BIO/WEST Report No. 134-3
January, 1990

THE ENDANGERED FISH OF CATARACT CANYON

FINAL REPORT

by

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(Contract No. 6-CS-40-03980)
Fisheries Biology And Rafting

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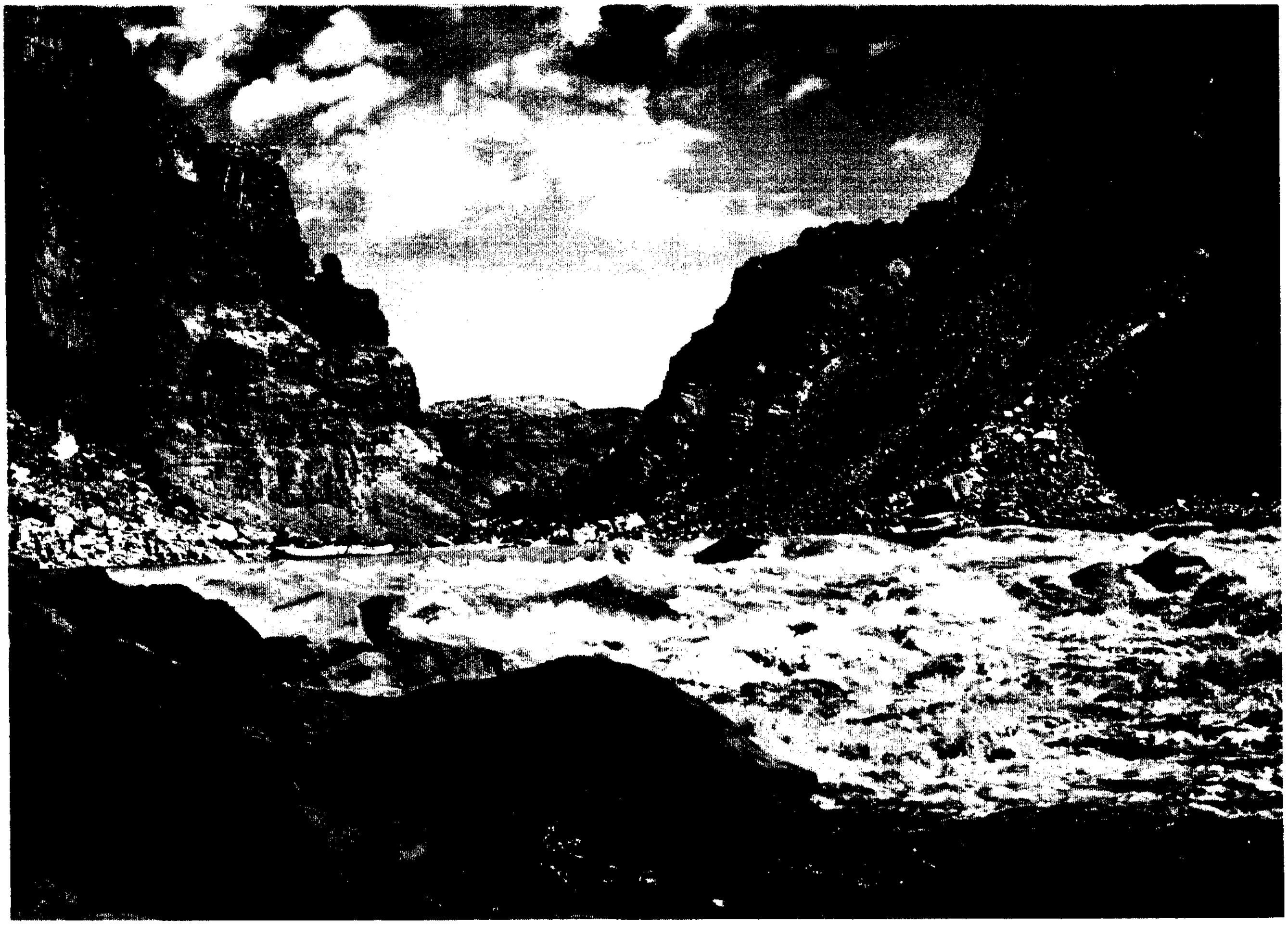
Suggested citation:

Valdez, R.A. 1990. The endangered fish of Cataract Canyon. Final Report prepared for the United States Department of Interior, Bureau of Reclamation, Salt Lake City, Utah. Contract No. 6-CS-40-03980, Fisheries Biology and Rafting. BIO/WEST Report No. 134-3. 94 pp + appendices.



July 23—On starting, we come at once to difficult rapids and falls, that in many places are more abrupt than in any of the canyons through which were have passed, and we decide to name this Cataract Canyon.

July 24—We examine the rapids below. Large rocks have fallen from the walls--great, angular blocks, which have rolled down the talus and are strewn along the channel. We are compelled to make three portages in succession, the distance being less than three fourths of a mile, with a fall of 75 feet. Among these rocks, in chutes, whirlpools, and great waves, with rushing breakers and foam, the water finds its way, still tumbling down. We stop for the night only three fourths of a mile below the last camp. A very hard day's work has been done, and at evening I sit on a rock by the edge of the river and look at the water and listen to its roar.

John Wesley Powell, 1869

PREFACE

This contracted study was performed by BIO/WEST, Inc. for the Bureau of Reclamation (Reclamation). It was conducted as part of the responsibility of federal agencies, under the Endangered Species Act of 1973, P.L.93-205, to protect and, where possible, promote the recovery of endangered species. Since inception of this legislation, Reclamation has been actively involved in collecting information on the Colorado squawfish (*Ptychocheilus lucius*), humpback chub (*Gila cypha*), bonytail (*Gila elegans*), and razorback sucker (*Xyrauchen texanus*), in cooperation with the U.S. Fish and Wildlife Service. In 1979, these agencies formed the Colorado River Fisheries Project to investigate and monitor the life history and biological requirements of the endangered fish in the Colorado River System.

In 1981, Reclamation initiated funding for the collection of biological data on the Colorado squawfish in the Gypsum Canyon area of Lake Powell, following the discovery of a concentration of 45 adults in that area in the spring of 1980. From 1982 through 1984, Reclamation monitored the movement of adult Colorado squawfish in this region using radiotelemetry. Sample efforts associated with this study also revealed small numbers of adults in the Imperial/Gypsum Canyon areas in July and August as well as larval Colorado squawfish, indicating that spawning was occurring in the area or immediately upstream in Cataract Canyon.

These initial investigations prompted further studies, and in 1985 Reclamation contracted Ecosystems Research Institute to conduct a 1-year pilot study in Cataract Canyon. This led to a 3-year contract to BIO/WEST, Inc. (1986-1988) and became known as the Cataract Canyon Studies.

This investigation was designed to answer three questions: (1) Where are the endangered fish spawning in Cataract Canyon?, (2) Is there a population of humpback chub in Cataract Canyon?, and (3) To what extent does the operation of Lake Powell influence nursery habitat of Colorado squawfish in the Gypsum Canyon area? Answers to these questions will assist Reclamation to more effectively operate Glen Canyon Dam and Reservoir along with other Reclamation facilities for the protection of the endangered Colorado River fishes, as prescribed under the Endangered Species Act of 1973.

This report is accompanied by two supplements documenting different aspects of this investigation: (1) The Cataract Canyon Database, which is a collection of six computer diskettes containing dBASE III+ data files, and a printout of all the data collected, and (2) The Chub Biography, which is a collection of photographs and detailed morphometric descriptions of all the *Gila* spp. collected. These supplements were distributed only to the Bureau of Reclamation, U.S. Fish and Wildlife Service, National Park Service, and Utah Division of Wildlife Resources. Copies of these supplements are only available at cost from BIO/WEST, Inc.

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SUMMARY OF FINDINGS

THIRTY-ONE SPECIES OF FISH WERE FOUND IN THE CATARACT CANYON STUDY AREA

Thirty-one species of fish were found in the lower 50 miles of the Colorado and Green Rivers, and the 16 miles of the Colorado River from their confluence to Lake Powell from 1985 to 1988. This included 23 non-native and only 8 native species. Of the eight natives, six were endemic to the Colorado River Basin; Colorado squawfish, humpback chub, bonytail, razorback sucker, roundtail chub, and flannelmouth sucker. The other two native species were not endemic; bluehead sucker and speckled dace.

NON-NATIVE SPECIES DOMINATED THE ICHTHYOFAUNA

Over 95 percent of the fish captured during this investigation were non-native while only 5 percent were native. Five species jointly accounted for 90 percent of the catch: red shiner, sand shiner, channel catfish, carp, and fathead minnow. Red shiners alone made up about 50 percent of the fish in all samples while sand shiners composed about 21 percent.

ALL FOUR OF THE COLORADO RIVER MAINSTEM RARE FISHES WERE FOUND

All three federally listed endangered species and the one federal candidate for listing were present in the Cataract Canyon Study Area. The total numbers of these endangered species made up only 3% of the total catch from 1985 to 1988. Colorado squawfish were found in each of the five regions of the study area, but were most numerous as young-of-the-year (YOY) in the lower 50 miles of the Green River. Of the 4348 Colorado squawfish captured, 4161 were YOY, 175 were juveniles, and only 12 were adults, including two that were previously tagged and released by the U.S. Fish and Wildlife Service 120 and 172 miles upstream in the Green River. Humpback chub were found in the 16-mile reach of Cataract Canyon closely associated with rocky, talus shoreline habitat and eddies next to deep, swift currents. Of 108 humpback chub captured, 11 were larvae, 19 were YOY, 56 were juveniles, and 22 were adults. Suspected bonytail were also captured in the 16-mile whitewater reach of Cataract Canyon, often in close association with humpback chub. The 14 suspected bonytails included 1 YOY, 7 juveniles, and 6 adults. Only 1 adult razorback sucker was captured during this investigation on a large alluvial cobble bar at the mouth of Salt Creek on the Colorado River, 3.6 miles upstream from the confluence.

SUMMARY OF FINDINGS
(Continued)

A POPULATION OF HUMPBACK CHUB EXISTS IN CATARACT CANYON

A new population of the endangered humpback chub was discovered in Cataract Canyon as a result of this investigation. This brings the total number of populations in the upper basin to five: Black Rocks, Westwater Canyon, Desolation/Gray Canyons, Yampa Canyon, and Cataract Canyon. The Cataract Canyon population was distributed from the confluence of the Green and Colorado Rivers downstream to the Lake Powell Inflow, a distance of about 16 miles, although the population was concentrated in a 4-mile reach of whitewater. The population was composed of all age categories, but the adults were relatively small geomorphs, perhaps the remnant of a larger more extensive population that once inhabited the 41 miles of Cataract Canyon prior to the closure of Glen Canyon Dam in 1963.

A POSSIBLE ENCLAVE OF BONYTAILS WAS FOUND IN CATARACT CANYON

A form of chub suspected to be the rare bonytail (*Gila elegans*) was found in Cataract Canyon. The 14 specimens captured exhibited the complement of morphologic and meristic features that more closely resembled this species than the other two congeneric Colorado Rivier chubs, humpback chub (*G. cypha*) and roundtail chub (*G. robusta*). Since these specimens did not exhibit definitive characteristics of *G. elegans*, and since a detailed taxonomic study of these forms was outside the scope of this investigation, a peer examination of the morphologic, meristic, genetic, and cytogenetic characteristics of the chubs from Cataract Canyon is recommended. The existence of *G. elegans* in this region would make Cataract Canyon very important to the recovery of this rarest of the upper basin fishes.

YEAR CLASS STRENGTH OF NON-NATIVE FISH WAS HIGHEST IN LOW WATER YEARS

Following the record high water years of 1984, 1985, and 1986, densities of three non-native cyprinids (red shiner, sand shiner, fathead minnow) were lower than in the more normal water year of 1987 and the low water year of 1988. These species showed a 3 to 4-fold increases in densities in a 2-year period during the normal and low water years. This implies that periodic and temporary control measures (i.e., floods) on these quickly maturing and rapidly reproducing species would be ineffective to long-term control. The only effective control of these non-native species would be long-lasting and persistent measures. The reasons for depressed populations in high water years was attributed to the elimination of large backwaters that harbored these species, a general reduction in quiet-water habitats, and delayed warming that prevented multiple spawns. The low water years were believed to have benefited these species because large backwaters maintained their permanency, reduced velocities provided more quiet water habitats, and prolonged warm temperatures allowed for multiple spawns.

SUMMARY OF FINDINGS
(Continued)

SPAWNING BY TWO SPECIES OF ENDANGERED FISH WAS SUSPECTED IN THE CATARACT CANYON STUDY AREA

Although specific spawning sites were not located and adults with expressible gametes were not found, the presence of numerous larval and YOY Colorado squawfish and humpback chub indicated that spawning by these species occurred within the study area. Spawning by Colorado squawfish in this region of the upper basin may have occurred consistently over unidentified cobble bars which presented the appropriate set of spawning conditions in a given year. Nine such cobble bars were located in the lower 50 miles of the Green River and four in the lower 50 miles of the Colorado River. The large complex of cobble bars in the middle of Cataract Canyon was also considered a possible spawning site for Colorado squawfish. Spawning by humpback chub was suspected in at least one location within Cataract Canyon, between river miles 201.5 and 212.4. Larvae, YOY, juveniles, and adults were captured in this reach, including two adults in spawning condition.

YOY COLORADO SQUAWFISH USED THE CATARACT CANYON STUDY AREA AS A NURSERY

This investigation showed that the lower 50 miles each of the Green and Colorado Rivers above their confluence, as well as the Colorado River from the confluence to Lake Powell were important nursery areas for YOY Colorado squawfish. Average catch per effort of YOY Colorado squawfish in the lower 50 miles of the Green River was among the highest in the upper basin with 72 fish/100 m^2. Maximum average catch rate in Cataract Canyon was 32 fish/100 m^2.

SPAWNING TIMES FOR COLORADO SQUAWFISH MAY DETERMINE YEAR CLASS STRENGTH

Time of hatching and thus size of age-0 Colorado squawfish may affect their overwinter survival. Spawning times, based on back-calculations from known length to age relationships, varied by as much as one month during this 4-year study. Of the 4 years studied, warming of water temperature and hatching times were delayed most in 1986 when spawning did not peak until early August and average length in early October was 30.6 mm TL, compared to average length of 34.0 to 38.7 for the other cohorts at the same time. This difference in size may determine lipid content and thus overwinter condition and survival.

SUMMARY OF FINDINGS
(Continued)

STRANDING MAY BE A SIGNIFICANT MORTALITY OF YOUNG COLORADO SQUAWFISH

Twenty percent of the young Colorado squawfish (larvae, YOY, juveniles) handled in this 4-year study were found stranded in isolated pools. These fish were in over 60 percent of the isolated pools sampled, often in sympatry with fathead minnows and red shiners. Stranding was believed to be a natural phenomenon with these native fish, but the effect of flow withdrawal and regulation (e.g., irrigation, municipal, industrial, mainstem dams) could not be assessed.

THE LAKE POWELL INFLOW SEASONALLY PROVIDED BACKWATER HABITAT FOR SMALL NUMBERS OF YOUNG ENDANGERED FISH

A 1-mile reach (RM 200-201) of the Lake Powell Inflow seasonally provided backwaters used as nurseries by small numbers of young Colorado squawfish. These backwaters were always inundated by high runoff flows from about mid-April to mid-June. Lowering lake levels after runoff created backwaters from about mid-June to August, but lower levels in late summer and fall desiccated these areas or created isolated pools. The number and surface area of backwaters in this 1-mile reach was maximized when the surface elevation of Lake Powell was between 3692 and 3698 feet above sea level. It was noted over the 4-year period that fish habitat in the area was dynamic because of large silt deposits and invasion of tamarisk. No specific recommendation for management of lake levels was proposed as a result of this investigation because of these habitat dynamics together with low numbers of endangered fish and large numbers of non-native predators.

FIVE RECOMMENDATIONS ARE SUBMITTED FOR CONTINUED STUDIES

Further studies are recommended for the Cataract Canyon Area to refine what was learned from this investigation. These study topics are: (1) Confirm spawning by humpback chub in Cataract Canyon, (2) Assess overwinter survival of YOY Colorado squawfish, (3) Assess transport of endangered fish into Lake Powell during spring runoff, (4) Monitor chubs in Cataract Canyon, and (5) Describe the *Gila* complex in Cataract Canyon.

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ABBREVIATIONS

Reclamation	Bureau of Reclamation
°C	degrees Celsius
cfs	cubic feet per second
cm	centimeters
CPE	catch per effort
CRFP	Colorado River Fishery Project
DC	direct current
ERI	Ecosystems Research Institute
fps	feet per second
FWS	U.S. Fish and Wildlife Service
hp	horsepower
ISMP	Interagency Standardized Monitoring Program
LFL	Larval Fish Laboratory, Fort Collins, Colorado
m	meter
mm	millimeters
NPS	National Park Service
RM	river mile, distance from Green/Colorado confluence
TL	total fish length
UDWR	Utah Division of Wildlife Resources
umhos	micromhos (conductivity measured as micromhos per centimeters)
USGS	U.S. Geological Survey
VVP-15	variable voltage pulsator made by Coffelt Electronics
YOY	young-of-the-year

ACKNOWLEDGEMENTS

Cataract Canyon may well be the most difficult region in the Upper Colorado River Basin for fisheries investigations. It is a 16-mile reach of hazardous whitewater rapids surrounded by the roadless expanse of Canyonlands National Park. The nearest boat launches are 50 miles upstream and the nearest take-out is 50 miles downstream in Lake Powell. Weather in the region is variable with searing summertime heat and severe wintertime temperatures that can produce massive river ice jams. The infrequent but heavy summer rains that helped carve this spectacular canyon country also produces dramatic flash floods. This inaccessibility and unpredictable weather compound the difficulty of sampling fish populations in a turbid and turbulent river that varied in flow from 3,000 to 120,000 cfs from 1984 to 1988.

This investigation could not have possibly been conducted without the assistance of many individuals, so many, in fact, that I may by oversight, and not from lack of appreciation, happen to omit some from this acknowledgement. Robert Williams, the Contract Officer's Technical Representative for Reclamation provided much valuable administrative and technical assistance, including participation in many of the field trips. Sharon Tully was also invaluable as assistant to Mr. Williams, and also participated in most of the field trips. Other Reclamation personnel who assisted in the field effort included Mike Pucherelli, Pat Koelsch, Jim Barton, Kirk Lashmett, Matt Dlugolecky, and Jeanine Surber. Bud Rusho and Gayla Heaton provided valuable photography of the study. I would also like to thank Reed Harris of Reclamation for his continued support and advice.

Many non-Reclamation biologists also assisted in the field work and provided much valuable advice. I would like to thank John Hamill, Lynn Kaeding, Chuck McAda and Bob Burdick, as well as Denise Hawn and Patty Schraeder of the U.S. Fish and Wildlife Service; and Maureen Wilson, Miles Moretti, Denise Knight, and Teresa Smith Berry of the Utah Division of Wildlife Resources. John Wise and Pete Schropp also assisted in the field effort while gathering information for a news article for the Logan Herald Journal (Wise 1987).

The majority of this work was conducted in Canyonlands National Park. I wish to thank the National Park Service, and especially past Superintendent Pete Parry and Superintendent Harvey Wickware and their staffs, Jeff Conner, Jim Braggs, Nick Easton, Stan Steck, and Kate Kitchell, for their assistance and support.

Key to the success of this investigation were the boatmen that assisted in 29 trips without a single mishap or injury. The 1985 study could not have been performed without the capable assistance of Ron Ryel, who served as both boatman and biologist. Steve Ferriole also assisted in that first year. The two principal boatmen/biologists from 1986 to 1988 were Bill Masslich and Larry Crist of BIO/WEST. Their continued assistance in the field effort and data analysis are appreciated. I also thank Bryan Cowdell for his meticulous care in entering the field data into the computer database; as well as Lydia "Penny" Trinca, Scott Cheney, Peggy Wood, and Laurie Goldner for their assistance afield.

I would also like to thank Robert Muth of the Larval Fish Laboratory in Fort Collins for his expert identification of the larval fishes. Deep thanks and appreciation go to Bob Jones of TAG-A-LONG Tours in Moab for his logistical support, and to the very capable TAG river guides: James Gordon, John Baker, Stu Smythe, Joe Borshanian, Dave Evans, Maura Bell Loveridge, John Franklin, Karl Prager, Bill and Judy Schroeder, Larry Bluth, Tom Wesson, Stacey Miller, Kathlene Murphy, Karla VanderZanden, Saina Lekarczyk, Robin Gyman, and Rachael Schmidt. I also extend a special thanks to Mr. and Mrs. R.C. "Bud" Barton of Green River, Utah, for their help in shuttling our vehicles and boats to and from the launch sites.

1.0 INTRODUCTION

This Final Report is submitted to the Bureau of Reclamation (Reclamation) in fulfillment of Contract No. 6-CS-40-03980, entitled "Fisheries Biology and Rafting". It integrates the results of 3 years of investigation (1986, 1987, and 1988) under this contract as well as a fourth year (1985) under a separate Reclamation contract (Contract No. 5-CS-40-02820) conducted by Ecosystems Research Institute (ERI). These 4 years of investigations are referred to as "The Cataract Canyon Studies". These investigations were documented annually in a report submitted by ERI (Valdez 1985) and in two Annual Summary Reports (Valdez 1987, Valdez 1988) submitted by BIO/WEST. This information is supported by progress reports submitted to Reclamation following each of the 29 trips, including 6 in 1985, 6 in 1986, 8 in 1987, and 9 in 1988. These progress reports and the associated field data sheets are in the files of Reclamation in Salt Lake City and of BIO/WEST, Inc. in Logan, Utah.

This report is accompanied by two supplements: (1) The Cataract Canyon Database, which is a collection of six computer diskettes containing the data in dBASE III+ files together with a printout of all the data collected, and (2) The Chub Biography, a collection of photographs and detailed morphometric descriptions of all the *Gila* spp. collected. These supplements were distributed only to the Biological Support Branch of the Bureau of Reclamation in Salt Lake City, UT; the Project Leader and the Database Manager of the U.S. Fish and Wildlife Service (FWS) in Grand Junction, CO; the Supervisor's Office of Canyonlands National Park, National Park Service (NPS) in Moab, UT; and the Nongame Section of the Utah Division of Wildlife Resources (UDWR) in Salt Lake City, UT.

1.1 Purpose and Objectives

The purpose of this investigation was to characterize the icthyofauna of Cataract Canyon and the surrounding area of the upper Colorado River Basin, and to assess the importance of the area to the endangered Colorado River fishes; Colorado squawfish (*Ptychocheilus lucius*), humpback chub (*Gila cypha*), bonytail (*Gila elegans*), and razorback sucker (*Xyrauchen texanus*). The objectives of the investigation were as follows:

1. Determine spawning locations of endangered fishes in Cataract Canyon.
2. Determine whether humpback chub populations exist in Cataract Canyon.
3. Describe to what extent Reclamation's operation of Lake Powell influences nursery habitat of Colorado squawfish in the Gypsum Canyon area.

1.2 Background

This investigation was conducted as part of Reclamation's ongoing program on endangered fishes of the upper Colorado River basin. Reclamation's commitment stems from the responsibility as a federal agency to protect and, where possible, promote the recovery of these fish, as prescribed by the Endangered Species Act of 1973.

Since 1979, Reclamation, in conjunction with the FWS, has funded and conducted studies to gain a better understanding of the life history and living requirements of the endangered Colorado squawfish, humpback chub, and bonytail, as well as the federal candidate species razorback sucker. A major portion of this effort has been to fund the ongoing Colorado River Fisheries Project (CRFP) being conducted by the FWS.

Generally, the investigations of CRFP have included the entire range of the endangered fishes in the upper basin, except for some regions that are not part of the sampling design or require special equipment because they are difficult to access and sample. One such area is Cataract Canyon, located between the confluence of the Colorado and Green Rivers and upper Lake Powell. Cataract Canyon is a 16-mile reach of whitewater within Canyonlands National Park administered by the National Park Service.

Attention was first drawn to this region of the upper basin in April 1980, when 45 adult Colorado squawfish were captured in upper Lake Powell during a study by the Utah Cooperative Fishery Research Unit (Persons et al. 1982, Valdez et al. 1982). The objective of that investigation was to assess spawning success of striped bass in that portion of the Colorado River flowing into Lake Powell. The Colorado squawfish were captured coincidentally in gill nets set for striped bass.

Initial efforts by FWS in 1979-81 in Cataract Canyon (Valdez et al. 1982) and continued efforts by Reclamation in 1981 near Gypsum Canyon also encountered Colorado squawfish, but not in the numbers seen in 1980. From 1982 to 1984, Reclamation equipped adult Colorado squawfish in upper Lake Powell with radio transmitters in an attempt to locate fish concentrations, monitor movements, and identify possible spawning areas. Small numbers of adults were found in the Imperial/Gypsum Canyon areas in July and August of these years, but no spawning sites were identified. Seining in these areas yielded numerous larval and young-of-the-year (YOY) Colorado squawfish, indicating that reproduction had occurred in either upper Lake Powell or in the river immediately upstream, within Cataract Canyon.

In 1985, Reclamation continued studies with radiotelemetry in the Imperial/Gypsum Canyon areas, and initiated a pilot study in Cataract Canyon (Valdez 1985). Six field trips were conducted from July through October. These efforts yielded YOY as well as juvenile and adult Colorado squawfish and humpback chub. Two fish, tentatively identified as bonytail (one adult and one YOY), were also reported. These findings indicated the need for additional studies to locate possible spawning areas in the canyon and to assess the importance of habitats within Cataract Canyon and upper Lake Powell.

Field efforts for the current investigation were initiated in Cataract Canyon on July 11, 1986 (Valdez 1987). Six trips were conducted through the canyon between that date and October 6, 1986, with the objectives as previously stated. In 1987, eight sample trips were conducted from April 13 to October 12, and in 1988, nine sample trips were conducted from March 21 to October 12.

1.3 Administration of the Study

This investigation was the result of a cooperative effort by several agencies and many individuals (Figure 1). The study was contracted and administered by the Bureau of Reclamation with the cooperation of the FWS, NPS, and UDWR. The work was conducted primarily by BIO/WEST, Inc. with participation in all field efforts by Reclamation biologists. Field work was conducted by one crew, generally composed of four biologists, and logistic support was from Tag-A-Long Tours, a commercial river company. All larval fish were identified by the Larval Fish Laboratory of Colorado State University.

2.0 STUDY AREA

This investigation was conducted on the Colorado River from near Potash (RM 50) downstream to Imperial Canyon in upper Lake Powell (RM 200, 16.4 miles below the confluence of the Green and Colorado Rivers), as well as that portion of the Green River from near Mineral Bottom (RM 50)

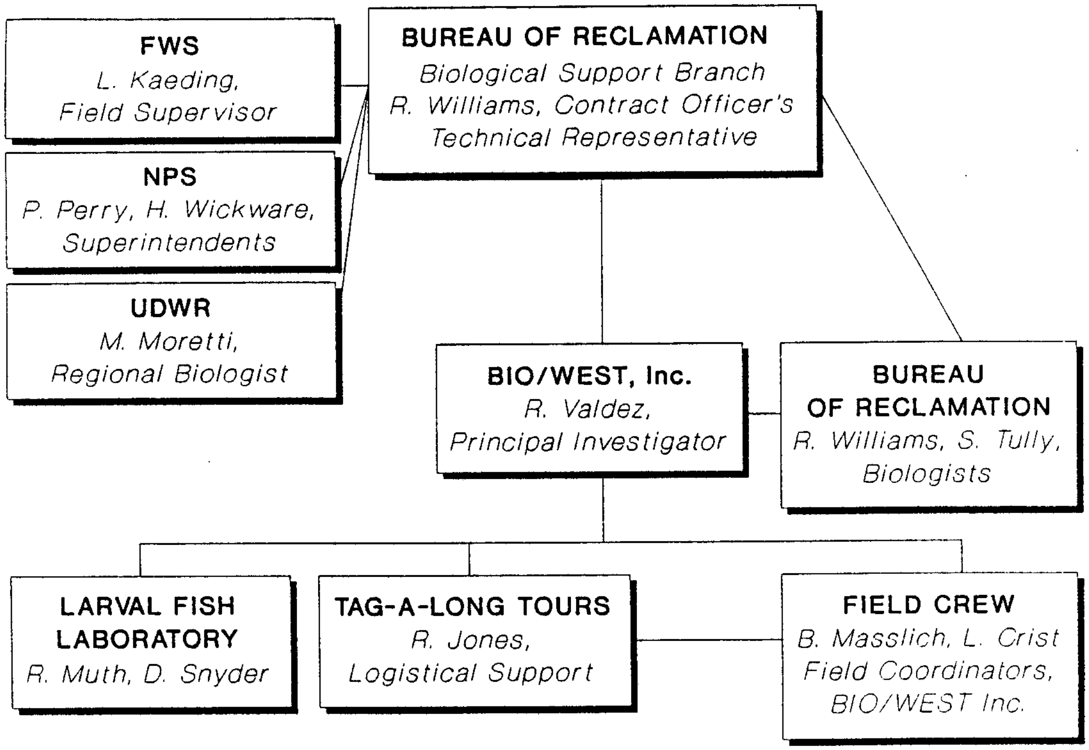


Figure 1. Administration of the Cataract Canyon Studies.

downstream to the confluence (Figure 2). Access to this study area was by motorized craft from launch sites at either Potash or Mineral Bottom. Detailed maps of the Green and Colorado Rivers in this study area are available in two river guides (Belknap and Belknap 1974, Baars 1987). A photographic record is provided in Appendix A of this document and referenced accordingly. The reader should note that the confluence of the Green and Colorado Rivers is RM 216.4, which represents the distance upstream from Lee's Ferry below Glen Canyon Dam. The confluence is also designated as RM 0 as the start of the mileage upstream from the confluence on either the Colorado or Green Rivers.

Fish habitat in this study area was largely determined or indicated by shoreline. Four types of shoreline habitats were present including: (1) tamarisk/willows, (2) talus slopes, (3) rock ledges, and (4) vertical walls (Photos A-1 through A-4). The **tamarisk/willow habitat** was the most common, particularly along silt/sand banks of bottomland areas. This habitat was characterized by dense growths of tamarisk and willow with overhanging and submerged branches and root wads. **Talus slope habitat** was present below steep unconsolidated slopes where boulders and other colluvial materials had spilled into the river. The boulder and cobble jetties formed by these talus slopes often created eddies and slackwaters which were important fish habitat. **Rock ledge habitat** was present where low walls of metamorphic or igneous rock overhung the river. These ledges characteristically had depressions and pockets worn by water action. **Vertical wall habitat** was most prevalent in the lower portion of the Green and Colorado Rivers just above their confluence. This habitat was created by high, steep walls of sedimentary or metamorphic rock emerging from below the water surface. These smooth walls had but few irregularities created by water action. Rock ledges and vertical walls were initially suspected of providing good habitat for chubs, a complex of species that in the upper basin are closely associated with rock substrates (Valdez et al. 1981). However, the prevalence of adjacent shifting sand substrate with its apparent low productivity reduced this habitat value.

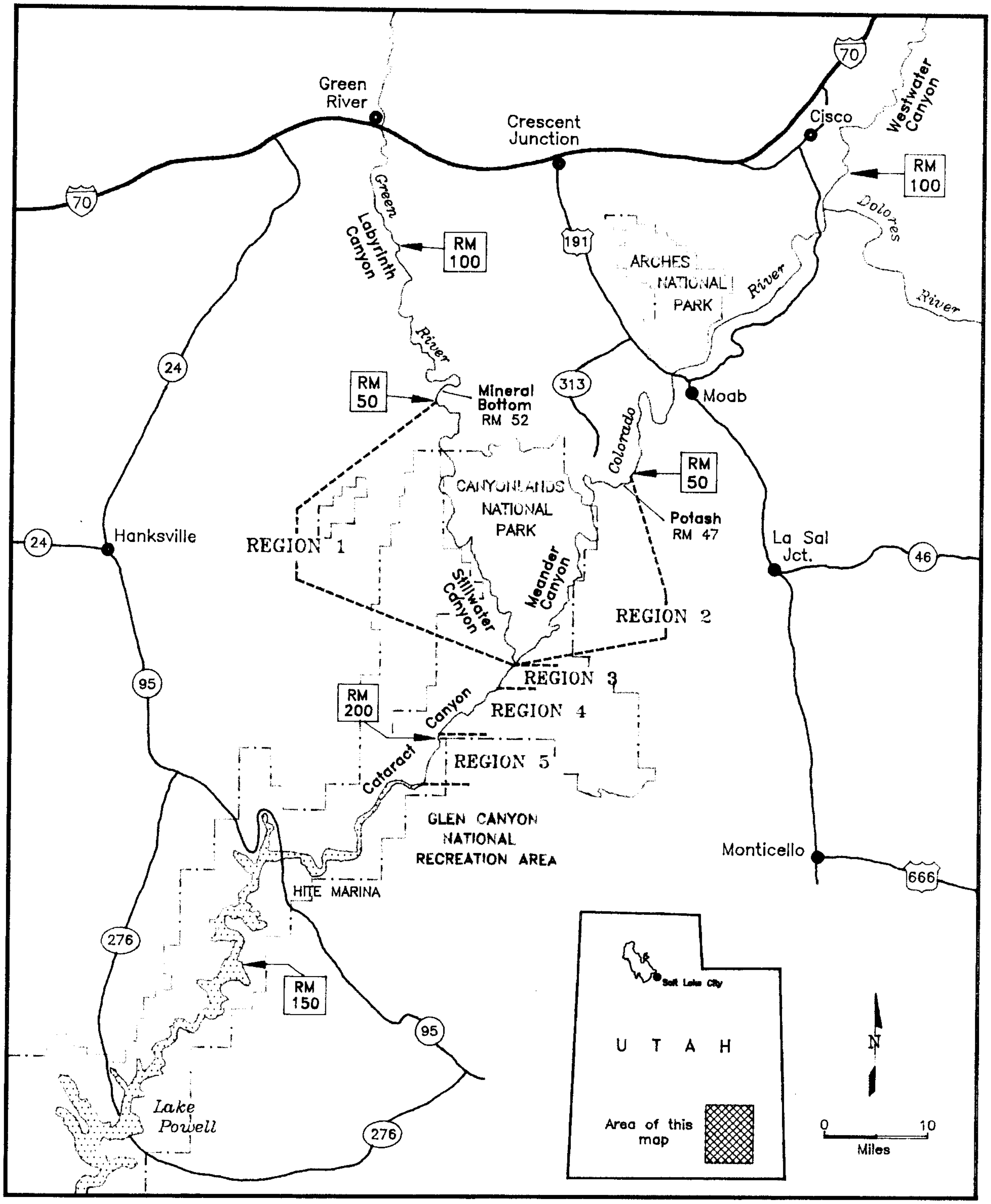


Figure 2. General location of the Cataract Canyon study area.

For the purposes of this investigation, the study area was divided into five regions:

1. Green River above the confluence (RM 50.0 to 0)
2. Colorado River above the confluence (RM 50.0 to 0)
3. Colorado River from the confluence to Brown Betty (RM 216.5 to 212.5)
4. Colorado River in Cataract Canyon (RM 212.4 to 201.5)
5. Inflow of the Colorado River into Lake Powell (RM 201.4 to 195.0)

2.1 Region 1: Green River above the Confluence

This region of the study area (Figure 3) encompassed the Green River from near the Mineral Bottom boat launch (RM 50.0) downstream to the confluence of the Colorado River (RM 0). Included in this region were the southern portion of Labyrinth Canyon and Stillwater Canyon. The two major drainages within this region were Millard Canyon (RM 33.7) and Horse Canyon (RM 14.3); there were numerous small ephemeral drainages such as Horsethief, Taylor, Deadhorse, and Jasper Canyons.

The Green River along this region was characterized by a low gradient of about 3 feet per mile, and a meandering channel with predominantly silt and sand substrates. The river course flowed alternately through wide floodplains and bottomlands with densely vegetated shorelines of tamarisk and willows, and steep canyons with talus and cliff shorelines. Cobble, gravel, and some boulders occurred as alluvial deposits at the mouth of tributary drainages. These deposits were particularly extensive below Millard and Horse Canyons, where they formed large cobble riffles (Photos A-5 through A-8).

The shoreline and riparian zone of this region was dominated by a tamarisk/willow association. Tamarisk is an exotic phreatophyte imported as an ornamental into California from Asia in the 1800's. The invasion of the entire Colorado River Basin by this plant is dramatically illustrated in a book entitled *In the Footsteps of John Wesley Powell* (Stephens and Shoemaker 1987), in which the authors rephotographed areas of the river in 1968 which had been photographed by E.O. Beamon on the second Powell Expedition of 1871-1872. These photographs clearly illustrate a change in the riparian zone from willows and cottonwood trees with unvegetated sand bars to a dominance of tamarisk in both riparian zones and sand bars in a period of about 100 years. Recent research (Graf 1978, Andrews 1986) suggests that the bankfull channel width of the Green River in this region has decreased by 10 to 27% within the past 2 to 3 decades. Bank stabilization by tamarisk, in addition to a decrease in the magnitude and duration of peak discharges due to flow regulation from Flaming Gorge Dam, were cited as the principal factors contributing to the decreasing channel width. A continuation of this trend could potentially decrease the number of backwaters in this region of river and subsequently reduce its value as a nursery for Colorado squawfish.

Fish habitat in this region was provided by backwaters, cobble riffles, slow runs, eddies, and shorelines. Backwaters were more abundant here than in any of the other four regions. Although densities of backwaters varied on any given year depending on flow regimes, estimated backwater densities based on their availability for the Interagency Standardized Monitoring Program, known as the ISMP (USFWS 1987) conducted by the UDWR in 1987 and 1988 were at least two per 5 miles of river (Personal communications with Mr. Miles Moretti, UDWR, February 1988). This included only backwaters that met the standardized monitoring criteria of a minimum of 30 m^2 in size and a maximum depth of 1 foot. Backwaters that did not meet these criteria occurred in the region but were considered marginal as fish habitat. This high relative density of backwaters made this region the most important of the study area in terms of survival and recruitment of YOY Colorado squawfish and other native fishes. These backwaters generally appeared during decreasing flows in mid to late summer and were typically formed by large eddies over sand bars and in dewatered side channels (Valdez and Wick 1981).

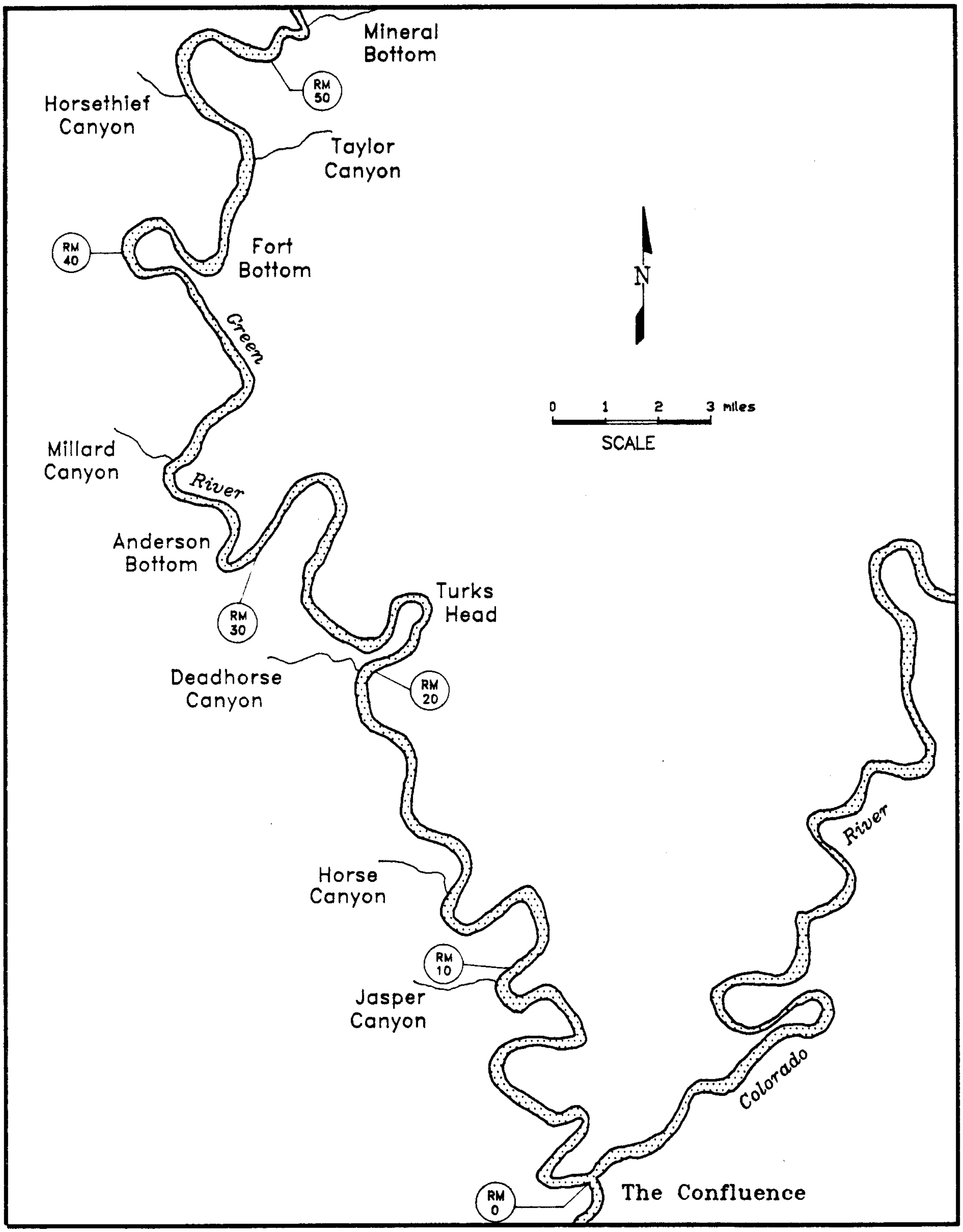


Figure 3. Detailed map of Region 1: Green River above confluence, RM 50.0 to 0.

During this study period, main channel water temperatures generally peaked in July and August at 25 to 30°C and often dropped to 0°C for extended periods in January and February depending on ambient conditions (See Section 2.6). Specific conductivities in this region ranged from 255 umhos/cm, during spring runoff to 3,250 umhos/cm in late summer and early fall. Flows in the Green River during this investigation ranged from a maximum of 35,000 cfs during peak runoff in late May and early June to a low of 1000 cfs in late summer and early fall. Flows in this region were controlled largely by Flaming Gorge Dam, located about 410 miles upstream from the confluence, as well as input from the Yampa, White, Duchesne, and San Rafael Rivers. Periodic rain storms in late summer and early fall caused dramatic flash floods that resulted in short-term increases in flow greatly reducing fish sampling efficiency.

The opportunity to observe the effects of one such periodic storm event came during a trip on August 26-27, 1988. A high intensity thunderstorm dropped 1 to 4 inches of rain in the canyonlands area within a 4-hour period on August 26, 1988. Subsequent rain freshets triggered large rock falls in Cataract Canyon and a high volume flash flood in Horse Canyon (RM 14.4) as well as smaller freshets from other less extensive drainages on the Green River. Increases in water level of 1.5 to 3 feet were observed in the Colorado River below the confluence over a 15-hour period following the rain, and it was estimated that the volume of water in the river doubled, from 5,000 to 10,000 cfs, during the peak of the flood although this was not reflected in any stream gage since it occurred downstream of the USGS gage near Cisco, Utah, (Colorado River) and the USGS gage near Green River, Utah, (Green River). Debris carried by the flood choked the Green River channel, and was deposited along shorelines or washed downstream to Lake Powell. The unusually high numbers of YOY Colorado squawfish observed in lower Cataract Canyon shortly afterward were probably transported by this flood from the lower Green River (See Section 4.3.4). The effects of the flash flood at the mouth of Horse Canyon were inspected 2 weeks later. Flood waters from Horse Canyon had been sufficiently strong to deposit a large alluvial fan that probably dammed the Green River temporarily. This short-lived dam breached and created a minor rapid that persisted through 1988.

2.2 Region 2: Colorado River above the Confluence

This region of the study area (Figure 4) encompassed the Colorado River from near the Potash boat launch (RM 50.0) downstream to its confluence with the Green River (RM 0). The canyon area included in this region, although not formally named, was designated as Meander Canyon in a recently published river guide (Baars 1987).

The Colorado River in this region was similar to the Green River above the confluence with some exceptions (Photos A-9 through A-12). Both rivers were characterized by a low gradient of about 3 feet per mile, and a meandering channel lined with tamarisk/willow, talus slopes, or vertical rock walls and ledges. However, the substrate of the lower Colorado River was predominantly sand, whereas that of the lower Green River was silt, probably accounting for differences in fish composition and species densities (See Section 4.3.6). Gravel and cobble substrate were also found in localized areas around the mouths of tributaries, but these were fewer than on the Green River. The largest deposits of cobble in this region were at Salt Creek (RM 3.6) and Elephant Canyon (RM 3.0). The only razorback sucker captured in the 4 years of this study was on the cobble bar at the mouth of Salt Creek.

Fish habitat in this region was the same as that described for the Green River above the confluence, except for a difference in the relative abundance of habitat types. This region provided the second highest density of backwaters of any in the study area. Bottomlands were less extensive on the Colorado River than on the Green River. Consequently, tamarisk/willow habitat, although still the most prevalent shoreline habitat, was less abundant on the Colorado. Conversely, talus slopes, rock ledges, and vertical walls were more common in this region. Rock ledges occurred primarily at RM 35.6, near

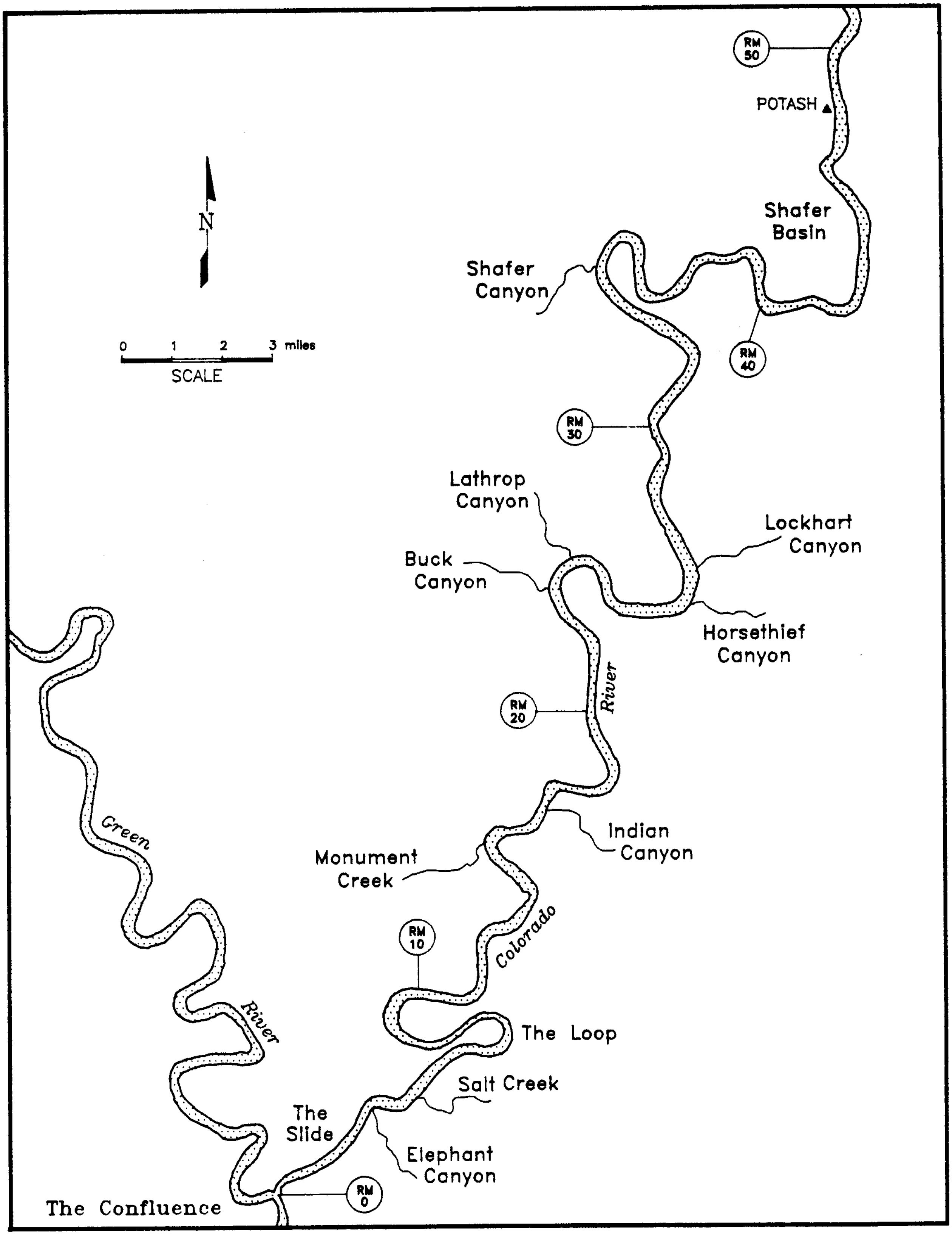


Figure 4. Detailed map of Region 2: Colorado River above confluence, RM 50.0 to 0.

Shafer Canyon and at the Upper Loop (RM 11.0), while vertical wall habitat was common at the Loop between RM 5 and 9.

A large rock slide at RM 1.5 on the Colorado River ("The Slide") had constricted the channel, forming a compression riffle and a large, deep eddy. Habitat at this locale was somewhat unique and diverse as compared to the rest of the region due to the presence of higher water velocities and deeper, turbulent eddies. Sampling in this location produced a variety of species including Colorado squawfish and humpback chub, as well as two razorback suckers in a previous investigation (Valdez et al. 1982).

Two major drainages flow into the Colorado River within this region including Indian Creek (RM 16.5) and Salt Creek (RM 3.6). Several smaller ephemeral drainages also empty into this region, including Lockhart, Shafer, Buck, Lathrop, and Elephant Canyons. Flow of the Colorado River in this region from 1985 to 1988 varied from about 2,000 to 42,000 cfs (See Section 2.6). The Colorado River above this region is not impounded by any large mainstem dams, but its flow is affected by irrigation, municipal, and industrial withdrawals as well as the flow of several major tributaries including the Gunnison and Dolores Rivers.

2.3 Region 3: Confluence to Brown Betty

This region (Figure 5) extended from the confluence of the Colorado and Green Rivers (RM 216.5) downstream to Rapid #1 (RM 212.5, 'Brown Betty Rapid'). It received the flow of both rivers and was characterized by a deep, swift, and voluminous channel. The gradient was steeper (5 feet per mile) than the areas above the confluence and the channel remained constricted by the talus slopes and small rock slides, except for the area of Spanish Bottom where the river widened before entering Cataract Canyon (Photos A-13 through A-16).

Fish habitat in this region was provided by deep runs, eddies, backwaters, cobble bars, and shorelines. Only two types of shoreline habitat were present including boulder talus and tamarisk/willow habitat. The boulder talus shoreline, which was interspersed with stretches of sand and silt, formed many eddies and slackwaters. Tamarisk/willow habitat was found primarily in the area of Spanish Bottom. Several backwaters formed in this region as flows dropped in early summer. Most were relatively small but deep and were habitat for YOY Colorado squawfish and chubs as well as many other species of native and non-native fishes.

The only tributary in this region of the study area was Lower Red Lake Canyon. Alluvial deposits from this ephemeral drainage were relatively extensive and formed a large, shallow cobble area below the mouth. Flows of the Colorado River below the confluence from 1985 to 1988 varied from 3,000 to 70,000 cfs (See Section 2.6).

2.4 Region 4: Cataract Canyon

This was the principal study region of this investigation (Figure 6). It encompassed 11 miles of deep channel from 'Brown Betty Rapid', Rapid #1 (RM 212.3) to the top of 'Ten Cent Rapid', Rapid #26, (RM 201.5). Depending on the level of Lake Powell, 24 to 26 major rapids occurred within this region. The gradient averaged 8 feet per mile with short sections of up to 30 feet per mile. This region of the Colorado River had the steepest gradient in the upper basin as well as the deepest water, recorded at 92 feet below Rapid #2 (RM 211.8) by Valdez et al. (1982). Before Lake Powell, Cataract Canyon was 41 miles long with 62 major rapids (Dellenbaugh 1908), and extended from its present upstream margin at RM 212 downstream to RM 171, about 1.5 miles above the confluence of the Dirty Devil River.

The character of the river within this region was dominated by rapids (Photos A-17 through A-24), and their nature was controlled by river flows. Fish sampling was best at flows of less than 10,000 cfs,

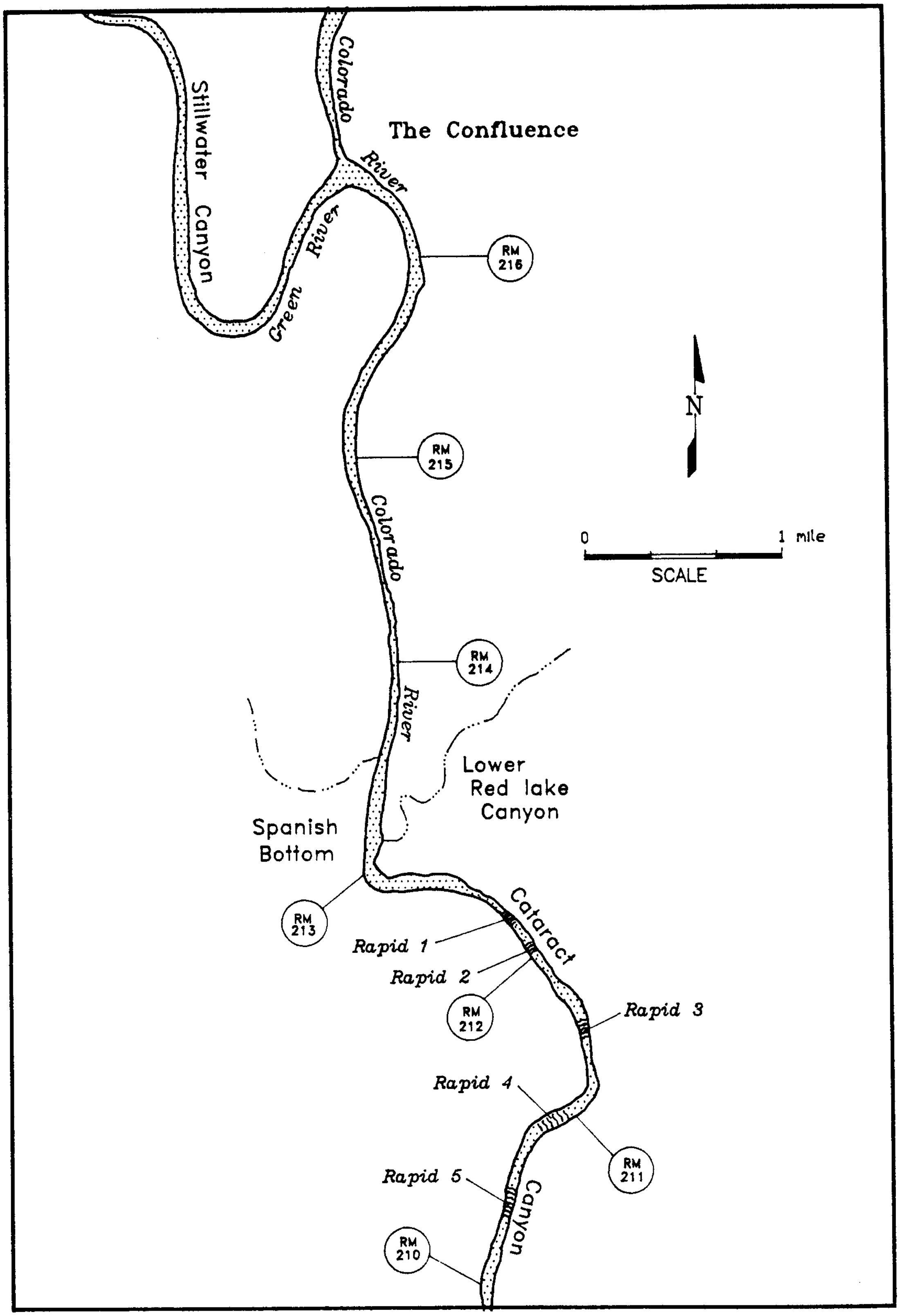


Figure 5. Detailed map of Region 3: Colorado River from confluence to Rapid #1, RM 216.5 to 212.5.

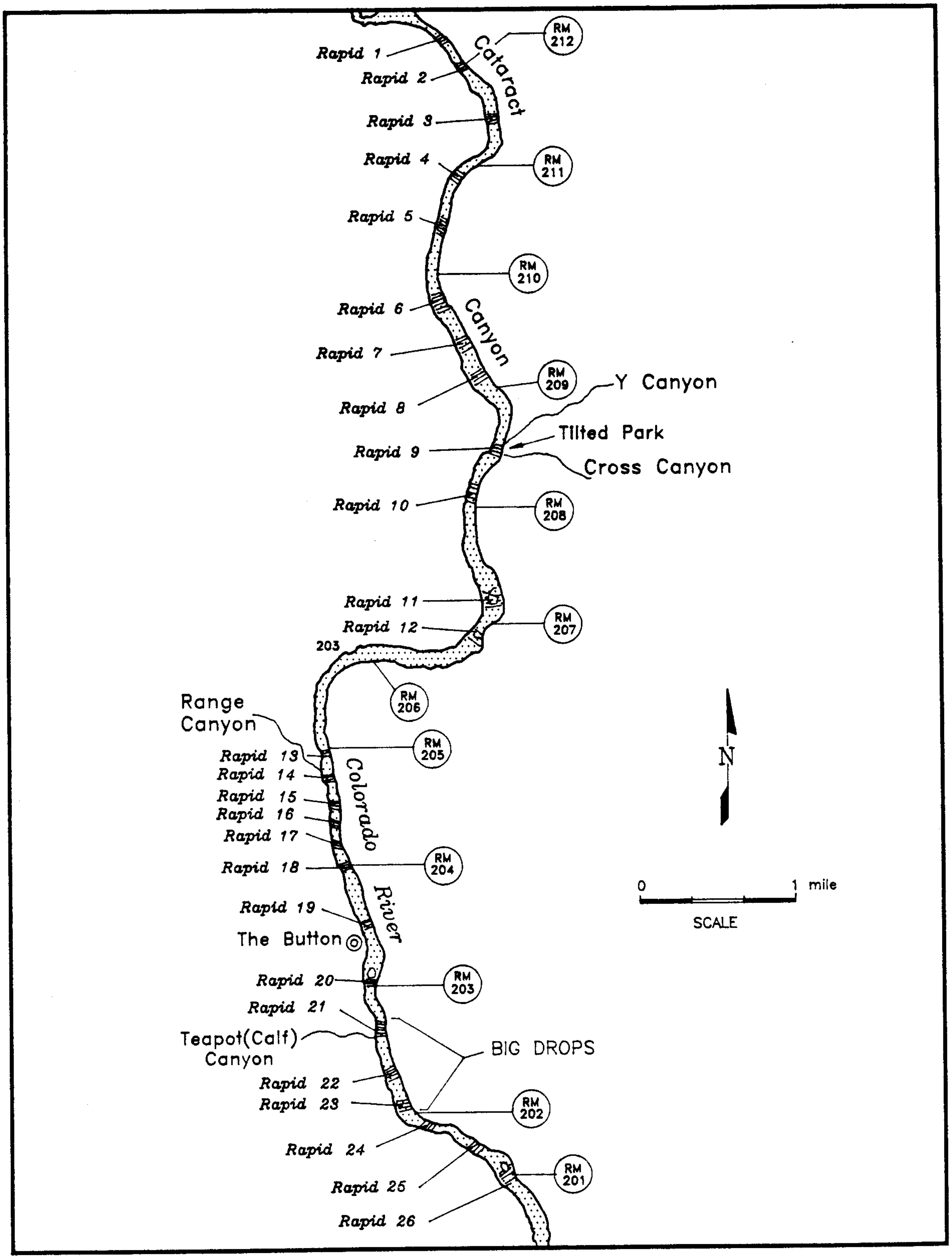


Figure 6. Detailed map of Region 4: Colorado River in Cataract Canyon, RM 212.4 to 201.5.

when most of the rapids were separated by short stretches of relatively calm water, ranging from several hundred yards to 1.2 miles in length. These reaches were often composed of large, deep shoreline eddies immediately below the rapid and sections of swift runs leading to the next rapid. Fish sampling was difficult at flows of 10,000 to 30,000 cfs, when the increased swiftness of the intervening runs and the strength of the eddies reduced available sampling area. Sampling was particularly inefficient at flows of over 30,000 cfs because of the swiftness and turbulence.

Two freshwater springs were located in this region providing additional habitat for fish. One was located at Rapid #3 (RM 211.5) and the other was at Rapid #11 (RM 207.2). At flows of under 10,000 cfs, a large side channel at each of these sites became cut off from the main channel forming a large isolated spring-fed pool and a spring-fed backwater at each location. The backwaters became isolated pools at flows of under 5,000 cfs but continued to support fish throughout the hot summer. Although young Colorado squawfish and humpback chub were commonly found in these pools, the icthyofauna was dominated by non-native species. These springs may have additional significance to the endangered fish. Tyus (1985) has suggested that the groundwater seepage hypothesis, proposed by Harden-Jones (1981), be considered as a possible olfactory imprinting mechanism for Colorado squawfish en route to spawning sites. Colorado squawfish may spawn in Cataract Canyon using the two identified springs for imprinting.

Because of the swiftness of most habitats in this region, most sampling was conducted in a 3-mile reach between Rapids #10 and 13. This area was informally known as "Cataract Lake", and at flows of under 10,000 cfs consisted of many eddies, one side channel, large cobble bars, and several backwaters. Below Cataract Lake was a 4-mile reach of closely spaced rapids that made sampling nearly impossible at levels of over 10,000 cfs. The few samples taken in this reach did not yield endangered fish, although the area contained favorable habitat. This region had the fewest backwaters of any in the study area; no backwaters occurred at flow levels greater than 20,000 cfs, while only five typically occurred at lower flows. Three of these backwaters were in Cataract Lake. Flows during this investigation ranged from about 3,000 to 70,000 cfs (See Section 2.6).

2.5 Region 5: Lake Powell Inflow

This region of the study area (Figure 7) was the transitional zone between the Colorado River and Lake Powell. It extended from 'Ten Cent Rapid' (RM 201.5) downstream to below Palmer Canyon (RM 195.0). The character of this area was dependent on the water level of Lake Powell. When the lake was full (surface elevation of 3,700 feet), its inundation effect reached upstream to the base of Rapid #25 ('Repeat Rapid'). At this lake level, Rapid #26, (Ten Cent Rapid) was mostly inundated, consisting of a series of small standing waves, and noticeable current usually extended downstream to Palmer Canyon. As the lake level receded in late summer and fall, Ten Cent Rapid emerged and noticeable current extended further downstream to Clearwater Canyon (RM 192.0).

This region underwent dramatic changes during the span of this investigation. Expansive silt/sand bars were deposited along the shoreline during the spring of 1983, 1984, and 1985 when the Colorado River Basin experienced record runoff in combination with a maximum lake level of 3708.34 feet above sea level on July 14, 1983 (Ferrari 1988). A large volume of sediment was transported by the Colorado River and deposited into this region during these years. Ferrari (1988) found average sediment depths in Lake Powell ranging from 1 foot in several channels to 182 feet in Cataract Canyon (RM 181, between Dark and Sheep Canyons). At the present sedimentation rate, it was estimated that it would take more than 700 years for sediment to fill Lake Powell to an elevation of 3700 feet.

The high lake levels allowed sediment deposits to reach higher levels on the shoreline. Beginning in 1986, the lake level subsided with more normal water years, and large silt/sand bars became exposed, particularly along the shoreline. These covered the former rocky shoreline, and filled small

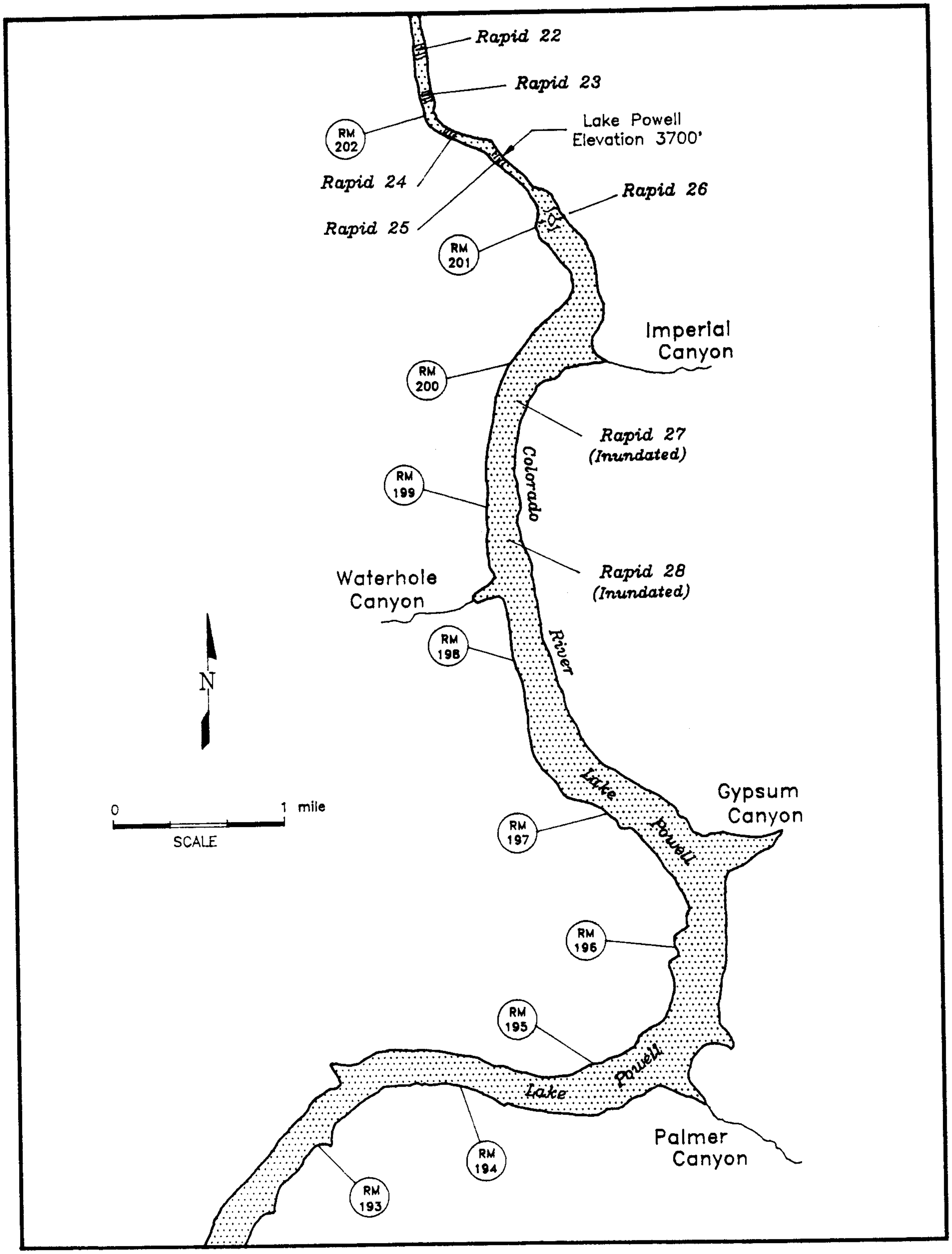


Figure 7. Detailed map of Region 5: Lake Powell Inflow, RM 201.4 to 195.0.

bays such as the outlet of Gypsum Canyon (Photos A-25 and A-26). For about the first year that these silt/sand bars were exposed, and while they were periodically inundated by fluctuating reservoir levels, they were soft mugmires (Photo A-27). As these dried, they were invaded by thick stands of tamarisk (Photo A-28). By 1987, most tamarisk stands were 3 to 5 feet tall, and had stabilized the silt/sand bars (Photo A-29 through A-32), much as this plant has done in the upper basin.

Fish habitat in this region changed dramatically over a period of about 5 years (1983-1988). The region was transformed from a slow flowing riverine environment lined with talus slopes to a riverine channel constricted in width by tamarisk-covered silt/sand bars. The few backwaters that formed as the silt/sand bars were developing were short-lived for only 1 or 2 years, and were largely eliminated by the stabilizing and constricting effect of the tamarisk invasion. The only backwaters in the region in 1988 were located between Rapids 25 and 26 (Photo A-30). These backwaters provided habitat for YOY Colorado squawfish and chubs as well as other native and non-native fishes (See Section 5.2.3). The low lake level of 1988 revealed that many sand bars in upper Lake Powell had been overgrown by tamarisk (Photos A-31 and A-32).

2.6 River Flows and Water Temperatures

Flow and temperature of the Green River, Colorado River, and Cataract Canyon for 1985-1988 are presented in Figure 8. It should be noted that the flows in Cataract Canyon in 1983 and 1984 were record highs of about 100,000 and 120,000 cfs, respectively. These two record wet years were followed by two more normal flow years (1985 and 1986), but peak and base flows remained high from high soil moisture content. Flows in Cataract Canyon in 1985 peaked at about 62,000 cfs, although base flows generally remained above 10,000 cfs. In 1986, flows peaked at about 70,000 cfs and base flows also remained around 10,000 cfs. The 2 years that followed -- 1987 and 1988 -- were relatively dry years with peak flows of about 40,000 and 28,000 cfs, and base flows of about 5,000 and 4,000 cfs, respectively.

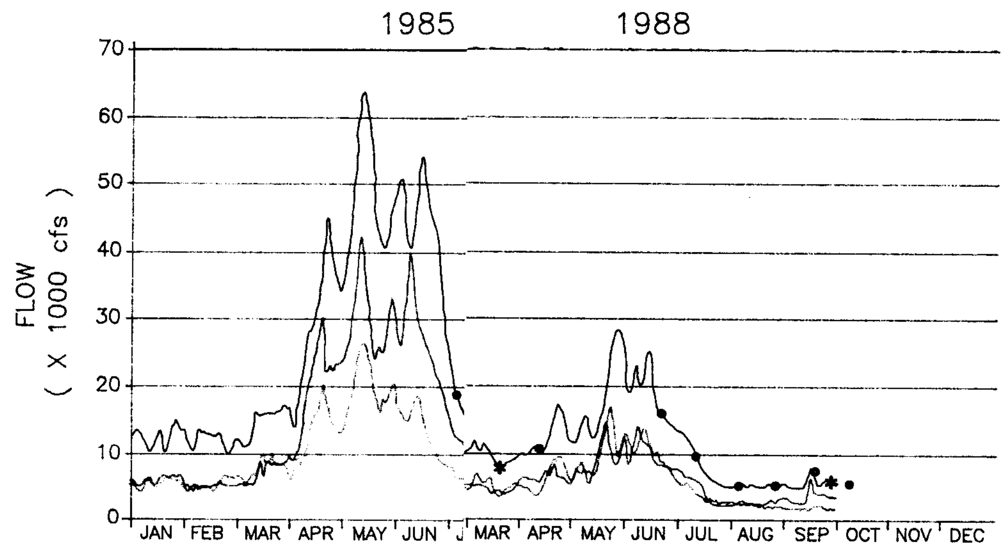
These flow scenarios had a marked impact on water temperatures. During the higher water years of 1985 and 1986, water temperatures did not reach 25°C until mid-July and early August, respectively. In 1987 and 1988, this temperature was recorded by late June. Since fish are poikilotherms, these different temperature regimes manifested dramatic differences in spawning, growth and perhaps overwinter survival of many species, including the endangered forms (See Section 5.1.1.3.4).

3.0 METHODOLOGY

3.1 Basic Study Design

The four basic elements of the Cataract Canyon Studies are presented in Figure 9. These studies were conducted for 4 years, from 1985 through 1988. Five study regions were established to stratify sampling by morphologically similar reaches of river. Four basic gear types were used in eight different habitat types. Since a complete analyses of all data partitions of this study design were too numerous and largely meaningless, data analyses were performed to address hypotheses directed at the specific study objectives.

The methodology used in the Cataract Canyon Studies was basically the same for all 4 years. Generally, a team of four biologists (2 Reclamation and 2 BIO/WEST) participated in either of two types of sample trips: (1) canyon trips or (2) confluence trips. **Canyon trips** were generally 7 days afield, and extended for about 100 miles from Potash or Mineral Bottom to Hite Marina on Lake Powell.


1985
1988
FLOW
(X 1000 cfs)
70
60
50
40
30
20
10
0
JAN
FEB
MAR
APR
MAY
JUN
J
MAR
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JUN
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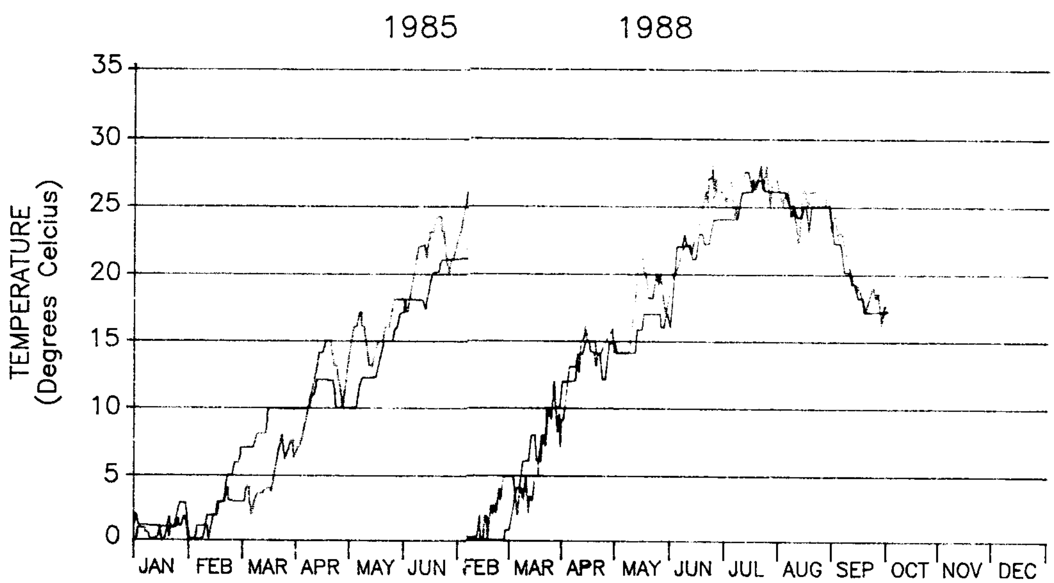
DEC


1985
1988
TEMPERATURE
(Degrees Celcius)
35
30
25
20
15
10
5
0
JAN
FEB
MAR
APR
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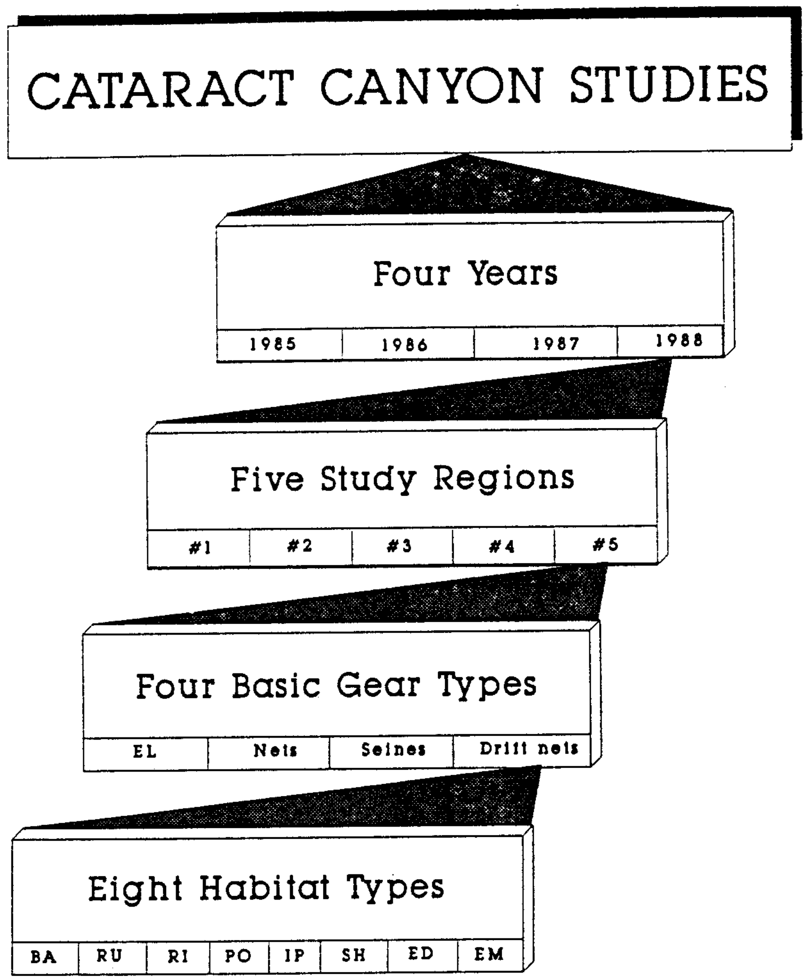


Figure 9. Basic study elements of the Cataract Canyon studies, 1985-1988.

Sample efforts were generally concentrated within Cataract Canyon, and included logistic support from Tag-A-Long Tours, a commercial river company in Moab. **Confluence trips** were usually 5 days afield, with sampling conducted only above the confluence of the Green and Colorado Rivers. Flatbottom boats and sportboats were launched and taken out at either Potash or Mineral Bottom, and all logistics were handled by BIO/WEST. The number of canyon trips (six) each year was constant for all 4 years of the study. Except for one spring confluence trip each in 1987 and 1988, and one spring canyon trip in 1988, all sample trips were conducted during the post-runoff period, from late June to mid-October (Figure 8). Trips were conducted for one of five primary purposes identified in Table 1.

Launch sites were alternated in late summer to systematically sample larval and YOY Colorado squawfish in the lower Green River. The lower Colorado River was not sampled in the same manner because work on YOY was being performed by the FWS/Grand Junction Field Station. Trips 3 and 5, each in 1985, 1986, and 1987, were launched from Mineral Bottom to sample the lower Green River. In 1988, trips 1, 3, 5, 7 and 8 were launched from Mineral Bottom. All other trips were launched from Potash on the Colorado River. Thus, in the 4 years of study, 29 trips were conducted, including 11 launches from Mineral Bottom and 18 from Potash. Of these 29 trips, 25 were canyon trips and 4 were confluence trips.

Table 1. Purpose and dates of sample trips for the Cataract Canyon Studies, 1985-1988.

PRIMARY PURPOSE	YEAR 1985	1986	1987	1988
YOY/OS[a]	—	—	—	MAR 21-25
HB/SS[b]	—	—	APR 13-17	APR 11-16
CS+HB/SS[c]	JUL 10-15	JUL 11-17	JUN 23-29	JUN 21-27
CS+HB/SS	JUL 24-29	JUL 23-29	JUL 8-14	JUL 12-18
CS+HB/SS CS+HB/YOY[d]	AUG 7-11	AUG 12-18	JUL 28-AUG 3	AUG 2-8
CS+HB/YOY	AUG 24-29	AUG 26-SEP 1	AUG 17-23	AUG 24-30
HB/SS	—	—	SEP 8-12	—
CS+HB/YOY	SEP 21-26	SEP 15-22	SEP 19-25	SEP 15-21
CS/MON[e] HB/SS	—	—	—	SEP 26-30
CS+HB/YOY	OCT 8-13	SEP 30-OCT 6	OCT 6-12	OCT 6-12

a *YOY/OS = assess overwinter survival of YOY Colorado squawfish above the confluence.*
b *HB/SS = locate concentrations of chubs and determine if reproduction is occurring.*
c *CS+HB/SS = locate spawning sites of Colorado squawfish and humpback chub by electrofishing, gill netting, and larval drift nets through the entire study area.*
d *CS+HB/YOY = sample for YOY, juvenile and adult Colorado squawfish and humpback chub through the entire study area.*
e *CS/MON = assist UDWR in ISMP for YOY Colorado squawfish from Mineral Bottom and Potash to the confluence.*

Four motorized hypalon rafts were used, including one 18-foot Riken Havasu, one 17-foot Riken Havasu, one 17-foot Achilles sportboat, and a 23-foot J-rig from Tag-A-Long Tours (Photos A-33 through A-40). The Havasus were powered by XD-25 hp Mercury outboards, and were used for fish sampling craft as described later in this report. The 23-foot J-rig was powered by twin 20 hp Mercury outboards, and was used as a support craft. The Achilles was powered by a 40 hp Yamaha outboard. This craft was first used in 1987 to decrease travel time to and from the principal study area, to provide greater mobility in swift whitewater sections, to expand sample areas, and to provide the capability for quickly transporting endangered fish live from the area, in concurrence with the 'Bonytail Protocol' (USFWS 1987). These four rafts were used on all canyon trips. Craft used on confluence trips included 16 and 14-foot aluminum Jon boats powered by 25 or 35 hp Mercury outboards, as well as the previously described Achilles.

Sampling was conducted where possible. Within Cataract Canyon, sampling often had to be confined to the less turbulent water between rapids. Since the motorized rafts were unable to ascend the larger rapids, sampling was concentrated in the section of river accessible from camp sites between rapids. Use of the Achilles starting in 1987 facilitated access to some areas that were not sampled in 1985 and 1986.

3.2 Data Collection and Storage

All data collected in the field were recorded on data forms recommended by Reclamation from the FWS's ISMP. The standard field data sheet was modified by BIO/WEST for this investigation and data codes were used that were consistent with the Upper Colorado River Basin Database Codes (USFWS 1987). The data were then stored in the database management system, dBASE III+, to facilitate storage, access, and analyses as well as to provide data compatible with the computer system and format used by Reclamation and FWS. The standard field data sheet is presented in Appendix C. A printout of all the data collected by this investigation, together with computer diskettes containing the corresponding dBASE III+ files was assimilated as The Cataract Canyon Database and is available from BIO/WEST as a supplement to this report.

3.3 Sampling Gear

Nine types of sampling gear were used in this investigation. A brief description of each is presented in Table 2. The standard sample gears for every trip were electrofishing, gill nets, trammel nets, and seines. Drift nets were used only in June and July of 1985, 1986, and 1987 to capture drifting larval fish from recent spawning activity. Other gear types such as dip nets, kick screens, minnow traps, and hoop nets were tried at various locations to sample specific habitats or conditions.

Table 2. Description of fish sampling gear used in the Cataract Canyon Studies, 1985-1988.

GEAR	CODE	DESCRIPTION
Electrofishing	EL	220-volt DC with Coffelt VVP-15 on 18' Havasu raft
Gill Net	GB	150'x 4' net with 1.5" mesh
	GF	150'x 4' floating net with 1" mesh
	GM	100'x 6' net with 2" mesh
	GN	100'x 6' net with 2.5" mesh
	GP	150'x 4' experimental net with 0.5, 1, 1.5, 2, 2.5" mesh
Trammel Net	TI	50'x 5' net with 1.5" and 10" mesh
	TJ	TI with brailes used as a float net
Seine	SA	10'x 4' with 1/8" delta mesh
	SB	15'x 4' with 1/4" delta mesh
	SE	10'x 4' with 1/16" delta mesh
Drift Net	DR	Larval drift net 10' long with 12"x 18" opening and with 560 micron Nitex plankton netting
Dip Net	DN	long handled dip net with 560 micron mesh
Kick Screen	KS, MU	4'x 3' net with 1/32" mesh with brailes
Minnow Trap	MT	standard commercial minnow funnel trap
Hoop Net	FY	fyke net with 3' diameter hoop and short wings

The numbers of fish by species and age category were recorded on field data sheets at the end of each sample effort. As with all sample efforts, each fish was classified into one of four age categories; (1) larvae = LAR, fish without complete muscle and fin development and either a yolk sac or yolk slit present; consistent with the Larval Fish Laboratory (1987) definition, (2) young-of-the-year = YOY, postlarvae less than one calendar year of age, (3) juvenile = JUV, immature fish greater than one year of age, and (4) adult = ADU, sexually mature fish.

A summary of sample efforts associated with each general gear type by year is presented in Table 3, and a detailed breakdown of sample effort by specific gear type for each year is presented in Tables D-1 through D-4.

Table 3. Summary of fish sample efforts by year.

YEAR CATEGORY	YEAR			
	1985	1986	1987	1988
Electrofishing Runs	71	95	170	140
Gill Net Sets	106	180	452	388
Trammel Net Sets	86	142	129	158
Seine Hauls	191	137	204	318
Larval Drift Net Sets	62	132	116	0
Dip Nets	3	0	0	0
Kick Screens	2	4	8	1
Minnow Trap Sets	0	26	0	0
Hoop Net Sets	0	0	0	9

3.3.1 Electrofishing

Electrofishing was used primarily to sample adults and juveniles along shorelines. A 220-volt DC system was used from the 18-foot Havasu raft (Photo A-41). The system was powered by a 4.5-kilowatt EMS Honda generator, and controlled by a Coffelt VVP-15 variable voltage pulsator. The normal operating level was 180-220 volts and 6-12 amps. Three-pronged anodes of 1/4-inch stainless steel braided cable were used. Efforts were made to replace the cable anodes with spherical anodes in light of the concern over possible injury to fish from electrofishing (Carouthers and Sharber 1988). The swiftness of most habitats in Cataract Canyon hampered efficient electrofishing using the spherical electrodes primarily because of the drag resistance which hung the spheres on rocks and prevented accurate steering of the boat.

Throughout this investigation, only the three principal BIO/WEST biologists operated the electrofishing system. Each exercised much care in monitoring voltage and amperage levels as well as fish reaction during each electrofishing operation. Ill effects were seen with only two fish. One was an adult flannelmouth sucker that appeared to have a spinal injury, and the second was a juvenile Colorado squawfish that received overexposure to the anode. The actual cause of death for this fish was not known. Other than these two fish, no adverse effects were observed with fish captured by electrofishing. In other studies (Valdez and Nilson 1982; Valdez and Masslich 1988) using similar electrofishing systems, no ill effects were seen even after fish caught by electrofishing were radiotagged and monitored over periods of several months.

Usually two netters dipped the fish from the bow of the raft, but at times only one netter was used. The actual electrofishing time was recorded for each sample directly from the timer on the VVP-15 in order to compute catch per unit effort (CPE) for each species within each sample. An average CPE (number of fish caught per 10 hours of actual electrofishing time) was then calculated for each species using the CPE's of each sample, including zeros, where the species was not captured in a given sample. All netted endangered fish as well as the native flannelmouth and bluehead suckers, roundtail chub and game species such as striped bass and walleye were measured and weighed.

3.3.2 Gill and Trammel Nets

Gill and trammel nets were used to sample adults and juveniles in eddies, pools, and slow runs (Photo A-42). Five mesh sizes of gill nets were used, including 1.5, 2.0, and 2.5-inch mesh, as well as a net with large floats for surface sets, and experimental gill nets. The experimental nets yielded numerous small chubs of a size not captured by other nets and proved most valuable in assessing size distribution. The trammel nets used were 50 feet long, 5 feet deep, and had 1.5-inch inside bar mesh and 10.0-inch outside mesh. All the nets were set and retrieved from the 17-foot Havasu raft or the 17-foot Achilles. When water temperature was warmest (>20°C) in July and August, each net was set for no longer than 2 hours to minimize stress on the netted fish. After temperature cooled in September and October (<20°C), some nets were set for up to 4 hours. CPE was computed for each species for each sample as the number of fish caught per 100 linear feet of net per 100 hours. Average CPE was then calculated using the CPE's for each species from each sample, including zeros, where the species was not captured in a given sample.

3.3.3 Seines

Small-mesh seines were used to sample larvae, YOY, and juveniles primarily in backwaters, shorelines, isolated pools, and small eddies. The seines were 10 feet long and 4 feet deep, with either 1/16 or 1/8-inch delta mesh (Photos A-43 and A-44). The smaller mesh seine was used when larvae and small YOY were present, and the larger mesh seine was used following the growth of these fishes. The surface area seined by each sample effort was measured and the CPE was computed for each species as the number of fish per 100 square meters of area sampled. An average CPE was computed for each species using the CPE's from each sample, including zeros, where the species was not captured in a given sample.

3.3.4 Kick Screens

Kick screens were used in a few concavities and isolated pools where seines could not be used. Each screen consisted of a 4-foot length of 1/32-inch mesh screen tacked to two hand-held brailes. No CPE statistics were computed for this gear.

3.3.5 Drift Nets

Larval drift nets were used to capture larvae and YOY being transported downstream by river currents. These fine-mesh nets were designed from the prototypes developed by Haynes et al. (1985). Each net was 10 feet long with a 12 by 18-inch opening (Photos A-45 through A-48). The mesh was 560 micron Nitex plankton netting. Drift nets were placed in sets of four in water 3-4 feet deep along the shoreline. Most sets were left in the water for only 15 to 20 minutes to prevent clogging and backup from the large volume of detritus carried by the river. A Marsh-McBirney current meter was used to determine average velocity at the mouth of each drift net during the duration of the set; a reading was taken at the beginning of the set and one at the end. The total volume of water filtered by each net during a set was computed as the basis for estimating the density of drifting fishes. An average CPE was computed for each species using the CPE's from each drift sample, including zeros, where the species was not captured in a given sample. CPE was computed as the number of fish in 1000 cubic feet of water by using the following formula (Valdez et al. 1985):

$$N_e = (N/(A \times V_m \times T)) \times 1000$$

where:

N_e = estimated number of drifting fish in 1000 cubic feet of water,
N = actual number of fish recovered from a drift sample,
A = area of net opening in square feet (1.5 square feet),
V_m = average water velocity in feet per second at the net opening during the set, and
T = total time of set in seconds.

All sample material collected in these drift nets was preserved in 10% formalin and placed in labeled Ziploc[R] plastic bags for later sorting at the BIO/WEST laboratories. Preliminary identification was made of these fish and all samples were sent to the Larval Fish Laboratory (LFL) in Fort Collins, Colorado, for verification and further identification. In the laboratory, each rare fish was measured for total length and classified by developmental phase (protolarva, mesolarva, metalarva, juvenile); the nontarget fish were only classified by phase. The first three classifications of protolarva, mesolarva, and metalarva were combined in this study into the age category of larva, while those individuals termed "juveniles" by LFL were placed into the YOY category.

3.4 Measurements of Gila Specimens

Because of the morphological variation in the genus *Gila* of the Upper Colorado River Basin, each juvenile and adult chub captured was photographed on a white background marked with a 1-cm grid pattern. Also, the following meristics were measured using calipers, and counts were made on each chub longer than 200 mm (Figure 10): (1) total length, (2) fork length, (3) distance between insertion of pectoral and pelvic fin, (4) nuchal depth, (5) minimum caudal peduncle depth, (6) caudal peduncle length, (7) head length, (8) length of dorsal fin base, (9) length of anal fin base, and (10) dorsal and anal fin ray counts. These measurements are recommended by FWS in the ISMP. Additionally, the following meristics were recorded: (11) maximum caudal peduncle depth, (12) maximum body depth, and (13) snout length. Each fish was also weighed in grams. These meristics were used in principal components analysis (Humphries et al. 1981; Kim and Mueller 1978) as a tool in segregating distinct forms of *Gila*.

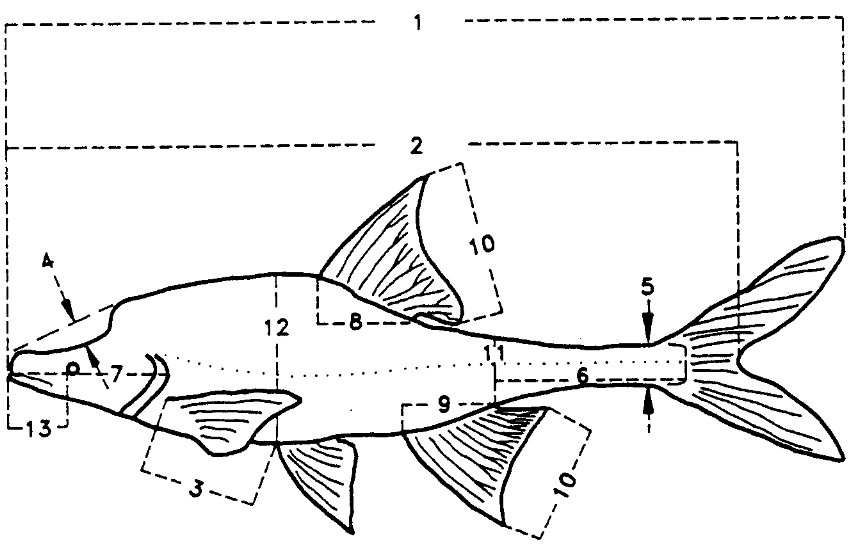


Figure 10. Morphometric measurements taken from each chub (*Gila* spp.) longer than 200 mm.

3.5 Hatching Dates of YOY Colorado Squawfish

In order to gain a better understanding of the environmental factors that influenced hatching success and survival of YOY Colorado squawfish, hatching dates were back-calculated for larvae and YOY using the length/age regressions developed by Haynes et al. (1985). The relationships are as follows:

REGRESSION A: For fish with a total length (L) of less than 22 mm:

$$\text{Age} = -76.7105 + 17.4949L - 1.055L^2 + 0.0221L^3 \quad (r^2 = 0.99)$$

REGRESSION B: For fish with a total length (L) of 22.0 to 47.0 mm:

$$\text{Age} = -26.6421 + 2.7798L \quad (r^2 = 0.99)$$

4.0 RESULTS

4.1 Summary of Fish Composition

A total of 31 species of fish, representing 11 families, were captured in the study area from 1985 to 1988 (Table 4). Of the 31 species, 23 were non-native (introduced), and only 8 were native to the Colorado River System (Tyus et al. 1982). The non-native species made up 95% of the catch, while the natives made up only 5%. Of the 8 natives, 6 were endemic (Colorado squawfish, humpback chub, bonytail, razorback sucker, roundtail chub, and flannelmouth sucker), and 2 were native but not endemic (bluehead sucker and speckled dace). The three endangered species (Colorado squawfish, humpback chub and bonytail) made up only 3% of the fish captured during these investigations. A discussion of each of the 31 species is presented in Appendix B.

When the numbers of fish caught in all 4 years and by all gears were summed, five species accounted for 90% of the catch (Figure 11). These included the red shiner, sand shiner, channel catfish, carp, and fathead minnow, all introduced species. Red shiners alone accounted for nearly 50% of the catch, sand shiners for 21%, and channel catfish, carp and fathead minnows for 9, 6, and 5%, respectively.

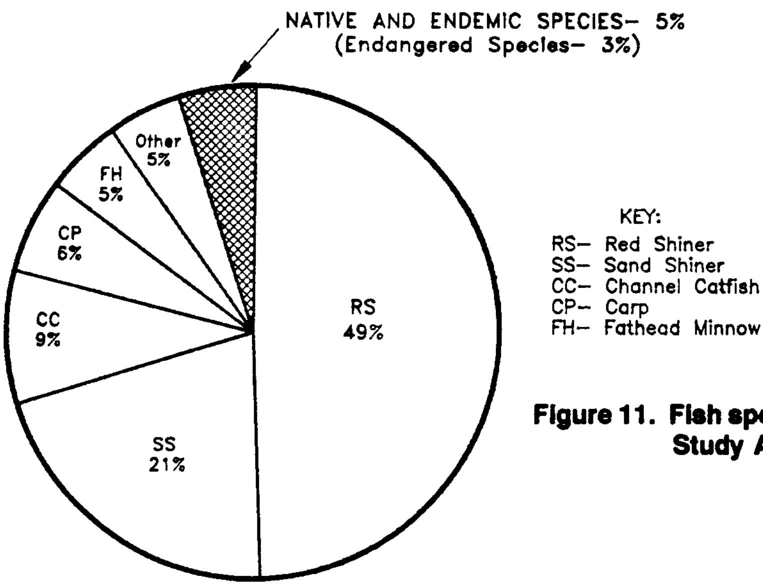


Figure 11. Fish species composition in the Cataract Canyon Study Area, 1985-1988.

Table 4. Fish species encountered in the Cataract Canyon Studies, 1985-1988.

SPECIES CODE	COMMON NAME	SCIENTIFIC[a] NAME	STATUS[b]
Family: Catostomidae (suckers)			
BH	bluehead sucker	*(Catostomus discobolus)*	NA
FM	flannelmouth sucker	*(Catostomus latipinnis)*	EN
RZ	razorback sucker	*(Xyrauchen texanus)*	EN
WS	white sucker	*(Catostomus commersoni)*	NN
FB	flannelmouth x bluehead hybrid		
SU	unidentified sucker		
Family: Centrarchidae (sunfishes)			
BC	black crappie	*(Pomoxis nigromaculatus)*	NN
BG	bluegill	*(Lepomis macrochirus)*	NN
GS	green sunfish	*(Lepomis cyanellus)*	NN
LG	largemouth bass	*(Micropterus salmoides)*	NN
SM	smallmouth bass	*(Micropterus dolomieui)*	NN
Family: Cyprinidae (minnows)			
BM	brassy minnow	*(Hybognathus hankinsoni)*	NN
BT	bonytail	*(Gila elegans)*	EN
CP	common carp	*(Cyprinus carpio)*	NN
CS	Colorado squawfish	*(Ptychocheilus lucius)*	EN
FH	fathead minnow	*(Pimephales promelas)*	NN
HB	humpback chub	*(Gila cypha)*	EN
RH	roundtail x humpback intergrade		
RS	red shiner	*(Notropis lutrensis)*	NN
RT	roundtail chub	*(Gila robusta)*	EN
SD	speckled dace	*(Rhinichthys osculus)*	NA
SH	shiner (red and sand)		
SS	sand shiner	*(Notropis stramineus)*	NN
UC	Utah chub	*(Gila atraria)*	NN
CH	unidentified chub	*(Gila sp.)*	
UM	unidentified minnow		
Family: Cyprinodontidae (killifishes)			
PK	plains killifish	*(Fundulus zebrinus)*	NN
Family: Clupeidae (herringa)			
TS	threadfin shad	*(Dorosoma petenense)*	NN
Family: Ictaluridae (catfishes, bullheads)			
BB	black bullhead	*(Ictalurus melas)*	NN
CC	channel catfish	*(Ictalurus punctatus)*	NN
Family: Percidae (perches)			
WE	walleye	*(Stizostedion vitreum)*	NN

Table 4. (Continued)

SPECIES CODE	COMMON NAME	SCIENTIFIC NAME	STATUS[a]
Family: Poeciliidae (livebearers)			
GA	mosquitofish	*(Gambusia affinis)*	NN
Family: Esocidae (pikes)			
NP	northern pike	*(Esox lucius)*	NN
Family: Salmonidae (trouts)			
BR	brown trout	*(Salmo trutta)*	NN
KS	kokanee salmon	*(Oncorhynchus nerka kennerlyi)*	NN
RB	rainbow trout	*(Oncorhynchus mykiss)*	NN
Family: Serranidae (sea basses)			
SB	striped bass	*(Morone saxatilis)*	NN
UN	unclassified		

a Scientific names from Robins et al. 1980, except for Oncorhynchus mykiss.
b NA = native to the drainage, EN = endemic to the drainage, NN = non-native, introduced.

It is also noted that small numbers (fewer than 25) of the crayfish, *Orconectes virilis*, were found in the Colorado River above the confluence and in Cataract Canyon. These crustaceans may be invading this area since they were not reported below Grand Junction in 1981 (Valdez et al. 1982). They may pose an additional predation or competition threat to the young endangered fish.

4.2 Fish Composition by Year

As a percentage of total numbers by year, the eight native species made up only 3 to 11% of the catch, while the six endemics alone made up only about 3 to 8% of the catch (Table 5). The non-native fish accounted for 89 to 97% of all fish caught from 1985 to 1988. These results show that the native ichthyofauna of the mainstem Upper Colorado River Basin was overshadowed by non-native species in all years of this investigation.

Table 5. Number and percentage of native, endemic, and non-native fishes captured by year, 1985-1988.

ORIGIN	1985		1986		1987		1988	
	N[a]	P[a]	N	P	N	P	N	P
Native	935	4.41	1,215	9.65	2,634	10.81	2,702	3.11
(Endemic)	(827)	(3.90)	(1,012)	(8.03)	(1,764)	(7.24)	(2,477)	(2.85)
Non-Native	20,274	95.59	11,380	90.35	21,725	89.19	84,216	96.89
Totals:	**21,209**		**12,595**		**24,359**		**86,918**	

[a] N = number, P = percentage of total

The three endangered species (Colorado squawfish, humpback chub, bonytail) were present in low numbers during each year of the investigation (Table 6). From 1985 to 1988, 4348 Colorado squawfish, 108 humpback chub, and 14 suspected bonytail were captured. Only one razorback sucker (a federal candidate for listing) was found in 1988. These four species accounted for less than 6% of the fish captured in any given year of the study.

When all fish were summarized by year, five non-native species consistently made up most of the catch (Table 7). These included the red shiner, sand shiner, channel catfish, carp, and fathead minnow. Except for 1986, red shiners made up over 50% of the catch in all years. Relative numbers of all non-native cyprinids were down in 1986, indicating poor year classes of these species during the record runoff years of 1984 and 1985 (See Section 4.2.5).

Table 6. Numbers of endangered fish by species and age category captured by year, 1985-1988.

SPECIES AGE	1985	1986	YEAR 1987	1988	TOTAL
Colorado Squawfish					
LAR	156	91	111	27	385
YOY	357	606	834	1979	3776
JUV	4	48	69	54	175
ADU	4	4	2	2	12
TOTAL	521	749	1016	2062	4348
Humpback Chub					
LAR	1	8	0	2	11
YOY	7	4	4	4	19
JUV	1	2	11	42	56
ADU	2	3	6	11	22
TOTAL	11	17	21	59	108
Bonytail (suspected)					
LAR	0	0	0	0	0
YOY	1	0	0	0	1
JUV	0	0	1	6	7
ADU	1	1	1	4	6
TOTAL	2	1	2	10	14
Razorback Sucker					
LAR	0	0	0	0	0
YOY	0	0	0	0	0
JUV	0	0	0	0	0
ADU	0	0	1	0	1
TOTAL	0	0	1	0	1
GRAND TOTALS	534	767	1040	2131	4471

Table 7. Number and percentage of all fish species captured by year, 1985-1988.

Name Code	1985		1986		1987		1988		SUM	
	N[a]	P	N	P	N	P	N	P	N	P
BB	7	0.03	13	0.10	191	0.78	33	0.04	244	0.17
BC	1	<0.01	2	0.02	7	0.03	5	0.01	15	0.01
BG	0	0	0	0	1	0.01	0	0	1	<0.01
BH	34	0.16	61	0.48	228	0.94	142	0.16	465	0.32
BM	4	0.02	0	0	0	0	0	0	4	<0.01
BR	0	0	1	0.01	2	0.01	0	0	3	<0.01
BT	2	0.01	0	0	2	0.01	10	0.02	14	0.01
CC	4,381	20.66	2,125	16.87	2,851	11.70	3,421	3.94	12,778	8.81
CH	11	0.05	76	0.60	379	1.56	69	0.08	535	0.37
CP	2,861	13.49	1,271	10.09	2,290	9.40	2,036	2.34	8,458	5.83
CS	522	2.46	749	5.95	1,016	4.17	2,061	2.37	4,348	3.00
FB	0	0	0	0	0	0	3	<0.01	3	<0.01
FH	527	2.49	1,149	9.12	1,231	5.05	3,981	4.58	6,888	8.29
FM	233	1.10	193	1.53	596	2.45	263	0.30	1,285	0.89
GA	28	0.13	31	0.25	29	0.12	1	<0.01	89	0.01
GS	0	0	13	0.10	4	0.02	15	0.02	32	0.02
HB	11	0.05	17	0.13	21	0.09	59	0.07	108	0.07
KS	1	<0.01	0	0	1	0.01	0	0	2	<0.01
LG	16	0.08	18	0.14	23	0.09	13	0.01	70	0.05
NP	1	<0.01	1	0.01	0	0	3	<0.01	5	<0.01
PK	4	0.02	4	0.03	12	0.05	17	0.02	37	0.03
RB	0	0	0	0	1	0.01	1	<0.01	2	<0.01
RH	0	0	0	0	1	0.01	0	0	1	<0.01
RS	11,206	52.85	3,132	24.87	12,838	52.70	44,262	50.92	71,438	49.24
RT	60	0.28	53	0.42	128	0.53	79	0.09	320	0.22
RZ	0	0	0	0	1	0.01	0	0	1	<0.01
SB	81	0.38	2	0.02	119	0.49	40	0.05	242	0.17
SD	74	0.35	142	1.13	642	2.64	83	0.10	941	0.56
SH	0	0	1,107	8.79	31	0.13	5,365	6.17	6,503	4.48
SM	0	0	1	0.01	0	0	0	0	1	<0.01
SS	1,003	4.73	2,426	19.26	1,518	6.23	24,864	28.60	29,811	20.55
SU	0	0	0	0	78	0.32	3	<0.01	81	0.06
TS	108	0.51	0	0	10	0.04	56	0.06	174	0.12
UC	0	0	0	0	1	0.01	0	0	1	<0.01
UM	5	0.02	0	0	0	0	0	0	1	<0.01
UN[b]	1	<0.01	0	0	90	0.37	11	0.01	102	0.07
WE	27	0.13	7	0.06	15	0.06	21	0.02	70	0.05
WS	0	0	1	0.01	1	0.01	1	<0.01	3	<0.01
TOTAL	**21,209**		**12,595**		**24,359**		**86,918**		**145,076**	

a N = number, P = percentage of total.
b vials containing specimens were damaged in shipment to Larval Fish Lab.

Detailed summaries of the fish captured for each of the 4 years by trip are presented in Appendix E, Tables E-1 through E-4. These include an alphabetical list of species, and the number of larvae, young-of-the-year, juveniles, and adults of each. The total numbers by species are given, as well as the percentage of total catch.

4.2.1 Fish Composition in 1985

In 1985, the five most common species handled were the red shiner, channel catfish, carp, sand shiner and fathead minnow (Table 8). Colorado squawfish were the sixth most common with 2.46% of the catch. Red shiners made up over 52% of the catch, and were numerous to abundant in most sheltered shoreline habitats. The relatively high number of adults and low number of YOY suggests that 1985 and 1986 were weak year classes for this species. This may be attributed to a near record runoff that flushed non-natives from their protected habitats and delayed river warming in both years to produce adverse conditions for spawning. The relatively low catch of red shiners in 1986 (Table 8) supports this hypothesis of a weak 1985 year class. An analysis of year class strength and annual fish abundance for several non-native and native species is presented in Section 4.2.5.

The second most abundant species in 1985 was the channel catfish. The total and relative catch of this species increased in 1986 and then decreased through 1988. These data suggest that this species experienced a strong year class in 1986 but weak year classes in 1987 and 1988 (Table 8), opposite of what was seen for red shiners. The relatively low numbers of sand shiners and fathead minnows in 1985 and 1986 also suggests that, like the red shiner, these species were adversely affected by the high flows of 1984 and 1985. Yearly trends in abundance of carp were attributed to movement rather than reproductive success. Seasonal differences in abundance of carp in Cataract Canyon (high numbers in spring and early summer and low numbers in late summer) indicate movement by this species into the region to spawn. Since large schools of carp were seen annually in late June milling and leaping at the base of Rapid #23 (Big Drop 3), it appears that many of the carp in Cataract Canyon immigrated seasonally from Lake Powell to spawn (See Appendix B: Species Discussions). The numbers of fish that successfully ascended the rapids above Lake Powell were not determined.

Two species were caught in 1985 that were rather unexpected, an adult northern pike and an adult gravid female (395 mm TL) kokanee salmon. The northern pike was captured in the middle of Cataract Canyon (RM 206.5), Region 4; and the kokanee salmon was captured September 25, 1985 at the inflow to Lake Powell (RM 200.4), Region 5. Since northern pike have not been introduced into Lake Powell, their occurrence in this region was probably the result of extensive downstream movement from impoundments located several hundred miles upstream (See Appendix B: Species Discussions). The northern pike probably originated in one of three reservoirs in Colorado; Elk Head Reservoir (500 miles from Cataract Canyon) in the Yampa River drainage, Taylor Park Reservoir (400 miles away) on the Gunnison River, or Rio Blanco Reservoir (450 miles away) in the White River drainage. Kokanee salmon were first released in Lake Powell at Kane Creek in 1963 and at Wahweap Creek in 1964 (Gustaveson et al. 1985), although there are no reports of reproductive success (Personal communication with Glen Davis, UDWR, December 27, 1989). Thus, the kokanee salmon captured in the inflow probably originated in either Flaming Gorge Reservoir (400 miles away) on the Green River or from the Wayne Aspinal Units (350 miles away) on the Gunnison River.

4.2.2 Fish Composition in 1986

The five most common species in 1986 were the red shiner, sand shiner, channel catfish, carp and fathead minnow (Table 8). Unlike the other 3 years, the relative abundance of the red shiner did not overshadow the other species; in 1986, this species accounted for about 25% of the catch, whereas in the other years, it consistently made up over half of the catch. This indicates that the species experienced at least one poor year of reproduction, probably in 1985. The greater relative abundance of sand shiners and fathead minnows in 1986 indicates that these species had weak year classes in 1984 and 1985, with initial recovery in 1986.

Table 8. Number and percentage of all fish species by age category captured by year, 1985-1988.

	1985						1986						1987						1988					
Name Code	L[a]	Y	J	A	N	P	L	Y	J	A	N	P	L	Y	J	A	N	P	L	Y	J	A	N	P
BB	0	1	0	6	7	0.03	1	8	0	4	13	0.10	2	182	0	7	191	0.78	0	22	4	7	33	0.04
BC	0	0	0	1	1	<0.01	0	0	2	0	2	0.02	0	2	1	4	7	0.03	0	1	3	1	5	0.01
BG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.01	0	0	0	0	0	0
BH	0	26	5	3	34	0.16	38	5	2	16	61	0.48	56	34	44	94	228	0.94	0	26	36	80	142	0.16
BR	0	0	0	0	0	0	0	0	0	1	1	0.01	0	0	0	2	2	0.01	0	0	0	0	0	0
BT	0	1	0	1	2	0.01	0	0	0	0	0	0	0	0	1	1	2	0.01	0	0	6	4	10	0.02
CC	0	3,180	599	602	4,381	20.66	45	1,570	384	126	2,125	16.87	48	1,667	755	381	2,851	11.70	0	2,712	428	281	3,421	3.94
CH	0	8	0	3	11	0.05	12	59	3	2	76	0.60	0	347	31	1	379	1.56	8	32	26	3	69	0.08
CP	0	30	74	2,757	2,861	13.49	4	107	69	1,091	1,271	10.09	8	20	59	2,203	2,290	9.40	120	130	46	1,740	2,036	2.34
CS	0	513	4	4	521	2.46	91	616	28	14	749	5.95	111	834	69	2	1,016	4.17	27	1,979	54	2	2,062	2.37
FB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	<0.01
FH	0	218	156	153	527	2.49	11	789	195	154	1,149	9.12	99	674	319	139	1,231	5.05	147	1,119	1,865	850	3,981	4.58
FM	0	35	32	116	233	1.10	1	11	6	175	193	1.53	1	86	20	4	596	2.45	0	29	18	216	263	0.30
GA	0	14	2	12	28	0.13	1	4	8	18	31	0.25	0	5	19	5	29	0.12	0	0	1	0	1	<0.01
GS	0	0	0	0	0	0	0	10	3	0	13	0.10	0	2	0	2	4	0.02	0	8	4	3	15	0.02
HB	0	7	1	2	10	0.05	8	4	2	3	17	0.13	0	4	11	6	21	0.09	2	4	42	11	59	0.07
KS	0	0	0	1	1	<0.01	0	0	0	0	0	0	0	0	0	1	1	0.01	0	0	0	0	0	0
LG	0	11	4	1	16	0.08	0	16	2	0	18	0.14	0	20	3	0	23	0.09	0	2	11	0	13	0.01
NP	0	0	0	1	1	<0.01	0	0	0	1	1	0.01	0	0	0	0	0	0	0	0	0	3	3	<0.01
PK	0	0	2	2	4	0.02	0	0	0	4	4	0.03	0	1	5	6	12	0.05	0	3	0	13	17	0.02
RB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.01	0	0	1	0	1	<0.01
RH	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0.01	0	0	0	0	0	0
RS	0	2,021	4,233	4,952	11,206	52.85	515	663	666	1,288	3,132	24.87	969	5,316	2,476	4,077	12,838	52.70	0	8,269	21,589	14,404	44,262	50.92
RT	0	60	0	0	60	0.28	35	18	0	0	53	0.42	74	40	11	3	128	0.53	41	25	5	8	79	0.09
RZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.01	0	0	0	0	0	0
SB	0	0	46	35	81	0.38	0	0	0	2	2	0.02	0	6	27	86	119	0.49	0	0	25	15	40	0.05
SD	0	55	12	7	74	0.35	38	6	77	21	142	1.13	38	365	162	77	642	2.64	1	20	14	48	83	0.10
SH	0	0	0	0	0	0	0	879	175	53	1,107	8.79	2	29	0	0	31	0.13	0	1,850	3,465	50	5,365	6.17
SM	0	0	0	0	0	0	0	0	0	1	1	0.01	0	0	0	0	0	0	0	0	0	0	0	0
SS	0	296	88	619	1003	4.73	17	223	695	1,491	2,426	19.26	43	472	426	577	1,518	6.23	0	6,474	10,541	7,849	24,864	28.60
SU	0	0	0	0	0	0	0	0	0	0	0	0	3	74	1	0	78	0.32	0	2	0	0	2	<0.01
TS	0	0	12	96	108	0.51	0	0	0	0	0	0	0	0	0	10	10	0.04	0	0	0	56	56	0.06
UC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.01	0	0	0	0	0	0
UM	0	5	0	0	5	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UN[b]	0	1	0	0	1	<0.01	0	0	0	0	0	0	90	0	0	0	90	0.37	0	11	0	0	11	0.01
WE	0	0	0	27	27	0.13	0	0	0	7	7	0.06	0	0	0	15	15	0.06	0	0	0	21	21	0.02
WS	0	0	0	0	0	0	0	0	1	0	1	0.01	0	0	1	0	1	0.01	0	0	1	0	1	<0.01
TOTAL	0	6,482	5,270	9,451	21,209	100.00	817	4,988	2,318	4,472	12,595	100.00	1,545	10,181	4,442	8,191	24,358	100.00	346	22,718	38,185	25,868	86,918	100.00

[a] L = larva, Y = young-of-the-year, J = juvenile, A = adult, N = number, P = percentage of total. [b] vials containing specimens were damaged in shipment to Larval Fish Lab.

4.2.3 Fish Composition In 1987

In 1987, red shiners far outnumbered all other species, with over 52% of the catch (Table 8). This was probably the result of a recovering population in 1986 which reflected as a strong year class in 1987. This species showed a strong recovery in numbers just 2 years after low reproductive success brought about by the high water years of 1984 and 1985. The other four most common species in 1987 were channel catfish, carp, sand shiner, and fathead minnow. The Colorado squawfish was sixth in abundance with 4.17% of the catch.

Channel catfish experienced high reproductive success in 1987 that produced a strong year class. Larvae and YOY were numerous in 1987 along with juveniles of the 1986 year class. Sand shiners and fathead minnows, like red shiners, also showed higher numbers in 1987 in what appeared to be a recovery from low reproductive success brought about by the high flows of 1984. These data suggest that these three short-lived species (red shiner, sand shiner, fathead minnow) were very resilient to periodic adverse river conditions.

At least two species of the genus *Gila* had good reproductive success in 1987: roundtail chub and humpback chub. Young-of-the-year chubs were numerous to abundant in many backwaters in Regions 3, 4, and 5 during the summer of 1987. Most were classified as *Gila* spp. since field separation of YOY of the three species was not possible. The capture of 128 YOY chubs in a single seine haul on July 13, 1987 from a backwater located at RM 206.3 was evidence of the reproductive success of this year class.

The second of two adult kokanee salmon was captured in 1987. A ripe male (406 mm TL) was caught October 11, 1987 at RM 201.0 (See Appendix B: Species Descriptions)

4.2.4 Fish Composition In 1988

The total numbers of fish caught in 1988 were high perhaps because of the relatively low and stable flows and little precipitation that favored reproductive success by certain species and produced good sampling conditions. The low flow resulted in reduced velocities that allowed sampling in more areas, and the lack of rainfall resulted in debris-free waters that allowed the setting of more gill and trammel nets. Nevertheless, we believe the greater numbers of most species in 1988 is a true reflection of relatively higher densities.

In 1988, red shiners dominated the catch with nearly 51% (Table 8), as in 1987. But, in 1988, numbers of sand shiners were also high, and these two species combined made up nearly 80% of the fish composition. The next three most common species were the fathead minnow, channel catfish, and Colorado squawfish. Colorado squawfish were approximately as abundant as carp with just over 2% of the catch.

The reproductive success of chubs (roundtail, humpback, and *Gila* spp.) in 1988 was very low, in contrast to their success in 1987. In 1988, only 112 larvae and YOY were collected compared to 465 in 1987. The factors that produced this variable success are not evident, although it is noted that the magnitude of runoff and average monthly flow in 1988 were lower than in 1987. Magnitude and timing of runoff may affect reproductive success of this species since humpback and roundtail chubs spawn immediately after runoff (Valdez and Clemmer 1982; Kaeding et al. 1985).

4.2.5 Year Class Strength of Endemic and Non-Native Species

As previously discussed, following the record high water years of 1984 and 1985, it was noted that the densities of certain fish species in the study area were depressed when compared to past investigations (Valdez et al. 1982). Several investigators have suggested that high flows favor reproductive success by native fishes and suppress year class strength of non-natives (Joseph et al.

1977; Holden and Wick 1982; Valdez and Clemmer 1982; Wick et al. 1982). The Cataract Canyon Studies provided an excellent opportunity to test this hypothesis since the flows of 1984, 1985, and 1986 were high with delayed warming, followed by normal to low flows in 1987 and 1988 (Figure 8).

The densities of four non-native (red shiner, sand shiner, fathead minnow, channel catfish) and two native species (Colorado squawfish and chubs) were compared from 1985 through 1988 (Figure 12). Only seining data from backwaters were used to reduce variation in catch observed with other gears and combinations of gears. The densities of each species are presented as YOY, juveniles, and adults in numbers of fish per 100 m^2. The chubs were not identified to species because of the difficulty of distinguishing the YOY, but most were probably humpback chub with a few roundtail chub.

Red shiners, sand shiners, and fathead minnows all exhibited their weakest year class in 1985, following the high flows of 1983 and 1984, and their strongest in 1988, when flows were low. These species showed increasing year class strength and total numbers with each low water year following the last high flow year of 1986, indicating a capacity to recover rapidly from suppressed numbers. Apparently these short-lived cyprinids, which mature in one year, were hindered from reproducing by the swift and turbulent water conditions and the delayed warming of the river during the high water years. Delayed warming may have prevented multiple spawning events, which are typical in low water years. The large backwaters, in which these species thrive, became large violent eddies at very high flows that probably flushed them into the main channel. Their rapid increase in numbers, over a 2 to 3-year period, indicates that control of these three species in the upper basin is not currently possible. Control measures are not now available to either discriminately eliminate the species from the system or impose a continued control to keep their numbers low. A one-time control to reduce numbers would not be effective since these species have a demonstrated ability to rebound in 2 to 3 years.

The concurrent decrease in year class strength of Colorado squawfish after 1986 indicates that either the low water years produced poor reproductive success or the higher densities of non-native species decreased survival through increased competition and predation. The case for good reproductive success of Colorado squawfish in high water years is not fully supported since the highest flows of 1985 and 1986 produced weak and strong year classes, respectively. The apparent relationship between reproductive success and flow or temperature suggests that the YOY in this area originated from several areas with different spawning cues (See Section 5.1.1.3.2), and that much needs to be learned about spawning and flow relationships for this species.

The weak year classes of chubs in 1985 and 1986 followed by a strong year class in 1987 suggests that this group of fish responded similarly to the red shiners, sand shiners, and fathead minnows. However, since the weakest year class of chubs was seen in the lowest water year of 1988, it appears that reproduction by this species is also adversely affected by very low flows.

4.3 Fish Composition by Region

As a percentage of total numbers by region, the non-native fishes accounted for 80 to 99% of the fish caught (Table 9). The eight native species made up less than 1 and up to 19% of the catch, while the six endemics alone were 1 to 6% of the catch. Thus, the native ichthyofauna of the mainstem Upper Colorado River Basin was overwhelmed by the numbers of introduced species in all regions, particularly Region 5 (Lake Powell Inflow).

The three endangered species (Colorado squawfish, humpback chub, bonytail) and the one federal candidate species (razorback sucker) were present in greatest numbers in Regions 1 and 4 (Table 10). Highest numbers of larval, YOY, and juvenile Colorado squawfish were captured in Region 1 (Green River), while the catch of juveniles was evenly distributed among Regions 2, 3 and 4. The greatest number of adults were in Regions 3 and 4.

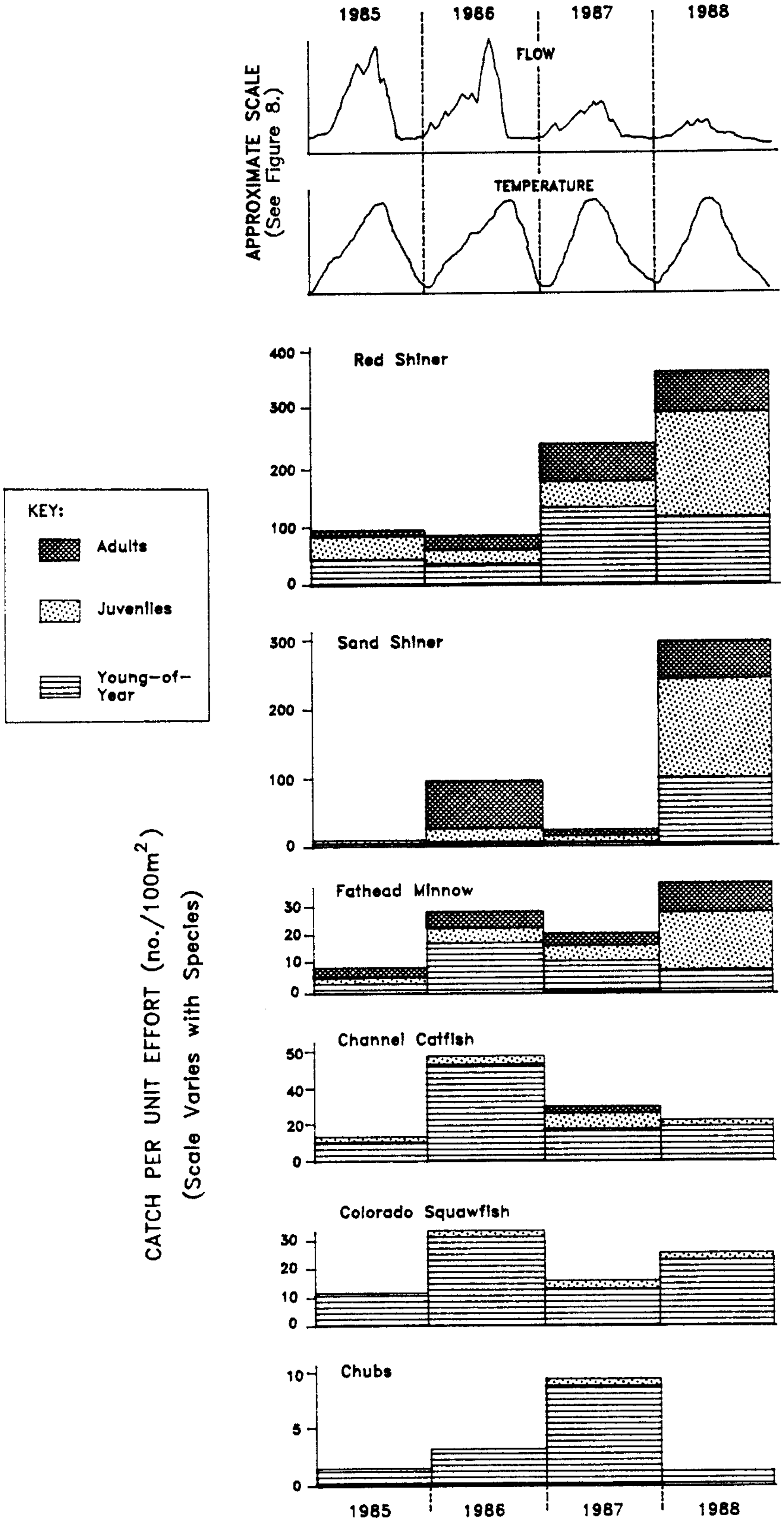


Figure 12. Catch rates of six fish species by age category in backwaters, 1985-1988.

Table 9. Number and percentage of endemic, native, and exotic fish species by region, 1985-1988.

ORIGIN	Region 1 N	Region 1 P	Region 2 N	Region 2 P	Region 3 N	Region 3 P	Region 4 N	Region 4 P	Region 5 N	Region 5 P
Native	2,712	19.36	349	6.77	805	4.16	3886	5.51	268	0.75
(Endemic)	259	(1.85)	294	(5.70)	662	(3.42)	2848	(4.04)	215	(0.60)
Non-Native	11,293	80.64	4,809	93.23	18,525	95.84	66,591	94.49	35,787	99.25
TOTALS	**14,005**	**100.00**	**5,158**	**100.00**	**19,330**	**100.00**	**70,477**	**100.00**	**36,055**	**100.00**

Table 10. Numbers of endangered fish by age category captured by region, 1985-1988.

SPECIES AGE	REGION 1	2	3	4	5	TOTAL
Colorado Squawfish						
LAR	266	1	37	60	21	385
YOY	2,132	50	355	1,149	90	3,776
JUV	65	32	36	38	4	175
ADU	1	1	3	5	2	12
TOTAL	**2,464**	**84**	**437**	**1,246**	**117**	**4,348**
Humpback Chub						
LAR	0	2	1	7	1	11
YOY	4	0	1	13	1	19
JUV	0	2	2	52	0	56
ADU	0	2	0	21	0	22
TOTAL	**4**	**6**	**4**	**92**	**2**	**108**
Bonytail (tentative)						
LAR	0	0	0	0	0	0
YOY	1	0	0	0	0	1
JUV	0	0	0	7	0	7
ADU	0	0	0	6	0	6
TOTAL	**1**	**0**	**0**	**13**	**0**	**14**
Razorback Sucker						
LAR	0	0	0	0	0	0
YOY	0	0	0	0	0	0
JUV	0	0	0	0	0	0
ADU	0	1	0	0	0	1
TOTAL	**0**	**1**	**0**	**0**	**0**	**1**
GRAND TOTALS	**2,469**	**91**	**441**	**1,351**	**119**	**4,471**

The greatest numbers of humpback chub were found in Region 4. The capture of four YOY in Region 1; two larvae and two juveniles in Region 2, and one larvae, one YOY and two juveniles in Region 3 indicates that either very limited reproduction was occurring in these regions or small numbers of young fish were being transported from populations upstream such as Westwater Canyon and Black Rocks on the Colorado River, or Desolation/Gray Canyons on the Green River. The numbers of humpback chub transported into the region were probably not significant to the population of Cataract Canyon. The cross section of sizes of humpback chub in Region 4 supports the hypothesis that a viable population of this endangered fish occurs in Cataract Canyon (See Section 5.1.2).

When summarized by region, five non-native species consistently made up most of the catch (Table 11). These included the red shiner, sand shiner, channel catfish, carp, and fathead minnow. Except for Region 2 where sand shiners outnumbered all species, red shiners dominated the ichthyofauna of the study area (See Section 4.3.6). The Colorado squawfish was second in abundance in Region 1.

The occurrence and abundance of some species in certain regions was a reflection of the availability of certain habitats, their proximity to permanent fish refugia, and to some degree sampling effort (See Appendix D). For example, black bullhead were most numerous in the large stable backwaters of Regions 3 and 4, perhaps because this species was transported downstream during runoff from the Colorado and Green Rivers (See Appendix B: Species Descriptions). Nearly 200 YOY were found in Region 4 in a tightly schooled cloud in a large spring-fed isolated pool at RM 207.2 confirming reproduction by black bullhead in Cataract Canyon. Although the black crappie found in Region 5 most likely originated in Lake Powell, the four specimens found in Regions 3 and 4 probably came downstream from stock ponds in either Grand Junction or Moab; it is unlikely that these fish swam upstream past the large rapids of Cataract Canyon. This is also the explanation offered for the occurrence of green sunfish and largemouth bass in all Regions 1-4. A full explanation of the occurrence of each species in the study area is offered in Appendix B: Species Descriptions.

A summary of the numbers and percentages of fish species caught by the five study regions during each of the 4 years is presented in Tables E-5 through E-9 and described in the following sections. This regional analysis was performed because the physical nature and thus the fish habitats of each of the five regions differed (See Section 2.0 - Study Area).

4.3.1 Region 1: Green River above the Confluence

The lower 50 miles of the Green River had the highest density of YOY Colorado squawfish of any region sampled in this investigation (See Section 5.1.1.3.1) with 58% or 2398 of the 4161 larval and YOY Colorado squawfish captured (Table 10). These fish are believed to have been spawned locally as well as transported from upstream spawning sites, although the proportion of each could not be determined. Colorado squawfish were the second most common species next to red shiners, and accounted for 15 to 30% of all the fish captured in this region during each of the 4 years (Table E-5). Only four YOY, tentatively identified as humpback chub and one YOY, tentatively identified as a bonytail were captured in this region.

The species that was consistently abundant in Region 1 was the red shiner which made up about 65% of the catch. Noticeably low in numbers, however, was the sand shiner, with less than 3% of the total numbers. This species appeared to be much more numerous in the lower Colorado River (Region 2) than in the lower Green River, possibly because the substrate was predominantly sand in the former and silt in the latter. The other species of abundance in this region included fathead minnows and channel catfish.

Table 11. Number and percentage of all fish species by region, 1985-1988.

NAME CODE	REGION 1 N	REGION 1 P	REGION 2 N	REGION 2 P	REGION 3 N	REGION 3 P	REGION 4 N	REGION 4 P	REGION 5 N	REGION 5 P	SUM N	SUM P
BB	5	0.04	3	0.06	18	0.09	215	0.31	3	0.01	244	0.17
BC	0	0	0	0	2	0.01	2	0.01	11	0.03	15	0.01
BG	0	0	0	0	0	0	0	0	1	0.01	1	<0.01
BH	69	0.50	28	0.54	74	0.38	284	0.40	10	0.03	465	0.32
BM	0	0	4	0.06	0	0	3	0	0	0	4	<0.01
BR	1	0.01	1	0.01	0	0	0	0	1	0.01	3	0.01
BT	1	0.01	0	0	0	0	13	0.02	0	0	14	0.01
CC	687	4.91	229	4.44	1001	5.18	666	9.45	4,200	11.65	12,778	8.81
CH	9	0.06	13	0.25	28	0.14	443	6.29	42	0.12	535	0.37
CP	116	0.83	237	4.59	621	3.21	3339	4.74	4,245	11.77	8,558	5.90
CS	2,464	17.59	84	1.63	437	2.26	1,246	1.77	117	0.32	4,348	3.00
FB	0	0	0	0	1	0.01	2	0.01	0	0	3	0.01
FH	910	6.50	286	5.54	1,534	7.94	3,140	4.46	1,018	2.82	6,888	4.75
FM	112	0.80	169	3.28	161	0.83	813	1.15	30	0.08	1,285	0.89
GA	1	0.01	31	0.60	14	0.07	42	0.06	1	0.01	89	0.06
GS	5	0.04	2	0.04	13	0.07	6	0.01	6	0.02	32	0.02
HB	4	0.03	6	0.12	4	0.02	92	0.13	2	0.01	108	0.07
KS	0	0	0	0	0	0	0	0	2	0.01	2	<0.01
LG	0	0	9	0.17	28	0.14	16	0.02	17	0.05	70	0.05
NP	0	0	0	0	0	0	3	0.01	2	0.01	5	0.01
PK	5	0.04	2	0.04	9	0.05	15	0.02	6	0.02	37	0.03
RB	0	0	0	0	1	0.01	1	0.01	0	0	2	0.01
RH	0	0	0	0	0	0	1	0.01	0	0	1	<0.01
RS	9,041	64.56	1,650	31.99	11,174	57.81	30,157	42.79	19,416	53.85	71,438	49.26
RT	3	0.02	21	0.41	32	0.17	240	0.34	24	0.07	320	0.22
RZ	0	0	1	0.01	0	0	0	0	0	0	1	<0.01
SB	0	0	0[c]	0	0	0	40	0.06	202	0.56	242	0.17
SD	50	0.36	27	0.52	69	0.36	752	1.07	43	0.12	941	0.65
SH	119	0.85	2	0.01	549	2.84	5,706	8.10	127	0.35	6,503	4.48
SM	0	0	0	0	0	0	0	0	1	0.01	1	<0.01
SS	403	2.88	2,266	43.93	3,554	18.39	17,198	24.40	6,290	17.45	29,711	20.49
SU	0	0	0	0	3	0.02	27	0.04	0	0	30	0.02
TS	0	0	0	0	0	0	2	0.01	172	0.48	174	0.12
UC	0	0	0	0	1	0.01	0	0	0	0	1	<0.01
UM	0	0	0	0	0	0	5	0.01	0	0	5	0.01
UN[b]	0	0	90[b]	1.74	0	0	12	0.02	0	0	102	0.07
WE	0	0	1	0.02	0	0	3	0.01	66	0.18	70	0.05
WS	0	0	0	0	2	0.01	1	0.01	0	0	3	0.01
TOTAL	14,005		5,158		19,330		70,477		36,055		145,076	

a N = number, P = percentage of total.
b vials containing specimens were damaged in shipment to Larval Fish Lab.
c one sighted during electrofishing on September 28, 1988.

4.3.2 Region 2: Colorado River above the Confluence

In contrast to Region 1, Region 2 supported a much lower density of Colorado squawfish. Only 1%, or 51, of the 4161 larval and YOY Colorado squawfish captured from 1985 to 1988 were in this region (Table 10). Most of these fish were encountered close to the confluence. Also found near the confluence was the only razorback sucker captured during this entire investigation. The fish was caught August 11, 1987, in a riffle formed by the large cobble alluvium off the mouth of Salt Wash at RM 3.6.

Also in contrast to Region 1, the Colorado River above the confluence yielded more chubs; 6 humpback chub, 21 roundtail chub, and 13 *Gila* spp. This relatively greater abundance of chubs in Region 2 than in Region 1 was attributed to habitat differences, primarily substrate. The lower Colorado River above the confluence had some areas of vertical rock walls, overhanging ledges and talus slopes with rock substrate, a combination of habitat parameters apparently essential to chubs (Valdez et al. 1982). Nevertheless, the population of chubs in this region was probably limited by the predominant shifting sand substrate. In contrast, the lower Green River appeared to have as many deposits of rock substrate, but these did not often occur together with vertical rock structure to provide the full complement of habitat used by chubs.

The predominantly sand substrate of Region 2 probably also accounted for the relatively greater abundance of sand shiners. This substrate association is well documented (Pflieger 1975). Sand shiners were the most common species in Region 2 with nearly 44% of the catch (Table 11). Red shiners made up 32% of the catch and channel catfish, fathead minnows and carp were each 4 to 5%.

A notable record was the sighting of a juvenile striped bass in this region on September 28, 1988. Although not captured, it is one of only three records of this species in the upper basin above Lake Powell. This study also recorded two striped bass captured above Lake Powell in Cataract Canyon in 1988 and 1989 (See Section 4.3.4).

4.3.3 Region 3: Confluence to Brown Betty

The fish composition of Region 3 reflected that of both Regions 1 and 2, largely because of the physical nature of the area that exhibited characteristics of both the lower Green and Colorado Rivers and its location immediately below their confluence. Species composition and abundance in this area were an extension of similar fish habitat above the confluence. The substrate in this region was a combination of silt and sand with some rock deposits, and the shoreline was both tamarisk-invaded sand bars and talus slopes that created rock jetties.

The predominant species of this region was the red shiner with 58% of the catch (Table 11, Table E-7). Sand shiners, fathead minnows, channel catfish, and carp were also abundant, and together with red shiners comprised over 90% of the catch.

Region 3 supported numerous larval and YOY Colorado squawfish. Since only one possible spawning area (Lower Red Lake Canyon) was evident in this region, many of these fish were probably transported from the lower Green and Colorado Rivers. The larval and YOY Colorado squawfish captured in Region 3 accounted for about 10%, or 398 of the 4161 fish of this size caught during this investigation (Table 10).

Region 3 also supported a number of incidental non-native species that were encountered primarily in the large seasonal backwaters formed in lower Spanish Bottom in summer, fall, and winter. Small numbers of black crappie, largemouth bass, green sunfish, Utah chub, plains killifish, black bullhead, mosquitofish, and rainbow trout were apparently washed downstream from either the Green or Colorado Rivers during spring runoff to find shelter in these large backwaters.

4.3.4 Region 4: Cataract Canyon

The large numbers of humpback chub of various sizes and ages indicated the presence of a reproducing population of this endangered species in this region (Table 10, Table E-8). From 1985 to 1988, this region yielded 108 humpback chub as well as 14 fish tentatively identified as bonytail, indicating the possibility of an enclave of this species. A total of 240 roundtail chub were also captured in this region. The possible occurrence of all three species of chubs in Cataract Canyon is significant because it may be the only area of the Colorado River Basin in which the three congeneric species occur sympatrically. Confirmation of bonytail in Cataract Canyon may provide the only source of genetic material for the species from the upper basin (See Sections 5.1.2.2 and 5.1.3).

Cataract Canyon also supported moderate numbers of larval and YOY Colorado squawfish. This region yielded 29%, or 1209 of 4161 of the young fish captured (Table 10). Although some local spawning probably occurred, many of these fish were probably transported by currents from upstream spawning areas in the lower Green and Colorado Rivers, although the proportions could not be assessed. Young fish may also be transported downstream by spring runoff and rain-induced freshets. Large numbers of YOY Colorado squawfish were transported into this region in August 1988 by a large flood in Horse Canyon (RM 14.4) on the Green River. An estimated 500 YOY were found in a single backwater at RM 205.8 in Cataract Canyon.

The dominant fishes in Cataract Canyon (Region 4) were non-native cyprinids and channel catfish. Overall, red shiners averaged over 43% of the catch (Table 11). In all years but 1986, red shiners were the most common species with 31 to 47% of the catch (Table E-8). In 1986, a strong year class of channel catfish, combined with low reproductive success of cyprinids in 1984 and 1985, resulted in a predominance of channel catfish. Sand shiners, fathead minnows and carp were also prevalent each of the years of sampling (Table E-8).

Several species exhibited large fluctuations in numbers in Region 4 during the 4 years, including carp, bluehead suckers, and flannelmouth suckers. The large numbers of carp seen congregated below the last major rapid (Rapid #23) of Cataract Canyon in June of each year suggests that this species moved back and forth between Cataract Canyon and Lake Powell. The large numbers of ripe and gravid carp often seen in the early summer and the reduced total numbers in the fall indicate that they ascended from Lake Powell into Cataract Canyon to spawn and returned to the lake to overwinter. In spite of large numbers of ripe and gravid carp, very few young fish were seen, indicating low reproductive success for the species in Cataract Canyon and the Lake Powell Inflow. The fluctuation in numbers of bluehead and flannelmouth suckers in Cataract Canyon could not be explained, but it was hypothesized that these fish moved into the region from upstream areas during periods and years of low flow, when velocities and turbulence in the canyon were greatly reduced.

This region also yielded the only two striped bass ever captured above Lake Powell. One was a male juvenile (TL = 388 mm) caught on August 4, 1988 at RM 207.2, which was just above Rapid #12 or 5.2 miles above any previous upstream capture of this species (the base of Rapid #23, Big Drop 3, RM 202). A second male juvenile (TL = 362 mm) was caught on August 10, 1989 at RM 207.3. These fish represent the upstream-most capture of striped bass above Lake Powell. A third fish was sighted but not captured on September 28, 1988, in the Colorado River, 2.9 miles above its confluence with the Green River (See Section 4.3.2). These records indicate that very few striped bass have ascended the Colorado River above Lake Powell since their introduction into that impoundment in July 1974 (Personal communication with Wayne Gustafson, UDWR, December 1989).

4.3.5 Region 5: Lake Powell Inflow

Fish habitat in this region was dynamic and influenced by both the flow and turbidity of the Colorado River as well as by the level of Lake Powell. Species that predominated in upstream riverine habitats (red shiner, sand shiner, fathead minnow, channel catfish, and carp) were abundant as well as the species associated with lake environments (striped bass, walleye, largemouth bass, and threadfin shad) (Table E-9). Striped bass and walleye moved into this region in the spring and early summer to spawn. Striped bass and carp were seen congregated in large numbers in late June of each year at the base of Rapid #23 (Big Drop 3), but the numbers of fish successfully ascending these rapids was not determined. However, the increase in abundance of carp in Cataract Canyon in early summer indicates that this species was more successful in ascending the rapids than the striped bass; only three striped bass were caught or sighted during this investigation in August and September. It is possible that more fish were in Cataract Canyon during the peak of spawning in May and June, but high flows prohibited sampling at that time. Although the inflow region appeared suitable for a number of species, survival of young endangered fishes entering this region could be low because of this diversity of predators. Only 3%, or 111 of the 4161 larval and YOY Colorado squawfish captured in the Cataract Canyon Studies were caught in Region 5. Also only two young humpback chub were caught in this region, and no bonytail or razorback suckers were found.

The most unusual and unexpected species encountered in this region were two adult kokanee salmon. One gravid female (395 mm TL) was captured September 25, 1985 at RM 200.4, and one ripe male (406 mm TL) was captured October 11, 1987 at RM 201.0. A discussion of the possible origin of these fish was presented in Section 4.2.1 and Appendix B: Species Descriptions.

4.3.6 Comparative Regional Densities of Native and Non-Native Species

Regional densities of the six most common species found in backwaters are represented by year in Figure 13. Expressed as the number of fish per 100 m^2 of area seined, densities of all six species increased dramatically in a downstream direction; densities were lowest in the Green (Region 1) and Colorado Rivers (Region 2) above the confluence but increased sharply below the confluence (Region 3), through Cataract Canyon (Region 4), and into the Lake Powell Inflow (Region 5). The reasons for this density distribution are not entirely clear. It is reasonable to hypothesize that the large assemblage of fish found in Lake Powell probably congregate at inflow areas like Region 5 because of the constant shower of nutrients brought in by the Colorado River. Fish habitat in Region 5 was amenable to most species since it resembled a large slow-moving river. It is also possible that many fish species are transported downstream annually by river currents, particularly during spring runoff from the Green and Colorado Rivers. This does not suggest that the Lake Powell Inflow receives most of the fish from the upper basin, although the number of endangered fish that are brought into the area by spring runoff needs to be assessed.

Red shiners and sand shiners dominated the fish density in backwaters of all five regions. These species seemed to displace each other in the Green (Region 1) and Colorado (Region 2) Rivers above the confluence; red shiners dominated the Green River ichthyofauna where there were greater amounts of silt in the backwaters, and sand shiners dominated the Colorado River backwaters where the substrate was predominantly sand. Sand shiners also occurred in greater densities in Region 5, the Lake Powell Inflow, for probably the same reason.

The density of young Colorado squawfish was greatest in Regions 1 and 4. The young of this species were the second most common fish in the backwaters of Region 1, the lower Green River. The relative densities of red shiners, sand shiners, fathead minnows, and channel catfish in the backwaters of Regions 3, 4, and 5 certainly indicate that the young native fishes in these backwaters were subject to competition and perhaps predation. This is particularly true of the Colorado squawfish since it is the last species to spawn in late summer. The 5-7 mm long larvae seek the shelter of these nursery backwaters long after the young of the other species have hatched, and as such are smaller and weaker than sympatric fishes.

4.4 Fish Collections by Gear with CPE Statistics

This investigation attempted to expend similar effort for seining, electrofishing, gill nets and trammel nets during each canyon trip, while additional gear types were used as conditions allowed (Table D-1 through D-4). Drift netting for larval fishes was conducted only in 1985, 1986, and 1987. A summary of gear types used and fish sampling efforts for each of the 4 study years was presented earlier in Tables 2 and 3. Summaries of fish species collected by life stage and CPE for each of the principal gear types are presented in Appendix F. Catch rates were computed as described in the methodology section for each species by each sample and then averaged. These catch statistics are presented by region for all habitats in which the particular gear was used. Catch statistics by habitat are presented in Section 4.5

4.4.1 Electrofishing

Electrofishing was a very effective and valuable tool to this investigation for capturing all but the very small fish. Seven of the 12 adult Colorado squawfish and 26 of the 175 juveniles were captured by electrofishing, as well as 14 of the 22 adult humpback chub and 15 of the 56 juveniles (Table 12). This gear was also used to capture two of the six suspected adult bonytails and one of the seven suspected juveniles. The only razorback sucker seen during this study was captured with electrofishing gear.

Table 12. Numbers of endangered fish by age category captured by gear type, 1985-1988. (L=larva, Y=young-of-year, J=juvenile, A=adult).

	Colorado Squawfish				Humpback Chub				Bonytail Chub			
GEAR	L	Y	J	A	L	Y	J	A	L	Y	J	A
Electrofishing	0	23	26	7	0	3	15	14	0	0	1	2
Gill Nets	0	0	0	2	0	0	0	0	0	0	0	0
Exp. Gill Nets	0	0	8	0	0	0	40	7	0	0	6	2
Trammel Nets	0	0	1	3	0	0	0	0	0	0	0	2
Seine	381	4,736	176	0	11	16	0	0	0	1	0	0
Drift Net	4	0	0	0	0	0	1	0	0	0	0	0
Kick Screen	0	2	0	0	0	0	0	0	0	0	0	0
Hoop Net	0	0	1	0	0	0	1	1	0	0	0	0
TOTALS	**385**	**3,776**	**175**	**12**	**11**	**19**	**56**	**22**	**0**	**1**	**7**	**6**

The electrofishing CPE statistics presented in Tables F-5 through F-8 represent several different habitat types associated with the shoreline, including runs, riffles, eddies, pools, and large backwaters. Electrofishing in a large river system like the Colorado River is effective primarily along shorelines less than 10 feet deep. This gear covered a swath of shoreline habitat about 20 feet wide, and effectively sampled a relatively small area of the entire river. Nevertheless, it was an effective gear for all species of fish found in the study area, when these occupied the shorelines. However, increased turbidity caused by spring runoff or summer rains usually resulted in low catch rates because the fish became more sedentary in deep water and because high turbidity impeded efforts to net stunned fish. Since the fish had to break the surface of the water before being seen, netters sometimes made "blind sweeps" to catch these unseen fish. CPE statistics were computed only for those species which were captured or could have been captured with this gear type. Many small fishes, such as red shiners,

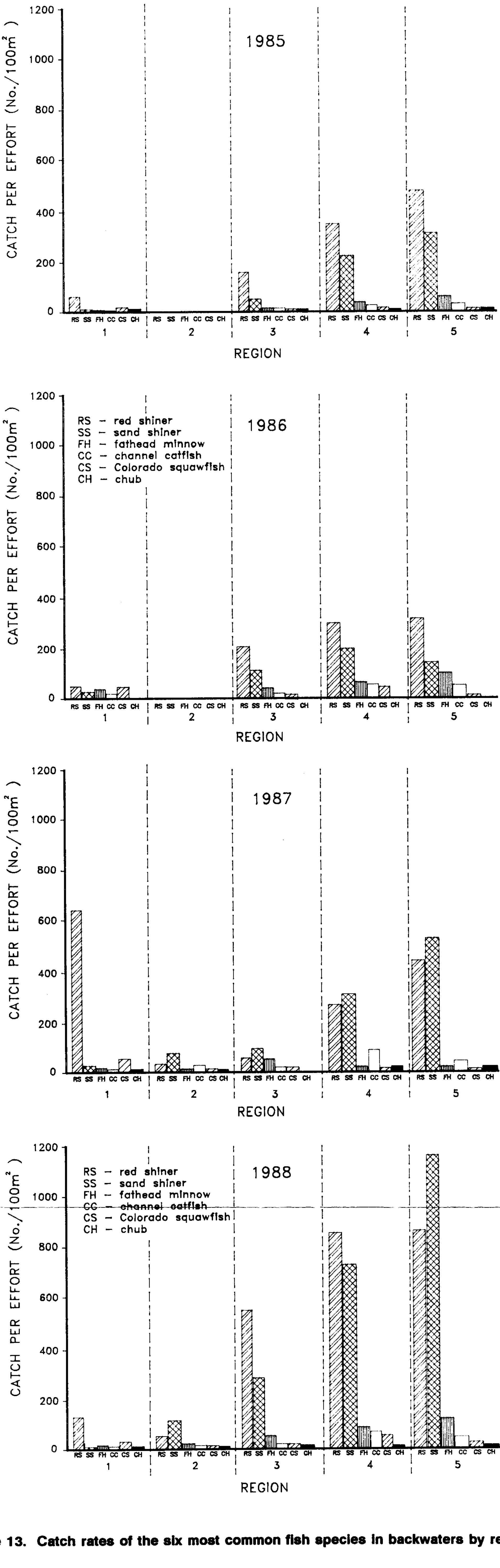


Figure 13. Catch rates of the six most common fish species in backwaters by region, 1988 data.

sand shiners, fathead minnows, and speckled dace were captured with electrofishing but excluded from this analysis because reliable capture of these fish was difficult; many were difficult to see and many escaped through the 0.5-inch mesh on the net bags.

The highest catch rates with electrofishing were for carp and channel catfish. The catch of these species was particularly high in Region 5 (Lake Powell Inflow), which indicates that large non-native species as well as the smaller non-natives were common.

Catch rates for Colorado squawfish and humpback chub as well as the other native species were relatively low, but accurately reflect their abundance relative to the non-native species. The highest catch rate for Colorado squawfish (adults and juveniles combined) was 24.1 fish/10 hours in 1986 in Region 3 (Table F-6), whereas the highest catch rate for humpback chub was 4.2 fish/10 hours in 1987 in Region 4 (Table F-7).

4.4.2 Gill and Trammel Nets

Only two adult Colorado squawfish were caught in uniform mesh gill nets (Table 12). This gear appeared to be have limited efficacy with this species. Because of the long, slender fusiform body of the Colorado squawfish, the only specimens captured with this gear were those that fit snugly into the mesh size being used. Both fish captured with gill nets had the net filaments wrapped tightly around their opercles. The only adult Colorado squawfish lost during this investigation was in a gill net. However, experimental gill nets, with panels of different mesh, proved very effective at capturing both humpback chub and bonytail, as well as juvenile Colorado squawfish (Table 12). This gear was most effective when the small mesh was placed closest to shore. Experimental gill nets were used only in 1987 and 1988, and consistently yielded higher catch rates (Tables F-17 and F-18) when compared to trammel nets (Tables F-13 through F-16). Trammel nets were also not very efficient at capturing these endangered fish; only three adult and one juvenile Colorado squawfish, and three suspected adult bonytail were captured with this gear type.

Catch rates for gill and trammel nets are presented separately in Tables F-9 through F-12 and F-13 through F-16, respectively, as the number of fish per 100 linear feet of net per 100 hours. Catch rates with both gear types were highest for carp, probably because of their relatively greater abundance and perhaps because the serrated first dorsal and anal spines of this species tend to wrap readily in nets. Channel catfish were also caught readily with these gear types.

4.4.3 Seines

Seines were unquestionably the most effective gear for capturing larvae and YOY of all the endangered species (Table 12). Nearly all of the young Colorado squawfish, humpback chub and the one suspected young bonytail were captured with seines. Seines were also effective for capturing juveniles, although the numbers were not as great probably because this size group occupied other habitats and/or mortality in the first year reduced their density.

The seine information presented in this analysis represents catch rates (numbers of fish per 100 m^2) from a total of eight habitat types (backwater, shoreline, pool, isolated pool, run, eddy, embayment, and concavity), although nearly 90% of the samples were taken in backwaters (See Section 4.5). These data should not be compared to ISMP data since that program contains a sampling design specific to backwaters. The CPE statistics presented in Tables F-1 through F-4 represent the catch of fish in shallow seinable waters, where the majority of small riverine fish were found.

When viewed across all habitats, catch rates with seines were highest for red shiners, sand shiners, fathead minnows, and channel catfish (Tables F-1 through F-4). The next highest catch rate was for Colorado squawfish. The young of this species were most abundant in Region 1 (Green River above the confluence) in all years, except for 1988 when an increased abundance of young Colorado squawfish was seen in Region 4 (Cataract Canyon) as a result of a large flash flood from Horse Canyon in the Green River that transported these fish downstream (See Section 2.1). It was also noted that the catch of chubs (humpback, roundtail, and *Gila* spp.) was generally greatest in Region 4, the area with the best habitat for this complex. These seine catch statistics also revealed that the highest catch rates were usually in Region 5 (Lake Powell Inflow), indicating that large numbers of non-native species inhabited this region.

4.4.4 Drift Nets

Although a total of 310 larval drift nets were set from 1985 to 1987, only 161 fish were captured with this gear type. This included a total catch of 12 fish for 62 sets in 1985, 75 fish for 136 sets in 1986, and 74 fish in 116 sets in 1987. The predominant species in drift nets in 1986 and in 1987 was the channel catfish (0.89 fish/1000 cubic feet of water in 1987). Roundtail chub (0.80) and red shiner (0.57) were found in low numbers in the drift, and one Colorado squawfish was captured in late July, 1987 in Cataract Canyon at RM 207.2, and four in mid to late July, 1986 in the Green River, 0.1 miles above the confluence (Table 12). Also, a juvenile humpback chub was inadvertently captured in a drift net. The catch of larval fishes in drift nets in the Cataract Canyon Region is considered low because of any or all of the following:

1. Sampling in July and August was too late to capture emerging and drifting fishes which probably hatched in the region in June.

2. According to Valdez et al. (1985), the majority of drift in the upper Colorado River is composed of native species that could be emerging in June, while non-native species emerging in July and August do not drift extensively and are not likely to be captured in drift nets (Personal communication with Robert T. Muth, Larval Fish Laboratory, February 24, 1987).

3. Reproduction by native fishes in the Cataract Canyon Region could be low, and the majority of native species (especially Colorado squawfish) were transported or moved downstream from spawning areas further upstream.

4.5 Species Associations by Habitat

4.5.1 Habitats Used by Rare Fish

Ten unique habitat types were identified in the Cataract Canyon Study Area, including backwaters, concavities, eddies, embayments, isolated pools, pools, riffles, runs, shorelines, and slackwaters; these are defined in Table 13. Each presented a unique set of microhabitat characteristics that were preferred by different age categories of each of the four rare fishes (Table 14).

Although Colorado squawfish were found in all habitats, except for riffles, larval and YOY were encountered most frequently in backwaters and isolated pools (Table 14); the consequences of their occurrence in isolated pools is discussed in Section 5.1.1.2. Juvenile Colorado squawfish were found most often in backwaters and along shorelines, suggesting that fish of this age continued to use backwaters but also occupy adjacent shorelines; other investigators report juvenile Colorado squawfish moving between backwaters and the main channel on a daily basis (Valdez et al. 1982; Personal communication with Chuck McAda, FWS, February 1986). Adult Colorado squawfish were found only in eddies and along shorelines. Adults may also use mid-channel slackwaters, which are important overwintering habitat in the Green River as shown by radiotelemetry (Valdez and Masslich 1988), but this habitat is difficult to sample with conventional gears and its summertime importance remains unknown.

Table 13. Definitions of the ten major riverine fish habitats.

HABITAT (CODE)	DEFINITION
Backwater (BA)	Sheltered body of water longer than wide, with no appreciable current, bound by land on three sides, and connected to the main channel or a side channel
Concavity (CO)	Small shoreline depression with little water circulation analogous to a pocket water in small streams
Eddy (ED)	Area with distinct counter current or whirlpool, generally deeper than adjacent waters
Embayment (EM)	Open shoreline depression similar to a backwater but wider than longer in dimension with some flow exchange
Isolated Pool (IP)	Small body of water in a depression, old backwater, or side channel, isolated from the main channel as a result of receding flows
Pool (PO)	Area deeper than adjacent low-velocity waters with downstream flow
Riffle (RI)	Shallow area with moderate gradient and small to moderate surface turbulence caused by cobble or sand substrate; severe surface turbulence over a steep gradient is classified as a rapid
Run (RU)	Area with moderate depth and laminar flow
Shoreline (SH)	Narrow zone along the river bank generally relatively shallow
Slackwater (SW)	Mid-channel habitat generally located below sand shoals or other instream structure where decreased velocity provides resting areas for fish

Larval and YOY humpback chub were found in backwaters, along shorelines, and in isolated pools. Their greater occurrence in backwaters is probably a reflection of greater sample efficiency in this habitat; greater numbers of young chubs were captured along shorelines and in eddies when experimental gill nets were used but this gear type was used only the last 2 years of the study. Juvenile and adult humpback chub were found most often in eddies and along shorelines. Larger numbers of larval and YOY humpback chub are also believed to use these habitats but cannot be sampled efficiently, except perhaps with small-mesh experimental gill nets (See Section 4.4.2). The only suspected YOY bonytail was captured in a backwater; this small sample size is not necessarily a reflection of habitat used by this age category. Vanicek (1967) reported young chubs (roundtail and bonytail, ages O - II) as common in still water or shallow pools over silt and occasionally over gravel or small-rubble bottoms. Eleven of the 13 suspected juvenile and adult bonytail were captured in eddies (Table 14), and only 2 were caught along shorelines. Vanicek (1967) reported catching juvenile and adult bonytail and roundtail chub in pools and eddies in the absence of, although occasionally adjacent to, strong current in the upper Green River.

The only rare fish caught in this investigation in a riffle was an adult razorback sucker. This species frequents large riffles and deep quiet pools and runs in the Green River (Wick et al. 1982).

Table 14. Numbers of endangered fish by age category captured by habitat type, 1985-1988. (L=larva, Y=young-of-year, J=juvenile, A=adult).

	Colorado Squawfish				Humpback Chub				Bonytail Chub			
Habitat	**L**	**Y**	**J**	**A**	**L**	**Y**	**J**	**A**	**L**	**Y**	**J**	**A**
Backwater	363	3,780	100	0	9	8	1	0	0	1	0	0
Concavity	1	14	1	0	0	0	0	0	0	0	0	0
Eddy	1	21	7	4	0	1	41	10	0	0	6	5
Embayment	2	31	2	0	0	2	0	1	0	0	0	0
Isolated Pool	15	807	27	0	2	3	0	0	0	0	0	0
Pool	0	7	0	0	0	0	0	0	0	0	0	0
Riffle	0	0	0	0	0	0	0	0	0	0	0	0
Run	0	26	3	0	0	0	2	3	0	0	0	0
Shoreline	3	53	33	8	0	5	15	9	0	0	1	1
Slackwater	0	22	2	0	0	0	0	0	0	0	0	0
TOTALS	**385**	**3,776**	**175**	**12**	**11**	**19**	**56**	**22**	**0**	**1**	**7**	**6**

4.5.2 Sympatric Associations with Rare Fish

This section focuses on species associations with the four rare fishes within each of the 10 identifiable habitats. Species associations are presented in Tables 15 and 16 as the percentage of sympatry between each of 10 selected native and non-native species and Colorado squawfish or humpback chub. For example, Colorado squawfish occurred in 51% of all backwaters sampled (Table 15), while red shiners were caught in 95% of the backwaters occupied by Colorado squawfish, sand shiners in 20% and fathead minnows in 26%. Visual displays of this sympatry within backwaters, eddies, shorelines, and isolated pools are presented in Figures 14 (Colorado squawfish) and 15 (humpback chub). For both endangered species, it was evident that non-native fishes occupied every habitat used to varying degrees of sympatry. McAda and Kaeding (1989) found limited habitat partitioning between Colorado squawfish and red shiners, sand shiners, and fathead minnows, and concluded that water management directed toward increasing the amount of habitat available to age-0 Colorado squawfish, while reducing that of the most common introduced species, may not be feasible.

Red shiners were captured in 95, 83, 100, and 100% of the backwaters, eddies, shorelines, and isolated pools, respectively, occupied by Colorado squawfish. This sympatric association in backwaters and isolated pools could represent competition and predation upon this endangered species, particularly in the nursery backwaters. Much has been written on the importance of this habitat (Holden 1977; Miller et al. 1982; Holden and Wick 1982). However, this association in eddies and shorelines may represent a source of forage for juvenile and adult Colorado squawfish. Channel catfish also showed a high degree of sympatry with Colorado squawfish in backwaters (62%), eddies (96%), and shorelines (92%), but were sympatric in only 25% of the isolated pools. This high degree of sympatry between these two species could mean competition and/or predation on larval and YOY Colorado squawfish. The degree of predation by Colorado squawfish on channel catfish is unknown, but may not be high because the spines of the catfish may deter extensive predation (McAda 1983). Sympatry between Colorado squawfish and other species varied considerably by habitat. Sand shiners occurred in 100% of all shoreline samples containing Colorado squawfish, while carp were caught in 92 and 68% of the eddy and shoreline samples, respectively, with Colorado squawfish. The interaction between these two

Table 15. Species associated with Colorado squawfish by habitat, 1985-1988 (i.e., red shiners (RS) were captured in 95% of backwaters occupied by Colorado squawfish).

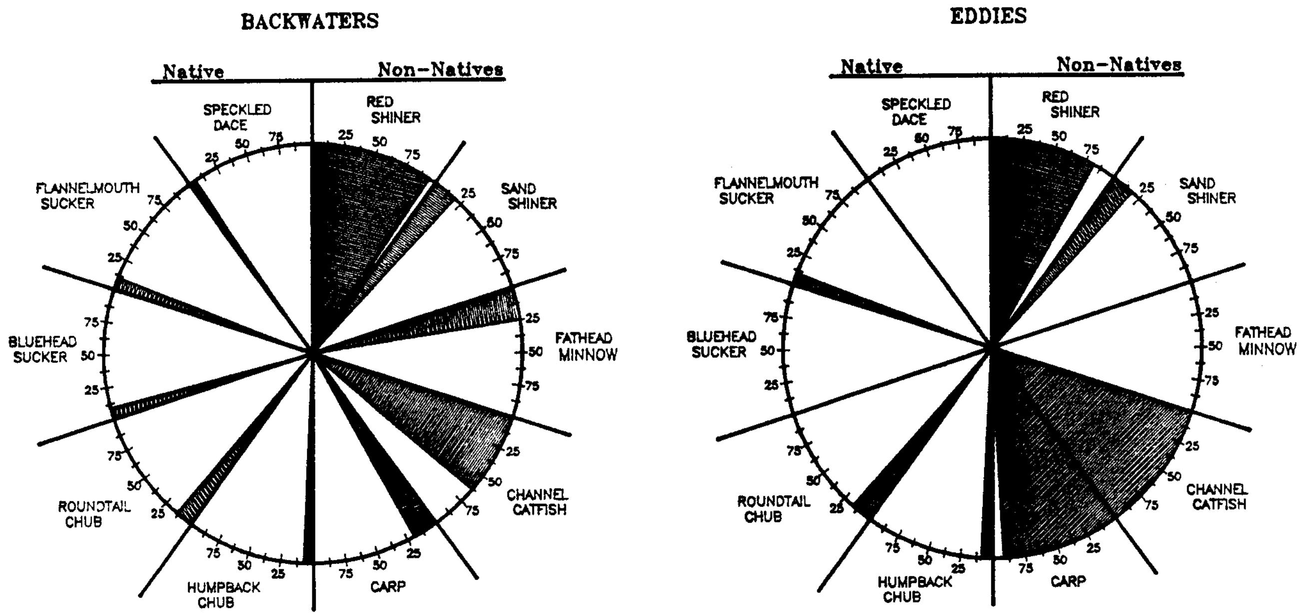
		PERCENTAGE OCCURRENCE OF ASSOCIATED SPECIES									
HABITAT[a]	OCCURRENCE[b]	NON-NATIVE					NATIVE				
CODE	OF CS	RS	SS	FH	CC	CP	HB	RT	BH	FM	SD
BA	51	95	20	26	62	17	3	14	8	10	8
CO	15	76	82	14	24	0	0	0	0	0	0
ED	2	83	17	0	96	92	8	16	0	8	0
EM	39	88	67	16	18	22	3	18	0	0	0
IP	67	100	28	100	25	12	10	12	0	0	32
PO	5	68	16	4	34	10	0	-	-	-	-
RI	0	-	-	-	-	-	-	-	-	-	-
RU	6	86	100	2	90	0	7	16	5	32	62
SH	11	100	100	22	92	68	42	38	6	16	18
SW	15	100	48	0	74	6	0	13	2	6	0

a BA=backwater, CO=concavity, ED=eddy, EM=embayment, IP=isolated pool, RU=run, SH=shoreline, SW=slackwater
b percentage of all backwaters sampled which contained Colorado squawfish

Table 16. Species associated with humpback chub by habitat, 1985-1988, (i.e. red shiners (RS) were captured in 100% of backwaters occupied by humpback chub).

		PERCENTAGE OCCURRENCE OF ASSOCIATED SPECIES									
HABITAT[a]	OCCURRENCE[b]	NON-NATIVE					NATIVE				
CODE	OF HB	RS	SS	FH	CC	CP	HB	RT	BH	FM	SD
BA	3	100	34	28	83	0	16	92	0	0	12
CO	0	-	-	-	-	-	-	-	-	-	-
ED	7	92	22	0	96	82	6	94	16	12	0
EM	4	100	82	20	12	18	33	62	14	3	0
IP	6	100	62	100	20	26	90	68	0	0	20
PO	0	-	-	-	-	-	-	-	-	-	-
RI	0	-	-	-	-	-	-	-	-	-	-
RU	2	100	76	0	50	0	5	82	5	0	0
SH	6	100	100	22	82	85	12	62	16	10	25
SW	0	-	-	-	-	-	-	-	-	-	-

a BA=backwater, CO=concavity, ED=eddy, EM=embayment, IP=isolated pool, RU=run, SH=shoreline, SW=slackwater
b percentage of all backwaters sampled which contained humpback chub



Shaded areas represent percentage of habitat occupied by Colorado squawfish in which each species was also captured (i.e., red shiners were captured in 95% of backwaters occupied by Colorado squawfish).

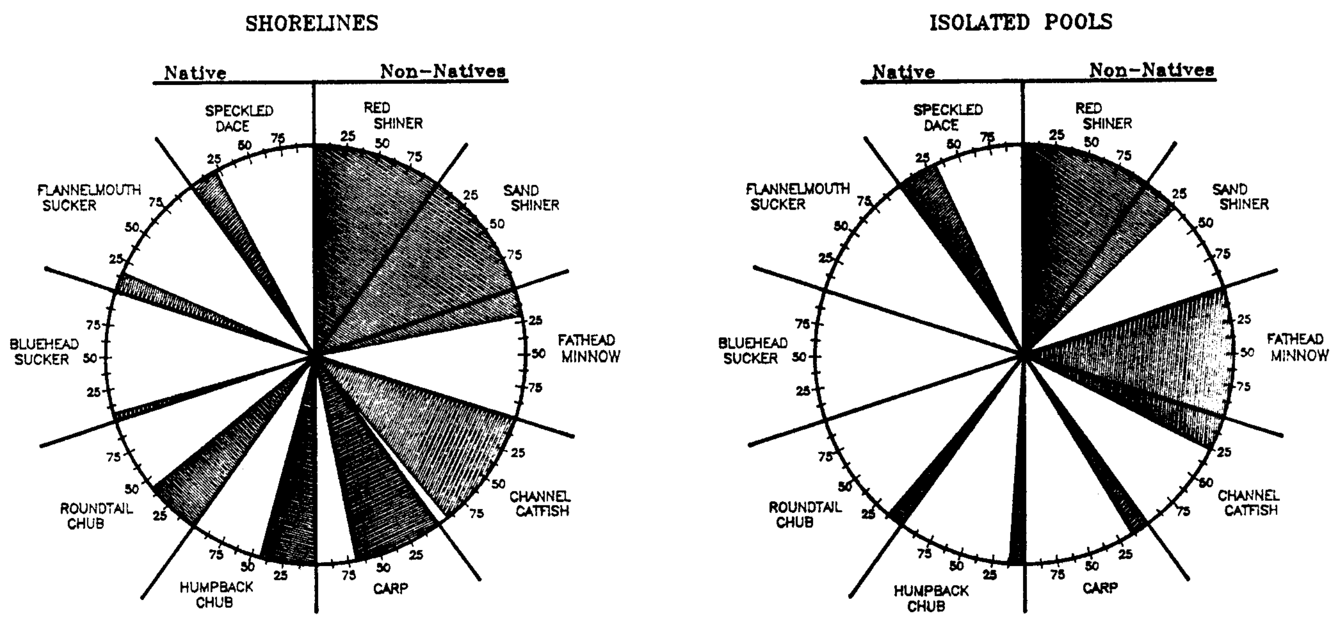
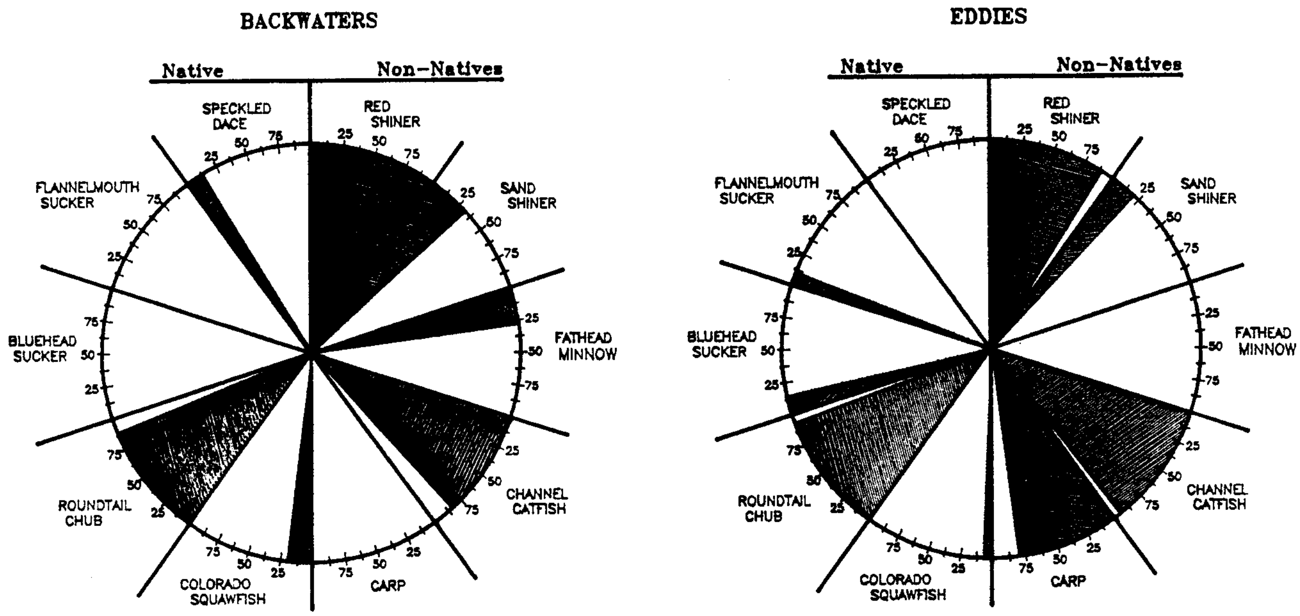


Figure 14. Species associations between Colorado squawfish and selected native and non-native species within four selected habitats.



Shaded areas represent percentage of habitat occupied by humpback chub in which each species was also captured (i.e., red shiners were captured in 100% of backwaters occupied by humpback chub).

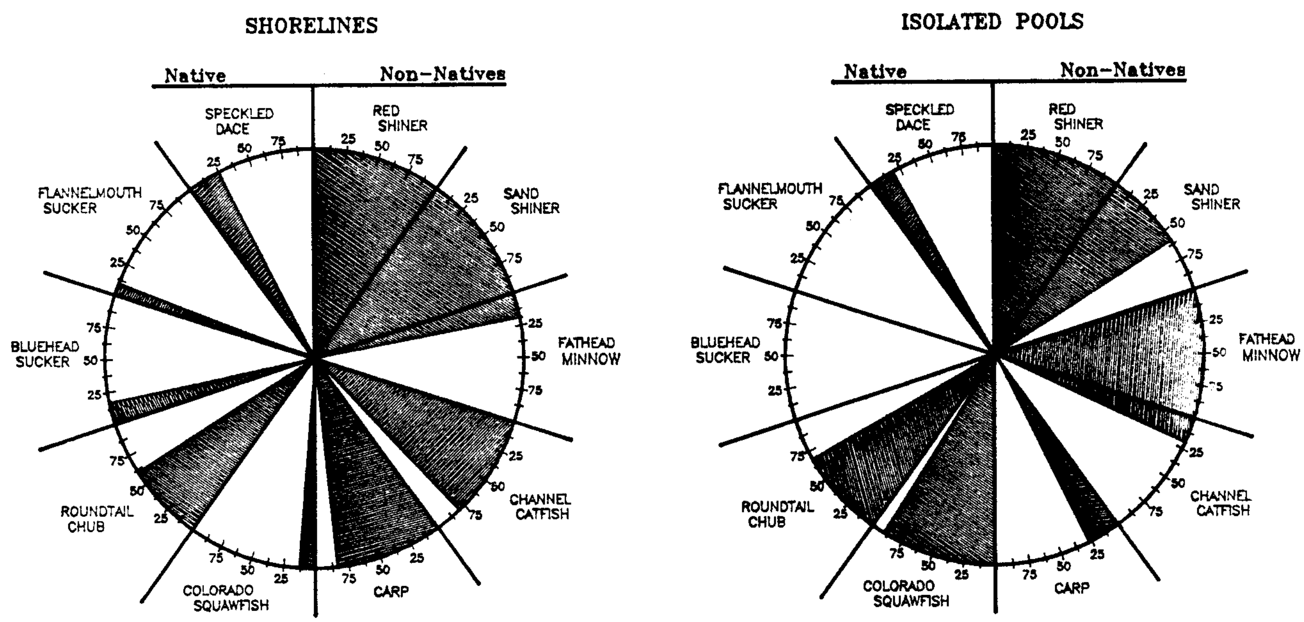


Figure 15. Species associations between humpback chub and selected native and non-native species within four selected habitats.

species is unknown. In all four habitats represented, the native species were uncommon; the highest degree of sympatry with Colorado squawfish was for roundtail chub (38%) and humpback chub (42%) along shorelines.

Red shiners were found in 100% of the backwaters, shorelines and isolated pools, and in 92% of the eddies containing humpback chub (Table 16, Figure 15). This sympatry in backwaters may mean a source of predation and/or competition on humpback chub, although nothing is known of these species interactions. Channel catfish also exhibited a high degree of sympatry with humpback chub in backwaters (83%), eddies (96%), and shorelines (82%), which may result in predation and/or competition on the endangered humpback chub. Although the diet of channel catfish captured in this study was not examined, one partially-digested but identifiable (Personal communication with Bob Muth, Larval Fish Laboratory, February 1988) juvenile humpback chub (about 160 mm TL) was found protruding from the mouth of a 312 mm channel catfish. Carp also had a high degree of sympatry with humpback chub in eddies (82%) and shorelines (85%), but the impact on this endangered species is unknown. Fathead minnows occurred in 100% of the isolated pools containing humpback chub. This species is common in habitats with high temperatures, extreme turbidity, and low oxygen levels (Pflieger 1975). The only native species in common sympatry with humpback chub was the roundtail chub, which occurred in 92, 94, 62, and 68% of the backwaters, eddies, shorelines, and isolated pools, respectively. The association between these two species is unknown, but believed to be innocuous since the species evolved together.

5.0 DISCUSSION

5.1 Biology of the Rare Fish

5.1.1 Colorado Squawfish

A total of 4348 Colorado squawfish were captured during this investigation (Table 6) including 12 adults, 175 juveniles, 3776 YOY, and 385 larvae. The data associated with each of these fish are presented in Appendix G. The following is a breakdown by age category of the biology of the Colorado squawfish in the Cataract Canyon Area. Adults were defined as sexually mature individuals, generally larger than 400 mm TL. Juveniles were immature fish greater than one calendar year of age and generally 60-400 mm TL. YOY were fish past their larval stage of development, less than one calendar year of age, and generally 20-60 mm TL, and larvae were fish without fully developed fins and generally 7-20 mm TL. Size range for each of the four age categories was based on literature. Vanicek and Kramer (1969) found that nearly all Colorado squawfish age VII (450 mm TL) and older were sexually mature. Seethaler (1978) found only fish over 400 mm TL at age VI were sexually mature. Vanicek and Kramer (1969) also found that Colorado squawfish were 41 to 49 mm TL when the first annulus was formed in early June, and were about 60 mm TL by the time the new year class hatched in late July and early August. The division between larvae and YOY (20 mm TL) was based on Snyder (1981); most determinations were made on fish sent to the LFL.

5.1.1.1 Adults

Adults were caught in each of the five study regions; one was caught in each of Regions 1 and 2; three in Region 3; five in Region 4; and two in Region 5. Thus, the largest number of adults was taken from Region 4 (Cataract Canyon), although this may have reflected greater sample effort. Nevertheless, 12 adult Colorado squawfish captured over a 4-year period from 116 miles of the upper Colorado River Basin is not considered a large number for this species, and indicates that this area is not occupied by large numbers of adults in the spring, summer and fall. Eight of the 12 adults were captured with electrofishing gear along shorelines, while four were captured with gill or trammel nets in eddies. The 12 adults ranged in size from 425 to 662 mm TL and averaged 519.3 mm TL; 11 ranged in weight from 540 to 2043 g with an average of 1002.5 g (Table G-1).

Although one of the objectives of this investigation was to determine spawning locations of the endangered fish in the Cataract Canyon Area, no adult Colorado squawfish were captured in spawning condition. Intensive sampling was conducted in likely spawning areas during estimated spawning times, but these efforts yielded no fish in spawning condition, i.e., tubercled males; females with swollen papillae, tubercles on body, rosy coloration with a pronounced dark lateral band (Hamman 1981). Based on the presence of larval fish less than 20 mm long and cobble areas with adjacent resting pools, some spawning by this species was suspected in this area. It could not, however, be confirmed. One approach to confirming this activity would be the use of radiotelemetry, which would be very labor and time intensive in this remote region, and could be difficult to perform considering the low number of adults available. This methodology has been effective in identifying spawning sites and habitat used by the species in other areas of the upper basin (Tyus 1988).

Two of the adults caught in 1986 had been previously captured and tagged upstream of Cataract Canyon by the FWS/CRFP Vernal Field Station (Personal communication with Harold Tyus, FWS, August 1986). Fish #477 was tagged and released on April 28, 1983, at RM 163.3 of the Green River and recaptured over 39 months later on August 14, 1986, and 172 miles downstream at RM 207.4 (9 miles below the confluence) in Cataract Canyon. This fish was 398 mm TL and weighed 498 g at capture, and was 516 mm TL and 907 g when recaptured. Fish #335 was tagged and released on May 4, 1983, at RM 119.9 on the Green River and recaptured over 38 months later on July 11, 1986, and 120 miles downstream at RM 216.3, at the confluence. This fish was 438 mm TL and weighed 620 g at capture, and was 500 mm TL and 794 g when recaptured. Fish #477 grew 118 mm and gained 409 g over 39 months between captures, while fish #335 grew 62 mm and gained 174 g over 38 months. Not enough is known about the growth of adult Colorado squawfish to assess the normalcy of this growth, and whether it was affected by tagging and handling. The recapture of these fish indicates movement by adults from the upper Green River into the Cataract Canyon area, but it is not known if this movement was seasonal or random.

5.1.1.2 Juveniles

A total of 175 juvenile Colorado squawfish were handled during this investigation. The greatest number of these (65) was found in Region 1 (lower Green River); this region also supported the greatest number of YOY of this species. Totals of 32, 36, and 38 juveniles were caught in Regions 2, 3, and 4, respectively, but only 4 were captured in Region 5 (Lake Powell Inflow). Juveniles were found in a variety of habitats and captured with a variety of gears. Most were captured in backwaters with seines, but many were caught along shorelines, in runs, and concavities with electrofishing gear and gill nets. Although the usual length range for juveniles is 60-400 mm TL, some juveniles of the 1986 year class were in the 40 to 50 mm size range at one calendar year of age. The small size of these individuals was explained by their relatively late hatching dates. A further explanation of this phenomenon is presented in Section 5.1.1.3.2.

A seemingly disturbing statistic was that 20% (849) of all Colorado squawfish captured (4348) were found stranded in isolated pools. This included 15 larvae, 807 YOY, and 26 juveniles; no adults were found stranded. Colorado squawfish were found in about 60% of the isolated pools sampled in both the Colorado and Green Rivers primarily above their confluence and mainly in 1986, 1987, and 1988. In all cases, stranding was observed in July, August, or September during descending flows following spring runoff. The majority of isolated pools were formed when descending flows cut off former backwaters or side channels. In most cases, several young Colorado squawfish were stranded with numerous non-native species, particularly fathead minnows and red shiners, as well as bullfrog tadpoles (*Rana catesbeiana*).

In 1986, 21 of the 48 juveniles (1985 year class, 65-99 mm TL) captured were found in two isolated pools at RM 1.5 and 1.6 of the Colorado River. This discovery was made on July 24 following a normal decrease in river flow following spring runoff. These fish were seined from the isolated pools and released alive in the main river channel. No assessment was made at the time to determine the extent of stranding in this region, although a few other isolated pools were seen but not sampled. A similar case of stranded juveniles was reported by the NPS (Personal communication with Tim Graham, NPS, September 27, 1989) about 3 miles below the confluence. Five juvenile Colorado squawfish (80-90 mm TL) were released from an isolated pool July 5, 1989; as many as 8 juveniles were present along with many other smaller unidentified fish. Stranding of juvenile and YOY Colorado squawfish was also seen along the Green River.

It could not be determined if stranding was natural or man-induced, since historic flow decreases following spring runoff were normally dramatic (Iorns et al. 1965), and stranding of Colorado squawfish probably occurred before human influence on the system. Current water uses (i.e., irrigation withdrawal, dam operation) may accelerate the rate of flow decrease and increase the likelihood of stranding. These human activities may also dampen flow spikes, caused by heavy mountain rains or late-season snow melt, and reduce river fluctuations that periodically reinundate these isolated pools. During this investigation, flow spikes in the study area were uncommon and were generally caused by flash floods produced by rain storms. It was noted in all 4 years of this study that heavy rains and the cessation of irrigation diversions in late summer and fall increased flows and reinundated many of these isolated pools, indicating that stranding was not necessarily fatal. If the stranded fish were able to survive desiccation, low oxygen, and fish and bird predation, they were likely to regain access to the river during increased flows in late summer. The number of fish actually dying in isolated pools was not determined and would be difficult to assess because dying fish are quickly eaten by foraging shorebirds such as great blue herons. One adverse effect of stranding was a higher exposure to the introduced parasitic copepod, *Lernaea cyprinacea*. Some Colorado squawfish captured in backwaters and isolated pools had a high degree of infestation by this parasite.

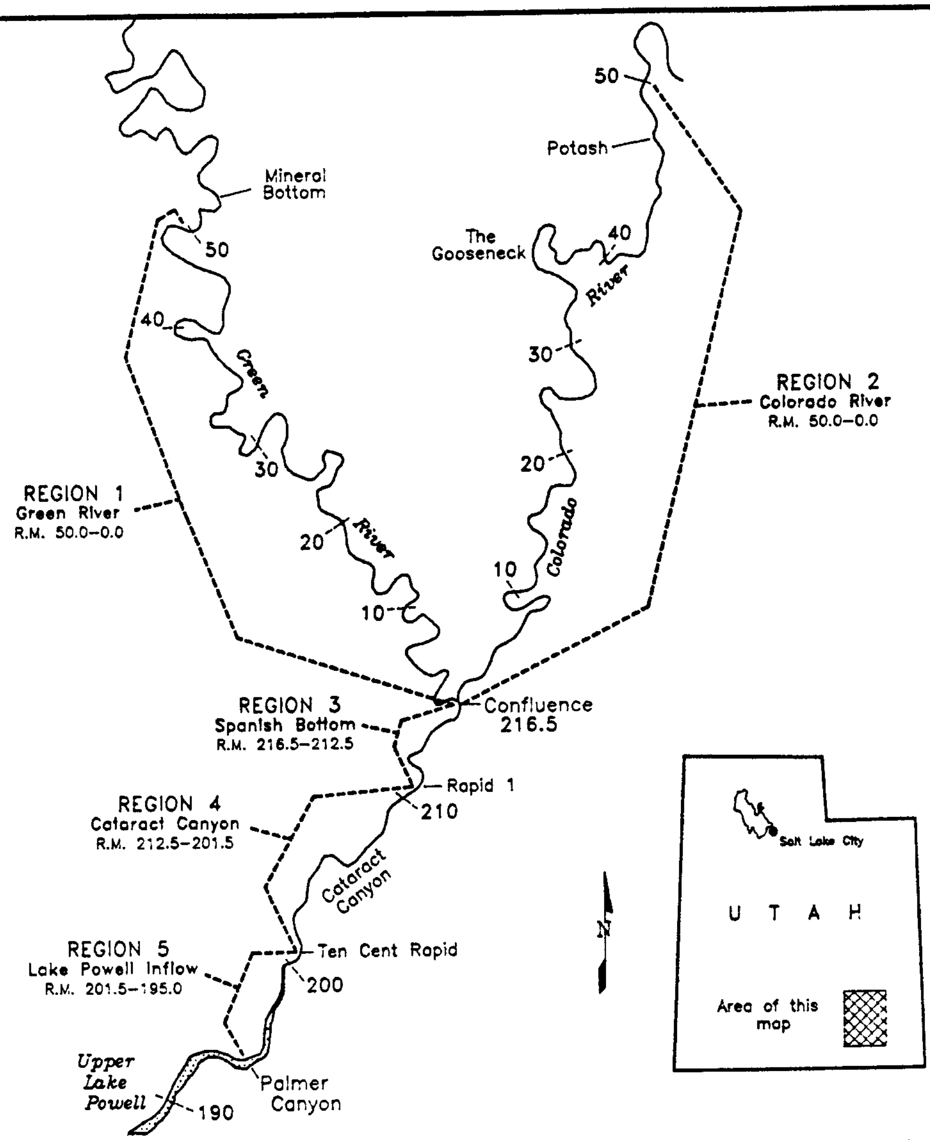
The effect of stranding on the population of Colorado squawfish and its implications on river management remain unknown. Stranding of young Colorado squawfish may be a natural phenomenon considering their affinity for backwaters, but the incidence of stranding may be more common as a result of human influence on flows. This relationship has not been determined, but considering that 20% of the Colorado squawfish captured in a 4-year period were found stranded, may mean that this is a significant source of mortality to larvae, YOY, and juveniles.

5.1.1.3 Young-of-the-Year and Larvae

A total of 3776 YOY and 385 larval Colorado squawfish were handled during this investigation. A list of the YOY and larvae with associated information are presented in Appendix G. To minimize mortality to these fish from handling, only representative samples were measured in the field. These lengths, along with those provided by the LFL, from specimens sent for identification, are included in Appendix G.

5.1.1.3.1 Distribution

The distribution of YOY Colorado squawfish was examined in the five study regions for 1985, 1986, 1987, and 1988 (Figure 16). In all 4 years, numbers of YOY captured by seining, percentage of total catch, and CPE were highest in Region 1, followed by Regions 3 and 4. The numbers of YOY Colorado squawfish were lowest in Regions 2 and 5. CPE of YOY in Region 1 in all 4 years exceeded the



Total number of fish (N), percentage of catch (P), and catch per unit effort (C) are presented.

	1985			1986			1987			1988		
	N	P	C	N	P	C	N	P	C	N	P	C
R1	320	74	14.12	396	74	61.90	392	69	71.64	586	36	20.44
R2	0	-	-	0	-	-	27	5	10.00	7	0	0.80
R3	20	5	2.71	73	13	13.18	86	15	8.63	145	9	14.83
R4	85	20	1.50	68	13	4.78	46	6	2.47	800	50	31.61
R5	4	1	1.55	1	0	0.39	16	3	2.26	82	5	14.00

Figure 16. Distribution of YOY Colorado squawfish by region, 1985-1988.

minimum of 9 fish/100 m², established to designate "high-density nursery areas" for the species (Biological Sub-Committee 1984). The reader is reminded that the CPE's in this report are the result of sampling backwaters throughout the summer, in contrast to the ISMP which assesses CPE for YOY Colorado squawfish only from sampling backwaters in the fall (September or October). As a result, the CPE's in this report reflect densities prior to summer mortality and are probably higher than comparable CPE's taken in the fall.

YOY Colorado squawfish were most numerous in the lower 50 miles of the Green River. This region is designated as a "high-density nursery area" in the Sensitive Areas Document (Biological Sub-Committee 1984), a designation that this investigation confirms. The Sensitive Areas Document also designates the lower 60 miles of the Colorado River, from Moab to the confluence, as a "nursery area" for Colorado squawfish where catch rates exceeded 0.9 fish/100 m². This investigation also concurs with that designation and recommends extending this nursery area downstream another 16.4 miles, from the confluence through Cataract Canyon to Imperial Canyon (RM 216.4-200.0); this investigation found a catch rate of 0.9 fish/100 m² or greater in all years in Regions 3, 4, and 5 (See Section 6.1.1).

5.1.1.3.2 Hatching Dates

When back-calculated hatching dates were plotted on a frequency histogram (Figure 17), it became evident that in 1986, YOY Colorado squawfish captured in the study area hatched much later than in 1985, 1987, or 1988. In 1985, hatching began the first of June, peaked during the first week of July, and continued through the first week of August (Valdez 1985). Hatching was later in 1986, and began in mid-June, peaked in early August and continued through August. In 1987, hatching began in early May and remained high from mid-June to late July. In 1988, hatching began in mid-May, peaked in early July and extended into August. Spawning dates can be determined by subtracting 3-5 days from hatching dates (Hamman 1981).

Some of the variation seen in back-calculated hatching dates was attributed to differential growth rates, errors in length measurements afield, or spawning events separated by time. But, the most likely explanation for this variation was that since the study area was located near the confluence of the Green and Colorado Rivers, recently hatched fish were transported from more than one spawning site upstream on either river. It is likely that some of these fish also originated from local spawning sites, although this was not confirmed through this study. A comparison of the histograms presented in Figure 17 with similar histograms developed for YOY captured near a known spawning site in the Yampa River (Haynes et al. 1985) revealed that the former has a much wider scatter of data bars, supporting the hypothesis that many of the YOY in the lower Green and Colorado Rivers originated from different spawning locations and events further upstream.

In an effort to assess the effect of two variables--water temperature and flow--on the hatching times of Colorado squawfish, these were plotted with the frequency histograms in Figure 17. Since no hydrologic stream gage was located in or near Cataract Canyon, temperature data for 1985 and 1986 were taken from bottom readings of the Reclamation gage at Clearwater Canyon in Lake Powell (about 8 miles below Imperial Canyon). Temperature data in 1987 were from field readings taken during this investigation, while data for 1988 were taken from a Reclamation Datason temporarily located in Cataract Canyon. Flow records were from the USGS gaging stations at Green River, Utah (for Green River) and Cisco, Utah (for Colorado River), and combined for the Cataract Canyon flows.

The histograms in Figure 17 indicate that spawning occurred during increases in water temperature and decreases in flows and peaked when temperatures were 22 to 23°C, which is similar to observations elsewhere in the upper basin (Tyus 1986, Nesler et al. 1988). By assuming that spawning occurred 3 to 5 days prior to hatching, it is difficult to visually identify a relationship between spawning and either temperature or flow spikes, or both. Such a relationship in this region of the upper basin may be masked by the large volume of water. Furthermore, such a relationship may not exist for YOY captured in the study area because many of these fish probably originated from different areas and spawning events that may have been influenced by environmental factors other than those recorded in the Cataract Canyon area. Nesler et al. (1988) reported that spawning activity by Colorado squawfish in the Yampa River increased during flow spikes caused by rainstorms. These environmental cues served as stimulants to spawning in that system but were not evident in the Cataract Canyon area.

5.1.1.3.3 Growth

Average lengths of YOY Colorado squawfish from four year classes (1985, 1986, 1987, 1988) were compared to determine if hatching times influenced size of overwintering YOY (Figure 18). As discussed in Section 5.1.1.3.2, peak hatching dates of these year classes differed by as much as one month, and therefore, the sizes of YOY varied considerably. Of the three year classes with peak hatching in early to mid-July (1985, 1987, 1988), summer monthly growth rates were similar (6.5, 5.2, and 7.7 mm/month, respectively) and only small differences in size remained evident throughout the summer. However, the 1986 year class, which hatched the latest of the four (in August), exhibited the greatest summer growth rate of 10.5 mm/month. During the first months, the average size of individuals of this 1986 year class was 10 to 15 mm smaller than that of the other year classes, but by early October, average size was only 4 to 8 mm smaller indicating that faster growth by this late-hatching year class partially compensated for the difference in length.

Wintertime growth of these fish from early October to late March and early April was small, as expected; average length increase for the 1987 year class was from 34.0 to 42.7 mm and for the 1988 year class was 38.7 to 42.0 mm. Average overwinter growth for these two cohorts ranged from 3.3 to 8.7 mm for a 4.5 to 5-month period. Similar winter growth was observed for the 1986 year class (30.6 to 33.2 = 2.6 mm), but the average length of fish in this cohort remained smaller than fish of comparable age of the other year classes. The comparative differences in average sizes of individuals between year classes remained into their second year of life (Figure 18). By late June of 1987, the 1986 year class averaged 54.3 mm TL, while the fish of comparable age from the 1988 year class remained about 8 mm larger. No statistics were applied because of small sample sizes and because averages were used to compute growth rates. It should be noted that average lengths of YOY captured in the Cataract Canyon Study Area during this investigation may have been influenced by immigration and emigration of fish.

This analysis showed that hatching dates influenced the average size of YOY Colorado squawfish during their first full year of life. It also showed that different growth rates during the first year of life may ameliorate differences in size over time, although this did not appear to fully compensate for these differences during the first summer of life for the 1986 year class. It still remains evident that Colorado squawfish hatched late in the season (August) enter their first winter of life relatively smaller than year classes spawned in July.

5.1.1.3.4 Overwinter Survival

Recent investigations in the lower 50 miles of the Green and Colorado Rivers, above their confluence, have revealed a discrepancy in numbers of YOY Colorado squawfish of the same cohort between fall and spring (Valdez 1985, 1987, 1988; Personal communications with Miles Moretti, UDWR, February 1988). This apparent decrease in numbers indicates that these young fish: (1) experience a substantial overwinter mortality, (2) occupy habitats unaffected by sampling gear, or (3) emigrate or are transported to other regions of the river. This study was not designed to address these hypotheses, but study results lend insight into this aspect of the life history of this species.

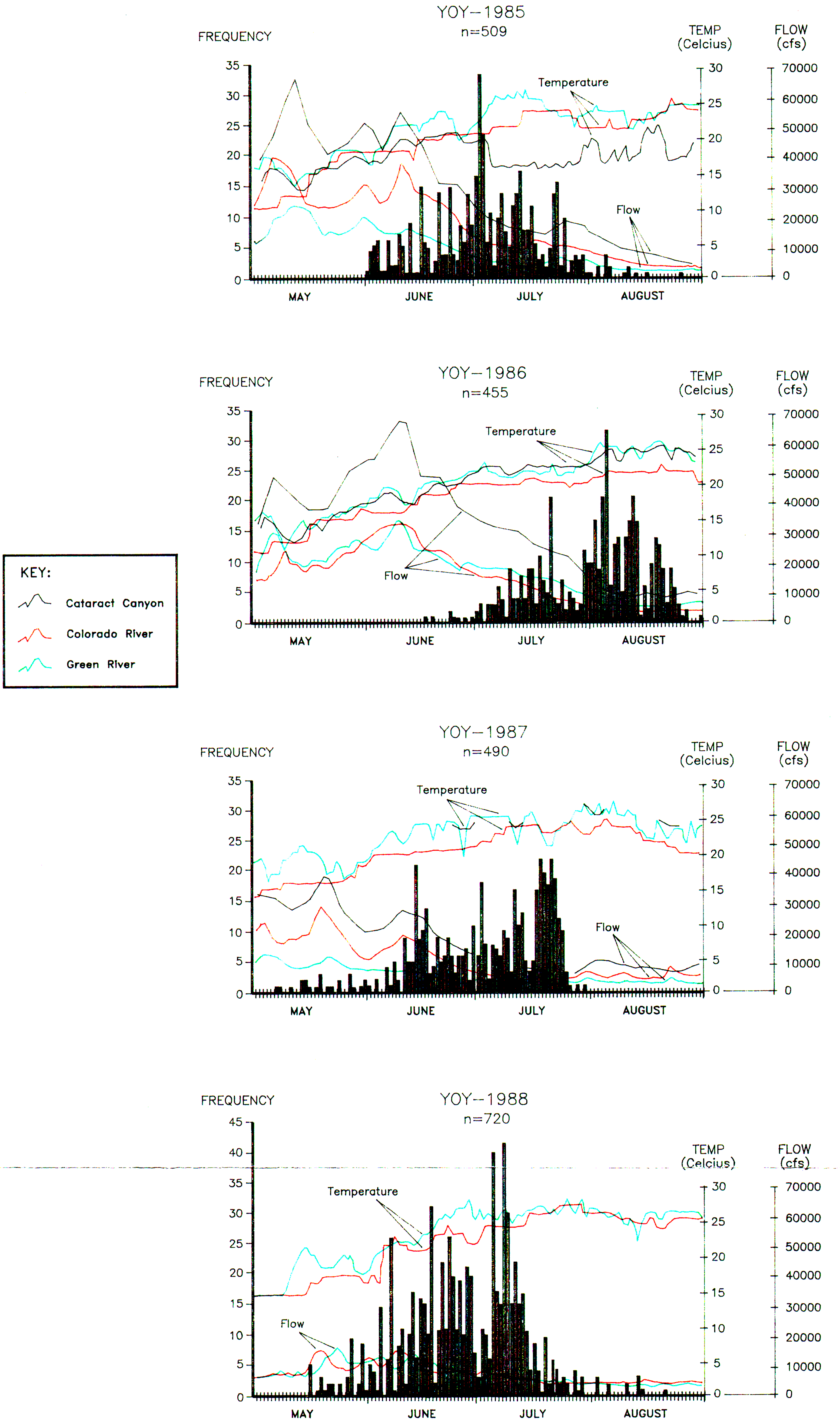


Figure 17. Frequency of back-calculated hatching dates for YOY Colorado squawfish compared to river temperature and flow of the Green River, Colorado River, and Cataract Canyon, 1985-1988.

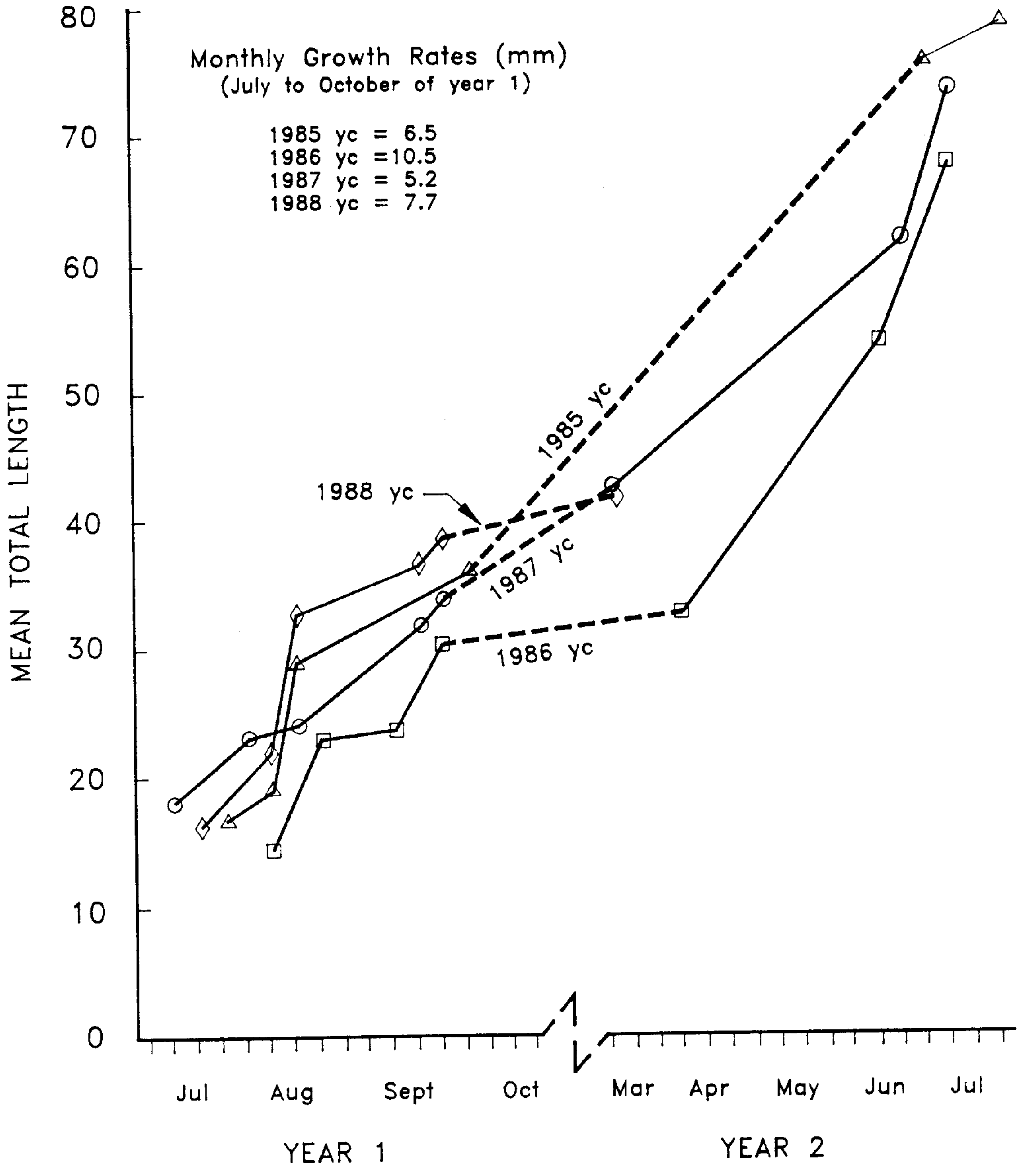
Since few wintertime investigations have been conducted on the fishes of the upper basin (Valdez and Masslich 1987; Wick and Hawkins 1987; Personal communication with H. Tyus, FWS, February 1988; Personal communication with L. Kaeding, FWS, February 1988), little is known of the winter stresses on these endangered fish, particularly the young. Winter riverine conditions may affect survival of YOY and influence cohort strength. Kaeding and Osmundson (1988) hypothesized that the interaction of slow growth and increased early-life mortality is an important cause of the decline of Colorado squawfish in the upper basin. They further state that the unusually small size of age-0 fish going into winter might be an important factor affecting recruitment to the adult stock. Thompson (1989) determined that overwinter survival of age-0 Colorado squawfish is dependent on fish size. "Larger fish had higher initial lipid contents and, therefore sufficient energy reserves to survive overwinter regardless of feeding regime."

The growth analysis conducted in Section 5.1.1.3.3. indicates that the late-hatching year class of 1986 probably experienced low overwinter survival. Perhaps one factor that enables age-0 fish to survive their first winter of life is their size at piscivory. It is reasonable to assume that if an age-0 Colorado squawfish can reach the size of piscivory before its first winter, its chances of survival are greatly enhanced. Vanicek (1967) reported Colorado squawfish as small as 50 mm TL with fish in their stomachs. Jacobi and Jacobi (1981) reported that 30% of the YOY Colorado squawfish examined from the Green River contained fish, primarily YOY *Cyprinella lutrensis* (red shiner). Other investigators have found Colorado squawfish less than 30 mm long with fish in their stomachs (Personal communication with Steve Grobowski, Reclamation, February 1989). Based on these observations, the 1986 year class probably had a lower survival rate than the 1985, 1987, or 1988 year classes, because the peak of spawning was delayed about one month by delayed warming of the river.

The second hypothesis addresses whether YOY Colorado squawfish use habitats unaffected by conventional sampling gear after their first winter of life, or if their decrease in density is a reflection of overwinter mortality. It is not known if YOY Colorado squawfish continue to occupy backwaters in the winter or if they abandoned these because of colder temperatures and ice buildup. To determine if YOY were using backwaters as extensively in the spring as in the fall, various shoreline habitats were sampled in the spring (March 21-25, 1988) when backwaters were 1 to 5°C warmer than the main channel. Of five shoreline seine hauls off the mouths of backwaters occupied by Colorado squawfish, only one yielded YOY; 22 were captured in a small slackwater adjacent to a backwater at RM 45.1. Although this represented only 14% of the YOY captured in this sample trip, the results were inconclusive, but suggest that some YOY occupy other sheltered habitats in the spring besides backwaters. This may explain some of the discrepancy in YOY densities between fall and spring if only backwaters are sampled.

The third hypothesis to explain differences in density of the age-0 cohort between fall and summer proposes that the fish emigrate or are transported from the region. The movement of larvae, YOY, and juvenile Colorado squawfish in the upper basin remains largely unknown. Haynes et al. (1984, 1985) proposed that Colorado squawfish larvae hatched in the lower Yampa River (RM 16-18) were transported into nursery backwaters in the Green River located 50 to 100 miles downstream. This hypothesis has generally been accepted (Tyus et al. 1987), but the extent of movement and transport of these young fish beyond these distances and at other times of the year is unknown. Movement of larval fish shortly after hatching may be mostly involuntary since the majority drifting in the water column were mesolarvae and metalarvae, or fish with poorly developed fins (Haynes et al. 1984). Although these larvae may be able to adjust their position in the water column, their dispersion is largely determined by river currents and eddies. Following the larval stage of development, the fish probably remain in or near backwaters with limited movement along quiet shorelines.

Overwinter movement is indicated by the difference in distribution of YOY Colorado squawfish in Region 1 between fall 1987 and spring 1988 sample periods. In the fall, 97% of the YOY in this region



Monthly growth rates are presented as millimeters per month for the first summer of life, July to October.

Figure 18. Mean total length (sample size) of YOY Colorado squawfish from the lower 50 miles of the Green River in four successive year classes.

were caught above Valentine Bottom (RM 26), with the majority in a 12-mile reach between Tent Bottom (RM 38) and Valentine Bottom. However, during spring sampling, there were no YOY between Tent Bottom and Valentine Bottom, although 74% of the YOY were above Tent Bottom. This suggests either a general downstream movement of YOY from fall to spring, or upstream movement. Extensive upstream movement of YOY Colorado squawfish less than 50 mm TL is unlikely because of river velocity. The remaining 26% of the YOY found in the spring were widely distributed from about Turk's Head (RM 25) downstream, and only two YOY were caught below Region 1. This indicates that either overwinter mortality is high or that many YOY are being transported downstream into Lake Powell and lost to predation, or both.

Another aspect of the transport hypothesis considers that many YOY Colorado squawfish are transported downstream by high spring flows. It is reasonable to assume that the young of a large river species probably disperse downstream during high flows. The sudden force of a flash flood from Horse Canyon in August 1988 (See Section 2.1) demonstrated how large numbers of YOY in the 20 to 30 mm size range can be carried downstream. This may be the case during runoff flows in spring, although by then, the fish are nearly one year old and 60 to 70 mm long and better able to cope with high flows. Sampling should be conducted at the Lake Powell Inflow during spring runoff to test this hypothesis (See Section 6.3).

5.1.2 Humpback Chub

5.1.2.1 Distribution

A total of 108 humpback chub were captured during this 4-year investigation (Table 6). This included 22 adults, 56 juveniles, 19 YOY, and 11 larvae. The data associated with each of these fish are presented in Appendix G. Of the 108 fish, 92 were captured within Region 4, Cataract Canyon (Table 10). Prior to this study, only small numbers of adults had been encountered in Cataract Canyon, and the presence of a reproducing population remained unconfirmed (Valdez et al. 1982, Valdez and Clemmer 1982). The capture of fish of all ages in this study is strong evidence of a reproducing population of humpback chub in this region, although turbulent canyon conditions precluded thorough sampling to define its size and limits of distribution.

Numbers per mile by age category of humpback, roundtail, bonytail, and unclassified chubs revealed three concentrations of fish (Figure 19). The first was located between Rapids 2 and 4, near the upper end of Cataract Canyon. These fish were caught along boulder and talus shorelines below Rapids 2 and 3 where a small number of larvae and YOY indicated some local spawning. The second and largest concentration of chubs was between Rapids 8 and 13 (RM 208 to 205). This reach was in the middle of Cataract Canyon and was characterized by widely spaced rapids with long intervening runs, including the area known as "Cataract Lake". The fish were generally captured amongst emergent boulders along talus shorelines. The only humpback chub in spawning condition were captured in this reach and the number of larvae and YOY indicate spawning by both roundtail and humpback chub in this reach. The third concentration of chubs was found immediately above the Lake Powell Inflow, between Rapid #23 (Big Drop 3) and Rapid 27 (Imperial Canyon Rapid), although these fish probably originated from the upstream population between Rapids #8 and 13.

Of the 16 fish captured outside of Cataract Canyon, 4 YOY were found in Region 1 (lower Green River); 2 larvae, 2 juveniles, and 2 adults were found in Region 2 (lower Colorado River); 1 larvae, 1 YOY, and 2 juveniles were found in Region 3 (Confluence); and 1 larvae and 1 YOY were found in Region 5 (Lake Powell Inflow). The absence of adults in Region 1 suggests that young fish were transported from upstream populations (perhaps Desolation or Gray Canyons). This may also be the case for Region 2, although the presence of some adults in this area suggests some local spawning. The young fish in Regions 2 and 3 may have also been transported from upstream (perhaps Westwater

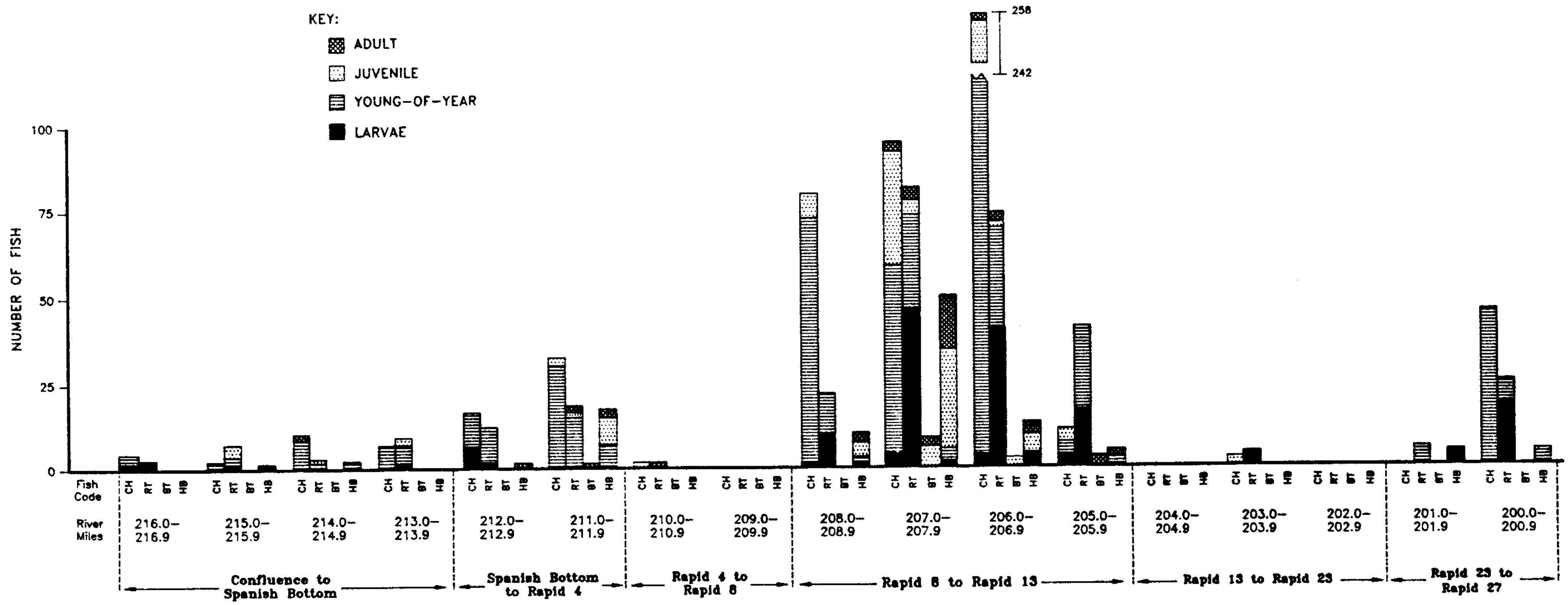


Figure 19. Longitudinal distribution by age category of humpback (HB), bonytail (BT), roundtail (RT), and unclassified chubs (CH) in Cataract Canyon (RM 200.0 to 216.5), 1985-1988.

Canyon or Black Rocks), while those in Region 5 probably originated from spawning areas within Cataract Canyon.

5.1.2.2 Taxonomy

The taxonomic dilemma characteristic to the upper basin *Gila* complex prevailed in Cataract Canyon, and it was sometimes difficult to confidently classify some chubs into *G. robusta*, *G. cypha*, or *G. elegans*. In order to address this problem and therefore, the second objective of this investigation (i.e., Determine whether humpback chub populations exist in Cataract Canyon), chubs were tentatively identified in the field, and photographs and a set of measurements (See Section 3.4) were recorded on each fish. A 'Chub Biography' was prepared as a supplement to this Final Report that contains a collection of photographs and descriptions of the *Gila* complex encountered in Cataract Canyon. Copies of this biography were sent to select investigators with expertise in chub taxonomy. These investigators were asked to render an opinion on the tentative identifications presented. There was general agreement by the experts on the classification of chubs in Cataract Canyon, although some fish were reclassified as a result of their opinions.

Using nine measurements taken in the field, a principal components analysis was conducted on 60 specimens to help with tentative identifications and to support or refute field classification. Principal components analysis revealed four clusters of individuals (Figure 20). Membership in each cluster is presented in Table 17, and individual measurements used for this analysis are presented in Table 18. Cluster 1 represented the individuals tentatively identified as *G. elegans*, and consisted of six fish, including four classified in the field as *G. elegans* and two classified as *G. cypha*. The two *G. cypha* were intermediate in appearance with relatively large nuchal humps, 9 instead of 10 dorsal rays, and long slender caudal peduncles. Holden and Stalnaker (1970) reported similar forms from Lake Powell with characters intermediate between *G. cypha* and *G. elegans*. They further stated that the number of integrades in the Lake Powell area may reflect hybridization resulting from habitat changes created by Glen Canyon Dam, which was closed in 1964. These are fish that were presumably related to the present day Cataract Canyon chubs.

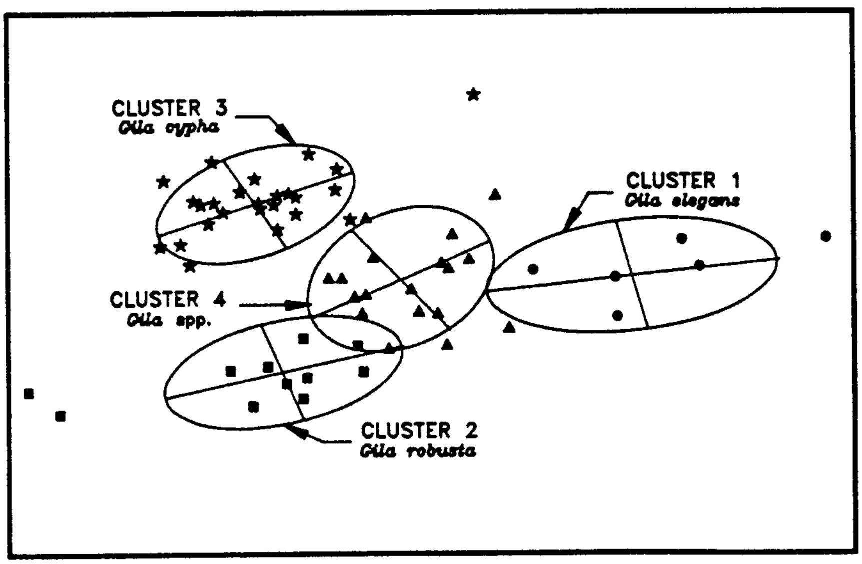


Figure 20. Principal components analysis of Cataract Canyon *Gila* showing the four clusters of maximum membership; analysis of principal components 1 vs principal components 2.

Table 17. Individual membership of Cataract Canyon *Gila*[1] to four clusters established through principal components analysis.

Sample (field classification)	Cluster 1	2	3	4
Cluster Number 1 (4 BT, 2 HB)				
16 : BT	0.53	0.07	0.07	0.33
17 : BT	0.64	0.10	0.08	0.19
20 : BT	0.84	0.04	0.03	0.09
59 : BT	0.67	0.08	0.09	0.15
60 : HB	0.92	0.02	0.02	0.05
61 : HB	0.88	0.03	0.03	0.06
Number of Maximum Membership Samples: 6				
Membership Summary	**0.75**	**0.06**	**0.05**	**0.16**
Cluster Number 2 (8 RT, 3 CH, 1 BT)				
1 : RT	0.08	0.48	0.24	0.19
8 : RT	0.03	0.79	0.08	0.10
11 : CH	0.03	0.85	0.04	0.08
27 : CH	0.06	0.47	0.09	0.38
29 : CH	0.01	0.95	0.01	0.03
30 : RT	0.02	0.79	0.05	0.13
33 : RT	0.03	0.81	0.05	0.11
34 : RT	0.01	0.93	0.02	0.04
39 : RT	0.06	0.61	0.07	0.26
40 : RT	0.03	0.83	0.06	0.09
53 : BT	0.02	0.86	0.04	0.09
58 : RT	0.08	0.53	0.21	0.18
Number of Maximum Membership Samples: 12				
Membership Summary	**0.04**	**0.74**	**0.08**	**0.14**
Cluster Number 3 (19 HB, 5 CH)				
2 : HB	0.06	0.08	0.48	0.38
3 : HB	0.04	0.10	0.74	0.12
4 : HB	0.03	0.07	0.77	0.14
6 : HB	0.02	0.05	0.87	0.06
7 : HB	0.04	0.16	0.65	0.15
9 : HB	0.04	0.11	0.70	0.14
24 : HB	0.01	0.02	0.93	0.04
25 : HB	0.01	0.03	0.89	0.06
26 : HB	0.02	0.04	0.81	0.12
28 : CH	0.04	0.21	0.57	0.18
31 : HB	0.04	0.15	0.67	0.15
32 : HB	0.02	0.07	0.83	0.08
35 : CH	0.05	0.06	0.67	0.22
42 : CH	0.01	0.03	0.91	0.05
43 : HB	0.06	0.07	0.64	0.22
44 : HB	0.06	0.07	0.70	0.17

Table 17. Continued

Sample	Cluster 1	2	3	4
<u>Cluster Number 3, Continued</u> (8 RT, 3 CH, 1 BT)				
45 : HB	0.01	0.02	0.94	0.03
46 : HB	0.02	0.04	0.85	0.09
48 : HB	0.01	0.02	0.93	0.04
49 : HB	0.03	0.05	0.85	0.08
50 : HB	0.02	0.04	0.85	0.09
51 : HB	0.04	0.07	0.77	0.12
55 : CH	0.01	0.03	0.92	0.04
56 : CH	0.25	0.12	0.33	0.30
Number of Maximum Membership Samples: 24				
Membership Summary	**0.04**	**0.07**	**0.76**	**0.13**
<u>Cluster Number 4</u> (2 RT, 8 BT, 7 HB, 1 CH)				
5 : RT	0.05	0.18	0.21	0.55
10 : BT	0.14	0.23	0.08	0.54
12 : HB	0.10	0.06	0.07	0.77
13 : BT	0.09	0.06	0.07	0.78
14 : HB	0.14	0.07	0.13	0.66
15 : HB	0.08	0.12	0.07	0.74
18 : BT	0.05	0.15	0.16	0.63
19 : BT	0.07	0.41	0.08	0.43
21 : HB	0.04	0.18	0.07	0.71
22 : BT	0.03	0.13	0.09	0.75
23 : BT	0.36	0.12	0.07	0.44
36 : HB	0.07	0.09	0.34	0.50
37 : BT	0.18	0.07	0.09	0.66
41 : HB	0.02	0.07	0.05	0.86
47 : HB	0.31	0.09	0.18	0.41
52 : BT	0.02	0.03	0.02	0.93
54 : CH	0.04	0.06	0.11	0.80
57 : RT	0.11	0.13	0.07	0.70
Number of Maximum Membership Samples: 18				
Membership Summary	**0.11**	**0.13**	**0.11**	**0.66**

1 - BT = bonytail, HB = humpback, RT = roundtail, and CH = unclassified chub.

Cluster 2 represented the *G. robusta* form and included eight fish classified afield as *G. robusta*, three as *Gila* spp., and one as *G. elegans*. These 12 fish typically had small nuchal humps, fusiform bodies, robust caudal peduncles, and 9 dorsal and 9 anal rays. Cluster 3 represented *G. cypha and* included 19 fish classified afield as *G. cypha*, and 5 as *Gila spp.* This cluster contained 19 of the 28 fish classified afield as *G. cypha*, and typically contained fish with larger nuchal humps and thinner and longer caudal peduncles. Cluster 4 included 18 fish that were classified as various forms, including 2

Table 18. Listing of meristics associated with Cataract Canyon *Gila* used in the principal component analysis.

#	sp	Coll#	RI	RMI	DATE	TL	WT	TAG	t	c	s	p1p2	Hmp	D	A	CPd	CP1	H1	DFb	AFb
1	RT	3-E14	CO	214.7	880623	192	50	99999	#	#	#	40.8	0.4	9	9	9.8	31.4	40.2	20.9	18.4
2	HB	3-N27	CO	207.4	880623	205	83	488	C	R	S	35.6	2.8	9	9	11.5	34.6	43.5	23.6	21.6
3	HB	3-E20	CO	207.6	880623	147	32	99999	#	#	#	30.5	1.8	9	10	10.3	22.0	29.5	18.2	15.3
4	HB	3-N36	CO	207.3	880624	207	82	104	C	R	S	38.6	2.1	9	9	9.1	34.0	43.0	20.2	17.0
5	RT	3-N45	CO	207.0	880624	235	136	99999	#	#	#	35.6	1.9	9	9	11.4	45.5	48.1	21.2	26.3
6	HB	3-N47	CO	206.6	880624	173	39	99999	#	#	#	30.9	1.7	9	9	9.0	32.9	37.8	19.2	17.3
7	HB	3-F02	CO	207.3	880624	173	42	99999	#	#	#	31.7	1.3	9	10	8.6	28.0	35.0	18.9	19.4
8	RT	3-N55	CO	206.6	880625	240	136	99999	#	#	#	48.8	0.9	9	10	13.2	33.1	49.0	27.1	27.2
9	HB	3-N53	CO	207.0	880625	150	33	99999	#	#	#	27.6	1.8	9	9	8.8	42.6	32.7	16.5	15.6
10	BT	4-N20	CO	207.5	880714	294	9999	99999	C	R	S	53.0	2.0	10	10	11.6	53.0	55.7	36.4	35.2
11	CH	4-N21	CO	207.4	880714	272	186	99999	#	#	#	58.3	1.0	9	10	14.2	48.4	58.5	29.9	25.8
12	HB	4-N23	GP	207.4	880715	276	159	425	C	R	S	45.0	3.0	9	10	11.2	42.1	46.5	30.3	31.5
13	BT	4-N23	CO	207.4	880715	257	117	427	C	R	S	45.0	3.0	9	10	11.2	42.1	46.5	30.3	31.5
14	HB	4-N23	CO	207.4	880715	246	9999	410	C	R	S	41.3	3.6	9	10	11.0	45.0	45.2	26.9	27.6
15	HB	4-N24	CO	207.5	880715	239	98	111	C	R	S	42.0	2.2	9	10	12.0	52.9	55.5	34.2	30.7
16	BT	4-N24	CO	207.5	880715	284	154	144	C	R	S	52.2	3.9	10	11	12.0	52.9	55.5	34.2	30.7
17	BT	4-N28	CO	207.3	880715	383	350	5027	C	R	L	69.9	4.1	9	10	15.0	82.8	73.7	42.5	20.4
18	BT	4-N29	CO	207.4	880715	245	92	118	C	R	S	41.9	2.0	9	10	10.3	46.5	45.3	20.2	27.7
19	BT	4-N29	CO	207.4	880715	278	152	128	C	R	S	47.5	1.6	9	10	12.7	52.2	50.8	32.9	32.1
20	BT	4-N40	CO	207.4	880715	365	298	448	C	R	S	57.7	4.1	9	10	15.1	73.7	60.5	40.6	37.8
21	HB	4-N45	CO	207.4	880715	252	107	420	C	R	S	44.2	1.8	9	10	10.7	47.1	48.6	29.5	27.2
22	BT	4-N51	CO	207.5	880716	235	84	429	C	R	S	44.8	1.9	9	10	10.5	44.8	44.2	29.4	25.4
23	BT	4-E18	EL	206.9	880716	306	173	474	C	R	S	55.0	2.8	9	10	12.8	59.7	56.1	35.8	35.6
24	HB	4-N54	CO	205.0	880716	180	49	446	C	R	S	32.9	2.3	9	9	9.9	28.8	38.3	21.5	20.3
25	HB	5-E02	CO	211.3	880803	180	54	409	C	R	S	28.7	2.4	9	9	9.1	31.0	36.6	22.5	20.7
26	HB	5-F01	CO	207.4	880805	190	63	411	C	R	S	34.7	2.4	9	9	10.7	34.0	41.1	21.5	19.1
27	CH	6-N47	CO	207.4	880827	274	142	477	C	R	L	48.4	1.5	9	10	10.0	58.3	52.0	28.5	27.7
28	CH	6-N50	CO	208.0	880827	178	32	99999	#	#	#	31.0	1.3	9	9	8.1	36.4	37.1	22.8	18.6
29	CH	6-N74	CO	206.0	880828	271	140	141	C	R	S	50.3	1.0	9	9	13.2	47.5	55.0	28.5	26.2
30	RT	7-N17	CO	210.1	880917	255	9999	99999	#	#	#	47.6	1.3	9	9	11.7	42.8	50.9	27.5	25.3
31	HB	7-N57	CO	207.0	880918	176	38	132	C	R	S	33.2	1.4	9	10	7.6	33.0	35.2	18.8	18.4
32	HB	7-E11	CO	208.0	880919	175	45	129	C	R	S	30.6	1.8	9	9	8.5	31.0	36.5	18.0	13.7
33	RT	8-N07	GR	11.5	880927	275	112	99999	#	#	#	49.6	1.0	10	10	11.2	48.4	49.8	35.4	33.0
34	RT	8-E02	GR	11.8	880928	265	109	99999	#	#	#	45.8	1.0	9	9	10.5	44.3	50.1	30.8	24.1
35	CH	9-E02	CO	211.6	881007	193	45	442	C	R	S	31.5	3.0	9	9	10.2	35.1	40.7	21.4	20.3
36	HB	9-E02	CO	211.6	881007	215	76	404	C	R	S	41.2	2.9	9	9	11.1	35.3	45.5	24.4	21.0
37	BT	9-N26	CO	207.3	881008	261	84	131	C	R	S	44.9	3.4	10	10	10.7	53.3	49.0	31.2	25.8
38[a]	RT	9-N33	CO	207.9	881008	259	110	99999	#	#	#	53.1	0.0	9	10	13.8	51.5	54.3	28.6	27.4
39	RT	9-N63	CO	207.3	881010	280	148	99999	#	#	#	52.8	1.4	9	10	13.8	54.8	56.3	32.3	26.6
40	RT	9-N69	CO	207.3	881010	257	90	99999	#	#	#	52.1	0.8	9	9	14.1	54.0	51.9	27.1	23.7
41	HB	9-N75	CO	207.4	881010	238	81	140	C	R	S	42.8	2.0	9	10	10.7	46.5	46.8	27.5	27.2
42	CH	9-E08	CO	206.7	881010	168	29	99999	#	#	#	31.3	1.9	9	9	8.4	31.1	35.5	18.4	16.2

Table 18 Continued

#	sp	Coll#	RI	RMI	DATE	TL	WT	TAG	t	c	s	p1p2	Hmp	D	A	CPd	CP1	H1	DFb	AFb
43	HB	3-N40	CO	207.6	870711	195	58	99999	#	#	#	35.0	3.4	9	9	9.5	29.3	36.4	21.8	20.0
44	HB	4-E05	CO	208.0	870730	175	50	99999	#	#	#	31.0	3.3	9	9	9.4	24.0	40.7	21.5	19.0
45	HB	5-E09	CO	208.0	870820	181	59	99999	#	#	#	34.5	2.2	9	9	9.8	30.8	40.3	20.5	16.6
46	HB	5-E11	CO	208.0	870821	182	49	99999	#	#	#	33.0	2.6	9	9	10.0	29.1	35.7	21.6	20.9
47	HB	6-E15	CO	3.0	870911	249	22	5043	C	R	L	41.0	5.0	10	10	11.0	44.8	44.8	28.2	24.1
48	HB	7-E22	CO	206.3	870923	185	9999	489	C	R	S	28.1	2.2	9	9	9.1	26.2	39.5	20.5	17.4
49	HB	7-E23	CO	206.2	870923	162	9999	470	C	R	S	27.6	2.3	9	9	8.2	25.6	33.5	17.7	15.5
50	HB	7-E24	CO	206.2	870924	196	0	460	C	R	S	35.1	2.6	9	9	10.0	30.8	39.4	21.1	17.1
51	HB	7-N19	CO	211.6	870921	179	30	400	C	R	S	22.9	2.4	10	10	10.4	32.3	31.4	20.8	18.2
52	BT	3-N10	CO	207.6	870710	264	120	5034	C	R	L	48.3	2.4	9	10	10.4	50.5	49.2	27.7	26.0
53	BT	5-E04	CO	211.6	870818	287	129	5036	C	R	L	44.0	1.1	9	10	10.8	49.6	54.2	30.6	29.8
54	CH	1-E04	CO	29.3	870414	238	98	99999	#	#	#	42.8	2.5	9	10	10.3	44.6	45.5	24.6	22.5
55	CH	3-S43	CO	206.5	870713	177	38	99999	#	#	#	29.4	1.9	9	9	8.9	27.5	36.7	21.8	19.2
56	CH	4-E11	CO	203.5	870801	203	60	99999	#	#	#	28.7	7.5	9	9	8.5	40.0	39.7	22.1	19.6
57	RT	4-N47	CO	207.8	870731	291	180	99999	#	#	#	51.7	2.3	9	9	11.4	50.6	60.9	31.7	27.6
58	RT	5-E18	CO	206.5	870822	222	9999	99999	#	#	#	36.5	0.4	9	10	9.5	34.7	45.1	24.8	21.8
59	BT	2-T09	CO	1.5	860725	383	355	2932	C	R	L	67.8	12.3	9	10	15.8	80.2	75.3	43.6	41.7
60	HB	3-E08	CO	207.2	860815	355	269	3126	C	R	L	60.0	5.0	9	10	11.0	59.5	67.0	35.5	35.0
61	HB	6-E09	CO	207.7	861002	361	368	3130	C	R	L	55.0	7.0	9	10	13.0	72.0	74.0	41.0	39.0

[a] *Specimen #38 not used in principal components analysis.*

G. robusta, 8 *G. elegans*, 7 *G. cypha*, and 1 *Gila* spp. This cluster showed distant but common membership to the three other clusters, suggesting that its members were either intergrades or intermediates. Principal components analysis revealed that the most important parameters separating these fish into groups were nuchal hump depth, caudal peduncle depth, and caudal peduncle length.

The taxonomic and distributional analyses supported the existence of a self-sustaining population of humpback chub (*Gila cypha*) in Cataract Canyon. It is believed to consist of a form unique to the region, perhaps a geomorph. The chubs classified as *G. cypha* in Cataract Canyon were generally smaller (most less than 200 mm TL), with a blunt head, shallow nuchal hump, overhung snout, scaleless nape and breast, and a relatively deep body. Dorsal and anal fin ray counts were not consistently 9/10, respectively, as is typical of the species; of the 28 fish identified as *G. cypha* in the field, 16 possessed 9/9, 10 had 9/10, and 2 had 10/10 dorsal/anal ray counts. The extreme morphological features such as a pronounced hump were also reduced. Closer examination of chubs from Cataract Canyon is needed to determine if these fish represent the genotype for *G. cypha*, even though they may differ phenotypically. A cross section of chubs captured in Cataract Canyon is shown in Photos A-49 through A-72. A more complete collection of photographs is presented in the "Chub Biography".

The humpback chub in Cataract Canyon may be but a remnant of a larger population that once inhabited the rest of Cataract Canyon, as indicated by collections of the species in Lake Powell shortly after closure of Glen Canyon Dam in 1963 (Holden and Stalnaker 1970; Holden and Stalnaker 1975). Collections taken from 1962 to 1967 revealed a large number of intergrades in the Lake Powell area that these authors felt may reflect hybridization resulting from habitat changes created by Glen Canyon Dam. This together with a remnant population in peripheral and perhaps marginal habitat, may account for the morphology of *G. cypha* currently encountered in Cataract Canyon.

5.1.2.3 Age and Growth

The capture of a 270 mm female in spawning colors on April 14, 1988, and two recently-spawned males (tubercled in spawning colors with scraped sides) measuring 205 and 207 mm TL on June 23, 1988, prompted an investigation into the age of these small humpback chub. Kaeding and Zimmerman (1983) found that male and female humpback chub in the Grand Canyon reached sexual maturity at 250 to 300 mm TL or 3 years of age. Scales from 23 humpback chub and 9 fish tentatively identified as bonytail were examined to age the fish and determined lengths at annulus formations (Table 19). This analysis revealed that the female humpback chub (270 mm TL) found in spawning condition was 5 years old and the two males (205 and 207 mm TL) were 4 years of age. This analysis also revealed that humpback chub in Cataract Canyon grew relatively slow when compared to the suspected bonytail. Although growth for the two groups was similar for the first two years of life, there was an increasing difference in average length at annulus formation starting the third year. Vanicek (1967) found similar accelerated growth rates in bonytail when compared to roundtail chub of the Green River following the third year of life. However, the back-calculated lengths of bonytails at annulus formation reported by Vanicek were greater than those from Cataract Canyon starting in the third year (Table 19, Figure 21).

5.1.2.4 Adults

Twenty-two adult humpback chub were handled during this 4-year investigation (Appendix G). Average length of these fish was 236 mm TL and average weight of 19 was 112 g. The more robust chubs were equipped with serially-numbered red Carlin tags and released. Although these fish were smaller than adult humpback chub from the Grand Canyon (Kaeding and Zimmerman 1983) and from Black Rocks and Westwater Canyon (Valdez and Clemmer 1982), they were classified as adults because of the fish described above in spawning condition and because of the absence of larger fish strongly in the presence of larvae and YOY.

Table 19. Mean calculated total lengths of *Gila cypha* and suspected *Gila elegans* from Cataract Canyon.

Year Class	Age Group	No. of Fish	Mean Length (mm)	Mean calculated total length at annulus (mm) 1	2	3	4	5	6
<u>Gila cypha</u>									
1987	I	0							
1986	II	2	162	52	123				
1985	III	5	184	54	98	141			
1984	IV	7	224	52	111	159	206		
1983	V	7	262	41	78	123	175	238	
1982	VI	2	374	57	125	171	266	300	355
Grand Average Length:			**235**	**50**	**100**	**144**	**200**	**251**	**355**
Number of Fish:			**23**	**23**	**23**	**21**	**16**	**9**	**2**
<u>Gila elegans</u> (suspected)									
1987	I	0							
1986	II	0							
1985	III	0							
1984	IV	3	242	53	108	173	228		
1983	V	6	286	54	93	160	215	269	
Grand Average Length:			**271**	**54**	**98**	**164**	**219**	**269**	
Number of Fish:			**9**	**9**	**9**	**9**	**9**	**6**	

Photographs representing the morphological variation of adult *Gila* spp. seen in Cataract Canyon during this investigation are presented in Photos A-49 through A-72. A complete set of photographs of chubs collected from Cataract Canyon is available in the "Chub Biography", a supplement to this report. Photos A-49 and A-50 were of fish classified as *G. robusta*, a form that was not common in Cataract Canyon. Photo A-49 is of a typical roundtail chub from the upper basin. The fish had a robust head and body, terminal mouth, and thick caudal peduncle. The fish in Photo A-50 had a smaller tapered head while still exhibiting a thick robust body and peduncle. Each fish had nine dorsal and nine anal rays with large coarse scales on the nape, belly, and breast. Coloration of these two fish was typical for the species in the upper basin; olive green back fading to a white belly with a tint of rosy red on the belly and paired fins.

The fish in Photos A-51 and A-52 had massive heads and deep semi-fusiform bodies with shallow broad nuchal humps. Both were fully scaled with nine dorsal and nine anal fin rays. These fish were classified as *Gila* spp. because of the intermediate characters that did not definitively ally them with any of the three congeneric Colorado River chubs. Their large heads and thick bodies suggest influence of *G. robusta*, while their slender caudal peduncle, moderate nuchal hump, and subterminal mouth indicates influence of *G. cypha*. This form is also reported from Desolation and Gray Canyons (Personal communication with Miles Moretti, UDWR, February 1989).

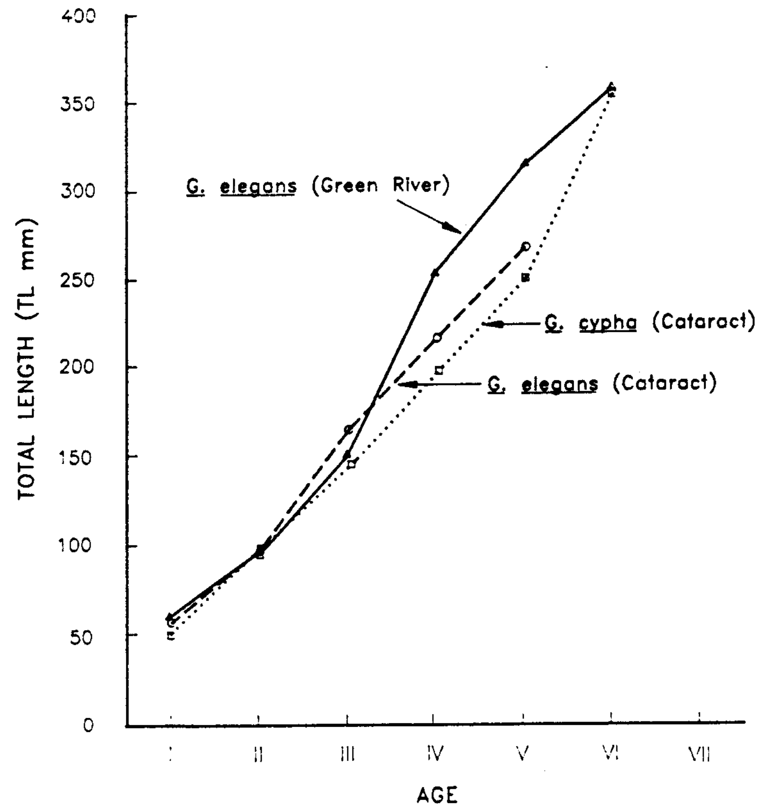


Figure 21. Growth of humpback chub and bonytail from Cataract Canyon, compared to bonytail from the Green River (Vanicek 1967).

The second set of photos (A-53 through A-56) are of a small form classified as *G. cypha*. This is the most common form in Cataract Canyon, and resembles specimens from Desolation Canyon (Personal communications with Miles Moretti, UDWR, April 1987). Each fish had a very deep body, with a relatively short blunt head and a slightly overhanging snout. These fish had no scales on the nape, breast, or belly, and the nuchal hump was small (Photos A-55 and A-56). Each fish had a characteristically slate gray color fading to white sides and belly. The fish in these photographs ranged from 175 to 190 mm TL and were thought to be immature, until the specimens shown in Photos A-57 and A-60 were captured on June 23-25, 1988. All three fish had tubercles on their head and fins, and the fish in Photos A-58 and A-59 had recent rub marks and scars on their body that indicated recent spawning activity. However, no eggs or milt were stripped from these fish. Photo A-60 is a closeup of the fish in Photo A-59, illustrating the dull gray hue and light rosy spawning colors of this form. Anal ray counts for this form were generally either 9 or 10, and dorsal ray counts were usually 9.

The few larger specimens of *G. cypha* found in Cataract Canyon are represented in Photos A-61 through A-64. The fish in Photos A-61 and A-62 is the only specimen of this form captured in Cataract Canyon. It was a deep-bodied robust fish, 280 mm TL, with an abrupt nuchal hump, not unlike fish found in Westwater Canyon. The form in Photos A-63 and A-64 was also uncommon in Cataract Canyon. This 249 mm long fish was not as deep bodied as the other forms, but exhibited a moderately concave frontal, a moderate nuchal hump, scaleless nape, breast, and belly, and usually 10 anal and 9 dorsal rays.

5.1.2.5 Juveniles

Fifty-six juvenile humpback chub were handled during this investigation (Appendix G). These fish were classified as juveniles on the basis of size relative to the largest fish caught, and on the development of morphological characters. A full collection of photographs and meristics for these fish are presented in the 'Chub Biography'.

In December of 1981, a shipment of 7600 one and a half year old humpback chub from the Willow Beach National Fish Hatchery were released immediately above Rapid 11 in Cataract Canyon. These fish had been hatched from eggs taken in the field from Black Rocks in May 1980 (Valdez and Gonzales-Valdes In press). Each was marked with a coded wire nose tag detectable with a special instrument. This instrument was not available during this investigation, and the only two fish sacrificed and transported from Cataract Canyon did not contain these metal tags. The survival, fate, and eventual influence of these fish on the genetics of the Cataract Canyon population is unknown.

5.1.2.6 Young-of-the-Year and Larvae

Nineteen YOY and 11 larval humpback chub were handled during this study (Appendix G). These fish were all identified by the LFL. Many more YOY humpback chub were probably captured, but were not classified to species because of the difficulty in distinguishing the three sympatric species of *Gila* in the upper basin. Nevertheless, the small numbers of adult roundtail chub (*G. robusta*) indicates that most YOY chubs found in Cataract Canyon were *G. cypha*.

A previous discussion in this report (Section 4.2.5, Figure 12) showed a difference in densities of YOY chubs caught in the Cataract Canyon area. This indicates differences in year class strength, such that in 1985, 1986, and 1988, the year classes were small; whereas in 1987, the year class was large. No relationship was evident between this trend of year class strength and river flows or temperatures, since flows were highest in 1985 and 1986 with late warming, but very low in 1988 with early warming. Monthly length-frequency histograms of YOY chubs in the Cataract Canyon area are presented in Figure 22.

5.1.3 Bonytail

Fourteen fish, tentatively identified as bonytail, were handled during the Cataract Canyon Study (Appendix G). This included two in 1985, one in 1986, two in 1987, and nine in 1988. Photographs of six adults are presented in Appendix A of this report. Additional photographs and more detailed descriptions were provided in the 'Chub Biography'.

The fish in Photos A-66 through A-71 were of fish tentatively identified as bonytail (*G. elegans*), and varied from 285 to 386 mm. Photo A-72 is provided for comparison; it is of a bonytail hatched and raised at the Dexter National Fish Hatchery whose parents were captured in Lake Mohave. The common character of these fish was the long slender fusiform body with elongated caudal peduncle. The fish in Photos A-66 through A-68 each had a slender head and body (head contour in Photo A-67 is blocked by the shadow), elongated caudal peduncle, and 9 dorsal and 10 anal fin rays. The body shape of these three fish was not unlike that of the hatchery-reared bonytail in Photo A-72.

The fish in Photos A-69 and A-71 had deeper bodies than the previously described fish and in spite of their moderate size (365, 383, and 284 mm TL, respectively) had small nuchal humps suggesting influence of *G. cypha*. These fish possessed several characteristics typical of *G. elegans* including a partially scaled nape, breast, and belly; terminal snout; shallow concave frontal, and a long tapering caudal peduncle. Although dorsal and anal ray counts for the fish in Photos A-69 and A-70 were 9 and 10, respectively, the fish in Photo A-71 had 10 dorsal and 11 anal rays. The small nuchal hump,

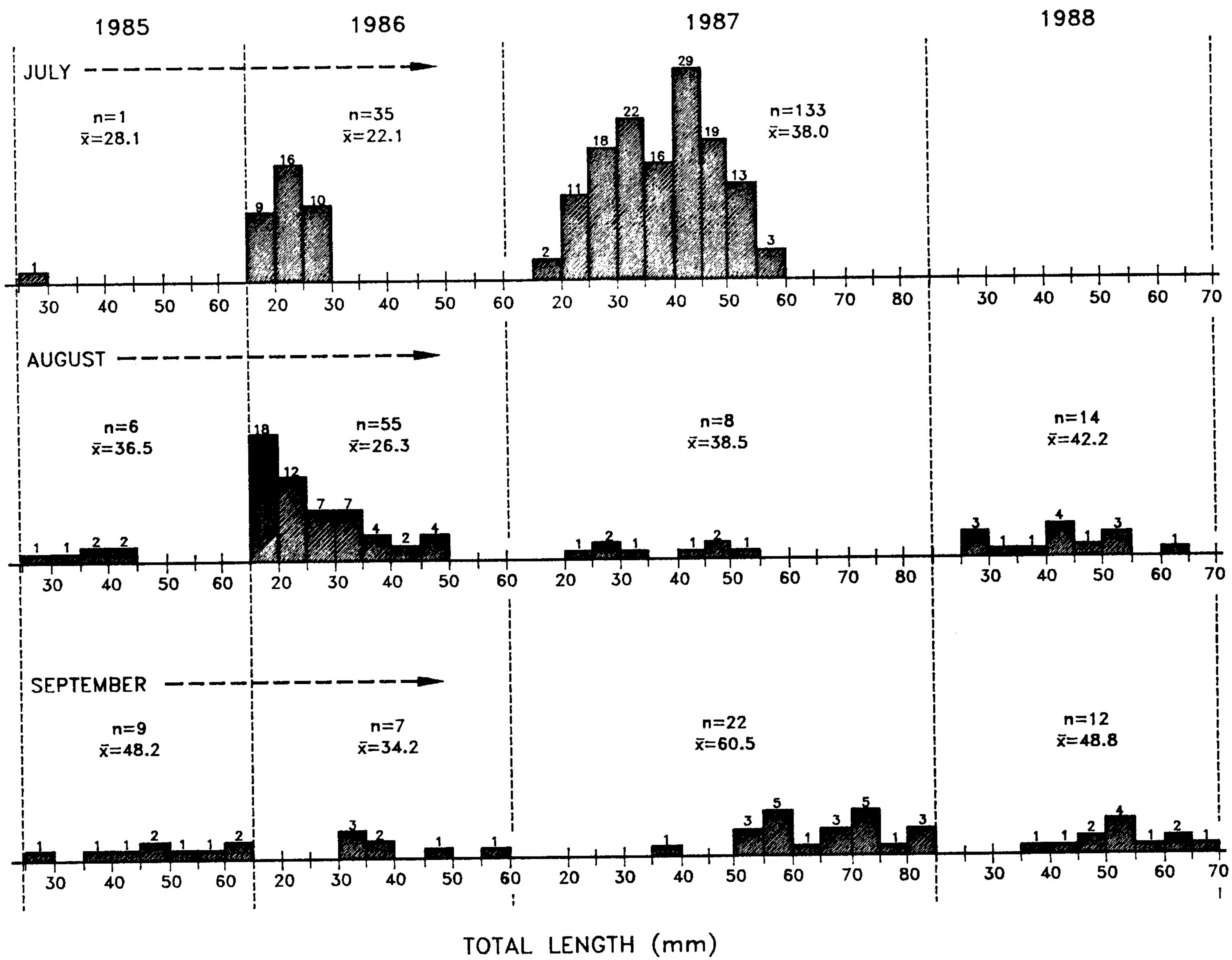


Figure 22. Monthly length-frequency histograms for YOY chubs (*Gila* spp.) in the Cataract Canyon Study Area for 1985-1988

elongated body, and confounding ray counts indicates possible influence of both *G. elegans* and *G. cypha* as reported by Holden and Stalnaker (1970) with specimens from Lake Powell. Principal components analysis on 60 fish (See Section 5.1.2.2) separated the fish in Photos A-67, A-69, A-70, and A-71 into cluster 1, which was identified as the fish representing the *G. elegans* form. This analysis also associated the fish in Photo A-68 with the cluster representing the *G. robusta* form. Meristics were not available on the fish in Photo A-66 for this analysis.

5.1.4 Razorback Sucker

One razorback sucker was handled during the 4-year Cataract Canyon Studies. The fish was an adult (TL = 493 mm, WT = 1618 g, Red Carlin Tag 5029) that was captured, tagged, and released at the large riffle at the mouth of Salt Creek, RM 3.6 on the Colorado River. This fish was captured September 11, 1987, and was the first razorback sucker captured during the investigations of the Cataract Canyon region from 1985 through 1988. Prior to this, 2 adult razorback were caught at The Slide (RM 1.4 and 1.5) in 1981 (Valdez et al. 1982), and 6 and 11 were caught at Gypsum Canyon in upper Lake Powell (RM 197.0) in 1980 and 1981, respectively (Persons et al. 1982). The latter investigators also captured two adult razorback at Spanish Bottom (RM 213.0) in 1980.

The capture of only one razorback sucker in 4 years of sampling 120 miles of the upper basin is a disturbing statistic. Spawning by this species has not been documented in the upper basin in over 10 years, and the number of adults captured is decreasing. Lanigan and Tyus (1989) estimated only 948 fish (95% confidence interval, 758-1138) in 169 miles of the Green River above Desolation Canyon.

5.2 Findings of Objectives

These are the major findings of this investigation relative to each of the three stated objectives.

5.2.1 Objective 1: Spawning Locations of Endangered Fish

Specific spawning sites for the three endangered fish species were not located during this 4-year study. Without the aid of radiotelemetry and a program of ongoing monitoring, this objective was difficult to satisfy because of high and turbid water conditions and small numbers of adult Colorado squawfish, humpback chub, bonytail, and razorback sucker. Nevertheless, the presence of various age groups and potential spawning areas enabled us to hypothesize on the location and timing of spawning. The following is a discussion relative to possible spawning locations for each of the three endangered species and the rationale that led to the development of these hypotheses.

5.2.1.1 Colorado Squawfish

Tyus et al. (1987) reported that Green River larval collections confirmed known spawning sites for Colorado squawfish in Gray and Yampa Canyons, and suggested the existence of seven other possible sites, six of which were supported by the presence of radiotagged adults during spawning season. Two of these suspected areas were Labyrinth Canyon (RM 41 to 66) and Stillwater Canyon (RM 3.2 to 28), which are within Region 1 of this study area.

We agree that spawning by Colorado squawfish probably occurs in this area as indicated by larval fish collections. It appears that the reason Tyus et al. (1987) were unable to annually radiotrack adult fish to a specific spawning site is that the fish opportunistically use any of several small and widely distributed cobble bars which may present the optimum set of spawning conditions on a given year. Nine such cobble bars were identified in the lower 50 miles of the Green River (Region 1), and three in the lower 50 miles of the Colorado River (Region 2) (Table 20). The relative difference in numbers of cobble bars may partly explain the difference in density of YOY Colorado squawfish between the two

Table 20. Cobble bars on the Lower Green and Colorado Rivers of the upper basin recognized as possible spawning sites for Colorado squawfish.

RIVER	LOCATION	RIVER MILE
Green	Tent Bottom	39.5
	White Rim Trail	36.3
	White Rim Trail[a]	36.0
	Millard Canyon	33.6
	Anderson Bottom	31.0
	Unnamed canyon	15.1
	Horse Canyon	14.2
	Jasper Canyon	9.2
	Shot Canyon	4.5
Colorado	Monument Canyon	15.3
	Salt Creek	3.6
	Elephant Canyon	3.0
	Lower Red Lake Canyon	212.8
	Below Rapid 12, Cataract Canyon	206.6

a This cobble area has a small spring draining into it, which may be an attraction for spawning fish.

regions. One site was also located in Region 3, between the confluence and Cataract Canyon, and the large complex of cobble bars in the middle of Cataract Canyon was also considered a potential spawning area.

Spawning was suspected on these isolated cobble bars because of the presence of very small larvae (<20 mm TL) in nearby downstream backwaters in late June and early July. This phenomenon was particulary evident below the large cobble bars at Tent Bottom (RM 39.5) and at the mouth of Millard Canyon (RM 33.6) on the Green River. In July of 1986 and 1987, this investigation and personnel from UDWR (Personal communications with Miles Moretti, UDWR, June 21, 1988) reported relatively higher densities of larval and YOY Colorado squawfish in the backwaters immediately below these areas with few or no young fish captured above these cobble bars, although backwaters were available throughout.

The size of these young fish was consistent early in the year, indicating that fish in a given sample hatched at about the same time in nearby areas. As summer progressed, the size of fish captured became more variable, indicating dispersal of YOY and transport from upstream spawning areas to mix with local fish. It was not known if larval and YOY Colorado squawfish drifted into the lower Green and Colorado Rivers from such distant confirmed spawning areas as the Yampa River (RM 335) or Three Fords (RM 156), but it is possible that some newly-hatched fish were transported from suspected spawning areas (Biological Sub-Committee 1984) located closer upstream, such as Labyrinth Canyon (RM 38-115), Tusher Wash (RM 124-129), Gray Canyon (RM 157), or Desolation Canyon (RM 180-210). The distance that a larval Colorado squawfish is transported downstream by river currents is unknown, although with an average post-runoff current speed of 2-3 mph, it is conceiveable that a larval fish could be transported 100 miles in 33 to 50 hours, or 1.5 to 2 days. Further movement and dispersal probably occurs as the YOY grow and find their way from one backwater to another along sheltered shorelines.

The high density of larvae and YOY Colorado squawfish in the lower 50 miles of the Green River indicates that reproduction occurred in this region, and their relatively low density immediately below the confluence indicates that few of these fish were being transported into Cataract Canyon and upper Lake Powell during their first summer, although transport during spring runoff was not evaluated. The low numbers of early larvae in Cataract Canyon also indicates that some spawning occurred in the canyon and immediately downstream in the Lake Powell Inflow, but the contribution of this spawning was not significant in the years 1985-1988.

The timing of spawning by Colorado squawfish in the study area was difficult to determine, even with the aid of back-calculating hatching dates from lengths of fish (See Section 5.1.3.2). This analysis of YOY from 1985 to 1988 consistently revealed a broad histogram with a large variation in hatching dates that we attributed to the capture of YOY from different upstream spawning sites with different spawning dates, and not necessarily to a large variation in spawning times by local fish. The mode of these back-calculated dates suggests that peak spawning times for 1985-1988 varied annually by as much as one month.

Larval Colorado squawfish, less than 15 mm long, were first captured annually in the study area on July 21, 1985; August 12, 1986; July 8, 1987; and July 13, 1988, of each of the 4 years of this investigation. The age of these fish varied from 16 to 25 days, suggesting that local hatching first occurred about July 5, 1985; July 21, 1986; June 17, 1987; and June 21, 1988. Previous analyses in this report showed that these spawning dates were generally related to delayed warming of river temperature. Colorado squawfish that were hatched relatively late in the year (e.g., August) were smaller in the fall than those hatched relatively early (e.g., July). This led to the hypothesis that overwinter survival was higher in early-spawned year classes because these fish were larger and more able to cope with winter riverine conditions when backwaters become too cold or ice laden to accommodate the young fish.

5.2.1.2 Humpback Chub

Although spawning by humpback chub was suspected in at least one area within Cataract Canyon, no spawning sites were found in either the lower Green or Colorado Rivers above Cataract Canyon or in the Lake Powell Inflow. However, since a 4-mile area (RM 205-209) within Cataract Canyon yielded most of the larvae and YOY (Figure 19), this was identified as the most likely area for reproduction by the species. This area contained talus shorelines with cobble and gravel deposits and bars that were considered good spawning habitat for the species. Within this 4-mile area, the reach between RM 207.4 and 207.6 was believed to be a specific spawning site, although unconfirmed. This 0.2-mile reach, between Rapids 10 and 11, produced most of the young fish as well as two adults in spawning colors in the spring of 1988.

This area was not confirmed as a spawning site because of the failure to strip eggs from any females, according to the criteria contained in the Sensitive Areas Document (Biological Sub-Committee 1984). However, the capture of five or more adults in this canyon area satisfied the criterion for a "suspected" spawning area, and we recommend this designation for Cataract Canyon (RM 201.5-212.4).

5.2.1.3 Bonytail

The uncertainty surrounding the taxonomy and systematics of the *Gila* complex of the Colorado River, particularly the young fish of the upper basin where the three species occur sympatrically, makes an assessment of spawning by bonytail difficult. Although this investigation reported a total of 14 specimens, including 1 YOY, 7 juveniles, and 6 adults, a determination of spawning by this form is not appropriate without further examination of specimens from this area.

This conclusion was reached because the forms classified as *G. elegans* in Cataract Canyon did not satisfy all of the meristic characters associated with the original description of the species (Baird and Girard 1853, Holden and Stalnaker 1970, Smith et al. 1979). The YOY captured on September 22, 1985, was classified as a "possible *Gila elegans*" (Muth 1985), primarily because of dorsal fin ray counts and total vertebral counts that were low for this species, although anal rays, postanal vertebrae, and gill raker counts were typical. The juveniles and adults also usually possessed 9 rather than 10 dorsal rays, although other body meristics were typical of bonytail. Because of the taxonomic uncertainty of the Cataract Canyon specimens, a determination of spawning by this suspected species in this area is not submitted at this time.

5.2.1.4 Razorback Sucker

Only one adult razorback sucker was captured during the 4 years of this investigation. This fish was captured at the mouth of Salt Creek on the Colorado River (RM 3.6), on September 11, 1987. The fish was captured too late in the year to show any evidence of spawning condition. Although many larvae, YOY, and juvenile suckers were examined by the Larval Fish Laboratory and by BIO/WEST, none was classified as a razorback sucker. This investigation, therefore, revealed no evidence of spawning by razorback suckers in either the lower 50 miles of the Green River, the lower 50 miles of the Colorado River, in Cataract Canyon, or in the Lake Powell Inflow.

5.2.2 Objective 2: Humpback Chub Population In Cataract

This investigation revealed the presence of a population of humpback chub in Cataract Canyon. This population was primarily concentrated in a 4-mile reach from RM 209 to 205, between Rapids #8 and 13. Smaller numbers were found in a 1-mile reach from RM 212 to 211, between Rapids #2 and 4. Other concentrations may be present in the canyon, but sampling conditions precluded confirming these. The first report of a possible population of humpback chub in Cataract Canyon was in 1980 (Valdez 1980).

A total of 108 humpback chub were captured in Cataract Canyon during this 4-year investigation; virtually all of these fish were within the the upper 7 miles of Cataract Canyon, from RM 212 to 205, between Rapids #2 and 13. The fish captured included 11 larvae, 19 YOY, 56 juveniles, and 22 adults, indicating that the population was small but reproducing. As previously stated in Section 5.1.2, most of this reproduction was suspected within a 4-mile reach between RM 205 and 209. The capture of five or more adults in one year meets the criterion of the Sensitive Areas Document (Biological Sub-Committee 1984) that would change Cataract Canyon from a designation of "collections in low numbers" to "concentration area". Although this population appeared to be self-sustaining, spawning was not confirmed; ripe females captured prior to spawning season could not be stripped of eggs. This may be a difficult task in Cataract Canyon because of the difficult sample conditions during runoff in May and early June, which is the normal spawning time for the species.

Humpback chub in Cataract Canyon tended to be smaller than those found in other regions of the upper basin. Average total length of the 22 adults captured was 236 mm, and average weight of 19 was 112 g. Specimens of this form were small and delicate in appearance with most features typical of *G. cypha*. The body was characteristically deep and laterally compressed, with a sharp taper to a narrow caudal peduncle and a flared and deeply forked caudal fin. The head was usually elongated with a concave frontal and an overhanging fleshy snout. An abrupt hump rose from the posterior margin of the head to the anterior insertion of the dorsal fin, although this hump was not as large as in other upper basin *G. cypha*. Dorsal ray counts were 9 for all but a few specimens having 8 or 10 rays; anal fin rays were either 9 or 10. The depth of the hump and the low number of anal rays were the only two external features not typical of the described *G. cypha*.

The nape and belly of these specimens was entirely scaleless, and there were few but deeply imbedded scales above the lateral line. The body of the juveniles and adults was slate gray blending to a white belly. Adults captured near spawning time had a pronounced slate gray color with rosy red fins and light rosy slashes on the belly; the skin of these fish was rough, and tubercles were present on the pectoral fins and dorsal aspect of the head.

We hypothesize that the small form of humpback chub in Cataract Canyon is the *G. cypha* genotype, but apparently differs phenotypically from other populations. Perhaps the fish seen today in Cataract Canyon are remnants of a more expansive population that inhabited Cataract Canyon prior to the construction of Glen Canyon Dam in 1963. Numerous humpback chub captured during and shortly after the closure of the dam supports this suspicion (Holden and Stalnaker, 1975). According to descriptions of *G. cypha* provided by Holden and Stalnaker (1970), the fish currently found in Cataract Canyon may differ morphologically from those captured in Lake Powell and at Lee's Ferry from 1962 to 1967. Further examination of *Gila* specimens from Cataract Canyon is needed to determine the relationship between this form and those from other regions in the upper and lower Colorado River Basin.

5.2.3 Objective 3: Nursery Habitat in the Lake Powell Inflow

Fish habitat in the Lake Powell Inflow was largely influenced by lake levels during this investigation (Figure 23). Generally, lake levels were highest in mid-July, and lowest in March, reflecting management of the reservoir for water storage and flood protection during spring runoff, and water delivery in summer, fall, and winter. During this investigation, the varying lake levels most influenced a 2-mile reach from Rapid 24 (RM 201.8) to lower Rapid 27 (RM 199.8), by inundating part or all of this area. When the lake was high, generally river flow was also high, and most backwaters became inundated; the maximum historic lake level of 3708.34 feet occurred July 14, 1983 (Ferrari 1988). Conversely, when the lake was low in late summer, river flow was also low, and backwaters were desiccated; minimum lake level during this investigation was 3685.03 feet on October 12, 1988.

The range of lake levels that resulted in the maximum number of observed backwaters in 1987 and 1988 was between 3692.0 and 3698.2 feet (Figure 24). This was determined by counting the numbers of backwaters on each trip and determining corresponding lake levels from Reclamation data. This maximum number of eight backwaters occurred on July 13, 1987, when the lake level was 3697.96 feet above sea level. It was noted that on June 28, 1987, just 2 weeks prior, there was only one backwater in the area, when the lake level was 3698.45 feet. Thus, a drop of only 0.49 feet resulted in the formation of numerous backwaters. The number of backwaters in 1987 dropped to five on August 2 and to four on August 22, when lake levels were 3695.83 and 3692.69 feet, respectively. The same numbers of backwaters were seen in the region in 1988 at approximately the same lake levels. Lake levels below about 3692.0 feet reduced the number of backwaters in the region dramatically, to only one or two. It should be noted that no backwaters were seen from this area downstream into Lake Powell, and so the only nursery backwater habitat for YOY Colorado squawfish was in this inflow region.

From 1985 to 1988, there was little nursery habitat for Colorado squawfish in upper Lake Powell. The maximum number of backwaters (eight) was observed in mid-July of 1987 in a 1-mile reach between RM 200.1 and 201.1. No other backwaters were observed in this upper region of Lake Powell, although quiet lake waters that backed into side canyons provided backwater-like habitat. Thus, nursery habitat was limited at the Lake Powell Inflow, and its availability varied seasonally with lake levels.

Only 3%, or 117 of the 4348 larval and YOY Colorado squawfish, were captured in the Lake Powell Inflow. All of these fish were caught in a 1-mile reach, between RM 200.1 and 201.1. Of the 117 young fish, 26 were captured in two seine hauls following a large flash flood that washed these fish into the region from upstream on August 27, 1988 (See Sections 2.1, 4.3.4, and 5.1.1.3.4).

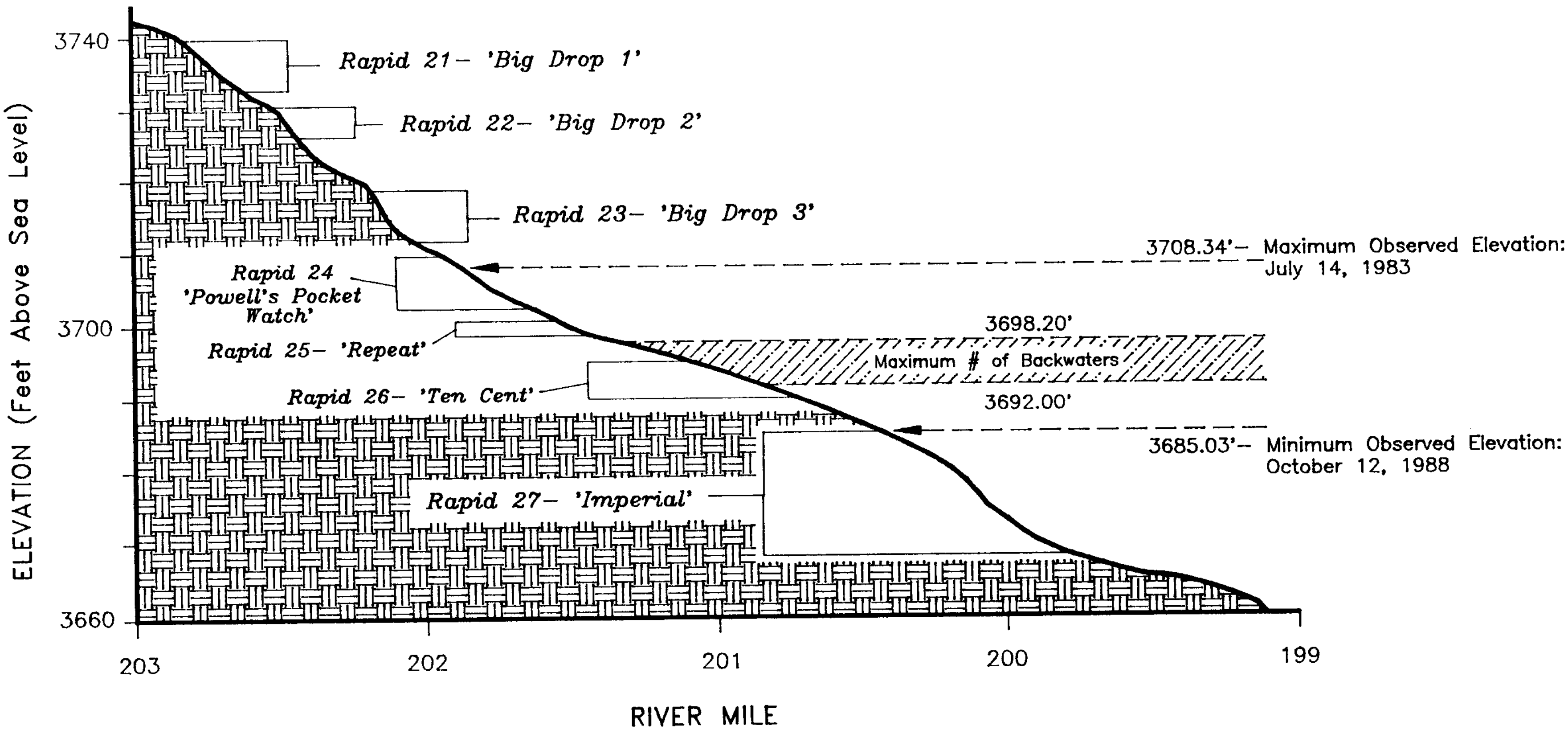


Figure 23. Gradient of a 4-mile reach of the Lake Powell inflow, with maximum recorded lake elevation, minimum observed elevation for this study, and range of levels that produced the maximum number of backwaters.

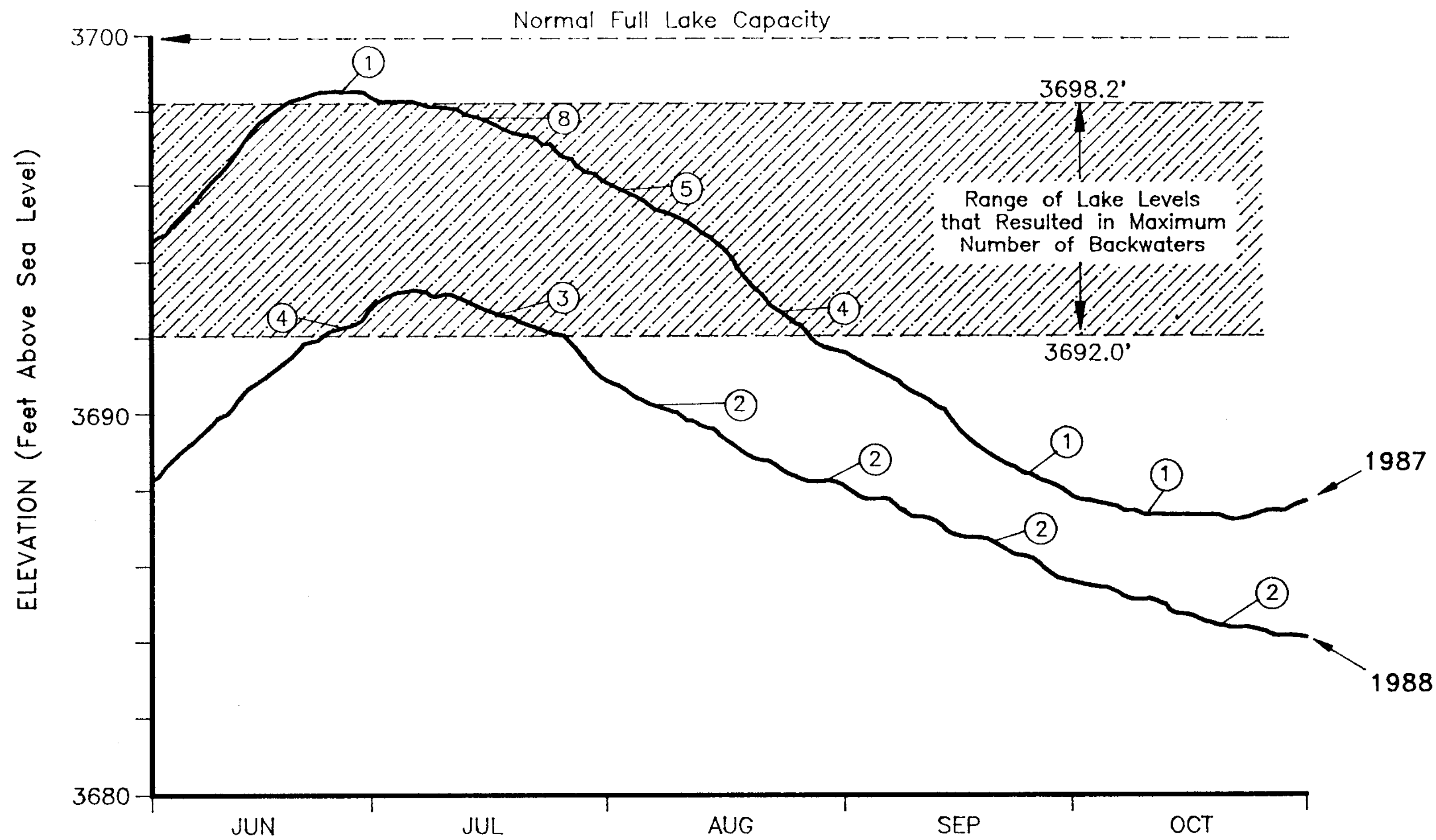


Figure 24. Levels of Lake Powell from June to October, 1987 and 1988, that produced the maximum number of backwaters (circled numbers) in a 2-mile reach (RM 201.8 to 199.8) of inflow.

This region supported the highest non-native fish diversity of any sampled during this investigation. Red shiners, sand shiners, fathead minnows, and channel catfish were abundant in the nursery backwaters, while young striped bass, largemouth bass, and black bullheads were numerous. Also, juvenile and adult carp, striped bass, channel catfish, and walleye were common in the main channel. These species probably impose severe competition and predation pressure on young Colorado squawfish, and combined with limited numbers of backwaters probably limits the value of this region as a nursery for Colorado squawfish.

This investigation does not recommend adherence to specific water levels in Lake Powell. This would be an unrealistic recommendation, considering that in a 4-year period, only 3% of the young Colorado squawfish were found in this region. This small number of fish is not considered a significant portion of the population in the upper basin. Even if lake levels that maximize backwater formation could be maintained, the number of predaceous fish of various sizes would probably offset whatever survival benefits could be gleaned from the long-term presence of a few backwaters. The same rationale applies to humpback chubs; the numbers of YOY that were transported into this region from Cataract Canyon was also insignificant.

Recommending adherence to specific lake levels would further be unrealistic considering the dynamics of the fish habitat in this region in the last 10 years. These changes are continuing today, and maintenance of specific lake levels to maximize habitats may not have the same effect in future years. Ferrari (1988) reported an average sediment thickness above Hite (RM 154-182) of 127 feet with the deepest sediment recorded on the entire reservoir of about 182 feet just below Cataract Canyon (RM 181, between Dark and Sheep Canyons). This accumulation of sediment has manifested significant changes in fish habitat. A brief discussion of these changes follows.

From 1979 to 1981, there were few sand bars where the Colorado River flowed into Lake Powell. The shoreline reflected the original talus slopes that were present before the lake. The mouths of most of the canyons (i.e., Gypsum, Palmer, Clearwater, Bowdie, Dark) were free of silt/sand bars. In 1981, the lake first reached its maximum fill capacity of 3700 feet elevation, and the receding waters began depositing large silt/sand bars at the mouths of canyons and in the inflow region. The record runoffs of 1984 and 1985 also filled the lake to capacity and further deposited vast quantities of silt/sand in upper Lake Powell. As the water receeded, these sand bars became permanent features of the shoreline and main channel. The shoreline bars were further stabilized by growths of tamarisk that sent vast networks of roots to bind the sand and silt (Photos A-25 through A-32). By 1988, tamarisk-covered sand bars lined the shore from Rapid #26 (RM 201) downstream to Palmer Canyon (RM 195), and occurred sporadically at the mouths of most canyons as far downstream as Dark Canyon (RM 183). At low lake levels in summer and fall of 1988 and 1989, many silt/sand bars also emerged in various locations of the channel as far downstream as Sheep Canyon (25 miles below Rapid #24). It appears that stabilization of sandbars in the upper region of Lake Powell has reduced the backwater potential of this area. Continued filling of the area with silt and sand, proliferation of tamarisk, and stabilization of the sand bars will continue to reduce the potential for these areas to form backwaters and provide potential nursery habitat.

One might speculate that prior to the 1963 closure of Glen Canyon Dam, large numbers of young Colorado squawfish were transported downstream through Cataract, Glen, and Grand Canyons to warmer river conditions in the lower basin. Perhaps that phenomenon still occurs during runoff. Or, perhaps, the remaining genetic stock of Colorado squawfish has imprinted wholly to the upper basin. No investigation to date has looked specifically at the numbers of fish being carried into Lake Powell by spring runoff, particularly in high water years. Persons et al. (1982) did not report young Colorado squawfish in 1980 with 374 minutes of plankton tows for eggs and larval striped bass between Gypsum Canyon (RM 196.5) and RM 198.0 just below the Lake Powell Inflow. It is possible that many fish are being transported into the lake and eaten by a large contingent of predators during runoff.

6.0 RECOMMENDATIONS

The following recommendations were made as a result of the 4-year Cataract Canyon Studies:

6.1 Recommended Changes to the Sensitive Areas Document

In 1984, the Biological Sub-Committee of the Upper Colorado River Basin Coordinating Committee issued a Sensitive Areas Document which established criteria for classifying different age categories of three of the four rare fishes of the upper basin (Colorado squawfish, humpback chub, and razorback sucker). These classifications are used to attach importance to specific river regions by quantifying the catch per effort for the age category of each species. A summary of the age categories, classifications, and criteria for each species are presented in Table 21. A summary of the current classification for each region and the recommended classification from this investigation are presented in Table 22.

The following recommendations are made relative to the Sensitive Areas Document (Biological Sub-Committee 1984) for the Cataract Canyon Study Area; i.e., for the five regions, jointly, or separately: (1) the lower 50 miles of the Green River, (2) the lower 50 miles of the Colorado River, (3) the Colorado River from their confluence to the first rapid of Cataract Canyon, (4) Cataract Canyon, and (5) the Lake Powell Inflow. Two systems of river mile designation are presented. This report deals with river miles below the confluence of the Green and Colorado Rivers as the river miles upstream from Lees Ferry, i.e., the confluence is RM 216.4; the Sensitive Areas Document designates river miles below the confluence as the distance from the confluence downstream with a minus value. Thus, RM 210.0 in this report is equivalent to RM -6.4 in the Sensitive Areas Document.

6.1.1 Colorado Squawfish

<u>**Adult Distribution**</u>: Adult Colorado squawfish were caught in all regions of the study area, and we recommend maintaining the current designation with the criterion that these are "River reaches from which adult Colorado squawfish have been captured within the last 10 years." A total of 12 were captured during this 4-year investigation.

<u>**High Concentration Areas**</u>: None of the study area is recommended for this designation since the catch rate of adult Colorado squawfish did not exceed the minimum criterion of 7 fish per 10 hours of electrofishing (Figure 25). We recommend no changes to this classification. The CPE of adult Colorado squawfish expressed as number of fish per 100 feet of net per 100 hours of gill or trammel net sets (Figure 26) is presented for other investigators to compare with catch rates from other areas. Gill and trammel net data are not used to classify areas for this species under the Sensitive Areas Document.

<u>**Concentration Areas**</u>: None of the study area is recommended for this designation since the catch rate of adult Colorado squawfish did not exceed the minimum criterion of 3 fish per 10 hours of electrofishing. We recommend no changes to this classification in the Sensitive Areas Document.

<u>**Spawning Migration Routes**</u>: No recommendation can be made to this classification, since no radiotelemetry equipment was used in this investigation; the criterion is "Migration routes traversed by radio telemetered or tagged Colorado squawfish two months prior, or following the spawning season." The study area is currently shown as a migration route for this species.

<u>**Confirmed Spawning Areas**</u>: No spawning areas were confirmed in the study area during this investigation, according to the three criteria of the Sensitive Areas Document: "(1) Occurrence of deep

Table 21. Criteria established by the Sensitive Areas Document (Biological Sub-Committee 1984) for the different ages of endangered fish.

SPECIES Age Category	CLASSIFICATION	CRITERIA
COLORADO SQUAWFISH		
Larvae	Distribution	Collection of fish <25mm TL
Young-of-Year	Distribution	Collection of fish 25-60mm TL in past 5 years
	High Density Nursery	Average seine catch >9 fish/100m²
	Nursery Area	Average seine catch >0.9 fish/100m²
Juvenile	High Concentration	Electrofishing rate >3 fish/10 hours
	Concentration Area	Electrofishing rate >1 fish/10 hours
Adult	Distribution	Collection of fish 450mm + in past 10 years
	High Concentration	Electrofishing rate >7 fish/10 hours
	Concentration Area	Electrofishing rate >3 fish/10 hours
	Migration Route	Traversed by adults 2 mo. pre-spawning
	Confirmed Spawning Area	Deep pools, cobble riffle; ripe female + 2 adults within 5 miles; larvae <15mm TL within 20 miles
	Suspected Spawning Area	Deep pools, cobble riffle; ripe male + 1 fish; larvae <25mm TL
HUMPBACK CHUB		
Larvae Young-of-Year Juvenile	Distribution	No criteria since larvae, YOY and juveniles are difficult to identify afield
Adult	Distribution	Capture of fish >200mm TL in past 5 years
	Concentration Area	Capture of 5 adults in 1 year from deep canyons.
	Confirmed Spawning Area	Capture of ripe females
	Suspected Spawning Area	Capture of 5 fish in deep canyon areas

Table 21. Continued

SPECIES Age Category	Classification	Criteria
RAZORBACK SUCKER		
Larvae Young-of-Year Juvenile	Distribution	No criteria since larvae, YOY, and juveniles have not been captured in upper basin in over 10 years.
Adult	Distribution	Capture of fish >450mm TL in past 5 years
	Concentration Area	Capture of 10+ adults from a 20-mile reach in past 5 years
	Confirmed Spawning Area	Capture of ripe females
	Suspected Spawning Area	Collection of 2 or more ripe males from gravel/cobble substrate

pools interspersed with cobble/riffle habitat and, (2) Collection of ripe females (strippable eggs) and observation of two or more radio-tagged adults within a 5-mile reach during the suspected spawning season and, (3) Presence of larval Colorado squawfish <15 mm TL collected within 20 miles downstream of suspected reach." Although criteria 1 and 2 were met in the lower Green River, the lower Colorado River, and in Cataract Canyon, criterion 3 was not satisfied. No changes are recommended to this classification.

Suspected Spawning Areas: We recommend designating the lower 50 miles of the Green River as a suspected spawning area. This would extend the current designation from lower Labyrinth Canyon (RM 38-66), downstream through Stillwater Canyon to the confluence. A similar recommendation is not made at this time for the lower 50 miles of the Colorado River; FWS and UDWR have conducted most of the work in this area, and can better assess this classification. We further recommend changing the area within Cataract Canyon currently designated as a suspected spawning area from RM -18 to -14, to RM -8 to -11. We did not find larval Colorado squawfish less than 25 mm TL in the former area, but did find these fish, as well as the occurrence of deep pools interspersed with cobble/riffle habitat, in the latter area. These recommendations are based on satisfying criteria 2 and 3 of the Sensitive Areas Document: "(1) Collection of ripe male Colorado squawfish (strippable milt) or one or more radio-tagged Colorado squawfish in the areas during suspected spawning period and, (2) Occurrence of larval Colorado squawfish (less than 25 mm TL) downstream and, (3) Occurrence of deep pools interspersed with cobble/riffle habitat". We deviate from satisfying all three criteria for this designation because our sampling was not geared for the use of radiotelemetry, nor for the constant monitoring of suspected spawning areas to capture ripe fish.

Larval Distribution: We concur with the current designation for the study area as an area of larval distribution, since we caught larval Colorado squawfish (less than 25 mm TL) as far downstream as RM 200 (-16).

Table 22. Current classifications and recommended changes to the Sensitive Areas Document (Biological Subcommitte 1984) for the different ages of endangered fishes.

SPECIES Classification	CURRENT REACH DESIGNATIONS	RECOMMENDED CHANGE
COLORADO SQUAWFISH		
Adult Distribution	GR: Lake Powell-Palisade (RM -16 to 185)	None
	CO: Confluence-Lodore (RM 0 to 364)	None
High Concentration	GR: Sand Wash-Yampa River (RM 211 to 345)	None
	CO: Westwater-Lona (RM 125 to 154)	None
Concentration	GR: Ruby Ranch-Gunnison Butte (RM 93 to 131)	None
	CO: Big Bend-Onion Creek (RM 71 to 86)	None
Spawning Migration Routes	GR: Confluence-Lodore (RM 0 to 364)	None
	CO: Lake Powell-Palisade (RM -16 to 188)	None
Suspected Spawning	GR: Labyrinth Canyon (RM 38 to 66)	None
	CO: Cataract Canyon (RM -18 to -14)	None
Confirmed Spawning	GR: Three Fords (RM 148 to 157)	None
	CO: —	—
Larval Distribution	GR: Green River (RM 0 to 345)	None
	CO: Cataract-Clifton (RM -18 to 180)	None
YOY Distribution	GR: Confluence-Yampa River (RM 0 to 345)	None
	CO: Lake Powell-Gunnison (RM -16 to 170)	None
YOY High Density Nursery	GR: Confluence-Gray Canyon (RM 0 to 160)	Confirm
	CO: Upper Professor Valley (RM 70 to 80)	None
YOY Nursery	GR: Confluence-Echo Park (RM 0 to 345)	Confirm
	CO: Confluence-Moab (RM 0 to 60)	Moab-Lake Powell (RM 60 to 16)
Juvenile High Concentration	GR: Confluence-Gunnison Butte (RM 0 to 131)	None
	CO: —	—
Juvenile Concentration	GR: Sand Wash-Split Mtn. (RM 211 to 320)	None
	CO: Hite-Cataract (RM -48 to -16)	Question

Table 22. Continued

Classification	Current Reach Designations	Recommended Change
HUMPBACK CHUB		
Adult Distribution	GR: Gray Canyon (RM 146 to 171) CO: Cataract Canyon (RM -11)	None Cataract Canyon (RM-4.4 to -11.4)
Adult Concentration	GR: Gray Canyon (RM 146 to 154) CO: —	 Cataract Canyon (RM-6.4 to -11.4)
Confirmed Spawning	GR: — CO: Black Rocks (RM 135 to 136)	— None
Suspected Spawning	GR: Gray Canyon (RM 146 to 171) CO: Westwater Canyon (RM 111 to 125)	None None Cataract Canyon (RM -15 to -4)
RAZORBACK SUCKER		
Adult Distribution	GR: Confluence-Green River (RM 0 to 120) CO: Gypsum-Confluence (RM -18 to 0)	None Refute
Adult Concentration	GR: Confluence-Duchesne River (RM 0 to 247) CO: Grand Junction-Clifton (RM 163 to 180)	None None
Confirmed Spawning	GR: Ashley Creek-Split Mtn. (RM 299 to 307) CO: Clifton (RM 179)	None None
Suspected Spawning	GR: Labyrinth Canyon (RM 90 to 110) CO: —	None —

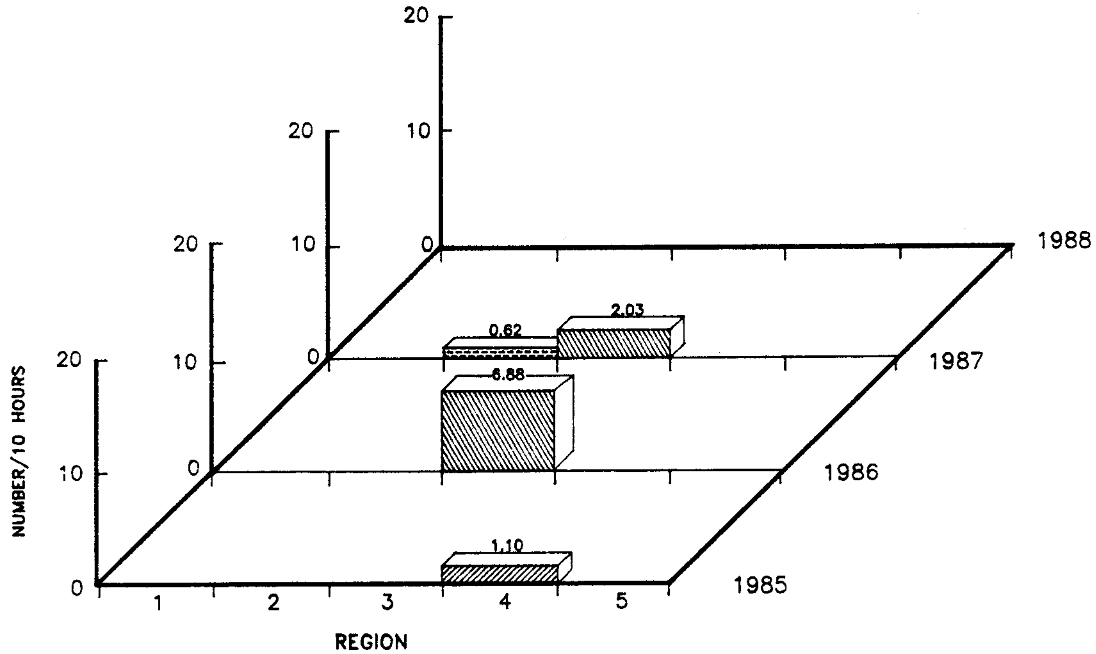


Figure 25. CPE for adult Colorado squawfish in the five study regions for 1985-1988, expressed as number of fish per 10 hours of electrofishing.

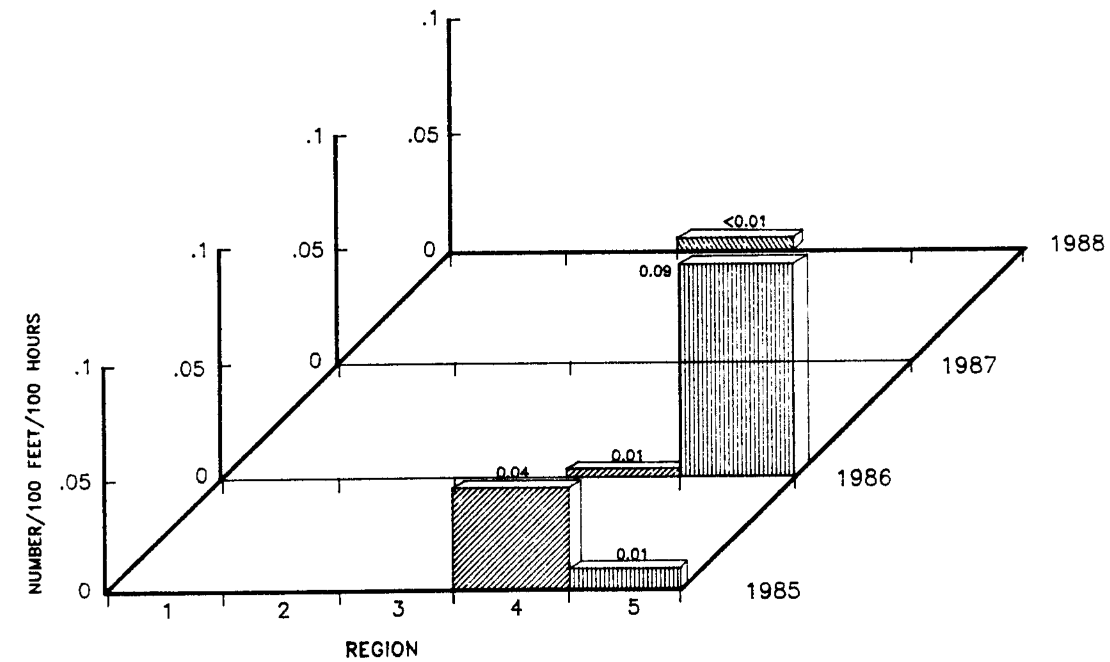


Figure 26. CPE for adult Colorado squawfish in the five study regions for 1985-1988, expressed as number of fish per 100 feet of net per 100 hours (includes both gill and trammel nets).

YOY Distribution: We concur with the current designation for the study area as an area of YOY distribution, since we caught YOY Colorado squawfish as far downstream as RM 200 (-16).

YOY High Density Nursery Area: We concur with the current designation of the lower Green River (RM 0 to 160) as a high density nursery area, consistent with the criterion that average catch per effort for years of record YOY by seines exceeds 9 per 10 m^2 (Figure 27). We do not recommend extending this designation to any other region of the study area.

YOY Nursery Area: We recommend extending the current designation of the lower Colorado River (RM 0 to 60) as a YOY nursery area downstream to the Lake Powell Inflow (RM 216.4 to 200.0, or RM 0 to -16.4), consistent with the criterion of catch per effort of YOY greater than 0.9 per 10 m^2 (Figure 27). This would include the confluence area as well as Cataract Canyon.

Juvenile High Concentration Areas: Since we did not conduct extensive electrofishing in the lower Green River, no recommendation is made relative to the current designation of this area as a juvenile high concentration area. Where electrofishing during this investigation was extensive, we failed to catch more than 3 fish per 10 hours. This included the Colorado River from the confluence (RM 216.4) downstream to the Lake Powell Inflow (RM 200.0). No recommendation is made to this classification.

Juvenile Concentration Area: Although juvenile Colorado squawfish were captured with electrofishing gear in the lower Colorado River region, the confluence region, and the Cataract Canyon region, catch rate for this size did not exceed 1 fish per 10 hours, which is the criterion for this designation. Electrofishing efforts by this investigation failed to capture any juveniles in Region 5 (Figure 28). Since this was just the upper end of the area classified in the Sensitive Areas Document, no recommendation can be made at this time to change this classification. However, the area of Lake Powell from Hite Marina to Cataract Canyon (RM 168 to 200) should be further investigated to either confirm or refute this classification. Although no juveniles were captured in the Lake Powell Inflow with electrofishing, the CPE for this age category exceeded the criteria for concentration area (>1 fish/10 hours) in Regions 2, 3 and 4 (Figure 28), which is the Colorado River from Potash (RM 47) downstream to the Lake Powell Inflow (RM 200). This extends the current classification, which is from the Dolores River to Potash, downstream another 63 miles. At this time, we question the current designation of Hite to Cataract Canyon (RM -48 to -16) as a concentration area of juvenile Colorado squawfish, although this investigation did not sample intensively in this area.

6.1.2 Humpback Chub

Adult Distribution: Adult humpback chub were captured during this study within Cataract Canyon (Figures 29 and 30), in the areas between Rapids #2 and 13 (RM 212 to 205, or RM -4.4 to -11.4). We recommend designating this area of Cataract Canyon as an area of adult distribution, changing the current designation which lists only RM 205.4 (RM -11).

Adult Concentration Area: We recommend designating the area within Cataract Canyon between Rapids #10 and 13 (RM 209 to 205, or RM -5.4 to -11.4) as an adult concentration area, since this deep canyon area yielded at least five adult humpback chubs in each of two years of this investigation; 6 in 1987 and 11 in 1988.

Confirmed Spawning Area: Although there was good evidence of spawning by humpback chub in Cataract Canyon, no spawning areas were confirmed using the criteria of the Sensitive Areas Document; "Presence of ripe females (strippable eggs) during spawning season...". However, we believe that this designation is likely for Cataract Canyon with continued investigations, based on the capture of an adult female that was tubercled and in pre-spawning condition on April 14, 1988. Also, two adults (one male, one female) were captured June 24, 1988, in the same location (RM 207.3) that showed

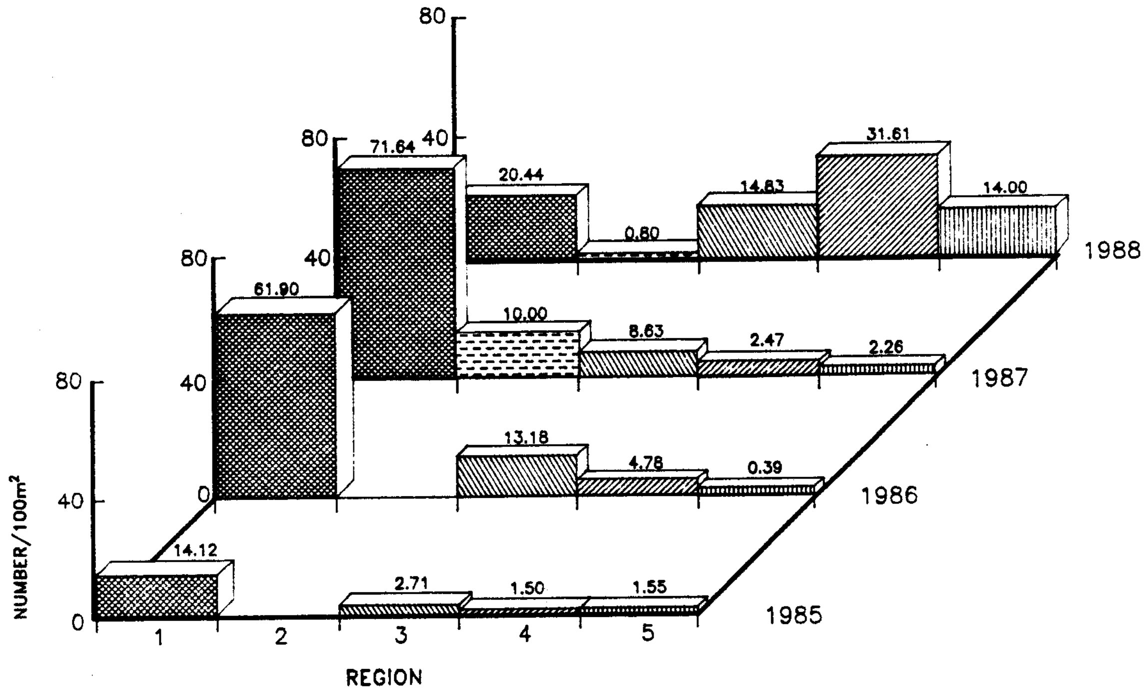


Figure 27. CPE for YOY Colorado squawfish in the five study regions for 1985-1988, expressed as number of fish per 100 m² seined.

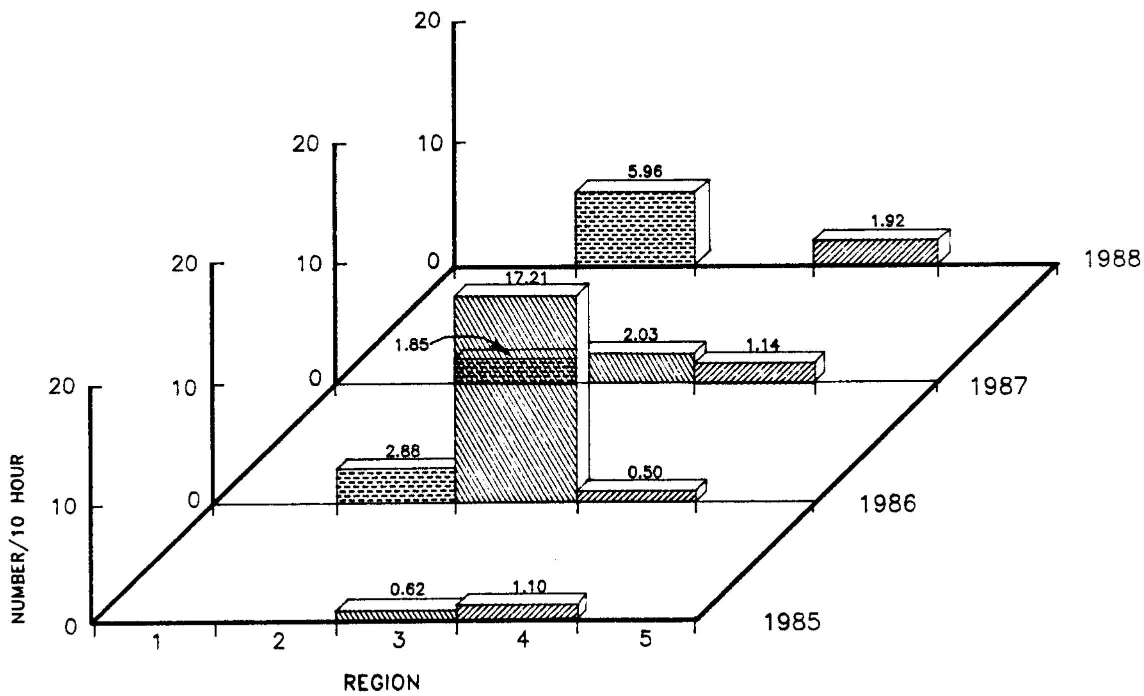


Figure 28. CPE for juvenile Colorado squawfish in the five study regions for 1985-1988, expressed as number of fish per 10 hours of electrofishing.

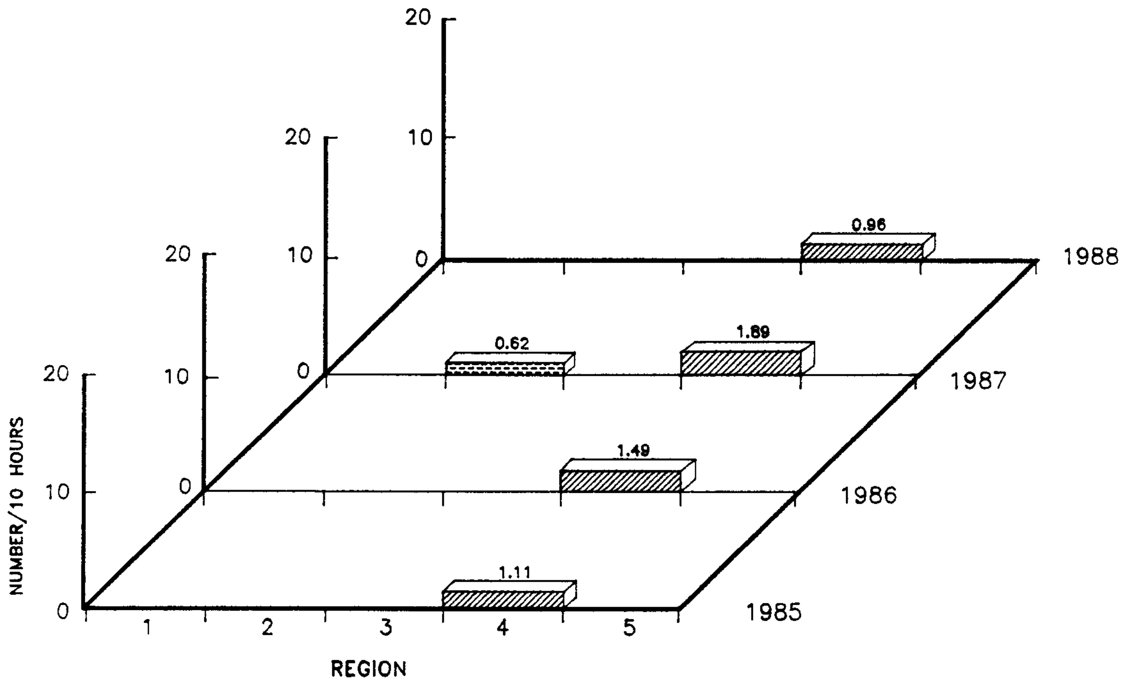


Figure 29. CPE for adult humpback chub in the five study regions for 1985-1988, expressed as number of fish per 10 hours of electrofishing.

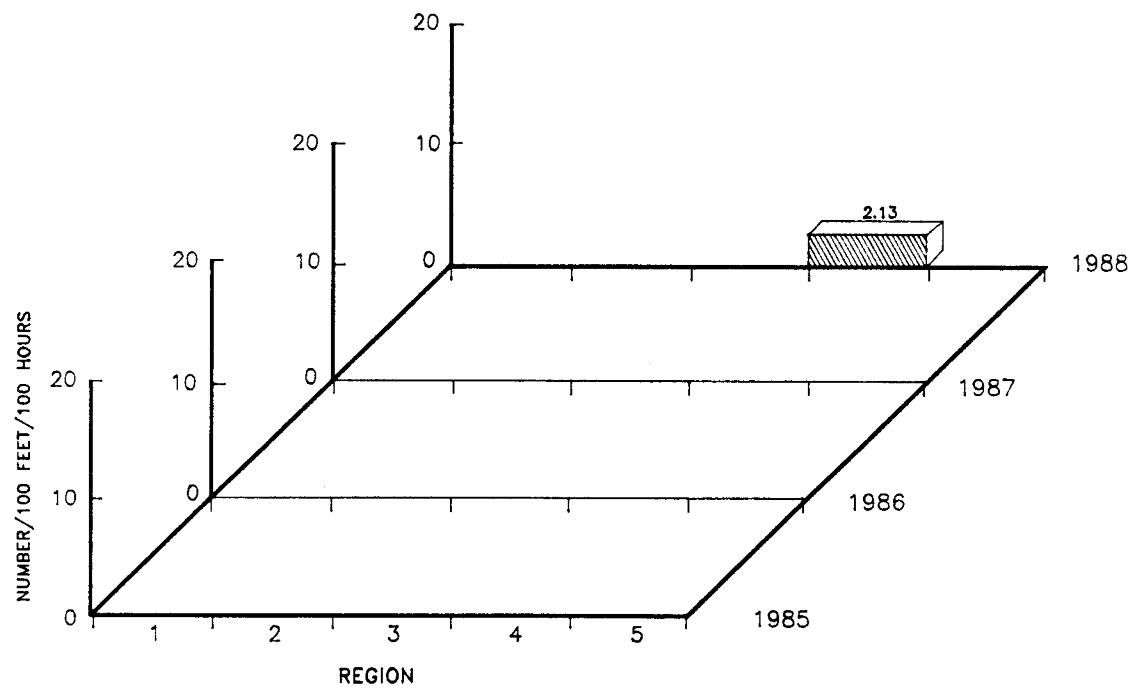


Figure 30. CPE for adult humpback chub in the five study regions for 1985-1988, expressed as number of fish per 100 feet of net per 100 hours (includes both gill and trammel nets).

signs of recent spawning activity; flaccid abdomen, tubercles on the head and pectoral fins, rosy fins, swollen papillae, and abrasions on the belly from rubbing on substrate. No recommendation is made at this time regarding this classification.

Suspected Spawning Area: We recommend designating the area within Cataract Canyon, RM 201.5 to 212.4 (RM -15 to -4), as a suspected spawning area for humpback chub. This is based on the capture of five adults in each of two years in the canyon, as well as on the evidence presented in the previous section on confirmed spawning areas.

6.1.3 Razorback Sucker

Adult Distribution: Only one adult razorback sucker was captured during the Cataract Canyon Studies; the fish was caught September 11, 1987, at the mouth of Salt Creek at RM 3.6 of the Colorado River. The capture of this adult satisfies the criteria of the Sensitive Areas Document of at least one capture within the last 5 years, and confirms the designation of an adult distribution area for the lower Colorado River. However, since the intensive electrofishing and netting effort from the confluence through Cataract Canyon to the Lake Powell Inflow did not yield any razorback suckers, we recommend dropping the designation of adult distribution area from the confluence (RM 216.4) downstream to the Lake Powell Inflow (RM 200.0). No razorback suckers have been captured in this area of the upper basin in the last 5 years.

Adult Concentration Area: No change in the current status for this classification of the Sensitive Areas Document is recommended for the Cataract Canyon area. The capture of only one adult razorback sucker did not satisfy the classification criteria; "Collection of 10 or more razorback sucker in a 20-mile reach of river in one year during the past 5 years" (1979 to present).

Confirmed Spawning Area: No evidence of reproduction by razorback suckers was encountered during the Cataract Canyon Studies. Thus the criterion of "Collection of ripe females with strippable eggs" was not met, and no recommendation is made for this classification.

Suspected Spawning Area: No evidence of reproduction by razorback suckers was encountered during the Cataract Canyon Studies. Thus the criterion of "Collection of two or more ripe males in river reach having gravel/cobble substrate" was not met, and no recommendation is made for this classification.

6.2 General Recommendations

The following recommendations are also submitted relative to subject areas not covered by the sensitive areas document, particularly with regard to the bonytail.

6.2.1 Confirm Spawning by Humpback Chub

The collection of three adult humpback chub in pre- and post-spawning condition at RM 207.3 of Cataract Canyon in April and June of 1988, was good evidence that the species spawns in the region. From this information, it appeared that spawning occurred between the two capture dates of April 14 and June 24, 1988. This approximately coincided with the spawning times determined for the species in Black Rocks of late April to early June, depending on the year (Valdez and Clemmer 1982).

Since spawning time by the species in the upper basin appears variable, and no definitive relationship has been established with water temperature or flow (Valdez and Clemmer 1982; Kaeding et al. 1985), the timing of a trip to capture females with strippable eggs would be difficult to estimate. This difficulty is compounded by spring runoff that makes sampling in Cataract Canyon highly inefficient.

We believe that the timing of a trip is best prior to the onset of spring runoff, at maximum flows of about 10,000 cfs, and when water temperatures are highest (14-16°C) before they are cooled by the runoff. We recommend at least one spring trip into Cataract Canyon sometime during April or May, depending on the timing of runoff and the level of water temperatures, to locate fish in spawning condition and assess the extent of spawning in the area. Although sampling with nets and electrofishing should be concentrated between Rapids #10 and 11, other areas should be sampled as well including the area between Rapids #12 and 13.

If adult humpback chub are captured, each should be examined in detail, as to its sex, the presence of tubercles, the degree of coloration, abdominal distention, and the expression of eggs or milt. Detailed morphometric and meristic measurements should be taken, and each fish should be photographed on a grid board.

The relative success of the year classes of chubs in Cataract Canyon should be assessed with an additional trip in late August or early September. Seining should be conducted in backwaters and along shorelines to determine the species composition of young fishes in the region. Specimens that cannot be identified afield should be sent to the Larval Fish Laboratory to confirm the presence of larval and YOY humpback chubs as an indication of ongoing reproduction.

6.2.2 Overwinter Survival of YOY Colorado Squawfish

Sample efforts should be continued for larval and YOY Colorado squawfish in the Green and Colorado Rivers to assess overwinter survival of year classes. The areas best suited for this assessment are the lower 50 miles of the Green and Colorado Rivers. These efforts should be coordinated and conducted with the UDWR and FWS. The YOY ISMP conducted by those agencies and normally scheduled for late September or early October should be maintained. A second trip using identical methods should be scheduled for March or April in order to compare the catch rates of the year class for the two sample periods. The spring trip should be timed prior to spring runoff, when flows are below 5,000 cfs, and main channel temperatures are 10-15°C; backwaters can be up to 5°C warmer than the main channel by this time of the year.

The number of YOY captured should be tabulated, and the area seined recorded in order to compute a catch rate. Also, each YOY Colorado squawfish should be measured in order to determine growth rates of the fish between the fall and spring samples.

6.2.3 Assess Transport of Endangered Fish during Spring Runoff

We recommend at least one 1-week sample effort into the Lake Powell Inflow region during spring runoff to assess whether large numbers of endangered fish, particularly Colorado squawfish, are being carried into Lake Powell by these high flows. A crew of two people can be stationed at Imperial Canyon for 1 week using seines, drift nets, minnow traps, and electrofishing. Access to the area is relatively quick and easy by speedboat from Hite Marina.

6.2.4 Monitor Adult Humpback Chub

The population of humpback chub in Cataract Canyon should be incorporated into the ISMP. Monitoring should be done yearly in the same manner as is done in Black Rocks and Westwater Canyon. Monitoring should be done by netting specific areas. All chubs should be photographed for later measurement of meristics. The best time to monitor chubs in Cataract Canyon is in July, when flows are moderate to low and weather patterns are generally dry; periodic rainstorms in August and September increase turbidity and sediment load in the river that hamper fish sampling efforts.

6.2.5 Describe the *Gila* Complex in Cataract Canyon

Collections of selected specimens of *Gila* spp. from Cataract Canyon are needed to provide scientists with materials to describe the forms found in this region of the upper basin. The uncertainty that surrounds the taxonomy of this complex in the upper basin has fueled doubts about the capture of *Gila elegans* in Cataract Canyon. The presence of this rarest of the Colorado River endemic fishes in this region needs to be confirmed. We recommend incorporating Cataract Canyon into a sampling scheme that includes collections and detailed morphometric, meristic, hematologic, genetic, and cytogenetic analyses of the *Gila* complex.

This "collection" should include preservation as well as evacuation of live specimens to a holding facility to maximize the opportunity for taking materials. Since the number of chubs in the Cataract Canyon region is difficult to assess, the sacrifice of fish should be kept to a minimum, and done only with sufficient justification and thorough documentation of the analyses to be performed.

Any effort to collect specimens from Cataract Canyon should be coordinated with Reclamation personnel involved in the Cataract Canyon Studies in order to minimize money, time and effort to capture the specimens needed. Biologists experienced in the area know the locations for capturing fish, the most effective capture methods, and the variety of morphotypes present.

6.3 Recommendations for Future Study

The following are recommendations for future study in the Cataract Canyon Study Area. Some of these have already been mentioned and discussed in previous sections of this report and are summarized in Table 23. This section provides an outline of these recommendations, but no extensive details are provided at this time.

Table 23. Recommended sample trips for the Cataract Canyon Area.

TRIP NO.	PRIMARY PURPOSE	TIME	PREFERRED FLOWS	PREFERRED TEMP.
1	Confirm Humpback Chub Spawning (canyon trip)	April-May	10,000	14-16
2	Assess YOY Overwinter Survival (confluence trip - spring)	March-April	5,000	10-15
3	Assess YOY Overwinter Survival (confluence trip - fall)	Sept-Oct	5,000	18-22
4	Assess Fish Into Lake Powell (motor from Hite Marina)	May-June	peak flows	
5	Monitor Chubs (canyon trip)	July	5,000	18-22
6	Describe *Gila* complex	July	5,000	18-22

A program of four trips per year is recommended to continue monitoring endangered fishes in the Cataract Canyon area. Each trip is planned to coincide with optimum sampling conditions for the primary purpose. It should be noted that no trips are proposed for August and early September because frequent rainstorms during these late summer months dramatically altered sampling efficiency. Increased debris from rainstorms clogged the gill and trammel nets and decreased the visibility of fish stunned by electrofishing. Increased silt levels also decreased visibility and apparently forced the fish to become less active. This inactivity and limited visibility consequently reduced the numbers of fish caught during and immediately after rainstorms. There would be five primary objectives associated with these sample trips as described in Section 6.2:

1. Confirm spawning by humpback chub in Cataract Canyon.
2. Assess overwinter survival of YOY Colorado squawfish in the lower Green and Colorado Rivers using the ISMP.
3. Assess transport of endangered fish into Lake Powell during spring runoff.
4. Monitor chubs in Cataract Canyon to assess trends in juveniles and adults, to ascertain the presence of bonytail and to assess the success of year classes.
5. Describe the *Gila* complex in Cataract Canyon.

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APPENDIX A

PHOTOGRAPHIC RECORD
(Photos by R.A. Valdez, or as identified)

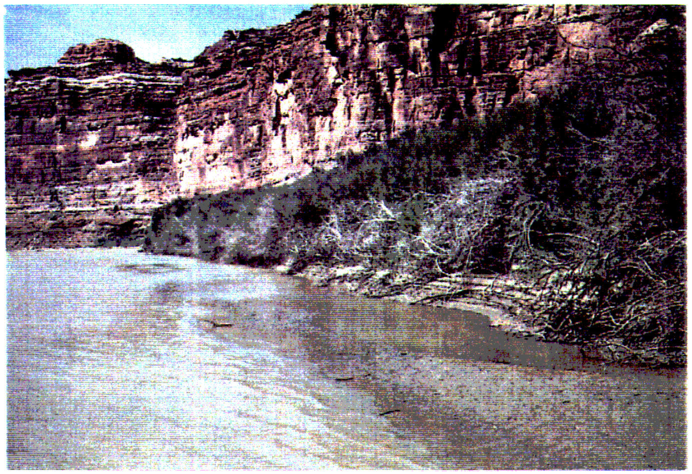

Photo A-1. Tamarisk/willow habitat on the Green River, RM 14.7, July 9, 1987.

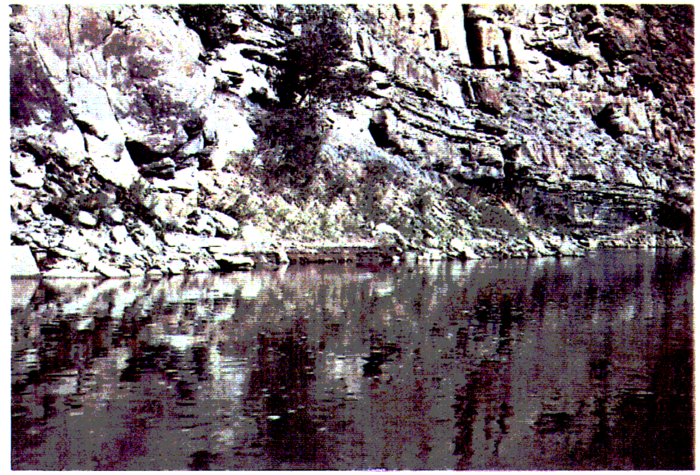

Photo A-2. Talus slope habitat on the Colorado River, RM 4.0, September 25, 1989.

Photo A-3. Rock ledge habitat on the Colorado River, near Lathrop Canyon, RM 23.5, April 13, 1987.

Photo A-4. Vertical wall habitat on the Colorado River RM 8.0, April 15, 1987.

Photo A-5. General setting of the Green River in Region 1, RM 25.5, September 22, 1985.

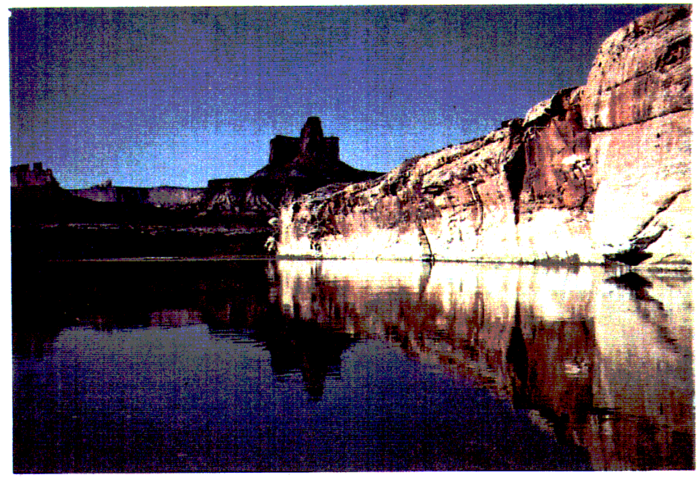

Photo A-6. Vertical wall habitat on the Green River near Cross Butte, RM 35.0, August 17, 1987.

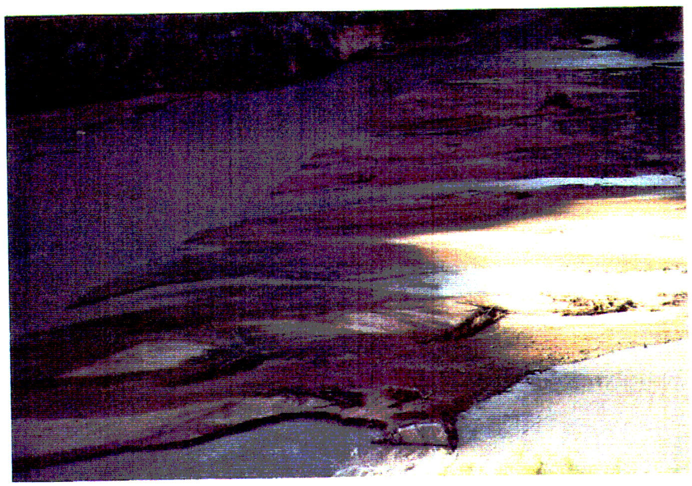

Photo A-7. Alluvial delta on the Green River formed by a large flash flood from Horse Canyon, RM 14.4, September 27, 1988.

Photo A-8. Large alluvial cobble bar on the Green River, RM 15.1, August 3, 1988.

Photo A-9. General setting of the Colorado River in Region 2, RM 22.0, September 25, 1989.

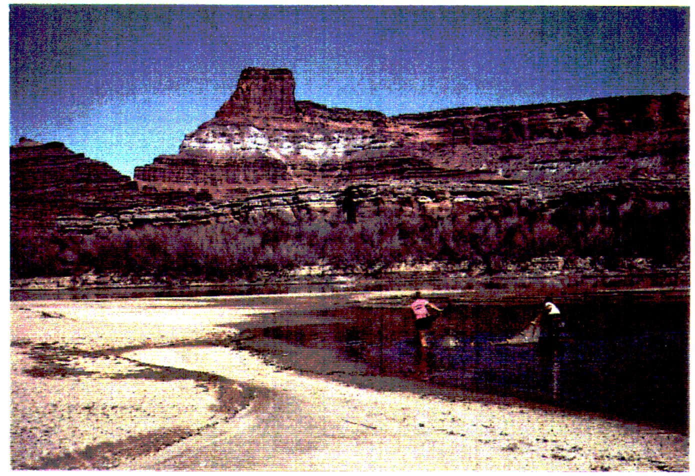

Photo A-10. Typical sandy backwater of the Colorado River in Region 2, RM 42.5, March 25, 1988.

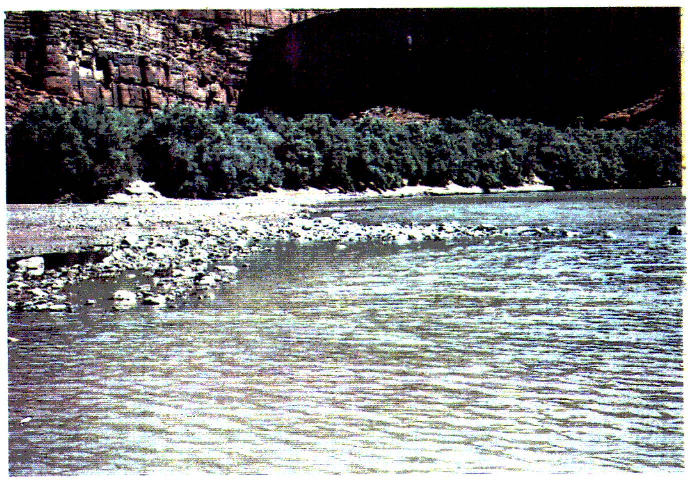

Photo A-11. Alluvial cobble bar on the Colorado River at Shafer Canyon RM 34.8, July 12, 1988.

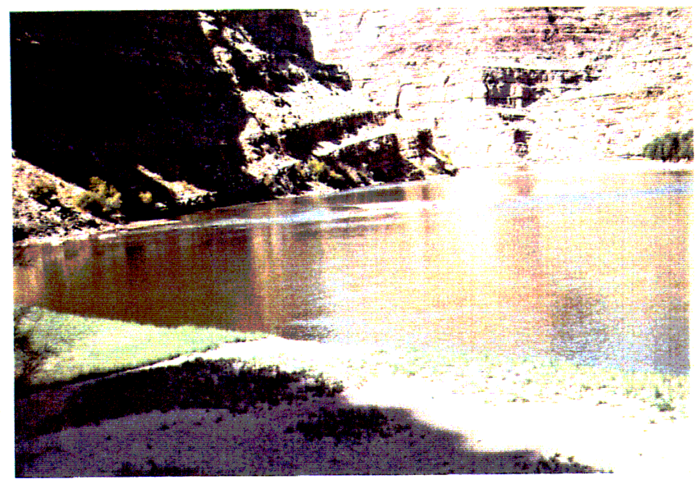

Photo A-12. Large alluvial cobble bar on the Colorado River at Salt Creek, RM 3.6, September 9, 1987.

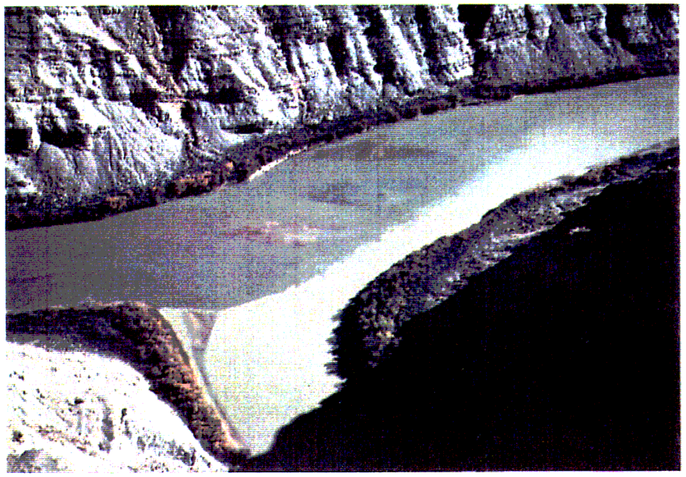

Photo A-13. Aerial view of the confluence of the Colorado (from left) and Green (from lower center) Rivers at the upper end of Region 3, November 1987.

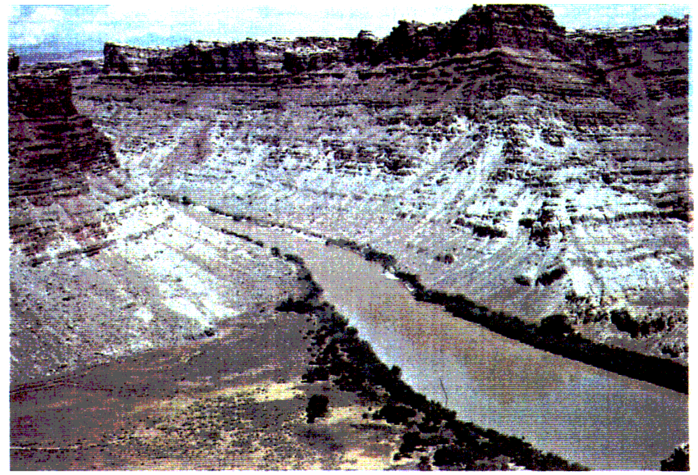

Photo A-14. View of the Colorado River at Spanish Bottom, RM 213.5, July 12, 1986.

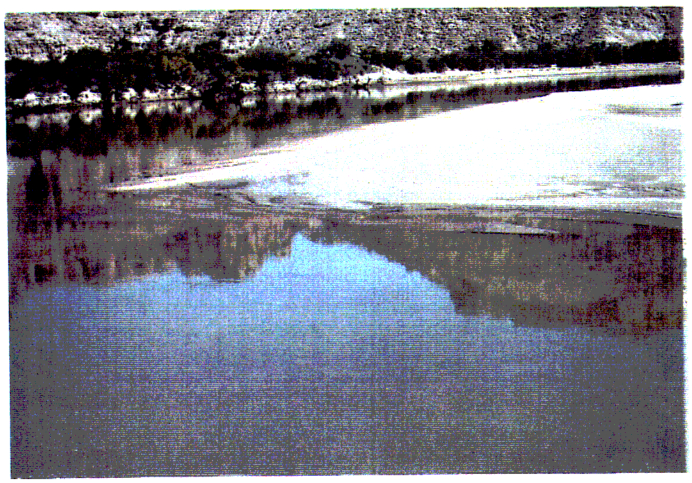

Photo A-15. Large sand bar on the Colorado River at Lower Red Lake Canyon, RM 213.0, August 25, 1985.

Photo A-16. Typical backwater in Region 3 of the Colorado River, RM 214.7, September 16, 1988.

Photo A-17. Typical talus slope habitat in Region 4, Cataract Canyon, RM 212.1, March 23, 1988.

Photo by G. Heaton.

Photo A-18. Electrofishing raft through Big Drop 2 (Rapid 22) of Cataract Canyon, RM 202.5, August 27, 1985.

Photo by G. Heaton.

Photo A-19. Electrofishing raft through Big Drop 3 (Rapid 23) of Cataract Canyon, RM 202.2, August 27, 1985.

Photo A-20. Electrofishing raft at lower end of Big Drop 3 (Rapid 23) of Cataract Canyon, RM 202.1, September 22, 1986.

Photo by G. Heaton.

Photo A-21. General setting of the Colorado River in Cataract Canyon Region 4, RM 208.8, August 26, 1985.

Photo by G. Heaton.

Photo A-22. Electrofishing along vertical wall habitat of Cataract Canyon, Region 4, August 26, 1985.

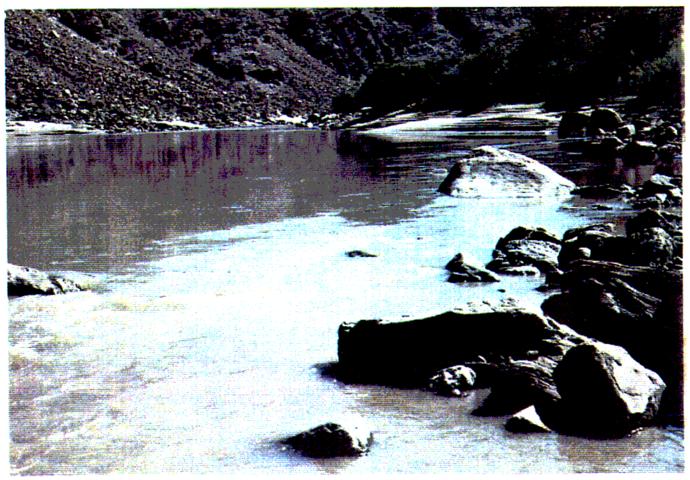

Photo A-23. Primary chub shoreline habitat in Cataract Canyon, RM 207.5, July 15, 1988.

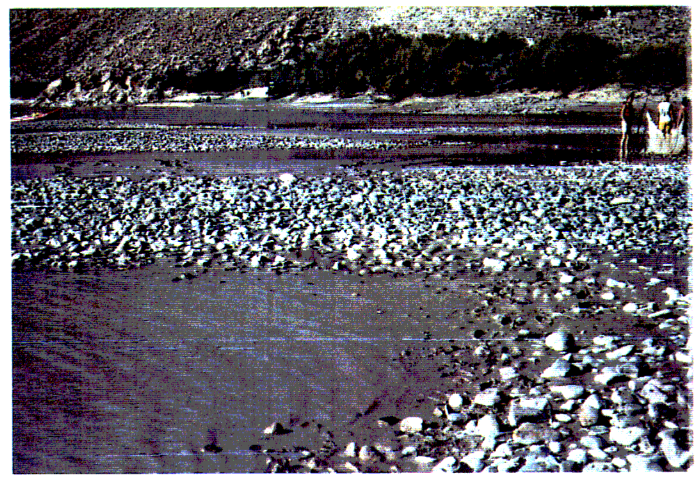

Photo A-24. Large midchannel cobble bar in Cataract Lake, RM 206.4, September 23, 1987.

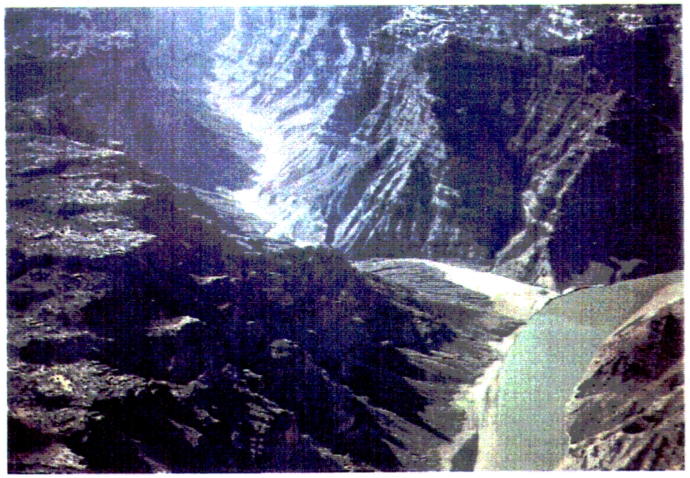

Photo A-25. Aerial view of Gypsum Canyon entering upper Lake Powell in Region 5, RM 196.6, August 14, 1985.

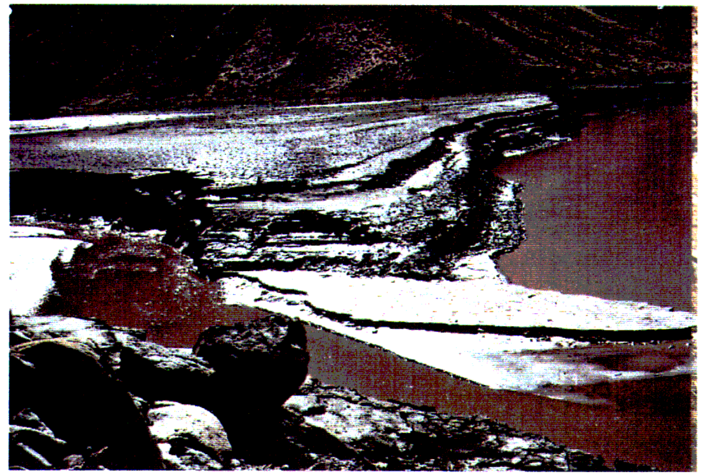

Photo A-26. Recent silt deposits at the mouth of Gypsum Canyon, RM 196.6, October 5, 1986.

Photo A-27. Recent silt deposits near the mouth of Palmer Canyon, RM 195.2, October 5, 1986.

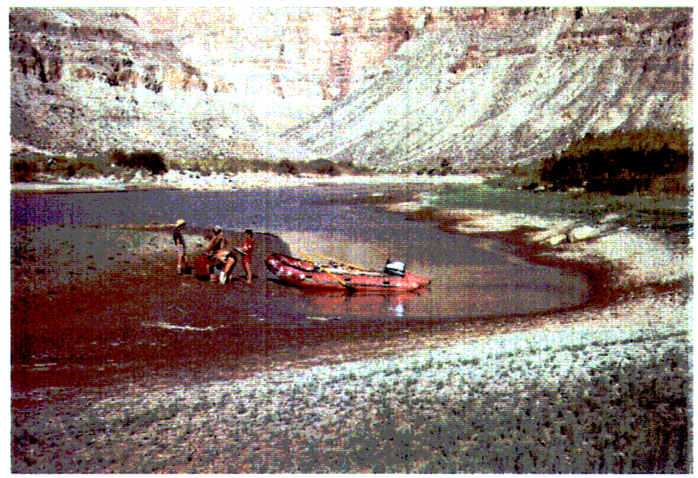

Photo A-28. Large backwater formed by silt deposits near Imperial Canyon, RM 200.2, September 20, 1988.

Photo A-29. Eroded sandbar exposing a 3-year stand of tamarisk near Gypsum Canyon, RM 197.0, August 7, 1988.

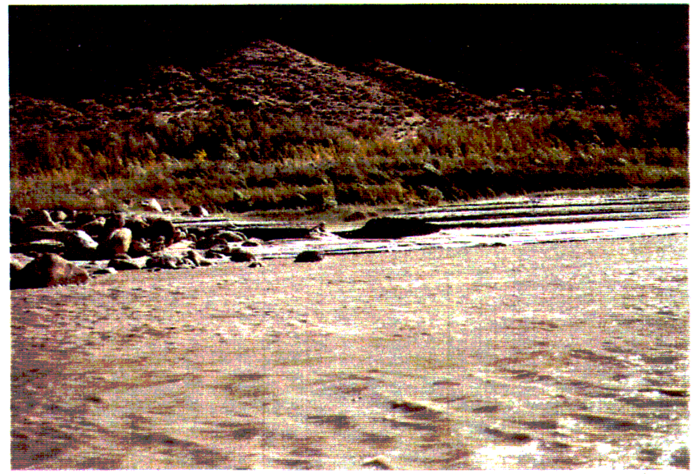

Photo A-30. Dewatered backwater near Imperial Canyon, RM 200.0, September 20, 1988.

Photo A-31. Eroded sandbar exposing 2-year stand of tamarisk at the mouth of Rockfall Canyon, RM 184.0, August 12, 1989.

Photo A-32. Two-year old stand of tamarisks on the shoreline of upper Lake Powell, RM 180.0, August 12, 1989.

Photo A-33. Eighteen-foot Riken Havasu used as an electrofishing raft.

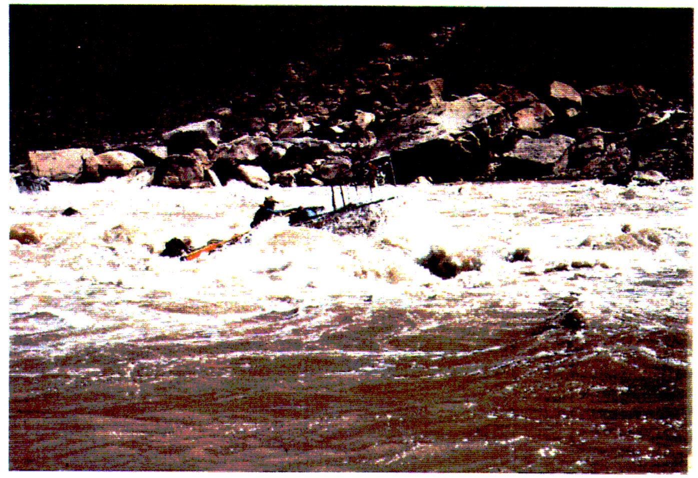

Photo A-34. Electrofishing raft through Big Drop 3 (Rapid 23) of Cataract Canyon, RM 202.2, August 31, 1986.

Photo A-35. Seventeen-foot Riken Havasu used as a netting raft.

Photo A-36. Netting raft through Big Drop 3 (Rapid 23) of Cataract Canyon, RM 202.2, August 31, 1986.

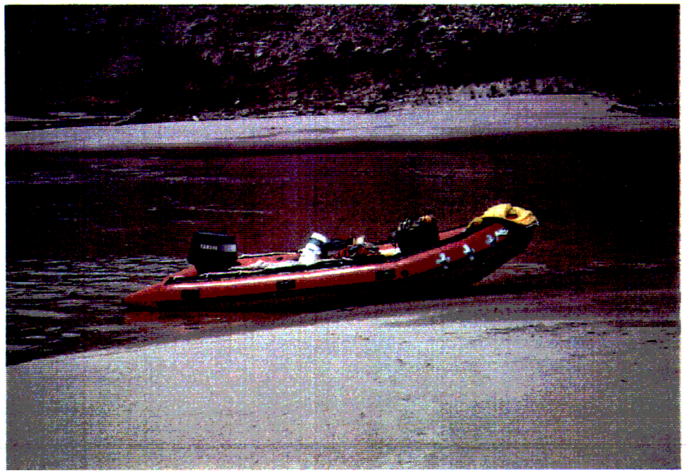

Photo A-37. Seventeen-foot Achilles sportboat used as a netting raft.

Photo by L. Crist.

Photo A-38. Achilles raft through Big Drop 1 (Rapid 21) of Cataract Canyon, RM 202.7, August 22, 1987,

Photo A-39. Twenty-two foot J-rig used as a support raft.

Photo A-40. J-rig in Big Drop 2 (Rapid 22) of Cataract Canyon, RM 202.4, October 11, 1985.

Photo A-41. Electrofishing raft in operation below Big Drop 3 (Rapid 23) of Cataract Canyon, RM 202.0, June 27, 1987.

Photo by G. Heaton.

Photo A-42. Reclamation biologists check gill nets in Cataract Canyon, August 26, 1985.

Photo A-43. Seine haul in a small shallow backwater in Cataract Canyon, RM 207.0, July 31, 1987.

Photo A-44. Biologists sort through fish in seine haul, September 22, 1985.

Photo A-45. Larval drift net used to capture recently hatched fish being transported by river currents.

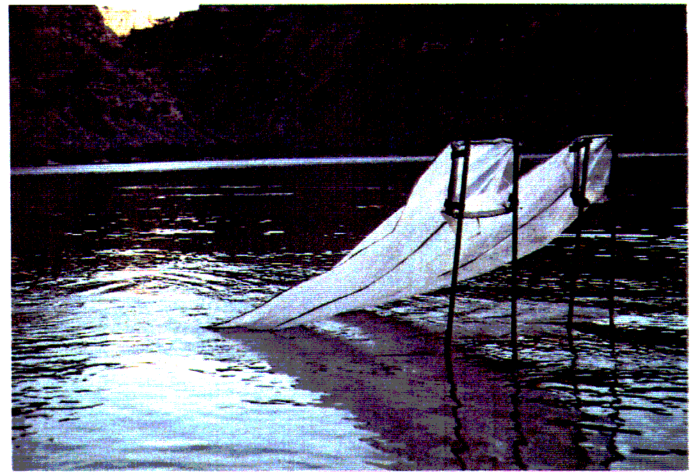

Photo A-46. Paired larval drift nets on rebar stakes used to slide nets into underwater position.

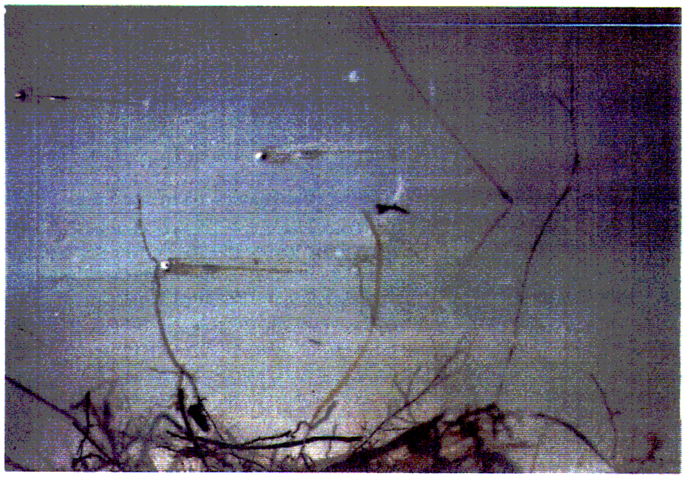

Photo A-47. Three semi-transparent larval fish captured in drift nets.

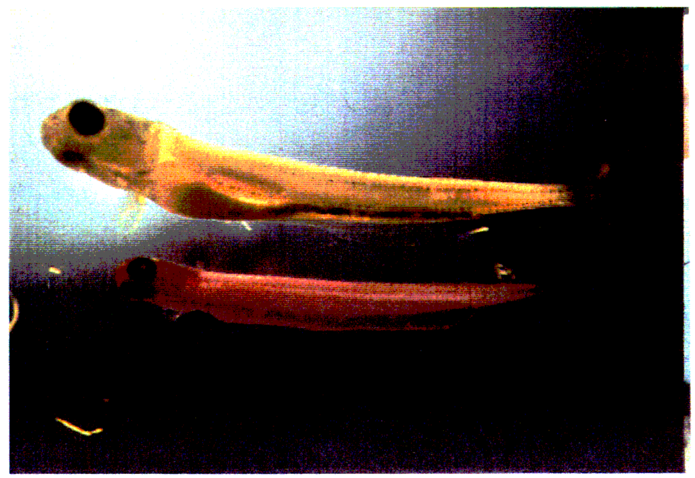

Photo A-48. Unstained (top) and stained (bottom) larval fish. 10X.

Photo A-49. Typical roundtail chub (*Gila robusta*) from the Colorado River, RM 5.8, TL = 291 mm, sample = 6-E01, September 9, 1987.

Photo A-50. *Gila robusta* from Cataract Canyon, RM 207.0, TL = 281 mr Sample = 2-E09, April 14, 1989.

Photo A-51. Large-headed *Gila* spp. from Cataract Canyon, RM 207.8, TL = 291 mm, Sample = 4-N47, July 31, 1987.

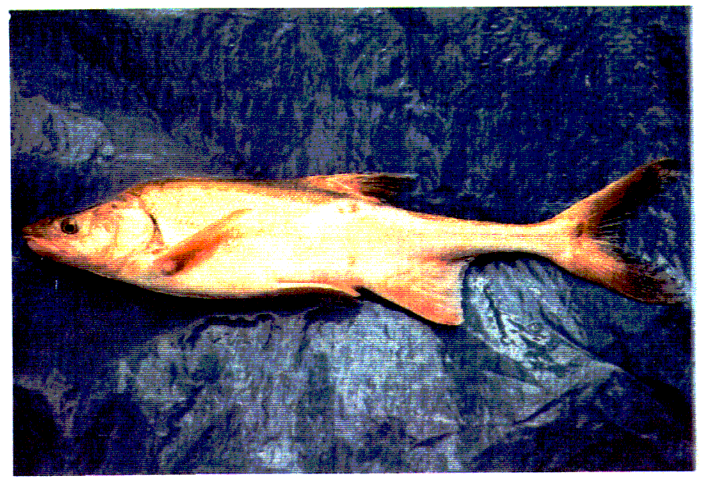

Photo A-52. Large-headed *Gila* spp. from Cataract Canyon, TL = 286 mm, August 1985.

Photo A-53. Small form of *Gila cypha* from Cataract Canyon, RM 207.8, TL = 175 mm, Sample = 4-E05, July 30, 1987.

Photo A-54. Small form of *Gila cypha* from Cataract Canyon, RM 207.6, TL = 182 mm, Sample = 5-E11, August 21, 1987.

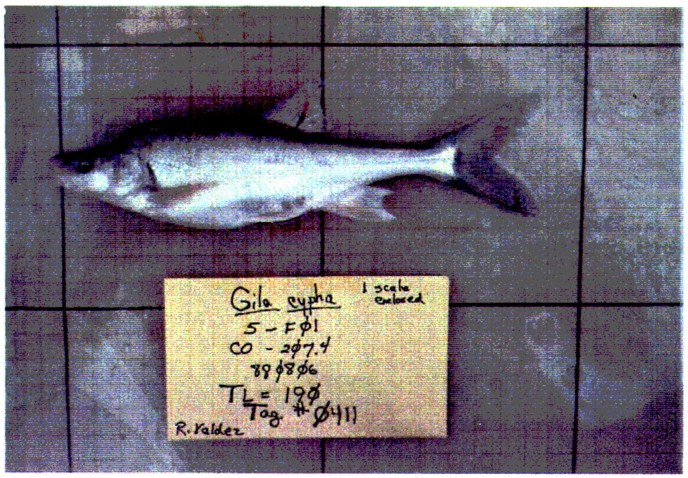

Photo A-55. Small form of *Gila cypha* from Cataract Canyon, RM 207.4, Tag = 0411, Sample = 5-F01, August 6, 1988.

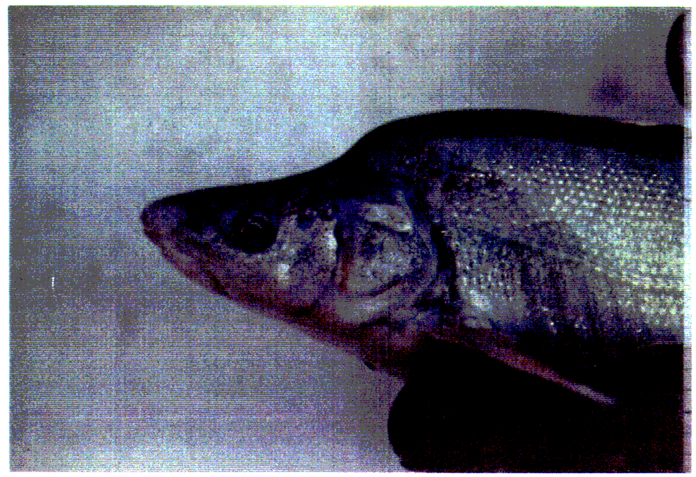

Photo A-56. Head of *Gila cypha* shown in Photo A-55.

Photo A-57. Small form of *Gila cypha* from Cataract Canyon, RM 207.4, TL = 150 mm, Sample = 3-N53, June 25, 1988.

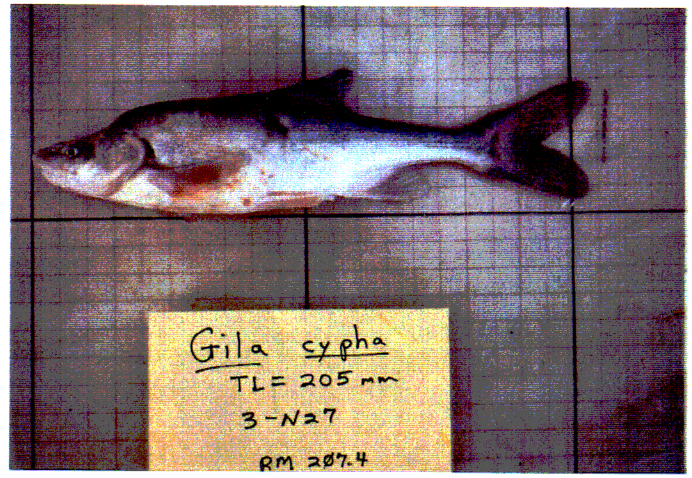

Photo A-58. Small form of *Gila cypha* in post-spawning condition from Cataract Canyon, RM 207.4, TL = 205 mm, Sample = 3-N27, June 23, 1988.

Photo A-59. Small form of *Gila cypha* in post-spawning condition from Cataract Canyon, RM = 207.2, TL = 207 mm, Sample = 3-N36, June 24, 1988.

Photo A-60. Head of *Gila cypha* shown in Photo A-59.

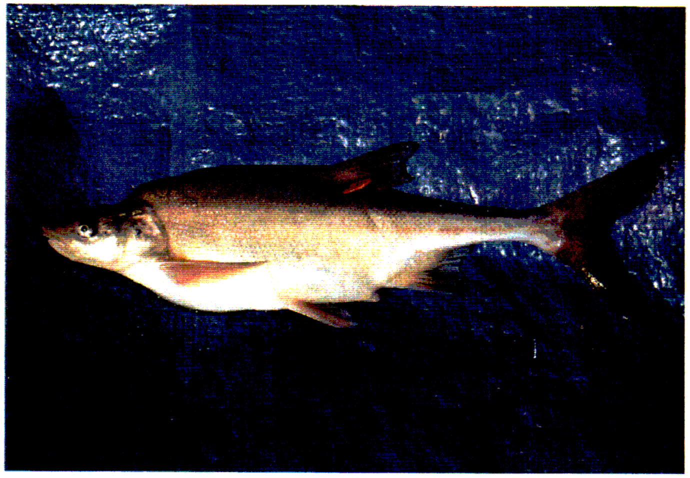

Photo A-61. *Gila cypha* from Cataract Canyon, RM 206.8, TL = 280 mm, Tag 3153, Sample = E034, August 10, 1985 (Preserved in USFWS collection).

Photo A-62. Head of *Gila cypha* shown in Photo A-61.

Photo A-63. *Gila cypha* from Elephant Canyon, Colorado River, TL = 249 mm, Sample = 6-E15-2, September 11, 1987.

Photo A-64. Head of *Gila cypha* shown in Photo A-63

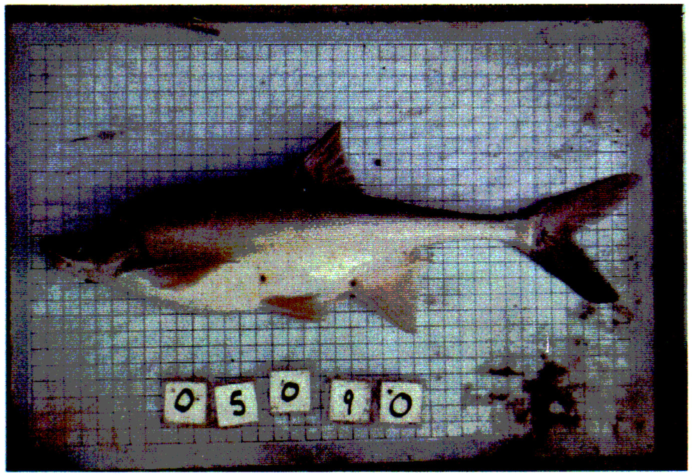

Photo A-65. Adult *Gila cypha* from Westwater Canyon, TL = ~380 mm, September 1988.

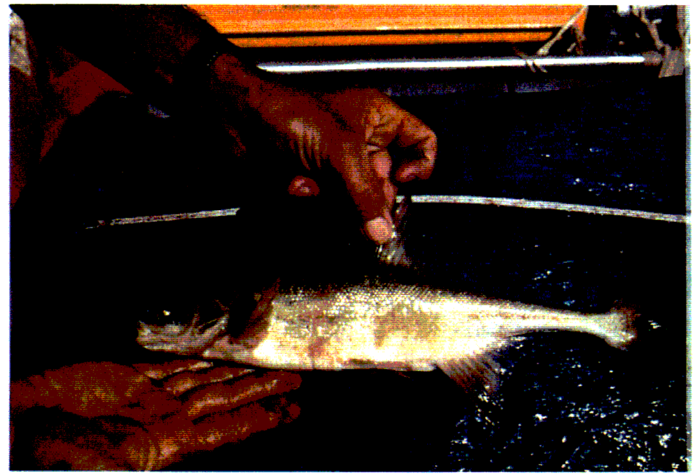

Photo A-66. Suspected *Gila elegans* from Cataract Canyon, RM = 207.4, TL = 386 mm, Sample = NET127, August 27, 1985.

Photo A-67. Suspected *Gila elegans* from above Cataract Canyon, RM 1.5, TL = 383 mm, Tag = 2932, Sample = 2-TN9, July 25, 1986.

Photo A-68. Suspected *Gila elegans* from Cataract Canyon, RM 211.8, TL = 287 mm, Tag = 5036, Sample = 5-E04, August 18, 1987

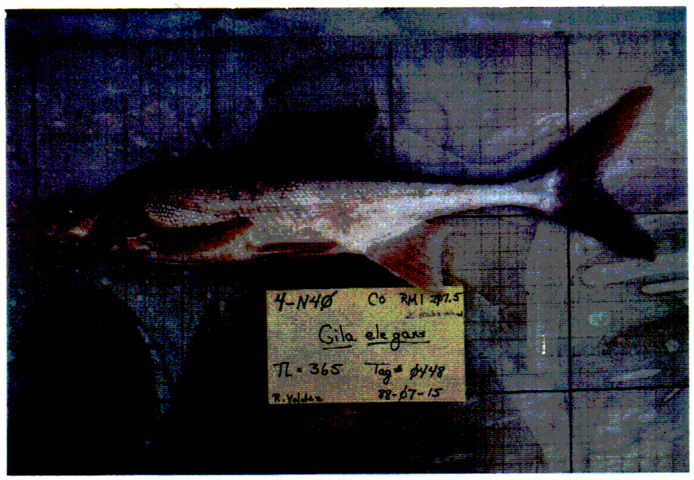

Photo A-69. Suspected *Gila elegans* from Cataract Canyon, RM 207.5, TL = 365 mm, Tag = 0448, Sample = 4-N40, July 15, 1988.

Photo A-70. Suspected *Gila elegans* from Cataract Canyon, RM 207.3, TL = 383 mm, Tag = 5027, Sample = 4-N28, July 15, 1988.

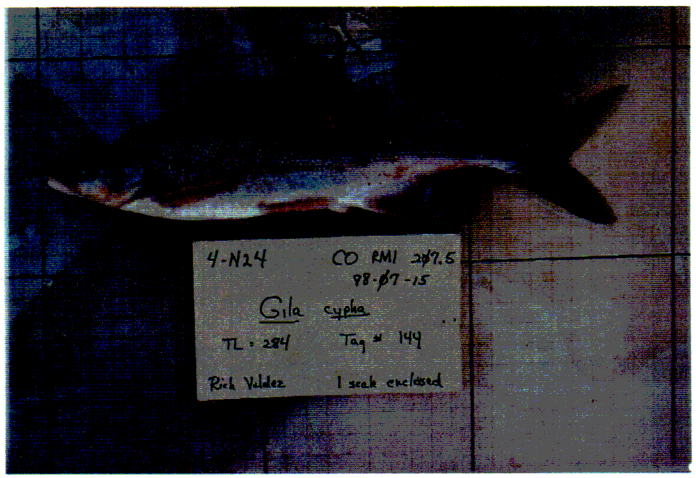

Photo A-71. Suspected *Gila elegans* from Cataract Canyon, RM 207.5, TL = 284 mm, Tag = 0144, Sample = 4-N24, July 15, 1988.

Photo A-72. *Gila elegans* from Dexter National Fish Hatchery. TL = 385 mm.

APPENDIX B

SPECIES DESCRIPTIONS

APPENDIX B: SPECIES DESCRIPTIONS

This appendix is provided to familiarize the reader with the basic life history of each of the 31 species of fish found in Cataract Canyon. This information is restricted to the Upper Colorado River Basin, although general occurrence and distribution information are also provided.

The endemic and endangered fishes of Cataract Canyon each possess rich and fascinating histories. Some, like the Colorado squawfish and razorback sucker, were once economically important to the development of the Colorado River Basin. Others, like the bonytail and humpback chub received little attention or notoriety until their value as evolutionarily unique life forms was recognized.

Man has had a dramatic impact on the populations of these endemic fishes. Impoundment of the mainstem rivers; water diversions; degradation of water quality through agricultural, municipal, and industrial practices; and the introduction of non-native or exotic fish species are often cited as the most important factors responsible for the endangerment of these species. Of these factors, perhaps the most evident during a fishery investigation of the Colorado River is the presence of large numbers of non-native species. It is assessed that in the Upper Colorado River Basin, there are currently 55 species of fish, only 13 of which are native; of these, 8 are endemic (found in no other drainage in the world). The Colorado River has one of the highest levels of fish endemism of any river system in North America.

Understanding the access mode of each non-native species and its new role and effect on the riverine ecosystem is important to understanding the management of these forms in concert with the native species and the valued game fishes. This knowledge can be gained by understanding the role of each species and its impact on the Colorado River Ecosystem.

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FAMILY CATOSTOMIDAE

BLUEHEAD SUCKER (*Catostomus discobolus*)

The bluehead sucker is native to the Colorado River Drainage. It is not endemic, since it is found in other drainages of North America, such as the Walker River of northern Nevada. Bluehead suckers are found primarily in the middle to upper reaches of the Colorado River and its tributaries (Tyus et al. 1982).

Bluehead suckers in the Upper Colorado River Basin are commonly associated with cobble and rubble substrate, and can be particularly abundant in relatively swift water over rocky jetties and bars. This species is commonly associated with flannelmouth suckers, but is distributed further upstream in cooler and clearer conditions. Bluehead suckers are particularly abundant in the Gunnison River, the upper Green River, and the upper Colorado River, above Moab. The species is probably not abundant in Cataract Canyon because of warm water temperatures and high turbidity.

Hybrids of bluehead and flannelmouth suckers are reported in the Green and Upper Colorado Rivers (Hubbs and Miller 1953, McAda 1977, Valdez et al. 1982), and possibility of hybridization with razorback suckers exists.

Morphologically, the bluehead sucker has a streamlined body with large scales that become smaller and denser toward the head region. The fish has a rounded head with distinct lateral notches on a subterminal sucker-like mouth. Bluehead suckers are usually blue-gray in color and can develop a bright red-orange lateral stripe during spawning. Bluehead suckers commonly spawn after runoff in mid to late June at water temperatures of 12 to 18°C, and the larvae emerge in about 1 week to become transported by river currents various distances downstream (Valdez et al. 1985). The young inhabit various quiet shoreline habitats, including backwaters and eddies. Juveniles and adults are commonly found in relatively swift water over rocky substrates.

FLANNELMOUTH SUCKER (*Catostomus latipinnis*)

The flannelmouth sucker is one of six endemic species found in Cataract Canyon. It was not very abundant in this region, and densities varied seasonally and annually indicating movement to and from this region depending on flow levels; fewer fish were seen during high flows. Few young flannelmouth suckers were seen in Cataract Canyon, indicating limited reproductive success. Flannelmouth suckers are common in the middle regions of the Green and Colorado Rivers and their tributaries (Tyus et al. 1982). They are most abundant in the Colorado River from Westwater Canyon to Grand Junction, and in the Green River from Sand Wash to Split Mountain. Like the bluehead sucker, flannelmouth suckers increased in abundance in Cataract Canyon when compared to the sandy regions of the Colorado and Green Rivers for about 100 miles above their confluence. When found in these reaches, they are common associated with cobble riffles and jetties often in sympatry with bluehead suckers and razorback suckers.

Hybridization between flannelmouth suckers and bluehead suckers or razorback suckers has been reported for many years from the upper basin (Hubbs and Miller 1953, Holden 1973). McAda and Wydoski (1980) reported the increasing incidence of hybrids in the upper basin as a threat to the rare razorback sucker. Three fish believed to be flannelmouth x bluehead hybrids were found in Cataract Canyon in 1988.

Flannelmouth suckers are a very distinct species in the upper basin. They have a mottled yellow-gray appearance with small scales that become slightly larger toward the tail. They are easily distinguished from the bluehead and mountain suckers by the absence of lateral notches between the maxillary and mandible and the presence of a deep medial notch in the mandible. They are the largest sucker in the Upper Colorado River and generally spawn from May to early August, depending on the area.

RAZORBACK SUCKER (*Xyrauchen texanus*)

The razorback sucker is currently a candidate species under the Endangered Species Act of 1973. It was proposed for listing in 1978 but was withdrawn because of the lack of an economic assessment (U.S. Fish and Wildlife Service 1980). In 1989, FWS was petitioned to list the razorback sucker as endangered; a decision is to be issued in March 1990.

The razorback sucker is declining in the upper basin because of a lack of reproduction, habitat alterations, and hybridization (Wick et al. 1982). Lanigan and Tyus (1989) estimated the population of the razorback sucker in the upper Green River at 948 fish (95% confidence interval, 758-1138).

Only one razorback sucker was found in the Cataract Canyon area in 4 years of extensive fishery surveys conducted under this investigation. The fish was a 493 mm adult captured September 11, 1987 on a large alluvial cobble bar at the mouth of Salt Creek (RM 3.6) on the Colorado River. Prior to this, two adults were captured at Spanish Bottom (RM 213.0) in 1980 by Persons et al. (1982) and two were captured in 1981 at the Slide (RM 1.4 and 1.5) by Valdez et al. (1982). These are the only razorback suckers reported from the area of the confluence from 1979 to 1989. In 1980 and 1981, Persons et al. (1982) captured 6 and 11 adults, respectively, from Gypsum Canyon in upper Lake Powell.

The literature in the last 15 years (Holden and Stalnaker 1975, McAda and Wydoski 1980, Wick et al. 1982) indicate a general decrease in numbers and distribution of the razorback sucker in the upper basin. A razorback sucker status report and management plan (Bestgen 1989) are currently being developed by Reclamation to address the needs of the species, pending the decision on the listing petition currently before the FWS.

Adult razorback suckers are easily identified by the keel-like hump on its back that is formed in early years by the fusion of the interneural bones (Personal communication with Bob Muth, Larval Fish Lab., August 1984. These bones fuse and grow to form the foundation of the keel or razor. An abbreviated keel is present in hybrids of razorback x bluehead, razorback x flannelmouth, and razorback x white suckers.

WHITE SUCKER (*Catostomus commersoni*)

White suckers are found throughout the eastern United States and Canada, and are slowly expanding west. The species is native to the Mississippi River and Great Lakes system, and has probably gained access to western drainages via trout plants from eastern hatcheries and through fishermen's bait buckets (Woodling 1985). Although it has been in the Colorado River drainage for at least 25 years (Vanicek 1967), it has never been reported as very abundant (McAda and Wydoski 1980, Holden and Stalnaker 1975, Miller et al. 1982).

The white sucker has a fusiform body, relatively large scales and generally with a light olivaceous back and white sides and belly. The mandible has a deep median cleft and the lateral notches between the mandible and maxillary are shallow. Most specimens of white sucker in the upper basin are small, less than 200 mm long, and few YOY are found, indicating limited reproduction.

In Cataract Canyon, white suckers were rare. Only three specimens were found, each less than 150 mm long and usually in backwaters or along shallow shorelines. Although hybridization with razorback suckers is reported from the upper basin (Holden and Stalnaker 1975), no evidence of this hybrid was found in Cataract Canyon.

FAMILY CENTRARCHIDAE

BLACK CRAPPIE (*Pomoxis nigromaculatus*)

Black crappie were first introduced into Utah in 1890 in a carload shipment of fish from the Illinois River Bottoms (Popov 1949). These were released in the Weber River and later (1895) into Utah Lake. Extensive distribution of the species in the 1930's and introduction into the Colorado River Storage Project reservoirs (Lake Powell, Lake Mead, etc.) in the 1960's resulted in a widespread distribution into most warm water lakes and ponds. Since it is a popular game fish, black crappie probably entered the upper Colorado River via riverside stock ponds in the Grand Junction, Moab, Jensen, and Green River areas.

The 11 black crappie found in the Cataract Canyon area were either YOY or juveniles that were probably washed downstream during spring runoff from stock ponds as described above. Apparently the species does not survive well in the main river as is evidenced by the absence of adults. The specimens found were usually in backwaters, however, their impact on the native fishes is unknown.

BLUEGILL (*Lepomis macrochirus*)

Bluegill are native to much of the eastern and southeastern United States, including the Great Lakes and Mississippi River. It is possible that the species was first introduced into the area in mixed carload shipments of fish from the Illinois River in about 1890 (Popov 1949). These fish were released into Utah Lake and the Weber River, but were quickly distributed throughout the area in the early 1900's as a popular game fish in reservoirs, lakes, and ponds.

Only one bluegill was found in the Cataract Canyon area (Lake Powell Inflow) during the 4-year investigation. This fish probably originated in Lake Powell where the species is abundant only 25 miles downstream (Valdez et al. 1982).

Bluegill can be distinguished from closely allied centrarchids by the presence of a black rectangular ear flap and a long pointed pectoral fin. These characters were evident and usable in distinguishing even YOY bluegill from green sunfish.

GREEN SUNFISH (*Lepomis cyanellus*)

Green sunfish, like bluegill, were probably first introduced to the area of the upper Colorado River basin in about 1890 in mixed carload shipments of fish from the Illinois River (Popov 1949). In the 1930's and 1940's, green sunfish and bluegill were introduced into many areas of Utah as "sunfish" and were promoted as a game fish by the U.S. Bureau of Fisheries (Leach et al. 1940).

Green sunfish are easily distinguished from bluegill by the presence of a short rounded black ear flap with a light margin, and a rounded pectoral fin. Specimens found in the upper basin often have turquoise vermiculi radiating across the cheeks.

Green sunfish were the most common centrarchid found in Cataract Canyon. They were usually found in backwaters and along protected shorelines. Most specimens were small (<100 mm) and appeared to be YOY or juveniles, suggesting that these fish are coming from riverside stock ponds near Grand Junction, Moab, Jensen, or Green River. Green sunfish were not abundant in Cataract Canyon, although the presence of even small numbers in backwaters and their omnivorous diet would suggest competition and predation on the native fish.

LARGEMOUTH BASS (*Micropterus salmoides*)

Largemouth bass were first introduced into Utah in September 1890 as a mixed carload with perch, crappie, and sunfish seined from the Illinois River Bottoms (Popov 1949). These fish were released into Utah Lake and the Weber River, and were distributed from that source throughout the state in 1894 and 1895. They were introduced as the most popular game fish in the reservoirs of the Colorado River basin in the 1960's, and are held as game fish in riverside stock ponds near Grand Junction, Moab, Jensen, and Green River.

Of 70 largemouth bass found in the Cataract Canyon area, most were YOY and juveniles that probably got washed downstream from stock ponds as described above. Although largemouth bass are common in Lake Powell, their numbers are very low in the inflow region, probably because of high silt loads. Nevertheless, a few largemouth bass were captured in the inflow.

SMALLMOUTH BASS (*Micropterus dolomieui*)

Smallmouth bass were first introduced in small numbers into Utah in 1912 (Popov 1949). Subsequent releases through the early 1900's failed to produce favorable results, and the species was not known to be present in the state in late 1940. Documentation of subsequent introductions is not available, but the species was first released in Lake Powell in 1982 and 1984 (Gustaveson 1985). They were also introduced into Flaming Gorge Reservoir about the same time. Currently, both impoundments have good fisheries for smallmouth bass.

Smallmouth bass are locally numerous on the Green River, particularly at the mouth of the Duchesne River. Unlike the largemouth bass, smallmouths are found as adults concentrated at some tributary mouths, although like largemouths they are also found occasionally in other reaches of the upper basin. The only smallmouth bass found in this study was in 1985 just below Rapid #25 at the Lake Powell Inflow. The fish was a small adult.

The impact of this species on the native fishes of the upper basin is unknown. It is a potential predator and the young could compete with young native fishes.

FAMILY CYPRINIDAE

BRASSY MINNOW (*Hybognathus hankinsoni*)

Either the brassy minnow has only recently gained access to the upper basin, or its resemblance to the fathead minnow (*Pimephales promelas*) has previously masked its presence. The main gross morphological feature separating the two is the presence of an incomplete lateral line and a more rounded dorsal fin on the fathead minnow. The first rudimentary ray in the dorsal fin of the fathead minnow is more or less thickened and distinctly separated from the first well-developed ray by a membrane; this ray if closely attached to the first long ray in the brassy minnow. Although both species have black pigment lining the peritoneum, the intestine of the brassy minnow is notably longer. A key characteristic of the brassy minnow is also the presence of about 20 faint radii on the scales, whereas the fathead minnow has fewer than 20 radii.

The brassy minnow probably gained access into the upper basin mixed with fathead minnows as bait fish. Fathead minnows are among the most popular bait fish used by crappie and bass fishermen in reservoirs of the Colorado River Basin.

The effect of the brassy minnow on the native species is unknown, but like fathead minnows and the other small non-native cyprinids, it can probably be implicated as being a competitor and perhaps a predator.

BONYTAIL (*Gila elegans*)

The bonytail is perhaps the rarest of the endemic fishes of the Colorado River Basin. It is listed as "endangered" by the FWS as well as the States of Utah and Colorado. The species was first determined endangered, without critical habitat designation, by FWS on April 23, 1980 (Federal Register, 45 FR27713) under the Endangered Species Act of 1973, as amended. A Recovery Plan was first developed in 1984 and was updated in 1989 (Colorado River Fishes Recovery Team 1984, 1989).

The bonytail is endemic to the rivers and large tributaries of the Colorado River Basin, where it was once common (Holden and Stalnaker 1975a, 1975b). Today, reduced wild populations indicate a trend toward extinction (Valdez and Clemmer 1982). Since 1979, only 11 adults have been caught in Mohave and Havasu Lakes of the lower basin. In the upper basin, where the species occurs sympatrically with roundtail and humpback chubs, it is extremely rare. Only a few individuals exhibiting some characteristics of *G. elegans* have been captured, one in Black Rocks (Kaeding et al. 1986) and several in Cataract Canyon as described in this report.

Bonytails in the lower basin reach a maximum size of about 22 inches, but the largest recorded from the upper basin is about 13 inches (Vanicek 1967). The species may be long lived, as indicated by estimated ages of 32 and 39 years (Ulmer 1983).

Vanicek and Kramer (1969) reported bonytails in spawning condition in the Green River within Dinosaur National Monument from mid-June to early July at a water temperature of 18°C. Young bonytails inhabit backwaters and other sheltered shoreline habitats, while adults appear to prefer pools and eddies absent of strong current, at varying depths, and over silt and silt-boulder substrates.

Several specimens of various sizes from Cataract Canyon were classified as bonytails. Unfortunately, the members of the *Gila* complex (bonytail, humpback and roundtail chubs) exhibit so much plasticity, and perhaps hybridization, that a definitive classification of some specimens is not currently possible. The reason for this uncertainty is that some specimens exhibit some, but not necessarily all, of the characteristics associated with the original species descriptions. This apparent overlap in morphology causes many biologists to classify specimens as *Gila* sp.

A possible enclave of bonytails is identified for Cataract Canyon; several young, juvenile, and adult fish were captured in this region that exhibit many of the characteristics associated with the species. Confirmation of this enclave is possible only through peer examination of morphologic, meristic, and genetic characters of these specimens. Nevertheless, the Cataract Canyon Region holds promise as a source of genetic material for the species from the upper basin.

COMMON CARP (*Cyprinus carpio*)

The carp is perhaps the most widespread and abundant non-native fish in North America. There is some question as to who first imported and propagated carp in the United States. Undocumented reports credit Captain Henry Robinson of Newburgh, New York with the first introduction of carp into the U.S. in 1931 or 1932. But, the first confirmed introduction of carp into this country is by Julius A. Poppe of Sonoma, California. He successfully transported live 5 of 83 small carp purchased in Reinfeld, Germany, to his pond in California in 1872. Mr. Poppe is also credited with the first shipments of carp to Honolulu and Central America (Cooper 1987).

The first official introduction of carp into the U.S. was as a result of recommendations by Professor S.F. Baird to the U.S. Fish Commission under President Ulysses S. Grant. Based on this recommendation and requests from persons of European origin, who valued it as a food fish, a total of 345 carp were imported from Europe and released in the Druid Hill Park ponds in Baltimore, Maryland, on May 26, 1877. The fish were quickly raised and distributed to many states; from 1879 to 1896, about 2.4 million carp were distributed by the U.S. Fish Commission throughout the U.S., Canada, Costa Rica, Ecuador, and Mexico. This wide distribution of the species enabled it to take hold in most drainages of North America, and in the late 1800's and early 1900's, the carp became a commercially important species. In the decade following World War II, annual catches reached 36 million pounds worth $2 million. Carp are still harvested commercially with over 70% of the harvest coming from the Mississippi River basin.

The mode and timing of introduction of carp into the Colorado River Basin is unknown, but it probably occurred in 1881, when they were first introduced into the State of Utah (Popov 1949, Sigler and Miller 1963). It has never received much commercial attention in this drainage, and biologists generally concede that carp are detrimental to game and nongame fish alike, including native species.

Carp are locally abundant in sheltered habitats of the Upper Colorado River Basin, particularly in off-river impoundments, backwaters, and shorelines; carp are about the only species that inhabits the sand-silt tamarisk-lined banks that now dominate the Colorado and Green Rivers. In Cataract Canyon, carp probably constitute the greatest biomass of any species. Hundreds of adult carp were observed at the base of Big Drop 3, in an apparent effort to ascend the Colorado River to spawn. The greater abundance of adult carp in Cataract Canyon in the early summer followed by smaller numbers in late summer and fall indicate that this species moved to and from Lake Powell. However, in spite of large numbers of ripe and gravid fish, very few young carp were captured in Cataract Canyon. Whether these fish have widespread reproductive success and where the young are harbored remains a mystery.

Although another large Asian cyprinid, the grass carp or white amur (*Ctenopharyngodon idella*) is rumored to be present in small private riverside ponds, it has not yet been reported in the rivers and tributaries of the Upper Colorado River Basin.

COLORADO SQUAWFISH (*Ptychocheilus lucius*)

The Colorado squawfish is the largest fish endemic to the Colorado River Basin. It is the largest member of the minnow family (Cyprinidae) in North America with an estimated length of 5 feet and weight of 80 pounds, although the largest confirmed weights are 27 and 34 pounds for two fish from Lake Mead (Wallis 1951). The largest Colorado squawfish recently caught was from the upper basin, and was slightly longer than 3 feet and weighed about 18 pounds (Colorado River Fishes Recovery Team 1989).

The Colorado squawfish is listed as "endangered" by the FWS as well as the States of Utah and Colorado. It was first included in the list of endangered species issued by the Office of Endangered Species and published in the Federal Register (32 FR 4001) on March 11, 1967. It received protection under the Endangered Species Act of 1973, as amended, and a Recovery Plan was first developed in 1978 and updated in 1989 (Colorado River Fishes Recovery Team 1989).

The Colorado squawfish evolved as the major predator of the Colorado River Basin. It can become piscivorous in its first year of life, and retains a nearly exclusive fish diet throughout its life. The species is apparently long lived, although accurate assessments of age have not been possible because of the difficulty of using scales and the lack of sufficient numbers of otoliths. Fish have been conservatively aged to 11 years, using scales (Vanicek 1967, Seethaler 1978), but probably live much longer.

The Colorado squawfish is currently distributed from Lake Powell upstream to Palisades, Colorado, on the Colorado River; and upstream to Echo Park on the Green River. It also inhabits many of the tributaries of these rivers, such as the Yampa, White, and Gunnison Rivers. The Green River subbasin supports the largest subpopulation of Colorado squawfish, where reproduction has been consistent for at least the last 10 to 15 years (Holden and Wick 1982). Although reproductive success is difficult is assess, the subpopulation of the Colorado River subbasin appears smaller.

Spawning by Colorado squawfish generally occurs in July and August at water temperatures of 18 to 22°C. Several areas, including the Yampa River and Three Fords Rapid have consistently supported spawning activity, although spawning probably also occurs opportunistically on numerous cobble bars in both the Green and Colorado Rivers. Females produce large numbers of small eggs; a large adult female, weighing 4,355 g produced 242,981 eggs under hatchery conditions (Hamman 1981).

Incubation time for the species is usually only 5 days, and the newly hatched larvae can be transported by river currents for varying distances downstream to nursery backwaters. These young fish spent their first year of life in these sheltered backwaters, and then move to other habitats as juveniles and adults. The habitat of adults is variable (Miller et al. 1982).

FATHEAD MINNOW (*Pimephales promelas*)

Fathead minnows are widely distributed in the warmer middle and lower regions of the upper basin. Their mode of access is unknown but was probably via bait buckets since the species is so popular as a bait fish for crappie and largemouth bass. The species may have gained access into the drainage as early as the late 1800's as an incidental in seine hauls of "bass and sunfish" brought to the west from midwestern drainages. A description of the fathead minnow is provided under the brassy minnow to distinguish to two species.

Fathead minnows were locally very abundant during this investigation. The largest numbers were always in backwaters and isolated pools. Very rarely was this species found in habitats with any velocity. Fathead minnows thrive in warm, turbid waters (Pflieger 1975) and can survive high temperatures and low oxygen levels better than probably any other species in the upper basin, except perhaps black bullheads. The high flows of the Colorado River in 1984 and 1985 apparently decreased the numbers of fathead minnows substantially, probably because the sheltered habitats such as backwaters were washed away and the fish were forced into the main channel. The few that survived were probably able to spawn only once because of the late warming of the river during these high runoff years. The density of fathead minnows increased dramatically in 1987 and 1988, during two low water years, when apparently sheltered habitats were preserved and early warming allowed for multiple spawning events. This rapid recovery to adverse conditions revealed that short-lived, early-maturing species like the fathead minnow can recover very rapidly (within 2 to 3 years) from suppressed population levels, indicating that discriminating control measures for these species are currently not available and that the only successful control measure will have to be ongoing.

The impact of the fathead minnow on native species is unknown. Like the other small cyprinids, it is implicated as a potential competitor and predator.

HUMPBACK CHUB (*Gila cypha*)

The humpback chub is one of three endemic fishes listed by the FWS as "endangered" under the Endangered Species Act of 1973, as amended. It is also designated as "endangered" by the States of

Utah and Colorado. The species was first included in the first List of Endangered Species issued by the Office of Endangered Species and published in the Federal Register (32 FR 4001) on March 11, 1967. A Recovery Plan was first developed in 1978, and updated in 1989 (Colorado River Fishes Recovery Team 1989).

The humpback chub is endemic to the rivers and large tributaries of the Colorado River Basin, where it was once apparently locally abundant. Today, the species is found in seven areas of the basin: (1) Little Colorado River, Arizona, (2) Colorado River in Marble and Grand Canyon, Arizona, (3) Colorado River in Black Rocks/Westwater Canyon, Colorado, (4) Colorado River in Cataract Canyon, Utah, (5) Green River in Desolation and Gray Canyon, Utah, (6) Green River in Dinosaur National Monument, Colorado and (7) Yampa River in Dinosaur National Monument, Colorado (Colorado River Fishes Recovery Team). Self-sustaining populations have been confirmed only in areas 1 and 3.

Humpback chub are apparently capable of spawning under a variety of flows and water temperatures; fish in Black Rocks were suspected of spawning in June 2-15, 1980, at water temperatures of 11.5-16.0°C and flows of 610-740 m^3/sec; in 1981, spawning was suspected May 15-25 at water temperatures of 16.0-16.5°C and flows of 85-140 m^3/sec (Valdez and Clemmer 1982). In 1983, the species spawned in Black Rocks under maximum daily water temperatures of 13-17°C and flows of 1,060-2,120 m^3/sec; and in 1984, spawning occurred at temperatures of 21-23°C and flows of 777-389 m^3/sec. This apparent ability to reproduce under variable conditions may account for the success of this species in the locally turbulent conditions of canyon areas.

Larval humpback chub hatch in about 5 days, and occupy sheltered shorelines, pocket waters among emergent boulders, and backwaters for their first year of life. Juveniles are found in water up to 30 feet deep over sand-silt and boulder-bedrock substrates in velocities of less than 1 fps. Adults were found in depths of 2.4 to 40 feet in velocities of 0.0 to 3.8 fps over bedrock, boulders, and sand (Valdez and Clemmer 1982, Valdez and Nilson 1982). All ages of humpback chub were found next to but rarely in, high velocity flow.

Extreme forms of the humpback chub have a pronounced dorsal hump and laterally compressed body tapering abruptly to a narrow caudal peduncle that flares to a deeply forked tail. Dorsal ray counts are 8-10 (usually 9), and anal ray counts are 9-11 (usually 10). Specimens of the Colorado River *Gila* complex have been collected in many locations of the upper basin (Holden and Stalnaker 1970, Wick et al. 1979, 1981; Valdez and Clemmer 1982) that do not fit the original species descriptions for either bonytail, humpback, or roundtail chub. Many of these have been classified as *Gila* sp., and indicate extreme plasticity or possible hybridization between these congeneric chubs.

The chub found in Cataract Canyon exhibited a great deal of phenotypic plasticity. Some were similar to typical *Gila cypha* forms found in Black Rocks or Westwater Canyon. Others were small with less pronounced features (moderate nuchal hump, shallow head depression, moderate caudal peduncle length and thickness, varying dorsal and anal rays), similar to fish found in Desolation Canyon. The variation seen here and in other regions of the upper basin warrants closer examination of the upper basin *Gila* complex.

RED SHINER (*Notropis lutrensis*)

The red shiner was the most common species of fish found in the Cataract Canyon area. Small immature forms resemble sand shiners, but juveniles and adults of the two species are usually easily distinguished. As adults, red shiners are usually deep bodied and laterally compressed, steel blue above and silvery below with orange fins. Breeding males are metallic blue with bright red fins and tubercles on the head and body. Red shiners typically have eight or nine anal rays, whereas sand shiners typically have only seven. Adult sand shiners are less compressed laterally, and are not deep bodied like the red shiner. A dark checkerboard pattern along the lateral line easily distinguishes adult sand shiners from red shiners. Sand shiners also have a dark stripe along the midline of the back that expands into a wedge-shaped spot at the front of the dorsal fin. A hint of fluorescence is often associated with this dorsal spot.

Red shiners were found in every habitat sampled except for swift riffles and small rapids. In its native habitat along the Mississippi drainage, it is primarily a stream fish that inhabits a variety of habitats including quiet pools and backwaters as well as riffles. It is tolerant of high turbidity and siltation but avoids waters that are continuously clear or cool (Pflieger 1975). The mode of introduction of the red shiner into the Colorado River Basin is unknown, but was probably incidental in seine hauls of "bass and sunfish" or in bait buckets, or both. Regardless, its overwhelming abundance and success in the Colorado River was predictable, considering it native habits.

The effect of red shiners on the native fishes is unknown, but like the other small cyprinid species, it is probably implicated as a potential competitor and predator because of its great abundance.

ROUNDTAIL CHUB (*Gila robusta*)

The roundtail chub is one of three congeneric species endemic to the Colorado River. It is the only species of this group not federally endangered; both the humpback chub and bonytail are listed as endangered under the Endangered Species Act of 1973.

The roundtail chub is common to abundant in certain areas of the upper basin, generally in the middle to upper reaches and in some tributaries. It decreased in distribution because of the construction of the mainstem dams in the 1960's (Vanicek 1967, Holden and Stalnaker 1975). The current status and trend of this species in the upper basin is not known, but some biologists suspect that it is decreasing in range and abundance.

The Final Report of the Cataract Canyon Studies addresses the morphological variation of the three species of the genus *Gila*. It appears that the species is phenotypically plastic and possibly hybridizing with humpback chub or bonytail.

Roundtail chub were not common in the Cataract Canyon area. It appears that in the upper basin, this species has an affinity for rock substrate, and the paucity of this feature in the Green and Colorado Rivers above their confluence limits its numbers in these regions. However, the species probably reoccurs in Cataract Canyon because of the presence of talus shorelines, rock jetties, and rock substrate which provide good habitat for the species. It probably does not occur in great numbers because of the warm water and high turbidity.

SAND SHINER (*Notropis stramineus*)

The sand shiner was the second most common species encountered during the Cataract Canyon Studies. Red shiners were consistently more abundant except in the lower 50 miles of the Colorado River and in the Lake Powell Inflow where sand shiners dominated, probably because of the predominantly sand substrate. In its native habitat, sand shiners have a strong affinity for sand substrate, as its name implies (Pflieger 1975). It occurs in streams of all sizes but is seldom abundant in the largest rivers. It is interesting to note that Pflieger (1975) also reported that the distribution of the red shiner and the sand shiner in Missouri was remarkably similar, and that in many Prairie streams the sand shiner was second in abundance only to the red shiner. Like the success of the red shiner in the Colorado River drainage, the success of the sand shiner was predictable, based on its native habits.

A description of sand shiners is presented under the red shiner to provide distinguishing characters for the two species. Both species probably feed on immature aquatic insects and bottom ooze containing adult insects, small crustaceans, and plant material (Pflieger 1975). Their abundance, like the red shiner, implicates these species as potential competitors and predators of the native fishes.

SPECKLED DACE (*Rhinichthys osculus*)

The speckled dace is native to many drainages throughout the country, including the Colorado River. Its great abundance, small size, and wide distribution make it valuable as a forage fish for predatory species, as well as a commercial bait fish.

The species is easily distinguished from the sympatric Colorado River fishes. It has a long fusiform body with a thick caudal peduncle. A black horizontal line runs the length of its body and forms a mask across the face and through the eye. This character is present in even very young speckled dace and is a reliable distinguishing feature of even the small fish. It has an elongated head and has a subterminal mouth with perhaps one or two small barbels at the corners of the mouth. At first glance, the body shape and color can be mistaken for that of a young Colorado squawfish leading to a case of mistaken identity made by more than one novice biologist.

Speckled dace were not found in large numbers during this study. They were generally associated with shallow riffles, but were also found along rocky shorelines and in backwaters. They appear to be a rather innocuous species that occupies a niche shared with only young bluehead and flannelmouth suckers. Little is known of the populations of speckled dace in the Colorado River, and whether this species is decreasing in abundance like so many of the other native forms.

UTAH CHUB (*Gila atraria*)

The Utah chub is native to the drainage basin of ancient Lake Bonneville in Utah, Idaho, Wyoming, and Nevada (Sigler and Miller 1963). It is also native to the Snake River drainage above Shoshone Falls. The species became established in the Colorado River drainage probably by way of the bait bucket in Strawberry Reservoir in 1933 (Strawberry Reservoir is on a tributary of the Duchesne River that flows into the Green River). They were collected in the Colorado River at the mouth of White Canyon and from Aztec Creek in 1957 by G.R. Smith (Sigler and Miller 1963).

The Utah chub is considered an undesirable species, particularly in shallow reservoirs where is thrives. UDWR plans to conduct a multimillion dollar rotenone treatment of Strawberry Reservoir in late summer 1990 to control this species and the Utah sucker (*Catostomus ardens*). It is also present in deep reservoirs such as Flaming Gorge but does not compete as seriously there because of a limited littoral zone for spawning and the presence of large predators (brown trout, lake trout) to control the species.

Utah chub are strictly a lacustrine species, and are found only occasionally in the rivers and tributaries of the upper basin. Only one was found during this 4-year study. Its affinity for lentic environments probably precludes this species from becoming established in the Colorado River and posing a major threat to the native fishes.

FAMILY CYPRINODONTIDAE

PLAINS KILLIFISH (*Fundulus zebrinus*)

Killifish are known as "topminnows" because of their habit of skimming along just beneath the surface of the water feeding on insects and other small invertebrates (Pflieger 1975). The top of the head and forward part of the back are broad and flat and the mouth is tilted upward so that is opens at the upper surface of the head to facilitate surface feeding. The species is easily distinguished by the presence of a seemingly massive protruding lower jaw with many teeth, thus the name "cyprinodont" which means "toothed carp".

Fundulus zebrinus (plains killifish) and *Fundulus sciadicus* (plains topminnow) are reported as incidental in the Colorado, Green, and White Rivers of the upper basin, and rare in the San Juan River (Tyus et al. 1982). The plain killifish has a dorsal fin base situated above or forward of the anal fin base; usually 13 to 16 dorsal fin rays; 40 or more lateral line scales; and 12 to 13 dark vertical bars on the sides of the body. The plains topminnow has a dorsal fin base situated above the anal fin base; usually 6 to 11 dorsal fin rays; 38 or fewer lateral line scales; and without vertical bars or horizontal streaks (Pflieger 1975). Another species (*F. kansae*) is described in Missouri (Pflieger 1975) and has been suggested as the species in the Colorado River drainage. A detailed taxonomic study of this form in this river system has not been conducted to resolve this dilemma.

The 36 specimens of plains killifish caught in this 4-year investigation were distributed throughout all five regions. All specimens caught were in backwaters or isolated pools. This species, like the mosquitofish, probably does not pose a major threat to the native fishes because of its low numbers and its habit of feeding on surface insects and invertebrates.

FAMILY CLUPEIDAE

THREADFIN SHAD (*Dorosoma petenense*)

Threadfin shad were first introduced into Lake Powell in 1968 and again in 1969 (Gustaveson et al. 1975) as a forage fish for largemouth bass, black crappie, and striped bass which were released in 1974. The fish is strictly lacustrine (lake dweller) and is a poor swimmer in currents. It is the single forage base on which striped bass largely rely. Declines in the population of threadfin shad in Lake Powell in 1982 and 1983 have affected the growth and condition of striped bass in that reservoir.

Threadfin shad were found only below the last active rapid (Rapid #26, RM 201) during this study. They were captured with electrofishing gear and seining, but were never numerous. Since this species is lacustrine and a plankivore, it probably poses little threat to the native species.

Recently, UDWR (Gustaveson and Bonebrake 1989) submitted a draft proposal to introduce rainbow smelt (*Osmerus mordax*) into Lake Powell to provide additional forage for all game fish in the reservoir. Several concerns were discussed in this proposal regarding the introduction of this non-native species, including their possible upstream ascent to compete with native fishes. The Cataract Canyon Studies indicate that it would be highly unlikely for any great numbers of rainbow smelt to ascend the Colorado River above Lake Powell. The Big Drops Rapids (Rapids #21, 22, 23), located about 0.5 miles above the 3700 foot elevation level of Lake Powell, are probably a barrier to most fish from Lake Powell, including species that are better swimmers than rainbow smelt (i.e., striped bass, walleye, largemouth bass, smallmouth bass). Since the lacustrine rainbow smelt usually ascend into stream mouths only to spawn in March, April, and May, and they are unable to ascend a drop of greater than 1 foot, it is very unlikely that this species will ascend into Cataract Canyon. Their spawning time would coincide with spring runoff in Cataract Canyon which would increase velocities and make ascent even more difficult.

FAMILY ICTALURIDAE

BLACK BULLHEAD (*Ictalurus melas*)

The catfish-like black bullhead is not native to the Colorado River drainage. It probably made its way into the Colorado River via introductions into the State of Utah following shipments of fry from the Midwest in 1871 and 1873 (Popov 1949). Although these fish were first released into the Jordan River (Popov 1949) of the Great Salt Lake drainage, it soon became widespread. It was established as a commercial fishery in Utah Lake in 1900, and in 1903 and 1904, 110,000 pounds were sold by commercial fishermen (Sharp 1905).

Black bullheads are distinguished from channel catfish primarily by their square tail, as compared to the deeply forked tail of the channel catfish. Black bullheads are dark brown to greenish-black dorsally, with a yellowish white belly. The species characteristically has black pigmentation on the chin barbels and the dorsal and caudal fin membranes are distinctly black; black bullheads also have pectoral spines that are weakly barbed on the posterior edge. The yellow bullhead (*I. natalis*) is reported from Lake Powell (Tyus et al. 1982) but remains unconfirmed upstream of that point.

Black bullheads are locally common in perennial backwaters and protected off-river impoundments, and are particularly abundant in gravel pits near Grand Junction (Valdez and Wick 1986). The artificial impoundments probably serve as refugia for the species and provide a continuous source of this species to the river. In the mainstem rivers, black bullheads are almost always found in large backwaters or isolated pools. The capture of a large "swarm" of about 300 YOY black bullheads in an isolated pool in Cataract Canyon in 1987 is evidence that the species reproduces successfully in sheltered habitats.

Black bullheads are probably one of the more voracious inhabitants of large backwaters, habitats commonly used as nurseries by native and endangered species. They are probably indiscriminate feeders, and even small numbers constitute a major threat to any small fish or macroinvertebrate. Their voracious indiscriminate nature is evidenced by the capture of an adult black bullhead with a stomach full of raisins and peanuts just one hour after accidentally spilling a can of these in a large backwater in Cataract Canyon.

CHANNEL CATFISH (*Ictalurus punctatus*)

Channel catfish were first introduced into the Colorado River near Moab, Utah in 1919. An active sportsman and public figure, Horace Stone Rutledge formerly from Missouri, found the Colorado River suitable for the introduction of catfish which he caught in his childhood. As Grand County Clerk, Rutledge applied to the Bureau of Fisheries in Washington, D.C. for a shipment of catfish. His application was approved, and on Sunday, October 12, 1919, a shipment of several milk cans containing fingerlings from a federal hatchery in Kansas arrived by train at Thompson, Utah, about 40 miles north of Moab. Rutledge released the fish into the Colorado River just upstream from the Moab bridge on the same day. Three cans of fingerlings from the same shipment were unloaded at Grand Junction, Colorado, and released in the Colorado River nearby (Newpaper article in the Times Independent, Moab, Utah, 1919).

Channel catfish are abundant in the middle reaches of the upper basin, particularly in canyons such as Desolation Canyon on the Green River and Ruby Canyon on the Colorado River. Their abundance declines progressively downstream to the confluence of these two rivers, but increases significantly in Cataract Canyon, indicating an association with rock substrate and swift canyon areas. Channel catfish were generally among the five most common fish in Cataract Canyon, but were probably second only to carp in biomass. The young were very numerous along shallow shorelines and backwaters, while juveniles and adults were abundant in eddies, often in sympatry with chubs. Their impact on the native fishes is unknown, but their abundance and omnivorous food habits suggest competition and possibly predation.

Although channel catfish are reported to reach nearly 50 pounds in weight, the largest specimens in the mainstem rivers of the upper basin are less than 10 pounds, although individuals of up to 20 pounds are reported from Lake Powell.

No other close relatives of the channel catfish, such as the blue catfish (*Ictalurus furcatus*) or the white catfish (*Ictalurus catus*) are reported from the Upper Colorado River Basin, although flathead catfish (*Pylodictus olivaris*) are common in the lower basin.

FAMILY PERCIDAE

WALLEYE (*Stizostedion vitreum*)

Walleye were first released in Utah as fry in 1951 (Sigler and Miller 1963). They were released in the lakes and reservoirs of the Salt Lake and Sevier drainages, and were transported to other impoundments across the state in the 1950's and 1960's. The manner in which the walleye entered the upper Colorado River basin is unknown, but the species was already present in the drainage before impoundment of Lake Powell in 1963 (Gustaveson et al. 1985). This species accounted for the highest gill-netting catch rates of four stations in Lake Powell in March 1984 (Gustaveson et al. 1985), but composes a relatively small percentage of angler harvest.

Walleye have been caught throughout the upper basin in the last 10 years and are more numerous in the Green River near Jensen (Miller et al. 1982). Of the 70 walleye captured during this study, only 3 were found in Cataract Canyon (above Rapid #23) and 1 was found in the Colorado River (RM 1.5). Like striped bass, walleye were seen in the inflow region of Lake Powell usually only in late June and early July, but their flaccid condition indicated that they had spawned earlier.

The impact of walleye on the native fishes was not determined. However, it is well known that the species is piscivorous and probably utilizes whatever forage species are available.

FAMILY POECILIIDAE

MOSQUITOFISH (*Gambusia affinis*)

Mosquitofish were first introduced into Utah from Selby County, Tennessee in 1931 (Sigler and Miller 1963). It is native to the central United States from southern Illinois and Indiana to Alabama and the lower Rio Grande in Texas. It has been distributed extensively since the 1950's by mosquito abatement districts to control mosquitos, and has received world-wide attention in helping to combat the malaria-carrying forms. It does not tolerate prolonged cold conditions (<40°F) and does not occur extensively in northern regions, although it is tolerant to warm temperatures and low oxygen conditions.

Of 86 mosquitofish captured during this 4-year study, only 1 was caught in the Lake Powell Inflow. The rest were distributed throughout the riverine regions upstream of the lake generally in backwaters and sheltered shorelines. The low numbers and insectivorous diet of this species probably does not pose a major threat to the native forms.

The mosquitofish belong to the family of live bearers or viviparous fish. The males are distinguished by the elongated anal fin which is a highly-specialized rod-like organ or gonopodium used to internally fertilize the female. Embryos develop internally within the female and the young are born live. All other species of fish in Utah, except for aquarium forms such as the guppy (*Lebistes reticulatus*) are oviparous, producing eggs that are fertilized after leaving the body of the female (Sigler and Miller 1963).

FAMILY ESOCIDAE

NORTHERN PIKE (*Esox lucius*)

Five adult northern pike were captured during the Cataract Canyon Studies. Three of these fish were found in the middle of Cataract Canyon, the area known as 'Cataract Lake', and two were found in the Lake Powell Inflow. Since this species has never been introduced into Lake Powell by UDWR (Personal communications with Glen Davis, UDWR, December 27, 1989), its occurrence in the area was probably the result of extensive downstream movement from impoundments located several hundred miles upstream in Colorado. There are currently reproducing populations of northern pike in Elk Head Reservoir (500 miles away) on a tributary of the Yampa River, Taylor Park Reservoir (400 miles away) on the Gunnison River, and Rio Blanco Reservoir (450 miles away) on a tributary of the White River. The fish found in Cataract Canyon probably originated from one of these impoundments.

The northern pike captured in the Cataract Canyon area were in generally poor condition. Although their numbers and condition are better further upstream in the Green River (Echo Park to Sand Wash), the Yampa River, and the Colorado River (near Grand Junction), they may not fare as well in this more downstream area because of higher water temperatures, higher turbidity and lower numbers of bluehead and flannelmouth suckers for forage.

The effect of the northern pike on native species in the upper basin is currently under investigation (Nesler 1989). It presently appears that this species cannot reside and thrive in the Cataract Canyon area because of habitat limitations: swift turbid flows, high temperatures, relatively low forage base. However, fish that successfully access Lake Powell could thrive and reproduce. There is a large forage base for this species in the reservoir, and the buildup of silt/sand bars with tamarisk growth in side canyons can provide the species with an opportunity to become established. Certainly there is a source of fish high upstream and over time, there may be sufficient numbers to survive the long descent to establish a reproducing population in Lake Powell.

FAMILY SALMONIDAE

BROWN TROUT (*Salmo trutta*)

Brown trout were first introduced into the United States from Europe in 1883 (Sigler and Miller 1963). They were first brought into the Colorado River System in the early 1900's as a species that adapted well to cool western streams and quickly established self-sustaining populations. Brown trout are currently distributed throughout the United States and Canada and are found in most streams and many lakes and impoundments. Although brown trout were first introduced into Flaming Gorge Reservoir in the mid-1960's, shortly after impoundment, they were probably already present in the upper streams of the drainage.

Only three brown trout were captured during this study; two in the Colorado River above Lake Powell, and one in the inflow region. These specimens probably originated any of a number of tributary streams. Brown trout do not seem to fare well in the main stem of the upper basin probably because of high water temperatures, turbidity, and salinity. The species does not appear to pose a major threat to the native fishes.

KOKANEE SALMON (*Oncorhynchus nerka kennerlyi*)

Kokanee salmon were first brought into Utah in 1922 (Popov 1949). They were first released as fingerlings in Bear Lake of northern Utah, and were introduced into Strawberry Reservoir in 1937. Kokanee salmon were also released in Lake Powell in 1963 and 1964 (Gustaveson et al. 1985), and into Flaming Gorge Reservoir about the same time. The species has succeeded in Flaming Gorge Reservoir, but not in Lake Powell. Most kokanee spawn at 2 to 3 years of age and are generally less than 400 mm long.

The two specimens captured in the Lake Powell Inflow probably originated in either Flaming Gorge Reservoir (400 miles upstream) on the Green River or one of the Wayne Aspinal Unit reservoirs (350 miles upstream) on the Gunnison River. One gravid female (395 mm TL) was captured September 25, 1985, at RM 200.4, and one ripe male (406 mm TL) was captured October 11, 1987, at RM 201.0. Both fish were apparently in a spawning mode.

RAINBOW TROUT (*Oncorhynchus mykiss*)

The rainbow trout is the most widely distributed freshwater fish in the states of the Colorado River Basin. Since its introduction into Utah in 1883 (Popov 1949), millions have been released in streams, lakes and reservoirs. The rainbow trout is native to the streams of the Cascade Range of northern California, and has been the most popular hatchery fish for western states for many years.

Only two rainbow trout were captured during this study. Their poor conditions indicated that this species could not thrive and reproduce in the Cataract Canyon area.

FAMILY SERRANIDAE

STRIPED BASS (*Morone saxatilis*)

Striped bass were first introduced into Lake Powell in 1974 (Gustaveson et al. 1985); 49,885 fish 2-3 inches long were released at Wahweap Creek by the UDWR. A second group of 94,878 fish of the same size was also released at Wahweap in 1975, and subsequent releases were made in 1976, 1977, 1978, and 1979. Striped bass were introduced into Lake Powell to alleviate a decline in spawning and nursery habitat of largemouth bass and black crappie as the lake approached full pool. Threadfin shad were introduced into Lake Powell in 1968 and 1969 to provide forage for largemouth bass and crappie as well as striped bass. The striped bass has been a very successful sport fish in this upper basin reservoir and is highly sought by trophy sport fishermen. A decline in threadfin shad in 1982-83 affected the condition of striped bass in the reservoir, and current environmental conditions seem to favor the proliferation of juvenile striped bass and adversely affect the numbers of large fish (Gustaveson et al. 1985).

Large numbers of striped bass were in the Lake Powell Inflow in every year of this investigation (1985-88). These fish were usually most abundant in late June and early July downstream of the base of Rapid #23 (RM 202); sampling was not conducted from early May to late June because of high flows. This rapid is the last in a series of three known as the Big Drops and represent a gradient of 30 feet per mile, which is the steepest in the upper basin. Since large numbers of striped bass were seen below this rapid and only three were seen above this point, it appears that the Big Drops of Cataract Canyon were a barrier to the majority of striped bass. It is possible, however, that these fish ascended and descended these rapids during peak runoff in May and June when fishery investigations were not possible because of high flows. In order to reach the base of Rapid #23, the fish ascended at least three active medium-sized rapids (26, 25, and 24), demonstrating an ability to ascend the smaller but not the larger rapids.

The impact of striped bass on the native fishes of the inflow was not determined. If the large numbers of adults found in the inflow region in late June and early July were spawning and not feeding, their predation effect may be negligible. However, the large numbers of YOY and juvenile striped bass found in backwaters and along shorelines of the inflow represented possible competition and predation for the native species. It appears that striped bass are not currently affecting native populations above the last major rapid of Cataract Canyon, and it is unlikely that this lacustrine species would reside and thrive in the turbid riverine ecosystem of the upper basin.

APPENDIX C

STANDARD FIELD DATA SHEET

BIO/WEST & BOR DATA SHEET

Cataract Canyon Fish Study

Sample Number: _ - _ _ _ River: _ _ Start RMI: _ _ _ . _ End RMI: _ _ _ . _

Type: S Date _ _ _ _ _ _ (Y Y M M D D) Gear: _ _ Habitat: #1 _ _ #2 _ _

Start Time: _ _ _ _ End Time: _ _ _ _ Hours: _ _ . _ Seconds(EL): _ _ , _ _ _

BA Length(m): _ _ _ BA Width(m): _ _ _ Samp Length(m): _ _ _ Samp Width(m): _ _ _

Ave Samp Depth(ft): _ _ . _ Max Samp Depth(ft): _ _ . _ Sub 1: _ _ Sub 2: _ _

Velocity(fps): _ _ . _ Mud Depth(ft): _ _ . _ BA Temp: _ _ . _ MC Temp: _ _ . _

Fish Preserved (Y/N): _ No. Bottles: _ _ Agency: _ _ _ _ Crew: _ _ , _ _ , _ _

Net No.: _ _ Start Velocity: _ _ . _ End Velocity: _ _ . _

COMMON NAME	CODE	LAR	YOY	JUV	ADU	TOTAL NUMBER COLLECTED
Bluehead sucker	BH	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
Flannelmouth sucker	FM	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
Carp	CP	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
Colorado squawfish*	CS	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
Fathead minnow	FH	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
Red shiner	RS	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
Rountail chub	RT	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
Sand shiner	SS	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
Speckled dace	SD	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
Channel Catfish	CC	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
________	_	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
________	_	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
________	_	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
________	_	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
________	_	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
________	_	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _

Preserved fish identified by: ____________________, Date ________

Keypunched by: ________, Date: ________, Edited by: ________, Date: ________

Photographs = Roll ______ Frame ______

*Record Total Length of ALL Colorado squawfish on back of sheet.

COMMON NAME	CODE	TL*	WT	CARLINTAG NO.	COLOR	RECAP (Y/N)	DISPOSITION

COLORADO SQUAWFISH TOTAL LENGHT (mm)*

COMMENTS:

*Please indicate fish preserved in bottles with asterisk next to TL.

APPENDIX D

SUMMARY OF FISH SAMPLING EFFORTS

Table D-1. **Summary of fish sampling efforts (number of sample efforts and total time) for each field trip of the 1985 Fisheries Biology and Rafting Project.**

GEAR	1	2	3	4	5	6
Electrofishing - EL (220-v DC, 6-10 A)	22	6	8	15	11	9
Gill Net - GM (100'x6'x2.0")	36	2	17	28	9	3
Gill Net - GN (100'x6'x2.5")	0	0	0	11	0	0
Trammel Net - TI (50'x5'x1.5"x10")	23	14	22	18	0	1
Trammel Net - TJ	0	5	3	0	0	0
Seine - SE (10'x4'x1/16")	4	18	35	7	0	0
Seine - SB (15'x4'x1/4")	0	0	0	31	56	40
Larval Drift Net - DR (10'x12"x18"x560 um)	0	8	32	22	0	0
Dip Net - DN	0	3	0	0	0	0
Kick Screen(Mundo) - MU (4'x3'x1/32")	0	0	2	0	0	0

Table D-2. **Summary of fish sampling efforts (number of sample efforts and total time) for each field trip of the 1986 Fisheries Biology and Rafting Project.**

GEAR	1	2	3	4	5	6
Electrofishing - EL (220-v DC, 6-10 A)	22 (7.0 hr)	18 (6.4 hr)	14 (9.0 hr)	9 (3.9 hr)	16 (5.2 hr)	16 (9.2 hr)
Gill Net - GM (100'x6'x2.0")	19 (38.5 hr)	27 (75.4 hr)	13 (27.2 hr)	15 (33.3 hr)	11 (33.0 hr)	6 (22.5 hr)
Gill Net - GN (100'x6'x2.5")	19 (38.0 hr)	27 (75.4 hr)	13 (27.3 hr)	14 (33.4 hr)	11 (33.0 hr)	5 (22.5 hr)
Trammel Net - TI (50'x5'x1.5"x10")	14 (28.0 hr)	25 (57.3 hr)	24 (52.5 hr)	43 (98.9 hr)	24 (72.0 hr)	11 (45.0 hr)
Trammel Net - TJ	0	0	1	0	0	0
Seine - SE (10'x4'x1/16")	24	26	24	26	24	13
Kick Screen - KS (3'x3'x1/32")	0	1	0	1	2	0
Larval Drift Net - DR (10'x12"x18"x560 um)	32 (8.0 hr)	44 (11.0 hr)	40 (20.0 hr)	16 (4.0 hr)	0	0
Minnow Trap - MT	0	0	0	0	26 (78.0 hr)	0

Table D-3. **Summary of fish sampling efforts (number of sample efforts and total time) for each field trip of the 1987 Fisheries Biology and Rafting Project.**

GEAR	1	2	3	4[a]	5	6	7	8
Electrofishing - EL (220-v DC, 6-10 A)	23 (7.2 hr)	35 (12.4 hr)	15[b] (3.6 hr)	14 (5.13 hr)	21 (7.66 hr)	16 (4.3 hr)	27 (7.49 hr)	19 (6.42 hr)
Gill Net - GM (100'x6'x2.0")	2 (15.2 hr)	41 (~ 82 hr)	33 (~ 66 hr)	33 (~ 66 hr)	23 (~ 46 hr)	8 (~ 16 hr)	21 (~ 52 hr)	30 (~ 70 hr)
Gill Net - GN (100'x6'x2.5")	6 (45.3 hr)	0 (~ 30 hr)	15 (~ 30 hr)	17 (~ 26 hr)	13 (~ 26 hr)	7 (~ 14 hr)	15 (~ 37 hr)	14 (~ 30 hr)
Gill Net - GB (150'x4'x1 1/2")	0	0	0	13 (~ 26 hr)	0	0	9 (~ 22 hr)	8 (~ 20 hr)
Floating Gill Net GF (150'x4'x1")	0	0	0	14 (~ 28 hr)	13 (~ 26 hr)	7 (~ 14 hr)	10 (~ 25 hr)	16 (~ 35 hr)
Experimented Gill Net - GP (100'x5';5x1/2"incr)	0	18 (~ 36 hr)	14 (~ 28 hr)	3 (~ 06 hr)	13 (~ 26 hr)	8 (~ 16 hr)	13 (~ 32 hr)	13 (~ 30 hr)
Trammel Net - TI (50'x5'x1.5"x10")	9 (61.7 hr)	15 (~ 32 hr)	14 (~ 28 hr)	12 (~ 24 hr)	10 (~ 20 hr)	8 (~ 16 hr)	12 (~ 30 hr)	14 (~ 30 hr)
Trammel Net - TK (75'x5'x1.5"x12")	0	18 (~ 36 hr)	15 (~ 30 hr)	3 (~ 06 hr)	0	0	0	0
Seine - SE (10'x4'x1/16")	1	43	56	34	38	0	18	15
Kick Screen - KS (3'x3'x1/32")	0	4	2	0	2	0	0	0
Larval Drift Net - DR (10'x12"x18"x560 um)	0	44	44	28	0	0	0	0

[a] water extremely turbid during this trip
[b] VVP - 15 malfunction

Table D-4. Summary of fish sampling efforts (number of sample efforts and total time) for the field trips of the 1988 Fisheries Biology and Rafting Project.

GEAR	1	2	3	4	5	6	7	8	9
Electrofishing - EL (220-v DC, 6-10 A)	0	15	31	22	14	18	15	16	9
Gill Net - GF (150'x4'x1", floating)	0	0	0	0	0	6	12	1 (15.5)	3 (~10)
Gill Net - GM (100'x6'x2.0")	0	8 (56.4)	21 (~50)	0	0	0	0	0	0
Gill Net - GN (100'x6'x2.5")	0	8 (56.1)	0	0	0	0	0	0	0
Experimented Gill Net - GP (100'x5';5x1/2"incr)	0	9 (58.9)	46 (~100)	42 (~90)	46 (~100)	71	56 (~150)	12 (~140)	47 (~150)
Trammel Net - TI (50'x5'x1.5"x10")	0	8 (43.4)	16 (~35)	34 (~75)	39 (~80)	12	20 (~50)	3 (30.5)	26 (~90)
Drift Trammel Net - TJ	0	0	0	0	0	0	0	0	0
Seine - SE (10'x4'x1/16")	90	0	85	30	43	21	28	1[a]	20
Kick Screen - KS (3'x3'x1/32")	0	0	1	0	0	0	0	0	0
Larval Drift Net - DR (10'x12"x18"x560 um)	0	0	0	0	0	0	0	0	0
Hoop Net - FC	0	0	4 (91.3)	2 (67.1)	1 (23.8)	0	2 (44.7)	0	0

[a] additional haul recorded by UDWR as part of YOY Monitoring Program.

APPENDIX E

SUMMARY OF NUMBERS AND PERCENTAGES OF FISH CAPTURED BY YEAR AND REGION

Table E-1. Summary of total numbers and percentage composition of fish captured by species for the 1985 Cataract Canyon Studies.

SPECIES	T[a]	P
Black bullhead	7	0.03
Black crappie	1	0.01
Bluegill	0	0
Bluehead sucker	36	0.14
Bonytail chub	2	0.01
Brassy Minnow	4	0.01
Brown trout	0	0
Carp	2965	11.26
Channel catfish	5401	20.52
Chub (Gila sp.)	11	0.04
Colorado squawfish	517	1.97
Fathead minnow	525	1.99
Flannelmouth sucker	241	0.92
Flannel x Bluehead	0	0
Gambusia	28	0.11
Green sunfish	0	0
Humpback chub	11	0.04
Kokanee salmon	1	0.01
Largemouth bass	16	0.06
Northern Pike	1	0.01
Plains killifish	4	0.01
Rainbow trout	0	0
Razorback sucker	0	0
Red shiner	15198	57.73
Roundtail chub	60	0.23
Roundtail x Humpback	0	0
Sand shiner	1002	3.81
Shiners (red & sand)	0	0
Smallmouth bass	0	0
Speckled dace	75	0.29
Striped bass	81	0.31
Threadfin shad	108	0.41
Unidentified[b]	5	0.02
Utah chub	0	0
Walleye	29	0.11
White sucker	0	0
TOTALS:	26329	100

[a] T = total, P = Percentage.
[b] Sent to Larval Fish Laboratory

Table E-2. Summary of total numbers and percentage composition of fish captured by species for the 1986 Cataract Canyon Studies.

SPECIES	T[a]	P
Black bullhead	13	0.10
Black crappie	2	0.02
Bluegill	0	0
Bluehead sucker	61	0.49
Bonytail chub	0	0
Brassy Minnow	0	-
Brown trout	1	0.01
Carp	1270	10.17
Channel catfish	2024	16.21
Chub (Gila sp.)	76	0.61
Colorado squawfish	749	6.00
Fathead minnow	1147	9.19
Flannelmouth sucker	192	1.54
Flannel x Bluehead	0	0
Gambusia	31	0.25
Green sunfish	13	0.10
Humpback chub	17	0.14
Kokanee salmon	0	0
Largemouth bass	14	0.11
Northern Pike	1	0.01
Plains killifish	4	0.03
Rainbow trout	0	0
Razorback sucker	0	0
Red shiner	3134	25.10
Roundtail chub	57	0.46
Roundtail x Humpback	0	0
Sand shiner	2421	19.39
Shiners (red & sand)	1107	8.87
Smallmouth bass	1	0.01
Speckled dace	142	1.14
Striped bass	2	0.02
Threadfin shad	0	0
Unidentified[b]	0	0
Utah chub	0	0
Walleye	7	0.06
White sucker	2	0.02
TOTALS:	12488	100

[a] T = total, P = Percentage.
[b] Sent to Larval Fish Laboratory

Table E-3. **Summary of total numbers and percentage composition of fish captured by species for each field trip of the 1987 Cataract Canyon Studies.**

SPECIES	1		2		3		4		5		6		7		8	
	T[a]	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P
Black bullhead	1	0.28	1	0.03	0	-	181	2.81	5	0.10	0	-	1	0.06	0	-
Black crappie	0	-	0	0.06	0	-	2	0.03	1	0.02	0	-	0	-	1	0.08
Bluegill	0	-	2	-	0	-	0	-	0	-	0	-	1	0.06	0	-
Bluehead sucker	1	0.28	37	0.95	14	0.28	13	0.20	19	0.39	16	7.27	24	1.46	34	2.83
Bonytail chub	0	-	0	-	0	-	0	-	1	0.02	0	-	0	-	0	-
Brassy Minnow	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Brown trout	0	-	1	0.03	1	0.02	0	-	0	-	0	-	0	-	0	-
Carp	94	26.55	1439	37.06	89	1.79	268	4.16	141	2.86	46	20.91	77	4.67	94	7.81
Channel catfish	45	12.71	238	6.13	188	3.78	1512	23.29	487	9.89	60	27.27	112	6.80	175	14.55
Chub (Gila sp.)	2	0.56	9	0.23	185	3.71	149	2.31	19	0.39	4	1.82	12	0.73	5	0.41
Colorado squawfish	21	5.93	85	2.19	56	1.12	56	0.87	673	13.67	0	-	6	0.36	11	0.91
Fathead minnow	11	3.11	52	1.34	20	0.40	203	3.15	696	14.13	0	-	13	0.79	28	2.33
Flannelmouth sucker	28	7.91	119	3.06	57	1.14	58	0.90	93	1.89	65	29.55	68	4.13	54	4.49
Flannelmouth x Bluehead	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Gambusia	0	-	0	-	5	0.10	15	0.23	4	0.08	0	-	1	0.06	1	0.08
Green sunfish	0	-	1	0.03	0	-	0	-	0	-	0	-	2	0.12	1	0.08
Humpback chub	0	-	0	-	5	0.10	2	0.03	2	0.04	2	0.91	6	0.36	1	0.08
Kokanee salmon	0	-	0	-	0	-	0	-	0	-	0	-	0	-	1	0.08
Largemouth bass	0	-	10	0.26	3	0.06	6	0.09	1	0.02	1	0.45	0	-	1	0.08
Northern Pike	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Plains killifish	0	-	7	0.18	3	0.06	0	-	1	0.02	0	-	0	-	0	-
Rainbow trout	0	-	1	0.03	0	-	0	-	0	-	0	-	0	-	0	-
Razorback sucker	0	-	0	-	0	-	0	-	0	-	1	0.45	0	-	0	-
Red shiner	0	-	1694	43.63	2606	52.33	3158	49.06	2297	46.65	11	5.00	1192	72.33	555	46.13
Roundtail chub	0	-	3	0.08	0	-	1	0.02	1	0.02	3	1.36	1	0.06	0	-
Roundtail x Humpback	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Sand shiner	151	42.66	70	1.80	186	3.73	218	3.39	454	9.22	11	5.00	127	7.71	216	17.96
Shiners (red & sand)	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Smallmouth bass	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Speckled dace	0	-	3	0.08	279	5.96	210	3.36	17	0.35	0	-	5	0.30	20	1.66
Striped bass	0	-	100	2.58	0	-	9	0.14	2	0.04	0	-	0	-	4	0.33
Threadfin shad	0	-	1	0.03	0	-	1	0.02	6	0.12	0	-	0	-	2	0.17
Unidentified[b]	0	-	0	-	1263	25.36	373	5.79	1	0.02	0	-	0	-	0	-
Utah chub	0	-	0	-	1	0.02	0	-	0	-	0	-	0	-	0	-
Walleye	0	-	10	0.26	0	-	1	0.02	3	0.06	0	-	0	-	1	0.08
White sucker	0	-	0	-	0	-	1	0.02	0	-	0	-	0	-	0	-
TOTALS:	354	100	3883	100	4961	100	6437	100	4924	100	220	100	1648	100	1205	100

[a] T = total, P = Percentage.
[b] Sent to Larval Fish Laboratory

Table E-4. **Summary of total numbers and percentage composition of fish captured by species for the field trips of the 1988 Cataract Canyon Studies.**

SPECIES	1		2		3		4		5		6		7		8		9	
	T[a]	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P
Black bullhead	1	0.03	1	0.17	3	0.05	1	0.04	12	0.13	5	0.03	9	0.02	0	-	1	0.03
Black crappie	0	-	0	-	0	-	0	-	3	0.03	0	-	1	<0/01	0	-	1	0.03
Bluegill	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Bluehead sucker	0	-	2	0.33	44	0.76	21	0.78	3	0.03	1	0.01	4	<0.01	16	4.51	27	0.72
Bonytail chub	0	-	0	-	0	-	9	0.30	2	0.02	1	0.01	0	-	0	-	1[b]	0.03
Brassy Minnow	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Brown trout	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Carp	2	0.06	210	35.00	1628	28.20	119	4.45	564	6.33	294	2.04	27	0.07	24	6.76	28	0.74
Channel catfish	1	0.03	235	39.17	165	2.86	320	11.95	426	4.78	1425	9.89	671	1.74	79	22.25	113	3.00
Chub (<u>Gila</u> sp.)	1	0.03	1	0.17	11	0.19	6	0.22	13	0.15	4	0.03	11	0.03	0	-	14	0.37
Colorado squawfish	164	5.00	3	0.50	504	8.73	13	0.49	98	1.07	223	1.55	211	0.05	14	3.94	34	0.90
Fathead minnow	256	7.75	10	1.67	336	5.82	523	19.54	507	5.69	222	1.55	1428	3.70	2	0.56	522	13.85
Flannelmouth sucker	6	0.18	16	2.67	84	1.46	42	1.57	10	0.11	20	0.14	16	0.04	36	10.14	23	0.61
Flannel x Bluehead	0	-	0	-	1	0.02	0	-	0	-	0	-	0	-	0	-	2	0.05
Gambusia	0	-	0	-	1	0.02	0	-	0	-	0	-	0	-	0	-	0	-
Green sunfish	2	0.06	1	0.17	3	0.05	2	0.07	1	0.01	0	-	1	<0.01	0	-	1	0.03
Humpback chub	0	-	1	0.17	8	0.14	5	0.19	31	0.35	1	0.01	2	<0.01	0	-	6	0.16
Kokanee salmon	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Largemouth bass	0	-	0	-	0	-	2	0.07	6	0.07	0	-	2	<0.01	3	-	0	-
Northern Pike	0	-	1	0.17	0	-	2	0.07	0	-	0	-	0	-	0	-	0	-
Plains killifish	1	0.03	0	-	9	0.16	2	0.07	1	0.01	0	-	0	-	0	-	2	0.05
Rainbow trout	0	-	1	0.17	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Razorback sucker	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Red shiner	1123	34.00	93	15.50	2615	45.30	1188	44.38	6564	73.65	10842	75.22	17417	45.12	55	15.49	1588	42.12
Roundtail chub	0	-	0	-	4	0.07	0	-	0	-	1	0.01	1	<0.01	3	0.85	6	0.16
Roundtail x Humpback	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Sand shiner	1744	52.80	0	-	334	5.79	411	15.35	238	2.67	365	2.53	18756	48.59	70	19.72	1344	35.65
Shiners (red & sand)	0	-	0	-	0	-	0	-	65	0.73	953	6.61	0	-	50	14.08	0	-
Smallmouth bass	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Speckled dace	0	-	8	1.33	10	0.17	8	0.30	5	0.06	2	0.01	36	0.09	3	0.85	13	0.34
Striped bass	0	-	5	0.83	11	0.19	1	0.04	7	0.08	3	0.01	1	<0.01	0[c]	-	10	0.27
Threadfin shad	0	-	0	-	0	-	0	-	17	0.19	7	0.05	2	<0.01	0	-	30	0.80
Unidentified	0	-	0	-	72	-	(25 vials)		337	3.78	44	0.31	2	<0.01	0	-	0	-
Utah chub	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Walleye	0	-	12	2.00	1	0.02	1	0.04	3	0.03	0	-	0	-	0	-	4	0.11
White sucker	0	-	0	-	1	0.02	0	-	0	-	0	-	0	-	0	-	0	-
TOTALS:	**3301**	**100**	**600**	**100**	**5773**	**100**	**2677**	**100**	**8913**	**100**	**14413**	**100**	**38598**	**100**	**355**	**100**	**3770**	**100**

[a] T = total, P = Percentage.
[b] transported to USFWS/Grand Junction, under Bonytail Protocol, 10-12-88.
[c] one 400-500 mm fish seen but not captured at RM 2.9, Colorado River.

Table E-5. A summary of fish species captured by year in Region 1: Green River above the confluence RM 50.0 - 0.0.

Name	1985						1986						1987						1988					
Code	L[a]	Y	J	A	N	P	L	Y	J	A	N	P	L	Y	J	A	N	P	L	Y	J	A	N	P
BB	0	0	0	0	0	0	1	0	0	1	2	0.11	0	1	0	0	1	0.02	0	0	1	1	2	0.04
BC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BH	0	14	1	0	15	0.64	10	3	0	0	13	0.73	4	4	5	0	13	0.25	0	0	6	22	28	0.59
BM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.02	0	0	0	0	0	0
BT	0	1	0	0	1	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CC	0	130	0	0	130	5.50	35	128	8	3	174	9.80	37	188	48	3	276	5.33	0	60	35	12	107	2.26
CH	0	1	0	0	1	0.04	0	0	0	0	0	0	0	0	4	0	4	0.08	0	4	0	0	4	0.08
CP	0	0	3	0	3	0.13	1	5	6	6	18	1.01	0	6	11	19	36	0.70	0	17	4	38	59	1.24
CS	0	344	0	0	344	14.56	47	483	1	0	531	29.90	63	682	35	0	780	15.06	0	796	12	1	809	17.07
FB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FH	0	16	15	32	63	2.67	0	210	19	16	236	13.29	2	204	174	75	455	8.79	0	0	0	156	156	3.29
FM	0	21	1	0	22	0.93	0	4	1	3	8	0.45	0	10	2	6	18	0.35	0	21	8	35	64	1.35
GA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.02	0	0	0	0	0	0
GS	0	0	0	0	0	0	0	1	1	0	2	0.11	0	0	0	0	0	0	0	0	1	2	3	0.06
HB	0	2	0	0	2	0.08	0	0	0	0	0	0	0	2	0	0	2	0.04	0	0	0	0	0	0
KS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	0.08	0	0	0	1	1	0.02
RB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RS	0	515	1079	171	1765	74.72	30	389	32	37	488	27.48	390	1110	513	1463	3476	67.12	0	526	52	2734	3312	69.89
RT	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0.02	0	0	0	2	2	0.04
RZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SD	0	4	2	5	11	0.47	14	0	4	2	20	1.13	1	2	11	1	15	0.29	0	0	1	3	4	0.08
SH	0	0	0	0	0	0	0	4	0	0	4	0.23	0	0	0	0	0	0	0	50	15	50	115	2.43
SM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SS	0	3	0	2	5	0.21	1	81	19	179	280	15.77	0	0	10	35	45	0.87	0	50	1	22	73	1.54
SU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UN[b]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	1051	1101	210	2362	100	139	1299	91	247	1776	100	497	2261	814	1607	5128	100	0	1524	136	3079	4739	100

[a] L = larva, Y = young-of-the-year, J = juvenile, A = adult, N = number, P = percentage of total.

[b] vials containing specimens were damaged in shipment to Larval Fish Lab.

Table E-6. A summary of fish species captured by year in Region 2: Colorado River above the confluence RM 47.0 - 0.0.

Name	1985						1986						1987						1988					
Code	L[a]	Y	J	A	N	P	L	Y	J	A	N	P	L	Y	J	A	N	P	L	Y	J	A	N	P
BB	0	0	0	0	0	0	0	0	0	1	1	0.07	1	0	0	1	2	0.18	0	0	0	0	0	0
BC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BH	0	0	0	0	0	0	1	0	0	0	1	0.07	0	0	10	10	20	1.79	0	1	4	2	7	0.26
BM	0	0	0	4	4	25.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.09	0	0	0	0	0	0
BT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CC	0	0	1	0	1	5.00	7	6	19	12	44	3.23	0	17	36	80	133	11.92	0	7	12	32	51	1.92
CH	0	0	0	0	0	0	2	0	0	0	2	0.15	0	5	3	1	9	0.81	0	1	1	0	2	0.08
CP	0	0	1	13	14	70.00	0	5	1	6	12	0.88	0	0	0	169	169	15.14	0	0	7	35	42	1.58
CS	0	0	0	0	0	0	0	17	17	0	34	2.49	1	26	3	1	31	2.78	0	7	12	0	19	0.71
FB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FH	0	0	0	0	0	0	1	0	7	43	51	3.74	4	1	3	18	26	2.33	0	3	1	205	209	7.85
FM	0	0	0	0	0	0	0	0	3	10	13	0.95	0	14	7	108	129	11.56	0	0	2	25	27	1.01
GA	0	0	0	0	0	0	0	2	3	18	23	1.69	0	0	6	2	8	0.72	0	0	0	0	0	0
GS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0.09	0	0	0	1	1	0.04
HB	0	0	0	0	0	0	2	0	0	1	3	0.22	0	0	2	1	3	0.27	0	0	0	0	0	0
KS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LG	0	0	0	0	0	0	0	0	2	0	2	0.15	0	2	1	0	3	0.27	0	1	3	0	4	0.15
NP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	0.08
RB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RS	0	0	0	0	0	0	95	0	147	370	612	44.87	31	57	21	178	287	25.72	0	4	1	746	751	28.20
RT	0	0	0	0	0	0	11	0	0	0	11	0.81	3	1	2	2	8	0.72	0	1	0	1	2	0.08
RZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.09	0	0	0	0	0	0
SB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	25	26	2.33	0	0	0	1	1	0.04
SH	0	0	0	0	0	0	0	0	0	2	2	0.15	0	0	0	0	0	0	0	0	0	0	0	0
SM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SS	0	0	0	0	0	0	1	0	221	331	553	40.54	0	1	20	147	168	15.05	0	4	3	1538	1545	58.02
SU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UN[b]	0	0	0	0	0	0	0	0	0	0	0	0	90	0	0	0	90	8.06	0	0	0	0	0	0
WE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.09	0	0	0	0	0	0
WS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	2	17	19	100	120	30	420	794	1364	100	130	125	115	746	1116	100	0	30	46	2587	2663	100

[a] L = larva, Y = young-of-the-year, J = juvenile, A = adult, N = number, P = percentage of total.
[b] vials containing specimens were damaged in shipment to Larval Fish Lab.

Table E-7. A summary of fish species captured by year in Region 3: Colorado River from the confluence to Rapid 1 RM 212.5 - 216.5.

Name	1985						1986						1987						1988					
Code	L[a]	Y	J	A	N	P	L	Y	J	A	N	P	L	Y	J	A	N	P	L	Y	J	A	N	P
BB	0	0	0	2	2	0.15	0	7	0	1	8	0.34	1	1	0	0	2	0.05	0	5	0	1	6	0.05
BC	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0.03	0	1	0	0	1	0.01
BG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BH	0	6	2	0	8	0.60	7	1	0	2	10	0.43	14	5	5	10	34	0.86	0	5	6	11	22	0.19
BM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CC	0	66	11	37	114	8.50	0	496	13	9	518	22.18	2	93	54	35	184	4.65	0	145	33	7	185	1.58
CH	0	0	0	1	1	0.07	2	1	0	0	3	0.13	0	14	0	0	14	0.35	5	5	0	0	10	0.09
CP	0	5	18	162	185	13.80	3	23	3	11	40	1.71	8	6	8	129	151	3.81	0	94	7	144	245	2.09
CS	0	25	2	0	27	2.01	24	54	9	2	89	3.81	17	72	22	1	112	2.83	2	204	3	0	209	1.79
FB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.01
FH	0	8	2	27	37	2.76	3	55	64	67	189	8.09	2	268	65	14	349	8.81	147	308	389	115	959	8.20
FM	0	3	19	50	72	5.37	1	5	1	10	17	0.73	0	4	1	36	41	1.04	0	7	0	24	31	0.27
GA	0	1	0	2	3	0.22	1	2	0	0	3	0.13	0	2	4	1	7	0.18	0	0	1	0	1	0.01
GS	0	0	0	0	0	0	0	8	1	0	9	0.39	0	1	0	1	2	0.05	0	1	1	0	2	0.02
HB	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2	0.05	1	0	1	0	2	0.02
KS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LG	0	8	1	0	9	0.67	0	14	0	0	14	0.60	0	5	0	0	5	0.13	0	0	0	0	0	0
NP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PK	0	0	0	0	0	0	0	0	0	2	2	0.09	0	0	4	1	5	0.13	0	0	0	2	2	0.02
RB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.03	0	0	0	0	0	0
RH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RS	0	455	246	67	768	57.27	339	82	52	221	694	29.72	224	1602	680	289	2795	70.58	0	2301	4357	259	6917	59.14
RT	0	6	0	0	6	0.45	1	2	0	0	3	0.13	3	4	4	0	11	0.28	2	6	4	0	12	0.10
RZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SD	0	31	2	0	33	2.46	1	0	1	1	3	0.13	7	7	15	1	30	0.76	0	0	3	0	3	0.03
SH	0	0	0	0	0	0	0	100	0	0	100	4.28	0	29	0	0	29	0.73	0	300	120	0	420	3.59
SM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SS	0	43	11	21	75	5.59	3	92	142	396	633	27.12	1	137	38	6	182	4.60	0	1089	1261	314	2664	22.78
SU	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0.03	0	2	0	0	2	0.02
TS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.03	0	0	0	0	0	0
UM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UN[b]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.03	0	0	1	0	1	0.01
TOTAL	0	657	314	369	1340	100	385	944	284	722	2335	100	280	2252	903	525	3960	100	157	4473	6187	878	11695	100

[a]L = larva, Y = young-of-the-year, J = juvenile, A = adult, N = number, P = percentage of total.
[b]vials containing specimens were damaged in shipment to Larval Fish Lab.

Table E-8. A summary of fish species captured by year in Region 4: Cataract Canyon, RM 212.4 - 201.5.

Name Code	1985 L[a]	Y	J	A	N	P	1986 L	Y	J	A	N	P	1987 L	Y	J	A	N	P	1988 L	Y	J	A	N	P
BB	0	1	0	4	5	0.11	0	1	0	1	2	0.05	0	180	0	6	186	1.90	0	14	3	5	22	0.04
BC	0	0	0	0	0	0	0	0	1	0	1	0.02	0	0	1	0	1	0.01	0	0	0	0	0	0
BG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BH	0	3	2	3	8	0.18	20	1	2	14	37	0.84	33	25	24	74	156	1.60	0	18	20	45	83	0.16
BM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BT	0	0	0	1	1	0.02	0	0	0	0	0	0	0	0	1	1	2	0.02	0	0	6	4	10	0.03
CC	0	914	39	45	998	22.29	3	861	116	85	1065	24.16	9	1286	449	198	1942	19.87	0	2266	222	168	2656	5.13
CH	0	7	0	2	9	0.20	8	58	3	2	71	1.61	0	287	24	0	311	3.18	3	21	25	3	52	0.10
CP	0	24	40	921	985	22.00	0	73	59	95	227	5.15	0	5	38	1169	1212	12.40	0	18	22	775	815	1.57
CS	0	132	2	3	137	3.06	20	68	4	1	93	2.11	20	48	8	0	76	0.78	14	901	24	1	940	1.81
FB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	<0.01
FH	0	182	76	72	330	7.37	7	283	105	28	423	9.60	49	181	75	20	325	3.32	0	579	1206	277	2062	3.98
FM	0	9	11	101	121	2.70	0	2	1	151	154	3.49	1	58	10	331	400	4.09	0	1	8	129	138	0.27
GA	0	13	1	10	24	0.54	0	0	5	0	5	0.11	0	3	8	2	13	0.13	0	0	0	0	0	0
GS	0	0	0	0	0	0	0	1	1	0	2	0.05	0	0	0	1	1	0.01	0	1	2	0	3	0.01
HB	0	5	1	2	8	0.18	5	4	2	2	13	0.29	0	1	8	5	14	0.14	1	3	41	12	57	0.11
KS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LG	0	2	1	1	4	0.09	0	1	0	0	1	0.02	0	6	2	0	8	0.08	0	0	3	0	3	0.01
NP	0	0	0	0	0	0	0	0	0	1	1	0.02	0	0	0	0	0	0	0	0	0	2	2	<0.01
PK	0	0	1	1	2	0.04	0	0	0	2	2	0.05	0	1	0	0	1	0.01	0	2	0	8	10	0.02
RB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	<0.01
RH	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0.01	0	0	0	0	0	0
RS	0	685	436	282	1403	31.33	41	141	137	140	459	10.41	290	2106	1189	442	4027	41.20	0	4074	12755	7439	24268	46.83
RT	0	54	0	0	54	1.21	23	14	0	0	37	0.84	57	27	5	1	90	0.92	35	18	1	5	59	0.11
RZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SB	0	0	18	3	21	0.47	0	0	0	0	0	0	0	0	7	11	18	0.18	0	0	1	0	1	<0.01
SD	0	20	8	2	30	0.67	23	6	71	18	118	2.68	21	331	134	48	534	5.46	0	17	10	43	70	0.14
SH	0	0	0	0	0	0	0	723	175	51	949	21.53	2	0	0	0	2	0.02	0	1425	3330	0	4755	9.18
SM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SS	0	225	47	54	326	7.28	12	50	161	524	747	16.95	35	148	173	72	428	4.38	0	3331	7011	5455	15797	30.48
SU	0	0	0	0	0	0	0	0	0	0	0	0	3	23	1	0	27	0.28	0	0	0	0	0	0
TS	0	0	0	2	2	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UM	0	5	0	0	5	0.11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UN[b]	0	1	0	0	1	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	11	0.02
WE	0	0	0	3	3	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WS	0	0	0	0	0	0	0	0	1	0	1	0.02	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	2282	683	1512	4477	100	162	2287	844	1115	4408	100	520	4717	2157	2381	9775	100	53	12700	24691	14373	51817	100

[a]L = larva, Y = young-of-the-year, J = juvenile, A = adult, N = number, P = percentage of total.
[b]vials containing specimens were damaged in shipment to Larval Fish Lab.

Table E-9. A summary of fish species captured by year in Region 5: Lake Powell Inflow, RM 201.4 - 195.0.

Name	1985						1986						1987						1988					
Code	L[a]	Y	J	A	N	P	L	Y	J	A	N	P	L	Y	J	A	N	P	L	Y	J	A	N	P
BB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	3	0.02
BC	0	0	0	1	1	0.01	0	0	1	0	1	0.04	0	1	0	4	5	0.12	0	0	3	1	4	0.02
BG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.02	0	0	0	0	0	0
BH	0	3	0	0	3	0.02	0	0	0	0	0	0	5	0	0	0	5	0.12	0	2	0	0	2	0.01
BM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR	0	0	0	0	0	0	0	0	0	1	1	0.04	0	0	0	0	0	0	0	0	0	0	0	0
BT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CC	0	2070	548	520	3138	24.12	0	79	228	17	324	11.95	0	83	168	65	316	7.30	0	234	126	62	422	2.64
CH	0	0	0	0	0	0	0	0	0	0	0	0	0	41	0	0	41	0.95	0	1	0	0	1	0.01
CP	0	1	12	1661	1674	12.87	0	1	0	973	974	35.91	0	3	2	717	722	16.68	120	1	6	748	875	5.47
CS	0	12	0	1	13	0.10	0	1	0	1	2	0.07	10	6	1	0	17	0.39	11	71	3	0	85	0.53
FB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FH	0	12	63	22	97	0.75	0	250	0	0	250	9.22	42	20	2	12	76	1.76	0	229	269	97	595	3.72
FM	0	2	1	15	18	0.14	0	0	0	1	1	0.04	0	0	0	8	8	0.18	0	0	0	3	3	0.02
GA	0	0	1	0	1	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	6	0.04
HB	0	0	0	0	0	0	1	0	0	0	1	0.04	0	0	0	0	0	0	0	1	0	0	1	0.01
KS	0	0	0	1	1	0.01	0	0	0	0	0	0	0	0	0	1	1	0.02	0	0	0	0	0	0
LG	0	1	2	0	3	0.02	0	1	0	0	1	0.04	0	7	0	0	7	0.16	0	1	5	0	6	0.04
NP	0	0	0	1	1	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.01
PK	0	0	1	1	2	0.02	0	0	0	0	0	0	0	0	1	1	2	0.05	0	0	0	2	2	0.01
RB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RS	0	366	2472	4432	7270	55.88	10	51	298	520	879	32.41	34	441	73	1705	2253	52.04	0	1364	4424	3226	9014	56.32
RT	0	0	0	0	0	0	0	2	0	0	2	0.07	11	7	0	0	18	0.42	4	0	0	0	4	0.02
RZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SB	0	0	28	32	60	0.46	0	0	0	2	2	0.07	0	6	20	75	101	2.33	0	0	24	15	39	0.24
SD	0	0	0	0	0	0	0	0	1	0	1	0.04	9	25	1	2	37	0.85	1	3	0	1	5	0.03
SH	0	0	0	0	0	0	0	52	0	0	52	1.92	0	0	0	0	0	0	0	75	0	0	75	0.47
SM	0	0	0	0	0	0	0	0	0	1	1	0.04	0	0	0	0	0	0	0	0	0	0	0	0
SS	0	25	30	542	597	4.59	0	0	152	61	213	7.85	7	186	185	317	695	16.05	0	2000	2265	520	4785	29.90
SU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TS	0	0	12	94	106	0.81	0	0	0	0	0	0	0	0	0	10	10	0.23	0	0	0	56	56	0.35
UC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UN[b]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WE	0	0	0	24	24	0.18	0	0	0	7	7	0.26	0	0	0	14	14	0.32	0	0	0	21	21	0.13
WS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	2492	3170	7347	13009	100	11	437	680	1584	2712	100	118	826	453	2932	4329	100	136	3991	7125	4753	16005	100

[a]L = larva, Y = young-of-the-year, J = juvenile, A = adult, N = number, P = percentage of total.

[b]vials containing specimens were damaged in shipment to Larval Fish Lab.

APPENDIX F

CATCH PER EFFORT STATISTICS

Table F-1. CPE (no./100m^2) with seines in all habitats by region, 1985.

SPECIES	REGION 1	2[a]	3	4	5
RS	102.89		80.00	15.86	161.71
SS	0.85		7.81	2.76	12.42
FH	1.87		3.33	3.77	12.55
CC	14.63		6.77	10.37	7.89
CP	0		0.10	0.18	0.77
CS	14.12		2.71	1.50	1.55
SD	1.19		3.44	0.33	0
HB	0.17		0	0.05	0
RT	0		0.63	0.66	0
CH	0		0	0.05	0
BH	0.34		0.63	0.06	0.39
FM	2.38		2.29	0.26	0.26

[a] Region 2 was not sampled

Table F-2. CPE (no./100m^2) with seines in all habitats by region, 1986.

SPECIES	REGION 1	2[a]	3	4	5
RS	57.21		85.69	23.43	204.31
SS	32.71		81.67	37.35	81.96
FH	27.67		29.58	22.21	9.80
CC	15.36		68.01	32.73	3.53
CP	1.17		1.45	2.76	0
CS	61.90		13.18	4.78	0.39
SD	2.23		0.32	5.42	0.39
HB	0		0	0.48	0.39
RT	0		0.32	1.97	0.78
CH	0		0.32	2.50	0
BH	0.82		0.64	0.85	0
FM	0.59		0.80	0.11	0

[a] Region 2 was not sampled

Table F-3. CPE (no./100m²) with seines in all habitats by region, 1987.

SPECIES	REGION 1	2	3	4	5
RS	319.34	121.46	219.57	135.57	167.38
SS	4.14	284.58	14.38	11.09	88.55
FH	41.90	53.14	27.80	10.74	10.12
CC	20.35	10.12	9.11	37.97	20.91
CP	1.56	0.18	1.60	0.21	0.40
CS	71.64	1.86	8.63	2.47	2.26
SD	1.29	18.40	1.36	17.80	4.73
HB	0.18	0	0.08	0	0
RT	0.09	0.69	0.72	2.83	2.40
CH	0.37	0.98	0.96	8.76	5.46
BH	1.20	0.84	1.44	2.16	0.67
FM	1.10	1.64	0.32	2.23	0

Table F-4. CPE (no./100m²) with seines in all habitats by region, 1988.

SPECIES	REGION 1	2	3	4	5
RS	83.32	212.62	490.49	521.83	616.17
SS	1.87	438.12	189.07	371.93	795.00
FH	3.96	108.64	68.06	70.44	99.17
CC	1.15	12.16	11.92	41.95	25.67
CP	0.54	0.62	7.17	0.45	1.00
CS	20.44	4.31	14.83	31.61	14.00
SD	0.64	0.78	0.21	1.04	0.83
HB	0	0	0.07	0.14	0.17
RT	0	0.91	0.78	1.84	0.67
CH	0.10	0.68	0.71	0.52	0.17
BH	0	0.31	0.35	0.59	0.33
FM	0.64	0.49	0.50	0.03	0

Table F-5. CPE (no./10 hour) with electrofishing in all habitats by region, 1985.

SPECIES	REGION (hours of effort)				
	1[a]	2 (0.8)	3 (16.0)	4 (18.1)	5 (8.5)
CP		100.0	90.0	466.9	1781.2
CC		12.5	25.6	47.5	3607.1
FM		0	23.8	34.8	15.3
BH		0	1.3	1.7	0
CS		0	0.6	3.3	0
HB		0	0	2.8	0
RT		0	0	0	0
CH		0	0.6	1.1	0
BT		0	0	0	0
RZ		0	0	0	0

[a] Region 1 was not sampled

Table F-6. CPE (no./10 hour) with electrofishing in all habitats by region, 1986.

SPECIES	REGION (hours of effort)				
	1[a]	2 (3.47)	3 (2.91)	4 (20.16)	5 (3.13)
CP		14.4	106.7	67.5	2846.7
CC		74.9	327.0	210.3	1000.0
FM		14.4	41.3	49.1	3.2
BH		0	6.9	7.4	0
CS		2.9	24.1	0.5	0
HB		0	0	2.0	0
RT		0	0	0	0
CH		0	0	10.9	0
BT		0	0	0	0
RZ		0	0	0	0

[a] Region 1 was not sampled

Table F-7. CPE (no/10 hour) with electrofishing in all habitats by region, 1987.

SPECIES	REGION (hours of effort) 1	2 (16.18)	3 (4.93)	4 (26.39)	5 (3.84)
CP	8.10	100.7	199.0	399.1	1618.1
CC	123.1	69.2	113.7	302.4	539.0
FM	91.3	61.2	62.9	86.0	7.8
BH	31.4	12.4	26.4	30.3	0
CS	1.2	2.5	8.1	2.0	0
HB	0	1.2	2.0	4.2	0
RT	2.1	1.2	2.0	2.0	0
CH	6.2	3.7	4.1	22.7	0
BT	0	0	0	0.4	0
RZ	0	0.6	0	0	0

Table F-8. CPE (no./10 hour) with electrofishing in all habitats by region, 1988.

SPECIES	REGION (hours of effort) 1	2 (3.36)	3 (2.46)	4 (31.32)	5 (2.85)
CP	321.2	107.2	561.0	155.2	2898.7
CC	104.6	119.2	65.0	412.2	872.8
FM	31.8	59.6	81.3	24.0	7.0
BH	19.2	17.9	69.1	19.8	0
CS	3.2	6.0	0	6.4	0
HB	0	0	4.1	3.0	0
RT	3.6	3.0	4.1	0	0
CH	4.1	3.0	0	7.3	0
BT	0	0	0	0.3	0
RZ	0	0	0	0	0

Table F-9. CPE (no./100 feet/100 hours) with gill nets in all habitats by region, 1985.

SPECIES	REGION 1[a]	2	3	4	5
CP		263.2	109.7	19.5	12.7
CC		0	4.2	1.0	0.4
FM		0	21.1	1.9	0.1
BH		0	0	0	0
CS		0	0	0	0
HB		0	0	0	0
RT		0	0	0	0
CH		0	0	0	0
BT		0	0	0	0

[a] Region 1 was not sampled

Table F-10. CPE (no./100 feet/100 hours) with gill nets in all habitats by region, 1986.

SPECIES	REGION 1[a]	2	3	4	5
CP		0.8	-	0.5	41.5
CC		0.8	-	0	0.9
FM		0	-	0.5	0
BH		0	-	0	0
CS		0	-	0	0
HB		0	-	0	0
RT		0	-	0	0
CH		0	-	0	0
BT		0	-	0	0

[a] Region 1 was not sampled

Table F-11. CPE (no./100 feet/100 hours) with gill nets in all habitats by region, 1987.

SPECIES	REGION 1[a]	2	3	4	5
CP		0.1	7.2	0.3	22.9
CC		0.2	1.3	0.1	5.4
FM		1.0	0.9	0.3	1.3
BH		0	0.5	0.1	0
CS		0	0	0	0
HB		0.1	0	<0.1	0
RT		0.1	0	<0.1	0
CH		0.1	0	<0.1	0
BT		0	0	<0.1	0

[a] Catch rate too small to compute

Table F-12. CPE (no./100 feet/100 hours) with gill nets in all habitats by region, 1988.

SPECIES	REGION 1	2	3	4	5
CP	31.2	0	77.7	0.4	4.1
CC	3.1	1.7	0	0.3	1.9
FM	2.1	1.7	58.3	0.1	0
BH	0	0	0	<0.1	0
CS	0	0	0	0.1	0.1
HB	0	0	0	0.1	0
RT	0	0	0	<0.1	0
CH	0	0	0	<0.1	0
BT	0	0	0	<0.1	0

Table F-13. CPE (no./100 feet/100 hours) with trammel nets in all habitats by region, 1985.

	REGION				
SPECIES	1[a]	2	3	4	5
CP		-	73.5	27.5	68.4
CC		-	36.8	4.8	5.5
FM		-	36.8	13.1	3.3
BH		-	0	0	0
CS		-	0	0.4	0
HB		-	0	0	0
RT		-	0	0	0
CH		-	0	0	0
BT		-	0	0.4	0

[a] Region 1 was not sampled

Table F-14. CPE (no./100 feet/100 hours) with trammel nets in all habitats by region, 1986.

	REGION				
SPECIES	1[a]	2	3	4	5
CP		0	-	1.6	428.2
CC		14.0	-	0.8	23.1
FM		17.5	-	2.6	0
BH		0	-	0.1	0
CS		0	-	0.1	0
HB		0	-	0	0
RT		0	-	0	0
CH		0	-	0	0
BT		3.5	-	0	0

[a] Region 1 was not sampled

Table F-15. CPE (no./100 feet/100 hours) with trammel nets in all habitats by region, 1987.

SPECIES	REGION				
	1[a]	2	3	4	5
CP		4.0	40.3	7.8	2051.3
CC		0	11.9	1.3	0
FM		4.0	9.5	2.1	0
BH		0	0	0	0
CS		0	0	0	0
HB		0	0	0	0
RT		0	0	0	0
CH		0	0	0	0
BT		0	0	0	0

[a] Catch rate too small to compute

Table F-16. CPE (no./100 feet/100 hours) with trammel nets in all habitats by region, 1988.

SPECIES	REGION				
	1	2	3	4	5
CP	62.0	68.0	106.4	6.5	189.4
CC	43.1	0	53.2	1.1	78.9
FM	28.6	34.0	53.2	0.7	15.8
BH	0	0	0	<0.1	0
CS	0	0	0	<0.1	0
HB	0	0	0	0	0
RT	0	0	0	<0.1	0
CH	0	0	0	<0.1	0
BT	0	0	0	0	0

Table F-17. CPE (no./100 feet/100 hours) with experimental gill nets in all habitats by region, 1987.

SPECIES	REGION 1[a]	2	3	4	5
CP		8.1	6.4	13.2	334.5
CC		13.1	14.1	23.1	268.2
FM		0.2	1.2	6.2	0
BH		0	0.9	0.6	0
CS		0	0.2	5.3	0.3
HB		0	0.2	13.6	0
RT		0.4	0.3	6.1	0
CH		0	0.8	12.8	0
BT		0	0	0.9	0

[a] Catch rate too small to compute

Table F-18. CPE (no./100 feet/100 hours) with experimental gill nets in all habitats by region, 1988.

SPECIES	REGION 1	2	3	4	5
CP	144.2	124.3	151.4	126.3	1223.6
CC	126.4	116.5	110.1	120.4	331.4
FM	34.2	42.1	58.4	13.6	0
BH	0	0.6	0	1.2	0
CS	0	0	0	4.2	0
HB	0	0	0	18.4	0
RT	0.2	0.8	0	3.1	0
CH	0	0	0.2	4.1	0.1
BT	0	0	0	0.8	0

APPENDIX G

DATA ASSOCIATED WITH ALL ENDANGERED FISH CAPTURED

Table G-1. Summary of Adult Colorado Squawfish Handled During the Cataract Canyon Fish Study, 1985-88.

SAMPLE NO.	RIVER	RIVER MILE	DATE	GEAR	HABITAT		TOTAL LENGTH	WEIGHT	TAG	TAG SIZE
8-E03	GR	10.6	880928	EL	MC	SH	445	625	RD-5320	L
1-E11	CO	6.2	870415	EL	MC	SH	572	1104	D-2942	L
3-E04	CO	216.3	870710	EL	MC	SH	662	2043	RD-0503	L
1-E06	CO	216.2	860712	EL	MC	SH	500	794	GR-0335	L
1-E06	CO	216.2	860712	EL	MC	SH	528	936	RD-2945	L
1-G37	CO	201.3	860715	GI	MC	ED	427	511	RD-2957	L
1-T05	CO	207.0	860714	TI	MC	ED	439	568	RD-2988	L
3-N09	CO	207.4	860814	TI	MC	ED	516	908	GR-0477	L
NET051	CO	201.2	850713	GI	MC	SH	604	1210	RD-2982	L
ELE033	CO	206.0	850809	EL	SC	SH	635	9999	RD-3133	L
ELE039	CO	207.4	850825	EL	MC	SH	525	1900	RD-3131	L
NET121	CO	207.3	850826	TI	MC	ED	425	540	RD-3141	L

Table G-2. Summary of Juvenile Colorado Squawfish Handled During the Cataract Canyon Fish Study, 1985-88.

SAMPLE	RIVER	RMI	DATE	GEAR	HABITAT		LAR	YOY	JUV	ADU	TOTAL
1-S07	GR	45.1	880321	SA	MC	SW	0	22	1	0	23
1-S08	GR	45.1	880321	SA	MC	SW	0	0	1	0	1
1-S13	GR	42.1	880321	SA	MC	BA	0	29	3	0	32
1-S41	GR	9.8	880322	SA	MC	BA	0	0	1	0	1
1-S62	CO	3.5	880324	SA	MC	BA	0	0	1	0	1
1-S81	CO	30.2	880325	SA	MC	BA	0	0	1	0	1
2-E06	CO	207.6	880414	EL	MC	SH	0	0	2	0	2
2-E10	CO	206.9	880414	EL	MC	SH	0	0	1	0	1
3-E03	GR	34.4	880621	EL	MC	SH	0	0	1	0	1
3-S13	GR	40.4	880621	SA	MC	BA	0	8	2	0	10
3-S22	GR	38.7	880621	SA	MC	BA	0	15	1	0	16
3-S40	GR	21.1	880622	SA	MC	BA	0	27	1	0	28
3-S41	GR	11.5	880622	SA	MC	BA	0	4	1	0	5
3-S48	CO	212.7	880623	SA	MC	IP	0	1	2	0	3
3-S66	CO	207.1	880624	SA	SC	SH	0	0	2	0	2
3-N50	CO	207.1	880624	GP	SC	SH	0	0	1	0	1
4-E01	CO	1.5	880712	EL	MC	ED	0	0	1	0	1
4-S03	CO	1.5	880713	SE	MC	BA	0	0	3	0	3
4-S04	CO	1.5	880713	SE	MC	BA	0	0	1	0	1
4-S07	CO	0.5	880713	SE	MC	BA	0	0	4	0	4
4-S10	CO	215.8	880713	SE	MC	BA	2	0	1	0	3
4-S15	CO	208.4	880714	SE	MC	IP	0	1	1	0	2
4-S28	CO	200.5	880717	SE	MC	BA	11	0	2	0	13
5-F01	CO	207.4	880805	FY	MC	ED	0	0	1	0	1
5-E09	CO	206.8	880806	EL	MC	SH	0	0	1	0	1
5-N85	CO	200.6	880807	GP	MC	ED	0	0	1	0	1
6-E04	CO	207.7	880827	EL	MC	SH	0	0	1	0	1
6-S10	CO	207.0	880828	SE	MC	BA	0	33	3	0	36
7-E14	CO	206.7	880919	EL	MC	ED	0	13	1	0	14
7-S20	CO	206.8	880919	SE	MC	BA	0	5	1	0	6
7-S23	CO	205.8	880919	SE	MC	BA	0	27	1	0	28
7-N57	CO	207.0	880918	GP	MC	BA	0	0	2	0	2
7-N65	CO	206.7	880919	GP	MC	BA	0	0	1	0	1
7-N77	CO	206.7	880920	GP	MC	BA	0	0	1	0	1
8-E12	CO	2.9	880929	EL	MC	SH	0	0	1	0	1
9-S11	CO	207.2	881009	SE	MC	EM	0	0	2	0	2
9-N32	CO	207.2	881008	GP	SC	IP	0	0	1	0	1
9-N36	CO	207.3	881008	GP	MC	ED	0	0	1	0	1
1-E06	CO	26.2	870414	EL	MC	SH	0	0	1	0	1
1-E20	CO	15.7	870416	EL	MC	SH	0	0	1	0	1
2-E02	CO	0.5	870623	EL	MC	SH	0	0	1	0	1
2-E23	CO	206.5	870627	EL	MC	ED	0	0	1	0	1
2-S41	CO	205.8	870627	SE	MC	BA	0	0	4	0	4
3-E04	CO	216.3	870710	EL	MC	SH	0	1	1	1	3
3-E12	CO	207.0	870711	EL	MC	BA	0	0	1	0	1

Table G-2. (cont.)

SAMPLE	RIVER	RMI	DATE	GEAR	HABITAT		LAR	YOY	JUV	ADU	TOTAL
3-S04	GR	45.7	870708	SA	MC	BA	10	0	1	0	11
3-S05	GR	40.5	870708	SA	MC	BA	3	0	1	0	4
3-S06	GR	35.5	870708	SA	MC	BA	13	0	1	0	14
3-S07	GR	30.8	870708	SA	MC	BA	0	0	5	0	5
3-S09	GR	25.5	870708	SA	MC	BA	0	0	3	0	3
3-S12	GR	20.5	870709	SA	MC	BA	2	1	6	0	9
3-S13	GR	14.7	870709	SA	MC	BA	0	0	2	0	2
3-S15	GR	10.3	870709	SA	MC	BA	0	0	10	0	10
3-S16	GR	5.0	870709	SA	MC	BA	0	0	6	0	6
3-S19	CO	215.0	870710	SA	MC	BA	0	0	5	0	5
3-S21	CO	212.7	870710	SA	MC	BA	0	0	5	0	5
3-S22	CO	212.7	870710	SA	MC	BA	0	0	6	0	6
3-S44	CO	206.3	870713	SA	SC	BA	0	0	1	0	1
3-S45	CO	200.9	870713	SA	MC	BA	0	0	1	0	1
4-S09	CO	213.6	870729	SA	MC	BA	8	3	3	0	14
8-E08	CO	207.9	871008	EL	MC	RU	0	0	1	0	1
8-S01	CO	215.5	871007	SE	MC	BA	0	0	1	0	1
8-S03	CO	214.0	871007	SE	MC	BA	0	1	1	0	2
1-E05	CO	0.0	860712	EL	##	##	0	0	1	0	1
1-E08	CO	215.0	860712	EL	##	##	0	0	1	0	1
1-E09	CO	214.0	860712	EL	##	##	0	0	1	0	1
1-E11	CO	214.5	860713	EL	##	##	0	0	1	0	1
2-E07	CO	207.8	860725	EL	##	##	0	0	1	0	1
5-E02	CO	212.7	860918	EL	##	##	0	0	2	0	2
3-N09	CO	207.4	860814	TI	MC	ED	0	0	1	0	1
1-S01	GR	0.1	860712	SE	MC	BA	0	0	1	0	1
1-S04	CO	0.0	860712	SE	MC	SH	0	0	1	0	1
1-S05	CO	0.0	860712	SE	MC	SH	0	0	4	0	4
1-S08	CO	1.4	860712	SE	MC	SH	0	0	2	0	2
2-S05	CO	1.4	860724	SE	MC	BA	0	0	3	0	3
2-S07	CO	1.4	860724	SE	MC	RU	0	0	2	0	2
2-S08	CO	1.5	860724	SE	MC	IP	0	0	17	0	17
2-S09	CO	1.6	860724	SE	MC	IP	0	0	4	0	4
3-S15	CO	208.0	860814	SE	MC	BA	0	0	1	0	1
4-S10	CO	212.6	860828	SE	MC	BA	13	13	1	0	27
5-S13	CO	212.8	860917	SE	MC	BA	0	2	3	0	5
5-S15	CO	211.7	860918	SE	SC	IP	0	0	1	0	1
ELE038	CO	215.0	850825	EL	MC	SH	0	0	1	0	1
ELE054	CO	207.1	850923	EL	MC	BA	0	0	1	0	1
ELE057	CO	206.8	850924	EL	SC	SH	0	0	1	0	1
SEI119	CO	212.8	850923	SB	MC	CO	0	5	1	0	6

Table G-3. **Summary of YOY and Larval Colorado Squawfish Handled During the Cataract Canyon Fish Study, 1985-88.**

SAMPLE	RIVER	RMI	DATE	GEAR	HABITAT		LAR	YOY	JUV	ADU	TOTAL
1-S01	GR	51.2	880321	SA	MC	BA	0	8	0	0	8
1-S02	GR	51.2	880321	SA	MC	BA	0	2	0	0	2
1-S07	GR	45.1	880321	SA	MC	SW	0	22	1	0	23
1-S12	GR	42.1	880321	SA	MC	BA	0	46	0	0	46
1-S13	GR	42.1	880321	SA	MC	BA	0	29	3	0	32
1-S15	GR	39.9	880321	SA	MC	BA	0	5	0	0	5
1-S16	GR	38.8	880321	SA	MC	BA	0	4	0	0	4
1-S17	GR	38.8	880321	SA	MC	BA	0	10	0	0	10
1-S29	GR	24.9	880322	SA	MC	BA	0	1	0	0	1
1-S35	GR	18.6	880322	SA	MC	BA	0	3	0	0	3
1-S37	GR	13.5	880322	SA	MC	BA	0	1	0	0	1
1-S38	GR	13.5	880322	SA	MC	BA	0	2	0	0	2
1-S39	GR	10.5	880322	SA	MC	BA	0	1	0	0	1
1-S40	GR	10.5	880322	SA	MC	BA	0	1	0	0	1
1-S43	GR	8.6	880322	SA	MC	BA	0	2	0	0	2
1-S47	GR	3.7	880322	SA	MC	BA	0	11	0	0	11
1-S48	GR	3.7	880322	SA	MC	BA	0	1	0	0	1
1-S51	CO	213.0	880323	SA	MC	BA	0	1	0	0	1
1-S53	CO	213.6	880323	SA	MC	BA	0	1	0	0	1
1-S64	CO	10.1	880324	SA	MC	BA	0	1	0	0	1
1-S66	CO	13.0	880324	SA	MC	BA	0	1	0	0	1
1-S67	CO	16.0	880324	SA	MC	BA	0	1	0	0	1
1-S79	CO	30.1	880325	SA	MC	BA	0	1	0	0	1
1-S80	CO	30.1	880325	SA	MC	BA	0	1	0	0	1
1-S82	CO	30.2	880325	SA	MC	BA	0	1	0	0	1
1-S86	CO	39.9	880325	SA	MC	BA	0	1	0	0	1
3-M01	GR	33.8	880621	MU	MC	BA	0	1	0	0	1
3-E29	CO	206.7	880626	EL	SC	SH	0	1	0	0	1
3-S01	GR	48.4	880621	SA	MC	IP	0	2	0	0	2
3-S02	GR	48.4	880621	SA	MC	IP	0	5	0	0	5
3-S03	GR	48.4	880621	SA	MC	IP	0	2	0	0	2
3-S04	GR	48.4	880621	SA	MC	IP	0	10	0	0	10
3-S05	GR	48.4	880621	SA	MC	IP	0	3	0	0	3
3-S06	GR	48.4	880621	SA	MC	IP	0	3	0	0	3
3-S07	GR	46.0	880621	SA	SC	SH	0	3	0	0	3
3-S08	GR	46.0	880621	SA	SC	CO	0	6	0	0	6
3-S09	GR	46.0	880621	SA	SC	SH	0	2	0	0	2
3-S10	GR	45.4	880621	SA	MC	BA	0	24	0	0	24
3-S11	GR	45.6	880621	SA	MC	IP	0	1	0	0	1
3-S12	GR	44.2	880621	SA	MC	IP	0	5	0	0	5
3-S13	GR	40.4	880621	SA	MC	BA	0	8	2	0	10
3-S14	GR	39.5	880621	SA	MC	IP	0	4	0	0	4
3-S15	GR	39.8	880621	SA	MC	IP	0	6	0	0	6
3-S16	GR	38.7	880621	SA	MC	IP	0	18	0	0	18
3-S17	GR	38.7	880621	SA	MC	IP	0	59	0	0	59

Table G-3. (cont.)

SAMPLE	RIVER	RMI	DATE	GEAR	HABITAT		LAR	YOY	JUV	ADU	TOTAL
3-S18	GR	38.7	880621	SA	MC	IP	0	3	0	0	3
3-S19	GR	38.7	880621	SA	MC	IP	0	2	0	0	2
3-S21	GR	38.7	880621	SA	MC	BA	0	74	0	0	74
3-S22	GR	38.7	880621	SA	MC	BA	0	15	1	0	16
3-S23	GR	35.8	880621	SA	MC	BA	0	32	0	0	32
3-S24	GR	35.8	880621	SA	SC	SH	0	1	0	0	1
3-S25	GR	35.8	880621	SA	MC	IP	0	8	0	0	8
3-S26	GR	34.2	880621	SA	MC	IP	0	2	0	0	2
3-S27	GR	34.2	880621	SA	MC	IP	0	13	0	0	13
3-S28	GR	34.2	880621	SA	MC	IP	0	18	0	0	18
3-S29	GR	34.0	880621	SA	MC	IP	0	1	0	0	1
3-S31	GR	33.6	880621	SA	MC	SC	0	3	0	0	3
3-S34	GR	31.1	880622	SB	SC	SH	0	6	0	0	6
3-S35	GR	33.6	880621	SA	MC	BA	0	3	0	0	3
3-S36	GR	33.0	880622	SA	SC	SH	0	1	0	0	1
3-S37	GR	30.8	880622	SA	MC	BA	0	12	0	0	12
3-S38	GR	29.5	880622	SA	MC	BA	0	1	0	0	1
3-S39	GR	26.4	880622	SA	MC	BA	0	10	0	0	10
3-S40	GR	21.1	880622	SA	MC	BA	0	27	1	0	28
3-S41	GR	11.5	880622	SA	MC	BA	0	4	1	0	5
3-S42	GR	11.5	880622	SA	MC	BA	0	2	0	0	2
3-S43	GR	11.5	880622	SA	MC	BA	0	2	0	0	2
3-S45	CO	214.8	880623	SA	MC	CO	0	1	0	0	1
3-S47	CO	212.7	880623	SA	MC	IP	0	8	0	0	8
3-S48	CO	212.7	880623	SA	MC	IP	0	1	2	0	3
3-S49	CO	212.7	880623	SA	MC	IP	0	1	0	0	1
3-S52	CO	213.5	880623	SE	MC	IP	0	4	0	0	4
3-S53	GR	213.6	880623	SE	MC	BA	0	3	0	0	3
3-S56	CO	212.5	880623	SI	MC	IP	0	44	0	0	44
3-S57	CO	208.5	880623	SA	MC	IP	0	2	0	0	2
3-S59	CO	208.2	880623	SE	SC	RU	0	5	0	0	5
3-S60	CO	208.2	880623	SE	SC	RU	0	1	0	0	1
3-S62	CO	207.4	880624	SE	MC	SH	0	1	0	0	1
3-S64	CO	207.1	880624	SA	SC	IP	0	5	0	0	5
3-S65	CO	207.1	880624	SA	SC	BA	0	2	0	0	2
3-S69	CO	207.3	880624	SA	MC	EM	0	1	0	0	1
3-S71	CO	206.6	880624	SA	SC	BA	0	3	0	0	3
3-S73	CO	205.7	880625	SE	MC	BA	0	1	0	0	1
3-S75	CO	205.7	880625	SE	MC	BA	0	5	0	0	5
3-S81	CO	200.7	880626	SE	MC	BA	0	2	0	0	2
3-S82	CO	200.7	880626	SE	MC	BA	0	1	0	0	1
4-S10	CO	215.8	880713	SE	MC	BA	2	0	1	0	3
4-S15	CO	208.4	880714	SE	MC	IP	0	1	1	0	2
4-S16	CO	207.2	880715	SE	MC	IP	3	0	0	0	3
4-S18	CO	207.1	880716	SE	MC	BA	2	0	0	0	2

Table G-3. (cont.)

SAMPLE	RIVER	RMI	DATE	GEAR	HABITAT		LAR	YOY	JUV	ADU	TOTAL
4-S19	CO	207.1	880716	SE	MC	BA	3	0	0	0	3
4-S20	CO	207.1	880716	SE	MC	BA	1	0	0	0	1
4-S22	CO	207.1	880716	SE	MC	BA	4	0	0	0	4
4-S25	CO	206.4	880717	SE	MC	EM	1	0	0	0	1
4-S28	CO	200.5	880717	SE	MC	BA	11	0	2	0	13
5-S02	GR	47.5	880802	SE	MC	BA	0	12	0	0	12
5-S03	GR	43.6	880802	SE	MC	BA	0	67	0	0	67
5-S05	GR	34.9	880802	SE	MC	BA	0	50	0	0	50
5-S06	GR	29.0	880802	SE	MC	BA	0	26	0	0	26
5-S07	GR	24.1	880802	SE	MC	BA	0	13	0	0	13
5-S09	GR	18.9	880803	SE	MC	BA	0	2	0	0	2
5-S10	GR	18.9	880803	SE	MC	BA	0	37	0	0	37
5-S11	GR	15.0	880803	SE	MC	BA	0	15	0	0	15
5-S12	GR	9.3	880803	SE	MC	BA	0	4	0	0	4
5-S14	GR	4.9	880803	SE	MC	BA	0	1	0	0	1
5-S16	GR	1.2	880803	SE	MC	BA	0	3	0	0	3
5-S18	CO	215.1	880803	SE	MC	BA	0	1	0	0	1
5-S19	CO	214.6	880803	SE	MC	BA	0	17	0	0	17
5-S20	CO	213.4	880803	SE	MC	BA	0	8	0	0	8
5-S22	CO	211.2	880804	SE	SC	IP	0	1	0	0	1
5-S24	CO	207.1	880805	SE	MC	BA	0	1	0	0	1
5-S25	CO	207.1	880805	SE	MC	BA	0	25	0	0	25
5-S27	CO	207.2	880805	SE	MC	IP	0	24	0	0	24
5-S28	CO	207.1	880805	SE	MC	IP	0	5	0	0	5
5-S31	CO	207.3	880805	SE	MC	RU	0	1	0	0	1
5-S32	CO	207.3	880805	SE	MC	RU	0	4	0	0	4
5-S33	CO	207.0	880806	SE	MC	BA	0	5	0	0	5
5-S34	CO	206.8	880806	SE	MC	BA	0	2	0	0	2
5-S35	CO	205.9	880806	SE	MC	BA	0	11	0	0	11
5-S37	CO	206.0	880806	SE	MC	EM	0	1	0	0	1
5-S39	CO	206.0	880807	SE	MC	IP	0	6	0	0	6
5-S41	CO	200.5	880807	SE	MC	BA	0	1	0	0	1
5-S42	CO	200.1	880807	SE	MC	BA	0	4	0	0	4
5-S43	CO	200.1	880807	SE	MC	BA	0	6	0	0	6
6-S01	CO	216.0	880825	SE	MC	BA	0	7	0	0	7
6-S02	CO	215.5	880825	SE	MC	BA	0	1	0	0	1
6-S03	CO	215.1	880825	SE	MC	BA	0	5	0	0	5
6-S04	CO	214.0	880825	SE	MC	BA	0	17	0	0	17
6-S05	CO	213.9	880825	SE	MC	BA	0	25	0	0	25
6-S06	CO	212.9	880825	SE	MC	BA	0	20	0	0	20
6-S07	CO	211.8	880825	SE	MC	BA	0	2	0	0	2
6-S08	CO	211.7	880825	SE	MC	BA	0	5	0	0	5
6-S10	CO	207.0	880828	SE	MC	BA	0	33	3	0	36
6-S11	CO	207.0	880828	SE	MC	BA	0	4	0	0	4
6-S12	CO	207.0	880828	SE	MC	BA	0	17	0	0	17

Table G-3. (cont.)

SAMPLE	RIVER	RMI	DATE	GEAR	HABITAT		LAR	YOY	JUV	ADU	TOTAL
6-S15	CO	206.2	880828	SE	SC	RU	0	7	0	0	7
6-S16	CO	206.2	880828	SE	SC	EM	0	25	0	0	25
6-S17	CO	205.8	880828	SE	MC	BA	0	625	0	0	625
6-S20	CO	200.6	880829	SE	MC	BA	0	6	0	0	6
6-S21	CO	200.0	880829	SE	MC	BA	0	20	0	0	20
7-E14	CO	206.7	880919	EL	MC	ED	0	13	1	0	14
7-S01	CO	216.4	880916	SE	MC	CO	0	2	0	0	2
7-S04	CO	215.8	880916	SE	MC	BA	0	29	0	0	29
7-S05	CO	215.1	880916	SE	MC	BA	0	1	0	0	1
7-S10	CO	207.3	880918	SE	MC	IP	0	1	0	0	1
7-S13	CO	207.0	880918	SE	MC	BA	0	1	0	0	1
7-S16	CO	206.9	880918	SE	MC	BA	0	1	0	0	1
7-S18	CO	207.0	880918	SE	MC	BA	0	4	0	0	4
7-S19	CO	207.0	880918	SE	MC	BA	0	1	0	0	1
7-S20	CO	206.8	880919	SE	MC	BA	0	5	1	0	6
7-S23	CO	205.8	880919	SE	MC	BA	0	27	1	0	28
7-S27	CO	200.5	880920	SE	MC	BA	0	9	0	0	9
7-S28	CO	200.0	880920	SE	MC	BA	0	19	0	0	19
8-S01	GR	11.8	880928	SE	MC	BA	0	9	0	0	9
8-S02	GR	11.8	880928	SE	MC	BA	0	3	0	0	3
9-S02	CO	215.5	881006	SE	MC	BA	0	5	0	0	5
9-S05	CO	212.9	881006	SE	MC	BA	0	5	0	0	5
9-S08	CO	211.8	881007	SE	SC	IP	0	2	0	0	2
9-S09	CO	211.7	881007	SE	MC	BA	0	2	0	0	2
9-S12	CO	207.2	881009	SE	SC	IP	0	2	0	0	2
9-S13	CO	207.1	881009	SE	MC	BA	0	1	0	0	1
9-S14	CO	206.8	881009	SE	MC	BA	0	1	0	0	1
9-S15	CO	206.6	881009	SE	SC	RU	0	2	0	0	2
9-S17	CO	205.9	881009	SE	MC	BA	0	1	0	0	1
9-S18	CO	205.9	881009	SE	MC	BA	0	5	0	0	5
9-S19	CO	200.1	881013	SE	MC	BA	0	3	0	0	3
1-S01	CO	16.4	870416	SE	MC	BA	0	18	0	0	18
2-E04	GR	0.9	870623	EL	MC	SH	0	2	0	0	2
2-E10	CO	214.0	870625	EL	MC	SH	0	1	0	0	1
2-E25	CO	205.7	870627	EL	MC	SH	0	1	0	0	1
2-S01	CO	7.0	870623	SA	MC	BA	0	3	0	0	3
2-S02	GR	0.0	870623	SA	MC	EM	0	1	0	0	1
2-S03	GR	0.0	870623	SE	MC	BA	0	5	0	0	5
2-S04	GR	0.0	860623	SE	MC	BA	0	18	0	0	18
2-S06	CO	215.0	870624	SE	MC	BA	0	1	0	0	1
2-S08	CO	215.1	870624	SE	MC	BA	0	3	0	0	3
2-S09	CO	215.1	870624	SE	MC	BA	0	2	0	0	2
2-S14	CO	213.0	870624	SE	SC	BA	0	4	0	0	4
2-S15	CO	213.0	870624	SE	SC	EM	0	1	0	0	1
2-S16	CO	213.6	870624	SE	MC	BA	0	10	0	0	10

Table G-3. (cont.)

SAMPLE	RIVER	RMI	DATE	GEAR	HABITAT		LAR	YOY	JUV	ADU	TOTAL
2-S17	CO	213.6	870624	SE	MC	BA	0	1	0	0	1
2-S19	CO	212.8	870625	SE	MC	BA	0	25	0	0	25
2-S20	CO	212.8	870625	SE	MC	BA	0	3	0	0	3
2-S32	CO	207.1	870626	SE	SE	BA	0	1	0	0	1
3-E04	CO	216.3	870710	EL	MC	SH	0	1	1	1	3
3-S03	GR	45.7	870708	SA	MC	BA	2	0	0	0	2
3-S04	GR	45.7	870708	SA	MC	BA	10	0	1	0	11
3-S05	GR	40.5	870708	SA	MC	BA	3	0	1	0	4
3-S06	GR	35.5	870708	SA	MC	BA	13	0	1	0	14
3-S12	GR	20.5	870709	SA	MC	BA	2	1	6	0	9
3-S36	CO	207.1	870711	SA	MC	BA	3	0	0	0	3
3-S41	CO	206.6	870713	SE	MC	CO	1	0	0	0	1
3-S43	CO	206.5	870713	SA	SC	BA	3	0	0	0	3
3-S54	CO	200.1	870713	SA	MC	BA	3	0	0	0	3
4-S01	CO	1.4	870728	SE	MC	BA	1	0	0	0	1
4-S02	CO	1.4	870728	SE	MC	BA	0	1	0	0	1
4-S03	CO	1.4	870728	SA	MC	BA	0	2	0	0	2
4-S04	CO	1.4	870728	SA	MC	BA	0	2	0	0	2
4-S05	CO	213.5	870729	SA	MC	BA	3	4	0	0	7
4-S08	CO	212.5	870729	SA	MC	BA	6	11	0	0	17
4-S09	CO	213.6	870729	SA	MC	BA	8	3	3	0	14
4-S15	CO	207.2	870730	SA	MC	IP	0	6	0	0	6
4-S17	CO	207.1	870731	SA	MC	BA	11	10	0	0	21
4-S18	CO	207.1	870731	SA	MC	BA	0	2	0	0	2
4-S21	CO	207.1	870731	SA	MC	BA	0	3	0	0	3
4-S22	CO	207.0	870731	SA	MC	BA	0	2	0	0	2
4-S25	CO	206.7	870801	SE	SC	RU	0	1	0	0	1
4-S27	CO	206.4	870801	SE	SC	BA	0	2	0	0	2
4-S28	CO	206.3	870801	SE	MC	BA	0	1	0	0	1
4-S32	CO	200.9	870802	SA	MC	BA	4	2	0	0	6
4-S34	CO	200.1	870802	SA	MC	BA	3	3	0	0	6
4-D10	CO	207.2	870730	DR	MC	ED	1	0	0	0	1
5-E13	CO	207.1	870821	EL	MC	BA	0	1	0	0	1
5-S01	GR	50.2	870817	SE	MC	BA	0	3	0	0	3
5-S02	GR	44.8	870817	SE	MC	BA	21	9	0	0	30
5-S03	GR	43.2	870817	SE	MC	IP	0	300	0	0	300
5-S04	GR	43.2	870817	SE	MC	IP	0	50	0	0	50
5-S05	GR	40.1	870817	SE	MC	BA	0	14	0	0	14
5-S06	GR	40.1	870817	SE	MC	BA	11	74	0	0	85
5-S07	GR	35.0	870817	SE	MC	BA	0	6	0	0	6
5-S08	GR	18.4	870818	SE	MC	BA	0	39	0	0	39
5-S09	GR	30.0	870817	SE	MC	BA	0	81	0	0	81
5-S10	GR	25.0	870817	SE	MC	BA	0	6	0	0	6
5-S11	GR	21.0	870818	SE	MC	BA	0	10	0	0	10
5-S12	GR	14.5	870818	SE	MC	BA	0	18	0	0	18

Table G-3. (cont.)

SAMPLE	RIVER	RMI	DATE	GEAR	HABITAT		LAR	YOY	JUV	ADU	TOTAL
5-S13	GR	9.9	870818	SE	MC	BA	0	12	0	0	12
5-S14	GR	9.9	870818	SE	MC	BA	0	32	0	0	32
5-S17	GR	4.5	870818	SE	MC	BA	1	1	0	0	2
5-S20	CO	215.0	870818	SE	MC	BA	0	1	0	0	1
5-S25	CO	207.1	870821	SE	MC	BA	1	4	0	0	5
5-S26	CO	207.1	870821	SE	MC	BA	0	1	0	0	1
5-S38	CO	200.0	870822	SE	MC	BA	0	1	0	0	1
7-S07	CO	207.1	870922	SE	MC	BA	0	2	0	0	2
7-S16	CO	206.4	870923	SE	SC	PO	0	4	0	0	4
8-S03	CO	214.0	871007	SE	MC	BA	0	1	1	0	2
8-S09	CO	206.5	871010	SE	SC	EM	0	2	0	0	2
8-S11	CO	206.5	871010	SE	SC	RU	0	5	0	0	5
1DR06	GR	0.1	860712	DR	MC	SH	1	0	0	0	1
1DR08	GR	0.1	860712	DR	MC	SH	1	0	0	0	1
2DR34	GR	0.1	860723	DR	MC	SH	1	0	0	0	1
3-S01	GR	48.6	860812	SE	MC	BA	1	0	0	0	1
3-S02	GR	48.6	860812	SE	MC	BA	13	0	0	0	13
3-S14	CO	211.9	860814	SE	SC	IP	1	0	0	0	1
3-S22	CO	206.3	860817	SE	MC	BA	2	0	0	0	2
4-S03	GR	0.0	860827	SE	MC	IP	0	23	0	0	23
4-S05	GR	0.0	860827	SE	MC	IP	8	100	0	0	108
4-S06	CO	216.4	860827	SE	MC	BA	8	9	0	0	17
4-S10	CO	212.6	860828	SE	MC	BA	13	13	1	0	27
4-S11	CO	207.2	860829	SE	MC	SH	0	2	0	0	2
4-S15	CO	211.7	860829	SE	MC	EM	1	0	0	0	1
4-S17	CO	211.7	860829	SE	SC	SH	2	2	0	0	4
4-S22	CO	207.1	860830	SE	MC	BA	4	20	0	0	24
4-S23	CO	207.1	860830	SE	MC	BA	0	3	0	0	3
4-S24	CO	207.1	860830	SE	MC	BA	8	17	0	0	25
4-S25	CO	207.0	860830	SE	MC	BA	1	1	0	0	2
4-S26	CO	206.9	860830	SE	MC	BA	1	0	0	0	1
5-S01	GR	45.8	860916	SE	MC	BA	2	26	0	0	28
5-S02	GR	39.5	860916	SE	MC	BA	0	225	0	0	225
5-S03	GR	30.9	860916	SE	MC	BA	0	10	0	0	10
5-S04	GR	21.1	860917	SE	MC	BA	0	1	0	0	1
5-S05	GR	21.1	860917	SE	MC	BA	4	20	0	0	24
5-S06	GR	14.9	860917	SE	MC	BA	1	13	0	0	14
5-S07	GR	9.5	860917	SE	MC	BA	15	54	0	0	69
5-S09	GR	6.0	860917	SE	MC	BA	0	11	0	0	11
5-S11	CO	216.4	860917	SE	MC	IP	3	2	0	0	5
5-S13	CO	212.8	860917	SE	MC	BA	0	2	3	0	5
5-S18	CO	207.2	860917	SE	SC	IP	0	7	0	0	7
5-S19	CO	207.2	860919	SE	MC	BA	0	10	0	0	10
5-S20	CO	207.0	860920	SE	MC	BA	0	1	0	0	1
5-S22	CO	201.1	860921	SE	MC	BA	0	1	0	0	1

Table G-3. (cont.)

SAMPLE	RIVER	RMI	DATE	GEAR	HABITAT		LAR	YOY	JUV	ADU	TOTAL
6-S01	CO	212.9	860930	SE	MC	BA	0	28	0	0	28
6-S06	CO	208.5	861001	SE	MC	IP	0	2	0	0	2
6-S07	CO	207.2	861002	SE	SC	PO	0	2	0	0	2
6-S08	CO	207.2	861002	SE	SC	PO	0	1	0	0	1
SEI020	CO	205.8	850726	SE	MC	BA	0	50	0	0	50
SEI021	CO	205.8	850726	SE	MC	BA	0	4	0	0	4
SEI022	CO	205.8	850726	SE	MC	BA	0	20	0	0	20
SEI024	GR	41.8	850807	SE	MC	BA	0	3	0	0	3
SEI025	GR	41.8	850807	SE	MC	BA	0	4	0	0	4
SEI026	GR	41.8	850807	SE	MC	BA	0	36	0	0	36
SEI027	GR	33.1	850807	SE	MC	BA	0	1	0	0	1
SEI028	GR	33.1	850807	SE	MC	BA	0	1	0	0	1
SEI030	GR	21.5	850807	SE	MC	SH	0	9	0	0	9
SEI032	GR	11.8	850807	SE	MC	BA	0	26	0	0	26
SEI033	GR	8.5	850808	SE	MC	BA	0	3	0	0	3
SEI044	CO	208.2	850809	SE	MC	BA	0	1	0	0	1
SEI046	CO	208.2	850809	SE	MC	IP	0	1	0	0	1
SEI047	CO	208.1	850809	SE	MC	IP	0	3	0	0	3
SEI048	CO	207.2	850809	SE	MC	BA	0	1	0	0	1
SEI056	CO	200.0	850811	SE	MC	BA	0	2	0	0	2
SEI057	CO	200.0	850811	SE	MC	BA	0	1	0	0	1
MUN001	CO	211.5	850808	MU	MC	IP	0	4	0	0	4
SEI059	CO	212.9	850825	SE	MC	BA	0	1	0	0	1
SEI061	CO	212.8	850825	SB	MC	BA	0	1	0	0	1
SEI062	CO	212.8	850825	SB	MC	BA	0	1	0	0	1
SEI063	CO	212.8	850825	SB	MC	BA	0	2	0	0	2
SEI071	CO	211.7	850825	SB	SC	IP	0	4	0	0	4
SEI073	CO	211.2	850825	SE	SC	IP	0	17	0	0	17
SEI076	CO	208.9	850825	SB	MC	ED	0	1	0	0	1
SEI077	CO	208.2	850825	SE	MC	BA	0	3	0	0	3
SEI083	CO	207.1	850826	SB	MC	ED	0	6	0	0	6
ELE059	CO	205.4	850924	EL	MC	BA	0	1	0	0	1
SEI096	GR	29.4	850921	SB	MC	BA	0	16	0	0	16
SEI098	GR	29.5	850921	SB	MC	SH	0	1	0	0	1
SEI098	GR	29.5	850921	SB	MC	SH	0	8	0	0	8
SEI099	GR	25.5	850921	SB	MC	BA	0	1	0	0	1
SEI100	GR	25.5	850921	SB	MC	BA	0	2	0	0	2
SEI102	GR	21.0	850922	SB	MC	SH	0	4	0	0	4
SEI103	GR	21.0	850922	SB	MC	BA	0	39	0	0	39
SEI105	GR	15.2	850922	SB	MC	SH	0	2	0	0	2
SEI106	GR	15.2	850922	SB	MC	BA	0	3	0	0	3
SEI107	GR	10.5	850922	SB	MC	BA	0	11	0	0	11
SEI108	GR	10.5	850922	SB	MC	BA	0	16	0	0	16
SEI109	GR	10.5	850922	SB	MC	BA	0	30	0	0	30
SEI110	GR	10.5	850922	SB	MC	BA	0	44	0	0	44

Table G-3. (cont.)

SAMPLE	RIVER	RMI	DATE	GEAR	HABITAT		LAR	YOY	JUV	ADU	TOTAL
SEI111	GR	5.0	850922	SB	MC	BA	0	84	0	0	84
SEI115	CO	212.9	850923	SB	MC	BA	0	1	0	0	1
SEI117	CO	212.8	850923	SB	MC	BA	0	6	0	0	6
SEI118	CO	212.8	850923	SB	MC	BA	0	4	0	0	4
SEI119	CO	212.8	850923	SB	MC	CO	0	5	1	0	6
SEI122	CO	211.8	850923	SB	MC	IP	0	8	0	0	8
SEI129	CO	208.3	850923	SB	MC	BA	0	1	0	0	1
SEI131	CO	208.3	850923	SB	MC	ED	0	1	0	0	1
SEI132	CO	207.1	850923	SB	MC	BA	0	1	0	0	1
SEI148	CO	200.1	850925	SB	MC	IP	0	8	0	0	8
SEI150	CO	199.6	850925	SB	MC	BA	0	1	0	0	1
ELE068	CO	205.6	851010	EL	MC	SH	0	1	0	0	1
SEI153	CO	216.4	851009	SB	MC	BA	0	1	0	0	1
SEI162	CO	212.7	851009	SB	MC	BA	0	1	0	0	1
SEI163	CO	212.7	851009	SB	MC	BA	0	2	0	0	2
SEI172	CO	207.1	851009	SB	MC	BA	0	2	0	0	2
SEI173	CO	207.1	851009	SB	MC	BA	0	2	0	0	2

Table G-4. Summary of Adult Humpback Chub Handled During the Cataract Canyon Fish Study, 1985-88.

SAMPLE NO.	RIVER	RIVER MILE	DATE	GEAR	HABITAT		TOTAL LENGTH	WEIGHT	TAG	TAG SIZE
2-E07	CO	207.2	880414	EL	MC	ED	270	155	RD-5040	L
3-N36	CO	207.3	880624	GP	MC	ED	207	82	RD-0104	S
4-N23	CO	207.4	880715	GP	MC	ED	276	159	RD-0425	S
4-N23	CO	207.4	880715	GP	MC	ED	252	9999	RD-0410	S
4-N24	CO	207.5	880715	GP	MC	ED	239	98	RD-0111	S
4-N45	CO	207.4	880715	GP	MC	ED	252	107	RD-0420	S
4-N54	CO	205.0	880716	GP	MC	ED	180	49	RD-0446	S
5-F01	CO	207.4	880805	FY	MC	ED	190	63	RD-0411	S
9-E02	CO	211.6	881007	EL	MC	SH	193	45	RD-0442	S
9-E02	CO	211.6	881007	EL	MC	SH	215	76	RD-0404	S
9-N75	CO	207.4	881010	GP	MC	ED	238	81	RD-0140	S
5-E09	CO	208.0	870820	EL	MC	SH	181	59	-	-
5-E11	CO	208.0	870821	EL	MC	SH	182	49	-	-
6-E15	CO	3.0	870911	EL	MC	SH	249	22	RD-5043	L
7-E22	CO	206.3	870923	EL	MC	RU	185	9999	RD-0489	S
7-E23	CO	206.2	870923	EL	MC	RU	162	9999	RD-0470	S
7-E24	CO	206.2	870924	EL	MC	RU	196	0	RD-0460	S
3-E06	CO	207.2	860815	EL	MC	SH	191	59	-	-
3-E08	CO	207.2	860815	EL	MC	SH	355	269	RD-3126	L
6-E09	CO	207.7	861002	EL	MC	EM	361	368	RD-3130	L
ELE034	CO	206.8	850810	EL	SC	SH	280	175	RD-3153	L
ELE058	CO	206.0	850924	EL	MC	SH	334	220	RD-3104	L

Table G-5. Summary of Juvenile Humpback Chub Handled During the Cataract Canyon Fish Study, 1985-88.

SAMPLE	RIVER	RMI	DATE	GEAR	HABITAT		LAR	YOY	JUV	ADU	TOTAL
3-F02	CO	207.3	880624	FY	MC	SH	0	0	1	0	1
3-E14	CO	214.7	880623	EL	MC	SH	0	0	1	0	1
3-E20	CO	207.6	880623	EL	MC	SH	0	0	1	0	1
3-N27	CO	207.4	880623	GP	MC	ED	0	0	1	0	1
3-N47	CO	206.6	880624	GP	SC	ED	0	0	1	0	1
3-N53	CO	207.0	880625	GP	MC	ED	0	0	1	0	1
3-N57	CO	207.0	880625	GP	MC	ED	0	0	1	0	1
5-E02	CO	211.3	880803	EL	MC	SH	0	0	1	0	1
5-E03	CO	211.2	880804	EL	MC	SH	0	0	1	0	1
5-E12	CO	206.0	880807	EL	MC	SH	0	0	2	0	2
5-N02	CO	211.7	880803	GP	MC	ED	0	0	1	0	1
5-N03	CO	211.7	880803	GP	MC	ED	0	0	2	0	2
5-N14	CO	207.4	880804	GP	MC	ED	0	0	2	0	2
5-N20	CO	207.4	880804	GP	MC	ED	0	0	2	0	2
5-N21	CO	207.5	880804	GP	MC	ED	0	0	1	0	1
5-N22	CO	207.6	880804	GP	MC	ED	0	0	1	0	1
5-N26	CO	207.4	880805	GP	MC	ED	0	0	2	0	2
5-N27	CO	207.5	880805	GP	MC	ED	0	0	1	0	1
5-N32	CO	207.4	880805	GP	MC	ED	0	0	2	0	2
5-N40	CO	207.6	880805	GP	MC	ED	0	0	2	0	2
5-N44	CO	207.4	880805	GP	MC	ED	0	0	1	0	1
5-N46	CO	207.6	880805	GP	MC	ED	0	0	2	0	2
5-N50	CO	207.4	880805	GP	MC	ED	0	0	2	0	2
5-N52	CO	207.6	880805	GP	MC	ED	0	0	1	0	1
5-N58	CO	207.6	880806	GP	MC	ED	0	0	1	0	1
5-N70	CO	205.4	880806	GP	MC	ED	0	0	2	0	2
5-N74	CO	205.8	880807	GP	MC	ED	0	0	1	0	1
7-E11	CO	208.0	880919	EL	MC	SH	0	0	1	0	1
7-N57	CO	207.0	880918	GP	MC	BA	0	0	1	0	1
9-N06	CO	211.7	881007	GP	MC	ED	0	0	2	0	2
9-N16	CO	207.3	881007	GP	MC	ED	0	0	1	0	1
3-E13	CO	208.0	870712	EL	MC	SH	0	0	2	0	2
3-N40	CO	207.6	870711	GP	MC	ED	0	0	1	0	1
3-N80	CO	206.6	870713	GP	SC	ED	0	0	1	0	1
4-E03	CO	214.5	870729	EL	SH	RU	0	0	1	0	1
4-E05	CO	208.0	870730	EL	SH	RU	0	0	1	0	1
6-E15	CO	3.0	870911	EL	MC	SH	0	0	1	1	2
7-E12	CO	207.2	870921	EL	MC	ED	0	0	2	0	2
7-N19	CO	211.6	870921	GP	MC	ED	0	0	1	0	1
8-N06	CO	4.5	871006	GP	MC	ED	0	0	1	0	1
6-E10	CO	206.3	861003	EL	##	##	0	0	1	0	1
3DR31	CO	207.4	860815	DR	MC	SH	0	0	1	0	1
ELE014	CO	207.3	850713	EL	MC	SH	0	0	1	0	1

Table G-6. Summary of YOY and Larval Humpback Chub Handled During the Cataract Canyon Fish Study, 1985-88.

SAMPLE	RIVER	RMI	DATE	GEAR	HABITAT		LAR	YOY	JUV	ADU	TOTAL
4-S08	CO	215.9	880713	SE	MC	BA	1	0	0	0	1
4-S13	CO	211.6	880714	SE	SC	IP	0	1	0	0	1
4-S19	CO	207.1	880716	SE	MC	BA	1	0	0	0	1
4-S30	CO	200.0	880717	SE	SC	SH	0	1	0	0	1
5-S21	CO	211.8	880804	SE	SC	IP	0	1	0	0	1
5-S22	CO	211.2	880804	SE	SC	IP	0	1	0	0	1
2-S04	GR	0.0	860623	SE	MC	BA	0	2	0	0	2
4-S08	CO	212.5	870729	SA	MC	BA	0	1	0	0	1
5-E04	CO	211.6	870818	EL	MC	SH	0	1	0	0	1
2-S09	CO	1.6	860724	SE	MC	IP	2	0	0	0	2
3-S17	CO	208.0	860814	SE	MC	BA	1	0	0	0	1
3-S22	CO	206.3	860817	SE	MC	BA	1	0	0	0	1
3-S23	CO	206.3	860817	SE	MC	BA	1	0	0	0	1
4-S13	CO	208.7	860829	SE	MC	SH	0	1	0	0	1
4-S15	CO	211.7	860829	SE	MC	EM	0	2	0	0	2
4-S23	CO	207.1	860830	SE	MC	BA	0	1	0	0	1
4-S25	CO	207.0	860830	SE	MC	BA	1	0	0	0	1
4-S26	CO	206.0	860830	SE	MC	BA	1	0	0	0	1
4-S27	CO	201.1	860831	SE	MC	BA	1	0	0	0	1
SEI026	GR	41.8	850807	SE	MC	BA	0	1	0	0	1
SEI037	CO	211.6	850808	SE	SC	SH	0	1	0	0	1
ELE055	CO	207.1	850923	EL	MC	BA	0	1	0	0	1
SEI107	GR	10.5	850922	SB	MC	BA	0	1	0	0	1
SEI131	CO	208.3	850923	SB	MC	ED	0	1	0	0	1
SEI133	CO	207.1	850923	SB	MC	BA	0	1	0	0	1
SEI142	CO	205.3	850924	SB	MC	BA	0	1	0	0	1
ELE068	CO	205.6	851010	EL	MC	SH	0	1	0	0	1

Table G-7. Summary of Suspected Adult Bonytail Handled During the Cataract Canyon Fish Study, 1985-88.

SAMPLE NO.	RIVER	RIVER MILE	DATE	GEAR	HABITAT	TOTAL LENGTH	WEIGHT	TAG	TAG SIZE
4-N28	CO	207.3	880715	TI	MC ED	383	350	RD-5027	L
4-N40	CO	207.4	880715	GP	MC ED	365	298	RD-0448	S
4-E18	CO	206.9	880716	EL	MC SH	306	173	RD-0474	S
3-N10	CO	207.5	870710	GP	MC ED	264	120	RD-5034	L
5-E04	CO	211.8	870818	EL	MC SH	287	129	RD-5036	L
2-T09	CO	1.5	860725	TI	MC ED	383	355	RD-2932	L
NET122	CO	207.4	850826	TI	MC ED	386	279	RD-3151	L

Table G-8. Summary of Suspected Juvenile Bonytail Handled During the Cataract Canyon Fish Study, 1985-88.

SAMPLE	RIVER	RMI	DATE	GEAR	HABITAT		LAR	YOY	JUV	ADU	TOTAL
4-E18	CO	206.9	880716	EL	MC	SH	0	0	1	0	1
4-N23	CO	207.4	880715	GP	MC	ED	0	0	1	0	1
4-N24	CO	207.5	880715	GP	MC	ED	0	0	1	0	1
4-N29	CO	207.4	880715	GP	MC	ED	0	0	2	0	2
4-N51	CO	207.5	880716	GP	MC	ED	0	0	1	0	1
5-N32	CO	207.4	880805	GP	MC	ED	0	0	1	0	1
5-N56	CO	207.4	880806	GP	MC	ED	0	0	1	0	1
3-N10	CO	207.6	870710	GP	MC	ED	0	0	1	0	1

Table G-9. Summary of Suspected YOY Bonytail Handled During the Cataract Canyon Fish Study, 1985-88.

SAMPLE	RIVER	RMI	DATE	GEAR	HABITAT	LAR	YOY	JUV	ADU	TOTAL
SEI111	GR	5.0	850922	SB	MC BA		1	0	0	1

APPENDIX H

SEQUENTIAL LIST OF FISH TAGS

Table H-1. A sequential list of fish tagged and associated information during the Cataract Canyon Fish Study.

TAG	CL	SZ	SP	TL	WT	DATE	RVR	RMI	GEAR	HAB		RE/CP
101	R	S	CS	305	181	880929	CO	2.9	EL	MC	SH	N
104	R	S	HB	207	82	880624	CO	207.3	GP	MC	ED	N
111	R	S	HB	239	98	880715	CO	207.5	GP	MC	ED	N
111	R	S	HB	252	118	890412	CO	207.6	GP	MC	SH	Y
112	R	S	CS	302	125	880918	CO	207.0	GP	MC	BA	N
118	R	S	BT	245	92	880715	CO	207.4	GP	MC	ED	N
118	R	S	BT	999	9999	880717	CO	205.5	GP	MC	ED	Y
128	R	S	BT	278	152	880715	CO	207.4	GP	MC	ED	N
128	R	S	CH	302	186	890809	CO	207.3	GP	MC	ED	Y
129	R	S	HB	175	45	880919	CO	208.0	EL	MC	SH	N
130	R	S	CS	357	282	880827	CO	207.7	EL	MC	SH	N
130	R	S	CS	381	400	881009	CO	207.9	TI	MC	ED	Y
131	R	S	BT	261	84	881008	CO	207.3	GP	MC	ED	N
132	R	S	HB	176	38	880918	CO	207.0	GP	MC	ED	N
133[a]	R	S	CS	147	8	880918	CO	207.0	GP	MC	BA	N
140	R	S	HB	238	81	881010	CO	207.4	GP	MC	ED	N
141	R	S	CH	271	140	880828	CO	206.0	GP	MC	ED	N
144	R	S	BT	284	154	880715	CO	207.5	GP	MC	ED	N
145	R	S	HB	266	120	890413	CO	207.1	ES	MC	BA	N
335	G	L	CS	500	794	860712	CO	216.2	EL	MC	SH	Y
335[b]	G	L	CS	438	620	830504	GR	119.9	-	-	-	N
400	R	S	HB	179	30	870921	CO	211.6	GP	MC	ED	N
404	R	S	HB	215	76	881007	CO	211.6	EL	MC	SH	N
409	R	S	HB	180	54	880803	CO	211.3	EL	MC	SH	N
410	R	S	HB	252	9999	880715	CO	207.4	GP	MC	ED	N
411	R	S	HB	190	63	880805	CO	207.4	FY	MC	ED	N
420	R	S	HB	252	107	880715	CO	207.4	GP	MC	ED	N
425	R	S	HB	276	159	880715	CO	207.4	GP	MC	ED	N
427	R	S	BT	257	117	880715	CO	207.4	GP	MC	ED	N
427	R	S	BT	999	9999	880717	CO	205.4	GP	MC	ED	Y
429	R	S	BT	235	84	880716	CO	207.5	GP	MC	ED	N
442	R	S	HB	193	45	881007	CO	211.6	EL	MC	SH	N
446	R	S	HB	180	49	880716	CO	205.0	GP	MC	ED	N
448	R	S	BT	365	298	880715	CO	207.4	GP	MC	ED	N
460	R	S	HB	196	110	870924	CO	206.2	EL	MC	RU	N
470	R	S	HB	162	9999	870923	CO	206.2	EL	MC	RU	N
474	R	S	BT	306	173	880716	CO	206.9	EL	MC	SH	N
477	R	L	BT	274	142	880827	CO	207.4	GP	MC	ED	N
477	G	L	CS	516	908	860814	CO	207.4	TI	MC	ED	Y
477[b]	G	L	CS	398	498	830428	GR	163.3	-	-	-	N
488	R	S	HB	205	83	880623	CO	207.4	GP	MC	ED	N
489	R	S	HB	185	9999	870923	CO	206.3	EL	MC	RU	N
503	R	L	CS	662	2043	870710	CO	216.3	EL	MC	SH	N
2932	R	L	HB	383	355	860725	CO	1.5	TI	MC	ED	N
2942	R	L	CS	572	1104	870415	CO	16.2	EL	MC	SH	N
2945	R	L	CS	528	936	860712	CO	216.2	EL	MC	SH	N

Table H-1 Continued

TAG	CL	SZ	SP	TL	WT	DATE	RVR	RMI	GEAR	HAB	RE/CP
2957	R	L	CS	427	511	860715	CO	201.3	GI	MC ED	N
2982[c]	R	L	CS	604	1210	850713	CO	201.2	GI	MC SH	N
2988	R	L	CS	439	568	860714	CO	207.0	TI	MC ED	N
3104	R	L	HB	334	220	850924	CO	206.0	EL	MC SH	N
3126	R	L	HB	355	269	860815	CO	207.2	EL	MC SH	N
3130	R	L	HB	361	368	861002	CO	207.7	EL	MC EM	N
3131	R	L	CS	525	1900	850825	CO	207.4	EL	MC SH	N
3133	R	L	CS	635	9999	850809	CO	206.0	EL	SC SH	N
3141	R	L	CS	425	540	850826	CO	207.3	TI	MC ED	N
3147	R	L	CS	400	9999	850923	CO	212.8	SB	MC CO	N
3151	R	L	BT	386	279	850826	CO	207.4	TI	MC ED	N
3153[d]	R	L	HB	280	175	850810	CO	206.8	EL	SC SH	N
5027	R	L	BT	383	350	880715	CO	207.3	TI	MC ED	N
5029	R	L	RZ	493	1618	870911	CO	3.6	EL	MC RI	N
5030	R	L	CS	397	428	880807	CO	200.6	GP	MC ED	N
5034	R	L	BT	264	120	870710	CO	207.6	GP	MC ED	N
5036	R	L	BT	287	129	870818	CO	211.6	EL	MC SH	N
5040	R	L	HB	270	155	880414	CO	207.2	EL	MC ED	N
5043	R	L	HB	249	22	870911	CO	3.0	EL	MC SH	N
5320	R	L	CS	445	625	880928	GR	10.6	EL	MC SH	N
5325[e]	R	L	CS	285	210	890412	CO	207.1	GP	MC BA	N
6072	G	L	CS	271	75	880621	GR	34.4	EL	MC SH	N

[a] Fish preserved frozen and sent to FWS/Grand Junction as possible recapture from Kenny Reservoir (believed to have right pelvic fin clip); fish was examined by FWS, absence of tetracycline dye eliminated possibility of fish originating in Kenny Reservoir.

[b] Original capture data from FWS (personal communications with Harold Tyus, FWS, August 1986).

[c] Fish died in net - preserved in formalin, transferred to FWS/Grand Junction.

[d] Fish sacrificed for voucher, transferred to FWS/Grand Junction for examination of coded wire nose tag - results negative.

[e] Fish died in net - preserved in formalin, transferred to FWS/Ft. Collins.