp.

Wick, E.J., T.A. Lytle, and C.M. Haynes. 1981. Colorado squawfish and humpback chub population and habitat monitoring, 1979-1980. Progress Report, Endangered Wildlife Investigations. SE-3-3. Colorado Division of Wildlife, Denver, Colorado. 156 pp.

Wick, E.J., D.E. Snyder, D. Langlois, and T. Lytle. 1979. Colorado squawfish and humpback chub population and habitat monitoring. Federal Aid to Endangered Wildlife Job Progress Report. SE-3-2. Colorado Division of Wildlife, Denver, Colorado. 56 pp. plus appendices.

Wick, E.J., D.L. Stoneburner, and J.A. Hawkins. 1983. Observations on the ecology of Colorado squawfish, (Ptychocheilus lucius) in the Yampa River, Colorado, 1982. Progress Report SE-3-5. U.S. National Park Service, Water Research Field Support Laboratory Report No. 83-7, Colorado Division of Wildlife, Fort Collins, Colorado. 55 pp.

Wiltzius, W.J. 1978. Some factors historically affecting the distribution and abundance of fishes in the Gunnison River. Colorado Division of Wildlife, Fort Collins, Colorado. 215 pp.

Wiltzius, W.J. 1985. Fish culture and stocking in Colorado, 1872-1978. Colorado Division of Wildlife, Denver.

# APPENDICES

**Appendix A. List of common and scientific species names contained within this document. Some scientific names given elsewhere in the document are not contained in this list. Important sientific names give in the document may be repeated in this table.**

| COMMON NAME | SCIENTIFIC NAME |
|---|---|
| **Invertebrates** | |
| amphipod | *Gammarus lacustris* |
| Asian tapeworm | *Bothriocephalus acheilognathi* |
| parasitic copepod | *Lernea sp.* |
| **Plants** | |
| algae | *Cladophora glomerata* |
| cottonwood | *Popular* spp. |
| tamarisk | *Tamarix* spp. |
| water hyacinth | *Eichhornia crassipes* |
| willow | *Salix* spp. |
| **Fishes** | |
| American (freshwater) eel | *Anguilla rostrata* |
| Apache trout | *Oncorhynchus apache* |
| Arctic grayling | *Thymallus arcticus* |
| bigmouth buffalo | *Ictiobus cyprinellus* |
| black buffalo | *Ictiobus niger* |
| black bullhead | *Ameiurus melas* |
| black crappie | *Pomoxis nigromaculatus* |
| blue catfish | *ktalurus furcatus* |
| blue tilapia | *Tilapia aurea* |
| bluegill | *Lepomis macrochirus* |
| bluehead sucker | *Catostomus discobolus* |
| Bonneville cisco | *Prosopium gemmiferum* |
| Bonneville cuthroat trout | *Oncorhynchus clarki utah* |
| bonytail | *Gila elegans* |
| brassy minnow | *Hybognathus hankinsoni* |
| brook trout | *Salvelinus fontinalis* |
| brown bullhead | *Ameiurus nebulosus* |
| brown trout | *Salmo trutta* |

Appendix A (continued).

| COMMON NAME | SCIENTIFIC NAME |
|---|---|
| Fishes (continued) | |
| common carp | *Cyprinus carpio* |
| channel catfish | *ktalurus punctatus* |
| chum salmon | *Oncorhynchus keta* |
| coho salmon | *Oncorhynchus kisutch* |
| Colorado cutthroat trout | *Oncorhynchus clarki pleuriticus* |
| Colorado squawfish | *Ptychocheilus lucius* |
| creek chub | *Semotilus atromaculatus* |
| cuttbow | *Oncorhynchus clarki x Oncorhynchus mykiss* |
| desert pupfish | *Cyprinodon macularius* |
| desert sucker | *Catostomus clarki* |
| fathead minnow | *Pimephales promelas* |
| flannelmouth sucker | *Catostomus latipinnis* |
| flathead catfish | *Pylodictis olivaris* |
| Gila chub | *Gila intermedia* |
| Gila topminnow | *Poeciliopsis occidentalis* |
| Gila trout | *Oncorhynchus gilae* |
| golden shiner | *Notemigonus crysoleucas* |
| golden trout | *Oncorhynchus mykiss aguabonita* |
| goldfish | *Carassius auratus* |
| grasscarp | *Ctenopharyngodon idella* |
| green sunfish | *Lepomis cyanellus* |
| green swordtail | *Xiphophorus hellerii* |
| humpback chub | *Gila cypha* |
| Iowa darter | *Etheostoma exile* |
| Johnny darter | *Etheostoma nigrum* |
| Kendall Warm Springs dace | *Rhinichthys osculus thermalis* |
| lake trout | *Salvelinus namaycush* |
| Las Vegas dace | *Rhinichthys deaconi* |
| largemouth bass | *Micropterus salmoides* |
| leatherside chub | *Gila copei* |
| Little Colorado spinedace | *Lepidomeda vittata* |
| loach minnow | *Tiaroga cobitis* |
| longfin dace | *Agosia chrysogaster* |
| longnose dace | *Rhinichthys cataractae* |
| longnose sucker | *Catostomus catostomus* |
| machete | *Elops affinis* |
| Mexican molly | *Poecilia mexicana* |

Appendix A (continued).

| COMMON NAME | SCIENTIFIC NAME |
|---|---|
| | Fishes (continued) |
| Mexican tetra | *Astyanax mexicanus* |
| Moapa dace | *Moapa coriacea* |
| Moapa/White River springfish | *Crenichthys baileyi* |
| Monkey Spring pupfish | *Cyprinodon sp.* |
| mosquitofish | *Gambusia affinis* |
| mottled sculpin | *Cottus bairdi* |
| mountain sucker | *Catostomus platyrhynchus* |
| Mozambique tilapia | *Tilapia mossambica* |
| northern pike | *Esox lucius* |
| pacu | *Colossoma* spp. |
| Pahranagat spinedace | *Lepidomeda altivelis* |
| Paiute sculpin | *Cottus beldingi* |
| plains killifish | *Fundulus zebrinus* |
| plains minnow | *Hybognathus placitus* |
| pumpkinseed | *Lepomis gibbosus* |
| rainbow trout | *Oncorhynchus mykiss* |
| Railroad Valley springfish | *Crenicththys nevadae* |
| razorback sucker | *Xyrauchen texanus* |
| red shiner | *Cyprinella lutrensis* |
| redear sunfish | *Lepomis microlophus* |
| redside shiner | *Richardsonius balteatus* |
| Rocky Mountain whitefish | *Prosopium williamsoni* |
| roundtail chub | *Gila robusta* |
| sailfin molly | *Poecilia latipinna* |
| sand shiner | *Notropis stramineus* |
| smallmouth bass | *Micropterus dolomieu* |
| smallmouth buffalo | *ktiobus bubalus* |
| finespot Snake River cutthroat | *Oncorhynchus clarki subsp.* |
| sockeye (kokanee) salmon | *Oncorhynchus nerka* |
| Sonora sucker | *Catostomus insignis* |
| southern platyfish | *Xiphophorus maculatus* |
| speckled dace | *Rhinichthys osculus* |
| spikedace | *Meda fulgida* |
| splake | *Salvelinus fontinalis x S. namaycush* |
| striped bass | *Morone saxatilis* |
| striped mullet | *Mugil cephalus* |
| thread fin shad | *Dorosoma petenense* |
| tiger trout | *Salvelinus fontinalis x Salmo trutta* |

**Appendix A (continued).**

| COMMON NAME | SCIENTIFIC NAME |
|---|---|
| **Fishes (continued)** | |
| Utah chub | *Gila atraria* |
| Utah sucker | *Catostomus ardens* |
| variable platyfish | *Xiphophorus maculatus* |
| sockeye (kokanee) salmon | *Oncorhynchus nerka* |
| Virgin chub | *Gila seminuda* |
| Virgin spinedace | *Lepidomeda mollispinus* |
| walking catfish | *Clarias batrachus* |
| walleye | *Stizostedion vitreum* |
| white bass | *Morone chrysops* |
| white crappie | *Pomoxis annularis* |
| White River spinedace | *Lepidomeda albivallis* |
| white sturgeon | *Acipenser transmontanus* |
| white sucker | *Catostomus commersoni* |
| woundfin | *Plagopterus argentissimus* |
| yellow bass | *Morone mississippiensis* |
| yellow bullhead | *Ameiurus natalis* |
| yellow perch | *Perca flavescens* |
| Yellowstone cutthroat trout | *Oncorhynchus clarki bouvieri* |
| Zilli's tilapia | *Tilapia zillii* |
| **Amphibians/Reptiles** | |
| bullfrog | *Rana catesbeiana* |
| **Birds** | |
| bald eagle | *Haliaeetus leucocephalus* |
| peregrine falcon | *Falco peregrinus anatum* |

Appendix B. Federally listed, proposed, or candidate species occurring or potentially occurring in or adjacent to Colorado River fish critical habitat.

PLANTS

| Scientific Name | Common Name | Category | Location |
|---|---|---|---|
| Allium gooddingii | Gooding's onion | 1 | NM |
| Aquilegia micrantha var. mancosana | Mancos columbine | 2 | CO |
| Arabis vivariensis | no common name | 2 | CO, UT |
| Astragalus anisus | Gunnison milkvetch | 2 | CO |
| Astragalus cronquistii | Cronquist milkvetch | 2 | CO, UT |
| Astragalus debequaeus | DeBeque milkvetch | 2 | CO |
| Astragalus deterior | Cliff Palace milkvetch | 2 | CO |
| Astragalus equisolensis | horseshoe milkvetch | 2 | UT |
| Astragalus hamiltonii | Hamilton milkvetch | 2 | UT |
| Astragalus humillimus | Mancos milkvetch | | CO, NM |
| Astragalus microcymbus | skiff milkvetch | 2 | CO |
| Astragalus osterhoutii | Osterhout milkvetch | | CO |
| Astragalus preussii var. cutlen | no common name | 2 | UT |
| Astragalus sabulosus | cisco milkvetch | 2 | UT |
| Astragalus schmolliae | Schmoll milkvetch | 2 | CO |
| Astragalus wetherillii | Wetherill milkvetch | 2 | CO, UT |
| Camissonia atwoodii | no common name | 2 | UT |
| Cirsium ownbeyi | Ownbey thistle | 2 | CO, UT |
| Cryptantha aperta | Grand Junction cat's-eye | 2 | CO |
| Dalea flavescens var. epica | no common name | 2 | UT |
| Echinocereus triglochidiatus var. inennis | spineless hedgehog cactus | | CO |
| Erigeron kachinensis | kachina daisy | 2 | CO, UT |
| Erigeron zothecinus | no common name | 2 | UT |
| Eriogonum pelinophilum | clay-loving wild buckwheat | | CO |
| Eriogonum ripleyi | Ripley wild buckwheat | 2 | AZ |
| Eriogonum smithii | Smith wild buckwheat | 2 | UT |
| Habenaria zothecina | alcove bog orchid | 2 | UT, CO |
| Hackelia gracilenta | Mesa Verde stickseed | 2 | CO |
| Ipomopsis polyantha var. mancosana | Pagosa gilia | 2 | CO |
| Ipomopsis polyantha var. polyantha | Pagosa skyrockets | 2 | CO |
| Lesquellaria con gesta | Dudley Bluffs bladderpod | | CO |
| Lesquerella pruinosa | Pagosa bladderpod | 2 | CO |
| Lomatium concinnum | Colorado desert parsley | 2 | CO |
| Lomatium latilobum | arches desert-parsley | 2 | CO, UT |
| Lupinus crassus | Paradox lupine | 2 | CO |
| Lygodesmia doloresensis | Dolores skeletonplant | 2 | CO, UT |
| Mentzelia multicaulis var. librina | no common name | 2 | UT |
| Mentzelia shultziorum | no common name | 2 | UT |
| Pediocactus knowtonii | Knowlton's cactus | | CO, NM |
| Pediocactus papyracanthus | grama-grass cactus | 2 | NM |

Appendix **B** (continued).

PLANTS (continued)

| Scientific Name | Common Name | Category | Location |
|---|---|---|---|
| *Pediomelum aromaticum var. tuhyi* | no common name | 2 | UT |
| *Penstemon albifluvis* | White River penstemon | 1 | UT, CO |
| *Penstemon debilis* | parachute penstemon | 2 | CO |
| *Penstemon flowersii* | no common name | 2 | UT |
| *Penstemon gibbensii* | Gibbens beardtongue | 2 | CO, UT, WY |
| *Penstemon goodrichii* | no common name | 2 | UT |
| *Penstemon grahamii* | Graham beardtongue | | CO, UT |
| *Penstemon harringtonii* | Harrington beardtongue | 2 | CO |
| *Penstemon mensarum* | tiger beardtongue | 2 | CO |
| *Penstemon parviflorus* | small-flowered beardtongue | 2 | CO |
| *Penstemon penlandii* | Penland beardtongue | | CO |
| *Penstemon retrosus* | adobe beardtongue | 1 | CO |
| *Perityle specuicola* | no common name | 2 | UT |
| *Phacelia submutica* | DeBeque phacelia | 1 | CO |
| *Physaria obcordata* | Dudley Bluffs twinpod | | CO |
| *Proatriplex pleiantha* | Mancos saltbush | 2 | CO, NM |
| *Psorothamnus polydenius var. jonesii* | no common name | 2 | UT |
| *Purshia subintegra* | Arizona cliffrose | | AZ |
| *Schoenocrambe angillacea* | clay reed-mustard | | UT |
| *Schoenocrambe suffrutescens* | shrubby reed-mustard | | UT |
| *Senecio quaerens* | Gila groundsel | 2 | NM |
| *Sclerocactus glacus* | Uinta Basin hookless cactus | | CO |
| *Sclerocactus mesae-verde* | Mesa Verde cactus | | CO |
| *Spiranthes diluvialis* | Ute ladies' tresses orchid | | CO, UT |

INVERTEBRATES

| Scientific Name | Common Name | Category | Location |
|---|---|---|---|
| *Apachecoccus kanabensis* | Bylas springsnail | 2 | AZ |
| *Boloria acrocnema* | Uncompahgre fritillary butterfly | | CO |
| *Cicindela oregona maricopa* | Maricopa tiger beetle | 2 | AZ |
| *"Fontelicella" gilae* | Gila springsnail | 1 | NM |
| *"Fontelicella" thermalis* | New Mexico hotspring snail | 1 | NM |
| *Hesperopsis gracielae* | MacNeill sooty wing skipper | 2 | UT |
| *Oxyloma haydeni kanabensis* | Kanab ambersnail | | AZ, UT |
| *Speyeria nokomis nokomis* | Great Basin silverspot butterfly | 2 | CO |
| *Tryonia gilae* | Gila tyronia snail | 2 | AZ |

FISH

| Scientific Name | Common Name | Category | Location |
|---|---|---|---|
| *Catostomous latipinnis* | flannelmouth sucker | 2 | AZ, CO, NM, UT |
| *Gila intermedia* | Gila chub | 2 | NM |
| *Gila nigrescens* | Chihuahua chub | | NM |
| *Gila robusta* | roundtail chub | 2 | AZ, CO, NM, UT |

Appendix B (continued).

FISH (continued)

| Scientific Name | Common Name | Category | Location |
|---|---|---|---|
| Meda fulgida | spikedace | T | AZ, NM |
| Oncorhynchus gilae | Gila trout | E | NM |
| Poeciliopsis occidentalis occidentalis | Gila topminnow | E | AZ, NM |
| Salmo clarki pleuriticus | Colorado River cutthroat trout | 2 | CO |
| Tiaroga cobitis | loach minnow | T | AZ, NM |

AMPHIBIANS

| | | | |
|---|---|---|---|
| Bufo boreas boreas | boreal western toad | 2 | CO |
| Bufo microscaphus microscaphus | Arizona southwestern toad | 2 | AZ, NM |
| Rana chiricahuensis | Chiricahua leopard frog | 2 | AZ, NM |
| Rana yavaipaiensis | lowland leopard frog | 2 | AZ, NM |

REPTILES

| | | | |
|---|---|---|---|
| Phrynosoma cornutum | Texas horned lizard | 2 | CO |
| Sauromalus obesus | chuckwalla | 2 | UT, AZ, NM, NV, CA |
| Thamnophis eques | Mexican garter snake | 2 | AZ, NM |
| Thamnophis rufipunctatus | narrow-headed garter snake | 2 | AZ, NM |

BIRDS

| | | | |
|---|---|---|---|
| Accipiter gentilis | northern goshawk | 2 | CO, NM |
| Buteo nitidus maximus | northern gray hawk | 2 | NM |
| Buteo regalis | ferruginous hawk | 2 | AZ, CO, NM |
| Charadrius alexandrianus nivostris | snowy plover | 2 | AZ, CO, NM, UT |
| Charadrius montanus | mountain plover | 1 | AZ(?), CO |
| Chlidonias niger | black tern | 2 | CO, UT |
| Empidonax traillii extimus | southwestern willow flycatcher | PE | AZ, NM, UT |
| Falco peregrinus anatum | peregrine falcon | E | AZ, CO, NM, UT |
| Falco peregrinus tundrius | artic peregrine falcon | T | NM |
| Glaucidium brasilianum cactorum | cactus ferruginous pygmy-owl | 1 | AZ |
| Grus americana | whooping crane | E | CO |
| Haliaeetus leucocephalus | bald eagle | E | AZ, CO, NM, UT |
| Ixobrychus exilis hesperis | western least bittern | 2 | UT |
| Lanius ludovicianus | loggerhead shrike | 2 | CO, UT |
| Laterallus jamaicensis | black rail | 2 | AZ |
| Plegadis chihi | white-faced ibis | 2 | AZ, CO, NM, UT |
| Rallus longirostris yumanensis | Yuma clapper rail | E | AZ |
| Strix occidentalis lucida | Mexican spotted owl | T | CO, UT |
| Tympanuchus phasianellus columbianus | Columbian sharp-tailed grouse | 2 | CO |

Appendix B (continued).

MAMMALS

| Scientific Name | Common Name | Category | Location |
|---|---|---|---|
| *Euderma maculata* | spotted bat | 2 | AZ, NM, UT |
| *Eumops perotis californicus* | greater western mastiff-bat | 2 | AZ |
| *Felis lynx canadensis* | North American lynx | 2 | CO |
| *Gulo gulo luscus* | North American wolverine | 2 | CO |
| *Lutra canadensis sonorae* | southwestern otter | 2 | AZ, NM, UT |
| *Macrotus californicus* | California leaf-nosed bat | 2 | AZ |
| *Mustela nigripes* | black-footed ferret | E | CO |
| *Myotis luciAgus occultus* | occult bat | 2 | AZ, NM |
| *Myotis velifer brevis* | southwestern cave myotis | 2 | NM |
| *Myotis thysanodes pahasapensis* | fringe-tailed myotis | 2 | CO |
| *Perognathus amplus amplus* | Yavaipai Arizona cotton mouse | 2 | AZ |
| *Sigmodon hispidus eremicus* | Yuma hispid cotton rat | 2 | AZ |
| *Thomomys umbrinus muralis* | Prospect Valley pocket gopher | 2 | AZ |
| *Thomomys umbrinus suboles* | Searchlight southern pocket gopher | 2 | AZ |

* Note:

E = species listed as endangered under the Act.

T = species listed as threatened under the Act.

PE = species proposed for listing as endangered under the Act.

PT = species proposed for listing as threatened under the Act.

1 = candidate category 1 species (taxa for which the Service has substantial data to support the biological appropriateness of proposing to list as endangered or threatened).

2 = candidate category 2 (taxa for which information now available indicates that a proposal to list as endangered or threatened is possibly appropriate, but for which conclusive data on biological vulnerability and threat are not currently available to support a proposed rule).