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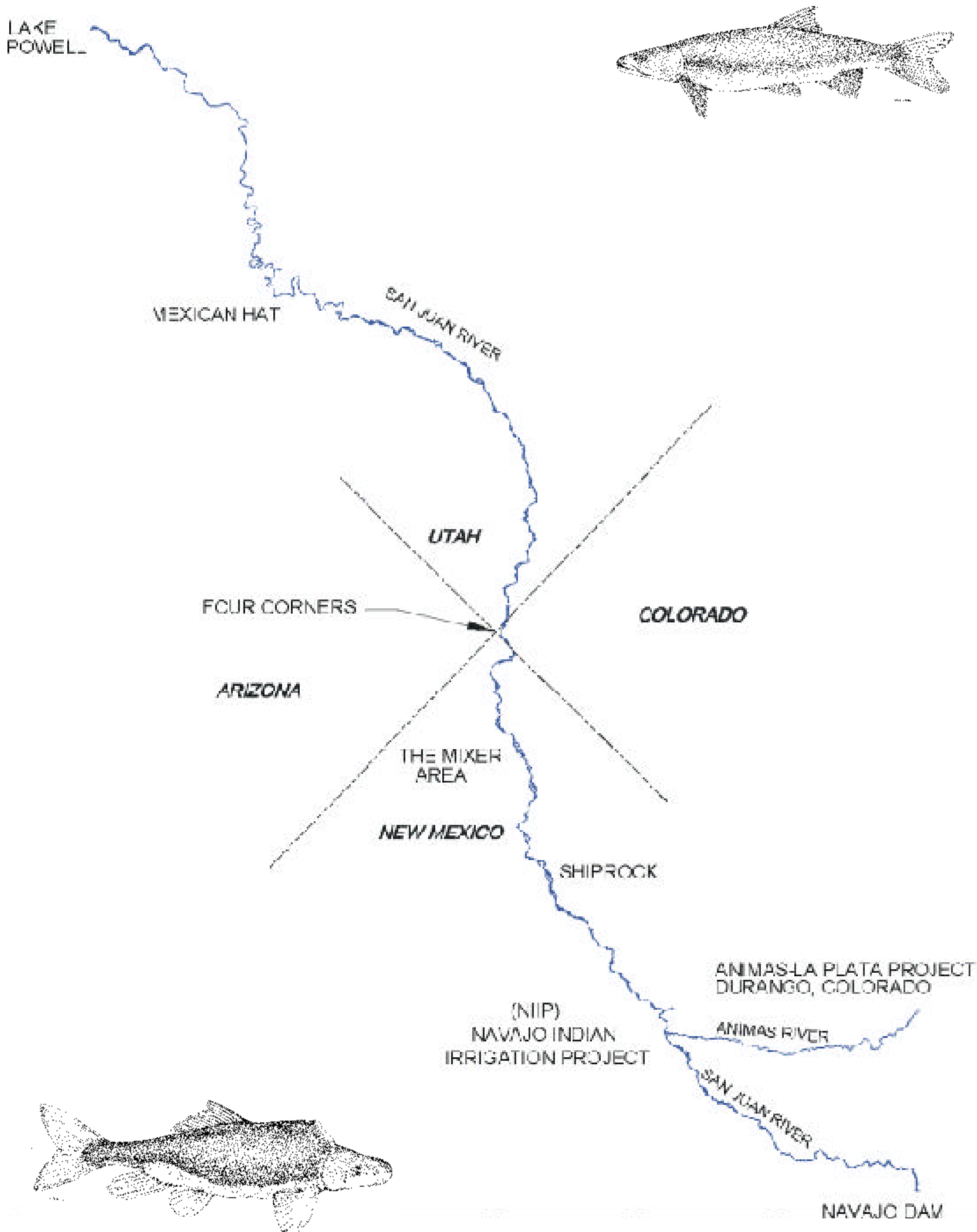
SAN JUAN RIVER
RECOVERY IMPLEMENTATION PROGRAM
BIOLOGY COMMITTEE

# Program Evaluation Report

for the 7-Year Research Period (1991 - 1997)



# ACKNOWLEDGMENTS

Although I served as the primary author for this document, I had considerable help from other members of the Biology Committee. All members reviewed and commented on the various drafts of the document, improving it considerably from the first draft. Several times the consensus of the Biology Committee was needed to determine what conclusions could be drawn or where the SJRIP should go from here. David Propst provided extensive editorial and technical comments that helped the document greatly. Vince Lamarra provided some new analyses related to habitat. Tom Pitts and John Wipple of the Coordination Committee provided comments that helped clarify several portions of the report. Although I am the only author shown on the front cover, many other people were important in shaping this document to meet the needs of the SJRIP.

In addition to the help from the SJRIP participants, I also wish to thank my editorial staff at BIO/WEST, Sandra Turner and JaNell Mathews, for putting in the extra effort to get drafts out on time and to make the document more readable and understandable for all readers.

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# EXECUTIVE SUMMARY

The Bureau of Reclamation (Bureau) initiated a 7-year research period in 1991 for the endangered Colorado pikeminnow and razorback sucker in the San Juan River of New Mexico, Colorado, and Utah in response to a Biological Opinion on the Animas-LaPlata Project. This research became part of the San Juan River Basin Recovery Implementation Program (SJRIP) formed later in 1991 by a group of agencies including: the U.S. Fish and Wildlife Service (USFWS); Bureau; Bureau of Indian Affairs (BIA); states of New Mexico and Colorado; Jicarilla-Apache, Ute Mountain Ute, and Southern Ute Indian Tribes; and San Juan River Basin water development interests. The Bureau of Land Management and the Navajo Nation joined the program later. The goals of the SJRIP were to conserve populations of the two endangered fish in the San Juan River consistent with the recovery goals established under the Endangered Species Act and proceed with water development in accordance with applicable laws and Indian trust responsibilities. From 1991 to 1997, the SJRIP conducted over 25 biological, physical, and chemical studies of the San Juan River. Management actions, including stocking endangered fishes and planning barrier removal (water diversion structures), were also initiated. Many studies focused on determining the effects of reoperating Navajo Dam to mimic a natural hydrograph on the fishes and their habitat. Reoperation involved releasing higher spring flows and lower late summer, fall, and winter flows than had been released since Navajo Dam's completion in 1962. This report summarizes the findings of those studies and how they relate to recovery of the two endangered species in the San Juan River and provides the basis for setting the future direction of the SJRIP.

The SJRIP accomplished most of the objectives it set during the 7-year research period. Life history and habitat information on the native fish community were gathered and key habitats determined. Physical studies defined habitat availability and quality in the San Juan River and, along with biological habitat use information, were used to develop flow recommendations. The flow recommendations provided for continuing water development in the San Juan Basin without harming the endangered fish species, a goal of the SJRIP. Other limiting factors, such as fish health, nonnative species interactions, water quality, and contaminants, were investigated and their importance was clarified. Experimental augmentation was initiated for both endangered fish species, and augmentation of razorback sucker began. These efforts resulted in the establishment of a razorback sucker population that is reproducing in the river and a Colorado pikeminnow population increase—from about 20 wild adults to perhaps as many as several hundred subadults and large juveniles. Limitations related to spawning and the larval stage of either of the endangered fishes were not studied because of the low population levels. These two life history stages will be easier to study as adult populations increase, more spawning occurs, and more larvae become available in the river. The primary objectives the SJRIP did not meet were development of interim population goals for the two species and development of a public information and education program. Emphasis on these areas increased in 1998 and 1999, with initiation of a bioenergetics study to determine interim population levels and development and implementation of an Information and Education program. Although recovery of the endangered fish species still requires a number of years of effort, the SJRIP made significant progress during the 7-year research period.

The overall goal of the SJRIP was recovering the two endangered fishes in the San Juan River Basin, and the studies were aimed at determining and eliminating or diminishing the limiting factors for the fishes recovery. The San Juan River was considered an important geographic component of recovery for Colorado pikeminnow in the 1991 Recovery Plan for that species. Presently, the USFWS is developing recovery goals for the two endangered species. It is the SJRIP's intent to provide demographically and genetically viable populations of these species in the San Juan River, aiding in their recovery throughout the Colorado River Basin. Demographically viable populations are self-sustaining with natural recruitment and an appropriate size and age-structure. Genetically viable populations are of sufficient size that inbreeding issues are not a concern.

The biological studies conducted during the 7-year research period showed that, although historically found in the river, razorback sucker did not presently have a San Juan River population and that the reproducing Colorado pikeminnow population was comprised of about 20 adults. Small population sizes were a critical factor limiting the ability of the two species to increase population size during the 7-year research period. These findings prompted experimental stocking of both species to determine if large-scale augmentation was feasible and if habitat for the fishes various life stages was available in the river. Radio telemetry was used to locate Colorado pikeminnow spawning sites and determine their seasonal habitat use, as well as to determine subadult stocked razorback sucker habitat use. At the same time, physical studies were underway that included mapping habitat and determining factors necessary to create and maintain key habitats for the endangered fishes. These various studies showed that: Colorado pikeminnow spawning habitat consisted of very clean cobble bars; a variety of low-velocity habitats, such as eddies and pools, were used heavily by both species most of the year; and young Colorado pikeminnow used backwaters and other low-velocity habitats. The mapping studies showed that many of these key habitats were uncommon to rare in the San Juan River; however the stocking studies showed that the fish found the areas containing these rare habitats and were able to survive and grow. Most previous stockings of both species in the Colorado River Basin were not successful.

The habitat studies led to developing flow recommendations that involved reoperating Navajo Dam to create and maintain key habitats for the endangered and other native fishes, and that would maximize key habitat availability at the correct time during the life history of each species. The key habitats not identified and included in the flow recommendations were habitats for larvae of the endangered species. These habitats, and limiting factors for larval endangered fishes, will be studied as the adult populations increase and more larvae become available to study.

In addition to habitat, factors that may limit the range of the endangered fish species in the San Juan River were also studied. Available habitat in the San Juan River was compressed as a result of constructing Lake Powell on the lower end (54 miles inundated) and Navajo Dam on the upper end (27 miles inundated), reducing the portion of river available to the fish by about 80 miles. Five water diversion structures in the upper portion of the San Juan River were evaluated as fish movement barriers. Based on fish distribution above and below them, one or two of the structures appeared to impede most species most of the time. Plans for removing one diversion and adding fish passage structures on two of the other diversions were initiated in 1998 and 1999. Cooler water temperatures from Navajo Dam releases created lower temperatures in the San Juan River, at least downstream as far as Shiprock, New Mexico, and may affect Colorado pikeminnow spawning success. Additional studies are needed to clarify this potential limiting factor.

Several studies focused on nonnative fish interactions, including predation and competition. Although negative effects of nonnative predation or competition documented by these studies were not substantial, partly because the endangered fish populations were too small, the sheer numbers of some species, such as channel catfish, common carp, and red shiner, suggest they negatively impact native species. In parts of the Colorado River Basin, some nonnative fish densities declined during years with high spring flows, but in the San Juan River during the 7-year research period this occurrence was not documented for nonnative fishes in general; channel catfish and common carp numbers actually increased during the study period. Red shiner numbers did decline in San Juan River secondary channels during high flow years.

Fish health, water quality, and contaminants were evaluated as potential limiting factors to the native fish community, but none of them proved to be important limiting factors. For both endangered species, an important factor limiting their ability to increase their population size during the 7-year research period was too few adults in their populations.

The studies showed that native flannelmouth sucker, bluehead sucker, and speckled dace were abundant in the river, but roundtail chub was rare. Roundtail chub was also a target species during the 7-year research study since it was rare in several Colorado River Basin areas and may be considered for listing under the Endangered Species Act. During the 7-year research period, flannelmouth sucker populations increased in the upper river but decreased in the lower river. Reasons for the decline in the lower river were not clear, but they will continue to be investigated.

The native fish community's overall good health, the razorback sucker and Colorado pikeminnow stocking success, and reoperating Navajo Dam to provide key habitats for these species indicated that the San Juan River has potential for providing demographically viable populations of both species that will be important in recovery of the species, not only in the San Juan River, but throughout the Colorado River Basin.

The results obtained during the 7-year research period will guide future recovery actions. Future actions will focus on expanding the San Juan River razorback sucker, Colorado pikeminnow, and roundtail chub populations. A razorback sucker Augmentation Plan was completed in 1997, and population augmentation is underway. Growout ponds were developed on Navajo Nation property near Farmington, New Mexico, to rear young fish, but problems with obtaining young fish need to be resolved. A Colorado pikeminnow Augmentation Plan will be developed and implemented to augment the small wild population. Colorado pikeminnow stocking will also occur above Shiprock, New Mexico, an area not presently occupied by the species but one that SJRIP studies determined to contain sufficient habitat. Limiting factors associated with recruitment and larval success of all three target species will be studied, since this is the life stage where recruitment failed in other portions of the Colorado River Basin. Nonnative fish control efforts will continue and may be expanded if effective control measures are developed. Monitoring will be an important component of future activities, and a Monitoring Plan was developed and initiated. Adaptive management will continue to be used to adjust SJRIP efforts as new information becomes available. In particular, the flow recommendations will be continually reviewed and adjusted, if needed.

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# CHAPTER 1: INTRODUCTION

## BACKGROUND

This document describes the results of 7 years of research on the biological, physical, and chemical resources of the San Juan River. The research focused on methods of recovering two endangered fish species, the Colorado pikeminnow (*Ptychocheilus lucius*) and razorback sucker (*Xyrauchen texanus*). Although the research was focused on these two endangered species, the entire native fish community was considered in the studies, because a healthy native fish community is important for recovery of the two endangered species. Research encompassed a variety of biological, physical, and chemical studies, from intensive studies of native and nonnative fish population structure and movement to studies of the effect of storm events on important fish habitats. Final research reports were prepared for each study undertaken and are cited throughout this document as the basis for analyses contained herein. This document is a companion document to *Flow Recommendations for the San Juan River* (*Flow Report*) (Holden [Ed.] 1999), which also used information from research summarized in this document. The *Flow Report* concentrated on the research results pertaining to the goal of developing flow recommendations. This report summarizes the research results pertaining to limiting factors for the two endangered fishes and other components of the native fish community and provides the basis for setting the future direction of the SJRIP.

Colorado pikeminnow and razorback sucker were widespread and common throughout much of the Upper Colorado River Basin (Upper Basin), likely including the San Juan River, during the settlement and initial development of the western United States (circa 1870s to 1950s) (Jordan 1891, Koster 1957, Quartarone 1993, Stanford 1994). Jordan (1891) noted that settlers reported both species in the San Juan River system upstream as far as Durango, Colorado. Three juvenile Colorado pikeminnow were collected in 1936 in the portion of the San Juan River now inundated by Lake Powell (Platania 1990). Several other adult and juvenile Colorado pikeminnow were collected in the river during the mid-20th Century (Koster 1960), some of which were collected during studies associated with the completion of Navajo Dam (Olson 1962). No fish collection studies encompassing the entire river were conducted until 1978, 16 years after Navajo Dam was completed. VTN Consolidated, Inc. and the Museum of Northern Arizona (1978) sampled the river from near Navajo Dam to Lake Powell in 1978, and they collected one juvenile Colorado pikeminnow and reported (secondhand) the occurrence of razorback sucker from an irrigation pond connected to the river. This study showed that both species still existed in the river but suggested that neither species was abundant in the system.

The current population sizes of these fish species are greatly reduced compared with earlier times, and recruitment is limited throughout the Upper Basin, including the San Juan River. Decline of the endangered Colorado pikeminnow and razorback sucker in the Colorado River Basin, including the San Juan River, was attributed to habitat fragmentation and loss, alteration of historical flow regimes, and other environmental changes associated with the construction and operation of reservoirs. Contaminants, eradication of native fishes, sportfish-management activities such as stocking of nonnative fishes, and predation and competition from introduced fishes have also been implicated in the decline of the Colorado pikeminnow and razorback sucker (Minckley et al. 1991, Tyus 1991, USFWS 1997).

In 1987, a 3-year research effort concentrating on the two endangered species in the San Juan River was initiated by the U.S. Fish and Wildlife Service (USFWS), Bureau of Reclamation (Bureau), New Mexico Department of Game and Fish (NMGF), and Utah Division of Wildlife Resources (UDWR). The study participants found a number of young and adult Colorado pikeminnow and an adult razorback sucker, confirming that both species still inhabited the San Juan River but apparently in relatively small numbers. These findings prompted reinitiation of Endangered Species Act Section 7 Consultation (Consultation) on major proposed water projects in the San Juan River Basin. Consultation on the Animas-La Plata Project (ALP) in 1991 resulted in the Bureau agreeing to reoperate Navajo Dam to mimic a natural hydrograph, fund approximately 7 years of research on the San Juan River to study the effect of flow changes, and participate in and help fund an implementation program for recovery of the endangered fishes in the San Juan River. Following Consultation on the Navajo Indian Irrigation Project in 1991, the Bureau of Indian Affairs (BIA) agreed to support and participate in the 7-year research effort and in the broader recovery implementation program.

Because of Consultation requirements, the Bureau, BIA, and USFWS organized a broader recovery program that included all agencies and entities involved with water use and resource development in the San Juan River Basin. The San Juan River Basin Recovery Implementation Program (SJRIP) was initiated in 1992, with overall goals to conserve populations of the two endangered fish in the San Juan River consistent with the recovery goals established under the Endangered Species Act and proceed with water development in accordance with applicable laws and Indian trust responsibilities. In addition to the USFWS, Bureau, and BIA, other original members of the SJRIP included: the states of New Mexico and Colorado; the Ute Mountain Ute, Southern Ute, and Jicarilla-Apache Indian tribes; and water development interests. Members of the SJRIP that joined later were the Bureau of Land Management (BLM) and the Navajo Nation. The 7-year research effort was incorporated into the SJRIP once the SJRIP was underway. Two primary committees were established within the SJRIP. The SJRIP Biology Committee (Biology Committee) was responsible for determining research priorities, conducting research and coordinating research activities, assessing progress of the SJRIP, and providing progress reports and budgets. The Biology Committee developed a *Long Range Plan (LRP)* (USFWS 1995) that guided SJRIP activities, especially research efforts. The SJRIP Coordination Committee (Coordination Committee) was responsible for: approving annual work plans, progress reports, and budgets; determining SJRIP membership; and assuring long-range funding.

Research and recovery actions under the SJRIP were carried out by a multiagency group including the USFWS, NMGF, Bureau, BIA, UDWR, BLM, National Park Service, Southern Ute Tribe, Jicarilla-Apache Tribe, Navajo Nation, University of New Mexico, and other organizations.

Funding for the SJRIP primarily came from the Bureau and BIA, with additional funding from the USFWS and some Indian Tribes, and from in-kind contributions of personnel time from all involved agencies. The SJRIP used the policy of adaptive management to guide research and monitoring activities throughout the 7-year research period.

The term "recovery" was used throughout the SJRIP documents, including this report, to mean recovery of the San Juan River populations of the two endangered fish species. When the SJRIP was initiated, a recovery plan for Colorado pikeminnow guided recovery activities throughout the Colorado River Basin, and the SJRIP activities were designed to fit into that plan. A recovery plan for razorback sucker was not complete at that time, so SJRIP activities were designed to be the most logical for recovery in the San Juan River. In late 1999 and early 2000, the USFWS (Denver) initiated a project to develop recovery criteria for both Colorado pikeminnow and razorback sucker at the species level, rather than at a given river basin level (i.e., San Juan River). Although still in draft form, the documents (Valdez et al. 2000 a, 2000b) are providing population size criteria and the number of populations needed for downlisting (from endangered to threatened) and delisting. Therefore, the term "recovery" has a somewhat different meaning under this new activity, recovery of the species. Throughout this document, "recovery" relates to the San Juan River populations only, unless otherwise specified. It is the intent of the SJRIP to provide demographically and genetically viable populations of Colorado pikeminnow and razorback sucker in the San Juan River that will aid in recovery of the two species throughout their range. Demographically viable populations are self-sustaining with natural recruitment and an appropriate size and age-structure. Genetically viable populations are of sufficient size that inbreeding issues are not a concern.

## DOCUMENT PURPOSE

The primary goals of the SJRIP studies were (1) to determine the factors that were limiting the endangered and other native fishes and (2) to determine ways to reduce or eliminate the important limiting factors in the San Juan River so the two endangered fish species could be recovered. This report synthesizes the results of the 7-year research period, identifies factors likely limiting population size of the endangered and other native fishes, and defines future direction for the SJRIP. A brief summary of various studies that were undertaken during the 7-year research period is provided in Chapter 2. Results of these studies are integrated in Chapter 3, which discusses how well the research answered questions about limiting factors and recovery of the two endangered fish species. Chapter 4 discusses accomplishments of the SJRIP, and Chapter 5 discusses the SJRIP's future direction by emphasizing recovery needs. A revised *LRP* is being prepared concurrently with this document, and it will guide the SJRIP into the future.

# CHAPTER 2: RESEARCH AND RECOVERY STUDIES ON THE SAN JUAN RIVER

## HISTORICAL STUDIES

No comprehensive studies of fish presence, abundance, distribution, or life history were conducted on the San Juan River until the late 1980s. Earlier studies are generally only usable to determine fish presence. The earliest accounts of fish in this area were from a U.S. Army geographic and geologic expedition to portions of the West during the early 1870s (Wheeler Survey): specimens collected by the expedition were identified by ichthyologists at the National Museum in Washington, D.C. (Cope and Yarrow 1875). Much of the early fish collections from the western United States came from similar explorations, and it was common to have mistaken location information for the specimens when they arrived at museums in the East. The first ichthyologist to actually visit much of the West was David Starr Jordan, the father of modern ichthyology in the United States, who was familiar with many of the fishes of the West from examining museum specimens. Jordan visited the Durango, Colorado, area in 1889 and sampled some of the streams there. As was his standard practice, he visited with local residents regarding fish they caught in the rivers and streams, and these conversations provided valuable information on historic native fish distribution and abundance (Jordan 1891). His collections from small streams verified the presence of cutthroat trout (*Onchorynchus clarki*), speckled dace (*Rhinichthys osculus*), bluehead sucker (*Pantosteus discobolus*), and mottled sculpin (*Cottus bairdi*), native fishes of cooler streams. Local residents told him about fish they caught for food, including flannelmouth sucker (*Catostomus latipinnis*), razorback sucker, and Colorado pikeminnow. Area residents indicated that Colorado pikeminnow and razorback sucker ascended the Animas River, apparently to spawn in the spring. These larger fish were generally well known by local residents of the Colorado River Basin because they were important in their diets, along with native trout (Jordan 1891). Jordan's accounts of razorback sucker and Colorado pikeminnow, although they are secondhand, are the first authentic accounts of these species in the San Juan Drainage. Based on what is known about the distribution and abundance of razorback sucker and Colorado pikeminnow today, the fact that these species were known by local residents and were common enough to be caught in the Animas River, a cool tributary, suggests they were likely common in the San Juan River.

Platania (1990) summarized museum specimens and collections in the San Juan Basin from 1900 to 1960. Of the several collections made by state fish and game biologists, most were either from the upper portion of the river near the present site of Navajo Reservoir, or from scattered collections at access points such as Mexican Hat, Utah (Figure 2.1). Most of these specimens were adults since collection techniques included angling and other methods targeting adult fish. Even

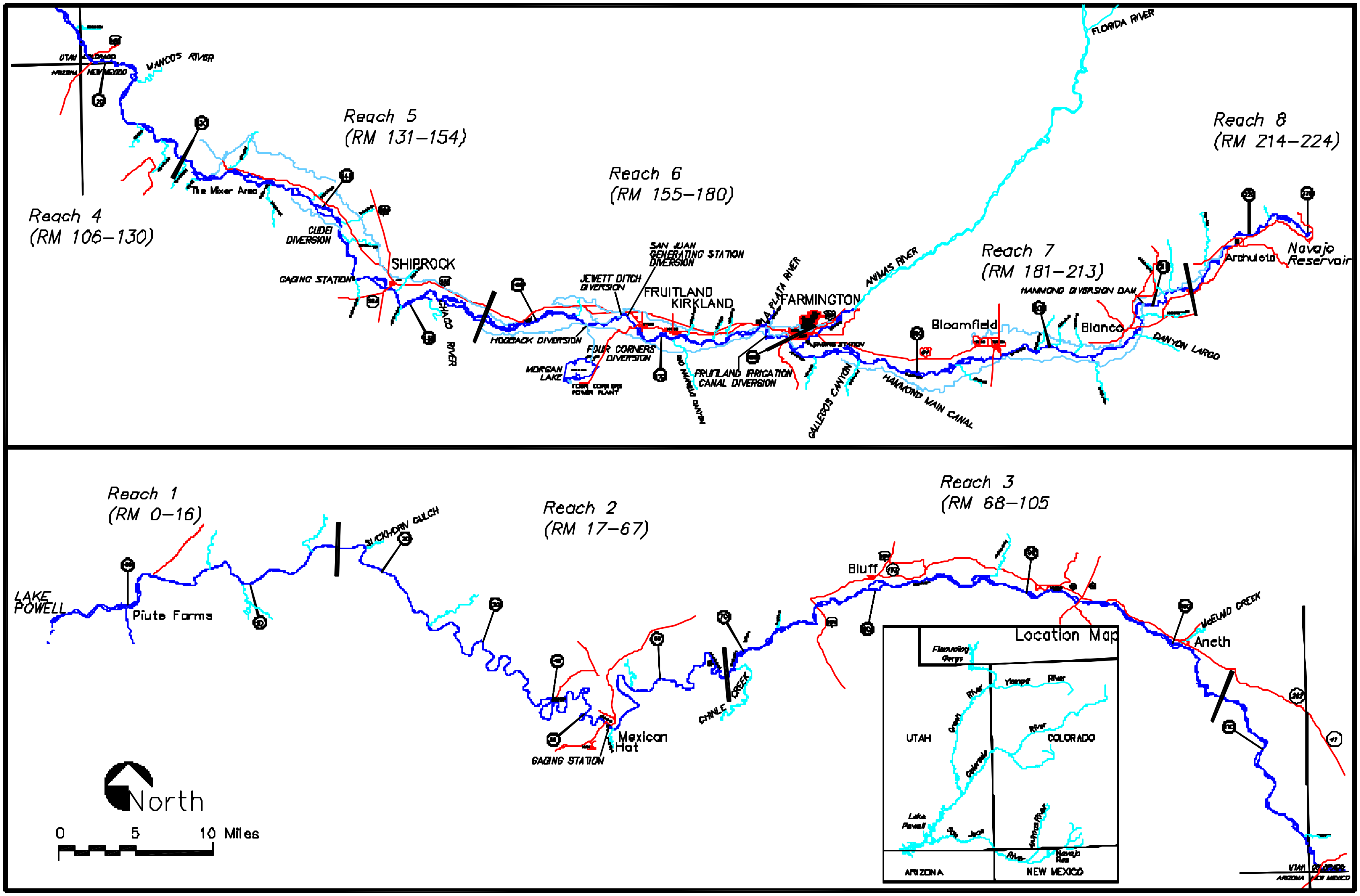



**Figure 2.1. San Juan River Basin Recovery Implementation Program (SJRIP) research study area.**

though only a small portion of river was likely sampled, these collections show that Colorado pikeminnow existed in the river from its mouth up to the present-day Navajo Reservoir Basin. Razorback sucker was not found in any of these collections.

During the mid-1900s, C. L. Hubbs and R. R. Miller, two noted ichthyologists from the University of Michigan, sampled throughout the West, usually stopping at bridge crossings and sampling with seines for 1 or 2 days at each site. Some of these collections were noted in various reports, but others were not documented and required reviewing collections at the University of Michigan's Museum of Zoology to find them. Miller collected young Colorado pikeminnow near Mexican Hat, Utah (Figure 2.1), in August 1960 (Sigler and Miller 1963). More recently, museum specimens from the University of Michigan Museum of Zoology provided information on more collections between 1934 and 1961 (S. Platania, University of New Mexico, personal communication). C.L. Hubbs collected 44 roundtail chub from the San Juan River near Shiprock, New Mexico, during two days in October 1944, and three roundtail chub were collected at Mexican Hat, Utah, in 1951. The collections by Hubbs and Miller are important for understanding the native fish abundance in the San Juan River. They were some of the first seine collections, and they were made by ichthyologists interested in the distribution and abundance of native fishes of the West. These collections verified that Colorado pikeminnow reproduced in the San Juan River, and they also verified that roundtail chub was common in the San Juan River, perhaps as far downstream as Shiprock, New Mexico. These collections, along with Jordan's earlier accounts and the scattered collection of adult Colorado pikeminnow, show that Colorado pikeminnow was common in the San Juan River and that roundtail chub was common at least in the river upstream from Shiprock, New Mexico, in the mid-1900s. The absence of razorback sucker in these scattered collections may mean that this species was relatively uncommon in the San Juan River, but it also may mean that this species used areas that were not readily accessible. Typically, razorback sucker adults are only collected during spring, when they often use flooded mouths of tributaries and other low-velocity habitats (Holden and Stalnaker 1975). During other times of the year, razorback sucker appears to use main channels (Tyus 1987), which were likely poorly sampled in the early to mid 1900s. Koster (1960) provides anecdotal accounts of razorback sucker in the San Juan River from the mid-1900s, suggesting the species was still found in the river.

Sampling of the San Juan River increased in the early 1960s as planning studies for Navajo Dam progressed. In addition, a poisoning operation was conducted just prior to the closure of Navajo Dam to rid the new reservoir basin of native and nonnative nongame fish. Olson (1962) of the NMGF conducted a pre-poisoning survey of the reservoir area in 1961 and collected both roundtail chub and Colorado pikeminnow. Olson (1962) also conducted spot surveys of fish killed by the poisoning operation. Fish were apparently killed below Farmington, further downstream than had been planned by the poisoning operation, and a few dead Colorado pikeminnow were found. Throughout the 1960s, the NMGF continued fishery sampling in the newly formed Navajo Reservoir, where roundtail chub were very abundant for several years after impoundment.

It was not until the late 1970s that relatively extensive surveys of the San Juan River were initiated. Sublette (1977) sampled the river and some of its tributaries from near Pagosa Springs, Colorado, to near Mexican Hat, Utah. Four roundtail chub were collected, but no Colorado pikeminnow or razorback sucker was collected. VTN Consolidated, Inc. and the Museum of Northern Arizona (1978) sampled the river from Navajo Dam to Lake Powell. They collected one Colorado pikeminnow, a juvenile, from near Aneth, Utah. Neither razorback sucker nor roundtail chub was caught during the latter survey. In 1976, Neil Armantrout, a BLM fishery biologist in Moab, Utah, took photographs of razorback sucker that were gathered from an irrigation pond near Bluff, Utah. The pond was connected to the river, and the fish were stranded when it was drained. He showed photographs of the fish to me for verification, and an account of the fish was included in a report by VTN Consolidated, Inc. and the Museum of Northern Arizona (1978), and Minckley and Carothers (1979). In 1977, the Colorado Squawfish Recovery Team sampled the river below Hogback Diversion for a week in June with the intent of finding Colorado pikeminnow. Electrofishing and seining were used, but neither Colorado pikeminnow nor roundtail chub was collected, although large numbers of flannelmouth sucker and bluehead sucker were found.

## SAN JUAN RIVER RECOVERY IMPLEMENTATION PROGRAM (SJRIP) AND RELATED STUDIES

By the late 1980s, the fish fauna of the San Juan River was still poorly understood. It was known that common native fish species included flannelmouth sucker, bluehead sucker, and speckled dace; that nonnative channel catfish (*Ictalurus punctatus*), common carp (*Cyprinus carpio*), fathead minnow (*Pimephales promelas*), and red shiner were very abundant; and that rainbow (*Onchorynchus gairdneri*) and brown trout (*Salmo trutta*) had replaced the native fishes below Navajo Dam. It was also known that a small, reproducing population of Colorado pikeminnow still occurred in the river, and that roundtail chub appeared to be relatively rare in the main river below Navajo Dam (Minckley and Carothers 1979). But abundance of razorback sucker was unknown, and reproductive success and detailed distribution for any of the native fish species were not well understood.

Therefore, the San Juan River's importance to the two endangered fish species in particular, and for roundtail chub and other native species, was not well understood. Hence, it was difficult to determine how this river system fit into recovery efforts for these species and what the effect of additional water development would be on these species. In 1987, following a request by the USFWS and NMGF to stock razorback sucker in the San Juan River, the Bureau funded a NMGF and UDWR 3-year study from Farmington, New Mexico, to Lake Powell to determine the distribution and occurrence of endangered fish species, describe the fish community, describe general habitat conditions, assess the suitability of the habitat for the rare fish species, and recommend future recovery or management actions. The results of that study were reported by Platania (1990). One adult razorback sucker and adult and young Colorado pikeminnow were captured during the study, which provided a more-complete picture of the San Juan River fish community. These findings prompted the USFWS to reinitiate consultation on the ALP, which resulted in the 7-year research plan and subsequent study.

When the 7-year research plan was initiated, its ultimate goals were (1) to identify the physical, chemical, and biological factors that limit endangered and native fishes and (2) to provide options for conserving and restoring the endangered fish community (Bureau et al. 1992). Specific objectives included:

1. Collect detailed information on the relative abundance and distribution of fisheries in the San Juan River Basin, with emphasis on areas downstream of Navajo Dam.

2. Characterize physical habitat for fisheries in the San Juan River and the relationship between flow and physical habitat.

3. Determine the biological response of fish populations to the reoperation of Navajo Dam.

4. Determine habitat use and needs of the Colorado pikeminnow and razorback sucker in the San Juan River.

5. Characterize water quality in the San Juan River and identify critical quality issues that may affect recovery of endangered species.

6. Identify interactions between native and nonnative species.

7. Identify and test management options which could improve reproduction and recruitment of target species.

As noted in the objectives, the 7-year research plan included investigation of the entire native fish community, rather than just the two endangered fish species. The roundtail chub was also identified as a target species. Although it was not listed as endangered, it was considered for listing in several parts of the Colorado River Basin and was rare in the mainstem San Juan River and other areas. In addition, the studies comprising the 7-year research plan were developed to examine the entire San Juan River, from Navajo Dam to Lake Powell, and investigate all life history phases of the fishes (larvae, young, juvenile, and adult). A major aspect of the 7-year research plan, and of the SJRIP, was evaluation of the biological effects of reoperation of Navajo Dam to mimic a natural hydrograph. Reoperation primarily involved releasing higher flows during spring runoff and lower flows during the rest of the year. Many of the studies were designed to investigate the biological and habitat changes that occurred with the more-natural flow pattern. In addition, adaptive management was included as an important component of the 7-year research plan. This meant that as new needs for research or management become evident, additional studies or management actions would be implemented, even though the initial plan may not have foreseen those needs.

To meet these objectives, a biological studies series was formulated, and sampling began in 1991. Table 2.1 shows the various studies that were implemented on the San Juan River in response to the 7-year research plan, as well as the 1987 to 1990 studies. Four core biological studies were

**Table 2.1. Research and recovery studies conducted on the San Juan River from 1987 to 1997 with starting year, length of study, and citation for final report.**

| STUDY AND FINAL REPORT CITATION | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pre-SJRIP Studies** | | | | | | | | | | | |
| Ichthyofaunal Study, New Mexico-Utah (Platania 1990) | x | x | x | | | | | | | | |
| Nursery Habitat Sampling, UDWR (Platania et al. 2000) | | | | x | | | | | | | |
| **7-Year Research Period and SJRIP Studies** | | | | | | | | | | | |
| Adult Monitoring and Radiotelemetry (Ryden 2000a) | | | | | x | x | x | x | x | x | x |
| Lower San Juan Fish Community Survey (Lashmett 1993) | | | | | x | x | | | | | |
| Early Lifestage - Nursery Habitat and Drift (Archer et al. 2000) | | | | | x | x | x | x | | | |
| Young-of-the-Year Survey in the Lower San Juan River (Lashmett 1994, 1995) | | | | | | | x | x | | | |
| Early Lifestage - Nursery Habitat (Archer et al. 2000) | | | | | | | | | x | x | x |
| Drift Netting (Platania et al. 2000) | | | | | | | | | x | x | x |
| Secondary Channel Ichthyofaunal Characterization (Propst and Hobbes 2000) | | | | | x | x | x | x | x | x | x |
| Nonnative Fish Interactions (Brooks et al. 2000) | | | | | x | x | x | x | x | x | x |
| Tailwater Trout Fishery Investigations (Ahlm 1993, Larson and Ahlm 1994) | | | | | x | x | x | x | | | |
| Mapping Instream Habitat Using Airborne Videography (Pucherelli and Clark 1990, Pucherelli and Goettlicher 1992, Goettlicher and Pucherelli 1994) | | | | x | x | x | x | | | | |
| Geomorphic Characterization, River Channel Dynamics, Flow/Habitat Relationships, Hydraulic Modeling, and Temperature Monitoring (Bliesner and Lamarra 2000) | | | | | | x | x | x | x | x | x |
| River Operation Simulation Model (Bliesner and Lamarra 2000) | | | | | | x | x | x | x | x | x |
| Fish Health Surveys (Landye et al. 2000)) | | | | | | x | x | x | x | x | x |
| Tributary Fish Community Surveys (Miller and Rees 2000) | | | | | | x | x | | | | |

**Table 2.1. (cont.).**

| STUDY AND FINAL REPORT CITATION | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **7-Year Research Period and SJRIP Studies** | | | | | | | | | | | |
| Secondary Channel Community Studies, Permanent Study Sites (Gido and Propst 1994, 1995) | | | | | | | x | x | | | |
| Colorado Squawfish Radiotelemetry Habitat Use (Miller and Ptacek 2000)[a] | | | | | | | x | x | | | |
| Summary and Synthesis of Existing Water Quality Information (Abell 1994) | | | | | | | x | | | | |
| Environmental Contaminants in Biota (Simpson and Lusk 1999) | | | | | | | | x | x | | |
| Hazard Assessment to Colorado Squawfish, Razorback Sucker, and Flannelmouth Sucker (Hamilton and Buhl 1997a, 1997b) | | | | | | | | x | x | | |
| Polynuclear Aromatic Hydrocarbon Surveys (Odell 1995, Odell 1997, Wirth 1999) | | | | | | | | x | x | x | |
| Razorback Sucker Experimental Augmentation and Monitoring (Ryden 2000b) | | | | | | | | x | x | x | x |
| Mainstream Habitat Quality (Bliesner and Lamarra 2000) | | | | | | | | x | x | x | x |
| Mechanical Removal of Channel Catfish (Brooks et al. 2000) | | | | | | | | | x | x | x |
| Backwater Productivity (Bliesner and Lamarra 2000) | | | | | | | | | x | x | x |
| Experimental Stocking of Young-of-the-Year Colorado Squawfish (Trammell and Archer 2000)[a] | | | | | | | | | | x | x |
| Chronic Toxicity of Dietary and Waterborne Selenium to Colorado Pikeminnow (Buhl and Hamilton 2000) | | | | | | | | | | x | x |
| Augmentation Plan for Razorback Sucker (Ryden 1997) | | | | | | | | | | | x |

[a] These reports include data from studies conducted in 1998 also.

developed and initiated in 1991. An adult monitoring and radiotelemetry study was initiated and continued for the duration of the 7-year research period. This study was conducted by the USFWS (Grand Junction), with assistance from NMGF, UDWR, and other agencies. This study addressed portions of Objectives 1, 3, and 4 for adult and juvenile fish. Generally, the study consisted of three electrofishing trips on portions of the study area that, when combined, created an annual sampling of the entire study area, from Farmington, New Mexico, to Mexican Hat, Utah. This study provided information on relative abundance, distribution, and age classes of all fish species collected. During 1991 and 1992, the portion of river within the fluctuation zone of Lake Powell and below a waterfall that developed in the late 1980s was sampled by the Bureau as a subset of this study. The area below Mexican Hat, Utah, was included in the USFWS study in 1993 and thereafter. In addition, captured adult Colorado pikeminnow were radio-tagged and monitored to determine habitat use and movement. The UDWR was responsible for an early life stage, nursery habitat, and larval drift study initiated in 1991 that continued throughout the research period. This study, which used seining as the primary sampling method, addressed Objectives 1, 3, and 4 for young of large-bodied species and young and adults of small-bodied species. The study was generally designed to locate young Colorado pikeminnow, although all species were sampled by seining backwaters and other low-velocity habitats. The study area was from Hogback Diversion to Clay Hills Crossing, Utah. In addition to seining, drift nets were used for larval drift sampling at two sites, Mexican Hat, Utah, and Four Corners. The larval drift sampling was assumed by the University of New Mexico in 1995. In 1993, 1994, and 1995 the Bureau conducted additional nursery habitat surveys in late summer and fall, looking primarily for young Colorado pikeminnow in the river near the Lake Powell interface below the area that the UDWR sampled. This study was discontinued in 1995, when Lake Powell inundated the lower study area; sampling that year (1995) was ineffective because of lake elevation.

In 1991, the NMGF began investigating the fish fauna of secondary channels. This study continued through the entire 7-year research period and consisted of electrofishing surveys in the spring and seining surveys in the late summer and autumn. This study addressed Objectives 1 and 3 and was initiated because other studies did not sample intensively in secondary channels, which made up a fairly large amount of potential habitat in the river. The study area was from Hogback Diversion to Bluff, Utah, where the majority of secondary channels existed in the river.

The other core study initiated in 1991, a nonnative fish interaction study, was conducted by the USFWS (Albuquerque) for the entire 7-year research period. This study addressed Objective 6 of the 7-year research plan and used information from the adult monitoring, early life history, and secondary channel studies to determine distribution and abundance of nonnative fish, primarily channel catfish, common carp, and other large-bodied predators. Specimens of nonnative fish were taken for food habits analysis, and invertebrate samples were taken to examine food availability. In 1996, radiotelemetry of channel catfish was added to determine their habitat use and movement. The study area consisted of the San Juan River from Farmington, New Mexico, to Clay Hills Crossing, Utah.

Other shorter-term studies were also conducted during the 7-year research period. The NMGF started a study of the tailwater trout fishery below Navajo Dam in 1991 that continued for 4 years. The study area was the first 15 miles below Navajo Dam. Although not a study of native fishes, this study was funded because of concerns that reoperation of Navajo Dam may impact the blue-ribbon trout fishery that existed below the dam. This study, which included trout population and movement studies and water quality and angler surveys, addressed Objective 3.

In 1990, the Bureau initiated a mapping study of backwaters and other low-velocity habitats using airborne videography. It was the only physical study that was conducted during 1991. This study continued until 1993, when it was discontinued as more-detailed habitat studies using other methods were initiated.

In 1992, as the studies of the 7-year research period were integrated into the SJRIP, another core study was initiated. The BIA, through Keller-Bliesner Engineering, initiated a study that included all of the physical and hydrologic efforts necessary to meet Objective 2. These studies were conducted throughout the study area and provided basic information on flow and water temperature, as well as a physical habitat mapping component that was adopted by most of the other studies. Another major task of these studies was determining geomorphic reaches in the San Juan River with similar habitat features. They were also adopted by the other studies for reporting data. These reaches are shown on Figure 2.1. In 1992, the BIA and Bureau initiated another study to meet part of Objective 2 that involved developing a river operation simulation model that became an important part of future flow recommendations. This study was also continued through the 7-year research period.

Another study that started in 1992 and continued through the 7-year research period concerned fish health. During sampling in 1991 and early 1992, biologists noted that many native suckers had lesions and sores. Consequentially, a fish health expert was added to adult monitoring trips in October 1992. This study was the first example of adaptive management within the SJRIP: a need was identified and the research element was quickly added to address that need. This study met part of Objective 2.

Also initiated in 1992 was a study that investigated the fish fauna of the various permanent tributaries to the San Juan River. Conducted by Miller Ecological Consultants for the Southern Ute Indian Tribe, the study lasted for 2 years and addressed Objective 1. It included both field sampling and summarizing other agencies' fish collections from 1994 through 1998.

Three studies were started in 1993. The NMGF examined fish population dynamics in several permanent, secondary channel sites. This study addressed Objectives 1 and 3 and was conducted for 2 years. Miller Ecological Consultants initiated more-intensive monitoring of Colorado pikeminnow that were radio-tagged by the USFWS during its adult monitoring study. This study addressed Objective 4, and fish were followed during spawning in order to locate spawning areas and define habitat used during that period. This study was also conducted in 1994, when winter habitat use was also investigated. The study was reinitiated in 1998 to monitor stocked radio-tagged Colorado pikeminnow in the San Juan River near Farmington, New Mexico. The third study reviewed water quality information and addressed Objective 5 of the 7- year research plan. While this review lasted only 1 year, studies of water quality and contaminants became a much larger part of the SJRIP in 1994, when several studies were initiated.

The USFWS (Albuquerque) investigated environmental contaminants in river biota. The study lasted 2 years and covered the entire study area. The National Biological Survey (now the U.S. Geological Survey, Biological Resources Division [USGS-BRD]) was contracted to conduct hazard assessment studies of the toxicity of irrigation return waters to larval endangered and native fishes. This study lasted 2 years. The BLM, which had joined the SJRIP because of a Consultation on oil and gas leasing in the San Juan Basin, investigated oil and gas contamination, including potential sources and routes to the river. This study continued through the remainder of the 7-year research period.

In 1994, experimental stocking of razorback sucker was initiated by the USFWS (Grand Junction) to determine habitat needs (Objective 4). This was the first research study to address Objective 7, testing management options, because it used hatchery-reared fish and tested razorback sucker stocking. The study was initiated because no wild razorback sucker was found in the river during adult monitoring studies.

Another component of the physical and hydrological studies being conducted by Keller-Bliesner Engineering was added in 1994. This study of habitat quality in mainstream riffles and runs throughout the study area addressed Objective 2 and provided a comparison of productivity between various portions of the San Juan River, as well as a comparison with similar habitats in the Colorado River.

Thus, by 1994, major studies addressing all of the original objectives of the 7-year research plan were implemented. Study designs continued to evolve during this period, and substudies within core studies were added. For example, studies of fish movement in and out of secondary channels were added to the nonnative fishes study in 1994; the evaluation of fish movement around water diversion dams between Farmington, New Mexico, and the Hogback Diversion, part of the adult monitoring study, was expanded in 1996.

In 1995, the major research activity added to the SJRIP was mechanical removal of all nonnative fishes, which was part of the nonnative fishes interactions study conducted by the USFWS (Albuquerque). This study resulted in collectors removing all channel catfish, common carp, and other nonnative fishes that were collected during the various studies from the river, rather than returning them to the river along with the native fishes. In addition, a study of backwater habitat quality and productivity was added to the BIA studies conducted by Keller-Bliesner Engineering. A variety of physical and biological parameters were measured in backwaters throughout the study area and compared with information from the Green and Colorado rivers.

Another major event in the SJRIP that occurred in 1995 was completion of the *LRP*, the guideline for research and management activities for the 15-year program period. The *LRP* relied heavily on the 7-year research plan, but it expanded the horizon for research and management actions. This document listed the major milestones of the SJRIP and provided a schedule for completing various research and management goals.

In 1996, two new studies were added to the research effort. The UDWR stocked young-of-the-year (YOY) Colorado pikeminnow to determine if there was sufficient habitat in the system to retain them. This study was directed at Objectives 4 and 7 of the 7-year research plan. It was initially controversial because it involved stocking a size of fish that had not been successful in other situations, but it was successful in the San Juan River. The other study initiated in 1996 was a toxicity test of Colorado pikeminnow conducted by the USGS-BRD. This was the last of the contaminant studies, and it used adult hatchery-reared fish that were exposed to various levels of selenium, a natural contaminant common in parts of the San Juan Basin, especially in irrigation returns.

In 1997, the first real management/recovery action was initiated when the USFWS (Grand Junction) was funded to develop an Augmentation Plan for razorback sucker. By this time the results of the studies showed the rarity of wild razorback sucker in the river. The razorback sucker Augmentation Plan was finalized, and 2,885 subadult razorback sucker were stocked into the river in September 1997.

Research into the means for recovering the endangered fish species in the San Juan River developed into a complex scientific undertaking. Scientists from a variety of federal, state, and private organizations worked together to investigate all potential issues that limit the two endangered fish species and other native fishes. Although much of the work did not stop after 7 years, a considerable amount of knowledge was gained during the 7-year research period. That knowledge is summarized in the next two chapters and in the *Flow Report*. The final chapter of this document describes remaining tasks for assuring recovery of the endangered fish species and the native fish community in the San Juan River. That information will be used, along with this document, to develop a revised *LRP*.

# CHAPTER 3: RESULTS OF THE 7-YEAR RESEARCH PROGRAM

## INTRODUCTION

The research projects undertaken by the SJRIP were aimed, in one way or another, at either determining factors limiting recovery of the two endangered fish species or developing strategies to reduce or eliminate limiting factors. Factors limiting recovery are those environmental conditions that prevent a population from increasing to a level where it is genetically viable, self-sustaining, and threats to its existence are removed. A population is self-sustaining when it can maintain itself indefinitely through natural reproduction. This chapter discusses how the SJRIP addressed each of the potential limiting factors, the findings regarding the importance of these limiting factors, and proposals to reduce or alleviate important limiting factors. Emphasis is placed on the two endangered fish species, although other components of the native fish community are discussed where appropriate. Final research reports, as noted in Table 2.1, are cited extensively, as are portions of the *Flow Report*, which synthesized results of the 7-year research plan as they relate to flow recommendations. While flow recommendations were primarily developed to address the limiting factor of habitat, they may also be important in addressing other limiting factors. In addition to research on the San Juan River, results and conclusions from relevant research in other portions of the Colorado River Basin are included.

The SJRIP studies addressed five broad categories of limiting factors. Initially, habitat limitation, including flow issues and reductions in range, was one of the major factors addressed. Reduced amounts of suitable habitat, presumably resulting from unnatural flow regimes, was a major reason why reoperation of Navajo Dam was part of the recovery program. Other limiting factors that received initial attention included interactions among endangered species and nonnative fishes, and chemical (contaminant) issues. As studies progressed, fish health was identified as a potential concern, and studies were added to address that issue. It was later recognized that populations of both endangered species in the San Juan River were too small to respond to improvements in their habitat within the time frame of the 7-year research period, and population size was recognized as a limiting factor.

Detailed methods used in SJRIP studies are not presented in this document, unless that information is pertinent to the discussion. Detailed methods can be found in each of the final research reports that are cited throughout this document and available from the SJRIP (http://southwest.fws.gov/sjrip). Summary reports (Holden and Masslich 1995, 1997a, 1997b) also detail the general methods and results of ongoing research efforts.

Throughout this chapter, references are made to locations in the San Juan River study area, the area between Lake Powell and Navajo Dam. The study area was divided into eight Geomorphic Reaches by Bliesner and Lamarra (2000) (Figure 2.1). Most researchers used the Geomorphic Reaches to organize and analyze their data. In addition, some locations are shown by river mile (RM); RMs were numbered from RM 0 (Piute Farms at the upper end of the San Juan Arm of Lake Powell) to RM 224 (Navajo Dam), and RMs are also shown on Figure 2.1.

# HABITAT LIMITATIONS

## Introduction

In the San Juan River, habitat may be limiting in a number of ways. Important or "key" habitat types may be too rare to support sufficient numbers of a species necessary for maintaining a self-sustaining population. Key habitats are those habitats the fishes require, and they are usually identified by comparing use and availability of habitats most-frequently used at various times in the fish's life cycle. Rare habitats that are important to a species are typically key habitats, and as such they may limit the species. Habitat quality may also be too poor to sustain sufficient numbers of a target species. At the onset of the SJRIP, there was a general concern that San Juan River key habitat quantity and quality were low. A basic premise of the SJRIP was that reoperation of Navajo Dam to mimic a natural hydrograph would improve both habitat quantity and quality by re-establishing a spring peak and low late-summer, autumn, and winter base flows. It was the consensus of biologists working with the endangered fishes in the Colorado River Basin that natural flow patterns and magnitudes were needed by these fishes (Holden 1979, Minckley et al. 1991, Tyus 1991). The life histories of most native species are integrally tied to the timing, duration, and magnitude of the natural hydrograph. Some species (e.g., razorback sucker) spawn during high spring flows, and their larvae are adapted to utilize habitats that are most available during that time of year. Other species (e.g., Colorado pikeminnow) spawn later in the summer as flows recede, and their larvae utilize habitats that are most available during the low flow periods of late summer and autumn. Chapter 6 of the *Flow Report* (Holden [Ed.] 1999) discusses the link between the natural hydrograph and the native fishes in more detail. Dams, such as Navajo Dam, alter the natural flow regime in both quantity and timing and, therefore, often have major impacts on the availability of habitat for native fishes (Holden 1979).

Native fish species evolved under certain flow patterns, and a basic hypothesis of the SJRIP was that those patterns were important in providing and maintaining key habitats for these species in the San Juan River. Therefore, the questions that the SJRIP studies were designed to answer were; are there sufficient amounts of key habitat for the two endangered fishes, is the habitat quality sufficient to maintain these species, and will reoperation of Navajo Dam improve key habitat quantity and quality? Also important was the temporal aspect of these questions: as reoperation of the dam continues, how does key habitat quantity and quality vary from year-to-year, from one flow rate to another, and over time? In addition, how are key habitats created, how are they affected by storm events and other natural phenomena, and how are they restored if they become degraded?

Evaluation of habitat as a limiting factor was a complex issue requiring a variety of biological and physical studies. The biological studies investigated the habitats that the fishes used and attempted to determine which habitats were key for their success. Spawning habitat and nursery habitat were generally considered key habitats for the two endangered fish species because lack of recruitment was a major factor influencing the fishes' endangered status (Minckley et al. 1991, Tyus 1991), and their spawning and nursery habitats were relatively rare and flow dependent. Physical studies were needed to describe the key habitats, determine their availability, determine their quality, and determine if habitat quantity and quality improvements in the San Juan River were needed. Key habitats may be in short supply, too poor in quality, or not available at the right time of year. This section describes how the SJRIP studies determined key habitats, key habitat availability, and key habitat quality for each of the two endangered species. Also presented are management actions taken to maximize key habitat quality and quantity.

## Habitat Use

### Colorado Pikeminnow

Studies in the Green and Colorado rivers during the 1970s and 1980s identified the major life history components of Colorado pikeminnow. Adults migrated during early summer, often over 200 miles, to two major spawning areas in the Green River (Tyus 1985, 1990, 1991). Young hatched in a matter of days and drifted downstream to suitable backwater nursery habitats (Haynes et al. 1984, Nesler et al. 1988). Young-of-the-year were found in backwaters in the fall (Holden 1977, Tyus and Haines 1991). Because of sampling inefficiencies, and perhaps low population numbers, 2-, 3-, and 4-year-old Colorado pikeminnow were seldom collected (Holden and Stalnaker 1975, Tyus and Haines 1991), so their habitat use is poorly understood. These efforts led to research focused on two key habitats: spawning areas and backwaters. Chapter 3 of the *Flow Report* (Converse and Holden 1999) summarizes what is known about the life history and habitat use of this species. The following highlights San Juan River habitats used by this species and those habitats that became the focus of studies.

#### *Adults*

Adult Colorado pikeminnow habitat use in the San Juan River was studied primarily through radiotelemetry. From 1991 to 1994, 13 adult Colorado pikeminnow were captured, radio-tagged, and followed, both on the ground (from shorelines and boats) and in the air (Ryden 2000a, Ryden and Ahlm 1996). Fish capture locations, along with 236 subsequent radiotelemetry contacts, provided information on portions of the river used, movements, likely spawning locations, and specific habitat use. Most of the fish remained within a relatively small area of the river (Figure 3.1), from about RM 109 to RM 142 (Figure 2.1). This 33-mile reach included the "Mixer" (RM 129.8 to RM 133.4), an area of structural complexity and numerous secondary channels. Only one of the 13 radio-tagged fish was found outside this 33-mile reach, a large female captured and tagged near Bluff, Utah. This fish remained in the area of RM 73 to RM 76, except in 1994 when

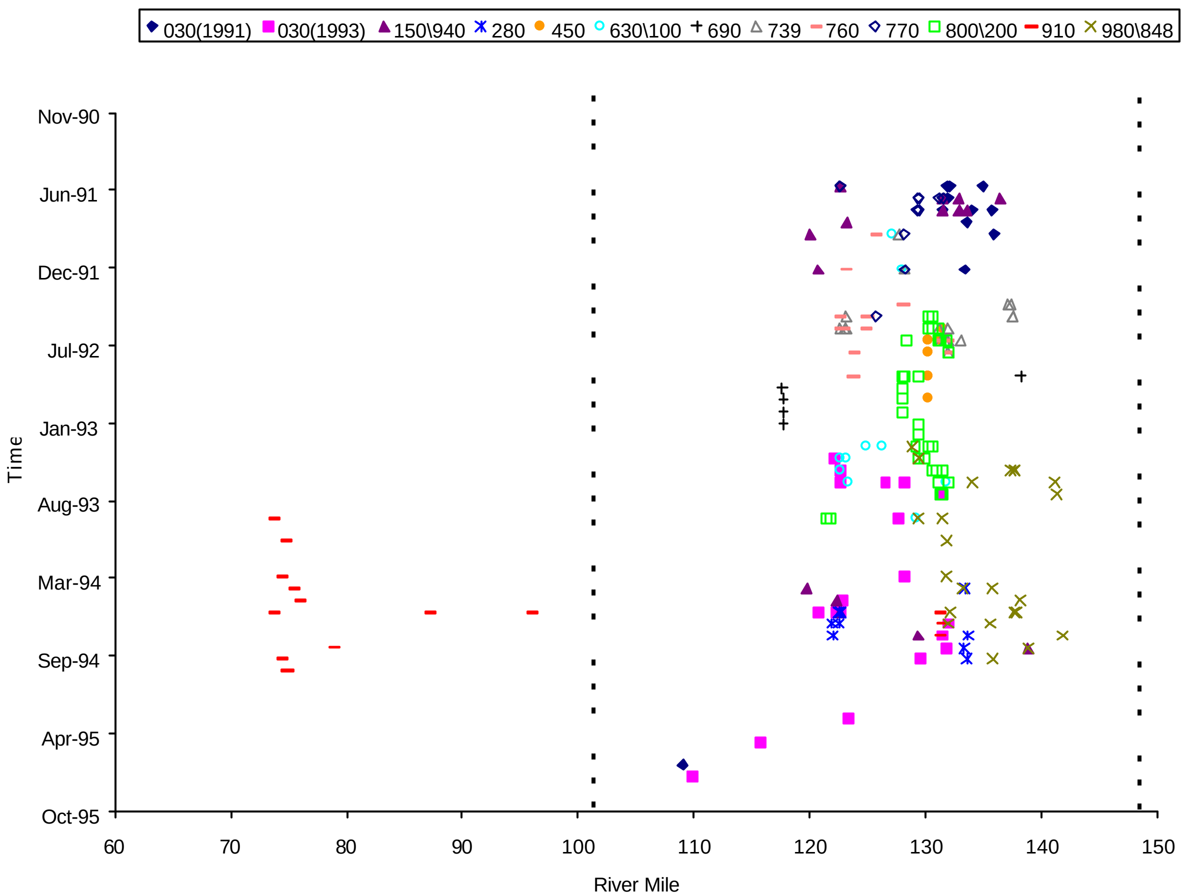



**Figure 3.1. Riverwide movements of 13 radiotelemetered adult Colorado pikeminnow in the San Juan River, 1991 to 1995. Dashed lines indicate the borders of the "preferred" reach (RM 109.0-142.0) utilized by the majority of radiotelemetered adult Colorado pikeminnow (Source: Ryden 2000a).**

she made a 57-mile spawning migration upstream to the Mixer (Miller and Ptacek 2000), only to return to the Bluff area in the autumn. Figure 3.2 shows monthly fish habitat use during the 83 ground contacts made by Ryden (2000a). Runs were used the most during all months except September, when the only radiotelemetry contact occurred in a pool. Other frequently used habitats included eddies and shorelines.

In 1993 and 1994, a more-intensive radiotelemetry study was conducted on some of the fish noted above with the purpose of locating spawning areas and providing an in-depth view of habitat use and selection (Miller and Ptacek 2000). From May through August 1993, four fish were followed, and daily and hourly telemetry observations were made. In 1994, five fish were monitored during February and during the May through August period. The sampling period was divided into pre-spawn (May and June), spawn (July), and post-spawn (August) periods. Post-spawn data were only collected in 1993.

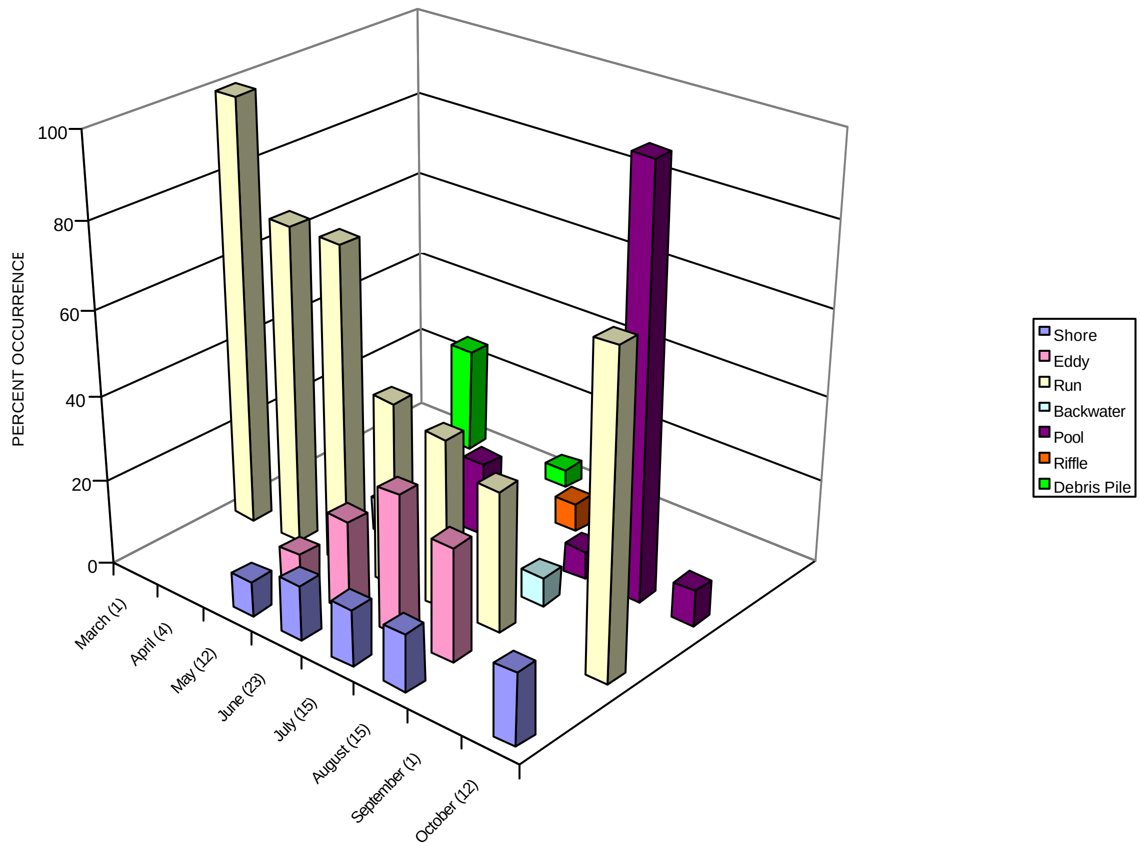



**Figure 3.2. Habitat use recorded for radiotelemetered Colorado pikeminnow in the San Juan River, 1991 to 1995. The total number of radiotelemetry observations during the specified calendar month is shown in parentheses (Source: Ryden 2000a).**

The top graph of Figure 3.3 shows the habitats used during the pre-spawn period for all Colorado pikeminnow combined. Several fish used the Mancos River confluence, which varied in habitat type depending on flow level. Eddies and runs were used the most, followed by undercut runs, slackwaters, and edge pools. The low-velocity habitats (eddy, slackwater, edge pool) were 2 to 3EC warmer than the main channel. This habitat use was similar to that documented in the Green, Yampa (Wick et al. 1983, Tyus 1990), and Colorado rivers (Osmundson and Kaeding 1989), where warmer backwaters, eddies, and tributary mouths were used extensively by Colorado pikeminnow during spring high flows.

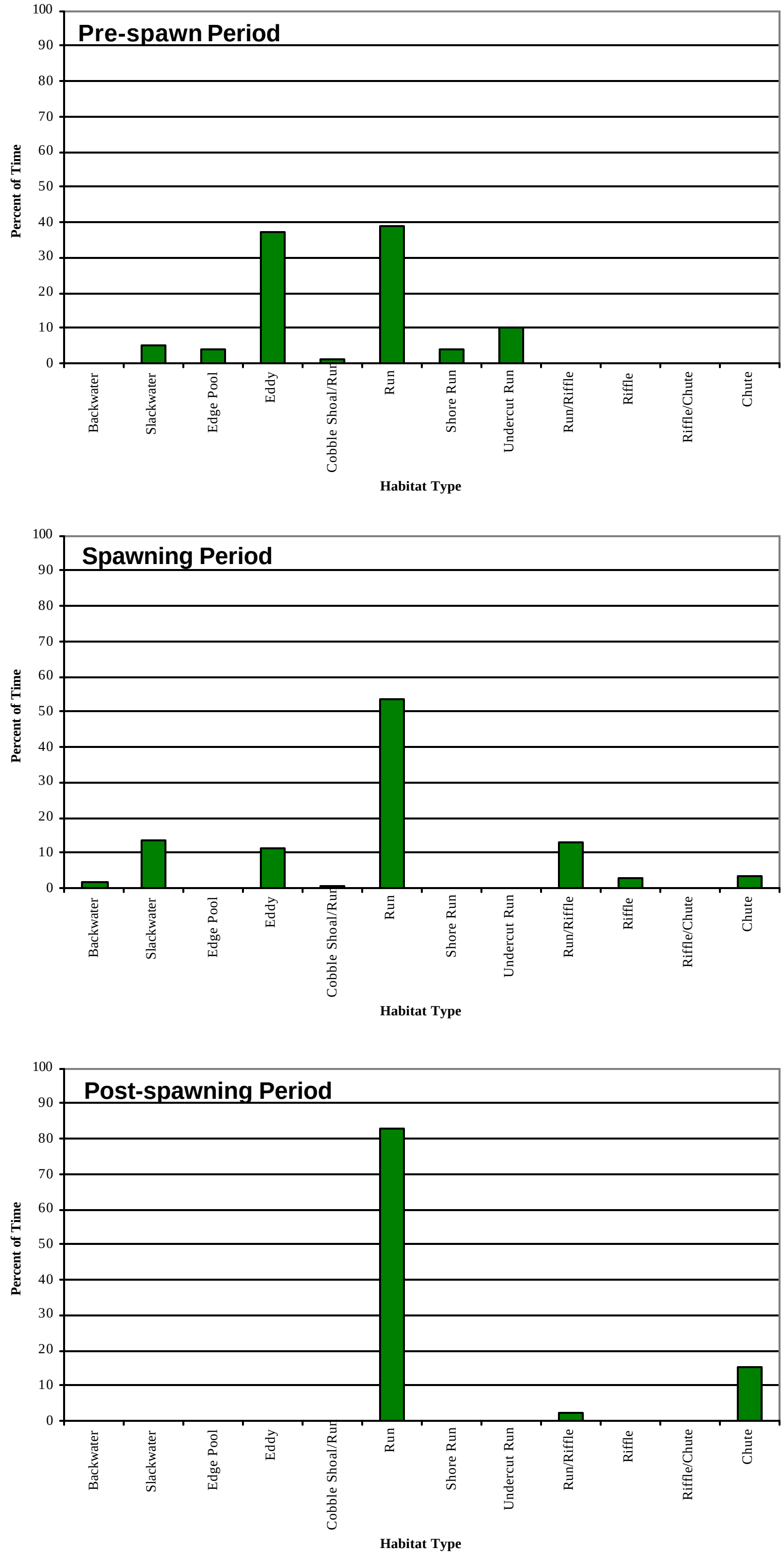



**Figure 3.3.** **Habitat use of Colorado pikeminnow as a percent of time monitored during 1993 and 1994 for all radio-tagged fish combined (Source: Miller and Ptacek 2000).**

The middle graph of Figure 3.3 shows the habitat use during the spawning period when runs were used most, followed by slackwaters, runs/riffles, and eddies. In 1993, fish movements and visual observations indicated that two spawning sites (RM 131.1 and RM 132.0) were used. The fish used a complex of habitats, including slower-velocity habitats (runs, eddies, slackwaters) and proximal higher-velocity riffle or chute habitats. The fish spent most of their time resting in low-velocity habitats, but they moved to riffle/run and chute habitats to spawn. Spawning habitat, therefore, included chutes and riffle/runs where they spawned and the adjacent eddy and slackwater resting areas. Similar habitat use and spawning behavior was identified in the Green, Yampa, and Colorado rivers (Wick et al. 1983, Osmundson et al. 1995).

During the August 1993 post-spawning period, the fish used mainly run and chute habitats (Figure 3.3, bottom graph). Autumn radiotelemetry contacts in 1994 indicated that runs were the primary habitat used, along with pools and eddies. Miller and Ptacek (2000) also conducted a brief radiotelemetry study in February 1994, and the three fish monitored used runs, undercut runs, and eddies. Others showed that Colorado pikeminnow used low-velocity habitats during the winter in the Green (Valdez and Masslich 1991) and Yampa (Wick and Hawkins 1991) rivers.

Habitats in the general area of radio-tagged Colorado pikeminnow were mapped by Miller and Ptacek (2000) to determine habitat "richness," which was calculated as the number of habitat types within the area mapped. Typically, a section of river, about 100 yards from the most upstream and downstream areas used by a radio-tagged fish, was mapped during a radiotelemetry encounter. This mapping showed an average habitat richness of eight habitats during the pre-spawning period, nine habitats during spawning and post-spawning periods, and five habitats during the winter (Miller et al. 1999).

Miller et al. (1999) also calculated habitat selection by comparing the availability of various habitats to Colorado pikeminnow use of those habitats. Habitat types used more than they would be by chance were considered "selected." This analysis showed that eddies, slackwaters, and pools were highly selected most of the time, and chutes were selected during the spawning period. As shown in Figure 3.3, the selected habitats were not the most used, but they were rare within the areas used by the fish; hence the habitats were used more than would be expected by chance. This suggests that the fish sought these habitats out, or selected them over more-available habitats, indicating that they are key habitats for the fish.

Tributaries are an important habitat component for Colorado pikeminnow in the Green River system, where tributaries are still available to the fish. Both the Yampa River and White River were heavily used by Colorado pikeminnow subadults and adults, apparently as foraging areas (Tyus 1991). Adults returned to these tributaries after spawning, making tributaries their primary area of residence. Tributaries to the San Juan River no longer provide this type of function for Colorado pikeminnow because they are dewatered or access is restricted. Miller and Rees (2000) summarized San Juan River tributary fish collections from the 1930s to the present, and they did not find any Colorado pikeminnow reported. Colorado pikeminnow utilized the Animas River in the late 1800s (Jordan 1891), and this river may still provide suitable habitat; however, the present

Colorado pikeminnow population is separated from the mouth of the Animas River by about 50 miles of river that include five diversion dams.

***Young-of-the-Year (YOY)***

Larval Colorado pikeminnow hatch in about 1 or 2 weeks and then drift downstream from spawning areas to nursery areas. These fish are typically found in shallow, low-velocity habitats along shorelines, such as backwaters (Vanicek and Kramer 1969). Larval studies on the San Juan River focused on the drifting portion of larval life history, and five larval Colorado pikeminnow were collected in drift nets (Platania et al. 2000). Key habitats for larvae were not determined by these studies.

Studies in the Green and Colorado rivers found that YOY Colorado pikeminnow (25 to 100 mm total length [TL]) used backwater habitats almost exclusively (Holden 1977, McAda and Tyus 1984, Tyus and Haines 1991). Backwaters were typically found in relatively low-gradient, sand-substrate reaches of these rivers. During the 7-year research period, autumn sampling of nursery habitats was conducted each year (Archer and Crowl 2000a), and 22 wild YOY Colorado pikeminnow were collected in the San Juan River (Platania et al. 2000). Most of these fish were collected in backwaters in the relatively low-gradient, sand-substrate reach of the river at the interface with Lake Powell (Reach 1). The numbers of wild fish collected were too low to adequately characterize San Juan River habitat use. In addition, wild YOY retention appeared low in the upper river. These findings suggested that nursery habitat may be limited in the river. To address habitat use and retention, YOY Colorado pikeminnow were stocked at Shiprock, New Mexico, and Mexican Hat, Utah, in 1996, 1997, and 1998 (Trammell and Archer 2000). Nearly 3,000 of these fish were collected from 1996 to 1998 (Trammel and Archer 2000, Propst and Hobbs 2000), with about 60% collected from backwaters, 15% from pools, and 13% from pocket water (Converse and Holden 1999). The YOY appeared to favor larger, deeper backwater habitats, and these habitats were often associated with the mouths of secondary channels (Trammell and Archer 2000). This information showed that in the San Juan River, similar to other rivers, YOY predominately used backwaters, but other low-velocity habitats were also used.

Although wild YOY Colorado pikeminnow were predominately found in the lower few miles of the San Juan River, the hatchery-reared YOY remained throughout the river and some moved downstream with storm-generated flow events (Trammell and Archer 2000). In 1997, 30 stocked YOY Colorado pikeminnow were collected up to 8 miles above the Shiprock, New Mexico, stocking site about 1 month after stocking (Propst and Hobbs 2000), indicating upstream as well as downstream movement. Few stocked YOY were found in the canyon sections below and above Mexican Hat, Utah, but they were found in the low-gradient reach in the lower 13 miles of the river near the interface with Lake Powell. Retention of fish stocked at Shiprock, New Mexico, was highest in the upper river.

***Juveniles***

Collection of 2- to 4-year-old wild Colorado pikeminnow (100 to 300 mm TL) is infrequent in the Colorado River system. This age class appears to use a variety of habitats, including main channel habitats that are swift and, therefore, difficult to seine. Their relatively small size and swimming ability make them difficult to catch using electrofishing or seines; hence they are not commonly caught. As stocked YOY grew in the San Juan River, they were captured in relatively large numbers through seining and electrofishing, especially above Mexican Hat, Utah. In 1997, 38 yearlings (stocked in 1996) were caught during main channel electrofishing (Ryden 2000a). They ranged in size from 124 to 235 mm TL and were primarily captured in shallow shoreline habitats. Most were found between the Hogback Diversion and Mexican Hat, Utah, and three were collected in RM 18 near the Lake Powell interface. The 1- and 2-year-old fish were collected in 1998 and 1999, and growth of these fish was comparable with, or greater than, growth seen in other Upper Basin rivers (Trammell and Archer 2000). This indicated that young Colorado pikeminnow found quality habitat in the San Juan River. This size-class appeared to use the greatest variety of habitats and was likely the least selective. Therefore, no specific key habitats were identified for juveniles and, based on the San Juan River collections, suitable habitat for this age class is found throughout the river between Hogback Diversion and Mexican Hat, Utah, and in the lower 20 miles of the river.

## Razorback Sucker

When the SJRIP was initiated in 1991, the life history and habitat requirements of razorback sucker were not as well understood as those of Colorado pikeminnow. Adult and larvae razorback sucker were found in both riverine and reservoir habitats in the Colorado River Basin, but very few YOY had been collected in recent times. Tyus and Karp (1989) identified razorback sucker spawning sites in the Green River and collected larvae, but it was not until 1994 that YOY razorback sucker were found in flooded bottomland habitat of the Green River (Modde 1996) and a more-complete picture of their habitat use emerged. These studies indicated that this species spawns on main channel gravel bars near the height of peak spring flow and that they show fidelity to certain bars (Modde and Irving 1998). The young hatch in a few days, drift downstream, and enter flooded bottomlands that are connected to the main channel during high flow. Backwaters and other low- velocity habitats are also used by larvae, but flooded bottomlands are thought to be a key habitat for survival of larvae. It is not known when young razorback sucker return to the main river. Recent studies using stocked fish (T. Modde, USFWS, Personal Communication) suggested that they may be able to spend an entire year in some off-channel bottomlands. Adults used a variety of main channel- and backwater-type habitats, the latter are used especially prior to and during the spawning period as apparent resting areas between spawning events on main channel cobble bars (Bestgen 1990, Minckley et al. 1991).

***Adults***

During the 7-year research period, no adult wild razorback sucker were collected in the San Juan River (Ryden 2000a), and only one was caught during studies conducted in the late 1980s (Platania 1990). Because of this, experimental stocking of hatchery-reared subadult (large juvenile) razorback sucker was initiated in 1994. Between March 1994 and October 1996, 939 fish were stocked at four sites (RM 79.6, RM 117.5, RM 136.6, and RM 158.6) below Hogback Diversion (Ryden 2000b). Radiotelemetry and electrofishing captures of some stocked fish provided information on subadult and adult fish habitat use.

In addition to habitat use, Ryden (2000b) mapped habitat in the general areas where radio- tagged fish were found, using methods similar to those used by Miller and Ptacek (2000). This resulted in habitat selection determinations based on the availability of the various habitats used and on habitat richness. Figure 3.4a shows radio-tagged razorback sucker habitat selection and Figure 3.4b shows mean habitat richness values from 1994 through 1997 averaged by month. Run habitats were selected during low-flow periods from late summer (August) through late autumn (December), and slow-water habitats (edge pools, pools, and eddies) were selected during the rest of the year. The fish also utilized inundated vegetation during peak spring flows. These data show the fish selected lower-velocity habitats year-round, utilizing run habitats only during low-flow times of year when velocities were reduced. The fish selected pools and eddies most of the remainder of the year.

Habitat richness values remained fairly high (6 to 7), except during late summer and autumn (Figure 3.4b). Although not as high as habitat richness values for Colorado pikeminnow, the values indicated that razorback sucker utilized fairly habitat-rich portions of the river, except during late summer and autumn.

No suspected spawning locations were found by monitoring radio-tagged razorback sucker. However, three adult ripe males were collected and three more adults were observed at RM 100.2 during May 1997 electrofishing surveys (Ryden 2000b). This probable spawning aggregation was collected over shoreline cobble run/riffle habitat, along with spawning flannelmouth sucker. During this same sampling trip, five other ripe male razorback sucker were individually collected from groups of spawning flannelmouth sucker in similar habitats. During 1999 sampling, both ripe male and female razorback sucker were collected in the same habitat at RM 100.2, although none of the fish collected in 1999 had been caught in 1997 (D. Ryden, USFWS, Personal Communication). This habitat was similar to Green River spawning habitat (Tyus 1987). It is not known if the stocked razorback sucker in the San Juan River will show fidelity to this area.

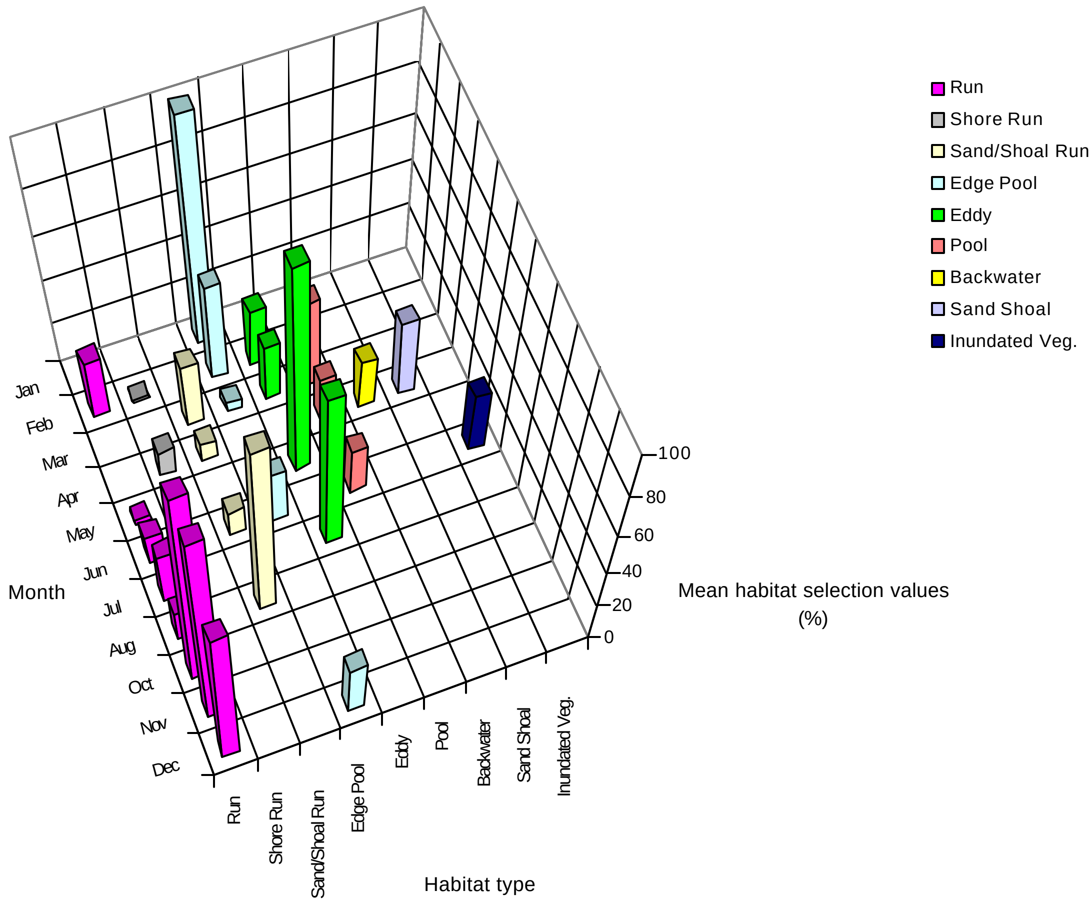



**Figure 3.4a. Mean habitat selection by month, calculated for radio-tagged razorback sucker in the San Juan River, 1994 to 1997. Mean habitat selection values for each calendar month were converted to a 100-percent scale to make them easier to compare between months (Source: Ryden 2000b).**

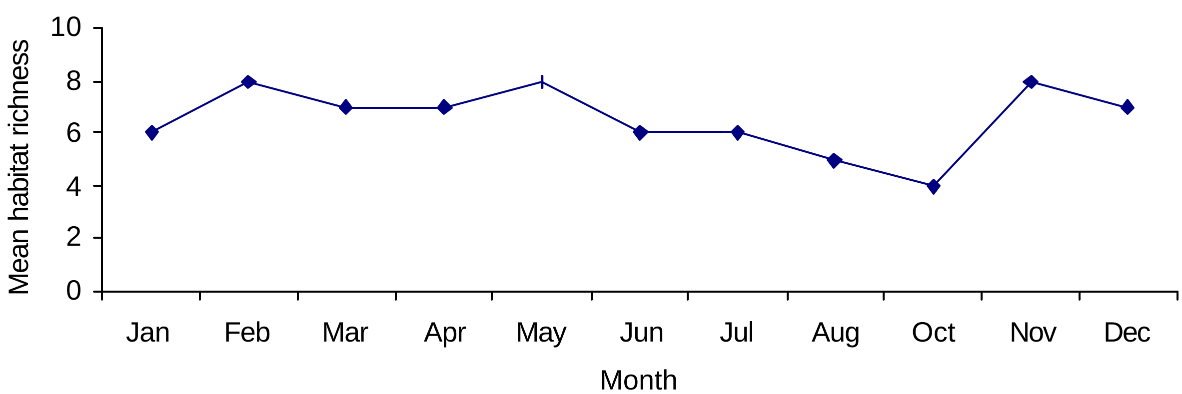



**Figure 3.4b. Mean habitat richness values, by month, calculated for radio-tagged razorback sucker in the San Juan River, 1994 to 1997 (Source: Ryden 2000b).**

### *Young-of-the-Year (YOY) and Juveniles*

Larval razorback sucker sampling was not conducted in the San Juan River during the 7-year research period. Some larval fishes were collected during nursery habitat studies, but no larval razorback sucker were collected. However, larval razorback sucker sampling began in 1998 because maturation of the stocked razorback sucker was expected, and two larvae were collected by seining low-velocity habitats (S. Platania, University of New Mexico, Personal Communication). In 1999, seven larvae were collected (S. Platania, University of New Mexico, Personal Communication). These captures verified successful spawning of fish experimentally stocked in the San Juan River. Future studies of larval habitat use will be needed to determine what habitats this life stage uses.

Juvenile habitat use determination also will have to wait until more juveniles are present in the river. It is assumed that both larval and juvenile razorback sucker will select low-velocity habitats and that these habitats will likely be important for recovery of this species.

## Other Native Fishes

Other native fishes of primary concern in the San Juan River during the 7-year research study were roundtail chub, flannelmouth sucker, bluehead sucker, and speckled dace. Because of its reduced numbers, roundtail chub is a concern in several parts of the Colorado River Basin, including the San Juan River. It is state-listed as endangered in New Mexico (Propst 1999). Roundtail chub was a target species for the SJRIP because it was rare in the San Juan River below Navajo Dam. The other three species were generally common-to-abundant in most of the Upper Basin and in the San Juan River (Table 3.1), although flannelmouth sucker is rare in some portions of the Lower Colorado River Basin. No radiotelemetry studies of these species were conducted, so specific adult habitat use was not identified.

The SJRIP emphasis on the entire fish community, rather than just the endangered fish species, provided considerable information on the more-common native fishes, such as flannelmouth sucker, bluehead sucker, and speckled dace. Although common throughout much of the Upper Basin, information on these species was seldom provided in recovery effort reports. The adult monitoring and secondary channel studies showed that bluehead sucker and speckled dace were densest in the cobble substrate-dominated upper portions of the San Juan River. Their density decreased in the middle river, and they nearly disappeared in the lower river.

Flannelmouth sucker, on the other hand, was not as tied to cobble substrates, and their density continued at relatively high levels further downstream than either bluehead sucker or speckled dace (Propst and Hobbes 2000, Ryden 2000a). The SJRIP studies showed that the habitat used by young of these species varied through the summer and autumn. Flannelmouth sucker, bluehead sucker, and speckled dace young were found in nursery habitats during early summer, but their numbers decreased in these low-velocity habitats in late summer and autumn. This change in habitat use was noticed at other locations, but it was seldom documented to the extent that it was in the San Juan River studies. Studies concerning abundance, general habitat use, and tributary habitat use were also used to develop the potential for limiting habitat for these species.

**Table 3.1. Total number of fish collected in standardized electrofishing collections, 1991-1997 (Source: Ryden 2000a).**

| SPECIES (STATUS) | TOTAL NUMBER OF SPECIMENS 1991-1997 | PERCENT OF TOTAL 1991-1997 | RANK 1991-1997 | FREQUENCY OF OCCURRENCE[a] 1991-1997 | COLLECTION RM[b] | |
|---|---|---|---|---|---|---|
| | | | | | Most Upstream | Most Downstream |
| Flannelmouth sucker (N) | 143,741 | 59.4 | 1 | 4,475 | 179.0 | 2.9 |
| Channel catfish (I) | 31,610 | 13.1 | 2 | 3,690 | 177.2 | 3.0 |
| Bluehead sucker (N) | 29,388 | 12.1 | 3 | 3,580 | 179.0 | 17.0 |
| Common carp (I) | 22,246 | 9.2 | 4 | 3,491 | 179.0 | 2.9 |
| Speckled dace (N) | 8,808 | 3.6 | 5 | 2,221 | 178.3 | 13.0 |
| Red shiner (I) | 4,006 | 1.7 | 6 | 1,171 | 163.0 | 2.9 |
| Fathead minnow (I) | 709 | 0.3 | 7 | 272 | 176.0 | 5.0 |
| Threadfin shad (I) | 452 | 0.2 | 8 | 25 | 20.0 | 2.9 |
| Bluehead x flannelmouth (H) | 305 | 0.1 | 9 | 260 | 179.0 | 19.0 |
| Brown trout (I) | 204 | —[c] | 10 | 145 | 178.3 | 59.0 |
| Mottled sculpin (N) | 145 | — | 11 | 73 | 178.0 | 155.0 |
| Largemouth bass (I) | 83 | — | 12 | 69 | 177.3 | 3.0 |
| Walleye (I) | 65 | — | 13 | 60 | 108.3 | 5.0 |
| Razorback sucker (N) | 63 | — | 14 | 59 | 159.0 | 37.0 |
| Green sunfish (I) | 62 | — | 15 | 51 | 176.0 | 4.0 |
| Colorado pikeminnow (N) | 58 | — | 16 | 49 | 178.0 | 7.9 |
| Striped bass (I) | 51 | — | 17 | 36 | 91.2 | 2.9 |
| Rainbow trout (I) | 47 | — | 18 | 44 | 179.0 | 96.0 |
| Black bullhead (I) | 39 | — | 19 | 33 | 176.0 | 15.0 |
| Roundtail chub (N) | 22 | — | 20 | 22 | 177.3 | 78.0 |
| Smallmouth bass (I) | 19 | — | 21 | 18 | 169.0 | 54.0 |
| White sucker x flannelmouth (H) | 11 | — | 22 | 9 | 177.2 | 138.0 |
| White sucker (I) | 10 | — | 23 | 10 | 175.0 | 96.0 |
| White sucker x bluehead (H) | 7 | — | 24 | 7 | 178.0 | 155.0 |
| Yellow bullhead (I) | 4 | — | 25 | 4 | 158.0 | 107.0 |
| White crappie (I) | 3 | — | 26 | 2 | 171.0 | 170.0 |
| Bluegill (I) | 3 | — | 26 | 3 | 164.0 | 141.0 |
| Plains killifish (I) | 1 | — | 27 | 1 | 96.0 | 96.0 |
| Grass carp (I) | 1 | — | 27 | 1 | 104.0 | 104.0 |
| Total | 242,163 | 1991-1997 Native = 75.4%<br>1991-1997 Introduced = 24.6% | | 1991-1997 = 4,606 collections | | |

Note: (N) = native, (I) = introduced, (H) = hybrid.
[a] Total number of collections in which this species was found.
[b] These collection RMs are for our study only, many of these species occur farther up and/or downstream.
[c] Less than 0.1%.

### *Roundtail Chub*

Collection of relatively few adult and juvenile roundtail chub during the 7-year research period led Ryden (2000a) to conclude that this species did not have a significant mainstem population. Roundtail chub was relatively common in some San Juan River tributaries, such as the La Plata and Mancos rivers, but in recent years their numbers declined in other tributaries, such as the Animas and Florida rivers (Miller and Rees 2000). Based on collections from 1934 and 1961 held in the University of Michigan Museum of Zoology, roundtail chub was relatively common in the mainstem San Juan River below Farmington, New Mexico, prior to 1962, but they have declined dramatically since then.

Reasons roundtail chub declined in the San Juan River are not known. One hypothesis is that a fish-poisoning project in 1962, prior to closure of Navajo Dam, killed roundtail chub downstream as far as Shiprock, New Mexico. Another hypothesis is that Navajo Dam has fragmented their habitat, preventing movement from upstream roundtail chub populations to the mainstem river below the dam. Some biologists believe that roundtail chub numbers were reduced by channel catfish predation (F. Pfeifer, USFWS, Personal Communication). This hypothesis is based on relatively large numbers of roundtail chub in the Gunnison and upper Colorado rivers, where irrigation diversion dams block access of channel catfish, compared with reaches of these rivers below the irrigation dams where channel catfish are abundant and roundtail chub are rare. It is also possible that a combination of these events caused the decline: the population was reduced by the poisoning operation and channel catfish predation kept it from rebuilding. Whatever the reasons, roundtail chub is not common in the San Juan River.

Miller et al. (1993) found roundtail chub in several San Juan River tributaries and determined habitat use based on the habitats where the fish were collected. Roundtail chub YOY were collected primarily in low-velocity glide and pool habitats. Juveniles and adults were typically found in pool habitats with woody debris cover. A few adults were also collected from glides. Vanicek and Kramer (1969) collected roundtail chubs primarily from pools and eddies in the Green River, and Holden and Stalnaker (1975) collected them from a variety of habitats throughout the Upper Basin. This information indicates that pools and eddies are key habitats for roundtail chub.

### *Flannelmouth Sucker*

Flannelmouth sucker was the most-abundant fish in San Juan River electrofishing surveys during the7-year research period (Ryden 2000a). All life stages were found, and at times the species numerically dominated collections. This suggests that habitat is not limiting for this species in the San Juan River. Flannelmouth sucker abundance increased in Reach 6, the upper San Juan River, but declined in the remainder of the study area during the course of the 7-year research period, raising concern for the status of this species. Ryden (2000a) hypothesized that flannelmouth sucker declined because of high numbers of fish with low condition factors resulting from drought prior to the 7-year research period. After comparing 1991 to 1997 data with the 1987 to 1989 data, Ryden (2000a) hypothesized that the decline may be a cyclic phenomenon in flannelmouth sucker populations. It is also possible that habitat changes from Navajo Dam's reoperation to mimic a natural hydrograph (higher spring flows and lower base flows) reduced the amount of habitat for flannelmouth sucker. Even with the decline in catch rates, flannelmouth sucker remained very abundant and comprised more of the total San Juan River collection than Colorado or Gunnison river collections (Ryden 2000a). More-recent analysis of the catch data indicates that flannelmouth sucker density river wide has not changed because the increase in Reach 6 offset the decrease in the other reaches. But numbers of juvenile flannelmouth sucker declined from 1992 to 1993, and they have not changed much from that time (K. Lawrence, Ecosystems Research, Inc., Personal Communication).

Flannelmouth sucker adults are the "generalists" of the Colorado River Basin, and they are found in a variety of habitats, including riffles, runs, pools, and eddies (Holden and Stalnaker 1975, McAda 1977). They use cobble bars throughout the rivers for spawning and are found on the same bars razorback sucker use for spawning. Larval and YOY flannelmouth sucker are found in backwaters and other low-velocity habitats in early summer. Abundance of the young declines as the summer progresses, likely because of mortality and a shift in habitat use to swifter main channel habitats. Collections of flannelmouth sucker in the San Juan River showed the same generalized habitat use (Lawrence 1999). Juveniles in the San Juan River were correlated with shoreline slackwater habitats in the spring and cobble-type habitats in the autumn (Lawrence 1999). The change in habitat use between juvenile and adult flannelmouth sucker was seen in their use of San Juan River secondary channels (Propst and Hobbes 2000). During high flow periods, secondary channels provided riffle and run habitat, and adult and larger juvenile flannelmouth sucker were the most-commonly collected fish in secondary channels. Ripe fish were collected, thus suggesting spawning also occurred in secondary channels. As flows receded in late summer and autumn, habitats in secondary channels became primarily low-velocity types, and larger flannelmouth sucker were seldom collected there. Although reduced in numbers, YOY flannelmouth sucker utilized the low-velocity habitats of secondary channels during that time (Propst and Hobbes 2000). Flannelmouth sucker used most available habitats, and no key habitats were identified.

#### *Bluehead Sucker*

Bluehead sucker was the third most-abundant fish in the San Juan River, and it was most abundant in the upper portions of the river where cobble substrates predominated. Bluehead sucker was most abundant in Reach 6, but their abundance decreased somewhat in the remainder of the river during the 7-year research period (Ryden 2000a). Adult and juvenile bluehead sucker were typically found in cobble substrate riffle and run habitats in the San Juan River (Ryden 2000a). Spawning appeared to occur on cobble bars, similar to other native suckers. Adult and juvenile abundance in the San Juan River was positively correlated with cobble-type habitats, particularly riffles (Lawrence 1999). Larvae and YOY were found in low-velocity habitats in the summer, but similar to flannelmouth sucker young, they tended to disappear from these habitats by late summer and autumn (Archer and Crowl 2000a). Similar to flannelmouth sucker, bluehead sucker habitat use was characterized by their seasonal use of secondary channels. Adults and larger juveniles used secondary channels during higher-flow periods when riffle and run habitats were available, and reduced numbers of young used them during low-flow periods when low-velocity habitats predominated (Propst and Hobbs 2000). Key habitats for bluehead sucker were cobble substrate riffles and runs.

***Speckled Dace***

Speckled dace, typically considered to be a riffle-dwelling species, was abundant in the San Juan River. Speckled dace is a small minnow and, therefore, is not as susceptible to collection by electrofishing as the two abundant native sucker species. Even with that caveat, speckled dace was the fifth most-common species collected in mainstream electrofishing surveys (Ryden 2000a). Most other San Juan River main channel sampling did not include riffle habitat, so few data are available on overall speckled dace abundance. Speckled dace was the second or third most-common species collected during summer and late summer seining surveys in secondary channels (Propst and Hobbes 2000). This species likely spawns in riffle gravel areas in the San Juan River, although spawning was not noted in SJRIP studies. Like bluehead sucker, key habitats for this species are cobble and gravel riffles and similar habitats.

## Habitat Availability and Distribution

Coincident with the initiation of biological studies looking at fish abundance and habitat use, studies of habitat availability and habitat change resulting from the reoperation of Navajo Dam to mimic a natural hydrograph were also initiated. The first study focused on backwater habitat, a key habitat for YOY Colorado pikeminnow, and investigated the relationship between flow and backwater area using aerial videography (Pucherelli and Goettlicher 1992). Backwater habitat was most abundant at either high flows or low flows. Initiated in 1992, habitat mapping studies used aerial videography and on-the-ground mapping at various flow levels (Bliesner and Lamarra 2000). From 1992 through 1997, 13 habitat-mapping surveys were made at several flows during different seasons. Habitats were classified into 36 types, and these individual types were placed in eight general categories for data summarization and analysis (Table 3.2). Key habitats for the endangered and other native fishes were generally in the low-velocity (adult Colorado pikeminnow, razorback sucker, and roundtail chub), riffle (spawning adult Colorado pikeminnow and razorback sucker and adult bluehead sucker and speckled dace), and backwater and slackwater (YOY Colorado pikeminnow and all other species) categories.

Figure 3.5 shows habitat area, and Figure 3.6 shows habitat as a percentage of total wetted area (TWA) for the eight general categories of habitats at high- (>7,000 cfs), medium- (3,000 cfs), and low-flow (<700 cfs) levels for data averaged over the study period. Run habitat was the most-common type in the San Juan River, comprising 80% or more of TWA throughout the study area at all flow levels. Run habitat also increased as flows increased, both in total area (Figure 3.5) and percentage (Figure 3.6). All other habitats combined comprised from about 16% to 20% of the total habitat area. Backwaters and low-velocity habitats, including many of the key habitats for both adult and young native fishes and the two endangered species, comprised less than 2% of the total habitat area, except during low flow when they comprised about 2.5%. Osmundson et al. (1995) mapped habitats at various flows in the 15-mile reach of the Colorado River and found that runs comprised about 60% of the habitat at most flows, followed by riffles at about 25%. Backwaters, eddies, and pools comprised about 5 to 10% of the total surface area at low and moderate flows, much higher amounts than seen in the San Juan River.

**Table 3.2. The detailed habitat types and the eight general categories used by researchers on the San Juan River (Source: Bliesner and Lamarra 2000).**

| HABITAT CATEGORY | HABITAT TYPES | DEFINITION |
|---|---|---|
| Backwater Habitats | Backwater | Typically an indentation of channel below an obstruction, water depth from <10 cm to > 1.5 m, no perceptible flow, substrate typically silt or sand and silt. Occurs at mouths of dry secondary channels and tributaries, lower ends of eddy return channels, mouths of dry scour channels, and behind debris. |
| | Backwater pool | Same as backwater except maximum depth >2 m. |
| | Embayment | Similar to backwater but formed when water pools up at upstream end of secondary channel with little or no outflow into the secondary channel. |
| Low-Velocity Habitats | Debris pool | Same as pool, except organic debris such as tree limbs or tumbleweeds in pool. |
| | Eddy | Same as pool, except water flow usually evident (but slow) and direction typically opposite that of channel or circular. |
| | Edge pool | Same as pool, except along shore and typically present downstream of shoreline or instream obstructions. |
| | Pool | Area within channel where flow is not perceptible or barely so; water depth usually $30 cm; substrate is silt, sand, or silt over gravel, cobble, or rubble. |
| | Riffle eddy | Area adjacent to riffle where water velocity slow to moderate (5-10 cm/sec) and flow often circular. Substrate sand, gravel, or cobble. Depths usually about same as adjacent riffle or slightly deeper. |
| | Rootwad pool | Pool formed by areas of rootwad piles; typically found along river margin. |
| Other Habitats | Abandoned channel (dry) | Non-flowing secondary channel. |
| | Boulders | Large (>30 cm diameter) rocks in channel. |
| | Cobble bar | Bar of exposed substrate consisting primarily of cobble, usually found within the river channel but may be located along river bank. |
| | Irrigation return | Channel where water is returning to river after application to agricultural fields. |
| | Island | Dry, typically vegetated area of land surrounded by water and located within the river channel. |
| | Isolated pool | Small body of water in a depression, old backwater, or side channel that is isolated from the main channel as a result of receding flows. |
| | Rootwad pile | Woody debris located within river channel. |
| | Sand bar | Same as cobble bar but composed primarily of sand or silt substrate. |
| | Tributary | Tributary channel with flowing water entering main river channel. |

**Table 3.2. (cont.).**

| HABITAT CATEGORY | HABITAT TYPES | DEFINITION |
|---|---|---|
| Riffle Habitats | Chute | Rapid velocity ( $30 cm/sec) portion of channel (often near center) where gradient $10 cm/m. Channel profile often U- or V-shaped. Depth typically $30 cm. Substrate cobble or rubble and often embedded. |
| | Rapid | Rapidly flowing (>150 cm/sec) water over boulder substrate; typically found in steep canyon areas. |
| | Riffle | Area within channel where gradient relatively steep, water velocity moderate to rapid (60 to 120 cm/sec), and water surface disturbed. Substrate usually cobble and portions of rocks may be exposed. Depths vary from <5 to 50 cm, rarely greater. |
| | Riffle chute | Same as riffle except tail of riffle terminates in a chute (>120 cm/sec), gradient steeper (>5 cm/m), and cobble substrate often embedded. |
| | Shoal/riffle | Intermediate between shoal and riffle, consists of steep, lateral cobble bar with shallow (<15 cm) and fairly rapid (>30 cm/sec) flowing water. |
| | Shore riffle | Same as riffle but along shore of channel, such areas do not extend across entire channel. |
| Run Habitats | Run | Typically, moderate to rapid velocity (30-90 cm/sec), and little or no surface disturbance. Depths usually 30-120 cm but may exceed 120 cm. Substrate usually sand but may be silt in slow-velocity runs and gravel or cobble in high-velocity runs. |
| | Run/riffle | Similar to run but some surface disturbance evident, typically shallower and swifter, and substrate usually cobble or rubble. |
| | Scour run | Same as run and where direction of flow cuts along or into bank. |
| | Shoal/run | Same as shoal, except deeper (>15 cm) and faster flowing (>30 cm/sec), with either a sand or cobble substrate. |
| | Shore run | Same as run and where direction of flow parallel to bank with no obvious cutting. |
| | Undercut run | Same as run but with overhanging bank, often bound by rootmasses of riparian vegetation. |
| Shoal Habitats | Sand/cobble shoal | Generally shallow (<15 cm) areas with laminar flow (<30 cm/sec). Such areas found most often on inside bends of river meanders or at downstream ends of islands or bars. |
| Slackwater Habitats | Pocket water | Slackwater areas with little or no flow occurring amongst boulder clusters; usually located in canyon areas. |
| | Slackwater | Low-velocity (0 to 20 cm/sec) habitat usually along inside margin of river bends, shoreline invaginations, or immediately downstream of debris piles, bars, or other in-stream features. |
| Vegetation Associated Habitats | Inundated vegetation | Riparian vegetation inundated by flowing or non-flowing water; formed when river water overflows bank. |
| | Overhanging vegetation | Vegetation hanging over river bank, often touching the water surface. |

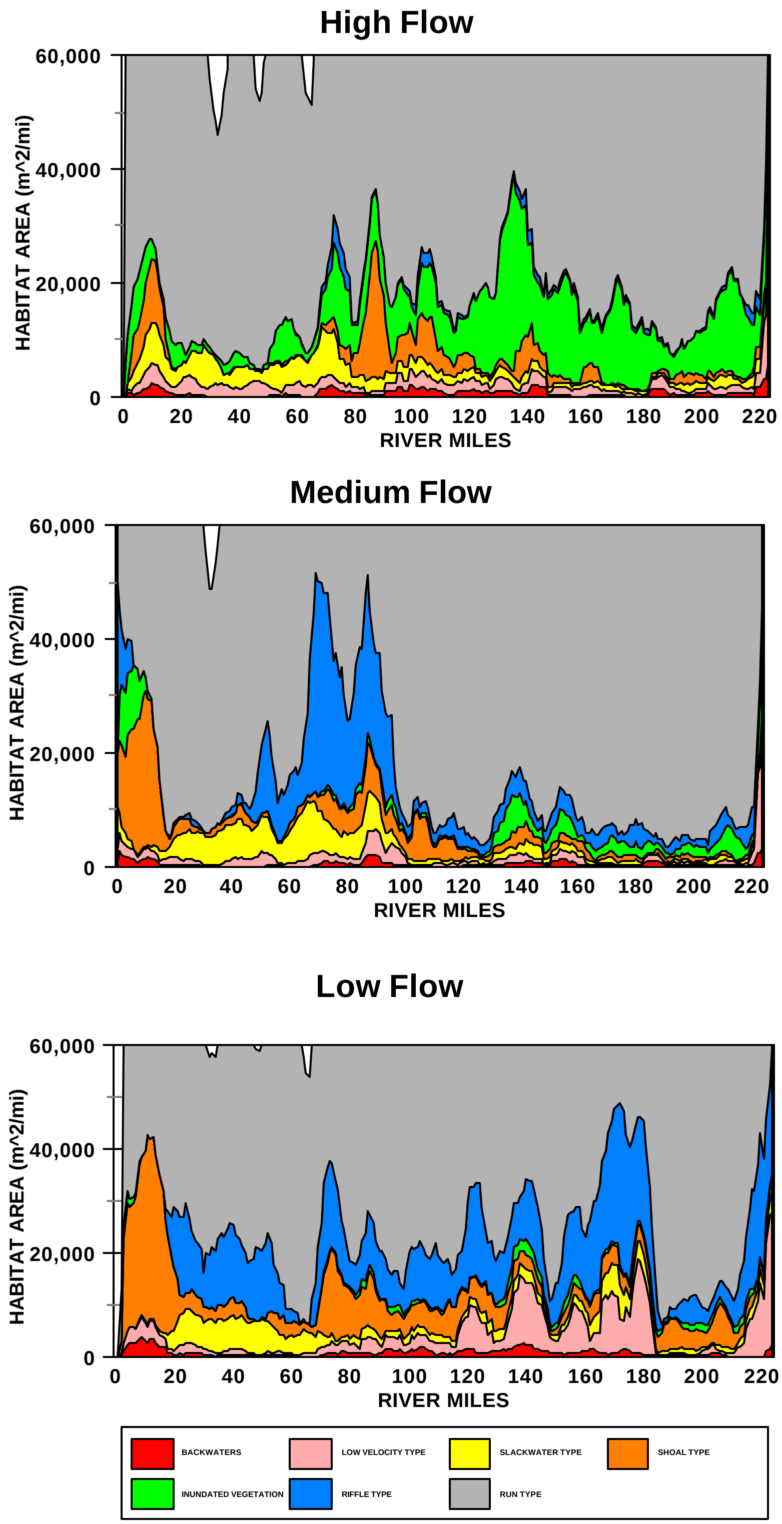



**Figure 3.5.** **The spatial distribution of seven habitat categories in the San Juan River at high (>7,000 cfs), medium (3,000 cfs), and low (<700 cfs) flows with expanded scales to allow viewing minor categories (Source: Bliesner and Lamarra 2000).**

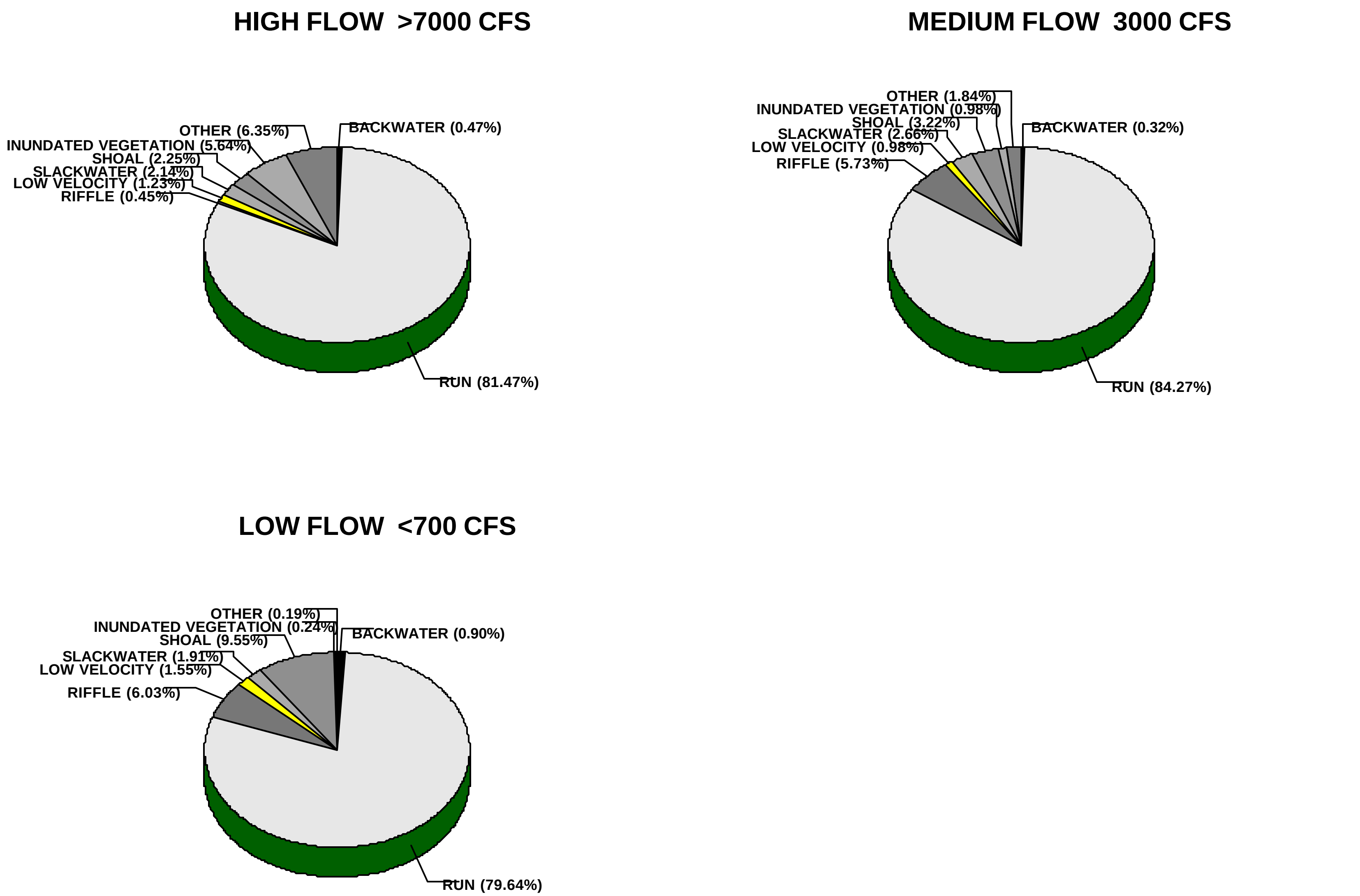



**Figure 3.6. A summary of the major habitat categories as a percent of total wetted area (TWA) for high-, medium-, and low-flow periods (Source: Bliesner and Lamarra 2000).**

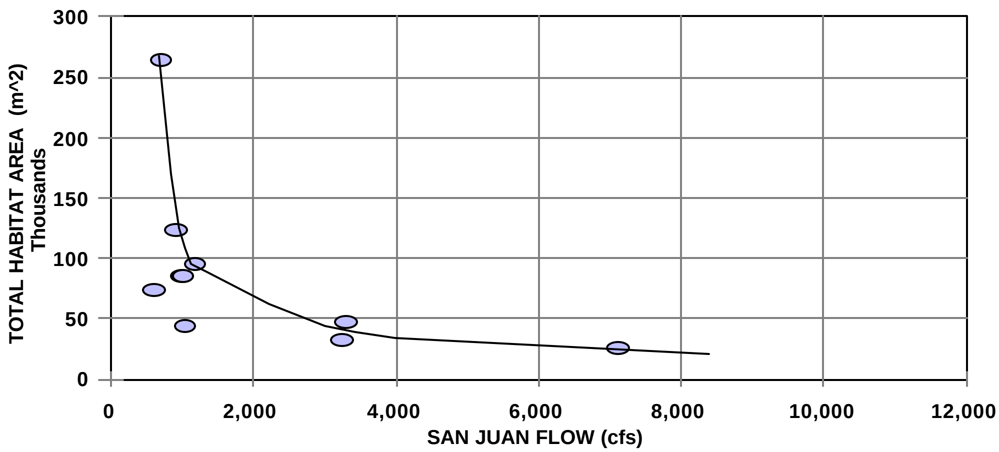
Figure 3.5 also shows the distribution of the general habitat categories in the study area. Because run habitat dominates the San Juan River, the scale on this figure was adjusted so that rarer habitat categories could be compared. Key habitats for the endangered fishes are fairly well distributed across the study area, except for the section from RM 20.0 to about RM 65.0, which is generally within Reach 2. This canyon-bound area has very few backwaters at any flow. It has relatively high amounts of slackwater and low-velocity habitats at all flows, and it has little inundated vegetation during high flows because of the canyon. The lack of backwater habitat in this section is the likely reason why stocked YOY Colorado pikeminnow retention was low in this reach.

Key habitats for adult Colorado pikeminnow and razorback sucker included edge pools, pools, eddies, slackwaters, and backwaters. These habitats fit into the low-velocity, slackwater, and backwater habitat categories (Table 3.2). Figure 3.7 shows the amount of pool and eddy habitat at various flow levels. Pool habitat area declined with increased flow, whereas eddy habitat increased with increased flow. Eddies were most available during high-flow periods, and pools were most available during low-flow periods. The two endangered fishes' habitat use followed this same pattern; eddies were used extensively during high-flow periods, and pools and eddies were used at lower-flow periods, suggesting the fish used the type of low-velocity habitat most available at the time.

Slackwater habitats did not change with flow (Figure 3.8) (Bliesner and Lamarra 2000). Backwater habitats, used by adult fish during high-flow periods and by YOY during late summer and autumn, were generally most abundant at low-flow periods, and varied at medium- and high-flow periods by reach. Reaches 1 and 2 were similar, as were Reaches 3, 4, and 5, but these two groups of reaches differed from each other (Figures 3.9 and 3.10). This variation in the relationship of the amount of backwater habitat versus flow results from the timing of flushing flows that clean the backwaters and the timing of the habitat mapping runs in relation to storm events and flushing flows (Bliesner and Lamarra 2000). Even though backwater habitat varied with flow and varied with the timing of flushing flows, stocked YOY Colorado pikeminnow primarily used backwater habitats and survived well in the San Juan River (Trammel and Archer 2000). This suggests that, even in low abundance, backwater habitat was sufficient for at least the number of stocked fish that survived in the San Juan River. It remains to be seen if this habitat type is sufficient for a larger, self-sustaining population of Colorado pikeminnow. Flooded vegetation was used by stocked razorback sucker during the high-flow period. As shown in Figure 3.7, that is the only time this habitat type is available.

Larval and YOY razorback sucker habitat use was not determined for the San Juan River. Flooded bottomland habitat, similar to that used by razorback sucker along the Green River, was essentially non-existent along the San Juan River because of its narrow floodplain, steep floodplain gradient, and lack of water-holding floodplain depressions. Inundated vegetation was an available habitat during high-flow periods in the San Juan River, but it disappeared rather quickly as flows receded (Figure 3.5).

## POOL HABITAT (REACHES 1-6)




## EDDY HABITAT (REACHES 1-6)

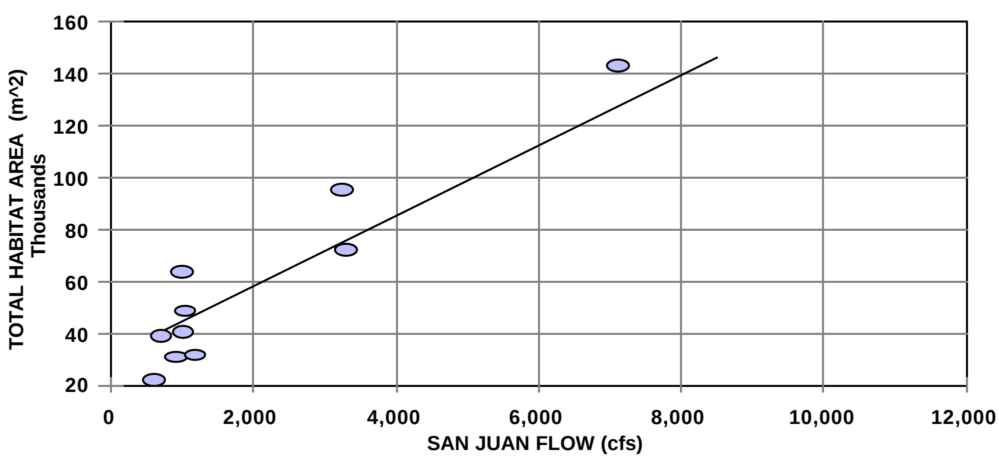



**Figure 3.7. The comparison between the sum of habitat area (square meters) for Reaches 1 through 6 and mapping flow in the San Juan River for pools (above) and eddies (below) (Source: Bliesner and Lamarra 2000).**

## SLACKWATER HABITAT (REACHES 1-6)

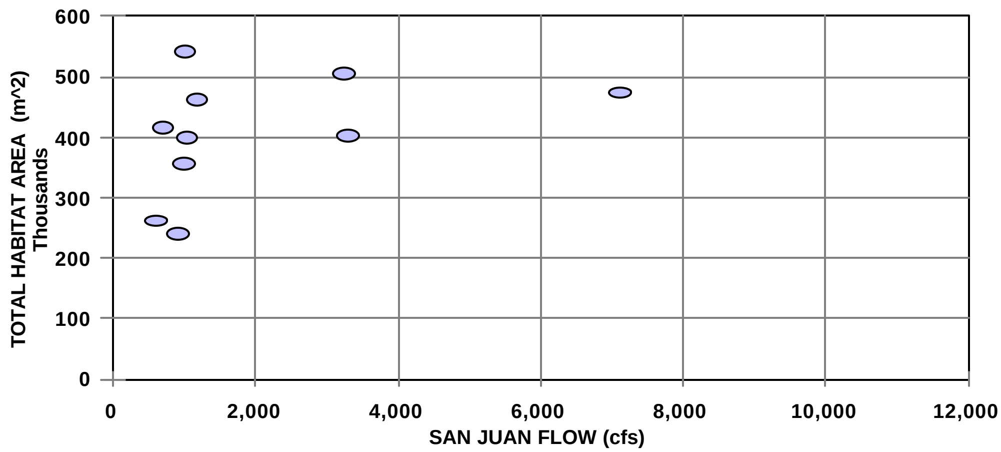



**Figure 3.8.** **The comparison between the sum of habitat area (square meters) for Reaches 1 through 6 and mapping flow in the San Juan River for slackwaters (Source: Bliesner and Lamarra 2000).**

## BACKWATER HABITAT (REACHES 1-2)

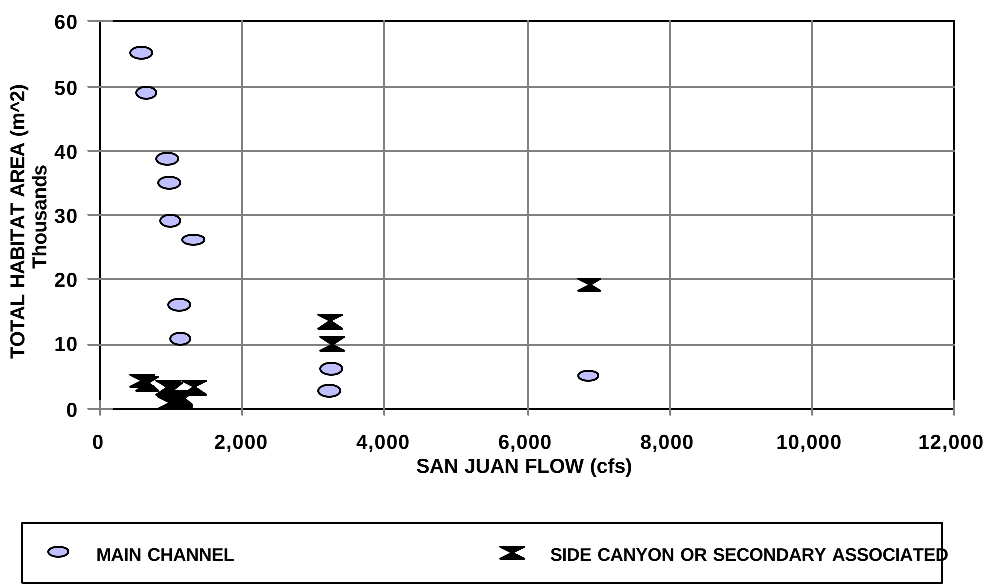
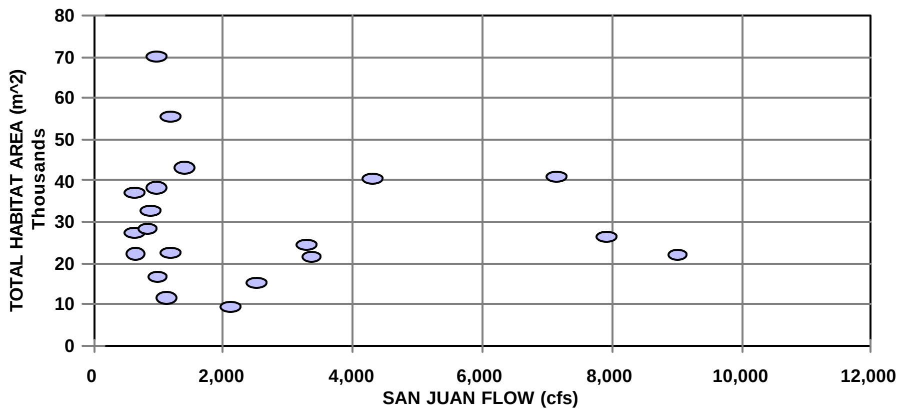



**Figure 3.9.** **The relationship between backwater surface area and flow for Reaches 1 and 2 based upon location within the channel (Source: Bliesner and Lamarra 2000).**

**BACKWATER HABITAT (REACH 3)**




**BACKWATER HABITAT (REACH 4)**

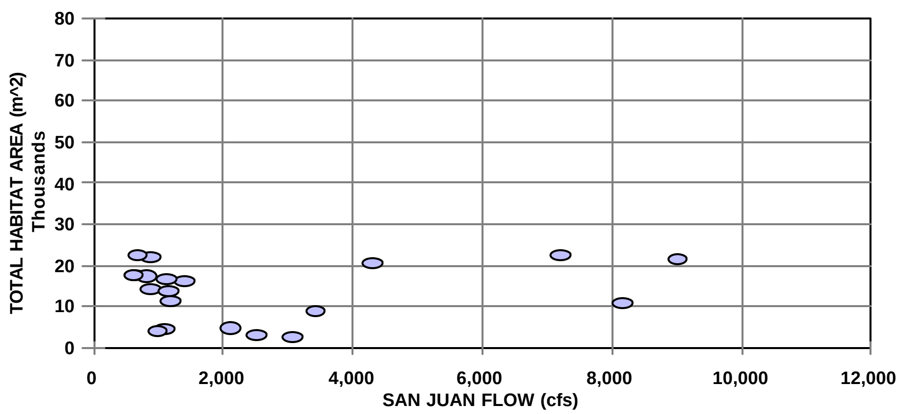
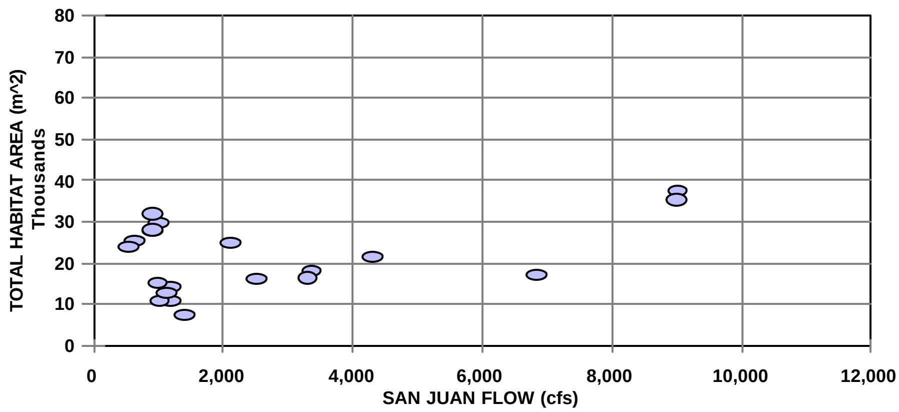



**Figure 3.10. The relationship between backwater surface area and flow for Reaches 3 and 4 in the San Juan River (Source: Bliesner and Lamarra 2000).**

## BACKWATER HABITAT (REACH 5)




## BACKWATER HABITAT (REACH 6)

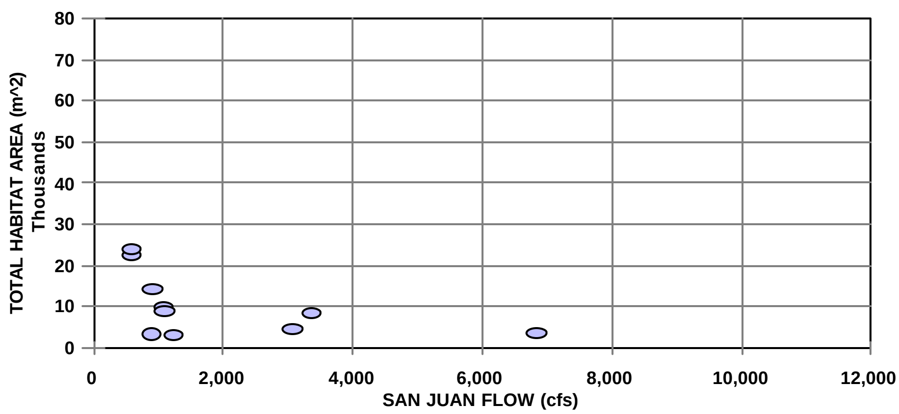



**Figure 3.10 (cont.).**

Bliesner and Lamarra (2000) searched portions of the upper half of the San Juan River study area for potential Colorado pikeminnow spawning habitat. They found several potential sites with cobble characteristics (cleanliness and size) similar to the two known spawning sites (RM 131 and RM 132) identified by Miller and Ptacek (2000) and other spawning sites in the Yampa and Colorado rivers. The fairly large Colorado pikeminnow population in the Green and Yampa rivers uses two major spawning areas, suggesting that the San Juan River can supply needed spawning areas for a relatively large population of Colorado pikeminnow, as well as razorback sucker and other native species that need clean cobble spawning bars.

Habitat for flannelmouth sucker (all habitats), bluehead sucker (riffles), and speckled dace (riffles) is common and abundant in the San Juan River. Because flannelmouth sucker use a variety of habitats, they are common throughout much of the river. Habitat was not limiting for this species; flannelmouth sucker abundance, which is higher in the San Juan River than in other Upper Basin systems (Ryden 2000a), suggested habitat for this species is more abundant in the San Juan River than in other rivers. Bluehead sucker and speckled dace were also abundant. Their key habitat, riffles, was also abundant, especially during low-flow periods (Figure 3.5). Habitat for these two native species was not limiting in the San Juan River. Habitats for roundtail chub (pools and eddies) were rare, but as seen for stocked Colorado pikeminnow and razorback sucker, rareness does not make a habitat limiting for the relatively small populations of these species; the case may be the same for roundtail chub habitat.

The endangered fishes used portions of the river that had high habitat richness. Figure 3.11 shows how habitat richness varied throughout the entire 180-mile study area at high flow (June 1994) and low flow (January 1996). This graph was developed from habitat mapping runs made by Bliesner and Lamarra (2000), and it reflects the average richness (number of habitat types) for overlapping 300-meter sections of the river with center points every 150 meters. Average richness by mile was generally less than five habitats per 300-meter reach. Areas selected by Colorado pikeminnow and razorback sucker averaged six to nine habitats, indicating that the fish selected relatively rare sections of the river. To examine the distribution of 300 meter reaches with higher richness, an exceedence evaluation by Geomorphic Reach was performed (Table 3.3). These data indicated that during both high and low flows, Reaches 1 and 2 have very few 300-meter reaches with more than five habitats, and richness is generally highest in Reach 5, the area containing the Mixer and Colorado pikeminnow spawning areas.

Another way to evaluate habitat richness was to look at the number of total habitats (versus total habitat types) within a river reach. Figure 3.12 shows total habitat counts from mapping runs (Bliesner and Lamarra 2000) for the study area at three flow levels. Total habitat count is lowest in Reaches 1 and 2 (RM 0 to RM 70), and it peaks around RM 130 in the Mixer. In the lower river, habitat count peaked at low flows, whereas in most of the remainder of the river it peaked at medium or high flows. This likely reflects the canyon area in the lower river, which is very habitat poor during high flows but increases in richness as flows recede. Higher values in the upper river result from flooding of areas that create more secondary channels and other habitat features adding to habitat richness.

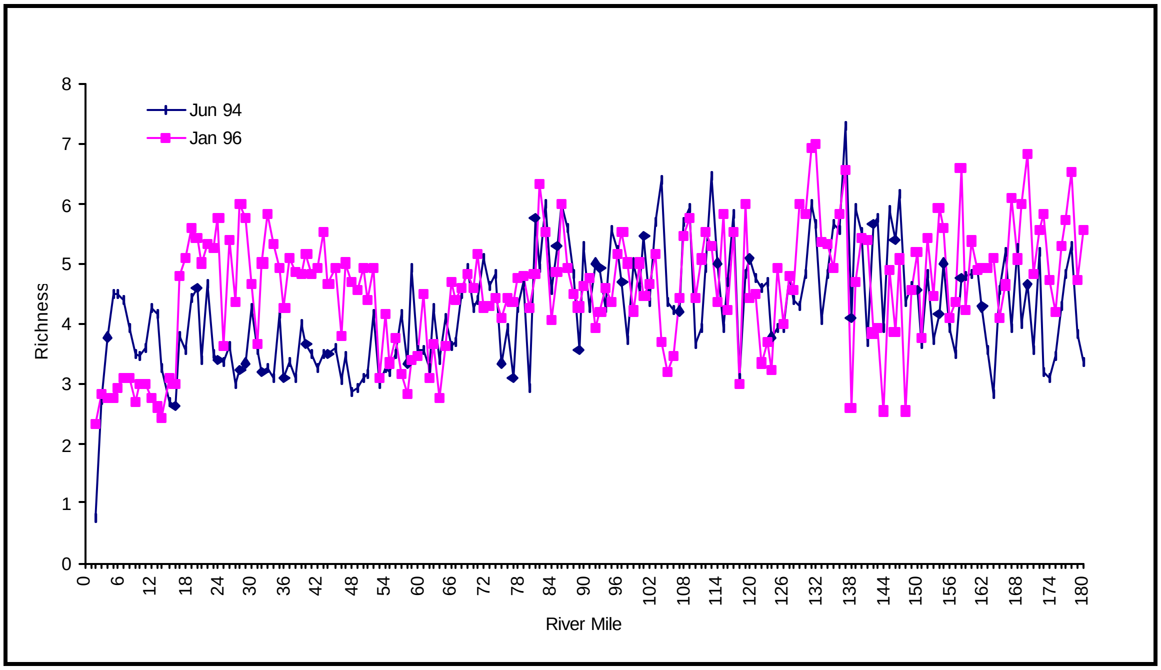



**Figure 3.11. Average habitat richness calculated for overlapping 300-meter river reaches with 150-meter centers by RM for the San Juan River. Habitat richness was determined as the number of habitat types per 300-meter reach. Data were derived from habitat mapping conducted by Bliesner and Lamarra (2000).**

**Table 3.3. The percent of each reach that exceeded various habitat richness values (5-10) in the San Juan River. Habitat richness was determined as the number of habitat types per 300-meter reach. Data were derived from habitat mapping conducted by Bliesner and Lamarra (2000).**

| | REACH | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Richness Exceeded | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| **June 1994 - High Flow** | | | | | | | | |
| 10 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 |
| 9 | 0.00 | 0.00 | 0.03 | 0.08 | 0.17 | 0.00 | 0.06 | 0.27 |
| 8 | 0.00 | 0.00 | 0.21 | 0.28 | 0.58 | 0.04 | 0.18 | 0.82 |
| 7 | 0.00 | 0.06 | 0.66 | 0.48 | 1.38 | 0.27 | 0.39 | 1.82 |
| 6 | 0.00 | 0.16 | 1.87 | 1.56 | 2.88 | 1.04 | 1.09 | 4.36 |
| 5 | 0.86 | 0.37 | 3.84 | 3.52 | 4.71 | 2.27 | 2.61 | 6.18 |
| **January 1996 - Low Flow** | | | | | | | | |
| 10 | 0.00 | 0.04 | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 |
| 9 | 0.00 | 0.04 | 0.00 | 0.12 | 0.13 | 0.12 | 0.03 | 0.09 |
| 8 | 0.00 | 0.14 | 0.11 | 0.44 | 0.29 | 0.35 | 0.21 | 0.09 |
| 7 | 0.00 | 0.47 | 0.45 | 0.68 | 0.79 | 0.92 | 0.82 | 0.45 |
| 6 | 0.00 | 1.51 | 1.61 | 2.04 | 2.50 | 2.19 | 2.42 | 1.91 |
| 5 | 0.00 | 3.04 | 4.00 | 4.12 | 4.75 | 4.65 | 5.03 | 4.45 |

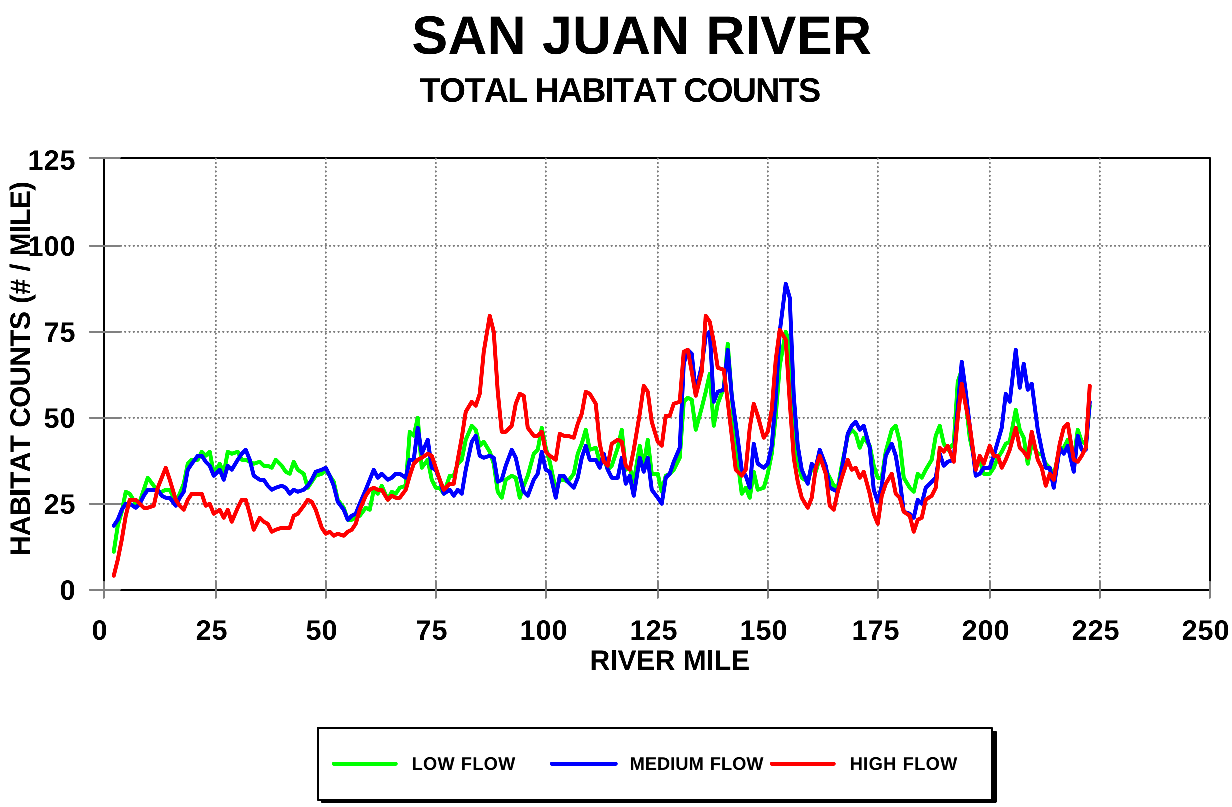



**Figure 3.12. Total count of habitats by river mile for the San Juan River averaged for all low-, medium-, and high-flow mapping runs conducted by Bliesner and Lamarra (2000). Habitat count was determined as the total number of different habitats (versus different habitat types) within each mile reach of river.**

Portions of the San Juan River with high habitat counts and richness were the most used by adult and juvenile Colorado pikeminnow, and by stocked razorback sucker. Although, on average, habitat richness was not very high in the river, as shown in Table 3.3, the San Juan River provided areas with high richness that were not only found, but heavily used, by the endangered fishes. Only the lower 70 miles of the river appear to be low in habitat richness, and that is likely a constraint of geological features.

Propst and Hobbes (2000) and Gido and Propst (1999) showed that secondary channels were an important habitat for fishes in the San Juan River. Secondary channels are not as common in other Colorado River streams as in the San Juan River, and it was thought that secondary channels may provide the same type of habitat that backwaters and low-velocity main channel habitats provide in other rivers. Initially, it was anticipated that YOY Colorado pikeminnow used these areas in late summer and fall, but low numbers of wild Colorado pikeminnow prevented verification. When YOY Colorado pikeminnow were stocked into the San Juan River, substantial numbers of YOY and juveniles were found in secondary channel-associated backwaters and low-velocity habitats (Propst and Hobbes 2000, Trammell and Archer 2000). Secondary channels are also common in portions of the river with high habitat richness, such as the Mixer, another indication of their importance to the native fish community.

Late summer and autumn studies of secondary channels were generally comparable with studies of backwaters in the Green and Colorado rivers, and the studies by Gido and Propst (1999) provided data that showed how the small fish portion of the San Juan River fish community varied with flow and other factors, such as late summer storm events. These studies helped to show that, even if the main channel San Juan River was dominated by run and riffle habitats, a considerable amount of low-velocity habitat existed for small fish in secondary channels.

The question of whether a rare, key habitat type is limiting remains unanswered. For the present low population levels of both endangered species in the San Juan River, there does not appear to be a shortage of key habitats. The YOY Colorado pikeminnow stocking study (Trammell and Archer 2000) showed that habitat for this age class was common, as shown by the large portion of river where the fish were retained, and sufficient for a high level of retention in the river. Archer and Crowl (2000b) compared the amount of nursery (backwater) habitat available in the San Juan River with that available in the Green and Colorado rivers using similar sampling techniques (Table 3.4). They concluded that the amount of habitat in Reach 1, near the Lake Powell confluence, was the highest in any reach studied in any of the three rivers, and that other San Juan River reaches had amounts of backwater habitat similar to the Green and Colorado rivers. Lamarra (1999) compared San Juan River backwaters as a percent of TWA (Figure 3.5) with similar data from the Colorado River. He concluded that, even in Reach 1, backwater habitat was three times less in the San Juan River. The difference in results is likely because of different habitat definitions (Archer and Crowl used nursery habitats of which backwaters, under Lamarra's definition, are only a part), and comparisons of different sections of the various rivers. Although rare, nursery habitats (backwater, low-velocity, and slackwater) do not appear to be limiting in the San Juan River for the numbers of Colorado pikeminnow in the river during the 7-year research period.

**Table 3.4. Total area (square meters) of low-velocity habitats per mile in nursery habitat study sections of the San Juan, Green, and Colorado rivers, September 1994 to 1997 (Source: Archer and Crowl 2000b). Flows in the San Juan River were generally 900 to 1,080 cfs during 1994 to 1996 and varied from 3,100 to 5,260 cfs during 1997.**

| YEAR | SAN JUAN | | | | GREEN | COLORADO |
|---|---|---|---|---|---|---|
| | RM 126-131 | RM 84-89 | RM 20-25 | RM 8-13 | | |
| 1994 | NA | 62.0 | 214.2 | 1861.6 | 1572.4 | 1,428.3 |
| 1995 | 496.6 | 349.2 | 371.0 | 881.6 | 359.9 | 307.4 |
| 1996 | 743.2 | 568.2 | 607.0 | 1,968.0 | 596.8 | 1,047.6 |
| 1997 | 464.6 | 1,282.4 | 332.8 | 1028.2 | NA | NA |

The experimental stocking of 939 razorback sucker provided an opportunity to assess the adequacy of habitat for subadults and adults of this species. Ryden (2000b) concluded that survival of these fish was "quite good compared to" other stocking efforts, an indication that habitat was sufficient. Population estimates of the number of stocked fish that survived have not been made. Although the stocked fish initially lost weight (approximately 5 to 10% of their stocked weight), they grew relatively rapidly after the first year or so in the river, and they generally maintained their position in the river, indicating that habitat was not a limiting factor. In addition, some spawning occurred and larvae were found, indicating at least one acceptable spawning site was found. All of this information suggests that habitat for juvenile and adult razorback sucker is available in the San Juan River for the numbers of stocked fish that survived.

The abundance of flannelmouth sucker, bluehead sucker, and speckled dace, and the abundance of habitats that these species use and apparently select, suggests that habitat is not limiting for these three native species. Most biologists familiar with roundtail chub and the San Juan River believe that there is adequate habitat for this species in the mainstem river. As noted above, factors other than habitat may be the primary reasons why this species has not been able to sustain mainstem populations.

The question of whether larval razorback sucker or Colorado pikeminnow will use inundated vegetation, backwaters, or some other habitat in the San Juan River will have to wait until a sufficient number of adults are spawning so that larval habitat use can be studied. It appears that larval razorback sucker habitat will be limiting in the San Juan River, but many biologists thought similarly about YOY Colorado pikeminnow prior to stocking, and they found adequate habitat. At this time it is not possible to determine how many adult razorback sucker or Colorado pikeminnow may be able to find adequate habitat in the San Juan River. Habitat will be limiting at some point, since the amount of acceptable habitat is one factor that limits populations in any situation. The lack of key razorback sucker bottomland habitat, and the lack of early and recent collection specimens (only one has been collected in the San Juan River), suggest that only a relatively small population of this species may be possible in the San Juan River. On the other hand, historical and more-recent collections of young and adult Colorado pikeminnow, and available habitat information, suggest larger populations of this species are possible. As razorback sucker population augmentation continues and the stocked Colorado pikeminnow grow to adulthood, habitat limitations for adults will be clarified.

## Habitat Quality

Quality is another component that may make habitat limiting. Habitat quality refers to the habitat characteristics that determine how good a habitat is for a fish species. Not all backwaters, or eddies, or spawning bars are equally useful to the endangered fish species. For example, deeper backwaters were used by YOY Colorado pikeminnow in the Green River (Holden 1977) more than shallow backwaters, and larger and deeper backwaters were selected over smaller and more shallow backwaters in the Green and Colorado rivers (Trammell and Chart 1999, Trammell et al. 1999). Backwaters also need to be productive to provide small food organisms for young fish. In addition, spawning bars need to be clean (have open spaces between the cobbles) so that eggs are not smothered or simply washed downstream. Although habitat quality studies were not an emphasis during the 7-year research period, several studies were conducted that assessed various components of habitat quality.

As noted above, critical components of Colorado pikeminnow spawning bars are cobble size and cleanliness. Bliesner and Lamarra (2000) evaluated Colorado pikeminnow spawning bar characteristics in the Yampa and Colorado rivers and compared those results with the characteristics of 23 bars in the San Juan River, including bars where Miller and Ptacek (2000) observed spawning behavior. They found that cobble in many of the San Juan River cobble bars was similar in size and size distribution to cobbles at the Yampa River spawning site (more than half the cobbles were 71 mm or larger), although bars at the Colorado River spawning sites had slightly larger cobble (more than half were 78 mm or larger) (Table 3.5). Although it was generally known that the Yampa spawning site had very clean, loose cobbles (O'Brien 1983, Harvey et al. 1993), these characteristic were not quantified. Bliesner and Lamarra (2000) developed a method to measure the depth-to-embeddedness characteristic of San Juan River cobble bars. Figure 3.13 compares cleanliness of 21 cobble bars investigated in the San Juan River during 1995 (data from the two [RM 132.0 and RM 131.0] spawning bars identified in 1994 are also included). The two spawning bars had measurements of 13 to 24 cm depth-to-embeddedness. In 1995, several other bars had similar cleanliness, which was similar to depths-to-embeddedness from Yampa River spawning bars. This analysis indicated that the spawning bars selected by Colorado pikeminnow were some of the cleanest bars in the San Juan River and that there were a number of potentially suitable, high-quality bars available.

**Table 3.5. Average cobble size distribution for potential spawning sites in the San Juan, Yampa, and Colorado rivers. Diameters (mm) represent the maximum size cobbles within the designated percentage (Source: Bliesner and Lamarra 2000).**

| RIVER | PERCENT | | | | |
|---|---|---|---|---|---|
| | 84% | 75% | 50% | 25% | 16% |
| San Juan | ≤ 106 | ≤ 95 | ≤ 71 | ≤ 51 | ≤ 45 |
| Yampa | ≤ 110 | ≤ 94 | ≤ 76 | ≤ 58 | ≤ 46 |
| Colorado | ≤ 125 | ≤ 104 | ≤ 78 | ≤ 49 | ≤ 38 |

Archer and Crowl (2000b) surveyed nursery habitats, primarily backwaters, in the San Juan River and found that deep backwaters (>0.5 meter) were relatively common, but their number declined from August to September every year from 1994 through 1997, although the differences were not statistically significant (Table 3.6). The loss of deep backwaters may be an effect of late summer storm events, which are common in the San Juan Drainage. Bliesner and Lamarra (2000) studied backwater depth and productivity in the San Juan River and how these factors varied with late summer thunderstorm activity. They also made comparisons between San Juan River nursery reaches and those of the Green and Colorado rivers. They found that backwater depths in the San

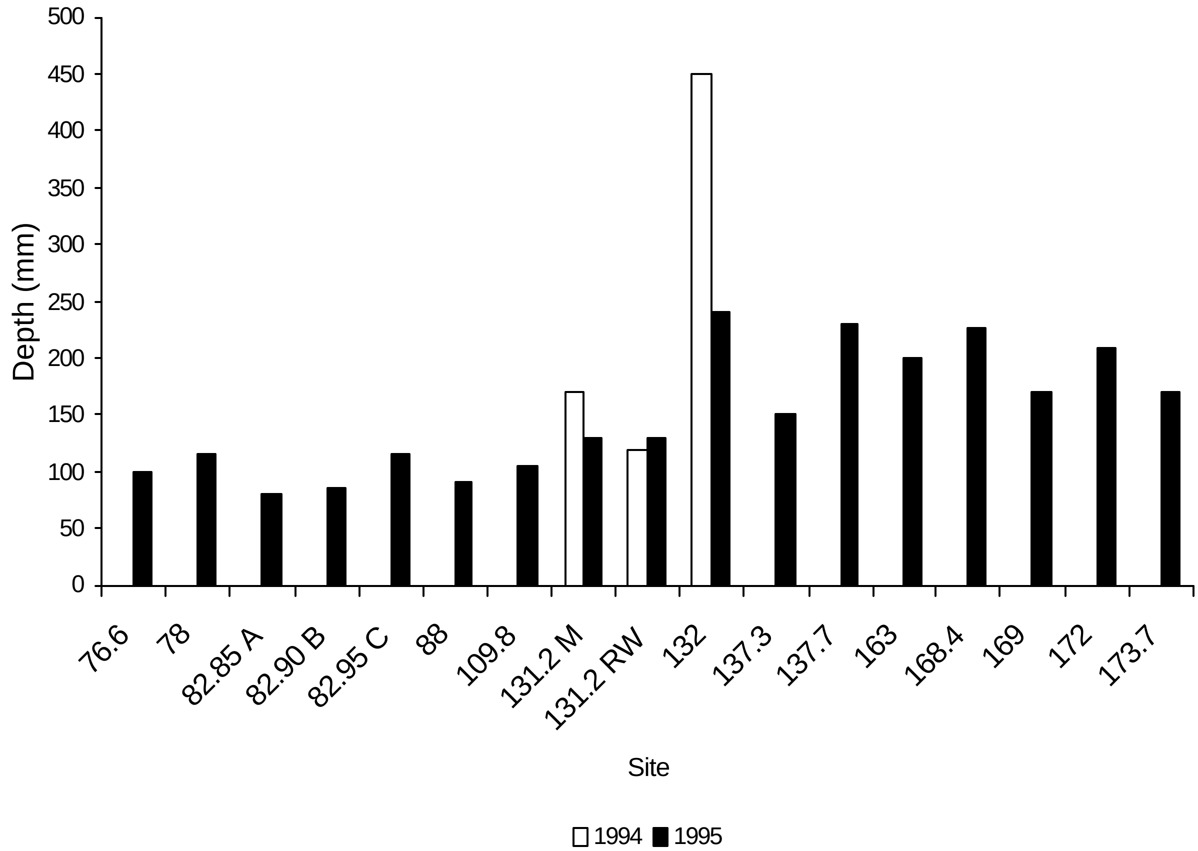



**Figure 3.13.** **Maximum depths of open interstitial space for potential spawning bars in the San Juan River (Source: Bliesner and Lamarra 2000).**

**Table 3.6.** **Total number of deep (>0.5 m), low-velocity habitats in nursery habitat study sections of the San Juan River for August and September 1994-1997 (Source: Archer and Crowl 2000b).**

| YEAR | RM 126-131 | | RM 89-84 | | RM 20-25 | | RM 8-13 | |
|---|---|---|---|---|---|---|---|---|
| | Aug | Sep | Aug | Sep | Aug | Sep | Aug | Sep |
| 1994 | NA | NA | 2 | 0 | 7 | 3 | 18 | 10 |
| 1995 | 6 | 2 | 1 | 1 | 12 | 4 | 6 | 10 |
| 1996 | 1 | 2 | 5 | 0 | 9 | 5 | 21 | 12 |
| 1997 | 4 | 0 | 2 | 2 | 4 | 6 | 15 | 5 |

Juan River were generally shallower than those in the Colorado River but similar to those in the Green River. San Juan River backwaters were similar to the other two rivers in water quality (temperature, dissolved oxygen) and productivity features (phytoplankton, periphyton, zooplankton, benthic invertebrates), indicating that overall productivity appeared to be similar to other areas considered good Colorado pikeminnow nursery areas. Bliesner and Lamarra (2000) found that backwater depth and productivity were reduced by storm events when fine sediments were deposited in backwaters. Archer (2000) compared invertebrate numbers from San Juan River Reach 1 and Reach 4 nursery habitats (backwaters) with a Colorado pikeminnow nursery area in the Green River near Ouray, Utah, during August and September of 1995 and 1996. He found that invertebrate numbers in Reach 1 were lower than in either Reach 4 or the Green River, and that numbers in the San Juan River declined from August to September, whereas in the Green River they did not decline. Archer (2000) concluded that late summer thunderstorm activity in the San Juan River decreased invertebrate numbers in nursery habitats, indicating food limitation may have occurred at this time. Retention and growth of stocked Colorado pikeminnow in the San Juan River in both 1996 and 1997 were high (Trammel and Archer 2000), suggesting that for the number of fish that were retained in the river, food did not appear to be a limitation. Archer (2000) also measured lipid content of YOY Colorado pikeminnow stocked in August1997. Lipid content was initially high in the hatchery-reared fish, declined in September and October shortly after stocking, and rose in December. Archer (2000) noted that the decline in lipid content after stocking was normal for stocked fish. The increase in lipid content by December, along with good growth of the stocked fish, shows that food was not limiting to them, even though flooding events occurred in September 1997. Information from these various studies clearly shows that food availability declines in the San Juan River in the fall as a result of thunderstorm flood events, but no evidence of food limitation could be seen in the stocked Colorado pikeminnow.

Bliesner and Lamarra (2000) also evaluated general habitat quality and productivity in the San Juan River and compared it with similar studies in the Colorado River. This study looked at runs and riffles, the two most-common habitat types. The results showed that the San Juan River was very similar in overall habitat quality to the Colorado River.

Habitat quality in San Juan River key habitats is comparable with similar habitats in the Green, Yampa, and Colorado rivers. This suggests that overall habitat quality in the San Juan River is not limiting. But the frequency of late summer storm events in the San Juan River has the potential to reduce habitat quality by depositing fine sediments, which could possibly cause habitat limitations for the native fishes.

### Habitat Summary

During the 7-year research period, many key habitats for Colorado pikeminnow and razorback sucker were identified. Key habitats for adult Colorado pikeminnow in the San Juan River include relatively low-velocity eddies, pools, and slackwaters, along with the riffle/runs and chutes used for spawning. More-common run habitat is used, but the other lower-velocity habitats are selected during most seasons, suggesting they are more important to the fishes. Warmer habitats, typically low-velocity habitats, appear important during the pre-spawning period. In addition, these habitats are apparently more important when they occur in relative proximity to each other, such as in habitat-rich river reaches. Key habitats for young Colorado pikeminnow in the San Juan River include backwaters, pools, pocket waters, and other slow-velocity habitats along shorelines. Key habitats for juvenile Colorado pikeminnow were not determined, but the fish appeared to utilize a variety of medium- to slow-velocity habitats.

Key habitats for subadult and adult razorback sucker in the San Juan River are slow-water habitats including eddies, edge pools, and backwaters found in relatively habitat-rich portions of the river. Cobble areas in shoreline runs are spawning locations. Habitat for young and small juvenile razorback sucker was not determined since these size classes were not collected during the 7-year research period.

Flannelmouth sucker use a great variety of habitats and do not appear to select any key habitats. Bluehead sucker and speckled dace select cobble substrates and riffle-type habitats. Roundtail chub were not common enough to determine key habitats, although they use pools and eddies in tributaries.

The habitat studies determined that key habitats for the two endangered fish species make up only a small portion of the available habitat in the San Juan River. This is especially true of backwater and low-velocity (eddies, pools) habitats. In comparison with the Green and Colorado rivers, however, actual habitat amounts are very similar. Cobble bars for spawning are fairly common in the upper San Juan River. Quality of backwater habitats in the San Juan River is at least comparable with that in the Green and Colorado rivers, and numerous cobble bars (Colorado pikeminnow spawning areas) with appropriate cobble size and cleanliness were found in the San Juan River. Late summer thunderstorm activity levels in the San Juan Basin are much higher than in either the Green or Colorado rivers, and sediment inflow from these storms has the potential to reduce the quality of backwaters, spawning bars, and other habitats in the San Juan River.

Key habitats are fairly well distributed in the San Juan River, except for the canyon reach from about RM 20 to RM 65. This reach has reduced habitat richness compared with other reaches and does not have sufficient habitat to retain stocked Colorado pikeminnow. Cobble bars suitable for Colorado pikeminnow are found in the upper portion of the river (Reaches 4, 5, and 6) and backwater habitat is also fairly abundant in this upper portion of the river. River reaches with high habitat richness were relatively rare in the San Juan River, and habitat richness peaked in Reach 5. Habitat quantity and quality was not limiting to the endangered fishes during the 7-year research period, but this may be due in part to the low numbers of the two species in the river. Habitat for the other native fishes was also not limiting.

## Management Implications

A major concern of the SJRIP during the 7-year research period was the development of flow recommendations (Holden 1999) that provide high levels of habitat quantity and quality timed to meet the critical habitat needs of the endangered fishes. The development of the flow recommendations concentrated on improving backwater and cobble bar habitat quantity and quality and providing high habitat richness. Bliesner (1999b) showed that backwater habitat quantity declined 27% on average from pre-dam to post-dam periods (Figure 3.14) during late summer and fall in Reaches 1 through 4, which are below the suspected Colorado pikeminnow spawning areas. The low peak flows during the post-dam period were not sufficient to create and clean backwaters, and relatively high low flows in late summer did not maximize backwaters during base-flow periods. Starting in 1992, the reoperation of Navajo Dam to mimic a natural hydrograph improved backwater availability by returning it to near or above pre-dam conditions. Projected backwater availability under various future conditions with the flow recommendations in place indicates that backwater habitat would remain higher than pre-dam conditions for most scenarios (Bliesner 1999b). The flow recommendations included 5,000 cfs for 21 days, in part to maintain backwater habitat quality by flushing out fine sediments, and a base flow of 500 cfs to maximize the extent of backwater habitat.

Flows needed for formation and maintenance of cobble bars are also important parts of the flow recommendations. The recommendation of 8,000 cfs for 10 days was made, in part, for cobble bar construction and maintenance. Cobble bar quality was also likely reduced during the post-dam period when peak flows were reduced. In addition, the 10,000 cfs recommendation was made to assist in creating and preserving islands, an important factor in creating habitat-rich areas. Figure 3.15 shows that as island count increases, habitat count, a measure of habitat richness, also increases.

If Navajo Dam is operated as prescribed in the flow recommendations, key habitats for the endangered fish species will be maximized in both quantity and quality, and they will be provided at the proper time of the year for use by the fish, based on information gathered during the 7-year research period. New information may improve the flow recommendations through adaptive management. However, larval habitat availability, a major potential habitat limitation for both endangered fish species, was not explored. In addition, YOY razorback sucker habitat availability was not researched. These potential habitat limitations will be studied when the adult populations of both species increase sufficiently to produce millions of larvae.

Habitat limitation is one of the primary factors restricting the population density of fish in any habitat, and habitat will likely limit the two endangered fishes in the San Juan River at some point. The river's recovery potential will not be known until the adult populations of these two species are increased and natural recruitment occurs. Based on the habitat quantity and quality studies conducted during the 7-year research period, as well as the retention and growth of the stocked endangered species, the San Juan River does provides habitat for both of these species. Because of this, the San Juan River has the potential to make a substantial contribution toward recovery of both Colorado pikeminnow and razorback sucker.

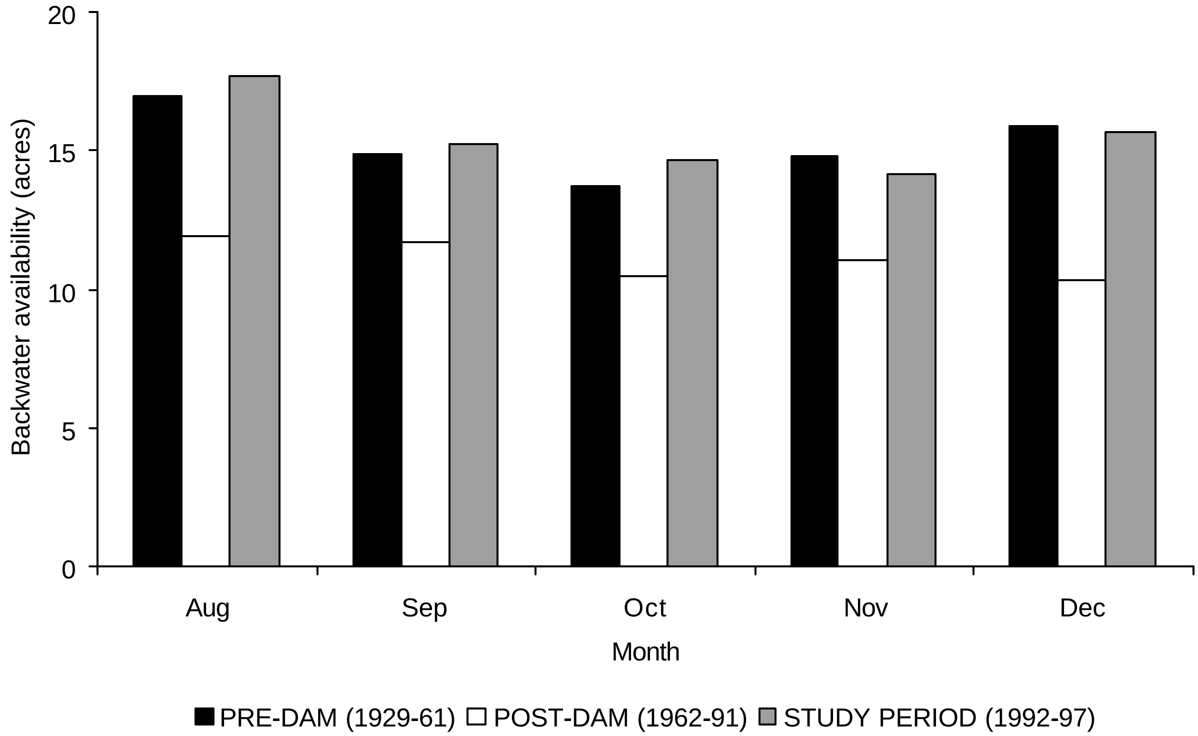



**Figure 3.14. Comparison of modeled backwater area for three historical periods in San Juan River Reaches 1 through 4 (Source: Bliesner 1999b).**

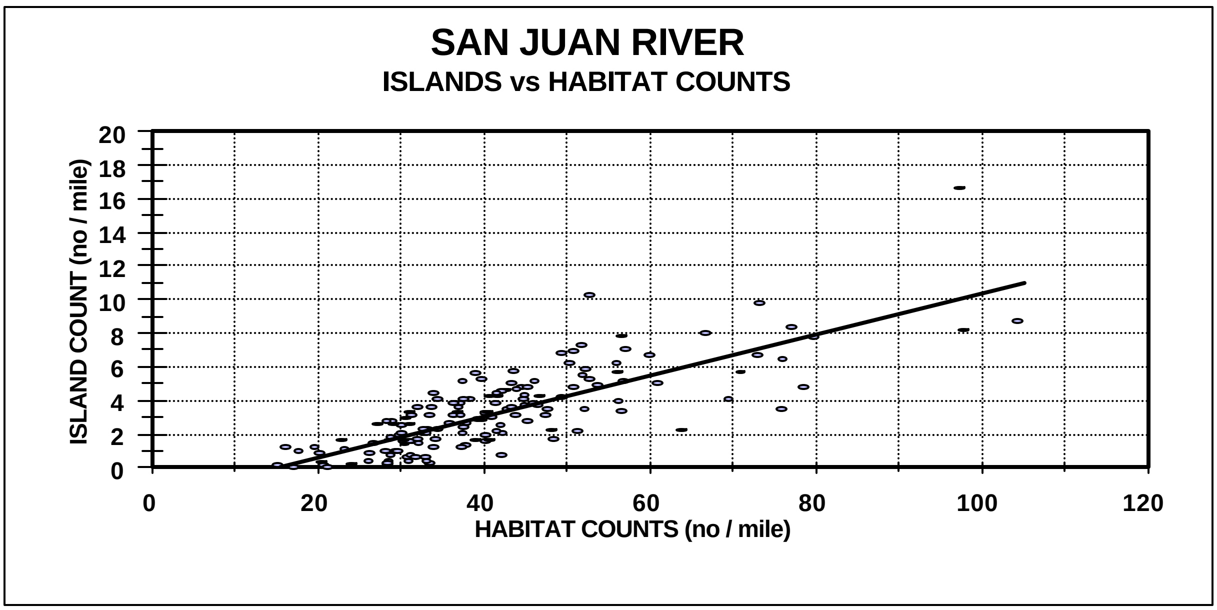



**Figure 3.15. Regression of paired data sets comparing island count and total habitat count average per RM for all non-canyon reaches of the San Juan River. Data were derived from habitat mapping conducted by Bliesner and Lamarra (2000). Habitat count was determined as the total number of different habitats (versus different habitat types) within each RM. $R^2=0.63$, $p=0.001$.**

# RANGE LIMITATIONS

## Introduction

Range limitation is the restriction of the area of habitat available to a species, and in rivers it typically occurs as a result of a major change in habitat length, such as a reservoir inundating a portion of a river, a blockage of access to a portion of river (e.g., by a dam), or a change in water quality that makes a portion of the river unusable by certain fish species. When the SJRIP was initiated, it was known that range limitation was a potential limiting factor to endangered fish species recovery within the river. Range limitation may reduce the possible overall population size of the endangered species by limiting available habitat, or by the loss of a portion of the range that included a key habitat. In the Green and Colorado rivers, Colorado pikeminnow larvae drift from 100 to 200 miles below spawning areas to find nursery habitats. Drifting that far in the San Juan River would result in the larvae entering Lake Powell, a poor nursery habitat because of abundant nonnative predators. Although no studies directly addressed range limitation, data collected by several studies allowed analysis of this issue.

## Habitat Length

The length of riverine habitat for the native fishes in the San Juan River was dramatically reduced by Lake Powell and Navajo Reservoir. Lake Powell inundated the lower 54 miles of the river (Bliesner 1999a), and Navajo Reservoir inundated another 27 miles. The two endangered fishes undoubtedly utilized the lower 54 miles of the river, and Colorado pikeminnow used 27 miles of what is now Navajo Reservoir for habitat, and roundtail chub used the entire inundated area. It is not known if any key habitats existed in the inundated areas but, based on collections of fish in that area and the location of other known spawning areas in similar upstream portions of other rivers (e.g., Yampa River), a Colorado pikeminnow spawning site was possible within the Navajo Reservoir section. It is probable that the lower San Juan River provided nursery habitat for Colorado pikeminnow much as it does below RM 131.0 today. Compared with the study area, the river in the Lake Powell reach was of similar, relatively steep gradient and did not provide the type of low-gradient reaches found in the Green and Colorado rivers (Figure 3.16) that are usually associated with Colorado pikeminnow nursery areas. The river in this reach may have been similar to the canyon reach (RM 20 to RM 65) of the SJRIP study area where backwaters and other low-velocity habitats are rare. Low-gradient, flooded bottomland habitat also did not likely occur in the Lake Powell reach; hence habitat for young razorback sucker would likely have been similar to the present study area. The two reservoirs reduced potential range and habitat for the two endangered fishes from about 325 miles to only 225 miles and inundated potential Colorado pikeminnow spawning areas in the upper San Juan River.

Some Colorado pikeminnow in the Green and Colorado river systems drifted up to 200 miles from spawning areas before finding nursery habitat, although some used nursery areas only a few miles below the spawning areas (Trammel and Chart 1999, Trammell et al. 1999). Questions not completely answered are: do the larvae need to drift so far, is the length of the drift related to the accessibility and availability of nursery habitat, or is the length of the drift related to some other factors? From 1964 to 1966, Vanicek and Kramer (1969) found relatively large numbers of YOY, age-1, and age-2 Colorado pikeminnow in the Green River from the mouth of Yampa River to

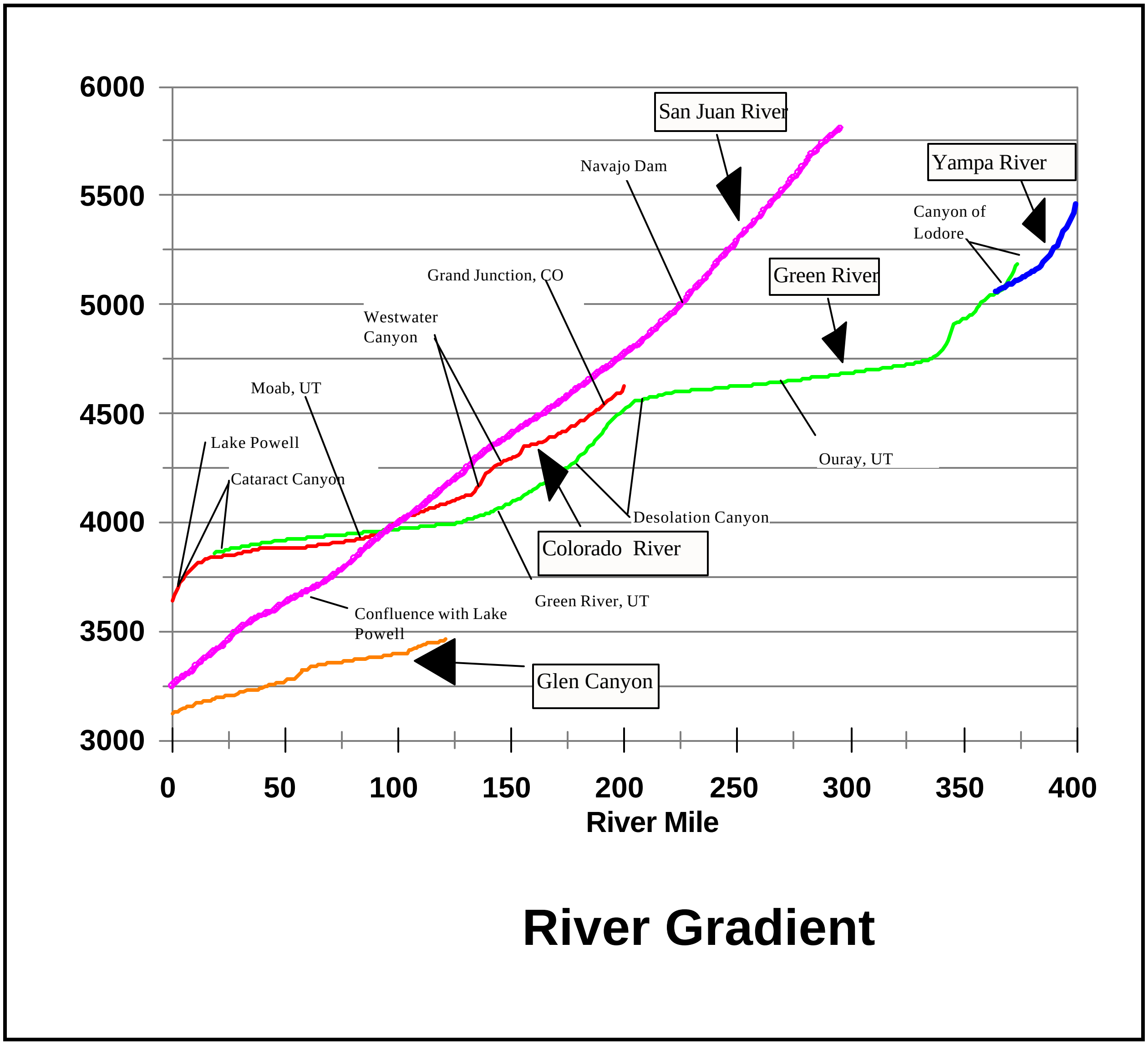



**Figure 3.16. River gradient comparison of the San Juan, Green, Yampa, and Colorado rivers and Glen Canyon (Source: Holden 1999).**

about 40 miles downstream. It is assumed that these larvae came from the Yampa River spawning area, which is about 20 miles up the Yampa River, resulting in a total drift of about 20 to 60 miles.

Colorado pikeminnow YOY were seldom found in this same portion of the Green River during recent studies (Holden and Crist 1981, Bestgen et al. 1998, Trammell et al. 1999); most were found well downstream. Vanicek and Kramer (1969) studied the Green River shortly after Flaming Gorge Dam was completed. Green River flows at the mouth of the Yampa River during that period were relatively low, because of dam filling, and warm, as a result of warming the low flows in the intervening 40 miles of river to the mouth of the Yampa River. Around 1968, the flows below the dam became colder and increased in volume as the reservoir filled. The larger volume of colder water did not warm as quickly as the water warmed during the first few years after the dam was completed, and it was still cold when it joined with the Yampa River. This change in volume, and the resultant decrease in temperature, may be a major reason why larval Colorado pikeminnow now drift so far downstream in the upper Green River. In addition to a temperature gradient, other factors may affect larval drift distance. A swifter river would be expected to push larvae further downstream than a slower river, and a river with little complexity (bends and current shifts) could keep larvae from reaching shoreline nursery habitats longer than a more-complex channel. Based on Green River information, it would appear that distance is not a requirement, but habitat accessibility may be more important.

In 1987 and 1988, Platania (1990) collected 7 of 13 YOY Colorado pikeminnow from RM 24 to RM 123 of the San Juan River, and five of the other six Colorado pikeminnow were collected in the lower 20 miles of the river near the Lake Powell interface. Of the 22 YOY collected during the 7-year research period, none were found above the lower 25 miles of the river. This indicates that most YOY Colorado pikeminnow in the San Juan River drift over 100 miles from the spawning area at RM 131-132 (although other spawning areas may not have been found), but not all did. Nursery habitats were available well above the lower 25 miles of the river (Bliesner and Lamarra 2000). It is not known why larval Colorado pikeminnow appeared to drift by favorable habitat during the 7-year research period, or why many found habitat in the middle river in the late 1980s. It is possible that sufficient larvae were not produced during the 7-year research period to adequately test if river length below the spawning area is a limiting factor for Colorado pikeminnow.

Two large juvenile Colorado pikeminnow were captured in the lower 12.9 miles of the San Juan River in 1996 (Ryden 2000a). Capture of these fish suggested that recruitment from fish that likely grew up in Lake Powell, or the lower section of the river, still occurred. This raises the question of whether Lake Powell, or the nursery habitat in the lower river, is actually a detriment to Colorado pikeminnow success. All drifting larvae found in the lower river may not necessarily be eaten by nonnative predators.

## Water Temperature

As Navajo Reservoir filled, water released from the dam turned colder. Bliesner and Lamarra (2000) showed that summer temperatures dramatically declined in the river from the dam downstream to the mouth of the Animas River. Figure 3.17 shows the change at Archuleta, New Mexico, about 7 miles below the dam, for pre- (1950-1961) and post-dam (1964-1968) periods; mid-summer water temperatures declined about 5EC. Nonnative trout replaced native fishes as the dominant species for about 10 to 20 miles below the dam (RM 205). Flannelmouth sucker, bluehead sucker, and speckled dace, species that inhabit and reproduce in both cooler tributaries and warmer mainstreams in the Colorado Basin, were still very abundant from RM 205 to the confluence with the Animas River (RM 180.0). It is not known if Colorado pikeminnow and razorback sucker would use the area above the Animas River confluence. In a similar situation in the Green River below Flaming Gorge Dam, flannelmouth sucker, bluehead sucker, speckled dace,

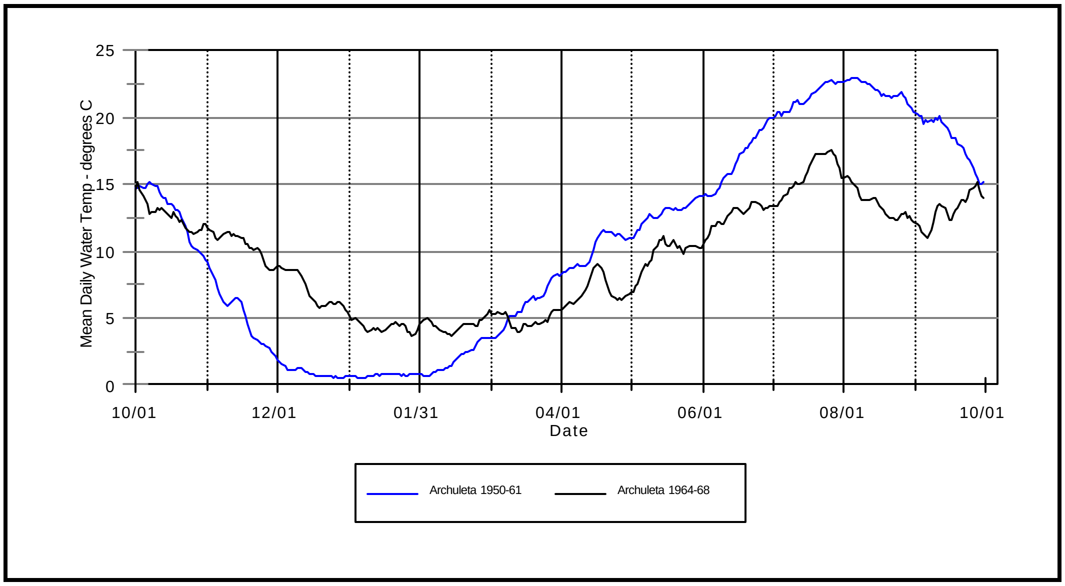



**Figure 3.17. Seven-day running mean daily water temperature for the San Juan River at Archuleta, New Mexico, during pre-dam and post-dam flow periods (Source: Bliesner and Lamarra 2000).**

and roundtail chub reproduced in the mainstem above the mouth of the Yampa River; but Colorado pikeminnow and razorback sucker used the area more sporadically (Holden and Crist 1981, Bestgen and Crist 2000). The Animas River provides a more-natural temperature regime, warming the colder San Juan River water during the spring and summer, similar to the Yampa River. The change in temperature caused by Navajo Dam effectively reduced the potential range of the endangered fish species by another 45 miles, from mouth of the Animas River (RM 180.0) to Navajo Dam (RM 225.0), although other native species still utilize most of this reach.

Bliesner and Lamarra (2000) also noted that summer water temperatures declined between the mouth of the Animas River and Shiprock, New Mexico. Figure 3.18 shows actual and modeled temperatures at Shiprock from pre- (1951-1961) and post-dam (1964-1968) periods and the 7-year research period (1993-1998). Colorado pikeminnow spawn at temperatures of about 20EC (Vanicek and Kramer 1969, Hamman 1981, Tyus 1990). Temperatures at Shiprock, New Mexico, reached 20EC in mid to late June during the pre-dam period. The colder post-dam releases delayed the time of reaching this temperature by about 2 weeks, and during the 7-year research period it was 3 weeks later (early to mid-July). It should be noted that the study period was a relatively high water period that resulted in above-normal flows both from Navajo Dam and the Animas River (Bliesner and Lamarra 2000). These higher flows likely contributed to a lower summer water temperature. The pre-dam period for which temperature data were available (1951-1961) was a relatively low-flow period. Average high flows during 1993 to 1998 were about 9,100 cfs, and during 1951 to 1961 they were 7,200 cfs. This suggests that the temperature difference during the 7-year research period may not reflect the long-term difference.

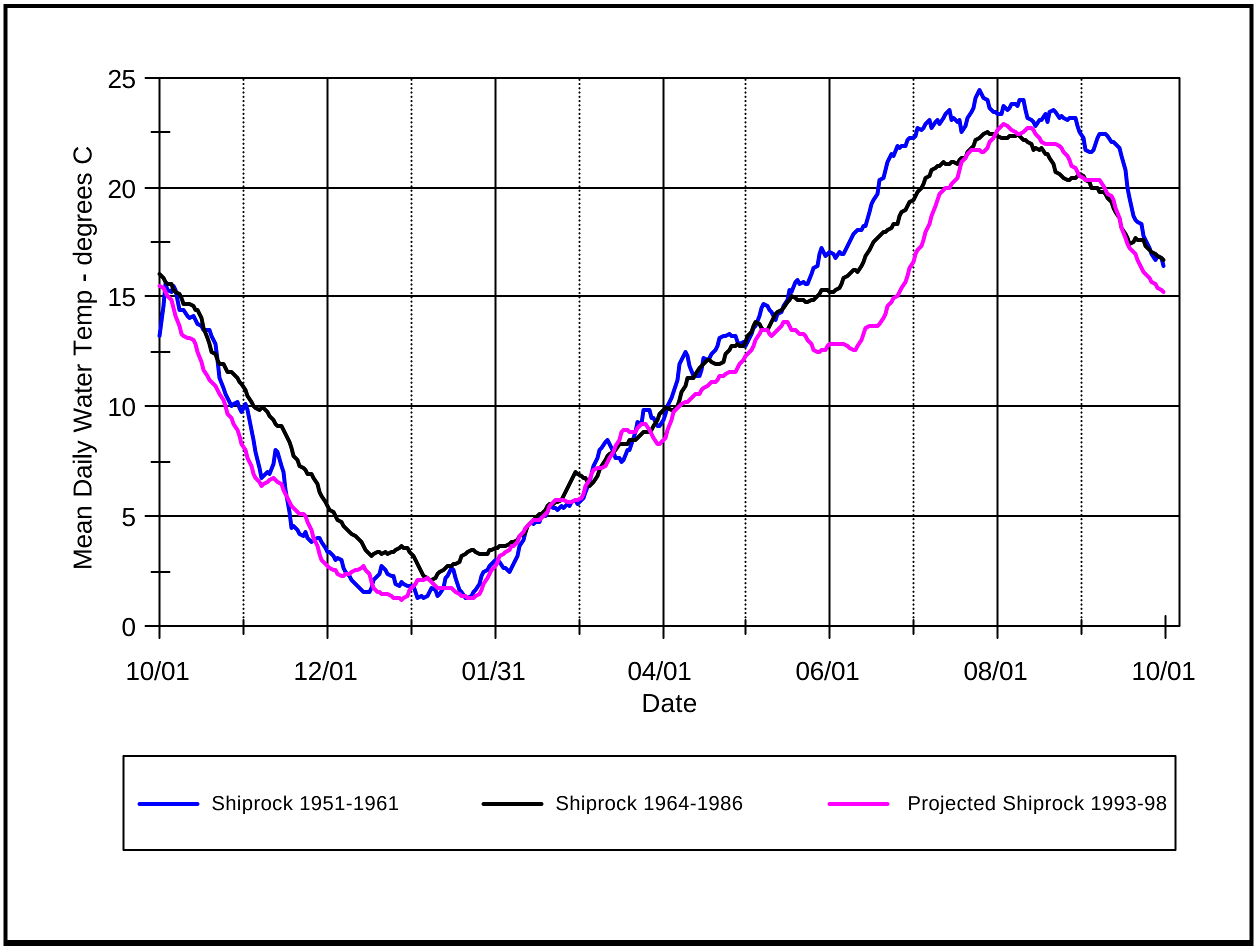



**Figure 3.18.** **Seven-day running mean daily water temperature for the San Juan River at Shiprock, New Mexico, during pre-dam, post-dam, and research flow periods (Source: Bliesner and Lamarra 2000).**

Colorado pikeminnow are known to spawn later in high-flow years when water temperatures are cooler (Trammell and Chart 1999, Trammell et al. 1999), and recent studies in the Yampa River found that spawning may be initiated at temperatures of only 16EC during some years (Bestgen et al. 1998). It is not known what effect later spawning may have on Colorado pikeminnow, although it would provide less time for YOY to grow during the autumn. Some authors suggested that smaller Colorado pikeminnow are less likely to survive the winter (Haines and Tyus 1990, Bestgen et al.1998), which may be a major factor in recruitment. Delaying Colorado pikeminnow spawning in the San Juan River also has the potential to place larvae in the river near the time of late summer thunderstorm flooding. Platania et al. (2000) calculated time of spawning for young Colorado pikeminnow collected from the San Juan River during the 7-year research period, and most spawning dates were in mid to late July on the descending limb of the hydrograph, the typical time for this species to spawn. This suggests that spawning of the existing wild population is not delayed because of cooler temperatures.

In summary, water temperature reduced the potential range for native fishes in the San Juan River and may be a limiting factor in the ability of Colorado pikeminnow to spawn at an appropriate time above RM 150. If a population of this species is established above RM 150, cool water from Navajo Dam may negatively impact recruitment as a result of late spawning times.

## Diversion Structures

In addition to the habitat lost by filling the two reservoirs, including the effect of reduced summer temperature, five diversion structures between RM 140.0 and RM 180.0 represent potential barriers to fish movement, especially upstream movement. The diversions include: the Cudei Diversion (RM 142.0); Hogback Diversion (RM 158.6); Arizona Public Service Company (Four Corners Power Plant) Weir (APS Weir) (RM 163.3); Public Service Company of New Mexico (San Juan Generating Station) Weir (PNM Weir) (RM 166.6); and the Fruitland Diversion (RM 178.5). Masslich and Holden (1996) provided a detailed description of each of these structures. Ryden (2000a) showed that Colorado pikeminnow used the portion of river between RM 115.0 to RM 138.0 extensively (the area below the lowest diversion), but he found no Colorado pikeminnow above RM 138.0. Miller and Ptacek (2000) noted that one adult radio-tagged Colorado pikeminnow moved up through the Cudei Diversion in 1994 and then back, the furthest upstream any wild Colorado pikeminnow was found. In 1988, Platania (1990) captured a Colorado pikeminnow about a mile above the Cudei Diversion, the most upstream collection since 1962 (pre-Navajo Dam).

Electrofishing catches from adult monitoring trips (Ryden 2000a) showed that common native species were found above and below the diversions, which is reasonable since they inhabited this area prior to construction of the dams. Ryden (2000a) reported that one subadult razorback sucker stocked just below the Hogback Diversion moved upstream over the diversion and that another stocked fish moved over the Cudei Diversion. Nonnative fish distribution was noticeably affected by the PNM Weir. Channel catfish, common carp, and red shiner were all fairly common below the PNM Weir, but not above. These data suggested the Cudei Diversion, Hogback Diversion, and the APS Weir were all passable by fish at some flows, but that the PNM Weir was a more-substantial barrier.

Because of the lack of endangered fishes in the river reach containing the five diversions, Ryden (2000a) floy-tagged 2,649 flannelmouth sucker and 1,303 bluehead sucker as surrogates, as well as 3,706 channel catfish and 2,778 common carp. A few of the latter two species were also radio-tagged. During adult monitoring trips, electrofishing was used to recapture the tagged fish and determine movement. Eighteen adult flannelmouth sucker were able to move upstream and downstream over all five structures, and eight adult bluehead sucker moved upstream over the APS Weir and Fruitland diversion but not over the PNM Weir. Thirty-five channel catfish and six carp also moved at least one way over a structure. These data suggest passage is possible over each of the weirs, but it is limited, and the diversions undoubtedly make it difficult for fish to traverse upstream in this portion of the river.

In addition to blocking upstream movement, the diversion dams also may reduce native fish recruitment by entraining larvae, hence reducing the suitability of the area above RM 142 for native fish. Colorado pikeminnow and razorback sucker larvae are known to drift downstream from spawning areas, as are the larvae of other native species. In 1996 and 1997, Trammell and Archer (2000) studied the potential entrainment of YOY Colorado pikeminnow stocked at the Cudei Diversion, approximately 3 miles below Shiprock, New Mexico. Young-of-the-year Colorado pikeminnow were found in the diversion canal both years, showing that even larger fish capable of swimming in the current were entrained in this canal. But the effect of this entrainment to the overall population is unclear; the stocking of YOY Colorado pikeminnow was considered to be successful since retention in the river was good (Trammell and Archer 2000). Populations of the other native species, especially flannelmouth sucker, bluehead sucker, and speckled dace, were high in the areas with the diversions, suggesting that entrainment of their young in the diversions does not effect overall population size. The potential limiting factor of entrainment will need to be studied in more detail after adult populations of the two endangered fish are established in and above the diversion reach.

## Management Implications

The potential limiting nature of water temperature was not fully studied. Additional research is needed to confirm that water temperature may be a limiting factor to Colorado pikeminnow and other species in the San Juan River above Shiprock, New Mexico. That study needs to examine historical and present water temperatures under similar flow conditions to determine to what degree water temperature is affected by cold releases from Navajo Dam. As seen during the 7-year research period, river temperature below the mouth of the Animas River reached 20EC every year by late July, and therefore may not limit spawning of Colorado pikeminnow, but rather delay it a week or two. This delay may affect the survival of young if spawning occurred above RM 150; therefore, it needs to be evaluated in more detail.

The diversion dams, especially the PNM and APS weirs, are much more likely limiting expansion of Colorado pikeminnow into the upper river near Farmington, New Mexico, than is water temperature. Stocking fish above the diversions may negate this factor initially, but as young are produced and drift downstream to nursery areas, they would have no unobstructed route back to the upper river. The Biology Committee, wanting to expand the range of Colorado pikeminnow and perhaps razorback sucker into the upper river, evaluated the five diversion dams and concluded that fish passage should be considered at each of the major dams. During 1999, the Biology Committee reviewed BIA plans to combine the Hogback and Cudei diversions at the Hogback site and to provide nonselective fish passage at the new Hogback Diversion. The Biology Committee also determined that a selective fish-passage structure should be added to the PNM Diversion so nonnative fishes can be removed from the river. Once complete, native and nonnative fish passage through these structures should be monitored to determine whether similar structures are needed at the other diversions.

# NONNATIVE FISH INTERACTIONS

## Introduction

Potential interactions among native and nonnative fishes include predation, competition, and hybridization. Interactions with nonnative fishes were implicated in the decline of razorback sucker and Colorado pikeminnow for many years (Holden and Stalnaker 1975, Minckley et al. 1991, Tyus 1991), and these interactions were identified as the primary cause for lack of recruitment of razorback sucker in the lower Colorado River (Minckley et al. 1991). Nonnative fish studies were part of the core studies conducted during the 7-year research period, and all aspects of potential interactions were studied (Brooks et al. 2000). Additional information was collected by several other studies, including nursery habitat studies (Archer and Crowl 2000a) and secondary channel studies (Propst and Hobbs 2000).

## Predation

Numerous authors hypothesized that predation by introduced nonnative fish species is one of the factors responsible for the decline of native fishes in the Colorado River Basin (Kaeding and Osmundson 1988, Marsh and Langhorst 1988, Minckley et al. 1991). Various nonnative species were documented as predators on native fishes, including channel catfish (Marsh and Brooks 1989), mosquitofish (*Gambusia affinis*) (Meffe 1985), and red shiner (Ruppert et al. 1993). Although nonnative fish species frequently dominate fish assemblages in many Colorado River Basin rivers and streams, including the San Juan River (Propst and Hobbes 2000, Brandenburg and Gido 1999), the degree of predation exhibited by a particular species can vary dramatically between different locales. Marsh and Brooks (1989) reported high predation by two species of catfish on hatchery-reared razorback sucker stocked in the Gila River, Arizona, with up to 55% of the channel catfish stomachs examined containing razorback sucker and up to 90% of flathead catfish (*Pylodictus olivaris*) stomachs containing razorback sucker. However, Tyus and Nikirk (1990) found fish remains in only 7% of the channel catfish stomachs examined from the Green and Yampa rivers, Colorado and Utah. A number of factors can impact predator/prey interactions, including the relative density of predators and prey (Wooten 1990), the availability of alternative food items, and feeding habits of the predator. Sampling time can also affect prey determinations, since digestion can be rapid for many predators. Hence, if predators feed primarily at night, and sampling occurs late in the day, predator stomachs may be nearly empty even though they fed the night before.

Native fishes (primarily flannelmouth sucker) comprised 75.4% of all fishes collected during adult monitoring efforts in primary channels from 1991 to 1997. However, nonnative fishes dominated the species assemblage: 19 of the 26 species collected were nonnative (Ryden 2000a). The most-abundant nonnative fish known to exhibit piscivory, the channel catfish, comprised 13.1% of all fish collected. Channel catfish are abundant throughout the river below RM 166.6, where the PNM Weir appears to inhibit upstream movement (Ryden 2000a). Common carp eat eggs of other fishes, and they made up 9.2% of total collections. Red shiner comprised 1.7% of total fishes collected, but because of their small body size, they are not as susceptible to electrofishing and were probably under represented in the primary channel collections (Ryden 2000a). Red shiner were often the most-abundant fish in secondary channels in late summer and fall (Propst and Hobbes 2000), and red shiner were either the first or second most-abundant species in main channel nursery areas in late summer and fall (Archer and Crowl 2000a). These data suggest that, numerically, red shiner are likely one of the most-abundant fishes in the San Juan River. Other predatory fish species of concern were walleye (*Stizostedion vitreum*) and striped bass (*Morone saxatilis*), which were collected from 1995 to 1997 after they gained access to the San Juan River when a waterfall barrier was inundated by Lake Powell during 1995. Numerically, these two lacustrine predators were not collected in large numbers and comprised less than 0.1% of total fishes collected. Overall, the San Juan River has a high density of potential predators on eggs, larvae, juveniles, and adult native fishes.

Diets of potentially piscivorus nonnative fishes collected during main channel adult monitoring efforts during 1991 to 1993 were examined by Brooks et al. (2000), as were diets of fishes collected from 1994 to 1996 in low-velocity habitats. Empty stomachs were excluded from the diet analysis. Because of their high abundance in the river, channel catfish were a primary target of the analysis. Piscivory by channel catfish in the San Juan River was infrequent, with only 7% of the stomachs containing fish (Brooks et al. 2000). Fish consumed by channel catfish were primarily flannelmouth sucker, although speckled dace, bluehead sucker, and red shiner were also consumed. Channel catfish diets primarily included a variety of aquatic insects and Russian olive fruit, as well as other vegetation, and piscivory increased with size of the catfish.

Eleven striped bass stomachs were examined, and five contained fish (the other six were empty). Of 38 walleye stomachs examined, 17 contained fish and 21 were empty. Black bullhead (*Amerius melas*), green sunfish (*Lepomis cyanellus*), bluegill *(Lepomis macrochirus*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), and brown trout (*Salmo trutta*) stomachs were also examined for food. Of the 24 stomachs examined 13 contained fishes, and identifiable remains included flannelmouth sucker, speckled dace, red shiner, fathead minnow, and mosquitofish (Brooks et al. 2000). Although not broken out by species, it was reported that all species except bluegill had fish in their stomachs. None of the nonnative fish species collected from low-velocity habitats from 1994 to 1996 exhibited piscivory.

Predation by large-bodied nonnative fishes on native fish species in the San Juan River was documented by the SJRIP studies, but the extent of predation appeared to be low. Channel catfish exhibited piscivory in only 1 year (1993) of six sampled, and at total levels similar to the 7% reported in the Green and Yampa rivers (Tyus and Nikirk 1990). Other nonnative fishes demonstrated piscivory, but none of those species made up more than 0.1% of fish collected in standardized electrofishing sampling from 1991 to 1997.

Predation on larval native fish by the numerous small bodied nonnative cyprinids, such as red shiner, in the Upper Basin was recently highlighted as, perhaps, a greater concern than predation by larger piscivores (Ruppert et al. 1993, Bestgen et al. 1998). Brandenburg and Gido (1999) investigated larval predation by a number of potential predators from San Juan River backwaters in early summer when many native fish larvae were present. Only eight of 529 predators contained larvae, and less than 1% of 414 red shiner contained larvae. This study showed that nonnative fish, including red shiner, eat larval native fish, but suggested the incidence of predation was not large.

Another form of predation impact noted in the Colorado River Basin was channel catfish becoming lodged in the throats of Colorado pikeminnow. Sometimes, when Colorado pikeminnow eat channel catfish, the pectoral fin spines of the channel catfish catch in the throat of the Colorado pikeminnow, causing the Colorado pikeminnow to eventually die. Upper Basin residents' observations were reported by Vanicek and Kramer (1969), and some anglers thought this was a major reason for Colorado pikeminnow decline. McAda (1983) reported an adult Colorado pikeminnow with a channel catfish lodged in its throat from the Green River. Pimental et al. (1985) conducted Colorado pikeminnow feeding experiments using despined and normal channel catfish, and rainbow trout, as prey. Channel catfish was not preferred by Colorado pikeminnow, compared with trout, and was only eaten after the Colorado pikeminnow starved for 5 days. Starved Colorado pikeminnow ate some of the despined catfish, and even fewer of the normal catfish, but they attempted to spit out any normal catfish they ingested. Pimental et al. (1985) also reported on three other collections of channel catfish lodged in the throats of wild Colorado pikeminnow from the early 1980s. In October 1999, during SJRIP adult monitoring sampling, a large juvenile Colorado pikeminnow (330 mm TL, likely one of the stocked fish from 1996) was captured with a juvenile channel catfish lodged in its throat. Although reports of channel catfish lodged in the throats of Colorado pikeminnow are rare, and this phenomenon is likely not a major limiting factor, channel catfish may also have a negative effect on adult Colorado pikeminnow.

Because channel catfish are abundant in the San Juan River, they likely are responsible for the major predation occurring there. Common native fishes were the primary species eaten, which is reasonable since they were the most abundant fishes in the river. None of the common species populations appeared to be limited in the river, suggesting that predation was not a major limiting factor to native fishes. Roundtail chub numbers in the San Juan River may be low because of predation, but this has not been confirmed. Predation on larval razorback sucker and Colorado pikeminnow was not adequately assessed during the 7-year research period because of the low numbers of the endangered species available. Red shiner exhibited predation on larval Colorado pikeminnow and razorback sucker in the laboratory (Ruppert et al. 1993), and predation in the wild was suggested as a major factor in determining year-class strength of Colorado pikeminnow in the Green River (Bestgen et al. 1998). Because red shiner are very abundant in the San Juan River (Propst and Hobbes 2000), they may be the most important predator on the two endangered fishes (Brandenburg and Gido 1999). Predation by nonnative fishes on larval endangered fishes may be a concern in the future as populations and reproduction of these two species increase.

## Competition

For competition to occur, one or more of the individuals or populations involved in the interaction needs to have reduced fitness while one of them has a net gain (Wooten 1990). This typically happens in limited-resource situations. Douglas et al. (1994) suggested a "displacement hypothesis," where nonnative species displace native species without an actual shortage of habitat. They studied red shiner (nonnative) and spikedace (*Meda fulgida*) interactions and noted that when the two species coexisted, spikedace used swifter habitats, suggesting red shiner displaced spikedace to lower-quality habitat. Competition can be difficult to demonstrate, and although widely cited as a major factor in declining native fish populations in the Colorado River Basin, it was established in very few cases (Douglas et al. 1994). Determining whether competition is a limiting factor among a myriad of other adverse impacts to native fish populations (Gido and Propst 1999) can be even more difficult. Unrelated species, such as the endemic fish fauna of the San Juan River and nonnatives introduced largely from the Mississippi River and other eastern river systems, will often compete if resources and habitats are limited. A number of factors and complicated interactions can affect competitive interactions, including temporal shifts in resource use and ontogenetic size-related changes in preferred habitats and diet (Wooten 1990, Gido and Propst 1999).

Nonnative fishes numerically dominate low-velocity habitats in the San Juan River (Archer and Crowl 2000a, Propst and Hobbes 2000). Yet whether nonnative fishes force native fish species into less-suitable habitat where resources are limited, or whether they out-compete the native species for food sources in short supply, thereby reducing their ability to grow, reproduce, and recruit into the population, still needs to be determined. Studies completed on the San Juan River provided some preliminary answers.

There was considerable overlap observed in habitat use among native and nonnative fish species in the San Juan River (Gido and Propst 1999). Speckled dace did not appear to suffer from competitive interactions with nonnative fishes because they occupied riffle habitats as juveniles and adults. No nonnative fishes currently inhabiting the San Juan River preferred riffle habitat, although red shiner and juvenile channel catfish may have used riffles at certain times (K. Lawrence, Ecosystems Research, Personal Communication). Gido and Propst (1999) reported a temporal separation between native and nonnative larval fishes (excluding common carp) because of the earlier spawning of native species. This may reduce the potential for competitive interactions among larval fishes. Although bluehead sucker and flannelmouth sucker decline was observed since 1991 below Reach 6, juveniles are still common and condition factors of both species increased over the same time period. Stocked Colorado pikeminnow and razorback sucker reintroduced into the San Juan River in 1996 to 1997 and 1994 to 1997, respectively, had relatively high survival rates and appeared to find adequate habitat. Therefore, there is little evidence to suggest that competition from nonnative species negatively affected native species in the numbers present during the 7-year research period.

Brooks et al. (2000) investigated food limitations by looking at dietary overlap and food availability for small native fishes and nonnative fishes. They found that most small fish consume benthic invertebrates, especially dipterans and ephemeropterans, and that channel catfish and red shiner have the greatest dietary diversity. The food-availability studies showed that invertebrates in the San Juan River were generally more abundant in spring samples than in autumn samples (Figure 3.19) and that density of invertebrates was lower than in other upper Colorado River Basin streams, but that there was considerable variation in the data. Dipterans and ephemeropterans were generally the most-abundant forms of benthic invertebrates in both main and secondary channels.

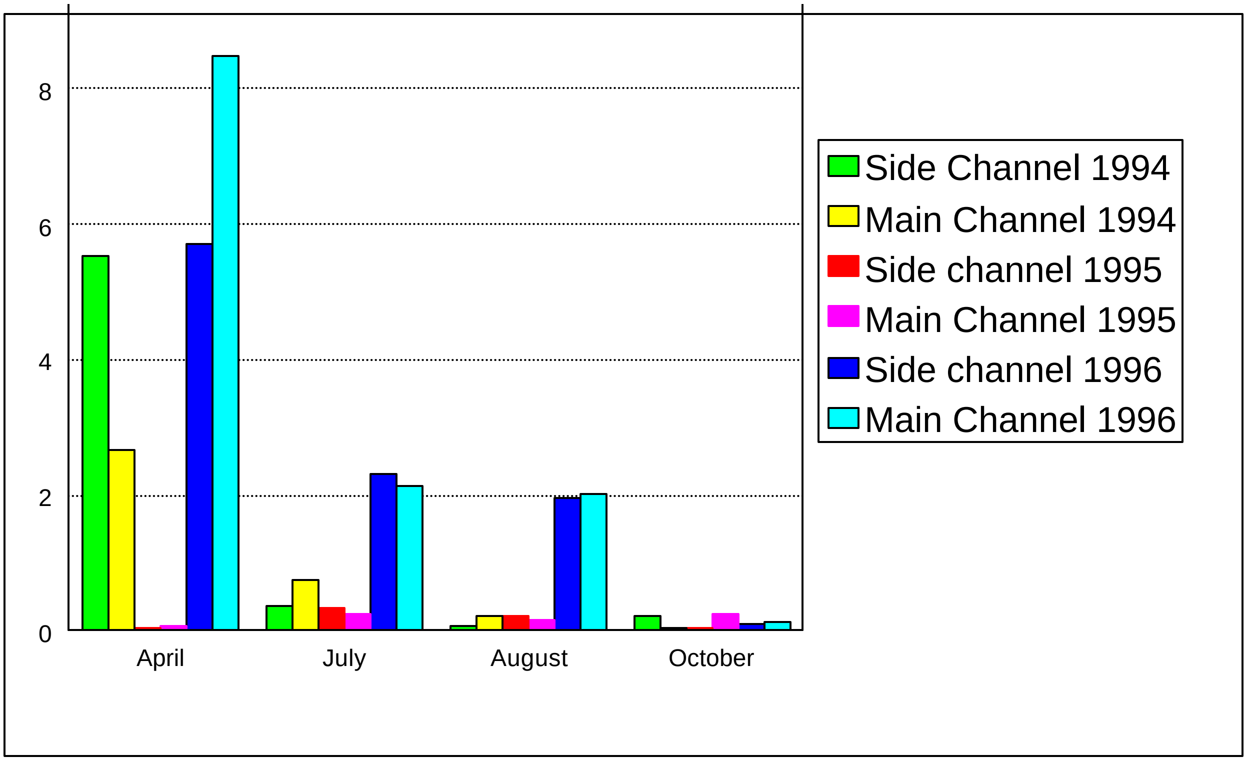



**Figure 3.19. Macroinvertebrate density in main and side channel habitats for sampling during 1994 through 1996 (Source: Brooks et al. 2000).**

The studies in the San Juan River found that invertebrate densities are variable. Brooks et al. (2000) concluded that sediments from late summer and fall thunderstorm activity in the San Juan River likely caused the drop in invertebrate numbers during that time period. They also noted that this reduction in density may limit food for young fish during that time period. Archer (2000) compared food availability and growth of stocked YOY Colorado pikeminnow from two reaches of the San Juan River, a portion of Reach 1 (RM 8.0 to RM 13.0) and a portion of Reach 4 near RM 120.0. Food availability (benthic invertebrates) was lower in Reach 1 than in Reach 4, but growth, condition factor, and lipid content of Colorado pikeminnow were not different between the two reaches. This lack of difference between the two study areas suggests that food was not limiting in Reach 1. Both study areas have extensive populations of red shiner, fathead minnow, and other nonnative fishes, suggesting that competition for food, even in a reach (Reach 1) with relatively low benthic invertebrate densities and during the fall when densities are at their lowest, is not occurring in the San Juan River.

Trammell and Archer (2000) showed that growth of Colorado pikeminnow stocked in the San Juan River in 1996, 1997, and 1998 was excellent (Figure 3.20) and similar to growth of wild Colorado pikeminnow in the Colorado River. Once Colorado pikeminnow switch to piscivory, their diets only have high overlap with other obligate piscivores, which occur in lower numbers than the abundant, omnivorous red shiner and fathead minnow. This suggests that food for YOY

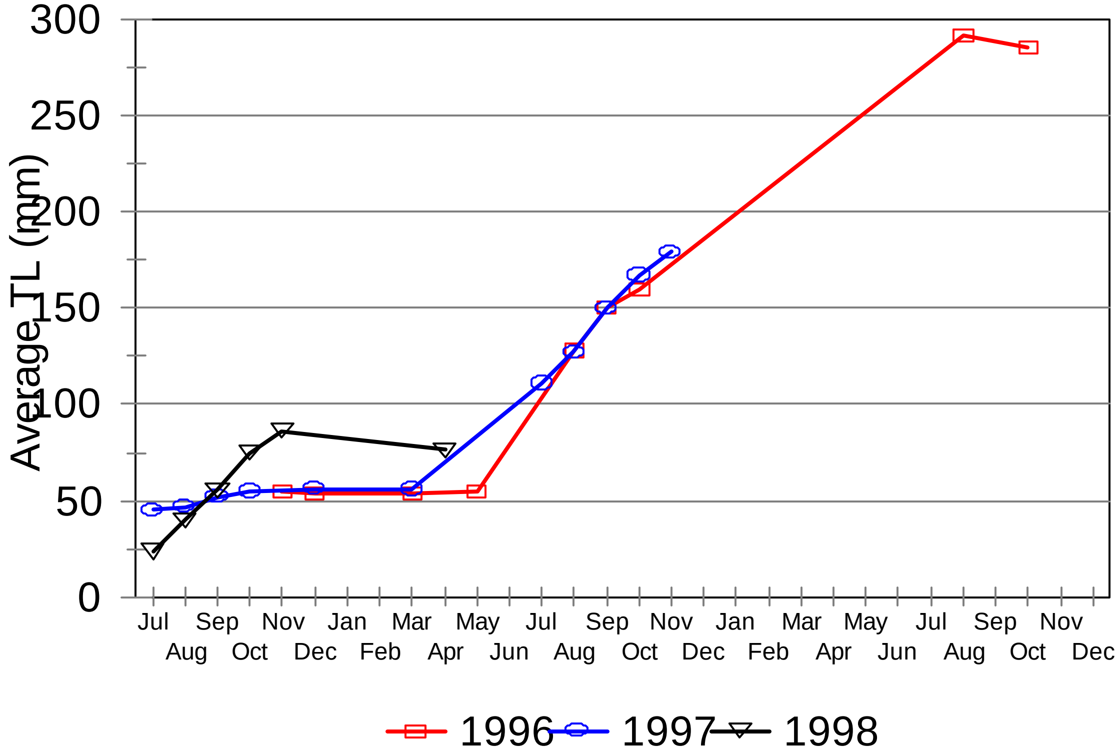



**Figure 3.20. Growth of Colorado pikeminnow stocked in the San Juan River, 1996 to 1998 (Source: Trammell and Archer 2000).**

Colorado pikeminnow is not limiting in the San Juan River and that competition with nonnative species for scarce food resources is not a major limiting factor. In addition, overall condition of native fishes during the 7-year research period improved (Ryden 2000a), with little evidence showing lack of, or competition for, food.

Although there is considerable overlap in resource and habitat use between nonnative and native fish species in the San Juan River, it does not appear that competition with nonnative fish species for food or habitat is a limiting factor for native fishes at current levels. However, the potential exists for competition to occur, especially as populations of rare and endangered species increase.

## Hybridization

Nonnative white sucker (*Catostomus commersoni*) inhabit the San Juan River study area in very low numbers, but they are common to abundant in the Animas and Florida rivers, and in the San Juan River above Navajo Dam (Miller and Rees 2000). During main channel monitoring between 1991 and 1997, 10 white sucker were collected, and they comprised < 0.1% of all fish collected (Ryden 2000a). Eleven white sucker × flannelmouth sucker hybrids and seven white sucker × bluehead sucker hybrids were collected between 1994 and 1997, out of a total of about 175,000 sucker specimens collected (Ryden 2000a). With such a low level of hybridization, it is likely not a limiting factor for bluehead sucker and flannelmouth sucker, at present. White sucker ×

razorback sucker hybrids have never been reported, but they may be possible because of the hybridization between the closely related flannelmouth sucker. Occurrences of razorback sucker × flannelmouth sucker hybrids are fairly well documented (Hubbs 1955, Holden and Stalnaker 1975) but not common. If white sucker become more common in the San Juan River, hybridization with razorback sucker, as well as flannelmouth sucker and bluehead sucker, may become a greater concern (Dowling and Minckley 1993).

Hybridization between razorback sucker and flannelmouth sucker likely occurs since flannelmouth sucker often use the same spawning bar as razorback sucker. Flannelmouth sucker also spawn on many different bars, whereas razorback sucker show fidelity to a few spawning areas. Razorback sucker begin spawning slightly earlier than flannelmouth sucker, but their spawning times overlap. With no wild razorback sucker population to attach to, or wild spawning site to use, stocked razorback sucker have the potential to spread out spawning rather than concentrating it in one or two areas. This could result in increased use of bars also used by flannelmouth sucker and increased chance of hybridization.

## Management Implications

Because of the concern for nonnative fish interactions, one of the original goals of the SJRIP was to reduce numbers of nonnative fishes. One reason for the reoperation of Navajo Dam in 1992 was the hypothesis that high flows, or a more-natural flow regime, may reduce numbers of red shiner, channel catfish, and other nonnative species. This hypothesis was proposed by Minckley and Meffe (1987) and Meffe and Minckley (1987) after reviewing fish populations in portions of Arizona where native species numerically dominated streams with natural flow patterns and magnitude, and nonnative species dominated regulated streams. These authors hypothesized that nonnative species are not well adapted to the flooding characteristic of Southwestern streams, where native species evolved. Several studies documented declines in nonnative minnows (red shiner, sand shiner, and fathead minnow) during high-flow years in the Upper Basin (McAda and Kaeding 1989, Osmundson and Kaeding 1989, Valdez 1990, Muth and Nesler 1993, Lentsch et al. 1996, McAda and Ryel 1999). McAda and Ryel (1999) also documented an increase in native fish YOY during higher spring flow years in the Colorado River, although this relationship was not always significant. These various studies on the Green and Colorado rivers support the hypothesis that higher spring flows, or mimicry of the natural hydrograph, improves conditions for native species and reduces conditions for nonnative species, at least within a year or two of the event.

Numbers of channel catfish and common carp in San Juan River primary channels increased since the reoperation of Navajo Dam, whereas other nonnative species either remained relatively stable or the trends are not clear (Brooks et al. 2000, Ryden 2000a). Propst and Hobbes (2000) saw similar trends in secondary channels, except in 1997 when numbers of all species were reduced in the autumn. During autumn, red shiner density in secondary channels was more related to summer flows than spring runoff flows (Propst et al. 1999). High summer flows, typically resulting from thunderstorms rather than dam releases, were associated with reduced numbers of red shiner in autumn. Archer and Crowl (2000a) studied San Juan River backwater nursery habitats in August and September. Young of native species were more abundant during high and late spring runoff years, and nonnative abundance was lower. But Archer and Crowl (2000a) noted that part of this difference resulted from later spawning and habitat shifts. Many native species shift from using backwater nursery habitats to habitats with more current in late summer or early fall, and those habitats were not sampled. Hence, the change in abundance may reflect this habitat shift. Lower numbers of nonnative species during higher runoff years may also result from later spawning by these species, rather than an actual lowering of the population.

This information suggests that higher flows resulting from the reoperation of the Navajo Dam were not detrimental to channel catfish and common carp, but it is not clear how they affected nonnative cyprinids. The decline in nonnative species in the Green and Colorado rivers primarily involved nonnative cyprinids. Lack of seining in all habitats in the San Juan River primary channel during the 7-year research period precludes a complete analysis of nonnative cyprinid response riverwide. Hence, it is not clear if the declines in nonnative cyprinids seen in other rivers during higher spring runoff years also occurred in the San Juan River. There may be several reasons for this lack of expected response from nonnative species. Flows from Navajo Dam are limited to a maximum release of 5,000 cfs, so flows in the river below the mouth of the Animas River peaked at about 12,000 cfs during the 7-year research period. Spring runoff during this period would have been higher without the dam. Some historic floods may have been more than 100,000 cfs (Bliesner and Lamarra 2000). Therefore, perhaps the magnitude of the flooding was not high enough to reduce numbers of nonnative species. Another potential reason for the stable or increasing populations of nonnative fishes is that the natural flow hypothesis may not fit all portions of the Colorado River system. Holden and Abate (1998) showed that red shiner numbers were not reduced in a portion of the Virgin River after large flood events.

Whatever the reason, flow reoperation on the San Juan River did not consistently reduce nonnative species numbers, but as noted above, it improved habitat for native species. Holden (1979) suggested that natural flow pattern and magnitude provided improved habitat and that native fishes appeared to be less affected by potential interactions with nonnative species in these situations. This appeared to be the case in the Green River, where nonnative fishes were abundant, but populations of Colorado pikeminnow were doing well (Bestgen et al. 1998, Trammell et al. 1999). It is suspected that habitat for all life stages of Colorado pikeminnow is relatively optimal in the Green River and that this results in less impact from the nonnative fishes than it does in other rivers where the habitat is not as optimal. Recent studies of razorback sucker in the Green River suggest that as flooded bottomland habitat for larval and YOY razorback sucker is restored, this species may also improve, even though nonnative fish numbers remain high (Modde 1996). If this hypothesis is correct, then improved habitat resulting from flow manipulation in the San Juan River will reduce the effect of nonnative fish interactions on native species, especially the two endangered species, without necessarily reducing nonnative fish numbers.

Recognizing the potential predation effect channel catfish may have on native fishes, the SJRIP initiated removal of channel catfish, and other nonnative species, from the San Juan River in 1995. Brooks et al. (2000) initiated studies in 1995 evaluating methods for mechanical removal of channel catfish. They used three primary methods: electrofishing, hoop netting, and trot lining. Hoop netting and trot lining were ineffective and they were dropped from the study in late 1995. Nonnative fishes collected during regular adult and juvenile monitoring studies were discarded on the river bank starting in late 1995 (Brooks et al. 2000). These efforts resulted in the removal of 12,660 channel catfish and 10,016 common carp from 1995 to 1997. However, catch rates for these species did not decline. In fact, they may have increased slightly by 1997 (Brooks et al. 2000, Ryden 2000a). Brooks et al. (2000) and Propst and Hobbes (2000) noted that the channel catfish size structure appeared to change by 1997, when fewer large fish and more smaller fish were caught. This may be a result of electrofishing removal, which is more effective on larger fish.

The data from the 7-year research period suggest that efforts to date were effective in reducing density of large channel catfish, which food habits studies showed were the most piscivorous, but efforts were not effective in reducing overall abundance of channel catfish in the river. Although the high numbers of this species suggest a concern for predation on native fishes, extensive predation was not verified. It is undoubtedly safe to assume that high numbers of channel catfish will result in predation on native fishes, and efforts to reduce their numbers should be continued if they are effective. In 1997, the SJRIP initiated a program of transporting channel catfish caught in the San Juan River to off-river impoundments on the Navajo Reservation where they were accessible to anglers (Brooks et al. 2000). Nonnative species removal will be continued as part of the long-term monitoring plan.

Propst and Hobbes (2000) noted reduced red shiner numbers in secondary channels during years when a summer flood event occurred. In 1998, the SJRIP initiated a 3-year study to investigate the timing and size of a summer flow spike that would reduce red shiner numbers. That study is not complete.

# FISH HEALTH

## Introduction

During 1991, biologists conducting adult monitoring studies on the San Juan River noticed high numbers of abnormalities in the flannelmouth sucker and bluehead sucker collected. Abnormalities included open sores, parasites, and body deformities. Biologists were most concerned with the relatively high number of open sores or lesions on the sides of some of the fishes, especially flannelmouth sucker. This prompted a concern for fish health, and fish health experts joined sampling trips in 1992 (Landye et al. 2000). As fish were weighed and measured during adult monitoring trips, they also were checked for abnormalities (Ryden 2000a). These data (Table 3.7) showed that abnormalities were typically found on less than 2% of the native bluehead sucker and

**Table 3.7.** **Six-year review (10/91 to 10/97) of fishery biologists' San Juan River *C. latipinnis* and *C. discobolus* abnormality data (Source: Landye et al. 2000).**

| DATE | NUMBER OF FISH SAMPLED | PERCENT OF FISH WITH ABNORMALITIES | PERCENT OF ABNORMALITIES THAT ARE LESIONS |
|---|---|---|---|
| 10/91 | 1,606 | 2.6 | 54 |
| 6/92 | 3,018 | 3.6 | 65 |
| 10/92 | 3,413 | 0.3 | 30 |
| 10/93 | 2,959 | 0.4 | 55 |
| 5/94 | 1,878 | 3.0 | 74 |
| 10/94 | 9,524 | 0.6 | 30 |
| 5/95 | 1,266 | 0.1 | 25 |
| 10/95 | 2,261 | 0.8 | 25 |
| 5/96 | 2,557 | 3.4 | 72 |
| 10/96 | 2,888 | 1.6 | 33 |
| 5/97 | 5,270 | 0.4 | 19 |
| 10/97 | 7,440 | 0.3 | 32 |

flannelmouth sucker collected and that spikes in the number of abnormalities occurred in October 1991, June 1992, May 1994, and May 1996. During these times, the incidence of lesions also increased (Table 3.7). A regression of percent abnormalities against year using the data from Table 3.7 showed that there was no significant relationship for spring ($p<0.314$) or fall ($p<0.442$) samples, suggesting that abnormalities neither increased nor decreased during the 7-year research period. The abnormalities tended to be highest in the river reach from RM 121.0 to RM 156.0, the area from about Four Corners to Hogback Diversion.

Flannelmouth sucker and channel catfish had the most abnormalities (Landye et al. 2000). No Colorado pikeminnow or razorback sucker with major abnormalities were found, although some Colorado pikeminnow had a few external parasites. Landye et al. (2000) concluded that for the San Juan River "abnormality incidence in all fish species is low with the exception of 'spikes' of lesions and other disease signs during the spring hydrograph."

The fish health data, which were difficult to compare with other rivers because the intensity of study on the San Juan River was much greater than the intensity of most other fishery studies, did not indicate that Colorado pikeminnow or razorback sucker were limited by health issues. Even flannelmouth sucker, the most affected species, typically had 5% or less of the population showing abnormalities. Landye et al. (2000), along with experts from the National Fish Health Laboratory, hypothesized that the lesions seen on flannelmouth sucker may have been caused by interactions with contaminants. It was possible that low-flow periods added to the intensity of contaminant interaction, causing outbreaks as observed in May 1996. In hypothesizing reasons for a general decline in flannelmouth sucker populations from 1991 to 1997, Ryden (2000a) suggested that this species was in poor condition and poor health at the start of the study. This condition resulted from low-flow drought periods during the late 1980s and early 1990s, and high population levels of flannelmouth sucker. As research flows and higher natural streamflow occurred in the mid-1990s, the poorer-condition fish were unable to survive, thus leaving a smaller but healthier population. This hypothesis suggests that flannelmouth sucker population levels may be limited to some degree by health, and that when populations become too large during low-flow periods, health issues caused by contaminants may be one factor that limits the population.

## Management Implications

The data collected in the San Juan River suggest that no special management is required for fish health because it is not a limiting factor for the endangered fish species or for other native fishes, except perhaps flannelmouth sucker. Incidence of abnormalities will continue to be recorded during monitoring, and if abnormalities increase, adaptive management will allow for appropriate studies to be conducted.

# CONTAMINANTS

## Introduction

The effects of contaminants were considered a potential limiting factor to the endangered and other native fishes in the Colorado River Basin (Holden and Stalnaker 1975, Seethaler et al. 1979). Human-caused contamination from oil and gas development along the Green and San Juan rivers; uranium mining and milling along the Green, Colorado, and Dolores rivers; and intensive irrigation along sections of almost all Upper Basin rivers were of concern. Recently, the effects of naturally occurring selenium raised concern because both natural and human-caused factors may concentrate this potential contaminant. These concerns were evident as the 7-year research period and SJRIP were initiated, and several studies were proposed to investigate this issue.

Abell (1994) summarized the existing water quality information for the San Juan River and found that existing information was not sufficient to determine potential effects on fish species. Wilson et al. (1995) conducted a synoptic survey of inorganic contaminants of plants, invertebrates, and fishes throughout the San Juan River. Additional studies on contaminants were conducted through 1996. Most of these studies were summarized by Simpson and Lusk (1999), who showed elevated concentrations of aluminum, arsenic, copper, selenium, and zinc in various portions of the basin in different types of biota, but no clear link to effects on native or endangered fishes was made.

The studies that showed potential significant contaminant levels in portions of the San Juan River Basin prompted additional studies relating contaminant levels to problems for native and endangered fishes. Of particular concern were effects on reproduction, the primary area where contaminants were shown to affect fish populations. Three studies evaluating contaminant level effects on fishes were funded by the SJRIP, and they were conducted by the U.S. Geological Survey. Hamilton and Buhl (1997a) studied the effect of several individual inorganics (arsenate, copper, selenate, selenite, zinc) and inorganic mixtures similar to those found in some irrigation drain locations in the San Juan Basin on larval razorback sucker and Colorado pikeminnow. They concluded that copper and mixtures of inorganics could adversely affect larvae of both species in specific sites where these contaminants were found in high levels, but in other sites, waterborne levels were not high enough to cause adverse effects. Drainages from irrigation fields in the Shiprock, New Mexico, area and streams such as the Mancos River and McElmo Creek, which were primarily irrigation return flow in late summer, were the major areas of concern.

The second study involved the effects of individual inorganics and five mixtures of inorganics on flannelmouth sucker larvae (Hamilton and Buhl 1997b). Copper was again found to be the major toxic component—singly and in four of the mixtures tested—and zinc was the major toxic component in the other tested mixture. Hamilton and Buhl (1997b) hypothesized that these elements and mixtures may be adversely affecting flannelmouth sucker recruitment in some localized portions of the river, but that the overall health and size of the flannelmouth sucker population in the river masked these detrimental effects. They also noted that elevated levels of selenium in flannelmouth sucker and in the San Juan River may be a causative agent for abnormalities noted in the Fish Health section of this report.

The third study investigated the effects of both elevated levels of waterborne selenium and selenium in the diet of adult Colorado pikeminnow on reproductive success (Buhl and Hamilton 2000). Different levels of waterborne and dietary selenium were used as different treatments in the experiment. The fish were spawned, and the survival of eggs and larvae was determined. Buhl and Hamilton (2000) found that elevated levels of waterborne and dietary selenium did not affect adult fish growth or survival. Not all females in the experiment spawned, so not all of the treatments in the study had replicate spawns. Selenium levels in eggs and newly hatched larvae were two-to-five times greater than those seen in the female parents. Table 3.8 shows the survival and growth of the larvae produced in the experiment. Larvae in the high-selenium treatments (both waterborne and dietary) had survival rates and growth similar to those larvae in control treatments. Although lack of replications did not allow Buhl and Hamilton (2000) to draw conclusions from their data, the results suggested that selenium, at the levels tested, had little effect on reproductive success of Colorado pikeminnow. This indicates that selenium was not a major limiting factor for this species in the San Juan River.

In 1993, the USFWS concluded in a Biological Opinion to the BLM that oil and gas leasing and development activities were reducing survival of the endangered fish species in the San Juan River. This resulted in the BLM joining the SJRIP and conducting a study evaluating the potential impact of oil and gas activity in the San Juan Basin. The study had several phases, including developing a baseline for polynuclear aromatic hydrocarbon (PAH) contamination in the basin, determining sites with the highest potential contamination risk, sampling for PAHs in the river, and conducting studies of PAH toxicity to native fishes. Samples in streams, dry arroyos, and well locations showed some PAH contamination, but contamination tended to be spotty and generally low level (Odell 1997). The BLM concluded that oil and gas activities were not contributing significant levels of PAHs to the San Juan River.

**Table 3.8 Survival and growth of Colorado pikeminnow larvae produced by adults exposed to selenium in the diet and water for 154 days prior to spawning (Source: Buhl and Hamilton 2000).**

| ADULT SELENIUM EXPOSURE[a] | | | PROGENY | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Survival (%) | | | Growth[b] | | | |
| Diet (Fg/g) | Water (Fg/L) | Female ID | Swimup (Day 5) | Day 10 | Day 30 | Total Length (mm) | Weight (mg) | K[c] | *N* |
| 2.18 | 0.15 | 1A-2 | 100 | 83.3 | 80.0 | 20.1 (1.1) | 55.3 (7.1) | 0.68 (0.06) | 44 |
| 2.18 | 5.74 | 2A-10 | 98.3 | 98.3 | 95.0 | 19.6 (1.1) | 53.3 (6.9) | 0.71 (0.08) | 51 |
| 7.28 | 1.21 | 3A-20 | 100 | 96.7 | 93.3 | 19.7 (1.4) | 50.6 (9.1) | 0.65 (0.06) | 53 |
| 7.28 | 1.02 | 3B-22 | 95.0 | 93.3 | 91.7 | 19.6 (1.3) | 53.2 (7.6) | 0.70 (0.07) | 52 |
| 7.28 | 1.62 | 3C-26 | 88.3 | 85.0 | 85.0 | 19.4 (1.0) | 51.1 (7.8) | 0.69 (0.06) | 47 |
| 7.28 | 5.95 | 4A-29 | 98.3 | 93.3 | 90.0 | 20.0 (0.8) | 54.3 (7.2) | 0.68 (0.05) | 52 |
| 7.28 | 5.82 | 4B-31 | 97.5 | 97.5 | 97.5 | 20.2 (0.9) | 56.1 (7.0) | 0.68 (0.05) | 37 |
| 11.83 | 2.38 | 5A-38 | 100 | 78.3 | 78.3 | 19.9 (0.9) | 52.1 (6.7) | 0.66 (0.05) | 45 |
| 11.83 | 1.63 | 5B-41 | 98.8 | 78.3 | 73.3 | 20.3 (1.1) | 58.8 (9.3) | 0.70 (0.06) | 39 |
| 11.83 | 8.12 | 6B-50 | 95.0 | 86.7 | 85.0 | 19.8 (1.1) | 52.6 (8.0) | 0.68 (0.06) | 42 |

[a] Mean measured concentrations in exposure tank with diet concentrations based on dry weight.
[b] Mean and SD in parentheses.
[c] Condition factor.

In summary, investigations by the SJRIP showed that some contaminant issues occurred in the San Juan River Basin, but they tended to be limited to irrigation drainage areas. It is also possible that contaminants were more prevalent during low-flow periods. It is doubtful that any of the populations of native fishes studied during the 7-year research period were limited by contaminants. However, this does not mean that contaminants were not a major limiting factor at some time in the past, when safeguards were not as prevalent as they are today.

## Management Considerations

Contaminants were not shown to be a major concern in the San Juan River at this time. It is possible that, historically, contaminants from oil and gas activities in particular, and perhaps other basin activities, led to the decline in razorback sucker and Colorado pikeminnow populations, although there is no evidence to either substantiate or refute such a claim. The extensive information collected during the 7-year research period suggested that contaminants would not limit recovery of the two endangered fish species.

# POPULATION SIZE

## Introduction

When the SJRIP was initiated, it was known that population levels of the two endangered fish species were low, but it was thought that improved reproductive success resulting from altered Navajo Dam flows would result in increased populations. It was also thought that the most likely "biological response" to the flow changes would be increased numbers of YOY, especially Colorado pikeminnow YOY; hence an emphasis was placed on seining backwater habitats in the fall. Because of this anticipated response, the need to stock either species was not realized until 1997 or later, and thus stocking was not included in the *LRP* (USFWS 1995) until the end of the 7-year research period. By 1994, no wild razorback sucker had been collected (Ryden 2000a, 2000b), suggesting that this species did not have a population remaining in the San Juan River, and that improved recruitment would not occur with the reoperation of Navajo Dam only.

Numbers of YOY Colorado pikeminnow did not increase during the 7-year research period (Table 3.9), and this escalated concerns that habitat for young fish was not available, predation on young was too high, or the population was too small to respond to changes in habitat. As discussed above, when YOY were stocked in the river to determine habitat availability and use, the stocking was very successful, suggesting that habitat for YOY and predation on YOY were not limiting, at least at the levels of stocked fish that survived. Two wild juvenile Colorado pikeminnow (363 and 432 mm TL) were captured in the lower San Juan River in 1996, indicating that some recruitment from wild fish still occurred (Ryden 2000a), but at a very low level. Ryden (2000a) reported 17 adult Colorado pikeminnow captures from 1991 through 1994, but only one was captured during the period of 1994 to 1997. However, YOY Colorado pikeminnow were found, suggesting adult fish learned to avoid electrofishing rafts. Ryden (2000a) used capture and recapture information between RM 119.0 and RM 136.0 to perform a population estimate resulting in 19 adult Colorado pikeminnow. Based on this information, it appeared that the population of Colorado pikeminnow in the San Juan River was very small and was likely too small to respond to improvements in habitat or other environmental features.

**Table 3.9. Number of young-of-the-year (YOY) and juvenile wild Colorado pikeminnow collected annually from 1987 to 1997 in the San Juan River during monitoring studies (Source: Converse and Holden 1999).**

| STUDY | YEAR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
| Platania (1990) | 18 | 1 | 0 | -[a] | - | - | - | - | - | - | - |
| Buntjer et al. (1993, 1994) | - | - | - | 1 | 0 | 0 | 2[b] | - | - | - | - |
| Lashmett (1993, 1994, 1995) | - | - | - | 0 | - | 1 | 11 | 0 | - | - | - |
| Archer et al. (2000) | - | - | - | - | - | - | - | 7[c] | 5[b] | 0 | 0 |
| Platania et al. (2000) | - | - | - | - | - | - | - | - | 2[b] | 2[b] | 0 |
| Number of seine hauls | 135 | 103 | 29 | ? | 1,390 | 892 | 796 | 235 | 240 | ? | ? |

[a]Data not collected or available.
[b]Larval fish taken in drift nets or by seining.
[c]Two of the fish collected in 1994 were captured in April and were 1993 year-class fish.

Population size is an important limiting factor for both razorback sucker and Colorado pikeminnow in the San Juan River. Although the small Colorado pikeminnow population appears to be able to maintain itself through a low level of recruitment, it may be too small to respond to improvements in its environment.

## Management Implications

Because of the lack of razorback sucker in the San Juan River, the SJRIP initiated experimental augmentation in 1994 (Ryden 2000b). The intent of the study was to determine if stocked razorback sucker would survive, grow, and reproduce. Past razorback sucker augmentation efforts had not been successful, and one of the reasons may have been the size of fish stocked (Marsh and Brooks 1989, Minckley et al. 1991). Previously stocked fish may have been too small to avoid predation or may not have been able to withstand the riverine environment. The experimental stocking of razorback sucker in the San Juan River was very successful. Ryden (2000b) recommended stocking larger-sized razorback sucker in the spring, although this would require holding them an additional winter in grow-out facilities. Hence, if such facilities are not available, stocking in the fall at a smaller size would be acceptable. Ryden (2000b) also recommended stocking as far upstream as possible, since stocked razorback sucker exhibited relatively large downstream movements shortly after stocking. His studies suggested that programs to reduce the potential of stocked fish loss to predatory nonnative fish species were important and that younger fish (less than 3 years of age) appeared to be better able to adapt to the riverine situation than older captive-reared razorback sucker. The success of experimental stocking between 1994 and 1996 resulted in preparation of an Augmentation Plan (Ryden 1997), and initiation of efforts in 1997 to stock about 75,000 subadult razorback sucker in the San Juan River over a 5-year period, under guidelines of the draft Genetics Management Plan (Crist 1997).

From 1997 through 1998, a total of 4,164 razorback sucker was stocked as part of the Augmentation Plan, well below the anticipated amount of 15,000 fish per year. Finding larvae for the augmentation program and then securing grow-out facilities in which to rear them limited the number of suitably sized fish available for stocking. In 1998, the SJRIP developed its own grow-out ponds on Navajo Nation property (Ojo Pond) near Farmington, New Mexico, and additional ponds followed (Avocet Ponds in 1999 and Hidden Ponds in 2000). Annual collection of larvae in Lake Mohave and attempts to obtain excess juvenile fish from a razorback sucker rearing program at Lake Mohave became standard procedure. In 1999, about 65,000 larvae were obtained from Lake Mohave and stocked into Ojo and Avocet ponds.

As augmentation of razorback sucker began (1997), experimentally stocked razorback sucker were recaptured during the course of adult monitoring studies. In 1997, a male razorback sucker group was captured in what appeared to be a spawning aggregation. Larval collections that concentrated on finding young razorback sucker in late spring were initiated in 1998; two larval razorback sucker were found that year, and additional larvae were captured in 1999. This confirmed that stocked razorback sucker grew and reproduced. As the larger number of stocked fish stocked attains reproductive size, the limitation of small adult population size should be eliminated or at least diminished.

Preparation of a Colorado pikeminnow Augmentation Plan was also approved in 1997, but it was postponed because of the success of experimental stocking of YOY in 1996 and 1997. As noted above, 100,000 YOY Colorado pikeminnow were experimentally stocked each year in 1996 and 1997 to determine habitat use and availability. Survival of those stocked fish appeared to be very good (Ryden 2000a, Trammell and Archer 2000), and this was one of the first successful attempts to augment Colorado pikeminnow populations (Tyus 1991, Masslich and Holden 1996). The YOY Colorado pikeminnow became acclimated to the riverine environment relatively quickly and moved around, both upstream and downstream (Trammell and Archer 2000). This study showed that even when the river of concern, such as the San Juan River, did not have the classic types of backwaters found in the Green River, stocked YOY Colorado pikeminnow could still find acceptable habitat, avoid predators, and grow as well as their wild counterparts.

In addition to successful experimental stocking, a small recruiting population of Colorado pikeminnow persists in the San Juan River, and there was concern that additional augmentation may dilute the genetics of the wild stock. Therefore, a Colorado pikeminnow Augmentation Plan was not completed.

By the end of the 7-year research period, it was likely that there were several hundred or more stocked juvenile Colorado pikeminnow in the San Juan River below Hogback Diversion. As they mature, the limitation of too small of an adult population should diminish. When these fish start reproducing, the potential limitation of larval habitat, or predation on larvae, will be the primary limitation of concern.

Monitoring will continue to evaluate the population status of the two endangered fish species in the San Juan River. Recovery requires that the species become self-sustaining, meaning that natural reproduction is sufficient to maintain the population. In 1998, the SJRIP initiated studies using an energetic or food-based approach to determine how many of the two endangered fish species could likely live in the San Juan River. In the end, it is likely that sustainable population levels in the San Juan River will be determined by the fishes. If habitat is maximized to the extent possible, and other potential limiting factors are minimized, then recruitment will be the factor determining what population levels the two endangered fish species can maintain.

## LIMITING FACTOR SUMMARY

All biological organisms are limited from infinite population expansion by their environment. Environments have a finite carrying capacity that restricts organismal population expansion through mechanisms such as food availability, habitat availability, predation, and competition. Very little information is available regarding the historical abundance of fish species in the San Juan River, but the available information indicates that some native species populations are smaller today than they were historically. Because the system was not continuously monitored, the exact reasons for their population declines cannot be definitively determined. Likewise, the factors that are limiting to the recovery of the rare fish species cannot be definitively determined. During the 7-year research period, the SJRIP attempted to define factors limiting the recovery of the endangered species, which are distinct from the factors that will limit their ultimate population expansion. At present, few, if any, factors can be definitively identified as limiting to the recovery of Colorado pikeminnow and razorback sucker, primarily because so few of these fishes currently exist in the San Juan River system.

The SJRIP determined that the introduction of large numbers of Colorado pikeminnow and razorback sucker will be required to accelerate the recovery of these species to naturally reproducing populations. As the SJRIP proceeds toward the goal of healthy populations, ecological limitations on their ultimate population expansion can be more readily determined. As that goal is approached, it will also become easier to determine what external factors may limit the species' recovery, such as flow regimes or introduced species. At present, incremental increases in their population size are likely as recovery and augmentation efforts continue. Continued monitoring and assessment will be necessary to determine which factors, if any, limit their recovery to system capacity, which is their ultimate ecological limit.

Although many potential limiting factors were investigated during the 7-year research period, the most likely factor limiting recovery of Colorado pikeminnow and razorback sucker during that time was population size. Razorback sucker did not have a population in the San Juan River, as evidenced by the lack of collection of even one wild adult fish. Adult Colorado pikeminnow numbers were likely around 20, which is well below numbers considered to be genetically viable (Valdez et al. 2000a, 2000b). How long this small population could maintain itself was unknown, but it was likely that the population has been very small since the completion of Navajo Dam and the eradication efforts accompanying that action.

As the adult populations of these two species increase through augmentation efforts, the factors limiting the populations will likely change. For razorback sucker, there is a real concern for larval and YOY habitat. What will they use if flooded bottomland habitat is not available? This question cannot be adequately answered until the augmented adult population is sufficiently large to produce millions of larvae, which will not likely occur until 2005 or later. Once this occurs, the number of larvae produced should increase dramatically because a large female razorback sucker can produce up to 100,000 eggs (Gustafson 1975), and potential habitat or predation limitations on larvae can be evaluated.

Is there sufficient habitat for larval Colorado pikeminnow survival? This question will not be answered for several more years, until the juvenile Colorado pikeminnow stocked in l996 and 1997 mature. Because so few larvae were available to study, larval habitat for both endangered fish species was not adequately assessed during the 7-year research period. A study was initiated in 1999 to determine larval Colorado pikeminnow habitat use through larval stocking. Reductions in larvae numbers, from the stocking site to Lake Powell, suggested that some were retained in the river; however, no YOY were found, suggesting that either survival was low or sufficient larvae were not provided. It must be remembered that 10 adult female Colorado pikeminnow or razorback sucker can produce 1 million larvae. When the San Juan River has 100 adult females producing 10 times that number of larvae, a reasonable experiment may be conducted.

As populations increase and expand upstream to near Farmington, New Mexico, other factors such as diversion dams, temperature, and predation by nonnative species may also become more evident. As numbers and range are expanded, more endangered fishes may use habitats where contaminants are a concern. Therefore, just because some factors were not found to be limiting during the 7-year research period does not mean that they will not be limiting in the future. The Monitoring Plan (Propst et al. 2000) developed by the Biology Committee recognizes these concerns and includes continuing assessment of factors that may become future concerns. The only factor that was eliminated for review during monitoring is fish health. But abnormalities will continue to be part of the adult fish monitoring protocol, and fish health experts will be added to the monitoring effort if warranted in the future.

The 7-year research period studies provided encouraging results for meeting the overall goal of recovering Colorado pikeminnow and razorback sucker in the San Juan River. Although initial studies of overall low populations of both species and low amounts of key habitats were discouraging, the introduction of YOY Colorado pikeminnow and subadult razorback sucker showed that the fish could survive, grow and, in the case of razorback sucker, reproduce in the San Juan River. Most other native fishes were abundant in the San Juan River, except roundtail chub, indicating that the river provided habitat for large populations of other members of the native fish community. Comparisons of habitat quantity and quality with other Upper Basin rivers showed that habitat quantity and quality in the San Juan River was comparable, and the fish found and used rare habitats. Reoperation of Navajo Dam allowed study of various flow regimes and their effects on key fish habitat. This provided for development of flow recommendations that will create, maintain, and maximize key habitats at the proper time of the year to meet the life history needs of the endangered fishes. Together, these factors indicate that the San Juan River has high potential for providing demographically viable populations of both species that will be important in recovering the two species not only in the San Juan River, but throughout the Colorado River Basin.

# CHAPTER 4: PROGRAM ACCOMPLISHMENTS SUMMARY

## INTRODUCTION

One purpose of the 7-year research studies was determining the feasibility of recovering the two endangered fishes in the San Juan River. The survival and growth of stocked razorback sucker and Colorado pikeminnow, along with a generally healthy native fish community, and the ability to mimic a natural hydrograph through reoperation of Navajo Dam to create, maintain, and maximize key habitats indicated a high potential for restoring both species in the San Juan River. This suggests that the San Juan River can be important in the recovery of the two species by supporting demographically viable populations. Although limiting factor studies were the main emphasis of the 7-year research period, the SJRIP had other goals and objectives. This chapter discusses the overall accomplishments of the SJRIP from 1992 to 1997, using the outline of the major objectives of the *LRP*, and summarizes the accomplishments for each objective. This summary "sets the stage" for the SJRIP's future focus.

## DEVELOP INTERIM MANAGEMENT OBJECTIVES FOR THE ENDANGERED FISH SPECIES AND NATIVE FISH COMMUNITY OF THE SAN JUAN RIVER

Interim management objectives are short-term population goals for the SJRIP that are "interim" to establishing actual recovery goals. These objectives provide population goals based on theoretical considerations, but they may be changed as recovery potential becomes clearer. The *LRP* proposed interim population goal establishment for each of the two endangered fish species and for the other native fishes. Interim management objectives were not addressed directly during the 7-year research period, but a razorback sucker target population was established in the Augmentation Plan (Ryden 1997). That target was 100 razorback sucker adults per mile, or 15,900 adults in the 159 miles below Hogback Diversion, which is designated Critical Habitat for razorback sucker. Based on anticipated mortality, a total of 75,000 subadult and adult razorback sucker were programed for stocking over a 5-year period to achieve the population goal of 100 razorback sucker adults per mile.

During 1998, the BIA and Southern Ute Tribe initiated a study to develop a bioenergetic model of the San Juan River that would show what population levels of the endangered and native fishes are sustainable in the San Juan River. These population levels may be applicable as interim management objectives, or they may assist in developing final population goals for the San Juan River. The USFWS is presently (summer 2000) developing recovery goals and criteria for the four large endangered fishes (Colorado pikeminnow, razorback sucker, bonytail [*Gila elegans*], and humpback chub [*Gila cypha*]) in the Colorado River Basin (Valdez et al. 2000a). Recovery goals include both downlisting and delisting criteria. These goals will likely include preservation and enhancement of San Juan River populations of Colorado pikeminnow and razorback sucker as important for recovery and may provide guidelines for a demographically and genetically viable population. Therefore, interim management objectives are being developed for the San Juan River, but the temporary nature of these objectives should be stressed. As such, the objectives will provide a target, but actual, sustainable populations that would contribute toward recovery of the species may be considerably different. Also, the USFWS recovery goals study may also provide recovery goals for the San Juan River, making interim population objectives unnecessary.

## IDENTIFY, PROTECT, AND RESTORE HABITATS WITHIN THE SAN JUAN RIVER BASIN NECESSARY FOR RECOVERY OF THE ENDANGERED FISH SPECIES AND MANAGEMENT OF THE NATIVE FISH COMMUNITY

The 7-year research period studies met most of this objective, except for the identification of key habitats for larval Colorado pikeminnow and razorback sucker, and perhaps key habitats for roundtail chub. The primary accomplishment was determining that mimicry of a natural hydrograph would create, maintain, and maximize key habitats, and that it could be accomplished below the mouth of the Animas River through reoperating Navajo Dam. The flow recommendations (Holden 1999) were the primary SJRIP undertaking that addressed this objective directly, and the *Flow Report* is the primary source of information concerning the research and management actions taken to meet this objective.

The SJRIP studies showed that, to maximize key habitats for native fishes, flows in the study area below the mouth of the Animas River needed to more-closely match a natural hydrograph in magnitude, duration, and timing than they had since Navajo Dam's completion. High spring flows were a natural San Juan River characteristic, an attribute that most fishes evolved with, a characteristic that is needed to create and maintain key habitats for the endangered and native species. The life histories of the endangered species, especially, are closely tied to the magnitude, duration, and timing of the natural hydrograph. Habitat for spawning and rearing young, although very different for the two species, is improved and maximized with a relatively natural annual hydrograph. To meet this need, the flow recommendations provided increased spring peak magnitude and duration, while maintaining timing more similar to pre-dam conditions than to post-dam flows. Base flows were also altered to resemble the magnitude and timing of pre-dam conditions. These studies also suggested that changes in river temperature resulting from cold, hypolimnetic Navajo Dam releases may be a limiting factor below, as well as above, the mouth of the Animas River and that this area needs further study.

Studies also showed that five irrigation and power plant diversion weirs in the upper river resulted in barriers to upstream migration of native fishes. Plans to alleviate this concern at three of the weirs (Cudei, Hogback, and PNM) were initiated in 1998 and 1999.

Portions of this objective that still need to be accomplished include legal protection for flows needed for recovery (the SJRIP has approved flow recommendations and the Biology Committee developed them as the flows needed for recovery), remediation of barriers to fish movements in the upper study area, and investigation of potential temperature limitations in the upper study area. This objective of the *LRP* included investigating habitat modification or restoration. The habitat and augmentation studies suggested that San Juan River habitat was sufficient for some still unknown population level of the endangered species and that large-scale habitat modification was not needed at this time.

## IDENTIFY, PROTECT, AND RESTORE THE ENDANGERED FISH SPECIES OF THE SAN JUAN RIVER BASIN AND MANAGE THE NATIVE FISH COMMUNITY

Most of the SJRIP biological studies were targeted at this objective. These studies showed that the San Juan River did not have a razorback sucker population and that the Colorado pikeminnow population consisted of about 20 adults. Roundtail chub was also very rare and did not have a population in the main stem San Juan River. Roundtail chub was common in some tributaries, but population densities in many tributaries recently declined. Other native species were common to abundant. Flannelmouth sucker was the most-common large fish in the river, and bluehead sucker and speckled dace were especially numerous in the upper river where cobble substrates were common. Flannelmouth sucker populations declined in all areas except Reach 6 during the 7-year research period, but even with this decline they remained the most-abundant large fish. Life history aspects of the endangered and other native fishes were determined, including location of Colorado pikeminnow spawning areas and habitat use information for both Colorado pikeminnow and razorback sucker. This information was used to develop the flow recommendations and to determine the importance of limiting factors.

The lack of a razorback sucker population initiated an experimental stocking study for the species. The success of this experimental study led to development of a Razorback Sucker Augmentation Plan in 1997, and augmentation began that year under Draft Genetic Management Plan guidelines. Larval offspring of the experimentally stocked fish were captured in the San Juan River in 1998 and 1999, confirming that stocked razorback sucker in the San Juan River survived and reproduced. The numbers of fish recommended in the augmentation plan were not stocked because of difficulties in securing fish and rearing them to suitable stocking size. These problems are being resolved, and the SJRIP developed three grow-out ponds for the species on BIA land near Farmington, New Mexico. In 1996 and 1997, YOY Colorado pikeminnow were stocked to study habitat use and retention in the river. Survival was good, and this experiment resulted in about

1,000 large juveniles in the river by 1999. This success, along with genetic concerns for the existing, small wild population, delayed development of an augmentation plan for this species. The success in using stocked fish to augment the two endangered species populations in the San Juan River is a major accomplishment of the SJRIP.

A Draft Long Term Monitoring Plan was developed and implemented in 1999, and finalized in 2000. This plan provides for: native fish community monitoring, including larvae, young, and adults; physical-feature monitoring related to key habitat maintenance; and continued evaluation of the flow recommendations.

## DETERMINE THE ROLE(S) OF NONNATIVE FISH SPECIES IN THE DECLINE OF NATIVE FISH SPECIES AND IMPLEMENT CORRECTIVE ACTIONS

Concurrent with studies of the native fish community, the nonnative fish community was also intensively studied. These studies included density estimates, habitat-use studies, food habit analyses, competition studies, and studies of flow effects on population levels. Channel catfish and common carp were the second and fourth most-commonly collected fish species in the San Juan River, respectively. Red shiner and fathead minnow were the most-common fish in low-velocity habitats. Although food habit studies did not show high levels of predation on native fishes, the sheer abundance of channel catfish makes it likely that even low levels of predation may impact the native fish community. Red shiner was also implicated as a potential predator of larval native fishes in other Upper Basin rivers, and its abundance in the San Juan River suggests it also may be a predator of concern. Because of the low population levels of the two endangered fishes, impacts to these species from nonnative interactions were difficult to document. Young Colorado pikeminnow, red shiner, and fathead minnow used the same habitats and ate the same foods, but good growth and survival of stocked Colorado pikeminnow suggested that they were not limited by competition from nonnative species.

Altered flows from Navajo Dam did not reduce numbers of nonnative fishes, and channel catfish and common carp increased in density during the 7-year research period. Preliminary information suggested red shiner was temporarily reduced by mid- to late-summer flow spikes caused by thunderstorms, and a study addressing the potential for planned flow spikes to limit this species was initiated in 1998. Starting in 1994, nonnative fishes were removed from the river when they were captured, and in 1998 a study to utilize collected channel catfish by stocking them in ponds on the Navajo Reservation began. Nonnative fish monitoring, and continued removal of nonnative fishes, are part of the Long Term Monitoring Plan.

Regulations limiting the introduction of nonnative baitfish or other nonnative stocking policies were not developed during the 7-year research period. These policies are generally the responsibilities of the affected states, although they were a milestone in the *LRP*, and they need to be completed.

## DETERMINE THE OCCURRENCE, EXTENT, AND ROLE(S) OF WATER QUALITY DEGRADATION AND CONTAMINANTS IN THE DECLINE OF THE ENDANGERED FISH SPECIES AND IDENTIFY AND IMPLEMENT CORRECTIVE ACTIONS

Water quality studies completed during the 7-year research period showed that, overall, the water quality of the San Juan River was good, but problems occurred in localized areas. No clear effects on fish populations were shown, although it was possible that poor water quality or contaminants caused flair-ups of lesions on flannelmouth sucker during low-flow years. The SJRIP conducted contaminant studies of the San Juan River, and laboratory studies of the effects of river contaminants on native fishes. These studies showed that high concentrations of contaminants, primarily metals (copper and zinc), caused negative effects to native fish larvae, but high concentrations were found in only a few localized areas, such as irrigation return flow drains. The effect of dietary and water-borne selenium on Colorado pikeminnow reproductive success was also studied, and the results showed that high selenium levels did not affect egg hatching success or larval survival. Although contaminants and water quality degradation in the San Juan River may have been a larger problem at some time in the past, the SJRIP studies indicated that neither was currently limiting the native fish community.

## IMPLEMENT AN INFORMATION AND EDUCATION PROGRAM TO INCREASE PUBLIC AWARENESS ABOUT ENDANGERED FISH SPECIES AND THREATS TO THEIR HABITATS

The SJRIP did not develop an Information and Education program (I and E program), and often fell short in public notices and information releases during the 7-year research period. In 1999, the SJRIP hired a Program Coordinator whose primary responsibilities were to develop an I and E program, develop an I and E website, and maintain better communication between the SJRIP and the public. The website came online in 1999 (http://southwest.fws.gov/sjrip) and contains: SJRIP meeting minutes; press releases; upcoming meeting agendas, times, and locations; and other information. The *Flow Report* was also published online, and final research reports are also available on the website. In addition, brochures and other public information are being prepared. The SJRIP recently committed to meeting this objective, and improved public information and education should result. The Biology Committee met at least three times per year during the 7-year period and often met much more frequently while preparing documents such as the *LRP* and *Flow Report*.

## IMPLEMENT AND MAINTAIN AN ADAPTIVE MANAGEMENT PROGRAM TO ENSURE CONDUCT OF APPROPRIATE RESEARCH AND MANAGEMENT ACTIVITIES TO ATTAIN AND MAINTAIN RECOVERY OF ENDANGERED FISH SPECIES. THE BIOLOGY COMMITTEE WILL MEET AS FREQUENTLY AS NECESSARY, BUT AT LEAST ANNUALLY, TO EVALUATE RESEARCH ACTIVITIES, MANAGEMENT ACTIONS, AND RECOVERY STRATEGIES TO REFINE AND IMPROVE THE PROGRAM FOR THE ENDANGERED FISH SPECIES OF THE SAN JUAN RIVER BASIN

The SJRIP used adaptive management to alter the research emphasis when new or different information became available. Examples of adaptive management included the addition of fish health studies in 1992, when relatively large numbers of flannelmouth sucker were noted with lesions, and the development of a razorback sucker Augmentation Plan prior to the time noted in the *LRP*. In addition, an electronic database of the information collected during the studies was developed in 1996 and updated annually. The data are made available to the researchers on a CD ROM. The development of this report and the *LRP* changes that are planned for completion in 2000 also meet this objective. As the populations of the two endangered species increase through augmentation, population goals for the San Juan River will be clarified. The development of recovery goals for these two species throughout their ranges will help determine how the San Juan River fits into the larger picture of recovery for these species.

# CHAPTER 5: FUTURE PROGRAM DIRECTION

## INTRODUCTION

With the 7-year research period completed, the SJRIP emphasis switches from research to management and recovery. The *LRP* developed in 1995 to guide the 7-year research effort included a wide range of studies since little was known about the San Juan River fish community and the factors that may limit the endangered fishes. These studies identified the status of the native fishes, clarified which potential factors may have limited the endangered fishes, and showed that the San Juan River did have habitat for endangered fish population expansion. The results of the studies provided considerable direction for future recovery actions.

The knowledge gained from those studies allows the SJRIP to focus its attention on restoring demographically and genetically viable Colorado pikeminnow and razorback sucker populations in the San Juan River that will aid in species recovery. Demographically viable populations are those that can be supported within the available habitat, including food and space, and that contain an appropriate size and age-structure. Genetically viable populations are of sufficient size that inbreeding issues are not a concern. The minimum size of demographically viable populations in the San Juan River is presently being worked on by the Biology Committee. Using preliminary information from an ongoing bioenergetics study, the Biology Committee agreed that a population that includes 800 Colorado pikeminnow adults could be supported in the San Juan River. This number was provided to the USFWS for their development of recovery criteria for Colorado pikeminnow throughout the Colorado River Basin. The Biology Committee did not develop a population number for razorback sucker.

Restoration of Colorado pikeminnow and razorback sucker populations in the San Juan River requires developing research, management, and monitoring activities to meet this goal. The Biology Committee developed a Monitoring Plan (Propst et al. 2000) using information from the 7-year research program to refine collecting techniques and sampling intensity. The Monitoring Plan defines baseline monitoring approaches for fish and habitat parameters, especially those related to the flow recommendations. Research activities will continue to be an important part of the SJRIP, but they will be focused on evaluating management and recovery actions rather than broad-based studies. The *LRP* will be revised to reflect the knowledge gained during the 7-year research program and to serve as a guide for future activities.

Adaptive management will continue to be important in the SJRIP's approach, allowing management actions to be modified, deleted, or added as new information becomes available. The SJRIP will continue to respond to new information as the program moves toward its demographically viable population goals. If viable populations of one of the endangered fish species cannot be achieved because of inadequate habitat, pressure from nonnative fishes, or some other factor, and that factor cannot be reasonably eliminated, then recovery of that species may not be possible in the San Juan River. Using adaptive management principals, the SJRIP will make that determination. The SJRIP's major goals during this management and recovery phase, and the important objectives and tasks that will be conducted to meet those goals, are discussed below. This chapter also serves as a guide for the revised *LRP*.

# GOALS

## 1. Restore a Demographically Viable Razorback Sucker Population in the San Juan River

Studies conducted during the 7-year research program showed that habitat was available for subadult and adult razorback sucker in the San Juan River and that subadult stocking resulted in relatively high survival and retention compared with other stocking attempts. Larval razorback sucker were found during monitoring studies conducted during 1998 and 1999, indicating that the stocked fish were maturing and reproducing. These successes suggest that developing razorback sucker populations in the San Juan River could be possible. This is a first step toward developing self-sustaining populations, a requirement of recovery. Population augmentation will continue, and factors limiting recruitment will be identified. Adaptive management will be used to reduce or eliminate factors limiting recovery.

### Goal 1 Objectives and Tasks (–)

**Objective 1:** Achieve recovery goal for razorback sucker in the San Juan River.

, Complete bioenergetics study initiated in 1998.

, Determine appropriate methods to achieve the recovery goal for razorback sucker in the San Juan River.

**Objective 2:** Continue razorback sucker augmentation in accordance with the Augmentation Plan.

, Find a more-reliable source of larvae so stocking goals can be achieved.

, Assure available grow-out facilities are adequate to achieve the timing and stocking goals of the Augmentation Plan.

**Objective 3:** Determine key razorback sucker habitats and limiting factors.

, Determine what factors limit and aid razorback sucker larval survival.

- Prepare a white paper on the temperature issues surrounding Navajo Dam releases and the endangered fish.

- Determine spawning habitats and locations using radiotelemetry.

- Determine the status and success of all razorback sucker life stages as reproduction increases and the population expands.

**Objective 4:** Monitor the availability, creation, and maintenance of key habitats and incorporate this information into the flow recommendations.

- Conduct monitoring in accordance with the Monitoring Plan

**Objective 5:** Evaluate potential hybridization between flannelmouth sucker and razorback sucker.

**Objective 6:** Control nonnative fish in the San Juan River.

- Continue with nonnative fish mechanical removal during monitoring and research activities.

- Evaluate other potential nonnative fish control measures (e.g., weirs, selective passage structures, reduced levels of Lake Powell, flow manipulation).

- Develop measurable objectives and methods for assessing and maintaining effectiveness of removal efforts.

- Develop nonnative fish stocking and baitfish policies in conjunction with the affected states.

## 2. Restore a Demographically Viable Colorado Pikeminnow Population in the San Juan River

Studies during the 7-year research period identified a small population (about 20 adults) of wild Colorado pikeminnow in the San Juan River below Shiprock. Experimental stocking of YOY proved successful and several hundred or more subadult Colorado pikeminnow now inhabit the river below Shiprock. They may start to spawn with the wild population in the next few years. The population below Shiprock needs to be studied to determine if the stocked fish reproduce successfully and how they interact with the wild population. The studies also showed that habitat for Colorado pikeminnow occurs in the San Juan River between Shiprock and the mouth of the Animas River (upper San Juan River). Colorado pikeminnow need to be established in the upper San Juan River, which is part of Critical Habitat for this species.

**Goal 2 Objectives and Tasks (–)**

**Objective 1:** Achieve recovery goal for Colorado pikeminnow in the San Juan River.

- Complete bioenergetics study initiated in 1998.
- Determine appropriate methods to achieve the recovery goal for Colorado pikeminnow in the San Juan River.

**Objective 2:** Expand the population size of the existing population of Colorado pikeminnow.

- Complete the Genetics Management Plan and a Colorado pikeminnow Augmentation Plan.
- Augment the population in compliance with the Augmentation Plan.
- Assure that a dependable source of fish for stocking is available.

**Objective 3:** Expand the population of Colorado pikeminnow to the area above Shiprock.

- Prepare a white paper on the temperature issues surrounding Navajo Dam releases and the endangered fishes and the need for modifying Navajo Dam release temperatures.
- Stock Colorado pikeminnow in the upper San Juan River and monitor the population to determine habitat use, survival, and additional stocking needs.
- Use radiotelemetry to determine spawning areas and movement throughout the upper river as the fish grow.
- Determine the need for additional fish-passage structures at the diversions and design and construct any required structures.
- Complete fish passage structures at Hogback and PNM weirs.
- Expand larvae and young monitoring upstream to the mouth of the Animas River as the population expands in the upper river.
- Determine the percentage of larvae entrained in, versus the percentage of larvae that drift past, the diversion structures.
- Develop screened intake options for the diversions from these studies, if needed.

- Determine the need for adult screening at the diversion structures.

**Objective 4:** Determine habitat use and limiting factors as the augmented population expands.

- Use radiotelemetry to determine spawning locations, overall habitat use, and range as the experimentally stocked Colorado pikeminnow reach adequate size (400 to 500 mm TL).

- Evaluate the importance of the lower 15 miles of the San Juan River as nursery habitat as larval numbers increase.

- Evaluate the availability of nursery habitat in the lower San Juan River under various Lake Powell water-level conditions if larvae primarily drift to this area.

**Objective 5:** Continue flow recommendations evaluations as recovery efforts intensify.

- Use monitoring and research results to modify flow recommendations as needed.

**Objective 6:** Control nonnative fish in the San Juan River.

- Continue with nonnative fish mechanical removal during monitoring and research activities.

- Evaluate other potential nonnative fish control measures (e.g., weirs, selective passage structures, reduced levels of Lake Powell, flow manipulation).

- Develop measurable objectives and methods for assessing and maintaining effectiveness of removal efforts.

- Develop nonnative fish stocking and baitfish policies in conjunction with the affected states.

## 3. Maintain and Enhance the Native Fish Community

The 7-year research period studies showed that most components of the native fish community were quite abundant (flannelmouth sucker, bluehead sucker, speckled dace), but that roundtail chub did not have a population in the San Juan River below Navajo Dam. Earlier studies indicated that a roundtail chub population occurred at least downstream as far as Shiprock, New Mexico. The common species of the San Juan River native fish community need to be maintained since a healthy native fish community will assist in recovery of the endangered species. Roundtail chub should be restored to the San Juan River below Navajo Dam. A status survey on this species in the Colorado River Basin is presently being conducted by the Bureau to determine if listing is warranted. Low populations of roundtail chub in some portions of the Colorado River Basin are a concern, and re-establishment in the San Juan River would be a proactive step toward rebuilding populations of this species. Studies also indicated that flannelmouth sucker declined in the lower San Juan River during the 7-year research period, and this decline needs to investigated.

### Goal 3 Objectives and Tasks (–)

**Objective 1:** Monitor native fish abundance and evaluate reasons for population changes if they occur.

- Determine if the flannelmouth sucker decline observed from 1991 to 1997 continues, and determine reasons for the decline.

**Objective 2:** Develop a roundtail chub population in the San Juan River.

- Stock roundtail chub in the San Juan River from the Animas River to the PNM Weir with the intent of re-establishing a self-sustaining population.
- Develop a Stocking Plan including stocked fish sources (within the basin), rearing facilities, and timing and size of stocking.
- Develop a more-intensive Augmentation Plan, if needed.
- Use radiotelemetry to follow fish once they reach adulthood, and determine habitat use and spawning areas.

**Objective 3:** Control nonnative fish in the San Juan River.

- Continue with nonnative fish mechanical removal during monitoring and research activities.
- Evaluate other potential nonnative fish control measures (e.g., weirs, selective passage structures, reduced levels of Lake Powell, flow manipulation).
- Develop measurable objectives and methods for assessing and maintaining effectiveness of removal efforts.
- Develop nonnative fish stocking and baitfish policies in conjunction with the affected states.

## PRIORITIZATION OF FUTURE TASKS

Objectives and tasks for each of the three goals were listed by priority. Since all of the tasks will be important in establishing demographically viable populations of the two endangered fish species, they all need to be accomplished as soon as practicable. In addition, the tasks related to the two endangered species (Goals 1 and 2) are higher priority than those for Goal 3. Although it was not listed among the tasks, monitoring is an ongoing annual activity. Some tasks may be completed using the monitoring data, but they will require separate analyses and reporting than those planned for the monitoring data (annual summaries with analyses in 3 and then every 5 years). Monitoring data should be used wherever possible to meet a task. New studies should be designed to complement rather than replace monitoring activities.

The highest-priority tasks are enlarging the existing populations of razorback sucker and Colorado pikeminnow in the San Juan River while maintaining or enhancing the native fish community. This is already occurring for razorback sucker but not for Colorado pikeminnow. Developing a Colorado pikeminnow Augmentation Plan is a high priority. Expanding Colorado pikeminnow range to the upper San Juan River is also a high priority and part of the population enlargement objective. If a Colorado pikeminnow population is established in the upper river and spawning is initiated, study emphasis will shift to the upper river to determine limiting factors to this population, which may be different that those for the existing population. Determining recruitment limitations is also a high priority for both of the endangered fishes because lack of recruitment is the main reason these species are endangered. Recruitment is needed to achieve self-sustaining populations, a requirement of recovery. Re-establishing a roundtail chub population in the upper San Juan River is also a priority and likely could be accomplished in conjunction with the Colorado pikeminnow efforts. Development of an effective nonnative fish control program is also a priority, and nonnative fish may need to be controlled before recovery can occur.

Adaptive management will continue to be important in determining future areas of emphasis. Focusing the SJRIP study goals on the endangered species and the declining portions of the native fish community (roundtail chub and flannelmouth sucker) will provide the best chance for success in reaching the goal of demographically and genetically viable populations in the San Juan River.

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