# U.S. FISH AND WILDLIFE SERVICE

## Grand Canyon Fishery Resources Office

## Flagstaff, Arizona

# Monitoring and Studies of Native Fishes of the Colorado River Ecosystem in Grand Canyon, Arizona

**INTERIM REPORT**
**Fiscal Year 1998**

# MONITORING AND STUDIES OF NATIVE FISHES OF THE COLORADO RIVER ECOSYSTEM IN GRAND CANYON, ARIZONA

## INTERIM REPORT

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U.S. Bureau of Reclamation
Upper Colorado Region
Salt Lake City, Utah

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# EXECUTIVE SUMMARY

## Introduction

Our monitoring and research program for native fishes of Grand Canyon was funded by the Grand Canyon Monitoring and Research Center (GCMRC) through a competitive peer-review process. Cooperators included in our program are Arizona Game and Fish Department, Navajo Nation, Hualapai Tribe, Northern Arizona University, University of Arizona, Willow Beach National Fish Hatchery, and Pinetop Fish Health Center.

Our funded work has two primary objectives. The first primary objective is to conduct studies and analyses that address the linkage of dam-controlled flow regimes to the ecology of native fishes in Grand Canyon. Ecological factors to be considered include: reproductive success, recruitment, dispersal of young-of-year (YOY) fish, food resources and diet, predator-prey and competitive interactions between native and non-native species, fish health and condition factor, available habitats and habitat use in near-shore areas, temperature and growth. Additional ecological factors to be considered include ontogenetic changes, seasonal patterns, movement, population age structure, and distribution (mainstem vs. tributaries). Our primary objective will be addressed by assembling integrated data sets of distribution of native and non-native fishes in relation to abiotic and biotic factors throughout the Grand Canyon, and by developing life history models for each species from existing data and published works. Linkages among dam operations, flow regimes, abiotic and biotic factors, and the native fish community will be identified in subsequent analyses.

The second primary objective is to monitor the status and trends of native fish populations, particularly in the context of changing dam operations and flow regime. Our monitoring program focuses especially on the endangered humpback chub (*Gila cypha*). Thus, we direct substantial monitoring effort on the lower 14 km of the Little Colorado River (LCR) because this is where the humpback chub successfully reproduces, and its associated mainstem Colorado River inflow reach (river miles 60-68). We also monitor other tributaries and adjacent mainstem reaches (Paria, Bright Angel, Shinumo, Kanab, Havasu), because almost all native fish in Grand Canyon are dependent on these streams for reproduction and early life history stages. Other mainstem areas where aggregations of humpback chub are known to occur, e.g., Fence Fault at river mile 29, and Middle

Granite Gorge at river mile 128 are included in the monitoring program. Selected backwaters are seined during summer sampling periods between Lees Ferry and Diamond Creek (225 miles of river). In addition to determining the status and trends of native fish populations, our sampling is designed to address many of the ecological factors listed under objective 1. Whenever possible, we sample habitats for fish so as to provide information on fish populations and their habitat relationships. Non-native fishes are included in our monitoring as these species represent a significant component of the fish community. Usual sampling approaches--electroshocking, trammel netting, minnow trapping, and seining, are employed to sample fish in mainstem near-shore habitats (shorelines, eddy complexes, backwaters).

Mini-hoopnets and point-centered habitat measurements are new sampling methods we are applying to mainstem near-shore habitat that were developed for our tributary studies in the early 1990s. Our fish and habitat sampling is linked to Northern Arizona University's food base studies (Dr. Dean Blinn and Joseph Shannon) and will provide a better understanding of diet and food resources for native fish in Grand Canyon. These new approaches are critical in linking past tributary and mainstem studies and will permit synthesis of more accurate and detailed native and non-native fish life histories. Fish health monitoring is included as a component of our fish sampling to develop a better understanding the relationship between fish diseases and environmental conditions in Grand Canyon. Growth experiments are underway to address the thermal requirements for growth and survivorship of the endangered humpback chub. Swimming performance studies will be conducted by University of Arizona (Dr. Gene Maughan and David Ward) to determine ranges of temperature and flow velocity where juvenile flannelmouth sucker (*Catostomus latipinnis*) and other native fishes are not displaced. This information is needed to identify target mainstem conditions for modification of dam operations (flow regime and thermal warming). These experiments are being conducted at the Willow Beach National Fish Hatchery, where we have constructed a state-of-the-art facility for research on growth, diet, behavior and swimming performance.

**Results and Discussion**

Approximately 100 days of field work was conducted between March and October 1998 during which 4,556 fish were captured in the Colorado River mainstem and tributaries. Field work was conducted during 2 mainstem trips (June and August 1998) and 6 sampling periods/trips in the LCR.

In the mainstem Colorado River 8,880 m shoreline habitat was sampled at both low and elevated flows. Because of fluctuating dam releases, river elevation changed 50-100 cm/d depending on location. Physical parameters (water temperature, dissolved oxygen, conductivity, pH, turbidity) were recorded for mainstem and tributary sampling sites. Paria River sampling was conducted monthly to maintain a monitoring program initiated there in 1992. Food base studies were initiated in the LCR to address the linkage between primary production, benthos, and fish. Four food base field trips were conducted in 1998 and biomass samples were prepared for stable isotope analysis.

Non-native species dominated the catch in the mainstem Colorado River (1212 of 2130 fish, 57%). Rainbow trout (*Oncorhychus mykiss*) was the most common non-native species (n=737, 35%). Of 908 native fish captured in the mainstem, speckled dace (*Rhinichthys osculus*) (n=396, 19%) and humpback chub (n=355, 17%) were the most abundant. The use of mini-hoopnets in mainstem habitats revealed a relative abundance of humpback chub in the 80-200 mm TL size class, a population feature not previously observed. In the smaller tributaries (Bright Angel, Shinumo, Kanab, Havasu) native species dominated the catch (717 of 808, 89%). Speckled dace (n=364, 45%) and humpback chub (n=122, 15%) were the most abundant native fishes. The LCR assemblage was dominated by native species (1362 of 1600, 85%) with humpback chub (n=914, 57%) and speckled dace (n=308, 19%) dominating.

Biopsies were performed on native and non-native fishes to determine the incidence and distribution of diseases and parasites in Grand Canyon fishes. Condition factor and body fat was higher and incidence of parasite infection was lower in fish captured in the mainstem compared to the LCR and other tributaries. Anchorworms (*Lernaea cyprinacea*) were relatively uncommon (0-5% occurrence, lowest value for mainstem fish) and lower in occurrence than in previous years. Asian tapeworm (*Bothriocephalus acheilognathi*) were relatively common (12-32% occurrence, lowest value for mainstem fish) but was also lower in prevalence compared to previous years. The reduced incidence of these parasites in 1998 may be related to prolonged spring flooding in the tributaries. For fish captured in Kanab Creek, we observed a high incidence of infection with the protozoan *Ichthyobodo* (*Costia*).

A wetlab facility was constructed at the Willow Beach National Fish Hatchery and growth experiments with YOY humpback chub were initiated in late 1998. Fish are being grown at 12, 18, and 24°C to evaluate the effects of temperature on growth of small fish. Studies on swimming performance of native fishes will commence in 1999 at Willow Beach NFH. Initial studies will be performed with YOY flannelmouth sucker. Subsequent work will include humpback chub and bluehead sucker (*Catostomus discobolus*).

Proposed field work for 1999 will mirror that of 1998. A winter (January) mainstem monitoring trip has been added to the field schedule for 1999 to address overwinter mortality of YOY humpback chub. Computer entry of 1998 data is nearly complete and synthesis and analyses will commence in 1999. Fish health monitoring will continue and will include more biopsies of YOY humpback chub. The temperature-growth experiment being conducted at Willow Beach NFH is expected to be completed by the end of 1999. Swimming performance studies will commence in the summer of 1999. Food base studies in the LCR will continue and results of 1998 stable isotope samples will be analyzed by late 1999.

Our monitoring and studies are designed to provide information to the Adaptive Management Program for development of conceptual ecosystem models, designing future experimental flows, and identifying information needs for future studies and monitoring. Furthermore, our work is intended to provide critical information for developing management plans and actions aimed at removing jeopardy to the endangered humpback chub and improving the status of other native fishes in Grand Canyon.

## INTRODUCTION

Our monitoring and research project on native fishes of Grand Canyon was funded by the Grand Canyon Monitoring and Research Center (GCMRC) through a competitive, peer-review process. The primary objectives of the funded work are two-fold. The first is to conduct studies and analyses that address the linkage of dam-controlled flow regimes to the ecology of native fishes in Grand Canyon. Ecological factors listed in the GCMRC's Request for Proposals (RFP) to be considered include: reproductive success, recruitment, dispersal of young-of-the–year fish, food resources and diet (RFP Objective 1); predator-prey and competitive interactions between native and non-native species (RFP Objective 3); diseases, parasites and condition factor (RFP Objective 4); available habitats and habitat use in near-shore areas (RFP Objective 5); temperature, physiology, and growth (RFP Objective 6). Additional ecological factors to be considered include ontogenetic changes, temporal activity patterns, movement, spawning, population age structure, and distribution (mainstem vs. tributaries). Our primary objective will be addressed by assembling integrated data sets of distribution of native and non-native fishes in relation to abiotic and biotic factors throughout the Grand Canyon, and by developing life history models for each species from existing data and published works. Linkages among dam operations, flow regimes, abiotic and biotic factors, and the native fish community will be identified in subsequent analyses.

The second primary objective is to monitor the status and trends of native fish populations in Grand Canyon (RFP Objective 2). Continued monitoring is necessary to assess the status of native fishes, especially the endangered humpback chub - particularly in the context of changing dam operations and flow regime. However, because of the limited scope of the present contract, new monitoring efforts must be more focused in detecting trends in native fish populations. Thus, our monitoring focuses on the lower 14 km of the Little Colorado River (LCR) because this is where the endangered humpback chub successfully reproduces, and on the mainstem Colorado River inflow reach (river miles 61-68) because this area contains the largest mainstem population. Other areas of focus are other tributaries and adjacent mainstem reaches (Paria, Bright Angel, Shinumo, Kanab, and Havasu), because almost all native fish in Grand Canyon are dependent on these streams for reproduction and early life history stages. Other mainstem areas where aggregations of humpback chub are known to occur, e.g., Fence Fault at river mile 29, and Middle Granite Gorge at river mile 128 are also included in the monitoring program. Whenever possible, we sample habitats for fish so as to provide critical information on fish populations and their habitat relationships. Our sampling is designed to detect reproductive success, survivorship of young-of-year, and status of adult populations. Non-native fishes are included in our monitoring as these species represent a significant component of the fish community and may be involved in significant interspecific interactions.

Conventional sampling approaches including electrofishing, trammel netting, minnow trapping, and seining will be employed to sample fish in mainstem near-shore habitats (shorelines, eddy complexes, backwaters). New sampling methods applied in mainstem near-shore habitat that we developed for our tributary studies in the early 1990s include mini-hoopnet and point-centered habitat measurements. Our fish and habitat sampling is linked to Dr. Dean Blinn and Joseph Shannon's food base studies and will provide a better understanding of diet and food resources for native fish in Grand Canyon. These new approaches are critical in linking past tributary and mainstem studies and will permit synthesis of more accurate and detailed native and non-native fish life histories. Fish health monitoring is included as a component of our fish sampling to develop a better understanding of the relationship between fish diseases and environmental conditions in Grand Canyon.

Growth experiments are in progress to address the thermal requirements for growth and survivorship of the endangered humpback chub. Swimming performance studies will determine ranges of temperature and flow velocity where juvenile flannelmouth sucker and other native fishes are not displaced. This information is needed to identify target mainstem conditions for modification of dam operations (flow regime and thermal warming). These experiments are being conducted at the Willow Beach National Fish Hatchery, where we have constructed a state-of-the-art facility for research on growth, diet, behavior, swimming performance, etc.

Our monitoring and studies will provide information to the Grand Canyon Adaptive Management Program for development of conceptual ecosystem models, designing future experimental flows, and identifying information needs for future studies and monitoring. Furthermore, our work will provide critical information for developing management plans and actions aimed at removing jeopardy to the endangered humpback chub and improving the status of other native fishes in Grand Canyon.

## INTERAGENCY COOPERATION

While the current contract was awarded to the U.S. Fish and Wildlife Service, we have endeavored to include, to the extent possible, participants of past Glen Canyon Environmental Studies programs in order to foster a spirit of collaboration among agencies with resource management responsibility in Grand Canyon. Toward this end we have developed cooperative agreements with the Navajo Nation, Hualapai Tribe, Arizona Game and Fish Department, University of Arizona Coop Unit, and Northern Arizona University.

## ACTIVITIES FY98

Notification of intent to award the Grand Canyon Fishery Resources Office (GCFRO) the contract for monitoring and research on native fishes in Grand Canyon occurred on 1 October 1997. Following this notification, the U. S. Fish and Wildlife Service (FWS), the Bureau of Reclamation (BOR), and the Grand Canyon Monitoring and Research Center (GCMRC) entered into negotiations and signatures were completed on 8 April 1998. To meet the needs of the newly contracted work, three fishery biologists and an office assistant were hired by 25 June 1998. Cooperative agreements were developed and finalized with Navajo Natural Heritage Program (NNHP) on 11 June, Hualupai Tribe on 3 June, Northern Arizona University (NAU) on 4 June, University of Arizona (UA) on 23 September, and Arizona Game and Fish Department (AGFD) on 1 June. Intra-agency agreements with Pinetop Fish Health Center and Willow Beach National Fish Hatchery were developed by 1 June for fish health studies and experimental growth experiments, respectively. Field work was initiated on 27 March 1998, prior to finalization of the contract. Over 500 person-days of field work were done during FY1998 during seven separate field trips (Table 1).

TABLE 1. Schedule of completed field work.

| Trip title | Dates | Trip objective |
|---|---|---|
| Spring Little Colorado River monitoring and research | 27 March-6 May 1998 | Fishery research and monitoring |
| Little Colorado River food base monitoring | 5-8 June 1998 | Macroinvertebrate, stable isotope studies |
| Mainstem Colorado River and tributaries monitoring and research | 16 June-1 July 1998 | Fishery research and monitoring |
| Little Colorado River monitoring and research | 22-31 July 1999 | Fishery research and monitoring |
| Little Colorado River food base monitoring | 3-6 August 1998 | Macroinvertebrate, stable isotope studies |
| Mainstem Colorado River and tributaries monitoring and research | 26 August-11 September 1998 | Fishery research and monitoring |
| Little Colorado River monitoring, research and food base monitoring | 20-24 October 1998 | Fishery research and monitoring and macroinvertebrate, stable isotope studies |
| Little Colorado River food base monitoring | 7-10 December 1998 | Macroinvertebrate, stable isotope studies |

## TRIP AND SUB-PROJECT SUMMARIES

### Little Colorado River Monitoring and Research, Spring 1998

Timothy L. Hoffnagle, Research Branch, AGFD
Owen T. Gorman, Grand Canyon Fishery Resources Office, USFWS

### Trip Objectives

1. Continue historical AGFD spring monitoring activities.

2. Monitor influx of adult humpback chub into the Little Colorado River during the spawning season.

3. Measure habitat use by humpback chub and other fishes at locations of net sets.

### Results and Discussion

Fish abundance was monitored in the Little Colorado River (LCR) during four 11-day trips from 27 March - 6 May. Teams from the U. S. Fish and Wildlife Service (USFWS) conducted Trips 1 (27

March - 6 April) and 4 (27 April - 6 May), while teams from the Arizona Game and Fish Department (AGFD) conducted Trips 2 (6 - 17 April) and 3 (17 - 27 April). Trip length varied from 9 - 11 days, due to weather.

Capture of fishes was accomplished using three different standardized gear types: large hoopnets, minihoopnets and minnow traps. Sixteen large hoopnets, two minihoopnets and two groups of five minnow traps were set at standard sites in the lower 1.2 km of the Little Colorado River (Robinson and Clarkson 1992; Robinson et al. 1996; Brouder and Hoffnagle 1998a; b). Capture gears were usually checked twice daily, at dusk and dawn. Water temperature and turbidity were measured in the Little Colorado River at Boulder Camp (2 km from the mouth) immediately preceding morning gear checks and following evening gear checks. Little Colorado River discharge data were obtained from the USGS gage at Cameron and 235 cfs was added to compensate for base flow from Blue Springs, approximately 48 km downstream from the gage (21 km from the mouth).

Monitoring trips were successful in capturing all species of native and common non-native fishes. The usual pattern of late February-early April spring flooding was prolonged through to early May because of unusually wet late winter and spring weather. Thus, we appear to have missed the usual March-April spawning run of humpback chub, since catches were not as high as in previous years, and there was a low frequency of fish in spawning condition (Hoffnagle 1998). Fish captured during spring monitoring are summarized in Table 2. Data collected by USFWS and AGFD are currently being merged for further analyses. Catch rates will be compared with those of previous years at these standardized sampling sites. In addition, condition factor and prevalence of *Lernaea cyprinacaea* infestation of fishes will be examined, as will temperature, turbidity, and discharge of the Little Colorado River. These factors have been shown to affect fish catch (Robinson and Clarkson 1992; Valdez and Ryel 1995; Arizona Game and Fish Department 1996).

USFWS personnel measured habitat around hoopnets at the start and end of the 40-day monitoring period to provide a sample of changing habitat conditions during the spring spawning season. Additionally, FWS measured stream cross-sections to provide data on changes in habitat as stream discharge dropped from high early spring flows to near-base flows in late spring. Trammel nets were set and run daily near the mouth of the Little Colorado River during the first and last 10-day portions of the monitoring period. Water quality data (temperature, dissolved oxygen, pH, conductivity, salinity) were recorded hourly, and turbidity was recorded daily during the first and last 10-day portions of the 40-day monitoring period.

TABLE 2. Preliminary summary of fish captured by gear type, lower 1.2 km of the Little Colorado River, 27 March-27 April, 1998.

| | Species[a] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gear type | BBH | BHS | CCF | CCP | FHM | FMS | HBC | PKF | RBT | RSH | SPD | Total |
| Hoopnet | 1 | 68 | 17 | 4 | 109 | 22 | 268 | 2 | 8 | 18 | 167 | 684 |
| Minnow trap | 0 | 1 | 0 | 0 | 2 | 1 | 14 | 0 | 0 | 2 | 5 | 25 |
| Trammel | 0 | 1 | 0 | 2 | 0 | 40 | 5 | 0 | 5 | 0 | 0 | 53 |
| Total | 1 | 70 | 17 | 6 | 111 | 63 | 287 | 2 | 13 | 20 | 172 | 762 |

[a] BBH = black bullhead (*Ameiurus melas*); BHS = bluehead sucker (*Catostomus discobolus*); CCF = channel catfish (*Ictalurus punctatus*); CCP = common carp (*Cypinius carpio*); FHM = fathead minnow (*Pimephales promelas*); FMS = flannelmouth sucker (*Catostomus latipinnis*); GRS = green sunfish (*Lepomis cyanellus*); HBC = humpback chub (*Gila cypha*); RBT = rainbow trout (*Oncorhynchus mykiss*); RSH = red shiner (*Cyprinella lutrensis*); SPD = speckled dace (*Rhinichthys osculus*).

**Little Colorado River Monitoring and Research, July 1998**

Robert G. Bramblett
Owen T. Gorman
Grand Canyon Fishery Resources Office, USFWS

**Trip Objectives**

1. Monitor humpback chub and other native and non-native fish in the Little Colorado River.

2. Sample shoreline habitat and use by resident fishes to complement mainstem Colorado River studies.

3. Monitor water quality and log water temperature in a variety of aquatic habitats.

4. Capture young-of-the-year (YOY) humpback chub for experimental studies at Willow Beach National Fish Hatchery.

5. Capture ~ 25 adult speckled dace and transport to Willow Beach National Fish Hatchery for fish health assay.

**Results and Discussion**

On day three of our 10-day trip (24 July) at about 0610 hrs, a large (~ 100 cm) flood entered the Salt Camp reach of the Little Colorado River. The high flows continued for 24 hours before receding, and several smaller spates of 15 – 30 cm occurred throughout the remainder of the trip. The flooding made fishing hoopnets, minnow traps, and seines impracticable, and thereby affected our ability to fully meet our trip objectives.

Objective 1, monitoring humpback chub and other native and non-native fish, was partially met. We were able to run fishing gear for four days only, rather than the nine days we planned. Additionally, the high flows and turbidity reduced capture efficiency of fishing gear. Despite the poor conditions, we were able to capture 230 fish of 4 native and 5 non-native species (Table 3). Initial conclusions from fish monitoring include documentation of reproduction by humpback chub, speckled dace, flannelmouth sucker, and bluehead sucker, and evident lack of reproduction by common carp, fathead minnow, and red shiner.

Full achievement of Objective 2, measurement of shoreline habitat and habitat use, was similarly limited by the flood. We had planned on measuring habitat at 180 hoopnet and minnow trap sets, and shoreline transects. However, the continued flooding limited our habitat measurements to 46 hoopnets, 34 minnow traps, and 39 shoreline transects.

Objective 3, water quality monitoring, was completed, although the flood probably masked temperature patterns that normally occur during summer base flow conditions. Also, while no thermographs were lost, several had been buried by sediment or swept ashore by the flood.

Objective 4, capture of YOY humpback chub for experimental studies, was achieved. Approximately 34.4 hours of seining effort over two days yielded ~399 YOY humpback chub. On Thursday, 30 July 1998, the humpback chub were transported to Willow Beach National Fish Hatchery by BOR helicopter (Steve Chubbuck, Pilot). The fish arrived in excellent condition; no mortalities occurred during transport.

Flood conditions and extreme turbidity (> 50,000 NTU) almost certainly reduced catch rates of YOY humpback chub. Most YOY humpback chub were captured by seining in areas with current velocities near zero, often over a sand substrate and in small pockets of quiet water adjacent to boulders. We speculate that the use of these habitats may be related to the flood conditions. Handling protocol for YOY humpback chub prohibited taking length and weight measurements; however, we estimated the size range of these fish at 35 – 50 mm. Many of the YOY humpback chub captured by seining were smaller than those occurring in our hoopnet and minnow trap catches; however, mesh size in seines was 3/16" and 1/8", while mesh size in hoopnet and minnow traps was 1/4".

Relative abundance of YOY based on seine catches indicated that humpback chub and bluehead sucker were most common and approximately co-dominant in abundance. Speckled dace were the next most abundant species and flannelmouth suckers were rare.

Adult fathead minnows, some probably over two years old (> 65 mm TL) and red shiners, some probably more than one year old (> 65 mm TL) were very common. However, we did not observe any YOY fathead minnows or red shiners. Also missing from seine catches were YOY common carp, although 1+ and 2+ fish were present. This pattern of YOY abundance suggests that native species had a more successful reproductive effort this year than nonnative species.

Objective 5, capture and transport of speckled dace for fish health assay, was completed. The speckled dace were examined by Jerry Landye, USFWS. Asian tapeworms (*Bothriocephalus acheiognathi*) were confirmed in this sample, but no anchor worms (*Lernaea cyprinacea*) were found in any fish sampled.

TABLE 3. Preliminary summary of fish captured by site gear type, Little Colorado River, 22-31 July 1998.

| | Species[a] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gear type | BHS | CCF | CCP | FHM | FMS | HBC | PKF | SPD | YBH | Total |
| Hoopnet | 5 | 5 | 24 | 5 | 1 | 164 | 2 | 10 | 3 | 219 |
| Minnow trap | 0 | 0 | 0 | 1 | 0 | 3 | 5 | 2 | 0 | 11 |
| Seine[b] | 0 | 0 | 0 | 0 | 0 | 399 | 0 | 0 | 0 | 399 |
| Total | 5 | 5 | 24 | 6 | 1 | 566 | 7 | 12 | 3 | 629 |

[a]BHS = bluehead sucker (*Catostomus discobolus*; CCF = channel catfish (Ictalurus punctatus); CCP = common carp (*Cypinius carpio*); FHM = fathead minnow (*Pimephales promelas*); FMS = flannelmouth sucker (*Catostomus latipinnis*); HBC = humpback chub (*Gila cypha*); PKF = plains killifish (*Fundulus zebrinus*); SPD = speckled dace (*Rhinichthys osculus*); YBH = yellow bullhead (*Ameiurus natalis*).

[b]Additional species captured during seining that were not counted: red shiner (*Cyprinella lutrensis*), yellow bullhead, fathead minnow, bluehead sucker, plains killifish, common carp, speckled dace.

## Little Colorado River Monitoring and Research, October 1998

Robert G. Bramblett
Owen T. Gorman
Grand Canyon Fishery Resources Office

### Trip objectives

1. Monitor humpback chub and other native and non-native fish in the Little Colorado River.

2. Sample shoreline habitat and use by resident fishes to complement mainstem Colorado River studies.

3. Monitor water quality and water temperature.

4. Assist NAU researcher Allen Haden in food base studies.

### Results and discussion

This trip was initiated as a partial make-up for the July trip, which was disrupted by flooding. Objective 1, monitoring humpback chub and other native and non-native fish, was met. We captured 214 fish of 3 native and 4 non-native species during four days of sampling (Table 4).

Speckled dace were the most abundant species, followed by humpback chub, fathead minnow, red shiner, common carp, flannelmouth sucker and yellow bullhead. No bluehead suckers were captured, and only one flannelmouth sucker was captured. Only speckled dace and humpback chub were abundant.

Preliminary analysis indicates that we captured 60 humpback chub total, of which 19 (32%) were YOY (65-85 mm, FIGURE 1). In contrast, during the July 1998 trip, we captured 162 humpback chub total, and 7% of these were YOY. Therefore, YOY humpback chub comprised a larger proportion of the catch in the October than in the July sample. The disparity in proportional catches may be because during July 1998 many YOY humpback chub were too small to be captured in the ¼" mesh of our hoopnets.

Moreover, seining efforts in July yielded more YOY humpback chub than our seining on this trip. In July, we captured 400 YOY humpback chub in roughly two days of seining with two crews under turbid water conditions. During the current trip, one crew seining for one day and another crew seining for 1.5 hours failed to capture any YOY humpback chub under blue water conditions. However, the larger size of humpback chub in October, together with the less turbid water conditions, may have reduced the capture efficiency for seining. Alternatively, abundance of YOY humpback chub in the Little Colorado River may have been reduced due to frequent flooding during the summer monsoon season, or in combination with volitional downstream movements. In any event, the presence of some YOY humpback chub during this trip indicates that flooding or volitional movements did not entirely deplete the local population of YOY humpback chub.

Objective 2 was met. We measured available habitat at 41 shoreline transects and at 4 full cross-section transects. Habitat was also measured at 41 hoopnet and 27 minnow trap sets. Objective 3, water quality and temperature monitoring, was completed. Water quality data are summarized in Table 5. Turbidity varied during the trip. Rains occurring 20-22 October caused a localized flow event from Big Canyon located about 700 m upstream from Salt Camp. Although the stage did not rise appreciably, turbidity increased from 10 NTU on 21 October to 45 NTU on 22 October as the water changed from typical blue base-flow color to brown. By 24 October, turbidity had declined to 32 NTU as the water returned to a primarily blue color.

Objective 4 was completed. We assisted Allen Haden, Northern Arizona University (NAU), in collecting and sorting food base samples from Salt Creek, the Little Colorado River at Salt Camp, and the Little Colorado River at Chute Falls.

TABLE 4. Preliminary summary of fish captured by gear type, Little Colorado River, 20-24 October 1998.

| Gear | Species[a] | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | CCP | FHM | FMS | HBC | SPD | RSH | YBH | |
| Hoopnet | 2 | 8 | 1 | 51 | 94 | 4 | 1 | 161 |
| Minnow trap | 0 | 4 | 0 | 5 | 29 | 0 | 0 | 38 |
| Seine | 1 | 4 | 0 | 5 | 1 | 4 | 0 | 15 |
| Totals | 3 | 16 | 1 | 61 | 124 | 8 | 1 | 214 |

[a]CCP = common carp (*Cypinius carpio*); FHM = fathead minnow (*Pimephales promelas*); FMS = flannelmouth sucker (*Catostomus latipinnis*); HBC = humpback chub (*Gila cypha*); SPD = speckled dace (*Rhinichthys osculus*); RSH = (*Cyprinella lutrensis*) YBH = yellow bullhead (*Ameiurus natalis*).

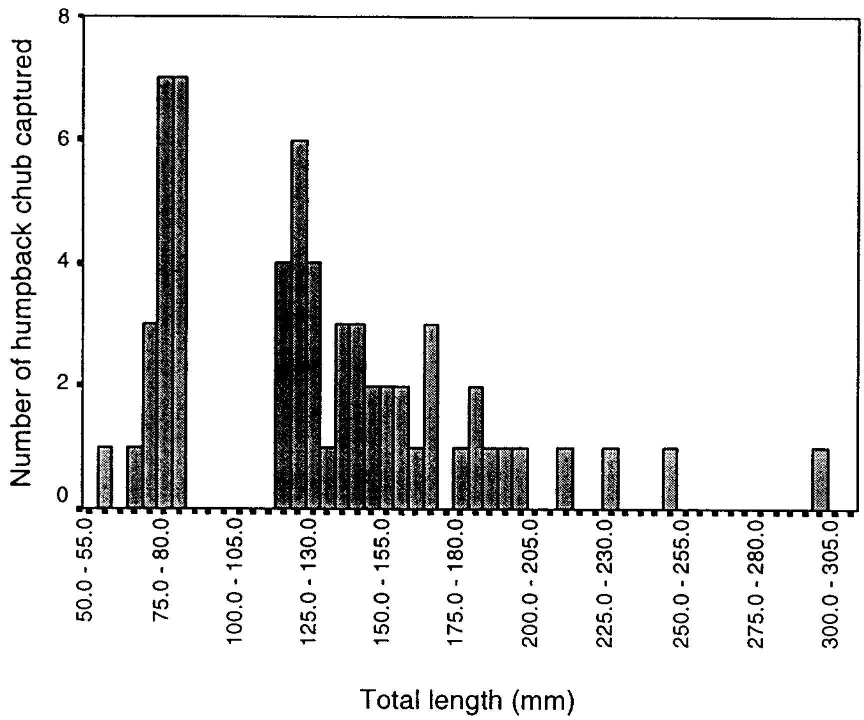


FIGURE 1. Length-frequency histogram of humpback chub captured at Salt Camp reach, Little Colorado River, 20-24 October, 1998.

TABLE 5. Summary of water quality data collected in the Little Colorado River at Salt Camp, 20 (1220 hrs)-24 (0640 hrs) October 1998. Temperature, dissolved oxygen, specific conductivity and pH samples were collected at 10 min intervals, *N*=542 readings. Turbidity was measured five times total.

| Parameter | Average | Minimum | Maximum |
|---|---|---|---|
| Temperature (°C) | 19.6 | 18.8 | 20.5 |
| Dissolved oxygen (mg/L) | 7.0 | 6.5 | 8.0 |
| Specific conductance (microseimens) | 4539.7 | 4431.0 | 4657.0 |
| pH | 7.4 | 7.3 | 7.6 |
| Turbidity (NTU) | 33 | 10 | 45 |

**Summary of 1998 sampling for the Little Colorado River.**

Over the three periods of sampling in the Little Colorado River in 1998, 1,605 fish were captured (Table 6). As observed in previous studies, e.g., Gorman (1994), native species fish dominated the fish community. Native fish comprised 85 % or 1362/1605 of fish captured and humpback chub was the most abundant species with 57 % or 914/1605 fish captured.

TABLE 6. Summary of catch, Little Colorado River, 1998.

| | Species[a] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampling period | BBH | BHS | CCF | CCP | FHM | FMS | HBC | PKF | RBT | RSH | SPD | YBH | Total |
| March-April | 1 | 70 | 17 | 6 | 111 | 63 | 287 | 2 | 13 | 20 | 172 | 0 | 762 |
| July | 0 | 5 | 5 | 24 | 6 | 1 | 566 | 7 | 0 | [b] | 12 | 3 | 629 |
| October[b] | 0 | 0 | 0 | 3 | 16 | 1 | 61 | 0 | 0 | 8 | 124 | 1 | 214 |
| Total | 1 | 75 | 22 | 33 | 133 | 65 | 914 | 9 | 13 | 28 | 308 | 4 | 1605 |

[a]BBH = black bullhead (*Ameiurus melas*); BHS = bluehead sucker (*Catostomus discobolus*); CCF = channel catfish (*Ictalurus punctatus*); CCP = common carp (*Cypinius carpio*); FHM = fathead minnow (*Pimephales promelas*); FMS = flannelmouth sucker (*Catostomus latipinnis*); HBC = humpback chub (*Gila cypha*); PKF = plains killifish (*Fundulus zebrinus*); RBT = rainbow trout (*Oncorhynchus mykiss*); RSH = red shiner (*Cyprinella lutrensis*); SPD = speckled dace (*Rhinichthys osculus*); YBH = yellow bullhead (*Ameiurus natalis*).

[b]Additional species captured during seining that were not counted: red shiner (*Cyprinella lutrensis*), yellow bullhead, fathead minnow, bluehead sucker, plains killifish, common carp, speckled dace.

## Mainstem Colorado River and Tributaries Monitoring and Research, 16 June-1 July 1998 (Trip 1) and 26 August-11 September 1998 (Trip 2)

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### Trip Objectives

1. Monitor fish populations at sites in the mainstem Colorado River and tributaries.
2. Sample available habitats and habitats used by fish at mainstem Colorado River sites and tributaries.
3. Conduct a fish health assessment survey for mainstem Colorado River and tributaries.
4. Collect samples for stable isotope analysis as part of native fish food base study.
5. Monitor water quality and temperature at mainstem sites and in tributaries.
6. Conduct survey of shoreline habitats in the mainstem Colorado River under diel fluctuating flow conditions.
7. Conduct a seining survey of backwaters in mainstem habitats.

### Study Areas and Methods

Fish populations were monitored with electrofishing, trammel nets, hoopnets, minnow traps, and seining at eight mainstem Colorado River locations (Tables 7, 8). During Trip 2, additional sampling was done at in the mainstem at Fence Fault (RM 30.5) and above Tanner Rapids (RM 68). In addition to the primary mainstem sites, backwaters were seined at locations along the mainstem from the vicinity of the Little Colorado River downstream to RM 192.

Fish populations were monitored at five tributary sites: Little Colorado River, Bright Angel Creek, Shinumo Creek, Kanab Creek, and Havasu Creek. Fish were captured in tributaries using hoopnets, minnow traps, and seining.

Available habitat and habitat used by fish was measured at mainstem Colorado River sites and five tributary sites. To assess the effects of fluctuating flow on fish habitat, available habitat was measured along transects at the eight mainstem sites under both low and high flow conditions during Trip 2. Study reaches for habitat studies were selected based on the habitat classification system of Valdez and Ryel (1995).

## Results and Discussion

*Effort.*-Total length of study reaches was 3040 m for mainstem reaches and 1250 m for tributary confluence sites during Trip 1 and 2880 m for mainstem reaches and 1150 m for tributary confluence sites during Trip 2. During Trip 1, electrofishing was conducted during 11 nights and one morning, trammel nets were set/run on 9 nights and one daytime period. Trapping effort for mainstem and tributary sampling included 179 hoopnet and 192 minnow trap sets with at total effort exceeding 700 trap-days (Tables 7, 8, Appendix Table 1). During Trip 2, 34 electrofishing runs were conducted, totaling 19,788 s of effort. Sixty-one trammel net were set, for a total effort of 114.1 hrs. Trapping effort included 229 hoopnet and 282 minnow trap sets, and 96 seine hauls were done (Tables 7, 8, Appendix Table 3).

*Fish.*-During Trip 1, a total of 752 fish of 4 native and 6 nonnative species were captured; 496 fish were captured at mainstem sites and 256 fish were captured at tributary sites (Tables 9,10). Speckled dace and flannelmouth sucker were the most abundant native species in the catch, followed by humpback chub and bluehead sucker, respectively. Eighty-seven humpback chub were captured at 4 of 8 mainstem Colorado River sites and at 4 of 5 tributary sites (Figure 2, Table 9, Appendix Table 2). Catches of native fish species at mainstem sites were lower than catch of non-native species at all mainstem Colorado River sites. In all tributaries, catches of natives were greater than non-native species. At tributary sites, 82% of the fish captured were native species, while at mainstem sites 22% of the fish captured were native species.

Rainbow trout were the most abundant nonnative species captured, as well as the most abundant overall. Brown trout was the next most abundant nonnative species. Catch of brown trout was highest in the mainstem Colorado River near Bright Angel Creek and catch of rainbow trout was highest in mainstem Colorado River near Havasu Creek.

TABLE 7. Sampling effort, Colorado River in Grand Canyon, 1998.

| Sampling period | Electro-fish | Trammel net | Minnow trap | Hoopnet | Seine |
|---|---|---|---|---|---|
| June 1998 | 417 min | 41 sets | 133 sets | 125 sets | 6 areas |
| August-September 1998 | 330 min | 61 sets | 202 sets | 157 sets | 40 areas |
| Totals | 747 min | 102 sets | 335 sets | 282 sets | 46 areas |

TABLE 8. Sampling effort in tributaries to the Colorado River in Grand Canyon (Bright Angel, Shinumo, Kanab, Havasu creeks) 1998.

| Sampling period | Minnow trap | Hoopnet | Seine |
|---|---|---|---|
| June 1998 | 79 sets | 54 sets | 6 areas |
| August-September 1998 | 80 sets | 72 sets | 56 areas |
| Totals | 159 sets | 126 sets | 62 areas |

TABLE 9. Summary of fish captured in the Colorado River in Grand Canyon, 1998.

| Sampling period | RBT | BRT | CCP | HBC | SPD | RSH | FHM | FMS | BHS | CCF | PKF | GRS | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| June | 274 | 61 | 12 | 57 | 25 | 3 | 30 | 29 | 4 | 0 | 0 | 1 | 496 |
| August-September | 463 | 70 | 18 | 298 | 371 | 40 | 231 | 87 | 37 | 1 | 8 | 0 | 1624 |
| Totals | 737 | 131 | 30 | 355 | 396 | 43 | 261 | 116 | 41 | 1 | 8 | 1 | 2120 |

TABLE 10. Summary of fish captured in tributaries (Bright Angel, Shinumo, Kanab and Havasu creeks) to the Colorado River in Grand Canyon, 1998.

| Sampling period | RBT | BRT | CCP | HBC | SPD | RSH | FHM | FMS | BHS | CCF | PKF | GRS | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| June | 1 | 7 | 4 | 30 | 85 | 27 | 6 | 81 | 13 | 0 | 0 | 2 | 256 |
| August-September | 9 | 2 | 9 | 92 | 279 | 3 | 15 | 56 | 81 | 0 | 6 | 0 | 552 |
| Totals | 10 | 9 | 13 | 122 | 364 | 30 | 21 | 137 | 94 | 0 | 6 | 2 | 808 |

Overall, capture of fish was higher during Trip 2 than Trip 1. During Trip 2, 2,176 fish of 4 native and 8 nonnative species were captured; 1,624 fish were captured at mainstem sites and 552 fish were captured at tributary sites (Tables 9,10; Appendix Table 4). As we observed during Trip 1, native species comprised more of the fish community at tributary sites than at mainstem sites. At tributary sites, 92.0% of the fish captured were native species, while at mainstem sites 48.6 % of the fish captured were native species.

During Trip 2, speckled dace (*Rhinichthys osculus*) were the most abundant native species, followed by humpback chub (*Gila cypha*), flannelmouth sucker (*Catostomus latipinnis*), and bluehead sucker (*Catostomus discobolus*), respectively. A total of 390 humpback were captured at 8 of 10 mainstem Colorado River sites and at 4 of 5 tributary sites (Tables 9, 10; Appendix Table 4).

A substantial number of the humpback chub we captured on this trip were between 150 and 200 mm total length (Figure 2). Length-frequency histograms presented by Valdez and Ryel (1995) indicate a relative lack of humpback chub between 150 and 250 mm total length. In contrast, preliminary results from our 1998 sampling trips indicate that humpback chub in this size class had a higher relative abundance than reported by Valdez and Ryel (1995). Further analysis indicates that most of these fish were captured in hoopnets (Figure 3), a gear not used extensively by Valdez and Ryel (1995). Moreover, length-frequency histograms for our captures from trammel nets and electrofishing (Figure 3) were similar to those presented by Valdez and Ryel (1995). These results suggest that we are sampling a portion of the humpback chub population that has not been well represented in previous investigations, e.g., Valdez and Ryel (1995).

Rainbow trout (*Oncorhynchus mykiss*) was the most abundant nonnative species, followed by fathead minnow (*Pimephales promelas*), brown trout (*Salmo trutta*), red shiner (*Cyprinella lutrensis*), common carp (*Cypinius carpio*), plains killifish (*Fundulus zebrinus*), channel catfish (*Ictalurus punctatus*) and yellow bullhead (*Ameiurus natalis*), respectively.

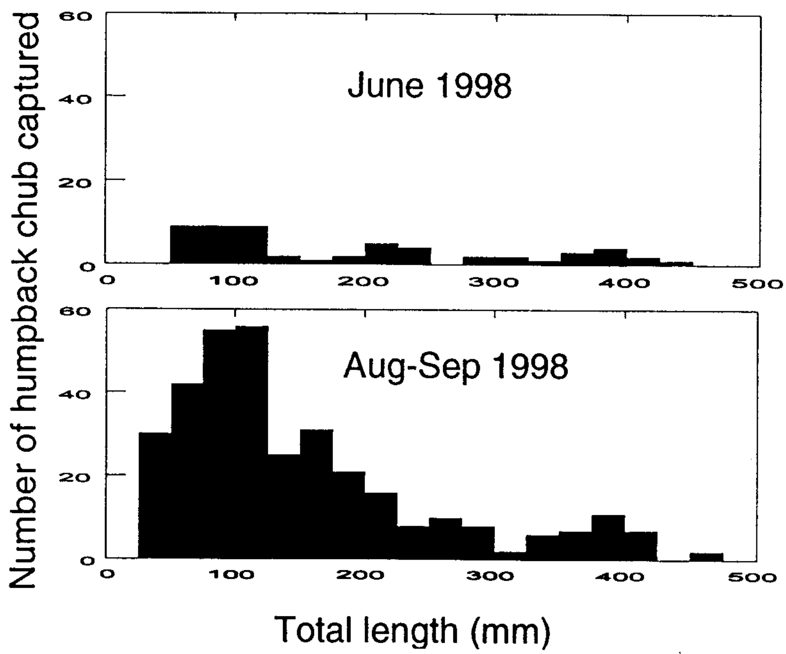


FIGURE 2. Length frequency histograms of humpback chub captured with all gear types in the Colorado River and confluence area of the Little Colorado River during monitoring trips in 1998.

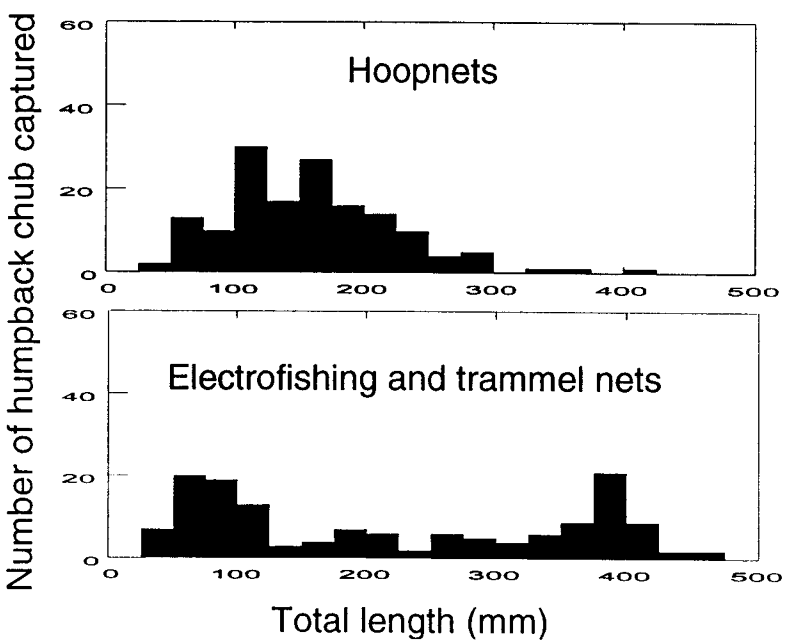


FIGURE 3. Length frequency histograms of humpback chub captured with hoopnets versus electrofishing and trammel netting in the Colorado River and confluence area of the Little Colorado River during monitoring trips in 1998.

*Stage fluctuations.*-During both trips, daily stage fluctuations ranging from 48–100 cm were measured at mainstem Colorado River sites. This diel stage fluctuation appeared to lower the utility of backwaters and vegetated shorelines as fish habitat and macroinvertebrate production areas. During daily low flows, backwaters were largely dewatered and available cover for juvenile fish was diminished along vegetated shorelines as water levels dropped below the vegetation.

*Food base studies.*-Cooperative food base studies with Dr. Blinn/NAU were addressed by collection of fish tissue samples from mainstem Colorado River and tributary sites for stable isotope analysis. Water quality parameters including temperature, dissolved oxygen, conductivity, pH, turbidity and Secchi depth were monitored at all sampling sites.

*Fish health assessment.*-During Trip 1, fish health samples were taken from 116 fish collected between Lee's Ferry and Diamond Creek. Species examined included speckled dace, humpback chub, rainbow trout, fathead minnow, bluehead sucker and plains killifish. Asian tapeworms (*Bothriocephalus acheilognathi*) were confirmed from fish collected from the Little Colorado River, but no anchor worms (*Lernaea cyprinacea*) were found in any fish examined. High numbers of Costia (*Ichthyobodo*) were found on moribund and trapped fish from Kanab Creek. The high infection level of Costia observed in Kanab fish may well contribute to increased summer mortality as water temperature increases and dissolved oxygen level decreases.

During Trip 2, 122 speckled dace from Bright Angel, Shinumo, Kanab, and Havasu creeks were collected for fish health samples. All fish were preserved in 10% formalin, except 35 live speckled dace from Havasu Creek that were delivered to Jerry Landye, who met us at Diamond Creek. Due to flash flooding, Diamond Creek was not sampled.

No anchor worms (*Lernaea cyprinacea*) were seen on any speckled dace. Asian tapeworms were observed in 8 of 39 fish from Kanab Creek. A nematode was found in the intestinal tracts of 3 of 25 speckled dace from Shinumo Creek, 16 of 35 dace from Havasu Creek and not observed in samples from Kanab and Bright Angel creeks. White grubs (*Posthodiplostomum* spp.) were found in the mesenteries of 4 of 39 speckled dace from Kanab Creek and 4 of 35 dace from Havasu Creek. During the external exam of the moribund dace from Havasu Creek, light infections of *Gyrodactylus* were present on skin and gills, and *Chilodonella* were observed on the gills. Viral and bacterial analysis from samples taken from Havasu Creek are being processed at the Pinetop FHC.

## Activities at Willow Beach National Fish Hatchery

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Construction of a laboratory facility at Willow Beach National Fish Hatchery (WBNFH) to conduct experimental growth and swimming performance studies commenced on 15 December 1997. An 800 square foot facility was completed by 1 July 1998 and operational by 9 October 1998. On 5 May 1998, 48 humpback chub were transported via helicopter to WBNFH to constitute a broodstock to produce fish for experimental studies. These fish arrived in excellent health, but subsequent disease problems depleted the stock by 5 July. An experimental stock of ~400 wild young-of-the-year (YOY) humpback chub (30-40 mm TL) were transported via helicopter from the Little Colorado River to the hatchery on 30 July 1998. Prior to transport, protocols for maintaining fish in the hatchery were revised. With the exception of a small loss of fish due to incorrect administration of an antiseptic agent, most of these fish have thrived at the hatchery. These YOY fish are being used to conduct temperature-growth studies during FY99.

## Summary of Fish Health and Parasitology Studies

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Section 1. AGFD.-Young-of-the-year humpback chub obtained during the August-September mainstem monitoring and research trip were examined for parasite infection, abdominal fat, and condition factor (K) as a measure of health during the fall research trip, as has been done as part of monitoring of the humpback chub population in Grand Canyon since 1996 (Hoffnagle et al. 1998a; b). Abdominal fat was measured using a scale modified from Goede (1993), where percentage of the internal organs covered by fat is estimated: 0 = 0%; 1 = 1-25%; 2 = 26=50%; 3= 51-75%; 4= 76-100%. Fish were examined for the presence of two species of parasites: the external parasite

*Lernaea cyprinacaea* (Copepoda) and the gastrointestinal parasite *Bothriocephalus acheilognathi* (Cestoda). These parasites have been shown to infect humpback chub more than other species and are contracted in the Little Colorado River (Brouder and Hoffnagle 1997; Hoffnagle and Cole 1998). Nineteen fish from the Little Colorado River and 16 from the Colorado River were examined.

For the 19 fish examined from the Little Colorado River, mean fish length was 56.2 mm TL, mean weight was 1.09 g, TL ranged from 51-63 mm, and weight ranged from 0.8-1.5 g. Mean K was 0.61 and K ranged from 0.54-0.68. Abdominal fat score in these fish ranged from 0-1 (0-25% coverage), with 13 of 19 (68.4%) having no visible abdominal fat. Only one humpback chub was infested with *Lernaea* and that fish harbored only one individual parasite. *B. acheilognathi* were found in six fish (31.6%).

For the 16 fish examined from the Colorado River, mean fish length was 61.75 mm TL and ranged from 41-87 mm - one fish was 129 mm. Mean weight was 6.12 g and ranged from 1.7-18.0 g; however, failure of the scale meant that only 5 of 6 fish were weighed. Mean K was 0.80 and ranged from 0.75-0.84. Mean abdominal fat score was 1.75 and scores ranged from 1-3 (1-75% coverage): 43.8% (7) had fat scores of 1; 37.5% (6) scored 2; 18.8% (3) had a score of 3. No humpback chub from the Colorado River were infested with *Lernaea* and two fish (12.5%) were infected with *B. acheilognathi*.

These results are similar to those reported previously by Brouder and Hoffnagle (1997), Clarkson et al (1997), Hoffnagle and Cole (1998) and Hoffnagle et al (1998a; b). In general, humpback chub from the mainstem Colorado River are healthier (i.e., higher K, more body fat and less parasites) than those from the Little Colorado River. This year, however, *Lernaea* prevalence was lower than in previous years, with only one of 35 fish being infected. In comparison, in 1997, 37.5% and 6.7% of the LCR and Colorado River fish, respectively, were infested. We speculate that the low infestation rate in 1998 is due to hydrographic conditions in the Little Colorado River. There was a prolonged spring flood and an early monsoon-flooding season, which may have limited the available time for *Lernaea* to complete its life cycle. *B. acheilognathi* infection rate was also lower (78.6% and 50% in 1996 and 1997, respectively) and may also reflect the protracted flooding and associated cooler water temperatures.

Section 2, USFWS.-During mainstem monitoring and research trips in June and August-September, 1998, fish health samples were obtained from 238 individual fish in the Colorado River and its tributaries from the Little Colorado River downstream to Diamond Creek, Arizona. Speckled dace were targeted as surrogate species for the endangered humpback chub for this study. Thus, speckled dace comprised 93% of the collections made, while flannelmouth suckers, bluehead sucker, fathead minnow, plains killifish, rainbow trout and humpback chub comprised the remaining 7% fish sampled. Non-lethal fish health samples were taken from four chubs; one moribund chub was sacrificed for a complete set of viral, bacterial, and parasitic samples. Most fish were obtained from the Little Colorado River, Bright Angel, Shinumo, Havasu, and Diamond creeks, but some came from shoreline areas along the Colorado River.

No anchor worms, *Lernaea cyprinacea*, were found in any fish sampled, but anchor worms were observed during fish monitoring activities at the confluence of Kanab Creek and the Colorado River. Asian tapeworms (*Bothriocephalus acheilognathi*) were found in specked dace and fathead minnow specimens from the Little Colorado River and in speckled dace specimens from Kanab Creek. Number of tapeworms per fish ranged from two to six in Little Colorado River specimens and one to two tapeworms from Kanab Creek speckled dace specimens. Infection rate from speckled dace from the Little Colorado River was 27%, while Kanab Creek was 21%.

High numbers of *Ichthyobodo (Costia)* were found on moribund and captured fish from Kanab Creek. In hatchery situations, this level of infection is normally considered basis for treatment to prevent mortality. This parasite was found only in Kanab Creek. Other parasites found in the study area include the protozoan *Trichodina* and the trematodes *Gyrodactylus* and *Posthodiplostomum*.

Although no viral agents have been detected in any samples obtained, several different types of bacteria were found. They include motile *Aeromonas*, *Pseudomonas*, *Staphylococcus*, and *Shigella*. Other gram positive rod-type bacteria were present but were not specifically identified. None of these bacteria were U.S. Fish & Wildlife Service fish health policy listed bacteria, however, under certain conditions could cause epizootic infections.

While care was taken to obtain the bacterial samples from kidney tissue only, the small size of the fish made this task difficult. Some bacterial contamination of these samples could have occurred from contact with other fish tissues.

Due to logistic constraints, the Paria River has not been sampled. Plans are being made to collect fish health samples from this stream in the future.

Another portion of the study is to review existing gray and published literature. While most of the study thus far has focused on field collections, gray literature has been reviewed from such agencies as U.S. Fish & Wildlife Service, U.S. Bureau of Reclamation, Arizona Game & Fish Dept., Museum of Northern Arizona, and consulting groups such as Bio/West Inc. and S. W. Carothers & Associates, Inc. Also, many journals have been reviewed and pertinent articles were noted. Literature searches and summaries will be continued during the winter.

## Little Colorado River Food Base and Stable Isotope Analysis

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### Introduction

The Little Colorado River is critical habitat for the continued existence of the endangered cyprinid, humpback chub in the Grand Canyon (U. S. Fish and Wildlife Service 1994). The Little Colorado River and the mainstem around the confluence is the site of the largest aggregation of humpback chub below Glen Canyon Dam. The importance of the Little Colorado River to the life history of these fishes in the Grand Canyon is two-fold. One, it is the location of a resident population of humpback chub (Douglas and Marsh 1996); two, it provides important warm water spawning habitat (Kaeding and Zimmerman 1983, Gorman and Stone in press, Douglas and Marsh 1996), not found in the mainstem due to the metalimnetic releases from Glen Canyon Dam. Adult humpback chub from the mainstem Colorado River migrate into the Little Colorado River to spawn and move out again after spawning (Douglas and Marsh 1996, Valdez and Ryel 1995, Gorman and Stone in press). Spawning success is thought to be low in the mainstem Colorado River and humpback chub that drift into the mainstem from the Little Colorado River may have low survival due to thermal shock (Kaeding and Zimmerman 1983, Lupher and Clarkson 1994). The fate of YOY humpback chub that survive drifting into the mainstem is unclear. Cold temperatures may limit growth and cause thermal shock, which may contribute to high losses to predation (Lupher and Clarkson 1994, Valdez and Ryel 1995). Food may also be a factor contributing to the survival of these fish. Little is known about the diet of sub-adult humpback chub in either the mainstem or the Little Colorado River. Kubley and Cole (1979) speculated that food might be limited in the Little Colorado River because of high travertine deposition. Valdez and Ryel (1995) showed that adult humpback chub from the mainstem Colorado River fed on the amphipod *Gammarus lacustrus*, simuliids, and chironomids as well as terrestrial insects. They also speculated that because sub-adult humpback chub use shoreline talus, boulders and vegetation rather than mid channel habitats food could be limiting to these size classes in the mainstem. The dependence on terrestrial insects is confusing since numbers of terrestrial insects in drift samples from the mainstem are low (Shannon et al. 1996). The diet of the smaller size classes of humpback chub is important to understanding the ecological limitations of these fish. No studies to date have described the diet requirements of young humpback chub either in the mainstem Colorado River or in the Little Colorado River.

Stable isotopes of carbon, nitrogen and other elements have been cited as good tools for identifying the source of energy in food webs (Rosenfield and Poff 1992, Barrie and Prosser 1993, Parker et al. 1993 and Schell and Ziemann 1993). Dietary studies based on stomach content and volume are biased by variable rates of digestion for specific food items (Barrie and Prosser 1993, and Parker et al. 1993). These studies may exaggerate the importance of food items that are large and easy to count in gut contents or have indigestible body parts. Small food items that are quickly digested may not appear in gut content analysis although their overall contribution to the diet of the study organisms may be great. Stable isotope analysis eliminates these types of biases by measuring the isotopic signal of the tissue of the study organism; measuring only the signal of food items that have actually been assimilated into the organism. These signals then can be tracked back to the available food items in the system to show the relative importance of specific energy sources (Angradi 1994).

This project has two main objectives. The first is to estimate the standing crop and seasonal availability of the aquatic benthos in this system, which is the likely source of energy for the system. The second is to describe the food resources of the humpback chub in the LCR using stable isotope techniques. Information from this research will be used to develop understanding of the Little Colorado River ecosystem and the resources that it provides to the resident and transient humpback chub population. An understanding of these resources will help managers to better understand the ecology of native fishes that depend on the Little Colorado River for portions of their life history. In addition, the stable isotope analysis of the diet of humpback chub found in the Little Colorado River will be incorporated into a stable isotope project being conducted by the Northern Arizona University Colorado River Food Base monitoring lab. The objectives of this project are to describe a food web for the greater Grand Canyon Ecosystem. Methods developed during this project for non-lethal sampling of stable isotopes in endangered fishes will be employed in future monitoring and research of these fishes.

## Methods

The benthos and aquatic drift of the Little Colorado River were sampled at two different sites (Fig. 1). The first site is above the Atomizer/Chute Falls complex at river kilometer 14.5. This site has low densities of humpback chub either due to high concentrations of dissolved $CO_2$ or because the falls act as a physical barrier to upstream migration. The small bodied speckled dace and fathead minnow are the only fish consistently caught in this area. The second site in the Little Colorado River is located at river kilometer 10.5 near Salt Canyon. This site has high densities of humpback chub and other fish. Dissolved $CO_2$ concentrations are often substantially lower in this area compared to the previous site. By comparing benthic standing mass and drift of the two sites, comparisons can be made as to the effect of $CO_2$ level and possibly the effect of fish density on aquatic benthos. One other site in Salt Creek, a tributary of the Little Colorado River was sampled. This site was chosen to provide information on the influence that the many springhead systems may have on the aquatic food base. Because these springs are not subject to high levels of suspended sediments on a regular basis they may provide a source for recolonization of the Little Colorado River after high flows. Springs may also directly contribute food to fish within the Little Colorado River as drift.

Hard benthic substrates were sampled using a Surber sampler. Six samples were taken at each site (3 in Salt Creek). Substrates were scraped for 30 s with a metal trowel to remove benthos. Depth and water velocities were recorded for each sample. Soft sediments in the Little Colorado River were sampled using a petite Ponar dredge. Six samples were collected along two transects running perpendicular to the shoreline. The three samples at each transect were taken with increasing distance from the shoreline to the thalweg. Depth and relative distance from shore were recorded for each sample. Additional invertebrate samples from soft and hard sediments were taken for taxonomic purposes.

Both fine particulate organic matter (FPOM) and coarse particulate organic matter (CPOM) drift were sampled. Both collections were made in triplicate at surface level. CPOM was collected in a rectangular 0.14 $m^2$ 0.5 mm mesh net. FPOM was collected in a 0.3 m diameter net with a 153 μm mesh. FPOM in Salt Creek tributary was collected with a 0.14 m diameter net with a 153 μm mesh because of the shallow depths at this site. Velocity for each sample was collected with a Marsh-McBirney electronic flow meter.

All CPOM and benthic samples were sorted live within 48 hrs of collection. Samples were sorted into 10 different categories including: annelid worms, tubificid worms (oligochaetes), simuliids, chironomids, gastropods, miscellaneous macroinvertebrates, *Cladophora glomerata*, cyanobacterial crust, detritus and miscellaneous algae, macrophytes and bryophytes. Samples were dried and weighed then converted to ash-free-dry-mass using regression equations.

FPOM samples were stored in 70% ETOH and sorted in the laboratory using a dissecting scope. Samples were sorted into the following categories: Copepoda, Cladocera, Ostracoda, miscellaneous invertebrates and detritus. Samples of invertebrates were dried and weighed then converted to ash-free-dry-mass using regression equations. Detrital ash-free-dry-mass was determined by combustion for 1h at 500°C.

Selected water quality parameters were measured to characterize each sampling site. Dissolved oxygen (mg/l) and temperature (°C) were determined using a YSI handheld DO meter. $CO_2$ was measured using a HACH field titration kit or a handheld $CO_2$ meter. Water samples were collected and stored on ice for determination of total alkalinity (mg CaCO3 by titration), specific conductance (µmho), turbidity (NTU), pH, and suspended particulate matter (mg/l) in the laboratory.

Stable isotope samples were dried in the field and the lab. Each sample was ground to a fine powder with a Whirl-a-bug amalgam shaker, weighed and sent to Institute of Ecology, University of Georgia, Athens for analysis.

Statistical analysis for benthic data was analyzed using natural logarithm transformed data to improve homoscedascity. Specific patterns were detected using MANOVA techniques in Systat 5.2.1 for the Macintosh (Systat, Inc. 1992).

## Results

The data in this report are preliminary dry-mass estimates of benthic standing crop. Final analysis will be based on ash free dry-mass estimates. These data represent two collecting trips in the Little Colorado River during 1998. A preliminary trip was made for stable isotope collections and selection of sites for benthic collections. Preliminary analysis were made in an effort to show trends detected during the first months of this project and may change as sampling effort is extended through more seasons and hydrologic conditions.

*Water Quality.*-Specific conductance and $CO_2$ concentrations where high at benthic collection sites in the Little Colorado River during base flow in June 1998 (Table 11). Both parameters where diluted by high flows from storm runoff in August 1998. Specific conductance decreased to 2.719 μS and 3.078 μS at Chute Falls and Salt Canyon sites respectively during runoff, while $CO_2$ concentrations decreased to 38.71 mg/L at Salt Canyon during storm runoff. Secchi depth also decreased at both sites to <1 cm during high flow.

Salt Creek water quality parameters where unaffected by high flows originating high in the Little Colorado River basin. Specific conductance of Salt Creek was generally higher than sites in the Little Colorado River while $CO_2$ concentrations where generally lower than at the Chute Falls site in the Little Colorado River during base flow conditions (Table 11).

*Benthic Standing Mass Estimates and composition.*-Preliminary multivariate analysis of variance of dry weights for specific biotic categories showed significant responses by trip and site (Table 12). Chute Falls site had the highest mass of cyanobacterial crust (*Oscillatoria* spp.) with 264.9 g/m2 dry weight (SE = 66.3) during base flow in June 1998. Dry mass of cyanobacterial crust declined during high flows in August 1998. Benthic detritus increased during high flows in August 1998; however, this increase is probably a sampling artifact since drifting detritus was captured by the open net of the Surber sampler. Miscellaneous algae and macrophytes (MAMB) had the highest mass in the Salt Creek site during June 1998 (44.96 g.m-2 dry weight, SE = 9.7). Dry mass of benthic macroinvertebrates declined in August 1998. The highest dry mass estimates of macroinvertebrates was at the Chute Falls site in June 1998 (0.214 g.m-2 dry weight, SE = 0.055).

The benthic macroinvertebrate communities on hard substrate at sampling sites in the Little Colorado River were dominated by chironomids and a caseless caddisfly during June and August sampling trips. Occasionally, mayflies and commonly terrestrial invertebrates make up a portion of the standing mass on hard substrates. The terrestrial insects presumably are entrained in the drift and captured in the open net of the Surber sampler. The benthic algae are dominated by the cyanobacteria *Oscillatoria* spp. at sites in the Little Colorado River. The filamentous green alga *Cladophora* spp. was rare or not found at sampling sites in the Little Colorado River canyon. Soft substrates contained chironomids and a burrowing odonate (Anisoptera).

Composition of the benthic community in Salt Creek is different from the Little Colorado River. The benthic algae were mostly the chain forming, halophillic diatom, *Biddulphia* sp. The macroinvertebrate community consisted mostly of chironomids and a damselfly (Zygoptera). As in the Little Colorado River, terrestrial insects comprised a substantial portion of the benthic standing mass.

*Drift mass estimates and composition.*-Detritus and miscellaneous algae and macrophytes were the only variables tested that showed significant variation by trip or site (Table 13) for CPOM drift. Miscellaneous algae and macrophytes in drift samples were highest at the Salt Creek tributary site during both trips in 1998. Detritus mass was highest at the Chute Falls site during August 1998, reflecting entrainment during peak runoff. The mass of invertebrates in the CPOM drift was highest at the Chute Falls during August 1998 (0.0022 g.m-3 dry weight, SE = 0.0022) and did not vary significantly by trip date or site (Table 13). FPOM drift samples are currently being sorted and weighed for future analysis.

*Stable Isotope analysis of humpback chub diet.*-Samples of algae (*Oscillatoria*, *Cladophora*, *Biddulphia*) and benthic and terrestrial invertebrates in the Little Colorado River have been collected on each sampling trip. These samples represent food items that our surveys indicate may be available for higher trophic levels. Tissue samples have been collected from humpback chub and other fish from the Little Colorado River as well as the mainstem Colorado River and other tributaries thanks to the efforts of USFWS personnel. Due to opportunistic sampling of other native/nonnative fish in the Little Colorado River and other areas of the Grand Canyon ecosystem, we currently have more samples for analysis than originally planned. We plan to take advantage of these samples by expanding our analysis pending funding in FY99. All samples are currently being processed for shipment and mass spectrometer processing.

TABLE 11. Water quality parameters for Chute Falls (RKM 14.7), Salt Camp (RKM 10.1) and Salt Creek tributary sites in the Little Colorado River canyon for June 1998 collecting trip.

| Site | Chute Falls | Salt Camp | Salt Creek (trib) |
|---|---|---|---|
| Date | 6/6/98 | 6/7/98 | 6/7/98 |
| Time | 1430 | 1600 | 1715 |
| Flow (m3/s) | 6.5 | 6.5 | 0.06 |
| DO (mg/L) | 8.21 | 7.49 | 5.95 |
| PH | 6.9 | 7.1 | 6.0 |
| Secchi (m) | >2.5 | 1.1 | >0.5 |
| Turbidity (NTU) | 1.29 | 9.84 | 1.41 |
| CO2 (mg/L) | 237.00, SE = 1.76, N = 3 | 141.25, SE = 2.21, N = 4 | 173.00, SE = 12.73, N = 4 |

TABLE 12. Results of multiple analysis of variance (MANOVA) for benthic dry mass on hard substrates at sites in the Little Colorado River during collection trips in June and August 1998. The predictor variables trip date and site were analyzed with respect to response variables of dry weight (g.m-2) for (C) Cladophora, (D) detritus, (O) Oscillatoria crust, (G) miscellaneous green algae and macrophytes, and (M) macroinvertebrates on ln+1 transformed data. Overall Wilks' lambda was significant ($p < 0.00001$). Only significant univariate response variables are listed ($p < 0.04$).

| Source | Wilks' lambda | Approximate F-statistic | Degrees of freedom | P | Response variable |
|---|---|---|---|---|---|
| Site | 0.036 | 16.9 | 1040 | <0.0001 | D,O,G |
| Trip | 0.116 | 30.3 | 520 | <0.0001 | D,O,G,M |
| Site*Trip | 0.120 | 7.5 | 1040 | <0.0001 | D,O |

TABLE 13. Results of multiple analysis of variance (MANOVA) for CPOM dry mass in drift samples at sites in the Little Colorado River during collection trips in June and August 1998. The predictor variables trip date and site were analyzed with respect to response variables of dry weight (g.m-3) for (C) Cladophora, (D) detritus, (G) miscellaneous green algae and macrophytes, and (M) macroinvertebrates on ln+1 transformed data. Overall Wilks' lambda was significant ($p < 0.00001$). Only significant univariate response variables are listed ($p < 0.04$).

| Source | Wilks' lambda | Approximate F-statistic | Degrees of freedom | P | Response variable |
|---|---|---|---|---|---|
| Site | 0.005 | 27.1 | 818 | <0.0001 | D,G |
| Trip | 0.024 | 88.7 | 49 | <0.0001 | D,G |
| Site*Trip | 0.006 | 26.5 | 818 | <0.0001 | D,G |

**Paria River Native Fish Monitoring**

Timothy L. Hoffnagle, Research Branch, AGFD

## Introduction

The lower Paria River, Arizona, is an interesting stream because of its depauperate ichthyofauna. Despite the myriad of non-native fishes that have been captured in or near its confluence with the Colorado River, it commonly contains only two species of fish, both of which are native to the stream: flannelmouth sucker *Catostomus latipinnis* and speckled dace *Rhinichthys osculus*. This is probably due to the wide range of temperatures that it experiences and the severe flooding that it experiences nearly every year. Despite this, the Paria River is an important spawning stream for these two Colorado River native fishes (Arizona Game and Fish Department 1996a). Flannelmouth sucker use the Paria only seasonally for spawning and early rearing (Weiss 1993; Brouder and Hoffnagle 1997a; Thieme 1997; Weiss et al. 1998). Juvenile flannelmouth suckers will stay in the Paria as long as possible - usually until a flood flushes them out (Brouder and Hoffnagle 1997a; b). Speckled dace may be the only year-round residents of the stream, but their numbers are also susceptible to temporary reduction by severe flooding.

Spawning of flannelmouth sucker in the Paria River has been documented since the 1970's (Suttkus and Clemmer 1976; Carothers and Minckley 1981; Maddux et al. 1987; Weiss 1993; Thieme 1997). Although eggs and/or larvae have been regularly observed in the Paria River since 1993, no indication of recruitment of these fish into the adult population had been found prior to the 1996 year class (Weiss 1993; Arizona Game and Fish Department 1996a), which has survived longer than any other recent year class (Brouder and Hoffnagle 1997a; b; Thieme 1997). This was probably due to a drought-induced lack of flooding in the Paria River, which allowed larvae to remain in the warmer Paria, instead of being displaced into the colder Colorado River. In addition, unusually high flows in the mainstem Colorado River in 1996 created a large, warm pool in the mouth of the Paria which may have provided rearing habitat for young-of-the-year (YOY) fishes (Thieme et al. 1997). In 1997, 80 - 120 mm total length (TL) flannelmouth suckers were captured in the mouth of the Paria River - probably fish from the 1996 Paria River cohort (Brouder and Hoffnagle 1997b). In 1998, a few flannelmouth suckers 200 - 250 mm were caught in the mouth of the Paria, indicating that the 1996 year class may be recruiting into the adult population (S. Rogers, Arizona Game and Fish Department, personal communication).

Monitoring the Paria River fish population, particularly flannelmouth sucker, is an important component of monitoring the abundance and cohort size of native fishes in Grand Canyon. This report documents the results of Arizona Game and Fish Department Paria River fish monitoring for 1998.

**Study Site**

Ten standardized Arizona Game and Fish Department sites in the Paria River were sampled in the lower 4.8 km of the Paria River (Figure 4; Table 1) (Arizona Game and Fish Department 1996a). Length of the sites ranged from 15 - 85 m and usually spanned the entire stream. These sites have been sampled by Arizona Game and Fish Department since 1994 and previously by Weiss (1993). Of these, nine were classified as runs, while sites located at the confluence of the Paria and Colorado rivers, were classified as pool habitat (Bisson et al. 1982). This pool is created by the ponding of the Paria River by the mainstem Colorado River. Size (area and volume) of the pool depends largely on Colorado River discharge and antecedent flows of the Paria River which may scour or deposit sediments in the mouth. Locations of sampling sites are noted as distance (m) upstream from the confluence of the Paria and Colorado rivers.

**Methods**

Samples were collected monthly beginning in June 1998. My plan was to sample beginning with the onset of the spawning run (usually April or May), but there was no observed spawning aggregation at the mouth of the Paria River nor a run upstream (S. Rogers, Arizona Game and Fish Department, personal communication). However, spawning did occur in the Paria River, since young suckers were observed there on 17 May 1998 (P. Sponholtz, Arizona Game and Fish Department, personal communication) and I began sampling on 4 June 1998. Sampling dates within each month were chosen based on availability of volunteer help (see Appendix 1 for list of participants) and Paria River discharge: i.e., if the Paria River discharge exceeded approximately 40 cfs, it was deemed unsafe and infeasible to sample.

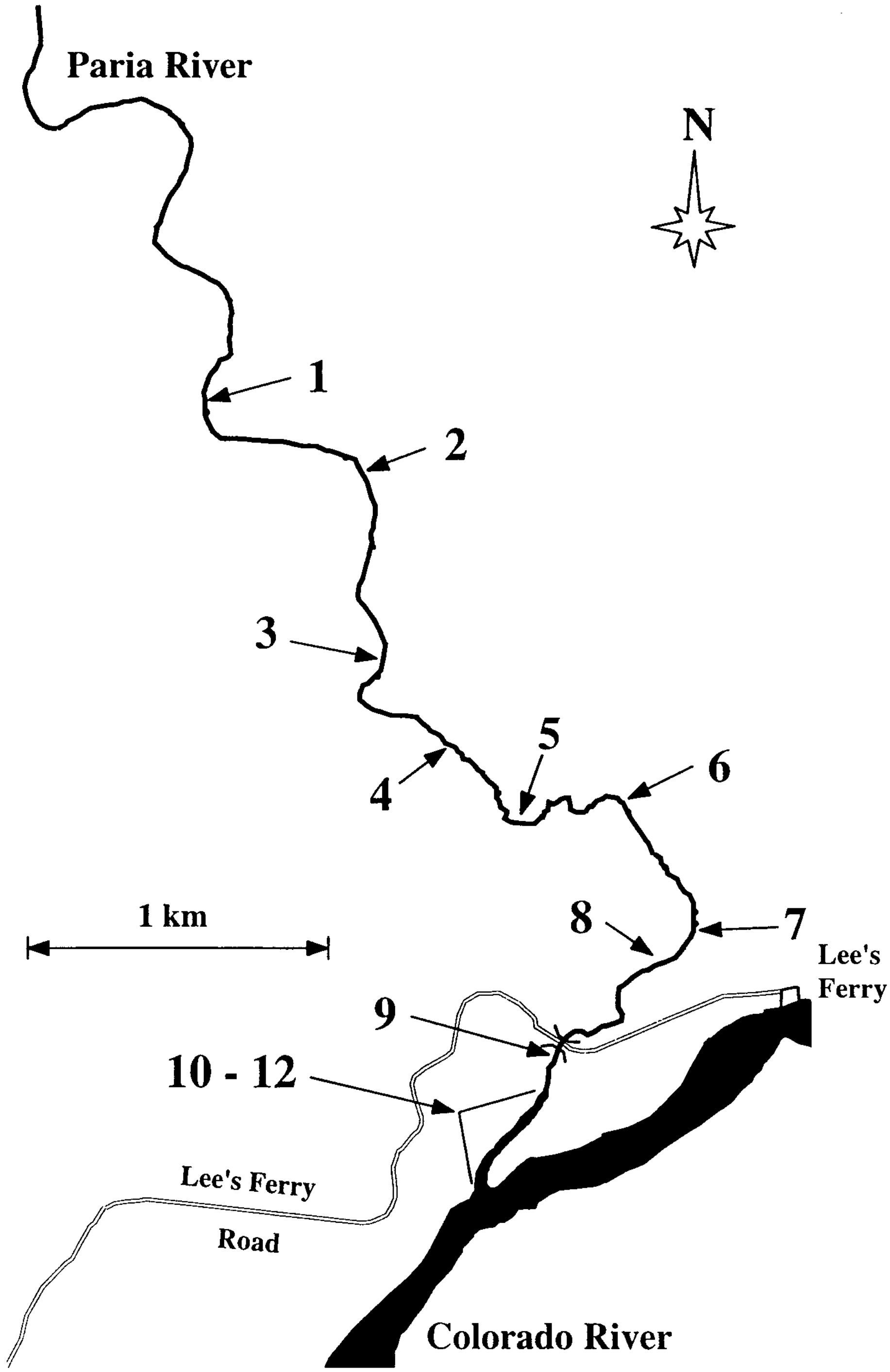


FIGURE 4. Sampling sites used by Arizona Game and Fish Department in the lower Paria River, Arizona (see Table 14 for description of sites).

TABLE 14. Site, location [distance (m) above the mouth] and description of sampling locations in the Paria River, Arizona.

| Site | Location | Description |
|---|---|---|
| 1 | 4.8 | "Devil's Diving Board" |
| 2 | 4.2 | 0.6 km downstream from "Devil's Diving Board" |
| 3 | 3.2 | 0.3 km upstream from Site 4 |
| 4 | 2.9 | Near abandoned ranch/corral site |
| 5 | 2.4 | ~ 35 m upstream from old water pump |
| 6 | 1.9 | USGS gauging station |
| 7 | 1.6 | Bedrock site, ~ 0.3 km upstream from Site 8 |
| 8 | 1.3 | ~ 90 m upstream from water pipeline |
| 9 | 0.8 | Bridge |
| 10-12 | 0 - 0.2 | Mouth of Paria River |

Habitat

Habitat data were recorded at each sampling site. Representative depth (cm), turbidity (NTU) and temperature (°C) were recorded from a representative location near the middle of each site. Maximum depth (cm) was recorded from the deepest point sampled within each site. Sediment was characterized (i.e., clay, silt, sand, gravel, pebble, cobble, boulder or bedrock) and primary and secondary sediment types were recorded for each sampling site. Stream velocity (cm/s) was also measured, when the instrument was available (November). Stream discharge data were obtained from the U.S. Geological Survey, Flagstaff, Arizona.

Fish

Fish were collected using one of two bag seines. The primary seine was 4.6 m long x 1.8 m high with a 3.2 mm nylon mesh on the wings and 1.6 mm mesh in the 1.8 x 1.8 m bag. This seine was used at all upstream sites (Sites 1-9) and occasionally at sites in the mouth of the Paria River. We usually used a larger bag seine when sampling the ponded mouth. This seine was 10 m long x 1.8 m high with 6.4 mm mesh on the wings and 3.2 mm mesh in the 1.8 x 1.8 m bag. The total surface area seined was estimated and recorded for each seine haul. Only one seine haul was made at each of Sites 1 - 9. In the mouth of the Paria River, three hauls were made at Sites 10 - 12, ranging from the mixing zone to 200 m upstream.

All fish captured were identified to species, measured for total length (mm), weighed (0.0 g) and released alive at the site of capture. Catch-per-unit-effort was calculated as the number of fish captured / 100 $m^2$ seined.

## Results and Discussion

### Habitat

*Discharge*.-The Paria River has a base flow of approximately 4 cfs, but is prone to severe flooding to over three orders of magnitude higher, particularly as a result of late summer monsoon rain storms. Spring discharge was relatively low and even, due to the prolonged, cool spring in 1998 (Figure 5). However, the monsoon season brought several spates between 6 July and 11 November; six exceeding 300 cfs and one that reached 5360 cfs.

Dramatic floods are probably the key to the ichthyofauna of the Paria River. Only species which evolved in such a dynamic system could withstand such conditions. Speckled dace appear to be particularly capable of withstanding these floods and/or quickly recolonizing the stream after being displaced. Flannelmouth suckers only use the Paria for spawning and early rearing. YOY suckers will stay in the Paria as long as possible (Thieme 1997; Brouder and Hoffnagle 1997a; b), but do not quickly recolonize after being displaced by flooding.

*Temperature*.-Temperature varied seasonally in the Paria River from a maximum of 32.2° C in July (Trip 98-2) to a minimum of 0.2° C in December (Trip 98-7) (Table 15). Temperature also varied daily with cooler temperatures being recorded in the morning with rapid warming through the day. The daily range of temperatures among trips ranged from 16.2° C in July to 4.6° C in November.

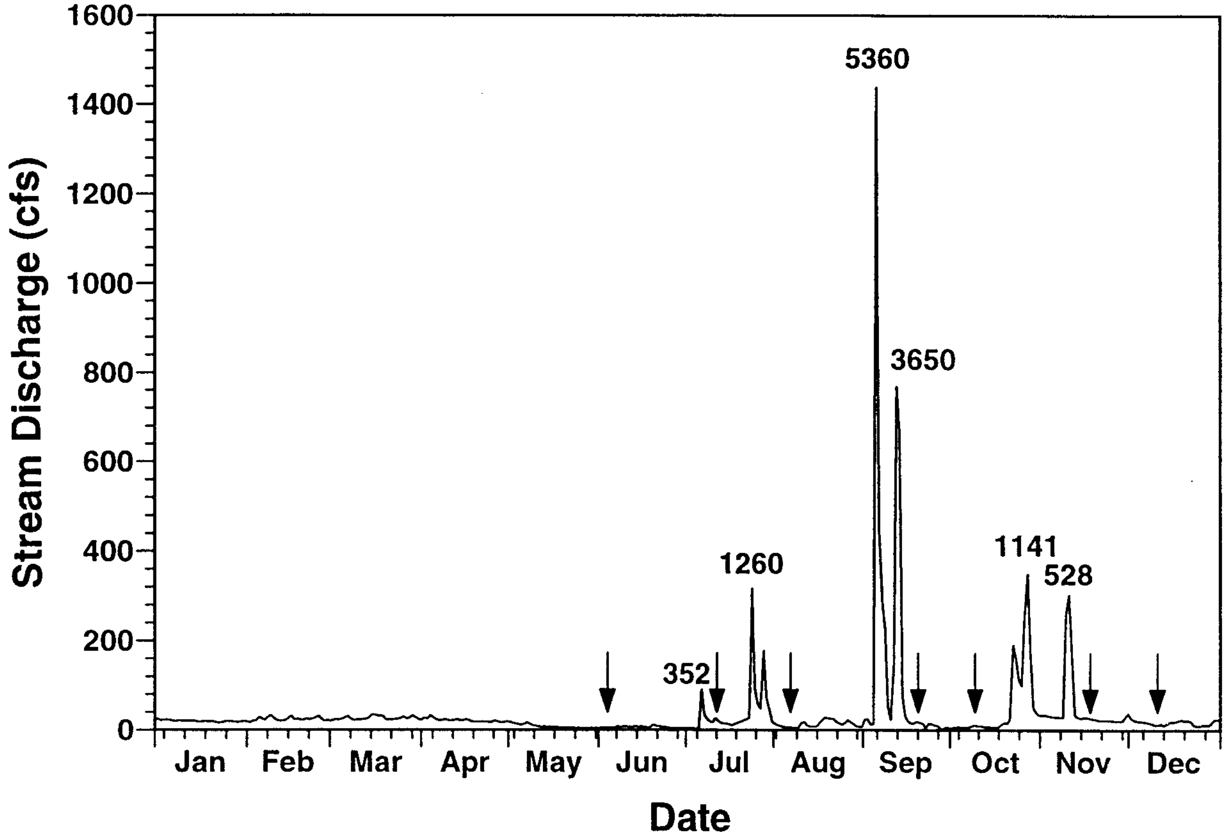


FIGURE 5. Mean daily discharge in the Paria River, 1998. Maximum discharge of flooding events is given above the peak. Arrows indicate sampling dates.

TABLE 15. Mean, minimum and maximum temperature (° C) at sites sampled on each trip during Arizona Game and Fish Department Paria River fish monitoring, 1998.

| Trip | Mean | Minimum | Maximum |
|---|---|---|---|
| June | 19.93 | 16.6 | 23.8 |
| July | 29.19 | 15.3 | 32.2 |
| August | 27.49 | 16.0 | 31.0 |
| September | 23.11 | 18.6 | 25.8 |
| October | 21.07 | 16.8 | 23.8 |
| November | 9.64 | 6.9 | 11.5 |
| December | 3.33 | 0.2 | 5.4 |

The wide, shallow character of the Paria and the open canyon in which it flows are conducive to wide fluctuations in water temperature. In the summer, the Paria River warms rapidly during the day, as evidenced by a 16.2° C temperature change over the approximately four hours that it took to sample all sites in July. Since our last temperature reading was taken at15:10, the maximum temperature and temperature range of the Paria River is undoubtedly higher. The converse is true during winter, when the stream cools rapidly at night. During the December sample, there was ice (2-3 mm thick) along shore and surrounding exposed rocks and frazil ice floating downstream. However, the ice melted by approximately 11:30 and water temperature increased from 0.2° C at 10:40 to 4.9° C at 13:50. Warmer temperatures (5.4° C ) were later recorded in the mouth where water from the Paria and Colorado rivers mixed.

*Turbidity*

In 1998, turbidity in the Paria River ranged from 22.9 NTU in June to 105,500 NTU in July (Table 16). Turbidity tends to be less in the ponded mouth of the Paria River, where the clear water of the Colorado River dilutes the sediment in the Paria and reduced velocity causes the fine sediment to precipitate.

Turbidity in the Paria River is mostly dependent upon flooding. At base flow, the Paria is a slightly turbid river, measuring approximately 30 NTU. The Paria River is an alluvial stream and drains 3730 $km^2$ of southern Utah and northern Arizona (Topping 1997). The Paria River is the second largest contributor of sediment to the Colorado River, delivering 23,000 tons of sediment / year (Andrews 1991). Turbidity appears to be used by native fishes as a form of cover - fish are more likely to be captured in shallow water at a turbidity of >30 NTU (Valdez and Ryel 1995; Arizona Game and Fish Department 1996a). Its characteristic high turbidity and high summer temperature may be a large factor in limiting the species diversity of the Paria River.

*Velocity.*-Velocity was only measured during November. Mean velocity for the 12 sites sampled was 50.9 cm/s and velocity ranged from 12 - 75 cm/s. Velocity in the Paria River is swift for larval fishes. However, it has a low base flow and, in places, a cobble/boulder substrate, making it easy for larvae to find slow water along shore or behind rocks.

TABLE 16. Mean, minimum and maximum turbidity (NTU) at sites sampled on each trip during Arizona Game and Fish Department Paria River fish monitoring, 1998.

| Trip | Mean | Minimum | Maximum |
|---|---|---|---|
| June | 36.52 | 22.9 | 81.0 |
| July | 96,630.00 | 16,800.0 | 105,500.0 |
| August | 161.39 | 67.1 | 186.0 |
| September | 469.78 | 217.0 | 645.0 |
| October | 109.93 | 85.1 | 142.0 |
| November | 1,371.67 | 1,270.0 | 1,448.0 |
| December | 327.42 | 195.0 | 442.0 |

TABLE 17. Mean, minimum and maximum representative depth (cm) and maximum depth (cm) at sites sampled on each trip during Arizona Game and Fish Department Paria River fish monitoring, 1998.

| | Representative Depth (cm) | | | Maximum Depth (cm) | | |
|---|---|---|---|---|---|---|
| Trip | Mean | Minimum | Maximum | Mean | Minimum | Maximum |
| June | 34.5 | 5 | 120 | 62.3 | 9 | 134 |
| July | 21.8 | 18 | 28 | 56.1 | 32 | 96 |
| August | 21.5 | 11 | 52 | 57.7 | 19 | 98 |
| September | 22.0 | 11 | 52 | 41.9 | 23 | 72 |
| October | 22.3 | 10 | 52 | 38.5 | 18 | 74 |
| November | 23.0 | 8 | 40 | 51.8 | 24 | 84 |
| December | 19.2 | 9 | 37 | 29.3 | 16 | 45 |

TABLE 18. Number of the sampled sites in which each sediment type was the primary or secondary sediment during each Arizona Game and Fish Department Paria River fish monitoring trip, 1998.

| | Sediment Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Trip | Clay | Silt | Sand | Gravel | Pebble | Cobble | Boulder | Bedrock |
| June | 0 | 10 | 11 | 1 | 0 | 0 | 0 | 0 |
| July | 0 | 7 | 10 | 2 | 0 | 1 | 0 | 0 |
| August | 2 | 6 | 9 | 4 | 2 | 0 | 0 | 1 |
| September | 2 | 7 | 10 | 3 | 2 | 0 | 0 | 0 |
| October | 3 | 6 | 9 | 5 | 0 | 1 | 0 | 0 |
| November | 2 | 7 | 10 | 2 | 1 | 1 | 0 | 1 |
| December | 2 | 5 | 10 | 5 | 1 | 1 | 0 | 0 |

*Depth.*-Representative and maximum depth of the sampling sites varied on each trip, largely due to variation in river discharge during the sampling period (Table 17). However, antecedent discharge also affects depth due to scouring and agradation of sites. Spring floods tend to be of lower volume and carry less sediment per volume of water than monsoon floods (Topping 1997). Mean representative and maximum depth of the sampling sites was greatest in June (Trip 98-1), following the spring floods. Conversely, the large monsoon flood in September changed the course of the stream in several sites and deposited loose sand in areas where there had been deep scour holes along bedrock banks.

*Sediment Characteristics.*-Sediment in the Paria River is primarily sand and silt (Table 18). In the ponded mouth, the sediment is primarily silt with clay and sand as secondary sediment types. Coarser sediment types, such as gravel and pebble sediments, tend to be found after flood events scour the finer sediments. The fine sediments return soon afterwards, with the return of lower flows.

Fish Collections

Six species of fish were captured during seven sampling trips in 1998 (Table 19). Three native species were captured: twp commonly captured species (flannelmouth sucker and

TABLE 19. Total catch and mean, minimum and maximum catch-per-unit-effort (CPUE; number caught / 100 $m^2$ seined) for each species caught on each trip during Arizona Game and Fish Department Paria River fish monitoring, 1998.

| | | CPUE (number / $m^2$ seined) | | |
|---|---|---|---|---|
| Species | Total Catch | Mean | Minimum | Maximum |
| Trip 98-1: 4 June 1998 | | | | |
| Flannelmouth Sucker | 53 | 3.643 | 0 | 18.421 |
| Trip 98-2: 9 July 1998 | | | | |
| Flannelmouth Sucker | 2 | 0.148 | 0 | 1.042 |
| Speckled Dace | 22 | 1.284 | 0 | 6.14 |
| Trip 98-3: 7 August 1998 | | | | |
| Flannelmouth Sucker | 5 | 0.792 | 0 | 6.25 |
| Speckled Dace | 6 | 0.601 | 0 | 4.412 |
| Golden Shiner | 1 | 0.149 | 0 | 1.786 |
| Trip 98-4: 19 September 1998 | | | | |
| Bluehead Sucker | 1 | 0.139 | 0 | 1.667 |
| Flannelmouth Sucker | 1 | 0.139 | 0 | 1.667 |
| Speckled Dace | 39 | 3.653 | 0 | 16.667 |
| Redside Shiner | 1 | 0.163 | 0 | 1.961 |
| Trip 98-5: 9 October 1998 | | | | |
| Flannelmouth Sucker | 3 | 0.313 | 0 | 3.75 |
| Speckled Dace | 21 | 1.605 | 0 | 5.556 |
| Trip 98-6: 19 November 1998 | | | | |
| Speckled Dace | 12 | 0.726 | 0 | 5.128 |
| Rainbow Trout | 1 | 0.103 | 0 | 1.235 |
| Trip 98-7: 11 December 1998 | | | | |
| Speckled Dace | 1 | 0.066 | 0 | 0.794 |
| Redside Shiner | 2 | 0.043 | 0 | 0.517 |

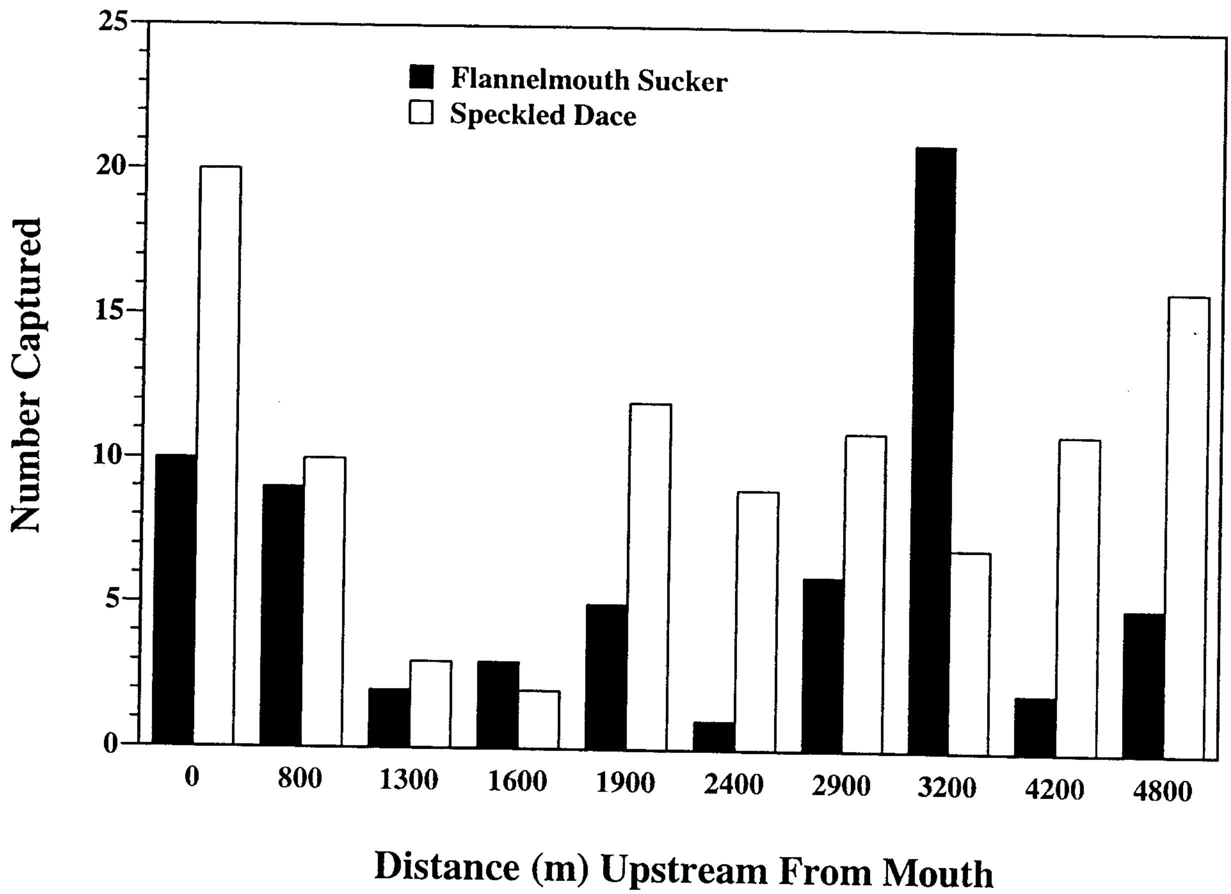


FIGURE 6. Number of flannelmouth sucker and speckled dace captured at each of the ten standard sampling sites during Arizona Game and Fish Department Paria River fish monitoring, 1998.

speckled dace) and bluehead sucker *C. discobolus* which is very rare in the Paria River. Three species of non-native fish were also captured: rainbow trout *Oncorhynchus mykiss*, golden shiner *Notemigonus crysoleucas* and redside shiner *Richardsonius balteatus*.

Flannelmouth sucker and speckled dace were commonly captured in all sampling sites (Figure 6). Rainbow trout were captured only from Site 9 (800 m upstream from the mouth). Bluehead sucker, golden shiner and redside shiner were only caught in the mouth of the Paria River. It is likely that high temperature, high turbidity and/or flash flooding keep numbers of non-native fish low in this stream.

*Bluehead Sucker*.-One bluehead sucker was captured in the Paria River in 1998. This adult (265 mm; 244 g) was captured in the mouth of the Paria River in September (Trip 98-4). This species is very rare in this region of the Colorado River. Another subadult/adult (146 mm; 30 g) bluehead sucker was captured 800 m upstream in the Paria River in February 1997 (Brouder and Hoffnagle 1997b). One hundred eleven juvenile (33 - 61 mm) bluehead suckers were captured in June 1994 (Figure 4) and may represent spawning by dispersing individuals.

Bluehead suckers are common in the Colorado River downstream from the Little Colorado River (60.6 river miles below the Paria River) where they spawn in all of the major tributaries and most of the smaller ones (Arizona Game and Fish Department 1996a). It is unknown why they are rare above the Little Colorado River. In the Paria River, it may be due to the predominance of fine, shifting sediments in this tributary. However, Nankoweap Creek (51.3 river miles below the Paria River) would appear ideal for bluehead suckers although none have been reported from there.

*Flannelmouth Sucker*.-Young-of-the-year flannelmouth suckers were captured at all sampling sites (Figure 6). Flannelmouth sucker catch was greatest in June, when 53 YOY were captured at a rate of 3.6 fish / 100 $m^2$ seined and many additional fish were observed in small sides channels and pockets of low velocity water (Table 19; Figure 8). These fish ranged in length from 18 - 36 mm and weighed from 0.1 - 0.4 g. (Tables 7 and 8). In July, three days after the first monsoon flood of the summer, only two YOY were captured and no more YOY were captured the remainder of the year. The lack of flannelmouth suckers in the Paria River in November and December may be due to the Paria being colder than the Colorado River at this time of year.

Adult flannelmouth suckers were captured in the mouth of the Paria River in August, September and October (Figures 3 and 5; Table 6). These fish ranged in length from 430 - 550 mm and in weight from 694 - 1614 g (Tables 7 and 8) and included several that were tuberculate, indicating the possibility of a fall spawning period for these fish. Tuberculate flannelmouth suckers were also captured in Havasu Creek in October (M. Douglas, Arizona State University, personal communication). Arizona Game and Fish Department (1996a) has documented fall spawning by bluehead suckers in Crystal Creek and I observed larval suckers in Crystal Creek in September and October 1998. It appears that some flannelmouth suckers may be induced to spawn in the

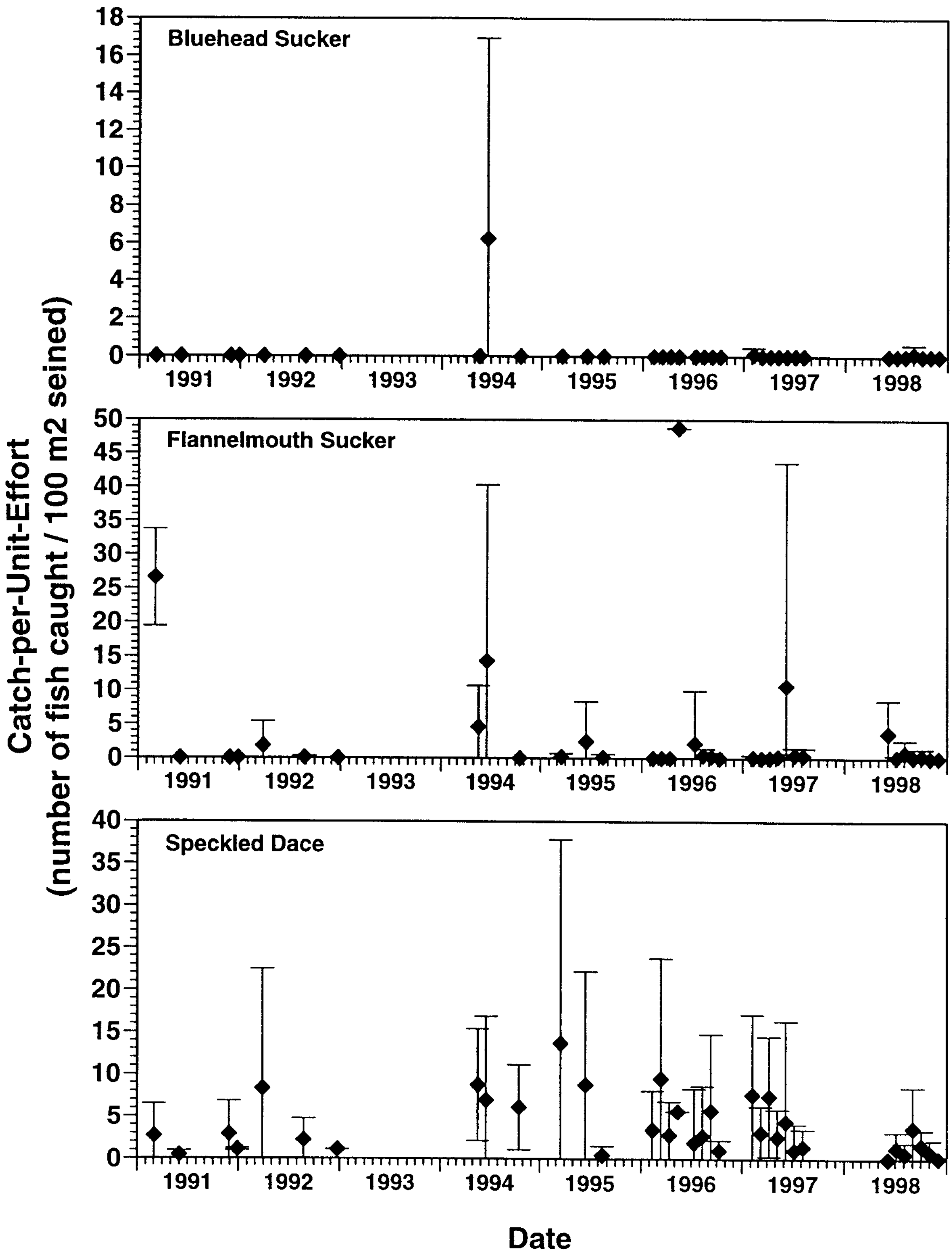


FIGURE 7. Mean (± 1 SD) CPUE of native fishes (bluehead sucker, flannelmouth sucker and speckled dace) caught on each sampling trip in the Paria River, Arizona, 1991-1998.

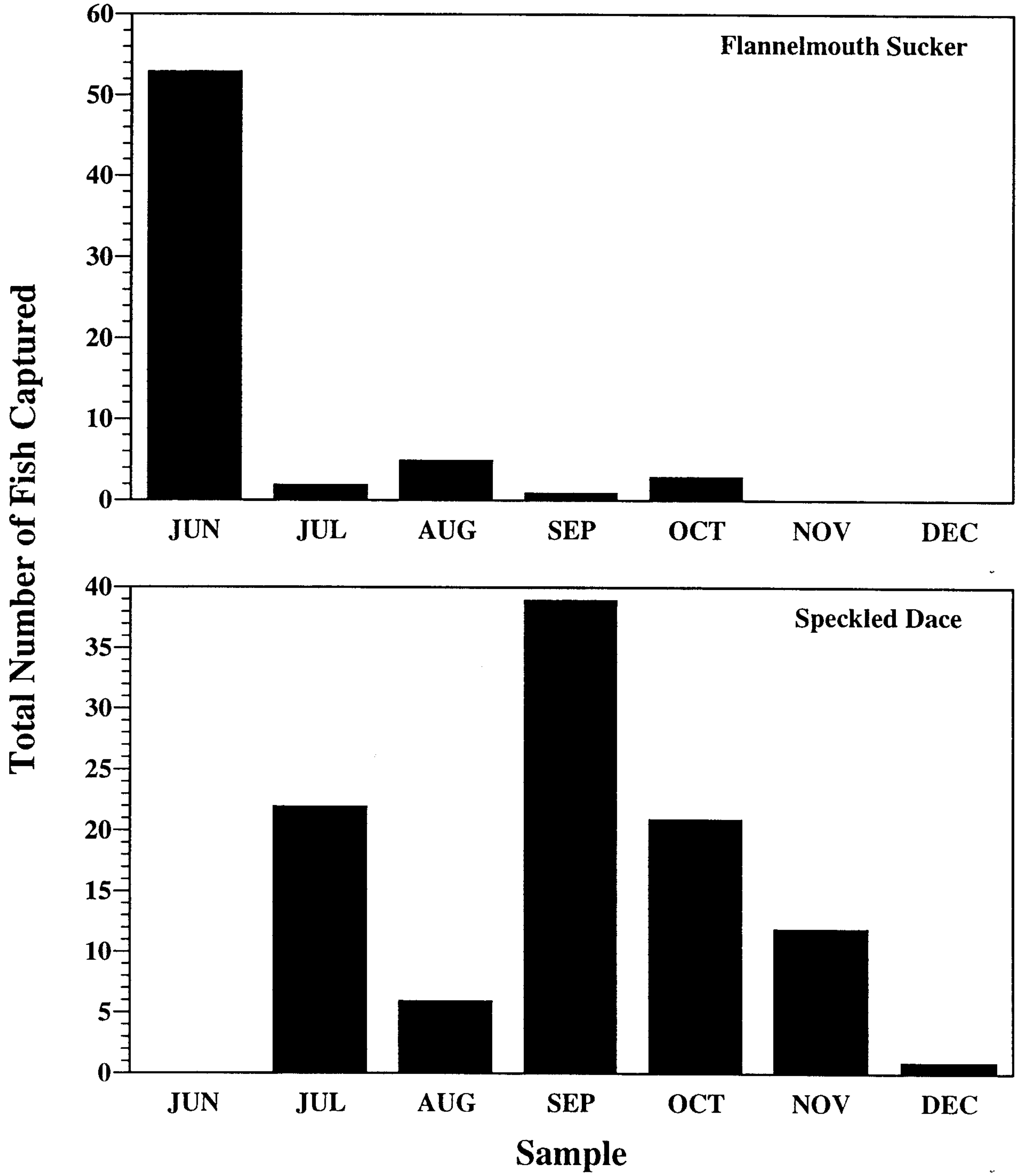


FIGURE 8. Number of flannelmouth suckers and speckled dace captured during each Arizona Game and Fish Department Paria River fish monitoring trip, 1998.

TABLE 20. Mean, minimum and maximum total length and weight of all species caught on each trip during Arizona Game and Fish Department Paria River fish monitoring, 1998.

| | Length (mm) | | | Weight (g) | | |
|---|---|---|---|---|---|---|
| Trip/Species | Mean | Min | Max | Mean | Min | Max |
| Trip 98-1: 4 June 1998 | | | | | | |
| Flannelmouth Sucker | 26.2 | 18 | 36 | 0.15 | 0.1 | 0.4 |
| Trip 98-2: 9 July 1998 | | | | | | |
| Flannelmouth Sucker | 35.0 | 32 | 38 | 0.35 | 0.2 | 0.5 |
| Speckled Dace | 36.4 | 20 | 82 | 0.70 | 0.1 | 4.1 |
| Trip 98-3: 7 August 1998 | | | | | | |
| Flannelmouth Sucker | 467.0 | 430 | 550 | 994.30 | 694.0 | 1614.0 |
| Speckled Dace | 67.3 | 37 | 96 | 3.67 | 0.3 | 7.3 |
| Golden Shiner | 65.0 | - - | - - | 2.40 | - - | - - |
| Trip 98-4: 19 September 1998 | | | | | | |
| Bluehead Sucker | 265.0 | - - | - - | 244.00 | - - | - - |
| Flannelmouth Sucker | 431.0 | - - | - - | 950.00 | - - | - - |
| Speckled Dace | 80.7 | 52 | 123 | 5.64 | 1.0 | 21.1 |
| Redside Shiner | 40.0 | - - | - - | 0.40 | - - | - - |
| Trip 98-5: 9 October 1998 | | | | | | |
| Flannelmouth Sucker | 479.0 | 433 | 519 | 1120.30 | 905.0 | 1310.0 |
| Speckled Dace | 82.6 | 46 | 120 | 2.60 | - - | - - |
| Trip 98-6: 19 November 1998 | | | | | | |
| Speckled Dace | 93.1 | 61 | 116 | 6.67 | 2.0 | 13.0 |
| Rainbow Trout | 112.0 | - - | - - | 13.00 | - - | - - |
| Trip 98-7: 11 December 1998 | | | | | | |
| Speckled Dace | 95.0 | - - | - - | 6.00 | - - | - - |
| Redside Shiner | 82.5 | 75 | 90 | 4.75 | 4.2 | 5.3 |

TABLE 21. Number of flannelmouth sucker and speckled dace of each length class captured on each trip during Arizona Game and Fish Department Paria River fish monitoring, 1998.

| Length | Flannelmouth Sucker | | | | | | | Speckled Dace | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Class (cm) | 98-1 | 98-2 | 98-3 | 98-4 | 98-5 | 98-6 | 98-7 | 98-1 | 98-2 | 98-3 | 98-4 | 98-5 | 98-6 | 98-7 |
| 1 | 1 | | | | | | | | | | | | | |
| 2 | 37 | | | | | | | | 8 | | | | | |
| 3 | 15 | 2 | | | | | | | 10 | 1 | | | | |
| 4 | | | | | | | | | 1 | 2 | | 1 | | |
| 5 | | | | | | | | | | | 5 | 2 | | |
| 6 | | | | | | | | | | | 3 | 4 | 1 | |
| 7 | | | | | | | | | 1 | | 10 | 4 | | |
| 8 | | | | | | | | | 2 | | 9 | 2 | 5 | |
| 9 | | | | | | | | | | 3 | 6 | 3 | 2 | 1 |
| 10 | | | | | | | | | | | 3 | 2 | 2 | |
| 11 | | | | | | | | | | | 2 | 2 | 2 | |
| 12 | | | | | | | | | | | 1 | 1 | | |
| 43 | | | 2 | 1 | 1 | | | | | | | | | |
| 44 | | | | | | | | | | | | | | |
| 45 | | | | | | | | | | | | | | |
| 46 | | | 2 | | | | | | | | | | | |
| 47 | | | | | | | | | | | | | | |
| 48 | | | | | 1 | | | | | | | | | |
| 49 | | | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | | | |
| 51 | | | | | 1 | | | | | | | | | |
| 52 | | | | | | | | | | | | | | |
| 53 | | | | | | | | | | | | | | |
| 54 | | | | | | | | | | | | | | |
| 55 | | | 1 | | | | | | | | | | | |

fall, as well. In all of these cases, the spawning fish have come from the mainstem Colorado River to spawn in a tributary. It may be that monsoon flooding induces this behavior, but this certainly warrants more investigation.

Thieme (1997) estimated that growth of YOY flannelmouth sucker in the Paria River was 0.52 mm / day. However, estimates based on wild fish can be misleading due to death of smaller fish, making growth seem faster than it really is. In the lab, flannelmouth sucker eggs hatched in 5-7 days at 18.5° C, the larvae were approximately 11 mm TL at hatching and grew at a rate of 0.31 mm / day at 20° C (Mike Childs, AGFD, personal communication). However, lab fish may not grow as fast as wild fish due to the ability of wild fish to feed at any time, whereas in the lab, fish can only feed when they are fed. Therefore, I estimated date of hatching based on a growth rate of 0.4 mm / day, which gave an estimated date of hatching between 2 April and 17 May 1998 and an estimated spawning date of 26 March - 10 May. This means that flannelmouth suckers probably spawned throughout the period of descending discharge in the Paria River. It appears from these data that the main spawning period occurred around 28 April based on the peak length class of 23 mm.

In 1996, the last year in which they were abundant, YOY flannelmouth suckers first appeared in samples during May (CPUE = 48.7 flannelmouth sucker / 100 m2 seined; Brouder and Hoffnagle 1997a). In 1998, we awaited word of spawning activity before beginning sampling. However, there was no observed spawning aggregation at the mouth of the Paria River nor a run upstream (S. Rogers, AGFD, personal communication). Discharge in the Paria River from 1 January through early June was typical of previous years (Graf et al 1991): spring 1998 air temperature was cool and mean daily discharge ranged from 20 - 35 cfs through early April, then steadily declined to base flow by the end of May (Figure 5). It is unknown why no spawning aggregation was observed this year. In the Little Colorado River, the cool spring and a prolonged runoff period extended the 1998 spawning period for all native fishes (Hoffnagle 1998). However, flannelmouth suckers may not require flooding or increasing water temperature for induction of spawning. Each spring flannelmouth suckers spawn on a gravel bar in the Colorado River approximately 5.4 miles upstream from the Paria (approximately 10.5 miles below Glen Canyon Dam). Due to the dam, there is little annual change in flow regime nor a change in water temperature in this area. Therefore, it is likely that photoperiod is a strong cue for spawning of flannelmouth suckers.

Flannelmouth sucker catch is highest in the spring, with the capture of spawning adults in the early spring and late spring/early summer YOY (Figure 7). All flannelmouth suckers captured after July 1998 were adults. The loss of the YOY suckers from the Paria River is likely due to monsoon floods which displace young fish into the Colorado River. High catches (4 - 50 fish / 100 $m^2$ seined) of YOY flannelmouth suckers occurred throughout 1996, when there were no floods until late in the summer (Brouder and Hoffnagle 1997a). Brouder and Hoffnagle (1997a) and Thieme et al. (1997) hypothesized that a lack of flooding and the presence of a ponded mouth permitted YOY flannelmouth suckers to rear in the Paria River throughout the summer of 1996 and Thieme (1997) later attributed this primarily to the presence of a ponded mouth. Results from 1998 sampling suggest that the lack of flooding may have been the primary factor. The Colorado River discharge has been higher than normal throughout 1998, significantly ponding the mouth of the Paria River. Flooding occurred in the Paria River this year and catches of YOY flannelmouth suckers were greatly reduced or absent after these events, even in the ponded mouth. At a minimum, it appears that this year's pool was an insufficient buffer to prevent young fish from being displaced by late spring floods into the Colorado River.

*Speckled Dace*.-Speckled dace were captured in the Paria River on all 1998 sampling trips, except in June (Figure 8; Table 19) and at all sampling sites (Figure 6). Mean CPUE for this species ranged from 0.1 - 3.7 fish / 100 $m^2$ seined, in December and September, respectively. Speckled dace ranged in length from 20 - 123 mm and in weight from 0.1 - 21.1 g (Table 20). Both YOY and adult speckled dace were captured (Table 21).

Speckled dace are the most abundant fish in the Paria River and they use this stream, at least throughout the period in which it is warmer than the Colorado River. Only one speckled dace was captured during December and that was caught in the mouth. Surprisingly, no speckled dace were captured in June. This was likely due to one, or both, of two reasons. First, larger speckled dace were probably able to evade the net in the clear, shallow water, and several larger fish were observed darting ahead of the net. Secondly, it was probably too early in the season for larval speckled dace to be present. In 1996 and 1997, YOY speckled dace appeared in the catches by late May (Brouder and Hoffnagle 1997a; b). However, it is likely that speckled dace also spawned later than usual in 1998, due to a late and prolonged spring flood, which is a spawning cue for this species (John 1963). Most of the speckled dace captured during July were YOY, indicating a successful spawn after or just prior to the June sampling period. John (1963) also noted that spawning was cued by monsoon floods in the Chiricahua Mountains, Arizona, which has not been noted in the Paria River.

Speckled dace also appear to be affected by flooding. Catches tend to be highest from late spring through summer (Figure 7). The August sample occurred in the middle of the monsoon flood period and only 6 speckled dace were captured (only two came from above the mouth). However, in contrast to flannelmouth sucker, speckled dace recolonized the Paria soon after flooding. By the September trip (13 days following the largest flood of the year; approximately 6,000 cfs), the speckled dace abundance reached its highest of the year (39 fish; 3.7 fish / 100 $m^2$ seined). It is unknown whether these fish withstood the flood, recolonized from the Colorado river or were flushed downstream from upper reaches of the Paria.

Speckled dace may not occupy the Paria River year-round, as was previously thought. During December, no dace were caught above the mouth and only one was caught in the mouth. Ice was present in the Paria as sampling began and water temperature was 0.2° C at the first site. The Colorado River is a nearly constant 8 - 10° C year-round. It is plausible that speckled dace leave the colder Paria for the relatively warmer Colorado when temperatures drop below their thermal preference.

*Golden Shiner*.-One golden shiner was caught in August (Table 19). This fish was 65 mm long and weighed 2.4 g (Table 20). Golden shiners have also been caught in 1996 in the mouth of the Paria (Figure 9).

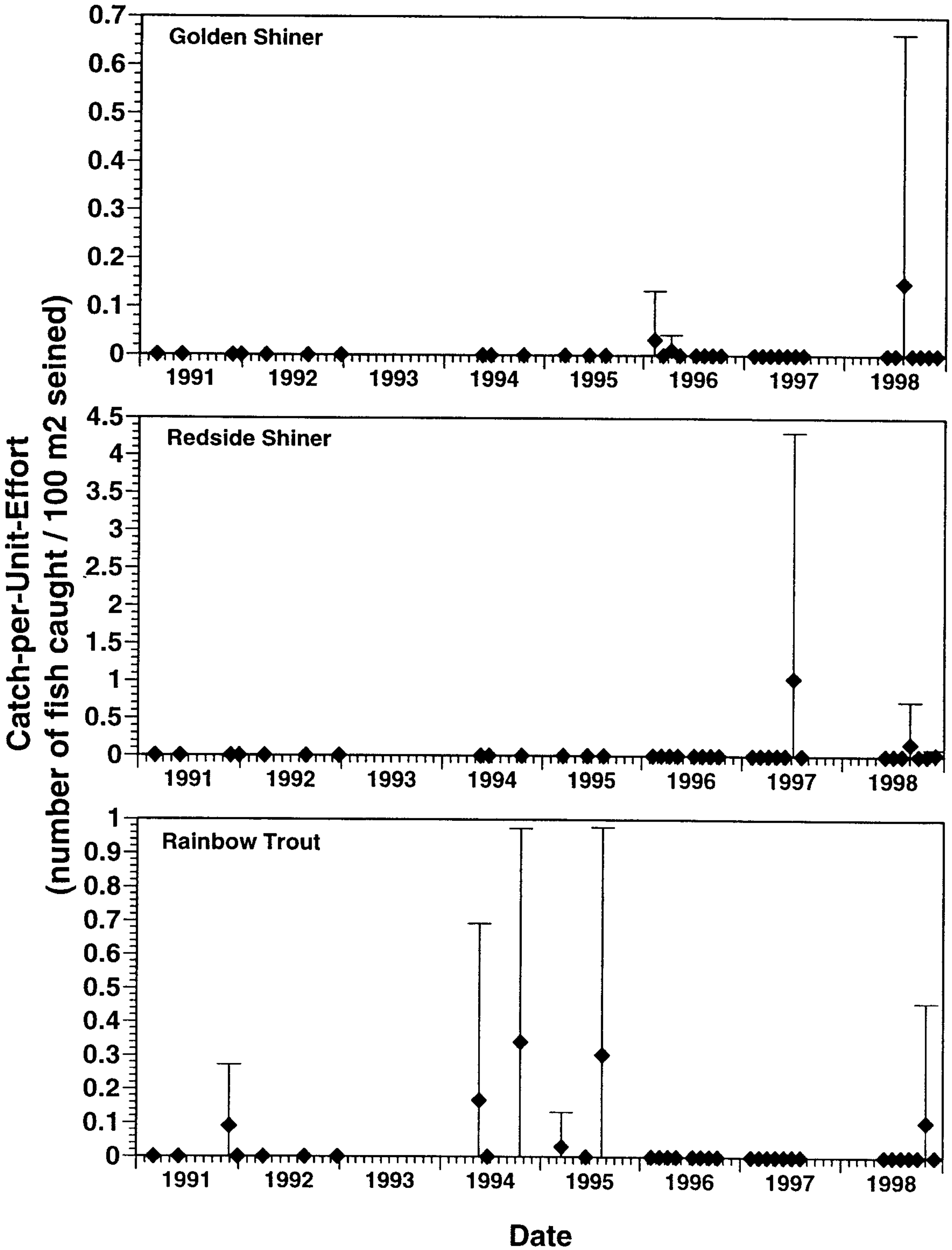


FIGURE 9. Mean (± 1 SD) CPUE of non-native fishes (golden shiner, redside shiner and rainbow trout) caught on each sampling trip in the Paria River, Arizona, 1991-1998.

The golden shiner is native to the Mississippi and Atlantic coast drainages (Sigler and Sigler 1996). It is rare in the Colorado River and its tributaries between Glen Canyon Dam and Diamond Creek - one was caught in the mouth of the Paria River in 1996 (Brouder and Hoffnagle 1997a) and another in a backwater of the Colorado River just above its confluence with the Little Colorado River in 1997 (Arizona Game and Fish Department 1996a). The golden shiner captured in the Paria in 1998 was probably an age 1 fish, based on growth data compiled by Carlander (1969). Since this species has been captured here before, it is possible that this fish was spawned in the mouth of the Paria, survived a trip through the Glen Canyon Dam turbines or is a released bait fish. Golden shiners prefer quiet pools and backwater habitat and is tolerant of moderate turbidity (Pflieger 1975), similar to that found in the ponded Paria River mouth. Golden shiners feed on algae, invertebrates and small fish (Minckley 1973; Pflieger 1975) and may compete with flannelmouth suckers and speckled dace for invertebrates (Arizona Game and Fish Department 1996a). Because of interactions with native fish, golden shiner has been implicated in the demise of the Little Colorado River spinedace *Lepidomeda vittata* in Chevalon Creek, Arizona (Minckley and Carufel 1967). It appears unlikely that golden shiners will colonize the Paria River upstream of its mouth and frequent flooding will probably keep their abundance low in the generally small ponded area. However, it is possible that long-term ponding of the mouth may allow this species to increase their numbers and impact the native flannelmouth suckers and speckled dace.

*Redside Shiner*.-One redside shiner was captured in September and another two were captured in December (Table 19). These fish ranged in size from 40 - 90 mm and 0.4 - 5.3 g (Table 20). Redside shiners were also caught in 1997, when 18 were caught in the mouth of the Paria in July (Figure 9).

The redside shiner is native to the Columbia River and Bonneville Basin drainages. It is also rare in the Colorado River and tributaries in Grand Canyon. They are occasionally caught in the Paria River mouth (Brouder and Hoffnagle 1997b) and they have been caught in the Colorado and lower Little Colorado rivers (Kaeding and Zimmerman 1983; Arizona Game and Fish Department 1996b). This fish is omnivorous and may compete with or prey on larval native species (Minckley 1973; Sigler and Sigler 1996). However, it is rarely captured in the Paria and Colorado rivers, probably due to the Colorado River being too cold and the Paria River being too warm (Sigler and Sigler 1996). Therefore, this species is unlikely to be detrimental to native fishes under the current environmental conditions in these streams.

*Rainbow Trout*.-One rainbow trout was captured at Site 9 (800 m upstream from the mouth) in November (Table 19). This fish was 112 mm long and weighed 13 g (Table 20). Rainbow trout are the most common species of fish in this reach of the Colorado River and they are occasionally captured in the mouth of the Paria River and a short distance upstream (Figure 9). However, the high summer temperature and year round high turbidity keep this species from invading the Paria. Rainbow trout are predators of larval fishes (Marsh and Douglas 1997) and no small flannelmouth suckers have been captured in the Colorado River below the Paria (Arizona Game and Fish Department 1996a). It is hypothesized that this is because cold-shocked larvae are being consumed by rainbow trout, although no data has substantiated this.

**Conclusion**

The Paria River fish community remains limited to flannelmouth sucker, speckled dace and the few uncommon species that are captured only in or near its mouth. Both flannelmouth sucker and speckled dace continue to spawn in the Paria, with only speckled dace successfully recruiting in 1998. However, flannelmouth sucker are a long-lived species (Minckley 1991) that probably does not require annual recruitment to maintain a healthy population. Continued monitoring and, possibly, management actions will be necessary to ensure that the fishes of this dynamic stream are maintaining themselves.

**Recommendations**

I believe that the protocols used in this monitoring/research should be evaluated to ensure that the data are being effectively and efficiently collected. For example, data collected prior to 1998 was collected whenever time permitted. The monthly sampling scheme implemented in 1998 is an effort to ensure that sampling is conducted during all periods of the year. It is expected that following the 1999 field season, the monitoring schedule will be reduced to spring, summer and fall, with more intensive sampling to be continued during the spring spawning period. However, any changes made to this protocol must be comparable with data collected from previous years. The following are some suggested changes for 1999 that will provide additional information, but will be compatible with previous data.

1 - Continue sampling the Paria River monthly, except from 1 April through 3 June, when trips should be conducted at least biweekly to better document spawning time and presence of YOY flannelmouth sucker and speckled dace.

2 - Since a spawning bar has been identified close upstream from Site 1 (M. Brouder, Arizona Game and Fish Department, personal communication) an additional sampling site should be located at there and another between the spawning bar and the present Site 1.

3 - Past seine sampling has been habitat-selective in favor of smooth-bottomed runs, which may have biased the catch. Therefore, additional samples should be taken from other areas. For example, rocky areas (e.g., riffles) may be sampled by using personnel to chase fish into a seine.

4 - Velocity was only measured on one trip in 1998 due to equipment not being available. Temperature, turbidity and velocity are known to be the factors primarily influencing habitat selection by small fishes (Arizona Game and fish Department 1996a). Therefore, these factors should be measured consistently on each trip.

5 - Use of the Paria River by adult flannelmouth suckers and speckled dace appears to be influenced by Colorado River temperature. Colorado River turbidity and discharge may also influence fish behavior. Therefore, these variables should be recorded from the Colorado River near the mouth of the Paria River on each sampling trip.

6 - Use night sampling with a winged hoop net to capture fishes, particularly adult flannelmouth sucker, entering the mouth of the Paria after dark.

Appendix 1. List of personnel for Arizona Game and Fish Department Paria River Fish Monitoring, 1998.

| Trip/Participant | Agency |
|---|---|
| Trip 98-1: 4 June 1998 | |
| Tim Hoffnagle | Arizona Game and Fish Department |
| Pam Sponholtz | Arizona Game and Fish Department |
| Kirsten Rowell | Grand Canyon Monitoring a0nd Research Center |
| Paul Bagdonas | Arizona Game and Fish Department volunteer |
| Trip 98-2: 9 July 1998 | |
| Tim Hoffnagle | Arizona Game and Fish Department |
| Mark Brouder | Arizona Game and Fish Department |
| Trip 98-3: 7 August 1998 | |
| Tim Hoffnagle | Arizona Game and Fish Department |
| Dave Baker | Arizona Game and Fish Department |
| Brian Hoffnagle | Arizona Game and Fish Department volunteer |
| Trip 98-4: 19 September 1998 | |
| Tim Hoffnagle | Arizona Game and Fish Department |
| Pam Sponholtz | Arizona Game and Fish Department |
| Brian Hoffnagle | Arizona Game and Fish Department volunteer |
| Trip 98-5: 9 October 1998 | |
| Tim Hoffnagle | Arizona Game and Fish Department |
| Mike Rabe | Arizona Game and Fish Department |
| Debbie Brown | Arizona Game and Fish Department |
| Trip 98-6: 19 November 1998 | |
| Tim Hoffnagle | Arizona Game and Fish Department |
| Debbie Brown | Arizona Game and Fish Department |
| Bob Bramblett | U.S. Fish and Wildlife Service |
| Randy Van Haverbeke | U.S. Fish and Wildlife Service |
| Trip 98-7: 11 December 1998 | |
| Tim Hoffnagle | Arizona Game and Fish Department |
| Pam Sponholtz | Arizona Game and Fish Department |
| Dan Redondo | U.S. Forest Service/Northern Arizona University |

## STATUS OF DATA INTEGRATION AND ANALYSIS

A lack of staff and funds prior to the delayed finalization of the contract impeded progress on data integration/analysis throughout most of FY1998. The field season commenced 27 March and more than 65 days were spent in the field by the staff prior to 12 September 1998. New project personnel were added to the Grand Canyon Fishery Resource Office staff during June, 1998. Data entry for FY1998 field data commenced on 15 April and has been completed. An integrated database for LCR spring native fish monitoring for the period 1978-1996 was completed by 1 February 1998 and will be updated through the 1998 field season by 1 December 1998.

### Projection for FY99 Monitoring and Studies

TABLE 14. Provisional fieldwork schedule for fiscal year 1999.

| Trip title | Dates | Trip objective |
|---|---|---|
| Little Colorado River food base monitoring | 3-6 December 1998 | Macroinvertebrate, stable isotope studies |
| Mainstem Colorado River and tributaries: monitoring and research. | 22 January-3 February 1999 | Fishery research and monitoring |
| Little Colorado River monitoring and research | 31 March-29 April 1999 | Fishery research and monitoring |
| Little Colorado River food base monitoring | 25-28 May 1999 | Macroinvertebrate, stable isotope studies |
| Mainstem Colorado River and tributaries monitoring and research | 16 June-1 July 1999 | Fishery research and monitoring |
| Little Colorado River monitoring and research | 21-30 July 1999 | Fishery research and monitoring |
| Mainstem Colorado River and tributaries monitoring and research | 15 September-1 October 1999 | Fishery research and monitoring |
| Little Colorado River food base monitoring | 27-30 September 1999 | Macroinvertebrate, stable isotope studies |

## OTHER ACTIVITIES

Lower Colorado River Ecosystem Workshop: 8-9 July, UNLV-Las Vegas
Grand Canyon Modeling Workshops: 20-22 May, 6-7 July, 23-24 October

## PARTICIPATING PERSONNEL AND INSTITUTIONS

U. S. Fish and Wildlife Service, Grand Canyon Fishery Resources Office, primary contract holders.

| | |
|---|---|
| Project Leader | Owen T. Gorman, Ph.D. |
| Assistant Project Leader | Robert G. Bramblett, Ph.D. |
| Project Biologist | David R. Van Haverbeke |
| Project Biologist | Richard Van Hoosen, Ph.D. |
| Assistant Project Biologist | Dennis M. Stone |
| Fish Health Biologist | Jerry Landye |
| Intra-agency participant | Cliff Schluesner |
| Intra-agency participant | Cynthia Martinez |
| Volunteer | Edward Woods |
| Volunteer | Virgil Frye |
| Volunteer | Bobbi Hervin |
| Volunteer | Christopher Hertz |
| Volunteer | Rachael Running |

Arizona Department of Game and Fish, Interagency Agreement

Timothy Hoffnagle, Ph.D.
William R. Persons

Northern Arizona University, subcontract holders

Dean Blinn
Joseph Shannon
Allen Haden

Arizona Cooperative Fishery Research Unit, University of Arizona, subcontract holders

O. Eugene Maughan, Ph.D.

Navajo Natural Heritage Program, subcontract holders for field technician support

David Mikesic
Daniella Roth
Ray Chischilly

Hualupai Tribe Department of Natural Resources, subcontract holders for field technician support

Dawn Bascomb
Michael Vaughn

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## APPENDIX

APPENDIX TABLE 1. Preliminary summary of habitat sampled at transects and gear fished by site, Colorado River and tributaries, 16-30 June 1998.

| | | Habitat measured and gear fished | | | | |
|---|---|---|---|---|---|---|
| Site/river mile | Dates | Length of transect (m) | Hoopnets | Minnow traps | Electrofish | Trammel netting |
| | | | *Mainstem Sites* | | | |
| Mainstem @ Little Colorado/61 | 16-18 June | 600 | 29 | 24 | 4 nights, 1 morning[a] | 3 nights |
| Hopi Salt/63.5 | 18-20 June | 600 | 30 | 30 | 4 nights, 1 morning[a] | |
| Lava Chuar/65.2 | 20-22 June | 600 | 28 | 30 | 4 nights, 1 morning[a] | |
| Mainstem @ Bright Angel/87.7 | 23-24 June | 600 | 16 | 16 | 1 night | 1 night |
| Mainstem @ Shinumo /108.7 | 24 June | N/A | N/A | N/A | 1 night | 1 night |
| Mainstem @ Middle Granite Gorge/126 | 25-27 June | 300 | 17 | 24 | 2 nights | 2 nights |
| Mainstem @ Kanab Creek/143.5 | 27 June | N/A | N/A | N/A | 1 night | 1 night |
| Mainstem @ Havasu/156.8 | 28-30 June | 340 | 5 | 9 | 2 nights | 1 night |
| | | | *Tributary Sites* | | | |
| Little Colorado/61.4 | 16-18 June | N/A | 0 | 8 | N/A | 4 sets |
| Bright Angel Creek/87.8 | 22-24 June | ~430 | 10 | 23 | N/A | N/A |
| Shinumo Creek/108.7 | 24-25 June | ~120 | 14 | 16 | N/A | N/A |
| Kanab Creek/143.5 | 27-28 June | 500 | 14 | 13 | N/A | N/A |
| Havasu Creek/156.8 | 28-30 June | 200 | 16 | 19 | N/A | 1 set |

[a] 17 electrofishing efforts were done from RM 60.1-65.1 during 6/17/98-6/21/98

APPENDIX TABLE 2. Preliminary summary of fish captured by site and gear type, Colorado River and tributaries, 16-30 June 1998.

| Site | Gear | Species[a] | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BHS | BRT | CCP | FHM | FMS | GRS | HBC | RBT | RSH | SPD | |
| | | | | | | *Mainstem Sites* | | | | | | |
| Mainstem | Electrofish | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 74 | 0 | 0 | 44 |
| @ Little | Trammel | 1 | 0 | 0 | 0 | 9 | 0 | 8 | 7 | 0 | 0 | 27 |
| Colorado | Hoopnet | 0 | 0 | 0 | 0 | 1 | 0 | 11 | 4 | 0 | 0 | 16 |
| 17-21 | Minnow trap | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| June | | | | | | | | | | | | |
| 1998 | **Totals** | **1** | **1** | **1** | **1** | **10** | **0** | **21** | **85** | **0** | **0** | **119** |
| Hopi Salt | Electrofish | 0 | 1 | 1 | 0 | 2 | 0 | 2 | 35 | 0 | 0 | 41 |
| 18-21 | Hoopnet | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 0 | 1 | 7 |
| June 1998 | Dip net | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | Minnow trap | 0 | 0 | 0 | 2 | 0 | 0 | 4 | 0 | 0 | 4 | 10 |
| | **Totals** | **0** | **1** | **1** | **2** | **2** | **0** | **9** | **39** | **0** | **5** | **59** |
| Lava | Electrofish | 0 | 0 | 0 | 19 | 0 | 0 | 14 | 23 | 1 | 5 | 62 |
| Chuar | Hoopnet | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 5 | 0 | 3 | 12 |
| Mainstem | Minnow trap | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 3 | 7 |
| 21-22 | **Totals** | **0** | **0** | **0** | **23** | **0** | **0** | **18** | **28** | **1** | **11** | **81** |
| June 1998 | | | | | | | | | | | | |
| Mainstem | Electrofish | 0 | 30 | 0 | 0 | 2 | 0 | 0 | 11 | 0 | 0 | 43 |
| @ Bright | Minnow trap | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |
| Angel | Hoopnet | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 22-24 | Trammel | 1 | 9 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 13 |
| June 1998 | **Totals** | **1** | **39** | **0** | **2** | **2** | **0** | **0** | **15** | **0** | **3** | **61** |
| Mainstem | Electrofish | 0 | 12 | 2 | 1 | 2 | 0 | 0 | 26 | 1 | 0 | 44 |
| @ | Trammel | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 |
| Shinumo | **Totals** | **0** | **12** | **2** | **1** | **2** | **0** | **0** | **28** | **1** | **0** | **46** |
| 24 June | | | | | | | | | | | | |
| 1998 | | | | | | | | | | | | |
| Mainstem | Electrofish | 0 | 5 | 0 | 0 | 1 | 0 | 5 | 24 | 0 | 0 | 35 |
| @ Middle | Hand | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Granite | Minnow trap | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 25-27 | Hoopnet | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 1 | 0 | 5 |
| June 1998 | Trammel | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | **Totals** | **0** | **6** | **0** | **0** | **1** | **0** | **9** | **26** | **1** | **0** | **43** |
| Mainstem | Electrofish | 0 | 0 | 2 | 1 | 2 | 0 | 0 | 10 | 0 | 0 | 15 |
| @ Kanab | Trammel | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 4 |
| Creek | **Totals** | **0** | **0** | **3** | **1** | **4** | **0** | **0** | **11** | **0** | **0** | **19** |
| 27 June | | | | | | | | | | | | |
| 1998 | | | | | | | | | | | | |

APPENDIX TABLE 2. Continued.

| Site | Gear | BHS | BRT | CCP | FHM | FMS | GRS | HBC | RBT | RSH | SPD | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Species | | | | | | | | | | |
| Mainstem @ Havasu Creek 28-29 June 1998 | Electrofish | 2 | 3 | 6 | 0 | 8 | 1 | 0 | 70 | 0 | 2 | 90 |
| | Minnow trap | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| | Hoopnet | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 |
| | **Totals** | **2** | **3** | **6** | **0** | **8** | **1** | **0** | **72** | **0** | **6** | **96** |
| | **Mainstem subtotals** | **4** | **61** | **12** | **30** | **29** | **1** | **57** | **274** | **3** | **25** | **524** |
| | | | | | | ***Tributary Sites*** | | | | | | |
| Little Colorado 17-21 June 1998 | Minnow trap | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 1 | 12 | 24 |
| | Seine | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 26 | 1 | 28 |
| | Trammel | 0 | 0 | 4 | 0 | 11 | 0 | 8 | 0 | 0 | 0 | 23 |
| | **Totals** | **0** | **0** | **4** | **1** | **11** | **0** | **19** | **0** | **27** | **13** | **75** |
| Bright Angel Creek 23-24 June 1998 | Minnow trap | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 46 | 48 |
| | Hoopnet | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 6 |
| | **Totals** | **1** | **2** | **0** | **0** | **0** | **0** | **0** | **1** | **0** | **50** | **54** |
| Shinumo Creek 25 June 1998 | Hoopnet | 7 | 5 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 4 | 19 |
| | **Totals** | **7** | **5** | **0** | **0** | **2** | **0** | **1** | **0** | **0** | **4** | **19** |
| Kanab Creek 28 June 1998 | Minnow trap | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 3 | 8 |
| | Hoopnet | 0 | 0 | 0 | 2 | 8 | 2 | 1 | 0 | 0 | 5 | 18 |
| | **Totals** | **0** | **0** | **0** | **5** | **10** | **2** | **1** | **0** | **0** | **8** | **26** |
| Havasu Creek 29-30 June 1998 | Minnow trap | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 6 | 7 |
| | Hoopnet | 5 | 0 | 0 | 0 | 31 | 0 | 6 | 0 | 0 | 4 | 46 |
| | Trammel | 0 | 0 | 0 | 0 | 26 | 0 | 3 | 0 | 0 | 0 | 29 |
| | **Totals** | **5** | **0** | **0** | **0** | **58** | **0** | **9** | **0** | **0** | **10** | **82** |
| | **Tributary subtotals** | **13** | **7** | **4** | **6** | **81** | **2** | **30** | **1** | **27** | **85** | **256** |
| **Grand Totals** | | **17** | **68** | **16** | **36** | **110** | **3** | **87** | **275** | **33** | **110** | **780** |

[a]BHS = bluehead sucker (*Catostomus discobolus*); BRT = brown trout (*Salmo trutta*); CCP = common carp (*Cypinius carpio*); FHM = fathead minnow (*Pimephales promelas*); FMS = flannelmouth sucker (*Catostomus latipinnis*); GRS = green sunfish (*Lepomis cyanellus*); HBC = humpback chub (*Gila cypha*); RBT = rainbow trout (*Oncorhynchus mykiss*); RSH = red shiner (*Cyprinella lutrensis*); SPD = speckled dace (*Rhinichthys osculus*).

APPENDIX TABLE 3. Preliminary summary of habitat sampled at transects and gear fished by site, Colorado River and tributaries, 27 August – 9 September 1998.

| Site/river mile | Dates | Length of study reach (m) | Hoopnets | Minnow traps | Electrofish efforts (s) | Trammel net sets (hr) | Seining efforts |
|---|---|---|---|---|---|---|---|
| **Mainstem sites** | | | | | | | |
| Fence Fault/30.5 | 27 August | N/A | N/A | N/A | 1 (218) | 2 (4.6) | N/A |
| Mainstem @ Little Colorado/61 | 28-31 August | 300 | 16 | 16 | 6 (3548) | 12 (25.1) | 3 |
| Hopi Salt/63.5 | 29-31 August | 600 | 30 | 30 | 8 (4479) | 4 (6.24) | 3 |
| Lava Chuar/65.2 | 31 August-1 September | 580 | 29 | 29 | N/A | 4 (6.75) | N/A |
| Tanner Rapids/68 | 1-3 September | 560 | 30 | 50 | 4 (2124) | 12 (23.2) | 1 |
| Mainstem @ Bright Angel/87.7 | 3-4 September | 200 | 18 | 18 | 4 (1668) | 6 (12.4) | N/A |
| Mainstem @ Shinumo /108.7 | 4 September | N/A | N/A | N/A | 2 (1550) | 9 (15.6) | N/A |
| Mainstem above Middle Granite Gorge/ 119-122.8 | 5 September | N/A | N/A | N/A | N/A | N/A | 3 |
| Mainstem @ Middle Granite Gorge/126 | 4-7 September | 340 | 18 | 43 | 4 (1784) | 8 (14) | 17 |
| Mainstem @ Kanab Creek/143.5 | 7-8 September | N/A | N/A | N/A | 2 (1894) | 3 (5.7) | N/A |
| Mainstem @ Havasu/156.8 | 8-9 September | 300 | 16 | 16 | 3 (2523) | N/A | N/A |

APPENDIX TABLE 3. Continued.

| Site/river mile | Dates | Length of study reach (m) | Hoopnets | Minnow traps | Electrofish efforts (s) | Trammel net sets (hr) | Seining efforts |
|---|---|---|---|---|---|---|---|
| Mainstem below Havasu/157-179 | 10 September | N/A | N/A | N/A | N/A | N/A | 4 |
| Mainstem below Lava Falls/180-198.2 | 10 September | N/A | N/A | N/A | N/A | N/A | 9 |
| | | | **Tributary Sites** | | | | |
| Little Colorado/61.4 | 28-31 August | ~160 | 9 | 9 | N/A | N/A | 2 |
| Bright Angel Creek/87.8 | 4 September | ~120 | 11 | 12 | | | 16 |
| Shinumo Creek/108.7 | 5 September | ~120 | 13 | 12 | N/A | N/A | 7 |
| Kanab Creek/143.5 | 7-8 September | 500 | 19 | 27 | N/A | N/A | 13 |
| Havasu Creek/156.8 | 8-10 September | 200 | 20 | 20 | | 1 (0.5) | 18 |

APPENDIX TABLE 4. Preliminary summary of fish captured by site and gear type, Colorado River and tributaries, 27 August – 9 September 1998.

| Site, date | Gear | Species[a] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BHS | BRT | CCF | CCP | FHM | FMS | HBC | PKF | RBT | RSH | SPD | YBH | Total |
| | | ***Mainstem sites*** | | | | | | | | | | | | |
| Fence Fault, 27 August 1998 | Electrofish | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 4 |
| | Trammel nets | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 0 | 27 | 0 | 0 | 0 | 34 |
| | **Totals** | **0** | **0** | **0** | **0** | **0** | **3** | **4** | **0** | **31** | **0** | **0** | **0** | **38** |
| Little Colorado River, 28-31 August 1998 | Electrofish | 0 | 0 | 0 | 1 | 3 | 5 | 0 | 0 | 61 | 0 | 6 | 0 | 76 |
| | Hoopnets | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 5 | 0 | 0 | 0 | 6 |
| | Seine | 0 | 0 | 0 | 0 | 5 | 0 | 26 | 0 | 4 | 1 | 16 | 1 | 53 |
| | Trammel nets | 2 | 0 | 0 | 2 | 0 | 11 | 28 | 0 | 37 | 0 | 0 | 0 | 80 |
| | **Totals** | **2** | **0** | **0** | **3** | **8** | **16** | **55** | **0** | **107** | **1** | **22** | **1** | **215** |
| Hopi Salt, 29-31 August 1998 | Electrofish | 0 | 1 | 1 | 0 | 13 | 0 | 33 | 0 | 12 | 6 | 10 | 0 | 76 |
| | Hoopnets | 2 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 2 | 0 | 0 | 0 | 35 |
| | Minnow traps | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 8 |
| | **Totals** | **2** | **1** | **1** | **0** | **13** | **0** | **72** | **0** | **14** | **6** | **10** | **0** | **119** |
| Lava Chuar, 31 August-1 September 1998 | Hoopnets | 1 | 0 | 0 | 2 | 1 | 0 | 27 | 0 | 43 | 0 | 0 | 0 | 74 |
| | Minnow traps | 1 | 0 | 0 | 0 | 6 | 0 | 24 | 0 | 0 | 1 | 0 | 0 | 32 |
| | Trammel nets | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 9 | 0 | 0 | 0 | 15 |
| | **Totals** | **2** | **0** | **0** | **2** | **7** | **0** | **57** | **0** | **52** | **1** | **0** | **0** | **121** |
| Tanner, 1-3 September 1998 | Electrofish | 0 | 0 | 0 | 0 | 5 | 0 | 19 | 0 | 13 | 2 | 9 | 0 | 48 |
| | Hoopnets | 2 | 0 | 0 | 0 | 5 | 0 | 12 | 0 | 37 | 0 | 0 | 0 | 56 |
| | Minnow traps | 0 | 0 | 0 | 0 | 13 | 0 | 18 | 1 | 3 | 2 | 0 | 0 | 37 |
| | Seine | 2 | 0 | 0 | 0 | 18 | 0 | 22 | 0 | 0 | 13 | 9 | 0 | 64 |
| | Trammel nets | 0 | 1 | 0 | 0 | 0 | 1 | 3 | 0 | 36 | 0 | 0 | 0 | 41 |
| | **Totals** | **4** | **1** | **0** | **0** | **41** | **1** | **74** | **1** | **89** | **17** | **18** | **0** | **246** |
| Bright Angel Creek, 3-4 September 1998 | Electrofish | 1 | 44 | 0 | 0 | 4 | 0 | 0 | 0 | 17 | 1 | 4 | 0 | 71 |
| | Hoopnets | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 7 | 1 | 0 | 0 | 10 |
| | Minnow traps | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | Trammel nets | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 26 | 0 | 0 | 0 | 30 |
| | **Totals** | **1** | **47** | **0** | **0** | **6** | **2** | **0** | **0** | **50** | **2** | **4** | **0** | **112** |
| Shinumo Creek, 4 September 1998 | Electrofish | 0 | 15 | 0 | 1 | 0 | 0 | 0 | 0 | 25 | 0 | 0 | 0 | 41 |
| | Trammel nets | 1 | 0 | 0 | 1 | 0 | 8 | 11 | 0 | 14 | 0 | 0 | 0 | 35 |
| | **Totals** | **1** | **15** | **0** | **2** | **0** | **8** | **11** | **0** | **39** | **0** | **0** | **0** | **76** |
| Above Middle Granite Gorge, 5 September 1998 | Seine | 2 | 0 | 0 | 0 | 2 | 3 | 1 | 3 | 0 | 1 | 67 | 0 | 79 |

APPENDIX TABLE 4. Continued.

| Site, date | Gear | BHS | BRT | CCF | CCP | FHM | FMS | HBC | PKF | RBT | RSH | SPD | YBH | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Species[a] | | | | | | | | | | | | |
| Middle Granite Gorge, 4-7 September 1998 | **Electrofish** | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 10 |
| | **Hoopnets** | 1 | 0 | 0 | 0 | 0 | 0 | 14 | 0 | 2 | 0 | 0 | 0 | 17 |
| | **Minnow traps** | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| | **Seine** | 5 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 2 | 3 | 4 | 0 | 17 |
| | **Trammel nets** | 0 | 0 | 0 | 1 | 0 | 0 | 4 | 0 | 17 | 0 | 0 | 0 | 22 |
| | **Totals** | **7** | **0** | **0** | **1** | **2** | **2** | **21** | **0** | **28** | **3** | **4** | **0** | **68** |
| Kanab Creek, 7-8 September 1998 | **Electrofish** | 0 | 2 | 0 | 2 | 6 | 0 | 1 | 0 | 8 | 0 | 1 | 0 | 20 |
| | **Trammel nets** | 0 | 0 | 0 | 3 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 13 |
| | **Totals** | **0** | **2** | **0** | **5** | **6** | **10** | **1** | **0** | **8** | **0** | **1** | **0** | **33** |
| Havasu Creek, 8-9 September 1998 | **Electrofish** | 0 | 3 | 0 | 1 | 1 | 0 | 0 | 0 | 15 | 0 | 9 | 0 | 29 |
| | **Hoopnets** | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 5 | 0 | 1 | 0 | 8 |
| | **Minnow traps** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| | **Totals** | **1** | **3** | **0** | **2** | **1** | **0** | **0** | **0** | **20** | **0** | **11** | **0** | **38** |
| Below Havasu Creek[b], 10 September 1998 | **Seine** | **0** | **1** | **0** | **0** | **53** | **18** | **0** | **2** | **19** | **1** | **65** | **0** | **159** |
| Below Lava Falls[c], 10 September 1998 | **Seine** | **15** | **0** | **0** | **3** | **92** | **21** | **2** | **2** | **4** | **8** | **164** | **0** | **311** |
| | **Mainstem subtotals** | **37** | **70** | **1** | **18** | **231** | **87** | **298** | **8** | **463** | **40** | **371** | **1** | **1625** |
| | | | | | | *Tributary sites* | | | | | | | | |
| Little Colorado River, 28-31 August 1998 | **Hoopnets** | 0 | 0 | 0 | 3 | 0 | 0 | 17 | 0 | 0 | 0 | 1 | 0 | 21 |
| | **Minnow traps** | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 4 |
| | **Seine** | 0 | 0 | 0 | 0 | 1 | 0 | 30 | 6 | 0 | 2 | 3 | 0 | 42 |
| | **Totals** | **0** | **0** | **0** | **3** | **1** | **0** | **51** | **6** | **0** | **2** | **4** | **0** | **67** |
| Bright Angel Creek, 4 September 1998 | **Hoopnets** | 5 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 3 | 0 | 15 | 0 | 26 |
| | **Minnow traps** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 0 | 28 |
| | **Seine** | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 19 |
| | **Totals** | **6** | **1** | **0** | **0** | **0** | **1** | **1** | **0** | **3** | **0** | **61** | **0** | **73** |
| Shinumo Creek, 5 September 1998 | **Hoopnets** | 6 | 1 | 0 | 0 | 1 | 1 | 15 | 0 | 2 | 0 | 19 | 0 | 45 |
| | **Minnow traps** | 0 | 0 | 0 | 0 | 1 | 2 | 7 | 0 | 0 | 1 | 7 | 0 | 18 |
| | **Seine** | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 28 | 0 | 31 |
| | **Totals** | **6** | **1** | **0** | **0** | **3** | **4** | **22** | **0** | **3** | **1** | **54** | **0** | **94** |
| Kanab Creek, 7-8 September 1998 | **Hoopnets** | 12 | 0 | 0 | 6 | 4 | 9 | 0 | 0 | 1 | 0 | 30 | 0 | 62 |
| | **Minnow traps** | 3 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 7 | 0 | 16 |
| | **Seine** | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 73 |
| | **Totals** | **38** | **0** | **0** | **6** | **7** | **12** | **0** | **0** | **1** | **0** | **87** | **0** | **151** |

APPENDIX TABLE 4. Continued.

| Site, date | Gear | BHS | BRT | CCF | CCP | FHM | FMS | HBC | PKF | RBT | RSH | SPD | YBH | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Species[a] | | | | | | | | | | | | |
| Havasu Creek, 8-10 September 1998 | Hoopnets | 17 | 0 | 0 | 0 | 2 | 24 | 17 | 0 | 2 | 0 | 16 | 0 | 78 |
| | Minnow traps | 7 | 0 | 0 | 0 | 2 | 10 | 0 | 0 | 0 | 0 | 40 | 0 | 59 |
| | Seine | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 24 |
| | Trammel nets | 0 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 6 |
| | **Totals** | **31** | **0** | **0** | **0** | **4** | **39** | **18** | **0** | **2** | **0** | **73** | **0** | **167** |
| | **Tributary subtotals** | **81** | **2** | **0** | **9** | **15** | **56** | **92** | **6** | **9** | **3** | **279** | **0** | **552** |
| | **Grand Total** | **118** | **72** | **1** | **27** | **246** | **143** | **390** | **14** | **472** | **43** | **650** | **1** | **2177** |

[a]BHS = bluehead sucker (*Catostomus discobolus*); BRT = brown trout (*Salmo trutta*); CCP = common carp (*Cypinius carpio*); FHM = fathead minnow (*Pimephales promelas*); FMS = flannelmouth sucker (*Catostomus latipinnis*); GRS = green sunfish (*Lepomis cyanellus*); HBC = humpback chub (*Gila cypha*); RBT = rainbow trout (*Oncorhynchus mykiss*); RSH = red shiner (*Cyprinella lutrensis*); SPD = speckled dace (*Rhinichthys osculus*); YBH = (*Ameiurus natalis*).

[b]Backwaters were seined at RM 165.0L, 165.5L, 165.7L, 166.0R.

[c]Backwaters were seined at RM 180.7L, 182.4R, 182.7R, 182.8R, 186.2R, 186.7R, 186.8R, 191.3L, 192.1R, 198.2R.

APPENDIX. TABLE 5. Summary of all fish captured by site and date during 1998, Colorado River and tributaries in Grand Canyon.

| Site/River mile | Dates | BBH | BHS | BRT | CCF | CCP | FHM | FMS | GRS | HBC | PKF | RBT | RSH | SPD | YBH | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Mainstem sites* | | | | | | | | | | | | | | |
| Fence Fault/30.5 | 27 August | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 4 | 0 | 31 | 0 | 0 | 0 | 38 |
| Little Colorado/61 | 16-18 June | 0 | 1 | 1 | 0 | 1 | 1 | 10 | 0 | 21 | 0 | 85 | 0 | 0 | 0 | 120 |
| Little Colorado/61 | 28-31 August | 0 | 2 | 0 | 0 | 3 | 8 | 16 | 0 | 55 | 0 | 107 | 1 | 22 | 1 | 215 |
| Hopi Salt/63.5 | 18-20 June | 0 | 0 | 1 | 0 | 1 | 2 | 2 | 0 | 9 | 0 | 39 | 0 | 5 | 0 | 59 |
| Hopi Salt/63.5 | 29-31 August | 0 | 2 | 1 | 1 | 0 | 13 | 0 | 0 | 72 | 0 | 14 | 6 | 10 | 0 | 119 |
| Lava Chuar/65.2 | 20-22 June | 0 | 0 | 0 | 0 | 0 | 23 | 0 | 0 | 18 | 0 | 28 | 1 | 11 | 0 | 81 |
| Lava Chuar/65.2 | 31 August-1 September | 0 | 2 | 0 | 0 | 2 | 7 | 0 | 0 | 57 | 0 | 52 | 1 | 0 | 0 | 121 |
| Tanner/68 | 1-3 September | 0 | 4 | 1 | 0 | 0 | 41 | 1 | 0 | 74 | 1 | 89 | 17 | 18 | 0 | 246 |
| Bright Angel/87.7 | 23-24 June | 0 | 1 | 39 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 15 | 0 | 3 | 0 | 62 |
| Bright Angel/87.7 | 3-4 September | 0 | 1 | 47 | 0 | 0 | 6 | 2 | 0 | 0 | 0 | 50 | 2 | 4 | 0 | 112 |
| Shinumo /108.7 | 24 June | 0 | 0 | 12 | 0 | 2 | 1 | 2 | 0 | 0 | 0 | 28 | 1 | 0 | 0 | 46 |
| Shinumo /108.7 | 4 September | 0 | 1 | 15 | 0 | 2 | 0 | 8 | 0 | 11 | 0 | 39 | 0 | 0 | 0 | 76 |
| Above MGG/119-122.8 | 5 September | 0 | 2 | 0 | 0 | 0 | 2 | 3 | 0 | 1 | 3 | 0 | 1 | 67 | 0 | 79 |
| Middle Granite Gorge/126 | 25-27 June | 0 | 0 | 6 | 0 | 0 | 0 | 1 | 0 | 9 | 0 | 26 | 1 | 0 | 0 | 43 |
| Middle Granite Gorge/126 | 4-7 September | 0 | 7 | 0 | 0 | 1 | 2 | 2 | 0 | 21 | 0 | 28 | 3 | 4 | 0 | 68 |

Species columns: BBH through YBH.

APPENDIX. TABLE 5. Continued.

| Site/River mile | Dates | Species | | | | | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BBH | BHS | BRT | CCF | CCP | FHM | FMS | GRS | HBC | PKF | RBT | RSH | SPD | YBH | |
| Kanab/143.5 | 27 June | 0 | 0 | 0 | 0 | 3 | 1 | 4 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 19 |
| Kanab/143.5 | 7-8 September | 0 | 0 | 2 | 0 | 5 | 6 | 10 | 0 | 1 | 0 | 8 | 0 | 1 | 0 | 33 |
| Havasu/ 156.8 | 28-30 June | 0 | 2 | 3 | 0 | 6 | 0 | 8 | 1 | 0 | 0 | 72 | 0 | 6 | 0 | 98 |
| Havasu/ 156.8 | 8-9 September | 0 | 1 | 3 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 20 | 0 | 11 | 0 | 38 |
| Below Havasu/157-179 | 10 September | 0 | 0 | 1 | 0 | 0 | 53 | 18 | 0 | 0 | 2 | 19 | 1 | 65 | 0 | 159 |
| Below Lava/180-198.2 | 10 September | 0 | 15 | 0 | 0 | 3 | 92 | 21 | 0 | 2 | 2 | 4 | 8 | 164 | 0 | 311 |
| **Mainstem totals** | | **0** | **41** | **132** | **1** | **31** | **261** | **113** | **1** | **355** | **8** | **765** | **43** | **391** | **1** | **2143** |
| | | | | | | ***Tributary sites*** | | | | | | | | | | |
| Little Colorado/61 | 16-18 June | 0 | 0 | 0 | 0 | 4 | 1 | 11 | 0 | 19 | 0 | 0 | 27 | 13 | 0 | 75 |
| Little Colorado/61 | 28-31 August | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 51 | 6 | 0 | 2 | 4 | 0 | 67 |
| Bright Angel/87.7 | 22-24 June | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 50 | 0 | 54 |
| Bright Angel/87.7 | 5 September | 0 | 6 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 3 | 0 | 61 | 0 | 73 |
| Shinumo /108.7 | 24-25 June | 0 | 7 | 5 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 4 | 0 | 19 |
| Shinumo /108.7 | 5 September | 0 | 6 | 1 | 0 | 0 | 3 | 4 | 0 | 22 | 0 | 3 | 1 | 54 | 0 | 94 |
| Kanab /143.5 | 27-28 June | 0 | 0 | 0 | 0 | 0 | 5 | 10 | 2 | 1 | 0 | 0 | 0 | 8 | 0 | 26 |
| Kanab /143.5 | 7-8 September | 0 | 38 | 0 | 0 | 6 | 7 | 12 | 0 | 0 | 0 | 1 | 0 | 87 | 0 | 151 |

APPENDIX. TABLE 5. Continued.

| Site/River mile | Dates | BBH | BHS | BRT | CCF | CCP | FHM | FMS | GRS | HBC | PKF | RBT | RSH | SPD | YBH | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Havasu/157 | 28-30 June | 0 | 5 | 0 | 0 | 0 | 0 | 58 | 0 | 9 | 0 | 0 | 0 | 10 | 0 | 82 |
| Havasu/157 | 28-31 August | 0 | 31 | 0 | 0 | 0 | 4 | 39 | 0 | 18 | 0 | 2 | 0 | 73 | 0 | 167 |
| **Tributary totals** | | **0** | **94** | **9** | **0** | **13** | **21** | **137** | **2** | **122** | **6** | **10** | **30** | **364** | **0** | **808** |
| | | | | | | | | ***Little Colorado River*** | | | | | | | | |
| Little Colorado confluence area | 27 March-27 April | 1 | 70 | 0 | 17 | 6 | 111 | 350 | 0 | 0 | 2 | 13 | 20 | 172 | 0 | 762 |
| Little Colorado@ Salt Camp | 22-31 July | 0 | 5 | 0 | 5 | 24 | 6 | 1 | 0 | 566 | 7 | 0 | 0 | 12 | 3 | 629 |
| Little Colorado@ Salt Camp | 20-24 October | 0 | 0 | 0 | 0 | 3 | 16 | 1 | 0 | 61 | 0 | 0 | 8 | 124 | 1 | 214 |
| Little Colorado totals | | 1 | 75 | 0 | 22 | 33 | 133 | 352 | 0 | 627 | 9 | 13 | 28 | 308 | 4 | 1605 |
| **Grand Totals** | | **1** | **210** | **141** | **23** | **77** | **415** | **602** | **3** | **1104** | **23** | **788** | **101** | **1063** | **5** | **4556** |

Species columns: BBH through YBH.

[a] BBH = black bullhead (*Ameiurus melas*); BHS = bluehead sucker (*Catostomus discobolus*); BRT = brown trout (*Salmo trutta*); CCF = (*Ictalurus punctatus*); CCP = common carp (*Cypinius carpio*); FHM = fathead minnow (*Pimephales promelas*); FMS = flannelmouth sucker (*Catostomus latipinnis*); GRS = green sunfish (*Lepomis cyanellus*); HBC = humpback chub (*Gila cypha*); PKF = (*Fundulus zebrinus*); RBT = rainbow trout (*Oncorhynchus mykiss*); RSH = red shiner (*Cyprinella lutrensis*); SPD = speckled dace (*Rhinichthys osculus*); YBH = (*Ameiurus natalis*).