EFFECTS OF INTERIM FLOWS FROM GLEN CANYON DAM ON THE AQUATIC RESOURCES OF THE LOWER COLORADO RIVER FROM DIAMOND CREEK TO LAKE MEAD

Quarterly Report No. 3
(Trip No. 3: December 1 - 13, 1992)

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EXECUTIVE SUMMARY

An investigation of the aquatic resources of the Colorado River in Lower Grand Canyon and Lake Mead Inflow was initiated by the Hualapai Wildlife Management Department in June 1992, with technical assistance from BIO/WEST, Inc. The area of study is the Colorado River and its tributaries from Diamond Creek (RM 226) to Lake Mead below Pierce Ferry (RM 286). The first field trip was conducted June 24 - July 2, 1992; the second trip was September 27 - October 9, 1992; and the third trip was December 1-13, 1992. The 60-mile reach of river was divided longitudinally into four sampling strata, each with different habitat complexes. Stratum A was a steep, swift canyon area that extended for 13 miles from Diamond Creek (RM 226) to Separation Canyon (RM 239); Stratum B was a canyon area that extended for 13 miles from Separation Canyon to Maxon Canyon (RM 252); Stratum C was a wide braided channel in a canyon area with sedimentary lake deposits that extended for 13 miles from Maxon Canyon to Dry Canyon (RM 265); Stratum D was an open alluvial delta and lake inflow that extended for 21 miles from Dry Canyon to below Pierce Ferry (RM 286).

Six basic fish sampling gears were used during trip 3, including electrofishing, gill nets, trammel nets, hoop nets, minnow traps, and seines. Eleven species of fish were captured during Trip No. 3 representing eight families. Only two of these species (speckled dace and flannelmouth sucker) are native to the Colorado River Basin, while the remaining 9 species are non-native or introduced. Red shiners, fathead minnows, and carp were the most common mainstem species, while red shiners, fathead minnows, mosquitofish, and plains killifish dominated the ichthyofauna of the tributaries. The endangered species, humpback chub (Gila cypha) and razorback sucker (Xyrauchen texanus) were not seen or captured during Trip No. 3.

Water quality parameters were collected at various locations with a constant recording Hydrolab Surveyor II and Datasonde with datalogger. Maximum mainstem water temperature was 14.0°C, and minimum water temperature was 8.6°C. A net river stage change of 42 cm was measured over a 5.9-hour period at Bridge Canyon (RM 235.1, 250.3 miles below Glen Canyon Dam), and a net change of 56 cm over a 10.3-hour period at RM 242.8 (258.0 miles below Glen Canyon Dam). Temporary bench marks were established during Trip No. 2 at RM 249.7 to allow reoccupation of the site for additional stage change measurements. Also, 30 drift samples were collected at Bridge Canyon (RM 235.1), Burnt Spring Canyon (RM 259.3), and RM 242.8 during the ascending and descending hydrograph to monitor drift volume in the mainstem Colorado River at different flow stages.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Rationale

The Hualapai Wildlife Management Department (HWMD), with the assistance of BIO/WEST, Inc., initiated an investigation of the aquatic resources of the Colorado River and Lake Mead Inflow, from Diamond Creek (RM 226) to below Pierce Ferry (RM 286) in May of 1992 (Figure 1). This reach of the Colorado River is part of the 108.5 miles (RM 165.0-273.5) of river that forms the northern boundary of the Hualapai Indian Reservation in northwestern Arizona. The purpose of the investigation is to monitor the effects of interim flows from Glen Canyon Dam on aquatic population structure, aquatic habitat, non-native fish interactions, and aquatic food resources. The methodologies used in this investigation are consistent with current research being conducted by Arizona Game and Fish Department (AGFD) and BIO/WEST, Inc. under the Glen Canyon Environmental Studies (GCES) in Grand Canyon. Representatives of the Hualapai Tribe provide the primary leadership to this investigation with technical support from GCES. The investigation is also being conducted in cooperation with the National Park Service and the U.S. Fish and Wildlife Service.

This investigation consists of seven field trips, three in 1992 (July, September, December), and four in 1993 (March, May, September, December). This Quarterly Report presents the results of Trip No. 3, and is the third quarterly report of 1992 (Figure 2). The 1992 Annual Report is due in January 1993, and the Final Project Report is due in February 1994. Quarterly reports contain basic findings that are more fully analyzed for presentation later in Annual Reports and the Final Report.

This investigation is funded by the HWMD and the Bureau of Reclamation (Reclamation) as part of the GCES Interim Flows Monitoring Program. Logistics and technical support are coordinated by GCES, and river logistics are provided by OARS, a commercial river concessionaire.

Background

Before impoundment of the Colorado River by Glen Canyon Dam in 1963, the mainstem in Grand Canyon supported eight species of native fishes, including Colorado squawfish (Ptychocheilus lucius), humpback chub (Gila cypha), bonytail (Gila elegans), razorback sucker (Xyrauchen texanus), roundtail chub (Gila robusta), flannelmouth sucker (Catostomus latipinnis), bluehead sucker (Catostomus discobolus), and speckled dace (Rhinichthys osculus). Colorado squawfish, roundtail chub, and bonytail have been extirpated from the Grand Canyon. Humpback chub and razorback sucker are federally endangered species, and flannelmouth sucker, bluehead sucker, and speckled dace

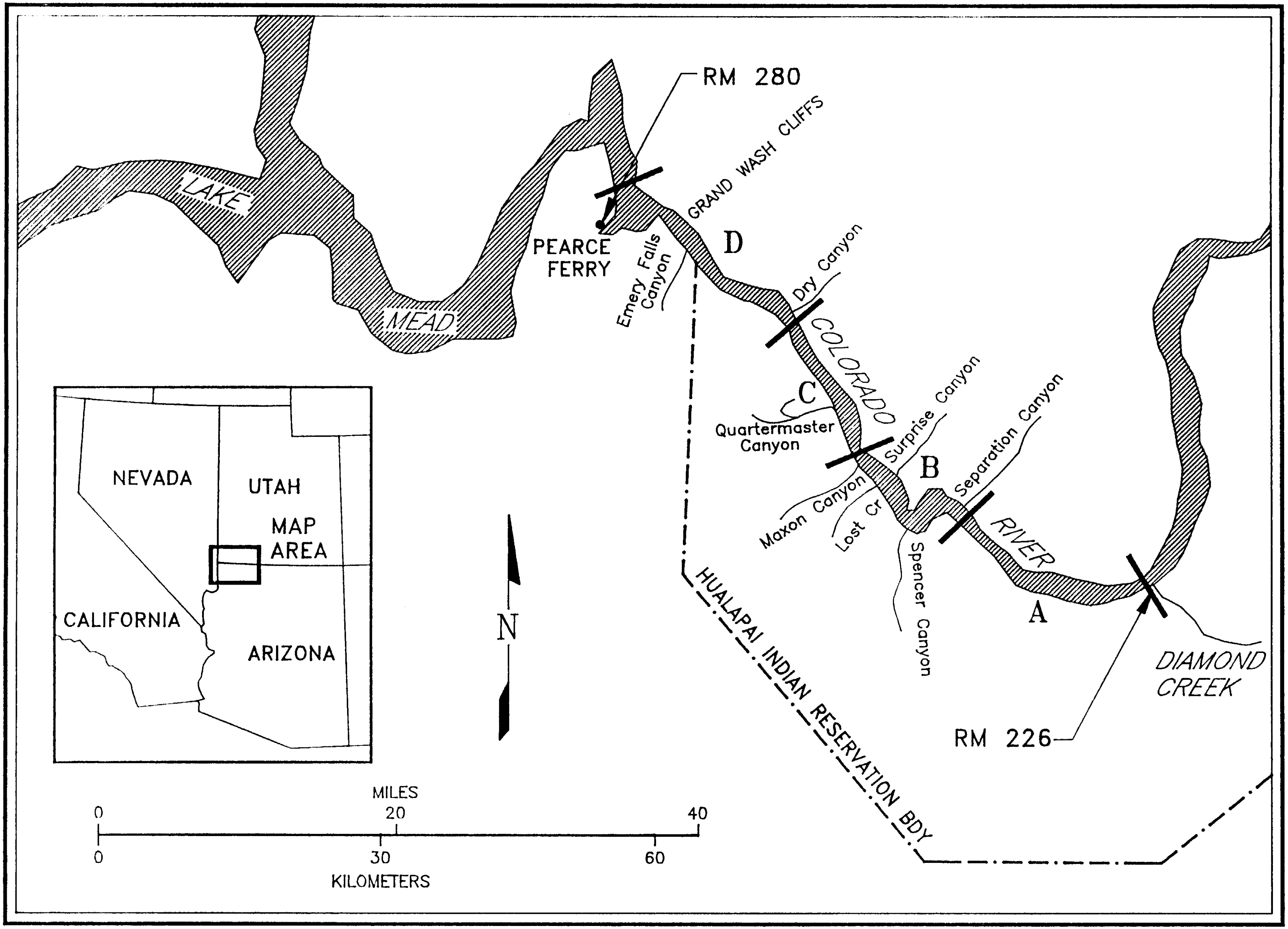

Figure 1. Study reach and sample strata A–D on the Colorado River in Lower Grand Canyon and Lake Mead inflow.

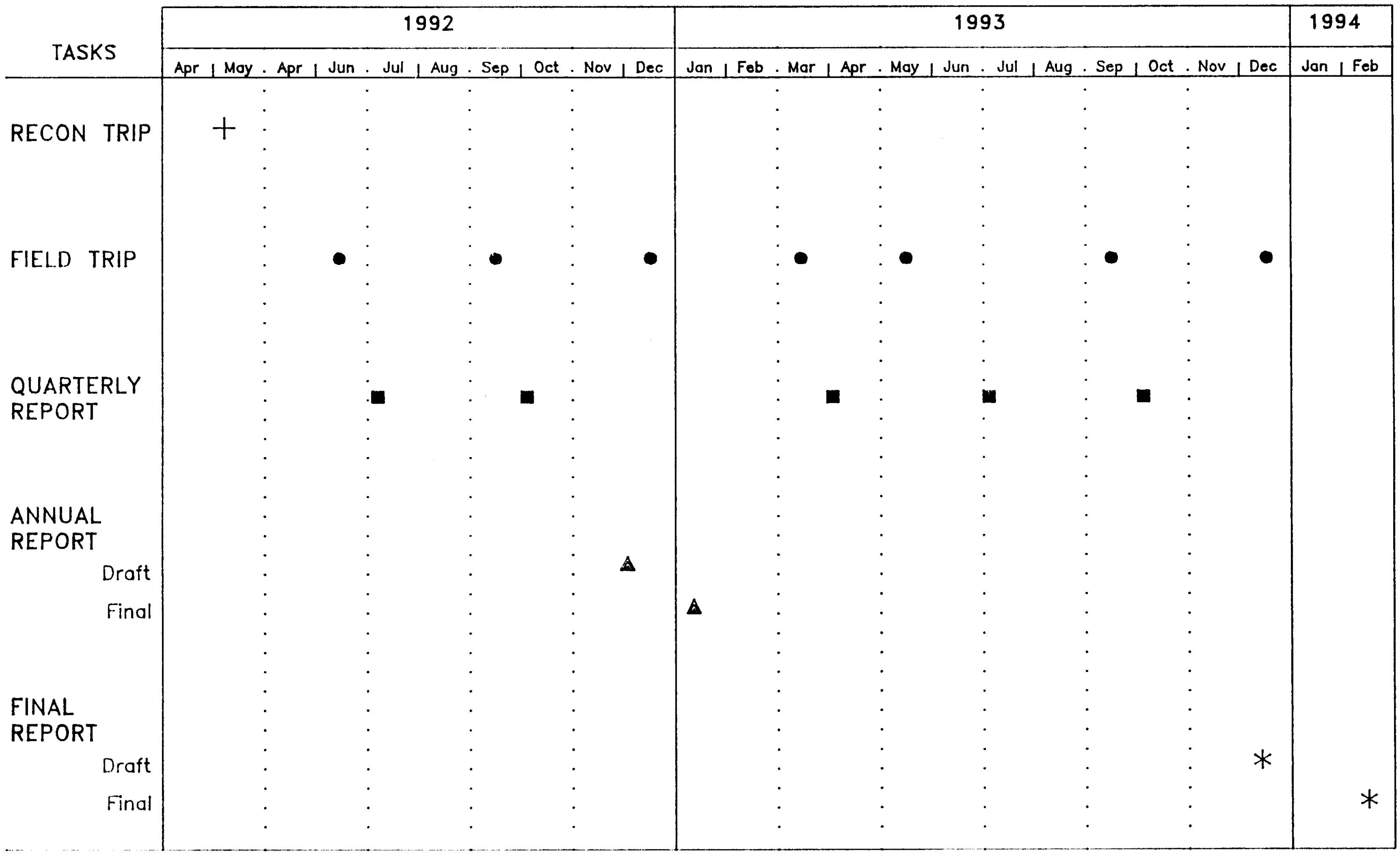

Figure 2. BIO/WEST schedule for Diamond Creek to Lake Mead Project.

are diminished in distribution and numbers in the region. Proper management of Glen Canyon Dam is vital to preserving the native ichthyofauna of the Colorado River throughout Grand Canyon.

Interim flow criteria for the operation of Glen Canyon Dam were implemented in August 1991. The purpose for these flows was to minimize damage to the Grand Canyon ecosystem resulting from previous operations (Department of Interior 1988). Monitoring programs are being initiated to describe the response of the ecosystem to these interim flows. Since the operation of Glen Canyon Dam potentially impacts all resources downstream to Lake Mead, an integrated monitoring program is vital for a comprehensive evaluation of aquatic ecosystem response.

Few detailed investigations have been conducted on the aquatic resources in the Lower Grand Canyon and Lake Mead Inflow (McCall 1979, Carothers and Minckley 1978). Prior to this investigation, intensive fishery investigations of the Grand Canyon ecosystem extended only to Diamond Creek (RM 226), primarily as part of the GCES, Phase I and Phase II. This investigation extends the area of study from Diamond Creek to Lake Mead below Pierce Ferry (RM 286). An evaluation of aquatic resources in this reach is important in order to evaluate the effects of interim flows through the entire river corridor from Glen Canyon Dam to Lake Mead. This investigation will also provide valuable information to evaluate the potential invasion of Grand Canyon by predaceous and competing non-native fishes from Lake Mead. The reach from Diamond Creek to Lake Mead may also contain significant numbers of endangered humpback chub and razorback sucker.

Objectives

The objectives of this investigation are for the Lower Grand Canyon from Diamond Creek (RM 226) to below Pierce Ferry at Lake Mead (RM 286):

1. Monitor the effects of interim flows from Glen Canyon Dam on the distribution, abundance, and behavior of native and non-native adult fish.
2. Monitor the effects of interim flows from Glen Canyon Dam on the distribution, abundance, and behavior of the larval and juvenile stages of native fishes.
3. Monitor the effects of interim flows from Glen Canyon Dam on the reproduction, food habits, and patterns of habitat use of piscivorous non-native fishes that may prey on native fishes.
4. Monitor the effects of interim flows from Glen Canyon Dam on the environmental conditions in the tributary mouths and shallow shore-line habitat. This will include water quality and degradation and/or aggradation of sediments.
5. Monitor the effects of interim flows from Glen Canyon Dam on the food base including productivity and algal standing crops.

SAMPLE SCHEDULE FOR TRIP NO. 3

Trip No. 3 was conducted December 1-13, 1992, from Diamond Creek (RM 226) to Lake Mead below Pierce Ferry (RM 286). Six camp sites were established and sampling was conducted in the area indicated in the schedule shown in Table 1. The Colorado River near Bridge Canyon was swift and deep with fast runs and eddies. The river near Spencer Canyon was more gentle, and lined with vertical cliffs, talus slopes, and emergent shoreline vegetation. The stream in Spencer Canyon had an abundance of fish. The river below Lost Creek and near Burnt Spring Canyon was slow and meandering with wide canyons and banks lined with heavily-vegetated lake sediment. The camp site at RM 267.5 was located in a braided area with numerous side channels, and the camp at Scorpion Island was located in the Lake Mead inflow, near Pierce Ferry, an area with shallow expanses of lake sediment lined with vegetation.

Table 1. Dates, camp sites and sample locations for Trip No. 3, December 1-13, 1992.

DATE	CAMP SITE	SAMPLE LOCATIONS
December 1-3	Bridge Canyon (RM 235.2)	Bridge Canyon Area (RM 234.2 - 236.0)
December 3-6	Above Spencer (RM 245.0)	Spencer Canyon Area (RM 241.6 - 249.1) & Tributary
December 6	Below Lost Cr (RM 249.7)	Lost Cr (RM 249.1 - 249.4)
December 7-9	Burnt Spring (RM 259.7)	Lost Cr to Res. Bound. (RM 249.5 - 271.5)
Dec 9-11	Braided Section (RM 267.5)	Above Res. Bound. (RM 270.0 - 272.8)
Dec 11-13	Scorpion Island (RM 277.5)	Lake Mead Inflow (RM 271.8 - 279.5)

PERSONNEL

A total of 10 people participated in Trip No. 3, including three representatives of the HWMD, four boatmen/biologists from BIO/WEST, Inc., and three river guides from OARS. Individuals participating in the trip are identified in Table 2.

Table 2. Personnel participating in Trip No. 3.

NAME	AGENCY, ADDRESS, PHONE NUMBER
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METHODOLOGIES

Study Area

The study area was 60 miles of the Colorado River from Diamond Creek (RM 226) to Lake Mead below Pierce Ferry (RM 286). This study area was designated as Reach 4, as a continuation of the BIO/WEST fishery investigation being conducted in the Grand Canyon. Reach 1 extends from Kwagunt Rapid (RM 56.0) to Red Canyon (RM 77.4), Reach 2 extends from Red Canyon to Havasu Creek (RM 160.0), and Reach 3 extends from Havasu Creek to Diamond Creek (RM 226.0).

The 60-mile reach was divided into four longitudinal strata that reflect different fish habitat complexes (Table 3). Stratum A extends for 13 miles from Diamond Creek (RM 226) to just above Separation Canyon (RM 239). Stratum B extends for 13 miles from just above Separation Canyon to Maxon Canyon (RM 252). Stratum C extends for 13 miles from Maxon Canyon to Dry Canyon (RM 265). Stratum D extends for 21 miles from Dry Canyon to below Pierce Ferry (RM 286).

Table 3. Longitudinal sample strata for Lower Grand Canyon to Lake Mead.

STRATA	RIVER MILES	DESCRIPTION
A	226 - 239	Steep, narrow canyon walls with swift, deep runs and eddies, few sand beaches, shoreline mostly vertical cliffs and talus; substrate predominantly boulder, cobble, gravel; major tributaries include Diamond Creek and Travertine Canyon
B	239 - 252	Steep, narrow canyon walls with moderate, runs and eddies, sedimentary lake sand deposits at most canyons and tributaries, shoreline variable with talus, sand, earthen banks with vegetation; substrate predominantly cobble, gravel; major tributaries include Separation, Spencer, Surprise, Lost Creek
C	252 - 265	Wide canyon with continuous sedimentary lake deposits heavily vegetated by willows, tamarisk, Baccus, shoreline dominated by vegetated sand/silt deposits but with intermittent talus and vertical rock cliffs; substrate predominantly sand/silt with gravel alluvial fans; major tributary Quartermaster
D	265 - 286	Large open canyon with expansive sedimentary lake deposits heavily vegetated by willows, tamarisk, Baccus, shoreline dominated by vegetated sand/silt deposits, channel with low gradient, extensively braided with side channels, backwaters, isolated pools; substrate predominantly sand/silt; major tributary includes Emery Falls Canyon

Stratum A was characterized by steep, narrow canyon walls with swift, deep runs and eddies, few sand beaches, and a shoreline composed mostly of vertical cliffs and talus. Major tributaries in this stratum included Diamond Creek and Travertine Canyon. This stratum contained habitat that appears suitable for humpback chub, flannelmouth suckers, bluehead suckers, speckled dace, and possibly razorback suckers. Stratum B was also characterized by steep, narrow canyon walls but the gradient was less steep with moderate runs and eddies. The level of Lake Mead has at times risen to Separation Canyon, and so this stratum contained sedimentary lake deposits at most canyons and tributaries. The shoreline was variable with talus, sand, earthen banks with shoreline as well as emergent vegetation. Major tributaries included Separation Canyon, Spencer Canyon, Surprise Canyon, and Lost Creek. Stratum C was characterized as a wide canyon with continuous sedimentary lake deposits heavily vegetated by willows, tamarisk, and Baccus sp. The shoreline was dominated by vegetated sand/silt deposits but with intermittent talus and vertical rock cliffs. This stratum contained several backwaters formed of sedimentary deposits and/or eddy return channels. The major tributary was Quartermaster Canyon. Stratum D was characterized by a large open canyon with expansive sedimentary lake deposits heavily vegetated by willows, tamarisk, Baccus sp., cattails, and bulrushes. The shoreline was dominated by vegetated sand/silt deposits, and the channel had a low gradient with an extensively braided region with side channels, backwaters, and isolated pools. This stratum contained habitat that appeared suitable for razorback sucker, flannelmouth sucker, and possibly bonytail. The major tributary was Emery Falls Canyon.

Fish Sampling Methods

Gear Types Used and Number of Samples

Fish were sampled with six principal gear types -- electrofishing, gill nets, trammel nets, hoop nets, minnow traps, and seines (Table 4). Electrofishing was conducted from an Achilles SU-16 motorized raft. The system was powered by a 5000-watt Honda generator (Model EB 5000X). Power from the generator was routed through a Mark XX Complex Pulse System (CPS) developed by Coffelt Manufacturing. The current was transformed from 220-volt AC to DC, and the system was usually operated at ranges of 110 volts/12 amps to 320 volts/20 amps, depending on water conductance. A single stainless steel, spherical anode was used from the bow of the boat and a single spherical cathode from the stern.

The gill nets used were each 100 feet long and 6 feet deep with uniform square mesh sizes of either 1.5 or 2.0 inches. Experimental gill nets were used with 20-foot panels of 0.5, 1.0, 1.5, 2.0, and

Table 4. Fish sample gears, codes, descriptions, and number of samples from the Lower Grand Canyon and Lake Mead.

SAMPLE GEAR CODE - DESCRIPTION	TOTAL NUMBER SAMPLES
Electrofishing	
EL - 220-v DC (Coffelt CPS)	32
Gill Nets	
GM - 100'x6'x2"	8
GP - 100'x6'x1.5"	5
GX - 100'x6'experimental gill net with 20' panels of 0.5, 1.0, 2.0, 2.5" mesh	10
GS - 300'x6'x2"	4
Trammel Nets	
TK - 75'x6'x1"x12"	48
TL - 75'x6'x1.5"x12"	40
TM - 50'x6'x1"x12"	16
TN - 50'x6'x1.5"x12"	16
Hoop Nets	
HM - 3' diameter (medium)	1
HS - 2' diameter (small)	2
Minnow Traps	
MT - commerical minnow traps	3
Seines	
SB - 30'x4'x1/4" seine	32
Total	217

2.5-inch mesh. A different dimension gill net was implemented in Trip 3--these nets were 300 feet long and 6 feet deep with 2.0-inch mesh, and were used in expansive, slow-flowing channels near the Lake Mead inflow. The trammel nets were either 75 or 50 feet long and 6 feet deep. Square mesh sizes were either 1.0 or 1.5 inches with 12-inch outer mesh. Gill and trammel nets were set by attaching one end to the shoreline and weighting the outer end in the river so that the nets fished at or near the bottom. All nets had a foam-core float line and lead-core bottom line. Gill and trammel nets were checked every 2 hours, and were usually set during crepuscular periods and at night. The amount of green algae, Cladophora glomerata, in the river limited the number of times a given net could be set to 4 to 6 hours before it had to be removed for cleaning. Gill and trammel nets were cleaned by allowing them to dry on sand beaches and brushing the dried Cladophora.

Hoop nets with 3-foot diameter hoops were set overnight in side channels, backwaters, and tributary mouths to capture fish moving into these habitats. The hoop nets were checked about every 12 hours. Minnow traps were set along rocky shorelines, in backwaters, and in tributaries to assess populations of small fish. These were checked about every 12 hours.

Seines were used in backwaters, tributaries, tributary mouths, shorelines, and shallow runs to sample for small fish in shallow habitats. The seine used was 10 feet long, 3 feet deep, with 1/8 inch delta mesh. This gear was particularly effective in capturing red shiners, fathead minnows, mosquitofish, plains killifish, young flannelmouth suckers, and young carp.

Distribution of Fish Sample Effort

The distribution of fish sample efforts by gear in the Lower Grand Canyon and Lake Mead Inflow are presented by 5-mile sections in Table 5. Sample codes were identified in Table 4. This distribution of sample efforts reflects proximity to the six camp sites, Bridge Canyon (RM 235.2), above Spencer Canyon (RM 245.0), below Lost Creek (RM 249.7), Burnt Spring (Rm 259.7), in the braided section (RM 267.5), and Scorpion Island (RM 277.5). There was virtually unlimited access to sample areas from these camp sites, which is a major advantage in this region of the Colorado River, where large whitewater rapids typically block access to and from sample sites. A record of sample distribution will be maintained following each trip in order to identify sections of river that have not been sampled or have received relatively little effort.

Table 5. Distribution of sample efforts in the Lower Grand Canyon and Lake Mead Inflow during Trip No. 3.

Sample Strata	River Mile[a]	EL	GM	GP	GX	GS	TK	TL	TM	TN	HM	HS	MT	SB
A	225-230	0	0	0	0	0	0	0	0	0	0	0	0	0
	230-235	4	3	0	0	0	0	5	0	3	0	0	0	0
	235-240	4	0	0	0	0	5	12	0	0	0	0	0	0
B	240-245	1	0	2	0	0	6	6	3	3	0	0	0	2
	245-250	8	2	0	0	0	13	11	0	6	1	1	3	16
C	250-255	2	0	0	0	0	0	0	0	0	0	0	0	0
	255-260	6	3	0	0	0	3	3	3	3	0	0	0	5
	260-265	2	0	3	3	0	6	0	3	0	0	0	0	1
D	265-270	2	0	0	0	0	0	0	0	0	0	1	0	0
	270-275	1	0	0	7	0	15	3	7	1	0	0	0	8
	275-280	2	0	0	0	4	0	0	0	0	0	0	0	0
	280-285	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS:		**32**	**8**	**5**	**10**	**4**	**48**	**40**	**16**	**16**	**1**	**2**	**3**	**32**

[a] significant land marks:

Diamond Creek	RM 225.7
Travertine Canyon	RM 229.0
Bridge Canyon	RM 235.2
Separation Canyon	RM 239.5
Spencer Canyon	RM 246.0
Surprise Canyon	RM 248.3
Lost Creek	RM 249.0
Salt Creek	RM 255.5
Burnt Spring Canyon	RM 259.5
Quartermaster Canyon	RM 259.8
Dry Canyon	RM 264.5
Hualapai Indian Reservation Boundary	RM 273.5
Emery Falls Canyon	RM 274.3
Grand Wash Cliffs	RM 276.5
Grand Canyon National Park/Lake Mead National Recreation Area Boundary	RM 276.6
Pierce Ferry	RM 280.0

Water Quality Parameters

Water quality parameters were measured and recorded with a Hydrolab Surveyor II at each camp site on the mainstem Colorado River. The instrument was deployed from the 33-foot S-rig support raft and left during the entire time at that location. The instrument was removed from the water when camp was moved. A Hydrolab Datasonde with datalogger was deployed at specific locations such as tributaries and sloughs to record water quality at locations other than the mainstem

River Stage Monitoring

Changes in river stage were monitored at each camp site by installing a temporary staff gage and periodically recording relative river level. The staff gage and thus river level were then tied to a temporary bench mark (TBM) that will be surveyed later for actual elevational changes in river level. Each TBM was designated by a 1-cm diameter dot of yellow enamel paint on a vertical rock face above the high water line. A complete description and photographs were taken of each TBM to facilitate reoccupying these sites.

Drift Netting

Samples of mainstem river drift were taken at each camp site using fine mesh drift nets. Each drift net was made of a 10-foot bag of 560 micron mesh with a screwtop PVC cup to facilitate removing the sample. Each net had a metal frame with an opening of 12 x 18 inches. At each location, six drift samples were taken during the ascending limb of the hydrograph, and six during the descending limb of the hydrograph. Each set of six samples included three surface (included river surface in net) and three subsurface sets. Thus, 12 drift samples were collected at each camp site. Drift samples were taken with two drift nets stacked and held in place with rebar driven into the river bottom. Water velocity at the mouth of each drift net was recorded at the beginning and end of each set using a Marsh-McBirney water velocity meter to allow for volumetric calculations of water filtered. Each net was set for a duration of 10 to 24 minutes, depending on the amount of perceptible drift in the river at the time of the set.

Each drift sample was placed in a quart-sized plastic Ziploc bag, preserved with 90 percent ethyl alcohol, and labeled with a black felt tip pen. Drift samples were returned to the laboratory, where they will be sorted, dried and the volume presented as dry weight in 100 cubic meters of water filtered.

RESULTS

Fish Composition, Distribution, and Abundance

A total of 11 different fish species were captured representing eight families (Table 6). Only two native species--flannelmouth sucker and speckled dace--were caught. The 14 flannelmouth suckers included 2 adults (>300 mm TL), 3 juveniles, and 9 young-of-year (YOY). The YOY were captured in Separation Canyon and ranged from 52 to 83 mm TL. Nine speckled dace were captured, primarily from Spencer Canyon. The remaining seven species were non-natives. Red shiners and fathead minnows were abundant in tributaries (Separation Canyon and Spencer Canyon), where plains killifish and mosquitofish were common. Common mainstem species included carp and channel catfish. Small numbers of striped bass (3), green sunfish (2), and walleye (1) were captured.

A detailed breakdown of fish species captured by life stage with each of thirteen individual gear types used is presented in Table 7. Electrofishing and 1.5-inch trammel nets were the most effective gears in the mainstem Colorado River on large and medium size fish. Hoop nets had limited success on large and medium size fish in side channels and tributary mouths. Seines were the most effective gear for capturing small fish in shallow shoreline habitats and in tributaries. A more detailed account of each species handled during Trip No. 3 is provided in Appendix A.

Water Quality Parameters

Water quality data were recorded at each camp site and tributary visited (Table 8). The data from the Hydrolab Surveyor II and the Hydrolab Datasonde were not available in time for this report, but will be analyzed and provided in the Annual Report. Some water temperature information was available from dialstem thermometers used during sampling. Minimum and maximum water temperatures at various mainstem locations (Table 9) show that in early December, mainstem temperature in the steep canyon area near Bridge Canyon was 8.6 C. Mainstem minimum and maximum temperature above Spencer Canyon was 9.3 C and 9.7 C, respectively, while temperatures below Lost Creek were 9.7 C and 9.9 C. Minimum and maximum water temperatures at Burnt Spring Canyon were 10.0 C and 10.2 C. Further downstream, in the Lake Mead inflow, minimum and maximum water temperatures were cooler at 9.8 C and 10.2 C (braided area), and 9.0 C and 10.2 C (Scorpion Island). The cooler water in the Lake Mead inflow is probably the effect of cooler air temperature on the more open, sedentary water mass near Pierce Ferry.

Table 6. Numbers of fish by species captured during Trip No. 3 in the Lower Grand Canyon and Lake Mead Inflow.

FAMILY COMMON NAME (Code)	SCIENTIFIC NAME	TOTAL CAPTURED
CYPRINIDAE (minnows)		
red shiner (RS)	Cyprinella lutrensis	885
fathead minnow (FH)	Pimephales promelas	486
common carp (CP)	Cyprinus carpio	120
speckled dace (SD)	Rhinichthys osculus	9
CATOSTOMIDAE (suckers)		
flannelmouth sucker (FM)	Catostomus latipinnis	14
PERCICHTHYIDAE (temperate basses)		
striped bass (SB)	Morone saxatilis	3
ICTALURIDAE (catfishes, bullheads)		
channel catfish (CC)	Ictalurus punctatus	21
PERCIDAE (perches)		
walleye (WE)	Stizostedion vitreum	1
CYPRINODONTIDAE (killifishes)		
plains kilifish (PK)	Fundulus zebrinus	28
POECILIDAE (livebearers)		
mosquitofish (GA)	Gambusia affinis	24
CENTRARCHIDAE (sunfishes)		
green sunfish (GS)	Lepomis cyanellus	2
TOTAL:		1,593

Table 7. Numbers of fish by species and life stage captured by sample gear in the Lower Grand Canyon and Lake Mead Inflow.

1	2	RS	GA	CP	FH	CC	SB	SD	FM	PK	GS	WE
EL	Y											
	J	9			1				1			
	A	170		66	20	2		3		5		
	T	179		66	21	2		3	1	5		
SB	Y			31					8		2	
	J	186	4	10	73				1	4		
	A	516	20		392			6	1	19		
	T	702	24	41	465			6	10	23	2	
TL	Y											
	J											
	A			10		7						1
	T			10		7						1
TK	Y											
	J											
	A			2		9	2		1			
	T			2		9	2		1			
TM	Y											
	J											
	A					2	1		1			
	T					2	1		1			

1	2	RS	GA	CP	FH	CC	SB	SD	FM	PK	GS	WE
TN	Y											
	J											
	A			1		1			1			
	T			1		1			1			
GM	Y											
	J											
	A											
	T											
GP	Y											
	J											
	A											
	T											
GX	Y											
	J											
	A											
	T											
GS	Y											
	J											
	A											
	T											
MT	Y											

[1]	[2]	RS	GA	CP	FH	CC	SB	SD	FM	PK	GS	WE
	J											
	A											
	T											
HS	Y											
	J											
	A											
	T											
HM	Y	0										
	J	0										
	A	4										
	T	4										
TOTALS		885	24	120	486	21	3	9	14	28	2	1

[1]- Gear Types
EL = Electrofishing
SB = 30'x4'x1/4" seine
TL = 75'x6'x1½"x12" trammel net
TK = 75'x5'x1"x12" trammel net
TM = 50'x6'x1"x12" trammel net
TN = 50'x6'x1 1/2"x12" trammel net
GM = 10'x6'x2" gill net
GP = 100'x6'x1½" gill net
GX = 100', 2" to ½" @ ½" increment, experimental gill net
GS = 300'x6'x2"
MT = minnow trap
HS = 2' diameter (small) hoop net
HM = 3' diameter (medium) hoop net

[2] - A = Adult
J = Juvenile
Y = Young of year

[3] - RS = red shiner
GA = mosquito fish
CP = common carp
FH = fathead minnow
CC = channel catfish
SB = striped bass
SD = speckled dace
FM = flannelmouth sucker
PK = plains killifish
GS = green sunfish
WE = walleye

Table 8. Locations and times for recording water quality parameters[a] using a Hydrolab Surveyor II and a Hydrolab Datasonde with datalogger.

SAMPLE SITE (River Mile)	OBSERVATION PERIOD (DATES)[b] TIME (Hours)
<u>HYDROLAB SURVEYOR II</u>	
Bridge Canyon (RM 235.2)	921201-921203
Above Spencer Canyon (RM 245.0)	921203-921206
Below Lost Creek (RM 249.7)	921206-921207
Burnt Spring Canyon (RM 259.7)	921209-921211
<u>HYDROLAB DATASONDE W/DATALOGGER</u>	
Spencer Creek (100 m above outflow)	921203-921205 1450-

[a] Water quality parameters included temperature, pH, dissolved oxygen, conductivity, redox potential.
[b] 921201 = December 1, 1992.

Table 9. Minimum and maximum water temperature recorded for the mainstem Colorado River and selected tributaries in Lower Grand Canyon and Lake Mead Inflow during Trip No. 3.

LOCATION (River Mile)	DATES[a]	WATER TEMPERATURE	
		MIN.	MAX.
MAINSTEM COLORADO RIVER			
Bridge Canyon (RM 235.0)	921201-921203	8.6	8.6
Above Spencer Cny (RM 245.0)	921203-921206	9.3	9.7
Below Lost Cr (RM 249.7)	921206-921207	9.7	9.9
Burnt Spring Cny (RM 259.7)	921207-921209	10.0	10.2
Braided Area (RM 267.5)	921209-921211	9.8	10.2
Scorpion Island (RM 277.5)	921211-921213	9.0	10.2

[a] 921201 = December 1, 1992

Changes in River Stage

Changes in river stage were monitored and recorded at four locations during Trip No. 3 (Table 10, Figure 3). The maximum stage change at Bridge Canyon (RM 235.1) on December 2-3, 1992 was 42 cm. The maximum stage change above Spencer Canyon (RM 242.8) on December 5-6, 1992 was 56 cm. Maximum stage change at Burnt Spring Canyon (RM 259.3) on December 8-9, 1992 was 25 cm, while the maximum change below Lost Creek (RM 249.7) on December 6-7, 1992 was 38 cm.

Drift Samples

A total of 30 drift net samples were taken from the Colorado River during Trip No. 3 (Table 12). Six of these were collected at Bridge Canyon (RM 235.1) during the ascending hydrograph. Twelve drift samples were collected above Spencer Canyon (RM 242.8), six during the ascending hydrograph and six during the descending hydrograph. Twelve drift samples were also collected near Burnt Spring Canyon (RM 259.3), including six during the ascending hydrograph and six during the descending hydrograph.

Table 10. Fluctuations in river stage measured at each sample site in Lower Grand Canyon and Lake Mead Inflow.

SAMPLE SITE (River Mile)	OBSERVATION PERIOD TIME (hours)	MAX. STAGE CHANGE (cm)
Bridge Canyon (RM 235.1)	921202-921203 1030-1010 (23.7 hrs)	42
Spencer Canyon (RM 242.8)	921205-921206 0723-0825 (25.0 hrs)	56
Burnt Spring (RM 259.3)	921208-921209 1203-1041 (22.6 hrs)	25
Below Lost Cr (RM 249.7)	921206-921207 1922-0646 (6.6 hrs)	38

Table 11. Locations and descriptions of temporary bench marks (TBM) established during Trip No. 3 in Lower Grand Canyon and Lake Mead Inflow.

TBM Number[a]	DATE[b]	DESCRIPTION
L 235.1 (Above Bridge Cn)	921202	Upstream of Bridge Canyon Rapid beach, on shear wall near fanged rock-upper end of beach.

[a] Each TBM marked on a vertical rock face with a 1-cm diameter dot of yellow enamel paint.
[b] 921202 = December 2, 1992

Table 12. Drift samples collected from the Colorado River in Lower Grand Canyon and Lake Mead Inflow.

		NO. SAMPLES[a]					
		RISE		FALL		EVEN	
SAMPLE SITE (River Mile)	DATE	SUR	SUB	SUR	SUB	SUR	SUB
Bridge Canyon (RM 235.1)	921202	3	3	0	0	0	0
Spencer Canyon (RM 242.8)	921205	3	3	3	3	0	0
Burnt Spring Canyon (RM 259.3)	921208	3	3	3	3	0	0

[a] Number of drift samples during rising (RISE), falling (FALL), or level (EVEN) hydrograph, taken from surface (SUR) and subsurface (SUB).

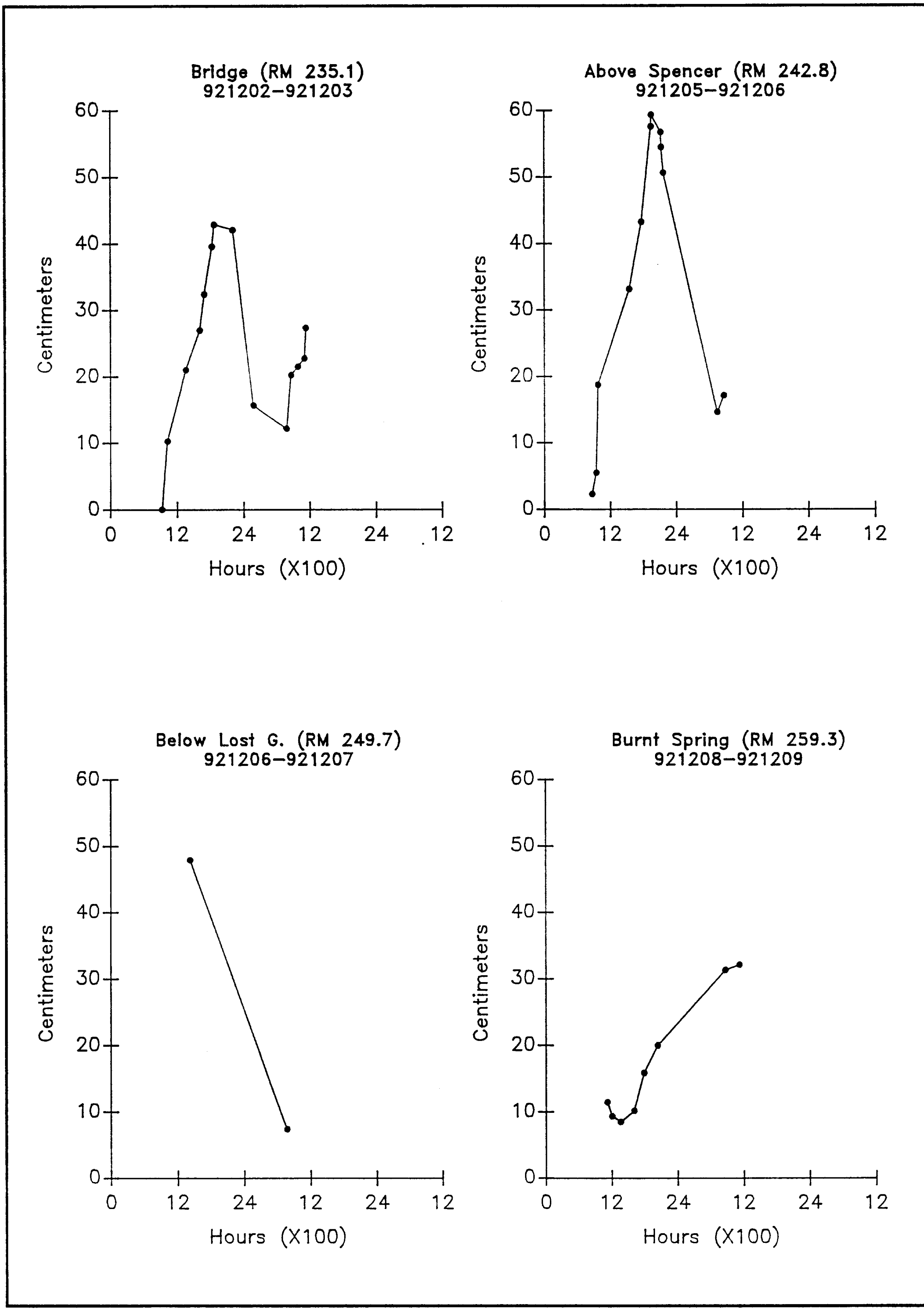

Figure 3. Relative changes in river stage recorded at three locations in Lower Grand Canyon and Lake Mead.

RECOMMENDATIONS

1. Sample Lost Creek slough, Spencer Creek, and Separation Creek for razorback suckers in the early spring.

2. Sample more intensively the braided region between RM 267-270.

3. Monitor YOY suckers in Spencer Canyon and Surprise Canyon, including taking specimens to determine if young razorback suckers are present.

4. Sample slough at Quartermaster Canyon.

5. Sample all tributaries in the reach to ascertain extent of red shiner distribution.

6. Preserve tapeworms in lower intestine of channel catfish for identification, to ascertain if Asian tapeworm is present in this population.

7. Employ angling and trotlines to fully survey fish populations in deep holes in reach.

8. Identify key locations (i.e., backwaters, tributaries) for location of remote camera stations.

9. Thoroughly document riparian vegetation, aquatic macroinvertebrates, and fish ecot- and endoparasites to fully characterize fish habitat and associated parameters.

LITERATURE CITED

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APPENDIX A
Fish Species Descriptions

This appendix is provided as a guide and an aid to better understanding the fish species in the Lower Grand Canyon and Lake Mead Inflow. It provides a brief description of each fish species encountered, as well as those that might occur in the reach. The ichthyofauna of the Lower Grand Canyon and Lake Mead Inflow has been greatly influenced by the presence of Lake Mead and Lake Powell. Since the completion of Hoover Dam in 1935 and Glen Canyon Dam in 1963, a large number of fish species have been introduced into the area as recreational sports fisheries. Many such as largemouth bass, bluegill, black crappie, green sunfish, walleye, striped bass, rainbow trout, cutthroat trout, and coho salmon were introduced to establish sports fisheries. Others such as threadfin shad and fathead minnows were added as forage for the large predators. Some of the more numerous and widespread species such as carp, channel catfish, black bullhead, and yellow bullhead proliferated with the creation of the reservoir. Species such as red shiner, redside shiner, and fathead minnow were used extensively as bait by fishermen.

FAMILY CATOSTOMIDAE

BLUEHEAD SUCKER (Catostomus discobolus)

The bluehead sucker was not found in the study area from Diamond Creek to Pierce Ferry during Trip No. 1, 2, or 3. It is a species that is expected to inhabit the area, particularly in the upper swift stratum A. The bluehead sucker is native to the Colorado River Drainage, although it is not endemic and is found in other drainages of North America, such as the Walker River of northern Nevada.

Bluehead suckers are found primarily in the middle to upper reaches of the Colorado River and its tributaries (Tyus et al. 1982). They are commonly associated with cobble and rubble substrate, and can be particularly abundant in relatively swift water over rocky jetties and bars. This species is commonly associated with flannelmouth suckers, but is distributed further upstream in cooler and clearer conditions. Bluehead suckers are particularly abundant in the Gunnison River, the upper Green River, and the upper Colorado River, above Moab. They are locally common in the mainstem and tributaries of the lower basin, and in the Grand Canyon they commonly spawn in tributaries such as Shinumo Creek, Kanab Creek, and Bright Angel Creek. The species is probably not abundant in Lower Grand Canyon and Lake Mead Inflow.

Hybrids of bluehead and flannelmouth suckers are reported in the Green and Upper Colorado Rivers (Hubbs and Miller 1953, McAda 1977, Valdez et al. 1982), and possibility of hybridization with razorback suckers exists in Grand Canyon. The most recently published List of Common and Scientific Names (American Fisheries Society 1991) applies the genus Catostomus, although there is disagreement that the original genus Pantosteus, established by Cope in 1875, is more appropriate.

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

FLANNELMOUTH SUCKER (Catostomus latipinnis)

The flannelmouth sucker is one of six endemic species once found in Grand Canyon. Flannelmouth suckers are common in the middle regions of the Green and Colorado Rivers and their tributaries (Tyus et al. 1982). They are low in numbers in the mainstem Colorado River and its tributaries in the lower basin. Flannelmouth suckers are commonly associated with cobble riffles and jetties often in sympatry with bluehead suckers and razorback suckers.

Flannelmouth suckers were reported as common in the tributaries of the upper reaches of Grand Canyon from Glen Canyon Dam to Phantom Ranch (McCall 1979), and they have been frequently collected throughout the Colorado River in Grand Canyon (Carothers and Minckley 1980). Aggregations were reported at the mouth of Spencer Creek (Suttkus et al. 1976) and Surprise Canyon (Deacon and Baker 1976). They were not collected from these tributaries in 1978-79, but two yearling fish were captured from a backwater near Bat Caves, and reported as the furthest downstream location for the species in the Lake Mead Recreation Area (McCall 1979).

Hybridization between flannelmouth suckers and bluehead suckers or razorback suckers has been reported for many years from the upper basin (Hubbs and Miller 1953, Holden 1973). McAda and Wydoski (1980) reported the increasing incidence of hybrids in the upper basin as a threat to the rare razorback sucker. Specimens captured by BIO/WEST (Valdez 1992) suggest hybridization between flannelmouth and razorback suckers.

Flannelmouth suckers are a very distinct species. They are a robust, fusiform fish with large broad fins (the genus latipinnis means broadfin). They have a mottled yellow-gray appearance with small scales that become slightly larger toward the tail. They are easily distinguished from the bluehead and mountain suckers by the absence of lateral notches between the maxillary and mandible, the presence of a deep medial notch in the mandible, and the absence of a scraping "radula". They are the second largest sucker in the Colorado River (razorbacks grow larger) and generally spawn from March to early August, depending on the area. Large numbers of adult flannelmouth suckers were observed spawning in Kanab Creek in late March and early April of 1992 (Personal Communication, Randy VanHaverbeke).

RAZORBACK SUCKER (Xyrauchen texanus)

Razorback sucker were not captured during Trip No. 1, 2, or 3. However, the presence of the species in Lake Mead and rare captures in the Grand Canyon suggest that the species is present in the study area. Much of the habitat in this reach of the Colorado River appears to be suitable for the species.

The razorback sucker is currently a federally-listed endangered species under the Endangered Species Act of 1973. It is endemic to the Colorado River Basin. The razorback sucker has declined vastly throughout its range in the upper basin because of a lack of reproduction, habitat alterations, and hybridization (Wick et al. 1982). Lanigan and Tyus (1989) estimated the population of the razorback sucker in the upper Green River at 948 fish (95% confidence interval, 758-1138).

Minckley and Marsh (1990) estimated the population of Lake Mohave at about 20,000 adults. The literature in the last 15 years (Holden and Stalnaker 1975, McAda and Wydoski 1980, Wick et al. 1982) indicates a general decrease in numbers and distribution of the razorback sucker throughout the Colorado River Basin. Only three specimens were captured by McCall (1979) in Lake Mead in 1978-79. The decline of the razorback in this area is attributed to desiccation of eggs and predation of eggs and larvae by introduced centrarchids (Gustafson 1974).

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

FAMILY CENTRARCHIDAE

BLACK CRAPPIE (Pomoxis nigromaculatus)

Black crappie were first introduced into Lake Mead soon after it began filling in about 1935 (Wallis 1951). Tremendous numbers of crappie were in the reservoir by the 1950's, but the numbers have dwindled with reduced reservoir production and silting of rocky shorelines used for spawning.

Black crappie are strongly laterally compressed and can reach weights of over 3 pounds. They are distinguished from white crappie in that black crappie usually have 7 or 8 dorsal spines (white crappie usually have 6) and black crappie have dark markings on the side irregularly arranged as speckles and blotches (white crappie have regular vertical black bars).

Black crappie are not a significant species in riverine inflow regions because they are strictly lacustrine (lake dwellers). They are sometimes found in perrenial sloughs or backwaters and could prey on young native species in these nursery areas. The only black crappie encountered on trip no. 1 was in a lake environment near Pierce Ferry.

GREEN SUNFISH (Lepomis cyanellus)

Green sunfish were probably first introduced to the area of the Colorado River basin in about 1890 in mixed carload shipments of fish from the Illinois River (Popov 1949). In the 1930's and 1940's, green sunfish and bluegill were introduced into many areas of Utah as "sunfish" and were promoted as a game fish by the U.S. Bureau of Fisheries (Leach et al. 1940). They were released into Lake Mead from 1937 to 1939 (McCall 1979).

Green sunfish are easily distinguished from bluegill by the presence of a short rounded black ear flap with a light margin, and a rounded pectoral fin; bluegill have an elongated earflap blackened to the margin and a long slender pectoral fin. Green sunfish often have turquoise vermiculi radiating across the cheeks, and yellow pectoral and pelvic fin margins.

Green sunfish are the most common centrarchid found in the mainstem Colorado River. They are usually found in backwaters and along protected shorelines. Most specimens are small (<100 mm), suggesting that these fish may reproduce but probably do not survive well in the river. Small numbers of green sunfish in backwaters and their omnivorous diet suggests competition and predation on the native fish. The only green sunfish encountered during trip no. 1 was near Pierce Ferry.

LARGEMOUTH BASS (Micropterus salmoides)

Largemouth bass were first introduced into California in 1847 (Emig 1966) and into Utah in September 1890 as a mixed carload with perch, crappie, and sunfish seined from the Illinois River Bottoms (Popov 1949). They were first released into Lake Mead as the reservoir was filling in 1935 (McCall 1979). Largemouth bass were introduced into Colorado River basin reservoirs as a sport and trophy fish where they met with great success in the first 20 to 30 years of the life of the reservoir. Production of largemouth bass has dwindled with decreased reservoir production and siltation of rocky shorelines used for spawning. Also, most western reservoirs are regulated for irrigation starting in spring, when fish are spawning in shorelines exposed to constant fluctutation.

Largemouth bass can exceed 20 pounds in weight, but are usually less than 10 pounds in Lake Mead. Largemouth bass are distinguished from smallmouth bass in that largemouths (greater than 6 inches long) have an upper jaw that extends well beyond the orbit of the eye (jaw of smallmouths does not extend beyond orbit). The length of the shortest dorsal spine in the notch between the two dorsal fins is less than half the length of the longest spine in largemouths and more than half the length in smallmouths. Young largemouth bass have a tail fin with two colors, whereas the tail fin of a smallmouth bass is tricolored (light margin, dark bar, light caudal base).

Small largemouth bass were encountered in the inflow region of Lake Mead during trip no. 1. Although this species is typically lacustrine (lake dweller), it survives well in riverine conditions and can be a significant predator in perrenial backwaters and sloughs. The largest largemouth bass captured during trip no. 1 were in the Lost Creek slough.

SMALLMOUTH BASS (Micropterus dolomieui)

Smallmouth bass were not captured during Trip No. 1, 2, or 3. The species became established in the lower Colorado River in Arizona by 1940 (Miller and Lowe 1967), but was not reported above Hoover Dam except for a single specimen observed near the mouth of the Moapa River by Dr. C.L. Hubbs (Miller and Alcorn 1946). Smallmouth bass were introduced into Lake Mead in the 1980's.

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

The impact of this species on the native fishes of the Colorado River Basin is unknown. It is a potential predator and the young could compete with young native fishes. Also, smallmouth bass, unlike largemouth bass, can inhabit and thrive in cool riverine environments.

Young largemouth bass are frequently mistaken for smallmouth bass since the most common key characteristic is the extend of the upper jaw (maxillary) relative to the orbit of the eye. The upper jaw of largemouth bass less than about 6 inches in length often fails to extend beyond the orbit, and so young bass need to be distinguished by the bicolor (largemouths) or tricolor (smallmouths) of the caudal fin and the length of the shortest dorsal spine relative to the longest (less than half in largemouths and more than half in smallmouths).

FAMILY CYPRINIDAE

BONYTAIL (Gila elegans)

Bonytail were not captured in the study area during Trip No. 1, 2, or 3. However, the species survives as enclaves in Lake Mohave and possibly Lake Mead. The bonytail is perhaps the rarest of the endemic fishes of the Colorado River Basin. It is listed as "endangered" by the FWS as well as the States of Utah and Colorado. The species was first determined endangered, without critical habitat designation, by FWS on April 23, 1980 (Federal Register, 45 FR27713) under the Endangered Species Act of 1973, as amended. A Recovery Plan was first developed in 1984 and was updated in 1989 (Colorado River Fishes Recovery Team 1984, 1989).

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

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

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

COMMON CARP (Cyprinus carpio)

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

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

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

Carp are locally abundant in sheltered habitats of the Colorado River Basin, particularly in off-river impoundments, backwaters, and shorelines; carp are about the only species that inhabits the sand-silt tamarisk-lined banks that now dominate the Colorado and Green Rivers. In Grand Canyon, carp probably constitute the greatest biomass of any species.

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

COLORADO SQUAWFISH (Ptychocheilus lucius)

Colorado squawfish have not been recently reported in the Lower Colorado River Basin, and the last one taken from Lake Mead was in 1967 (Minckley 1973). They are unlikely to be found during this investigation, however, AGFD recently reported a single specimen from near the site of the Willow Beach National Fish Hatchery that was probably escaped from that facility.

The Colorado squawfish is the largest fish endemic to the Colorado River Basin. It is the largest member of the minnow family (Cyprinidae) in North America with an estimated length of 5 feet and weight of 80 pounds, although the largest confirmed weights are 27 and 34 pounds for two fish from Lake Mead (Wallis 1951). The largest Colorado squawfish recently caught was from the upper basin, and was slightly longer than 3 feet and weighed about 25 pounds (Personal communication, Tom Chart, Utah Division of Wildlife Resources, 1991).

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

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

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

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

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

FATHEAD MINNOW (Pimephales promelas)

Fathead minnows are widely distributed in the warmer middle and lower regions of the Colorado River Basin. Their mode of access is unknown but was probably via bait buckets since the species is so popular as a bait fish for crappie and largemouth bass. The species may have gained access into the drainage as early as the late 1800's as an incidental in seine hauls of "bass and sunfish" brought to the west from midwestern drainages. They were reported from bait shops near Lake Mead in the 1940's and 1950's.

Fathead minnows rarely exceed 3 inches in length. They are a stout, dark or brassy minnow with small scales and a characteristic black blotch on the dorsal fin. The lateral line is incomplete and first ray of the dorsal fin is thickened and separate from the second ray. Spawning males have prominent tubercles (raspy projections) on the head.

Fathead minnows were abundant during this investigation in Surprise Canyon and Lost Creek slough, with fewer numbers in Spencer Canyon. Small numbers were captured in backwaters of the mainstem. In 1978-79, McCall (1979) reported that fathead minnows were not established in Lake Mead and that only seven were captured; six at the mouth of Spencer Canyon and one from lower Surprise Canyon. During this investigation, fathead minnows were abundant in Surprise Canyon and Lost Creek Slough indicating that the species has flourished in these locations since 1979.

Fathead minnows thrive in warm, turbid waters (Pflieger 1975) and can survive high temperatures and low oxygen levels better than probably any other species, except perhaps for black bullheads and mosquitofish. The impact of the fathead minnow on native species is unknown. Like the other small cyprinids, it is implicated as a potential competitor and predator.

HUMPBACK CHUB (Gila cypha)

Humpback chub were not found in the study reach during Trip No. 1, 2, or 3. The river in stratum A appears suitable for the species with a complex of habitats similar to those found further upstream.

The humpback chub is one of three endemic fishes listed by the FWS as "endangered" under the Endangered Species Act of 1973, as amended. It is also designated as "endangered" by the States of Utah and Colorado. The species was first included in the first List of Endangered Species issued by the Office of Endangered Species and published in the Federal Register (32 FR 4001) on March 11, 1967. A Recovery Plan was first developed in 1978, and updated in 1989 (Colorado River Fishes Recovery Team 1989).

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

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

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

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

RED SHINER (Cyprinella lutrensis)

Red shiners were probably introduced into the Colorado River in the early 1900's incidental in seine hauls of "bass and sunfish" from the Illinois river bottoms (Popov 1949), or in bait buckets, or both. In its native habitat along the Mississippi drainage, the red shiner is primarily a stream fish that inhabits a variety of habitats including quiet pools and backwaters as well as riffles. It is tolerant of high turbidity and siltation but avoids waters that are continuously clear or cool (Pflieger 1975). Red shiners were the most common fish species in the upper Colorado River basin (Valdez 1990), reported primarily from backwaters and shallow sheltered habitats. The species is implicated in predation and competition with the native fishes of the basin. Red shiners have not been reported recently in surveys of the Grand Canyon (Valdez et al. 1992).

This investigation first encountered red shiners at Spencer Canyon (RM 246). The species was the most numerous fish species encountered in tributaries, including Spencer Creek, Surprise Creek, Lost Creek, and Quartermaster Creek. The species was most abundant in the lower reaches of these streams, the lower 300 m. They decreased in numbers progressively upstream, where other species such as fathead minnows, mosquitofish, or speckled dace became more numerous. Red shiners were also found in the mainstem Colorado River from Spencer Canyon downstream, but their upstream-most location in Lower Grand Canyon still needs to be more definitively determined through additional sampling. Red shiners were observed spawning in Spencer Creek during Trip No. 1; measurements of water depth, velocity, and substrate size were recorded, along with water quality parameters. This information will be released later as a note to a scientific journal following review by the cooperating agencies.

Adult red shiners are usually deep bodied and laterally compressed, steel blue above and silvery below with orange fins. Breeding males are metallic blue with bright red fins and tubercles on the head and body. Red shiners typically have eight or nine anal rays.

SPECKLED DACE (Rhinichthys osculus)

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

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

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

FAMILY CYPRINODONTIDAE

PLAINS KILLIFISH (Fundulus zebrinus)

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

Fundulus zebrinus (plains killifish) and Fundulus sciadicus (plains topminnow) are reported as incidental in the Colorado, Green, and White Rivers of the upper basin, and rare in the San Juan River (Tyus et al. 1982). The plain killifish has a dorsal fin base situated above or forward of the anal fin base; usually 13 to 16 dorsal fin rays; 40 or more lateral line scales; and 12 to 13 dark vertical bars on the sides of the body. The plains topminnow has a dorsal fin base situated above the anal fin base; usually 6 to 11 dorsal fin rays; 38 or fewer lateral line scales; and without vertical bars or horizontal streaks (Pflieger 1975). Another species (F. kansae) is described in Missouri (Pflieger 1975) and has been suggested as the species in the Colorado River drainage. The most current List of Common and Scientific Names (American Fisheries Society 1991) recognizes the plains killifish (F. zebrinus), but does not recognize F. kansae. In the Grand Canyon, numerous reports refer to a "Rio Grande killifish". This common name is also not recognized by the American Fisheries Society (1991).

FAMILY CLUPEIDAE

THREADFIN SHAD (Dorosoma petenense)

Threadfin shad were first introduced into Overton Arm of Lake Mead in 1954 (from Kentucky Lake, Tennessee River) (McCall 1979). The species was also introduced into Lake Powell in 1968 and again in 1969 (Gustaveson et al. 1975) as a forage fish for largemouth bass, black crappie, and striped bass which were first released in Lake Mead in 1969 and in Lake Powell in 1974. Threadfin shad are strictly lacustrine (lake dweller) and are poor swimmers in currents. This species is the most significant forage base for striped bass. Declines in the population of threadfin shad in Lake Powell in 1982 and 1983 dramatically affected the growth and condition of striped bass in that reservoir.

Threadfin shad are a delicate, laterally-compressed fish with an elongated final ray of the dorsal fin, and a strong midline abdomenal keel of sharp-edged spiny scales or "scuts". The genus Dorosoma means "lace-body" which describes the eel-like larvae and the species petenense was derived from Lake Peten, Guatemala, where the first specimens were described. The species characteristically has a single black spot behind and slightly above the operculum and a bright yellow caudal fin. Threadfin shad are distinguished from gizzard shad in that the lower jaw of the former projects beyond the tip of the snout (lower jaw of gizzard shad does not project beyond tip of snout), and the rays of the anal fin are 20-25 in threadfin shad and 29-35 in gizzard shad.

Recently, UDWR (Gustaveson and Bonebrake 1989) submitted a draft proposal to introduce rainbow smelt (Osmerus mordax) into Lake Powell to provide additional forage for all game fish in the reservoir. Several concerns were discussed in this proposal regarding the introduction of this non-native species, including their possible escape from the reservoir into the Colorado River upstream and downstream.

FAMILY ICTALURIDAE

BLACK BULLHEAD (Ameiurus melas)

Black bullhead were one of the first non-native fishes to be brought to the west, first introduced into California in 1874 (LaRivers 1962) and into the Colorado River about 1890. The species was first reported from Lake Mead in 1937 (Wallis 1937) and as increasing numbers during the filling of the lake. However, the species does not do well in large open reservoirs and is rare in the impoundment; only three were reported by anglers in 1977 (Liles 1977). During trip no. 1 of this investigation, one black bullhead was captured near Pierce Ferry, together with a yellow bullhead.

Black bullheads are distinguished from channel catfish primarily by their square tail, as compared to the deeply forked tail of the channel catfish. Black bullheads are dark brown to greenish-black dorsally, with a yellowish white belly. The species characteristically has black pigmentation on the chin barbels and the dorsal and caudal fin membranes are distinctly black. Black bullheads also have pectoral spines that are weakly barbed on the posterior edge with 17 to 21 rays in the anal fin. The yellow bullhead (I. natalis) is similar but has white chin barbels, light dorsal and caudal fin membranes, and 24 to 27 anal fin rays.

Black bullheads are probably one of the more voracious inhabitants of large backwaters, habitats commonly used as nurseries by native and endangered species. They are probably indiscriminate feeders, and even small numbers constitute a major threat to any small fish or macroinvertebrate.

YELLOW BULLHEAD (Ameiurus natalis)

The yellow bullhead is the most heavily bodied of the catfishes, the specific name natalis means "having large buttocks". Large specimens usually have unusually large heads, and vary considerably in color. Maximum size exceeds 1 kg. The chin barbels are white, the fin membranes are light colored, and there are usually 24 to 27 anal fin rays.

Yellow bullheads are rare in the Colorado River in Grand Canyon. McCall (1979) reported twelve adults from Emory Falls Canyon and Green Rock backwater in 1978, and possibly one at Spencer Canyon. The specimen captured during trip no. 1 of this investigation was captured near Pierce Ferry in a trammel net containing a black bullhead.

Like black bullheads, yellow bullheads are probably one of the more voracious inhabitants of large backwaters, habitats commonly used as nurseries by native and endangered species. They are probably indiscriminate feeders, and even small numbers constitute a major threat to any small fish or macroinvertebrate.

CHANNEL CATFISH (Ictalurus punctatus)

Channel catfish were first introduced into California in 1874 (Shelby 1917), and into the lower Colorado River in 1892-93 (Worth 1895). They quickly became abundant and popular with sport fishermen. Although they were never stocked directly into Lake Mead, by the 1950's, channel catfish were the second most common fish in angler creel, exceeded only by largemouth bass (Jonez and Sumner 1954). Channel catfish were common in the inflow region of Lake Mead during trip no. 1 of this investigation.

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

Although channel catfish are reported to reach nearly 50 pounds in weight, the largest specimens in the Colorado River system are less than 30 pounds. No other close relatives of the channel catfish, such as the blue catfish (Ictalurus furcatus) or the white catfish (Ictalurus catus) are reported from the Upper Colorado River Basin, although flathead catfish (Pylodictus olivaris) are common in the lower basin below Hoover Dam.

FAMILY PERCIDAE

WALLEYE (Stizostedion vitreum)

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

Walleye were first released in Arizona in the mid-1960's (Minckley 1973). They were caught by anglers in the Colorado River below Glen Canyon Dam in 1967, 1971, and 1972 (Stone 1967, 1971, 1972), but soon disappeared. Few walleye have been documented from Lake Mead, and only one has been captured by BIO/WEST (Valdez 1992) at the base of Lava Falls in Grand Canyon and one captured near the mouth of Spencer Canyon on trip no. 1 of this investigation. This specimen had a large threadfin shad in its stomach.

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

FAMILY POECILIIDAE

MOSQUITOFISH (Gambusia affinis)

Mosquitofish were first introduced into Utah from Selby County, Tennessee in 1931 (Sigler and Miller 1963). It is native to the central United States from southern Illinois and Indiana to Alabama and the lower Rio Grande in Texas. It has been distributed extensively since the 1950's by mosquito abatement districts to control mosquitos, and has received world-wide attention in helping to combat the malaria-carrying forms. It does not tolerate prolonged cold conditions (<40°F) and does not occur extensively in northern regions, although it is tolerant to warm temperatures and low oxygen conditions. It was first reported in Arizona in 1926 (Miller and Lowe 1967) and was common in the basin before Lake Mead. Mosquitofish do not fare well in large reservoirs and was soon gone from the area. The species was abundant from the inflow region below Grand Wash Cliffs in 1978-79

(McCall 1979), and it was abundant in Surprise Canyon, Lost Creek slough, and numerous in Spencer Canyon and Quartermaster Canyon during trip no. 1 of this investigation.

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

FAMILY SERRANIDAE

STRIPED BASS (Morone saxatilis)

Striped bass were first introduced into the lower Colorado River in Arizona in 1959 (St. Amant 1959), into Lake Mead in 1969 (McCall 1979), and into Lake Powell in 1974 (Gustaveson et al. 1985). Striped bass were introduced into lakes Mead and Powell to alleviate a decline in spawning and nursery habitat of largemouth bass and black crappie as the lakes approached full pool. Threadfin shad were introduced into these reservoirs as forage for the stripers as well as for largemouth bass and crappie. The striped bass has been a very successful sport fish in the Colorado River Basin and is highly sought by trophy sport fishermen, although a decline in threadfin shad in 1982-83 affected the condition of striped bass in both reservoirs.

Small numbers of striped bass migrate into the inflow regions of both reservoirs during spring and summer. Fewer than 25 individuals were found by BIO/WEST in Grand Canyon during July, August, and September of 1991 as far upstream as the mouth of Havasu Creek (RM 156.4). Other investigators (Personal communications with Dennis Kubley) have reported striped bass as far upstream as the Little Colorado River (RM 61.3). It is unknown if cold water releases from Glen Canyon Dam prevent greater numbers of spawners from migrating into the Colorado River in Grand Canyon.

The impact of striped bass on the native fishes of the river system has not been assessed. Striped bass typically fast (do not feed) during spawning ascents and events. This suggests that if this species occupies the Colorado River in Grand Canyon only during spawning events, it is not likely to prey upon other fishes. Extensive sampling above Diamond Creek have failed to yield young stripers, indicating that the young are not taking residence in the river in Grand Canyon.