Report No. TR-354-01
BIO/WEST, Inc.

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

Annual Report - 1992

Submitted To

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EXECUTIVE SUMMARY

An investigation of the aquatic resources of the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286) in Lake Mead, was initiated at 1992 by the Hualapai Wildlife Management Department, with technical assistance from BIO/WEST, Inc. The purpose of the investigation was to determine the effects of interim flow releases from Glen Canyon Dam, located about 240 miles upstream of the upper end of the study reach. Three trips were conducted in 1992 (June 24 - July 2, September 27 -October 9, December 1 - 13) to sample fishes, macroinvertebrates, and water quality, as well as record river stage changes. 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 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 filled 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 21 miles from Dry Canyon to below Pearce Ferry (RM 286).

Fish sampling was conducted with seven primary gear types including electrofishing, gill nets, trammel nets, hoop nets, minnow traps, seines, and angling. Seventeen species of fish were captured representing nine families. Only two of these species (speckled dace and flannelmouth sucker) were native to the Colorado River Basin, while the remaining 15 species were non-native or introduced. Carp and channel catfish were the most common mainstem species, while red shiners, fathead minnows, and mosquitofish dominated the ichthyofauna of the tributaries, including Spencer Canyon, Surprise Canyon, Lost Creek, and Quartermaster Canyon. Plains killifish were found in local aggregations in tributaries. Striped bass, largemouth bass, green sunfish, black crappie, white crappie, bluegill, threadfin shad, and walleye were lake species that were found in small numbers in tributaries or sheltered riverine habitats. The endangered species, humpback chub (Gila cypha), razorback sucker (Xyrauchen texanus), Colorado squawfish (Ptychocheilus lucius), and bonytail (Gila elegans), were not seen or captured.

Water quality parameters were collected at various locations with a constant recording Hydrolab Surveyor II and Datasonde with datalogger. Maximum mainstem water temperature ranged from 17.0°C at Travertine Canyon (RM 229.0) on June 24, to 20.0°C at Grand Wash Cliffs (RM 276.0) on July 1. Surface temperature at Pearce Ferry was 24.5 to 26.0°C on July 1. Water temperature ranged from 15.0°C at Bridge Canyon (RM 235.0) on September 27, to 23.0°C at Pearce Ferry (RM

280.0) on October 7. December water temperatures ranged from 8.6°C at Bridge Canyon on December 1, to 10.2°C at Scorpion Island (RM 277.5) on December 11, 1992.

River stage changes were recorded during each of the three 1992 sampling trips. During Trip 1 (late June), river stage changed by 60 cm during a 6-hour period at Spencer Canyon (RM 246, 261.5 miles below Glen Canyon Dam), while a change of 54 cm was measured in 6 hours near Lost Creek (RM 249, 265.2 miles below Glen Canyon Dam). During Trip 2 (late September - early October), river stage changed by 36 cm in 8 hours at Bridge Canyon (RM 235), and by 42 cm in 8 hours at Spencer Canyon. During Trip 3 (early December), river stage changed by 42 cm at Bridge Canyon, 56 cm at Spencer Canyon, and 38 cm below Lost Creek.

Few studies have been conducted on the aquatic resources of this lower reach of the Colorado River in Grand Canyon. Fish species composition showed that the reach was dominated by non-native species, but that specific areas in this reach may be suitable for native and endangered species. The steep canyon between Diamond Creek (RM 226) and Bridge Canyon (RM 235) may be suitable for humpback chub, while the open, braided area between Dry Canyon (RM 264) and Pearce Ferry (RM 280) has suitable habitat for razorback suckers. The presence of young suckers (probably all flannelmouth suckers) in Spencer Canyon and Surprise Canyon indicates that these tributaries may be suitable spawning and nursery sites for razorback suckers. Spencer Canyon may also be a suitable site for introducing young razorback suckers as a program to augment the population of Lake Mead and the inflow region.

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INTRODUCTION

Rationale For This Study

Proper management of Glen Canyon Dam is vital to preserving the native ichthyofauna of the Colorado River throughout Grand Canyon. In May of 1992, the Hualapai Wildlife Management Department (HWMD), with technical assistance from BIO/WEST, Inc., initiated an investigation of the aquatic resources of the Colorado River and its tributaries from Diamond Creek to below Pearce Ferry (Fig. 1). The purpose of the investigation was 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 of this reach of lower Grand Canyon. This reach of the Colorado River is part of the 108.5 miles (RM 164.5-273.5) of river that forms the northern boundary of the Hualapai Indian Reservation in northwestern Arizona.

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 are diminished in distribution and numbers in the region. Alterations of the natural flow regime are thought to play a major role in the current status of these fish.

Patterns and magnitude of flow of the Colorado River through Grand Canyon are largely regulated by Glen Canyon Dam. Spring runoff and periodic rain storms occasionally increase tributary inflow that affects mainstem hydrology. Since August 1, 1991, releases from Glen Canyon Dam have been regulated by interim flow criteria instituted by the Secretary of Interior. Maximum flow is restricted to 20,000 cfs, and minimum flow is restricted to 5,000 cfs for a maximum of 6 hours at night, and 8,000 cfs from 7:00 am to 7:00 pm. Changes per day are limited to 5,000 cfs during low volume months (March, April, May, October, November), 6,000 cfs during medium volume months (January, February, June, December), and 8,000 cfs for high volume months (July, August, September). Ramping rates are not to exceed increases of 8,000 cfs over 4 hours, with a maximum of 2,500 cfs per hour, and decreases of 1,500 cfs per hour.

Interim flow criteria were implemented in August 1991 for the operation of Glen Canyon Dam, to minimize damage to the Grand Canyon ecosystem that had resulted from previous operations

(Department of Interior 1988). Since the operation of Glen Canyon Dam potentially impacts all aquatic resources downstream to Lake Mead, an integrated monitoring program was initiated in 1992 to describe the response of the ecosystem to these interim flows. This Hualapai Aquatic Resources Study is intended to evaluate the effects of interim flows on aquatic resources of lower Grand Canyon as part of the monitoring program.

Background

Few detailed investigations have been conducted on the aquatic resources of the Lower Grand Canyon and Lake Mead inflow (McCall 1979, Carothers and Minckley 1978). Prior to this investigation, intensive fishery studies of the Grand Canyon ecosystem extended only to Diamond Creek (RM 226), primarily as part of the Glen Canyon Environmental Studies (GCES), Phase I and Phase II. This investigation extends the area of study from Diamond Creek to Lake Mead below Pearce Ferry (RM 286), in order to evaluate effects of interim flows throughout the river corridor from Glen Canyon Dam to Lake Mead. The methodologies used in this investigation were consistent with research being conducted in the Grand Canyon by Arizona Game and Fish Department (AGFD, Angradi et al. 1992) and BIO/WEST, Inc. (Valdez et al. 1993) under GCES Phase II.

The Hualapai Aquatic Resources Study includes seven sampling trips, three in 1992 (July, September, December), and four in 1993 (March, May, September, December). Quarterly reports were submitted for each of the three trips in 1992, and will be submitted for each of the trips in 1993. This 1992 Annual Report integrates and summarizes the findings of the three sampling trips conducted in 1992. A Final Report will be submitted in February 1994 to integrate the results of the entire investigation. The study schedule is shown in Figure 2.

Representatives of the Hualapai Tribe provide the primary leadership for this investigation with logistical support from GCES. The investigation is being conducted in cooperation with the National Park Service and the U.S. Fish and Wildlife Service. Funding is provided by the HWMD and the Bureau of Reclamation (Reclamation) as part of the GCES Interim Flows Monitoring Program. The program is being coordinated by GCES, and river logistics in 1992 provided by OARS, a commercial river concessionaire.

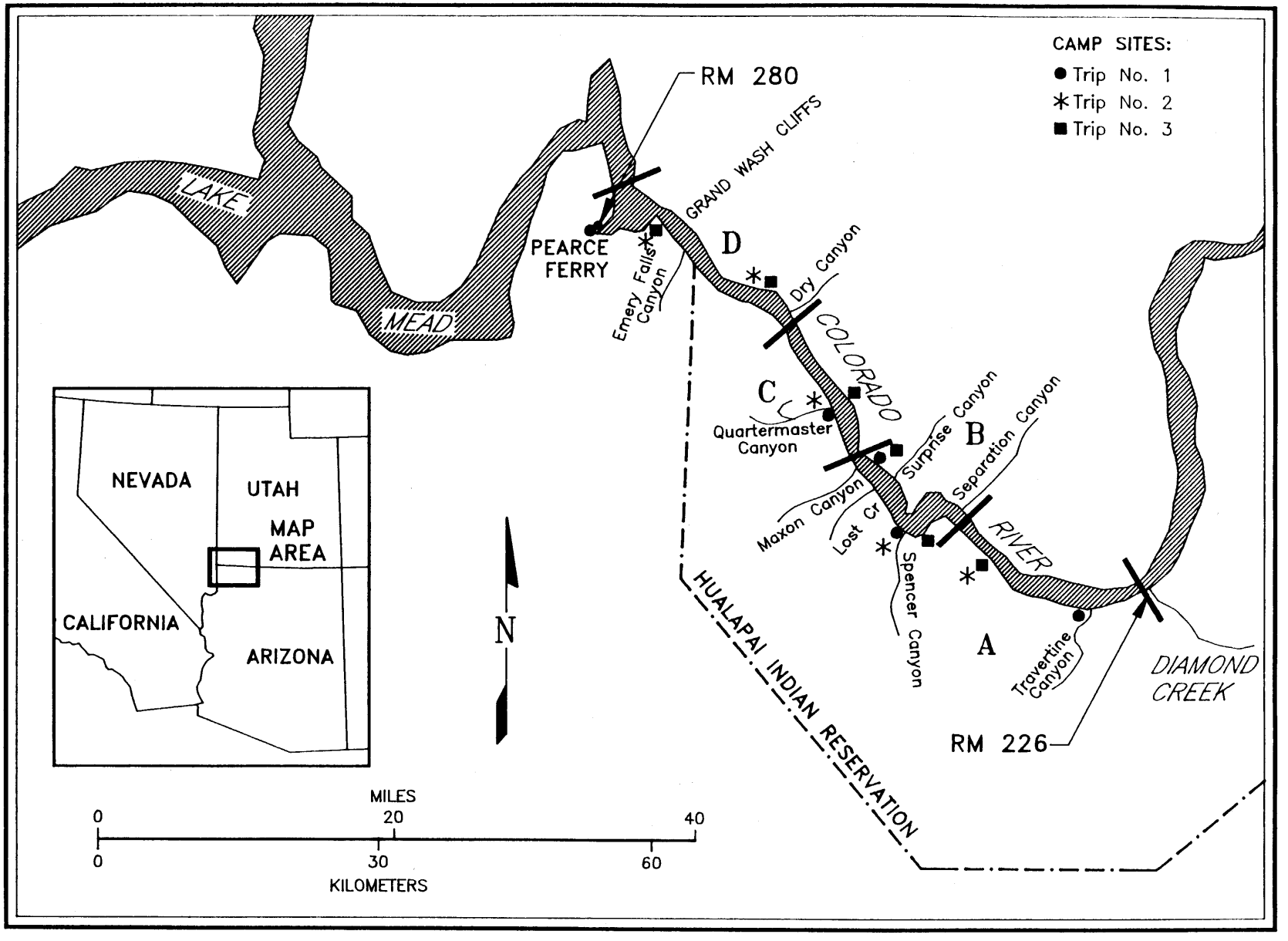

Figure 1. Study reach 4, sample strata A-D, and camp sites on the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

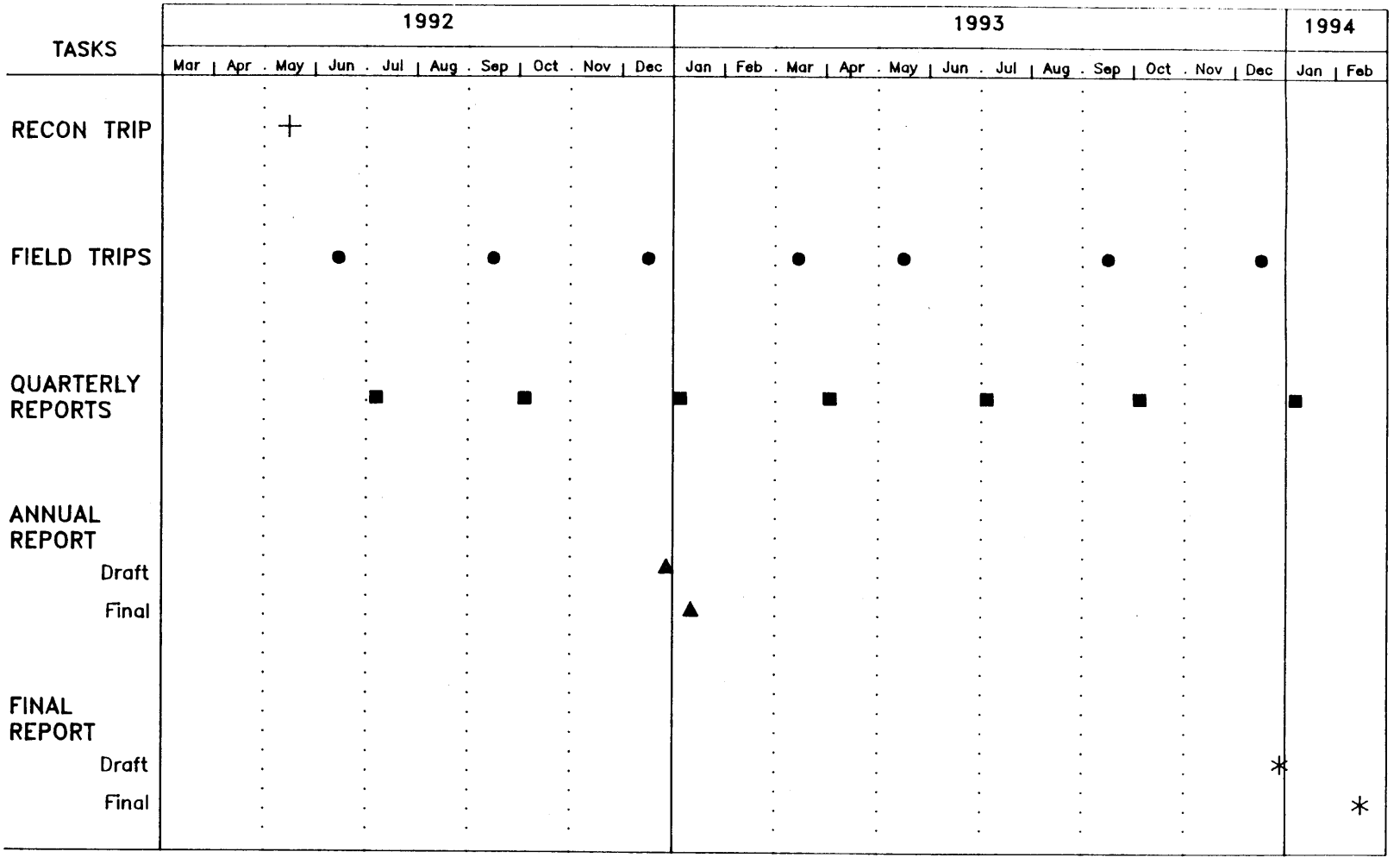

Figure 2. BIO/WEST schedule for the Hualapai Aquatic Resources Study.

Objectives

This investigation addresses the effects of interim flows in Lower Grand Canyon from, Diamond Creek (RM 226) to below Pearce Ferry (RM 286) at Lake Mead. The objectives are as follows:

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 shoreline 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.

Trip Schedule And Personnel

Three sampling trips were conducted in 1992, during the periods June 24 - July 2, September 27 - October 9, and December 1-13 (Table 1). A reconnaissance of the study reach was conducted by helicopter on the morning of June 24, 1992, to survey the area for camp sites and sampling locations. Five or six camp sites were selected from which sampling could be conducted. An effort was made to evenly distribute sampling effort throughout the reach so that aquatic resources could be thoroughly characterized. Camp sites were established in areas that would not conflict with recreational boaters, and would provide maximum access to sampling sites. We frequently camped at or near tributaries (Travertine Canyon, Spencer Canyon, Surprise Canyon, Lost Creek, Quartermaster Canyon) to facilitate sampling these tributaries and inflows.

A total of 24 people participated in the three field trips in 1992. A typical crew included three BIO/WEST biologist/boat handlers, three HWMD representatives, and two OARS river guides (Table 2).

Table 1. Dates, camp sites and sample locations for three trips on the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Date	Camp Site	Sample Locations
	Trip No. 1 (June 24 - July 2, 1992)	
Jun 24-25	Travertine Canyon (RM 229.1)	Traverine Canyon Area (RM 228.3 - 229.8)
Jun 26-27	Spencer Canyon (RM 246.0)	Spencer Canyon Area (RM 245.4 - 246.1) and Tributaries
Jun 28-29	Lost Creek (RM 249.7)	Lost Creek, Surprise Canyon Area (RM 247.1 - 249.7)
Jun 30	Quartermaster (RM 259.8)	Quartermaster Canyon Area (RM 250.3 - 262.3)
Jul 1-2	Pearce Ferry (RM 280)	Pearce Ferry Area (RM 274.0 - 280.0)
	Trip No. 2 (September 27 - October 9, 1992)	
Sep 27-28	Bridge Canyon (RM 235.2)	Bridge Canyon Area (RM 234-237.5)
Sep 29-Oct 2	Spencer Canyon (RM 246.0)	Spencer, Surprise Canyon Area (RM 245.4-249.5) and Tributaries
Oct 3-4	Below Quartermaster (RM 260.5)	Quartermaster Canyon Area (RM 250.3-263)
Oct 5-6	Braided Area (RM 268.5)	Braided Area (RM 266-274)
Oct 7-9	Park Boundary (RM 277.5)	Pearce Ferry Area (RM 274.0-280.0)
	Trip No. 3 (December 1 - 13, 1992)	
Dec 1-3	Bridge Canyon (RM 235.2)	Bridge Canyon Area (RM 234.2 - 236.0)
Dec 3-6	Above Spencer (RM 245.0)	Spencer Canyon Area (RM 241.6 - 249.1) and Tributaries
Dec 6-7	Below Lost Creek (RM 249.7)	Lost Creek (RM 249.1 - 249.4)
Dec 7-9	Burnt Spring (RM 259.7)	Lost Creek 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)

Table 2. Personnel participating in 1992 field trips.

Name	Trip	Agency, Address, Phone Numbers
Richard Valdez	1	BIO/WEST, Inc., 1063 W. 1400 N., Logan, UT 84321 (801)752-4202
Kirsten Tinning	1, 2, 3	BIO/WEST, Inc., 1840 W. Kaibab Ln. Suite 100, Flagstaff, AZ 86001 (602)774-8069
Erika Prats	2, 3	BIO/WEST, Inc., 1840 W. Kaibab Ln. Suite 100, Flagstaff, AZ 86001 (602)774-8069
Chris Heck	3	BIO/WEST, Inc., 1063 W. 1400 N., Logan, UT 84321 (801)752-4202
Brian Dierker	1, 2	BIO/WEST, Inc., 1840 W. Kaibab Ln. Suite 100, Flagstaff, AZ 86001 (602)774-8069
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Alyssa Reischauer	2	BIO/WEST, Inc., 1840 W. Kaibab Ln. Suite 100, Flagstaff, AZ 86001 (602)774-8069
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Clay Bravo	1	Hualapai Wildlife Management Department, P.O. Box 300, 947 Rodeo Way, Peach Spring, AZ 86434 (602)769-2254
Morris Sampson	1, 2, 3	Hualapai Wildlife Management Department, P.O. Box 300, 947 Rodeo Way, Peach Spring, AZ 86434 (602)769-2254
Travis Magenty	1	Hualapai Wildlife Management Department, P.O. Box 300, 947 Rodeo Way, Peach Spring, AZ 86434 (602)769-2254
Mario Bravo	1	Hualapai Wildlife Management Department, P.O. Box 300, 947 Rodeo Way, Peach Spring, AZ 86434 (602)769-2254
Warren Powskey	1, 2, 3	Hualapai Wildlife Management Department, P.O. Box 300, 947 Rodeo Way, Peach Spring, AZ 86434 (602)769-2254
Ben Zimmerman	3	Hualapai Wildlife Management Department, P.O. Box 300, 947 Rodeo Way, Peach Spring, AZ 86434 (602)769-2254
Jerry Cook	2	Hualapai Wildlife Management Department, P.O. Box 300, 947 Rodeo Way, Peach Spring, AZ 86434 (602)769-2254
Ross Haley	1	Resource Management Specialist, Lake Mead Recreation Area, 601 Nevada Highway, Boulder City, NV 89005 (702)293-8946
Denise Freitas	1	Resource Management Specialist, Lake Mead Recreation Area, 601 Nevada Highway, Boulder City, NV 89005 (702)293-8946
Stuart Reeder	3	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Lars Neimi	1	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Steve Bledsoe	3	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Kelly Burke	1, 2	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Rachael Running	3	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Chris Geanious	2	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Kelly Smith	2	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526

STUDY REACH

Grand Canyon Study Reaches

The study reach was 60 miles of the Colorado River, from Diamond Creek (RM 226) to Lake Mead below Pearce Ferry (RM 286). This area was designated Reach 4, as a continuation of the BIO/WEST fishery investigation being conducted in the Grand Canyon, from 1990 through 1994 (Valdez et al. 1991, 1992). The study reaches include Reach 0 -- Lees Ferry (RM 0) to Kwagunt Rapid (RM 56.0). Reach 1 -- Kwagunt Rapid to Red Canyon (RM 77.4), Reach 2 -- Red Canyon to Havasu Creek (RM 160.0), and Reach 3 -- Havasu Creek to Diamond Creek (RM 226.0).

Longitudinal Sampling Strata

Reach 4 was divided into four longitudinal sampling strata that reflected different fish habitat complexes (Table 3) and gradients (Fig. 3); Stratum A--13 miles from Diamond Creek (RM 226) to just above Separation Canyon (RM 239), Stratum B--13 miles from just above Separation Canyon to Maxon Canyon (RM 252), Stratum C--13 miles from Maxon Canyon to Dry Canyon (RM 265), and Stratum D--21 miles from Dry Canyon to below Pearce Ferry (RM 286).

Table 3. Longitudinal sample strata for the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Strata	River Miles	Description
A	226-239	Steep, narrow canyon walls with swift, deep runs and eddies, gradient approximately 0.19%. 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, gradient approximately 0.07%. 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 with willows, and tamarisk, and Baccharis, gradient approximately 0.10%. Shoreline dominated by vegetated sand/silt deposits, with intermittent talus and vertical rock cliffs. Substrate predominantly sand/silt with gravel alluvial fans. Major tributary Quartermaster Canyon.
D	265-286	Large open canyon with expansive sedimentary lake deposits heavily vegetated with willows, tamarisk, low gradient of approximately 0.04%. Shoreline dominated by vegetated sand/silt deposits, extensively braided with side channels, backwaters, isolated pools. Substrate predominantly sand/silt. Major tributary includes Emery Falls Canyon.

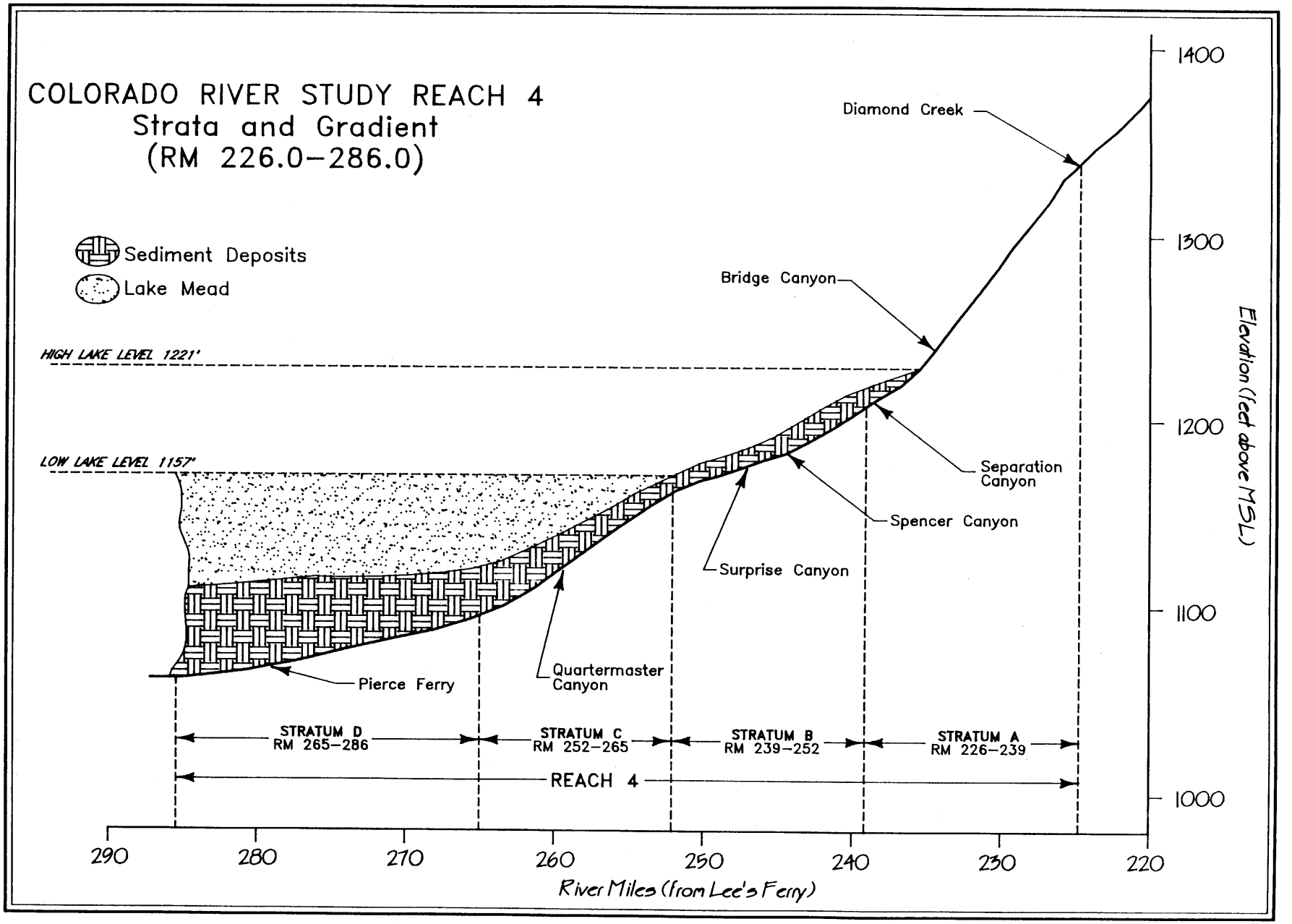

Figure 3. Cross-section of study reach 4 of the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286).

Stratum A was characterized by steep, narrow canyon walls with swift, deep runs and large recurrent eddies, few sand beaches, and a shoreline composed mostly of vertical cliffs and talus. Gradient was approximately 10 feet per mile (0.19%). Major tributaries in this stratum included Diamond Creek (RM 225.7) and Travertine Canyon (RM 229.1). This stratum contained high velocity habitats that appeared suitable for humpback chub, flannelmouth suckers, bluehead suckers, speckled dace, and possibly razorback suckers. Stratum B was characterized by steep, narrow canyon walls, a gradient of about 3.5 feet per mile (0.07%), with moderate runs and eddies. The level of Lake Mead had, at times, risen to Separation Canyon, and this stratum contained sedimentary lake deposits at most canyons and tributaries. The shoreline was variable with talus, sand, and earthen banks, as well as emergent vegetation. Major tributaries included Separation Canyon (RM 239.5), Spencer Canyon (RM 246.0), Surprise Canyon (RM 248.4), and Lost Creek (RM 248.9). Stratum C was characterized as a wide canyon with continuous sedimentary lake deposits, heavily vegetated with Coyote willows (Salix exiqua), goodding willow (Salix gooddingii), and tamarisk (Tamarix rasmosissima). Channel gradient was approximately 5.5 feet per mile (0.10%), and the shoreline was dominated by vegetated sand-silt deposits, with intermittent talus and vertical rock cliffs. This stratum contained several backwaters formed from chute channels and overflow channels in sedimentary deposits, as well as eddy return channels. The major tributary was Quartermaster Canyon (RM 259.8). Stratum D was characterized by a large open canyon with expansive sedimentary lake deposits heavily vegetated with coyote willow, goodding willow, seep willow, tamarisk, cattails (Typha sp.) and rushes (Juncus torreyi). The shoreline was dominated by vegetated sand-silt deposits. Channel gradient was about 2 feet per mile (0.04%), and there was 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 (RM 274.3).

METHODS

Sampling effort for fishes, macroinvertebrates, and water quality parameters was evenly distributed among the four longitudinal sampling strata. Camp sites were usually established near tributary inflows, sampling strata. Camp sites were usually established near tributary inflows, where sampling intensity tended to be highest. Sampling was conducted in the mainstem Colorado River and lower regions of each tributary.

Fish Sampling Methods

Gear Types Used and Number of Samples

Fish were sampled with seven principal gear types--electrofishing, gill nets, trammel nets, hoop nets, minnow traps, seines, and angling. Descriptions and codes for sampling methods are presented in Table 4. Electrofishing was conducted from an Achilles SU-16 motorized raft. The electrofishing 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/8 amps to 200 volts/12 amps, depending on water conductance. A single 12-inch diameter, stainless steel, spherical anode (positive electrode) was used from the bow of the boat, and a single spherical cathode (negative electrode) was located at the stern.

Each gill net was 100 feet long and 6 feet deep, with uniform square mesh sizes of either 1.5 or 2.0 inches. Longer nets--300 feet long and 6 feet deep, with 2.0-inch mesh--were used on Trip 3, and will continue to be used in 1993 in habitats with low velocity. Experimental gill nets were used with 20-foot panels of 0.5, 1.0, 1.5, 2.0, and 2.5-inch mesh. 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 time that 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 mesh to dislodge 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 small fish in shallow habitats. The seines used were 10 feet long, 3 feet deep, with 1/8 inch delta mesh; 30 feet long, 4 feet deep with 1/4-inch delta mesh; and 30 feet long, 5 feet deep, and 1/4-inch delta mesh. Angling was used to capture large predators and game fish--striped bass and channel catfish were caught using whole red shiners as live bait.

Table 4. Fish sampling equipment, codes, descriptions, and number of samples per trip from the Colorado River and tributaries, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Sampling Equipment Code - Description	Number of Samples			
	Trip 1	Trip 2	Trip 3	Totals
Electrofishing				
EL - 220-v DC (Coffelt CPS)	21	52	32	105
Gill Nets				
GM - 100'x6'x2"	5	7	8	20
GP - 100'x6'x1.5"	13	13	5	31
GX - 100'x6'experimental gill net with 20' panels of 0.5, 1.0, 2.0, 2.5" mesh	10	4	10	24
GS - 300'x6'x2"	0	0	4	4
Trammel Nets				
TK - 75'x6'x1"x12"	15	31	48	94
TL - 75'x6'x1.5"x12"	41	36	40	117
TM - 50'x6'x1"x12"	4	0	16	20
TN - 50'x6'x1.5"x12"	3	33	16	52
TF - Sweeping trammel net with electrofishing	2	0	0	2
Hoop Nets				
HM - 3' diameter (medium)	5	0	1	6
HS - 2' diameter (small)	0	4	2	6
Minnow Traps				
MT - commercial minnow traps	13	26	3	42
Seines				
SA - 10'x3'x1/8" seine	11	0	0	11
SB - 30'x4'x1/4" seine	0	18	32	50
SG - 30'x5'x1/4" seine	0	6	0	6
Angling				
AN - angling with artificial or live bait	1	0	0	1
Total	144	230	217	591

A face mask and snorkel were used in tributaries to assess species composition and determine relative abundances of fishes in areas too vegetated to seine or otherwise sample. Although some streams were less than 6 inches deep, an observer could lay prone in the water and observe the fish without disturbing them.

Distribution of Fish Sampling Effort

The distribution of fish sampling effort in the Colorado River and its tributaries, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), is presented by 12 arbitrarily-selected, 5-mile substrata. The large sampling effort in the substrata of RM 245-250 was conducted primarily in Spencer Canyon, Surprise Canyon, and Lost Creek (Table 5). The distribution of sampling effort was roughly equal for all substrata, except for low numbers of samples in substrata of RM 250-255, 265-270, and 280-285 (Table 6, Fig.4). Efforts will continue in 1993 to evenly distribute sampling throughout the study area.

Access to sampling locations from adjacent camp sites was restricted only from the Travertine Canyon site, because of the difficulty in uprunning a rapid at RM 232. Unlimited access to the lower 48 miles of the study area from pre-selected camp sites was a major advantage to sampling this reach of the Colorado River. In more upstream reaches, large whitewater rapids can block access to some sampling locations from camp sites. A record of sampling 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. Fish sampling efforts by trip in four tributaries of the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Tributary	Inflow River Mile	Samples by Trip			Totals
		1	2	3	
Spencer Canyon	246.0	7	12	3	22
Surprise Canyon	248.4	3	9	9	21
Lost Creek	248.9	5	3	0	8
Quartermaster Canyon	259.8	2	4	0	6
	Totals	17	28	12	57

Table 6. Distribution of sampling efforts by gear types in the Colorado River and its tributaries, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Sample Strata	River Mile[b]	Gear Type[a]																	
		EL	GM	GP	GX	GS	TK	TL	TM	TN	TF	HM	HS	MT	SA	SB	SG	AN	Totals
A	225-230	3		3	4		3	18				1		9					41
	230-235	8	3				4	10		3						2			30
	235-240	10					9	17						7					43
B	240-245	6		2	2		6	6	3	17						2			44
	245-250	27	4	9			30	44		18		4	3	18	6	25	4	1	193
C	250-255	5														4			9
	255-260	13	3				3	3	3	3	2	1			5	8			44
	260-265	8		15	7		13	11	6	4				4		1			69
D	265-270	6	4				3	3					3	3			1		23
	270-275	7	3		7		21	3	7	7				1		8			64
	275-280	9	3	2	4	4	2	2	1									1	28
	280-285	3																	3
Totals:		**105**	**20**	**31**	**24**	**4**	**94**	**117**	**20**	**52**	**2**	**6**	**6**	**42**	**11**	**50**	**6**	**1**	**591**

[a] See Table 4 for gear codes.

[b] Significant land marks:

Diamond Creek	RM 225.7	Quartermaster Canyon	RM 259.8
Travertine Canyon	RM 229.1	Dry Canyon	RM 264.5
Bridge Canyon	RM 235.2	Hualapai Indian Reservation Boundaries	RM 164.5-273.5
Separation Canyon	RM 239.5	Emery Falls Canyon	RM 274.3
Spencer Canyon	RM 246.0	Grand Wash Cliffs	RM 276.5
Surprise Canyon	RM 248.4	Grand Canyon National Park/Lake Mead	
Lost Creek	RM 248.9	National Recreation Area Boundary	RM 276.6
Salt Creek	RM 255.5	Pearce Ferry	RM 280.0
Burnt Spring Canyon	RM 259.5		

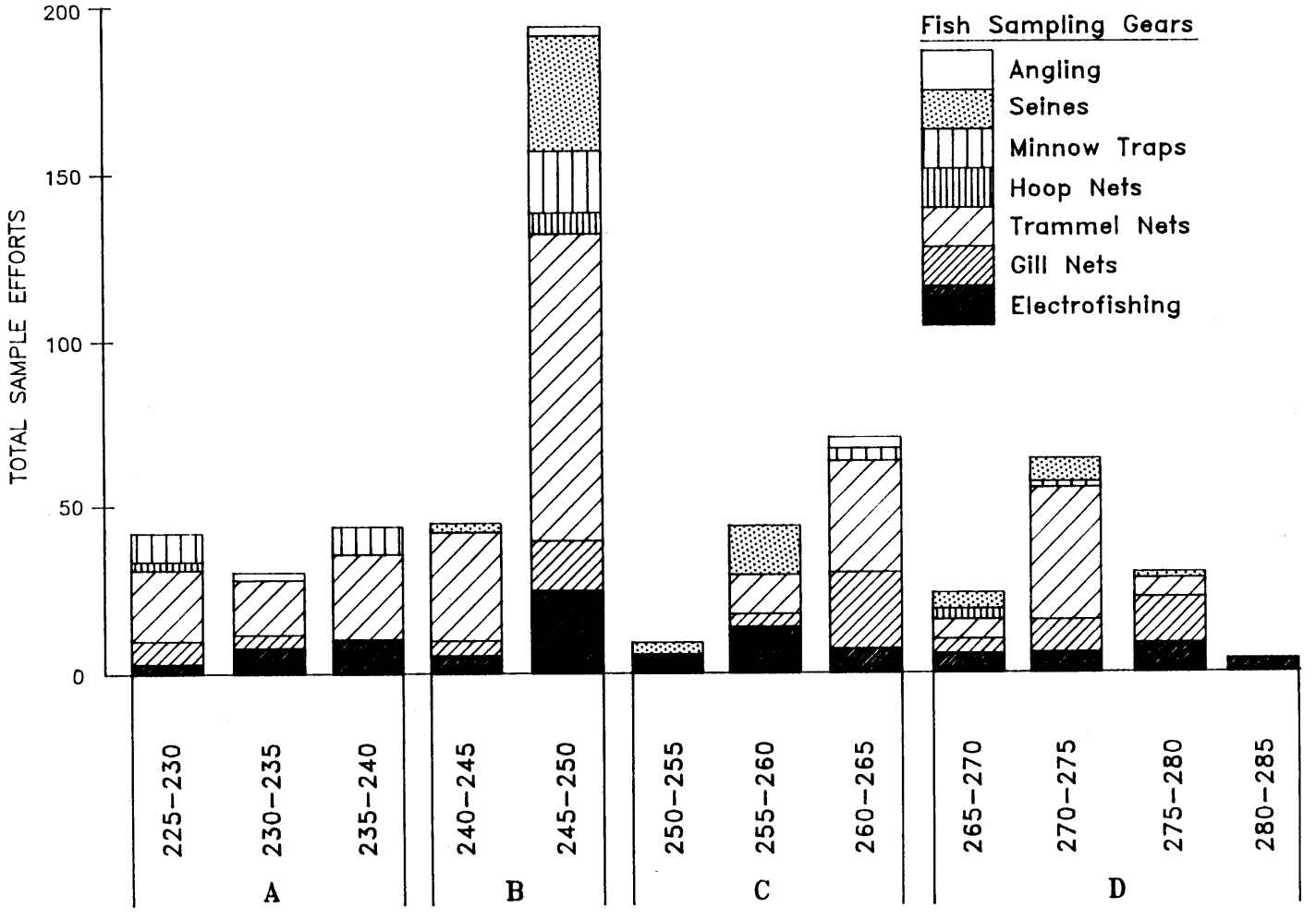

Figure 4. Distribution of sampling efforts with 7 primary gears in 12 longitudinal substrata (denoted by river miles) within 4 strata (A-D), in the Colorado River and tributaries, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

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 screw-on PVC cup to facilitate removing the sample. Each net had a metal frame with an opening of 12 x 18 inches. Twelve drift samples were collected at each camp site. At each location, six drift samples were taken during the ascending limb of the hydrograph, and six during the descending limb of the hydrograph (Table 7). Each set of six samples included three surface (included river surface in net) and three subsurface sets. 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 labeled quart-sized plastic Ziploc bag, and preserved with 90% ethyl alcohol. Drift samples were returned to the laboratory where they were sorted, dried, and analyzed. Drift volume was presented as dry weight in 100 cubic meters of water filtered.

Water Quality Parameters

Water quality parameters on the mainstem Colorado River were measured and recorded at each camp site with a Hydrolab Surveyor II (Table 8). The instrument was deployed from the 33-foot S-rig support raft. The instrument was removed from the water only 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 river level. The staff gage, and thus river level, were then related to a temporary bench mark (TBM) that will be surveyed later to determine actual elevational changes in river stage and river flow. A total of six temporary bench marks were established during the three field trips in 1992 (Table 9). These were located above Bridge Canyon, at Bridge Canyon, at Spencer Canyon, near Lost Creek, at Quartermaster Canyon, below Quartermaster Canyon. Descriptions and photographs of the TBM's were taken to allow reoccupation of these sites. Each TBM was designated by a 1-cm diameter dot of yellow enamel paint on a vertical rock face above the high water line.

Table 7. Drift samples collected from the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Sample Site (River Mile)	Date	NO. SAMPLES[a] RISE Sur	RISE Sub	Fall Sur	Fall Sub	Even Sur	Even Sub
Trip No. 1							
Spencer Canyon (RM 246.0)	Jun 27	3	3	3	3	0	0
Lost Creek (RM 249.7)	Jun 29	3	3	3	3	0	0
Quartermaster Canyon (RM 259.8)	Jun 30	0	0	0	0	3	3
Trip No. 2							
Bridge Canyon (RM 235.0)	Sep 28	3	3	3	3	0	0
Spencer Canyon (RM 245.8)	Oct 2	3	3	0	0	0	0
Quartermaster Canyon (RM 262.0)	Oct 4	3	3	3	3	0	0
Trip No. 3							
Bridge Canyon (RM 235.0)	Dec 2	3	3	0	0	0	0
Spencer Canyon (RM 245.8)	Dec 5	3	3	3	3	0	0
Burnt Spring Canyon (RM 259.3)	Dec 8	3	3	3	3	0	0

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

Table 8. Locations and times for recording water quality parameters[a] using a Hydrolab Surveyor II and a Hydrolab Datasonde with datalogger, 1992.

Sample Site (River Mile)	Observation Period (Dates) Time (Hours)
Hydrolab Surveyor II	
Travertine Canyon (RM 229.1)	Jun 25-Jun 26 1030-0800 (21.5 hrs)
Spencer Canyon (RM 246.0)	Jun 26-Jun 28 1230-1043 (46.2 hrs)
Lost Creek (RM 249.7)	Jun 28-Jun 30 1206-0744 (43.7 hrs)
Quartermaster (RM 259.8)	Jun 30-Jul 1 1245-1339 (24.9 hrs)
Colorado River at Spencer Canyon[b]	Dec 1-Dec 4 2008-0639(58.5 hrs)
Hydrolab Datasonde w/Datalogger	
Spencer Creek (100 m above outflow)[b]	Jun 26-Jun 28 0815-1015(26 hrs)
Spencer Creek (100 m above outflow)[b]	Sep 30-Oct 3 1300-0800(66 hrs)
Spencer Creek (100 m above outflow)[b]	Dec 3-Dec 6 1500-0930(66.5 hrs)
Lost Creek (200 m above outflow)	Jun 29-Jun 30 0900-0900 (24 hrs)

[a] Water quality parameters included temperature, pH, dissolved oxygen, conductivity, redox potential.
[b] Sites with water quality data presently available.

Table 9. Locations and descriptions of temporary bench marks (TBM) established on the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

TBM Number[a]	Date	Description
		Trip No. 1
L 246.0 (Spencer Canyon)	Jun 26	First large rock point about 100 m downstream of Spencer Creek at end of vegetate sand beach on river left.
R 249.7 (Lost Creek)	Jun 28	On upstream base of large prominent rock fin, at upstream end of large vegetate sand beach on river right.
L 259.8 (Quartermaster)	Jun 30	On downstream end of large travertine formation about 200 m upstream of quartermaster stream at end of large vegetate sand beach on river left.
		Trip No. 2
L 234.9 (Bridge Canyon)	Sep 29	On upstream end of Bridge Canyon rapid, at downstream side of shearwall.
L 262.0 (Below Quartermaster)	Oct 4	On upstream side of beach, there is a large rectangular rock, the reference point is just above this rock.
		Trip No. 3
L 235.1 (Above Bridge Canyon)	Dec 2	Upstream of Bridge Canyon Rapid beach, on shear wall near fanged rock-upper end of beach.

[a] L = left river bank, facing downstream; R = right river bank, facing downstream.

RESULTS

Fish Populations

Fish Species Composition And Relative Abundance

A total of 17 different fish species were captured representing nine families (Table 10). The most common species captured in the study reach were red shiners (51.0%) and fathead minnows (32.2%). These species outnumbered all other fishes in the catch, because they occurred in large aggregations in tributaries and tributary mouths, where they were easy to capture. Carp and channel catfish were the predominant large mainstem species, while striped bass were found in relatively low numbers throughout the reach, and threadfin shad were concentrated in the lacustrine environment of the Lake Mead inflow. The 63 native flannelmouth suckers included 26 young-of-year (YOY), 30 juveniles, and 7 adults. All YOY flannelmouth suckers, but one, were taken from tributaries--15 from Spencer Canyon and 10 from Surprise Canyon. The juveniles and adults were captured in the mainstem, primarily near tributary inflows at Spencer Canyon (RM 246.0), Surprise Canyon (RM 248.4), and Lost Creek (RM 248.8), and the braided area (RM 265-269.9) above the lake inflow.

Striped bass, found in the mainstem in late June, were primarily small males with pink, maturing gonadal sacs, indicating the fish were 2 to 3 weeks from spawning. Several channel catfish captured near Spencer Canyon had 3 to 5 inches of their lower intestine protruding from their anal vent. Further examination revealed large masses of tapeworms in the lower intestine, probably the "catfish tapeworm" (Bothriocephalus claviceps). The "Asian tapeworm" (Bothriocephalus acheilognathi) has been reported in humpback chub from the Little Colorado River (Angradi et al. 1992). It is unlikely that the tapeworms in channel catfish are Asian tapeworms, since this species of cestode is generally specific to cyprinids, such as red shiners, carp, and fathead minnows.

A detailed breakdown of fish species captured by life stage with each of the 17 specific gear types is presented in Table 11. Electrofishing and trammel nets were most effective in the mainstem Colorado River on juveniles and adults of large and medium-size species, such as carp, channel catfish, striped bass, and largemouth bass. Electrofishing was also effective at capturing small fishes such as red shiners, fathead minnows, and mosquitofish. Hoop nets had limited success on large and medium size fish in side channels and tributary mouths. Seines were effective at capturing small fish in shallow shoreline habitats and in tributaries. Angling with live bait proved to be an effective method for catching striped bass and channel catfish.

Table 10. Numbers of fish captured by trip and by species from the Colorado River and tributaries, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Family Common Name (Code)	Scientific Name	Number Captured				
		Trip #1	Trip #2	Trip #3	Totals	Percent
CYPRINIDAE (minnows)						
red shiner (RS)	Cyprinella lutrensis	1,474	1,224	886	3,584	51.0
fathead minnow (FH)	Pimephales promelas	1,572	203	486	2,261	32.2
common carp (CP)	Cyprinus carpio	118	158	120	396	5.6
speckled dace (SD)	Rhinichthys osculus	1	37	9	47	0.7
CATOSTOMIDAE (suckers)						
flannelmouth sucker (FM)	Catostomus latipinnis	16	33	14	63	1.0
PERCICHTHYIDAE (temperate basses)						
striped bass (SB)	Morone saxatilis	12	1	3	16	0.2
ICTALURIDAE (catfishes, bullheads)						
channel catfish (CC)	Ictalurus punctatus	45	32	22	99	1.4
black bullhead (BB)	Ameiurus melas	2	0	0	2	<0.1
PERCIDAE (perches)						
walleye (WE)	Stizostedion vitreum	1	0	1	2	<0.1
CYPRINODONTIDAE (killifishes)						
plains killifish (PK)	Fundulus zebrinus	5	1	28	34	0.5
POECILIDAE (livebearers)						
mosquitofish (GA)	Gambusia affinis	76	40	24	140	2.0
CENTRARCHIDAE (sunfishes)						
largemouth bass (LM)	Micropterus salmoides	6	22	0	28	0.4
green sunfish (GS)	Lepomis cyanellus	1	0	2	3	<0.1
black crappie (BC)	Pomoxis nigromaculatus	1	1	0	2	<0.1
white crappie (WC)	Pomixis annularis	1	0	0	1	<0.1
bluegill (BG)	Lepomis macrochirus	0	37	0	37	0.5
CLUPEIDAE (shads)						
threadfin shad (TS)	Dorosoma petenense	13	297	0	310	4.4
Totals		3,344	2,086	1,595	7,025	100.0

Table 11. Numbers of fish by species and life stage captured with 17 gear types in the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Gear Types[a]	Life Stage[b]	Fish Species Codes[c]																
		RS	FH	CP	SD	FM	SB	CC	BB	WE	PK	GA	LM	GS	BC	WC	BG	TS
EL	Y	29										20						
	J	29	1	38		2	2					1	16					
	A	792	24	226	12	1	1	23			6	25	6	1	2	1		220
	T	850	25	264	12	3	3	23	0	0	6	46	22	1	2	1	0	220
GM	Y																	
	J																	
	A			5						1								
	T	0	0	5	0	0	0	0	0	1	0	0	0	0	0	0	0	0
GP	Y																	
	J																	
	A			3				3										
	T	0	0	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0
GX	Y																	
	J																	
	A						1	8										
	T	0	0	0	0	0	1	8	0	0	0	0	0	0	0	0	0	0
TK	Y																	
	J																	
	A			6		1	2	26										
	T	0	0	6	0	1	2	26	0	0	0	0	0	0	0	0	0	0

Gear Types[a]	Life Stage[b]	Fish Species Codes[c]																
		RS	FH	CP	SD	FM	SB	CC	BB	WE	PK	GA	LM	GS	BC	WC	BG	TS
TL	Y																	
	J																	
	A			35		2	2	29		1								
	T	0	0	35	0	2	2	29	0	1	0	0	0	0	0	0	0	0
TM	Y																	
	J																	
	A			4		1	4	2	2									
	T	0	0	4	0	1	4	2	2	0	0	0	0	0	0	0	0	0
TN	Y																	
	J																	
	A			9		1		3										
	T	0	0	9	0	1	0	3	0	0	0	0	0	0	0	0	0	0
TF	Y																	
	J																	
	A																	
	T	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HM	Y																	
	J						1											
	A	158		4								1						
	T	158	0	4	0	0	1	0	0	0	0	1	0	0	0	0	0	0

Gear Types[a]	Life Stage[b]	Fish Species Codes[c]																
		RS	FH	CP	SD	FM	SB	CC	BB	WE	PK	GA	LM	GS	BC	WC	BG	TS
HS	Y																	
	J																	
	A			1				1										
	T	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
MT	Y		1	1														
	J	3		1														
	A	9			3													
	T	12	1	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0
SA	Y	120	10	1		14						10						
	J	515	541								4	18	2					
	A	607	1020								1	39						
	T	1,242	1571	1	0	14	0	0	0	0	5	67	2	0	0	0	0	0
SB	Y			31		12								2				
	J	259	105	29	1	10					4	4						
	A	594	393		8	1					19	20						
	T	853	498	60	9	23	0	0	0	0	23	24	0	2	0	0	0	0
SG	Y																	
	J			1		18							4				33	
	A	469	166	1	23							2					4	90
	T	469	166	2	23	18	0	0	0	0	0	2	4	0	0	0	37	90

Gear Types[a]	Life Stage[b]	Fish Species Codes[c]																
		RS	FH	CP	SD	FM	SB	CC	BB	WE	PK	GA	LM	GS	BC	WC	BG	TS
AN	Y																	
	J																	
	A						3	4										
	T	0	0	0	0	0	3	4	0	0	0	0	0	0	0	0	0	0
TOTALS		3,584	2,261	396	47	63	16	99	2	2	34	140	28	3	2	1	37	311

[a] See table 4 for gear codes
[b] Y = young-of-year
J = juvenile
A = adult
T = total
[c] See table 7 for fish species codes

Fish Species Distribution

The distribution of fish species captured, as number and percentage of total by 5-mile substrata, is presented in Table 12 and Figure 5. Although red shiners dominated the mainstem ichthyofauna, they were found only downstream of Bridge Canyon Rapid (RM 235.2) during this 1992 investigation. From that point downstream, this species accounted for 47.3 to 76.1% of mainstem species composition in each of the remaining nine substrata. Fathead minnows were similarly found only downstream of Bridge Canyon Rapid, whereas carp and channel catfish were evenly distributed throughout the mainstem. Red shiners, fathead minnows, plains killifish, mosquitofish, and young flannelmouth suckers were found primarily in tributaries, while carp, speckled dace, striped bass, channel catfish, largemouth bass, and threadfin shad were found primarily in the mainstem. Black bullheads, walleyes, green sunfish, black crappie, white crappie, and bluegill were found in small numbers, primarily in the lower mainstem near Pearce Ferry.

Red shiners, fathead minnows, and mosquitofish dominated the ichthyofauna of tributaries, including Spencer Canyon, Surprise Canyon, Lost Creek, and Quartermaster Canyon (Table 13, Fig. 6). Plains killifish were found in smaller numbers, and speckled dace were more numerous where numbers of red shiners and fathead minnows were low -- indicating displacement of speckled dace by the two non-native species. The numbers of red shiners and fathead minnows were greatest in the lower 200 m of Spencer Canyon and Surprise Canyon, where native speckled dace were virtually absent. Numbers of speckled dace increased upstream of the outflow, with decreasing numbers of red shiners and fathead minnows. A large concentration of adult carp--estimated at 50 individuals--was encountered in a large semi-isolated pool of Surprise Canyon, about 800 m upstream of the outflow.

Patterns and magnitude of flow of the Colorado River through Grand Canyon are largely regulated by Glen Canyon Dam. Spring runoff and periodic rain storms occasionally increase tributary inflow that affects mainstem hydrology. Since August 1, 1991, releases from Glen Canyon Dam have been regulated by interim flow criteria instituted by the Secretary of Interior. Maximum flow is restricted to 20,000 cfs, and minimum flow is restricted to 5,000 cfs for a maximum of 6 hours at night, and 8,000 cfs from 7:00 am to 7:00 pm. Changes per day are limited to 5,000 cfs during low volume months (March, April, May, October, November), 6,000 cfs during medium volume months (January, February, June, December), and 8,000 cfs for high volume months (July, August, September). Ramping rates are not to exceed increases of 8,000 cfs over 4 hours, with a maximum of 2,500 cfs per hour, and decreases of 1,500 cfs per hour.

Table 12. Number and percentage fish species composition in 12 substrata of the mainstem Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Substrata River Mile	Fish Species Codes[a]																
	RS	FH	CP	SD	FM	SB	CC	BB	WE	PK	GA	LM	GS	BC	BG	TS	Total
225-229.9			6 (37.5)	2 (12.5)	1 (6.3)	1 (6.3)	6 (37.5)										16 (100%)
230-234.9			52 (82.5)				11 (17.5)										63 (100%)
235-239.9	59 (48.8)	2 (1.7)	33 (27.3)	3 (2.5)			23 (19.0)		1 (0.8)								121 (100%)
240-244.9	23 (74.2)		7 (22.6)		1 (3.2)												31 (100%)
245-249.9	233 (65.3)	3 (0.8)	68 (19.0)	3 (0.8)	11 (3.1)	6 (1.7)	25 (7.0)		1 (0.3)		7 (2.0)						357 (100%)
250-254.9	52 (71.2)		15 (20.5)		1 (1.4)		2 (2.7)				3 (4.1)						73 (100%)
255-259.9	175 (73.8)	1 (0.4)	18 (7.6)	1 (0.4)	4 (1.7)					1 (0.4)	23 (9.7)	1 (0.4)		1 (0.4)		12 (5.1)	237 (100%)
260-264.9	89 (76.1)		8 (6.8)		2 (1.7)	2 (1.7)	15 (12.8)									1 (0.9)	117 (100%)
265-269.9	468 (67.4)	166 (23.9)	11 (1.6)	31 (4.5)	16 (2.3)		1 (0.1)				1 (0.1)						694 (100%)
270-274.9	66 (66.0)	4 (4.0)	19 (14.0)		2 (2.0)	2 (2.0)	4 (4.0)				2 (2.0)			1 (1.0)			100 (100%)
275-279.9	195 (47.3)	1 (0.2)	37 (9.0)			1 (0.2)	11 (2.7)				33 (8.0)	7 (1.7)			37 (9.0)	90 (21.8)	412 (100%)
280-284.9	9 (3.4)		31 (11.6)			3 (1.1)		2 (0.7)				15 (5.6)	1 (0.4)			207 (77.2)	268 (100%)
Total	1367	177	305	40	38	15	98	2	2	1	69	23	1	2	37	310	2,489

[a] See table 7 for fish species codes.

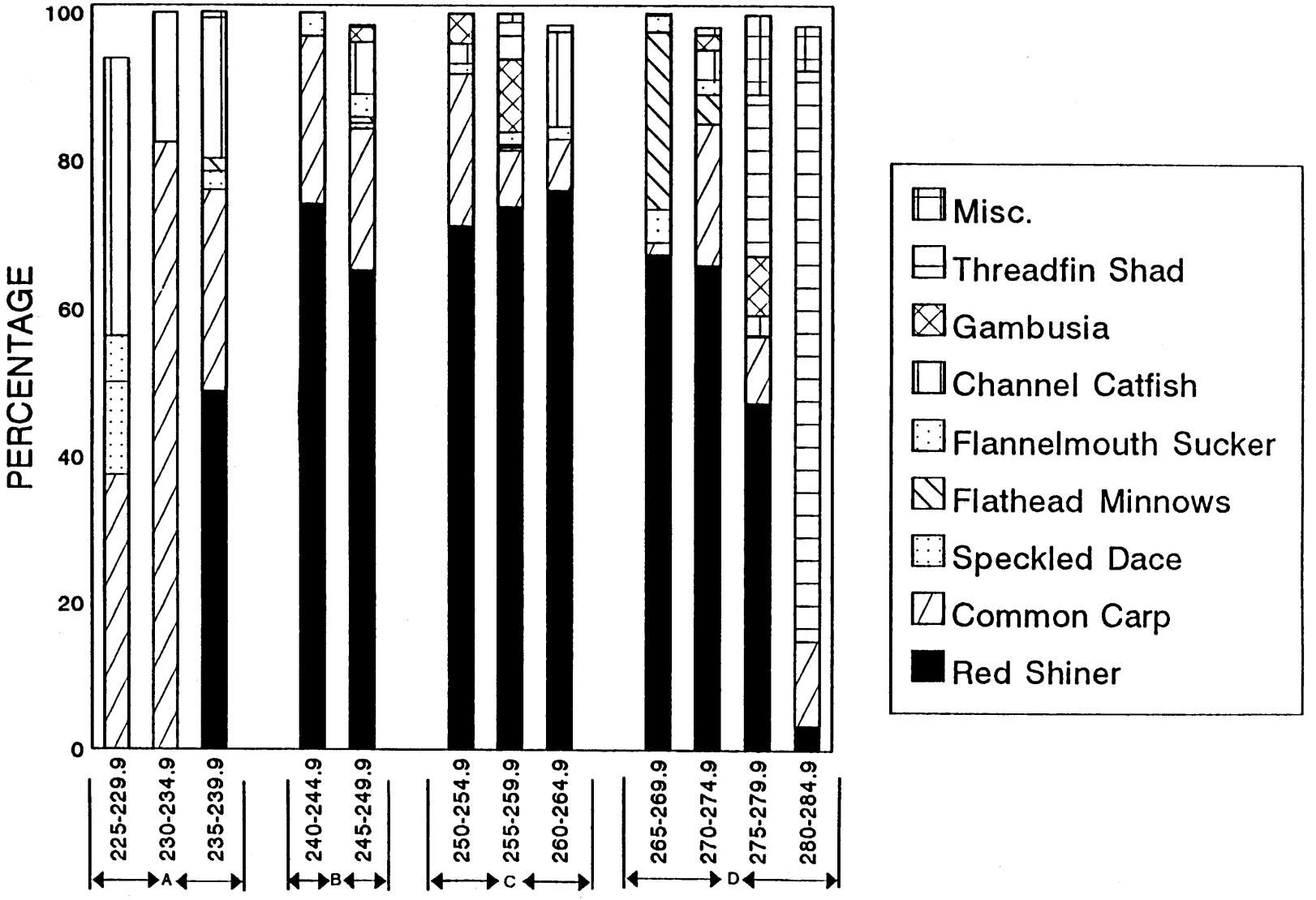

Figure 5. Percentage fish species composition in 12 substrata (denoted by river miles) within four strata (A-D) of the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Table 13. Number and percentage fish species composition in four tributaries of the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Tributary (River Mile)	Fish Species Codes[a]																
	RS	FH	CP	SD	FM	SB	CC	BB	WE	PK	GA	LM	GS	BC	BG	TS	Total
Spencer Canyon (RM 246.0)	627 (92.5)	21 (3.1)	2 (0.3)	4 (0.6)	15 (2.2)					9 (1.3)							678 (100%)
Surprise Canyon (RM 248.4)	1,404 (38.9)	2,063 (57.1)	84 (2.3)	3 (0.1)	10 (0.3)					23 (0.6)	24 (0.7)		2 (0.1)				3,613 (100%)
Lost Creek (RM 248.9)	14 (58.3)		5 (20.8)			1 (4.2)	1 (4.2)					3 (12.5)					24 (100%)
Quartermaster Canyon (RM 259.8)	170 (77.3)									1 (0.5)	47 (21.4)	2 (0.9)					220 (100%)
Total	2,215	2,084	91	7	25	1	1	0	0	33	71	5	2	0	0	0	4,535

[a] See table 7 for fish species codes

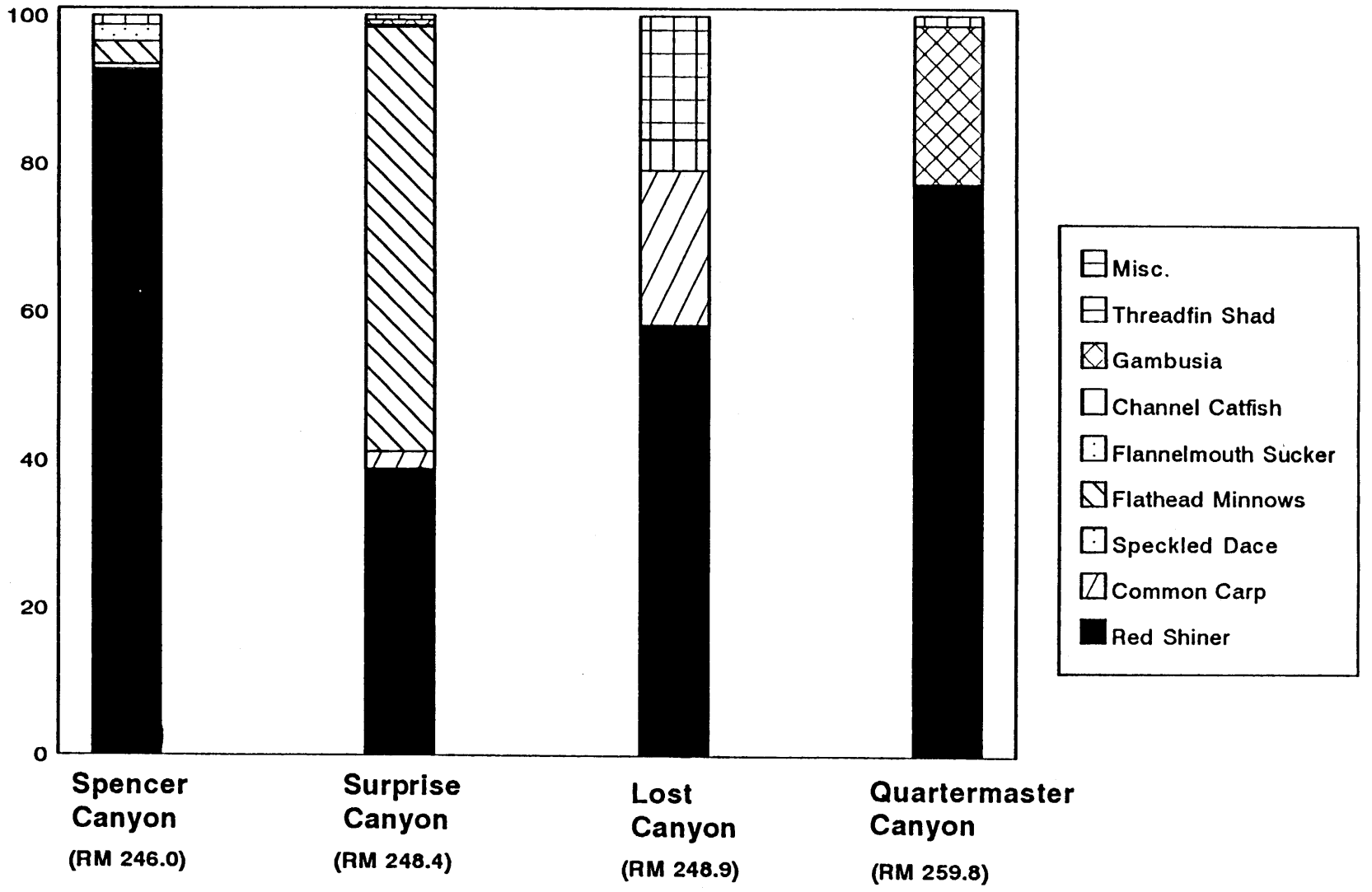

Figure 6. Percentage fish species composition in four tributaries of the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Macroinvertebrates In Drift

Two classes of macroinvertebrates were found in drift samples from the study reach in 1992, including the Class Insecta and the Class Crustacea (Table 14). The Class Crustacea was represented by only one form--the freshwater amphipod or "scud" (Gammarus lacustris), of the Order Amphipoda. The Class Insecta was represented by seven orders, including Diptera (flies), Hemiptera (true bugs), Hymenoptera (wasps), Trichoptera (caddisflies), Homoptera (cicada, hoppers), Thysanoptera (thrips), and Coleoptera (beetles). Identified families of dipterans included simuliidae (black flies) and chironomidae (midges). Identification and analysis of all samples were not completed in time for this report, but will be presented at a later date.

Numbers of Simuliidae and Chironomidae, by life stage, are presented in Table 15. The terrestrial forms (Hemiptera, Hymenoptera, Homoptera, and Thysanoptera) were in far greater abundance in samples from Reach 4 (Diamond Creek, RM 226 to Pearce Ferry, RM 280) than in samples taken in upstream Reaches 1-3 (Kwagunt Rapid, RM 56 to Diamond Creek, RM 226) during previous investigations (Valdez et al. 1992). Hemiptera were the most abundant terrestrial form, while Gammarus lacustris were reduced in abundance from samples taken in Reaches 1-3.

Table 14. Macroinvertebrate taxa found in drift samples taken from the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Class	Order	Family
Insecta (insects)		
	Diptera (flies)	
		Simuliidae (black flies)
		Chironomidae (midges)
	Hemiptera (true bugs)	
	Hymenoptera (wasps)	
	Trichoptera (caddisflies)	
	Homoptera (cicada, hoppers)	
	Thysanoptera (thrips)	
	Coleoptera (beatles)	
Crustacea (amphipods, copepods, etc.)		
	Amphipoda (scuds, sideswimmers)	
		Gammaridae (Gammarus lacustris)

Table 15. Life stages of Simuliidae and Chironomidae in drift samples taken from the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Taxa Life Stage	No. Organisms/30 Samples	Organisms/Minute[a]
	Trip 1	
Simuliidae		
Adult	17	6.92
Pupae	13	5.35
Larvae	27	28.78
Chironomidae		
Adult	24	19.60
Pupae	23	12.16
Larvae	22	19.30
	Trip 2	
Simuliidae		
Adult	8	2.12
Pupae	3	0.71
Larvae	8	2.05
Chironomidae		
Adult	9	2.07
Pupae	6	2.05
Larvae	0	0.00
	Trip 3	
Simuliidae		
Adult	5	1.07
Pupae	0	0.00
Larvae	14	4.82
Chironomidae		
Adult	14	3.40
Pupae	1	0.20
Larvae	2	0.40

[a] Organisms/minute will be expressed volumetrically as organisms/cubic meter in later reports.

Water Quality

Mainstem Colorado River

Water temperature for the Colorado River at Spencer Canyon on December 1-4 varied from about 8.6 to 9.4°C, over a 55-hour period (Fig. 7). This low variation in temperature was not unusual, and may be related to flow variation or local warming of air temperature. Dissolved oxygen during the same time varied from about 11.1 to 11.9 mg/l. Levels of pH varied from about 8.0 to 8.1, and conductivity varied from about 875 to 1,000 umhos/cm.

Tributaries

The continuous recording Datasonde in Spencer Creek revealed strong diel pulses in temperature and dissolved oxygen for June 26-28 (Fig. 8) and September 30 - October 3 (Fig. 9). Water temperature in June varied daily from about 21 to 29°C, or a change of about 8°C over a 16-hour period. The highest readings were observed about 3:00 pm, and lowest readings about 7:00 am. Diel water temperature in September-October varied from about 20.5°C at 7:00 am to about 26.5°C at 4:00 pm, or about 6°C over a 15-hour period. Daily water temperature in December varied from about 15 to 17°C, with a change of about 2°C over a 16-hour period (Fig. 10). Highest readings were observed about 4:00 pm, and lowest readings occurred between midnight and 9:00 am.

Observed levels of dissolved oxygen varied inversely with water temperature, as expected, i.e. cold water can dissolve more oxygen than warm water. This inverse relationship was particularly evident in June and September-October, when warmer water displayed decreased oxygen content. However, the relationship was not as evident in December, when cooler water temperature allowed for more stable oxygen levels. Dissolved oxygen in Spencer Creek varied from about 6.6 to 8.0 mg/l in June, 4.4 to 7.0 mg/l in September, and 7.0 to 8.0 mg/l in December. Low oxygen level in December may be due, in part, to low stream volume or decreased primary productivity during winter months.

Level of pH in Spencer Creek varied from about 8.0 to 8.3 in June, 7.5 to 8.1 in September-October, and 7.7 to 7.9 in December. The low variation in pH indicates that the stream has a fairly high buffering capacity. Conductivity varied from about 650 to 690 umhos/cm in June, 650 to 680 umhos/cm in September-October, and 640 to 680 umhos/cm in December. This variation in conductivity is normal with variation in temperature and stream flow.

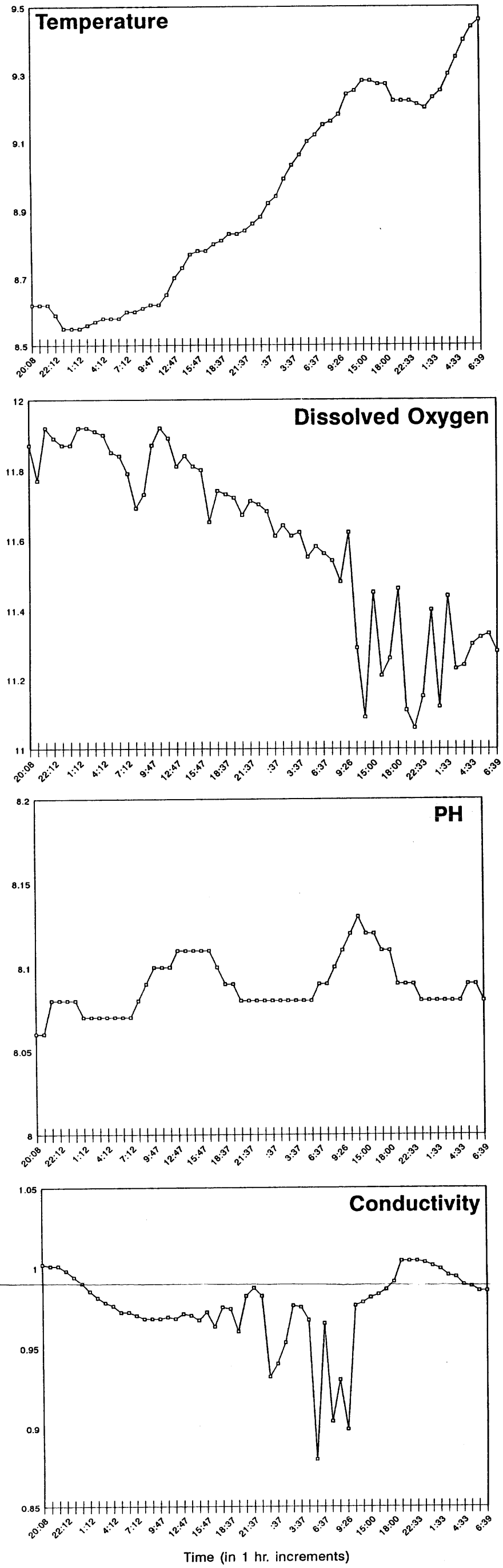

Figure 7. Water quality parameters from the mainstem Colorado River at Spencer Canyon recorded with a Hydrolab Surveyor II on December 1-4 (2008-0639), 1992.

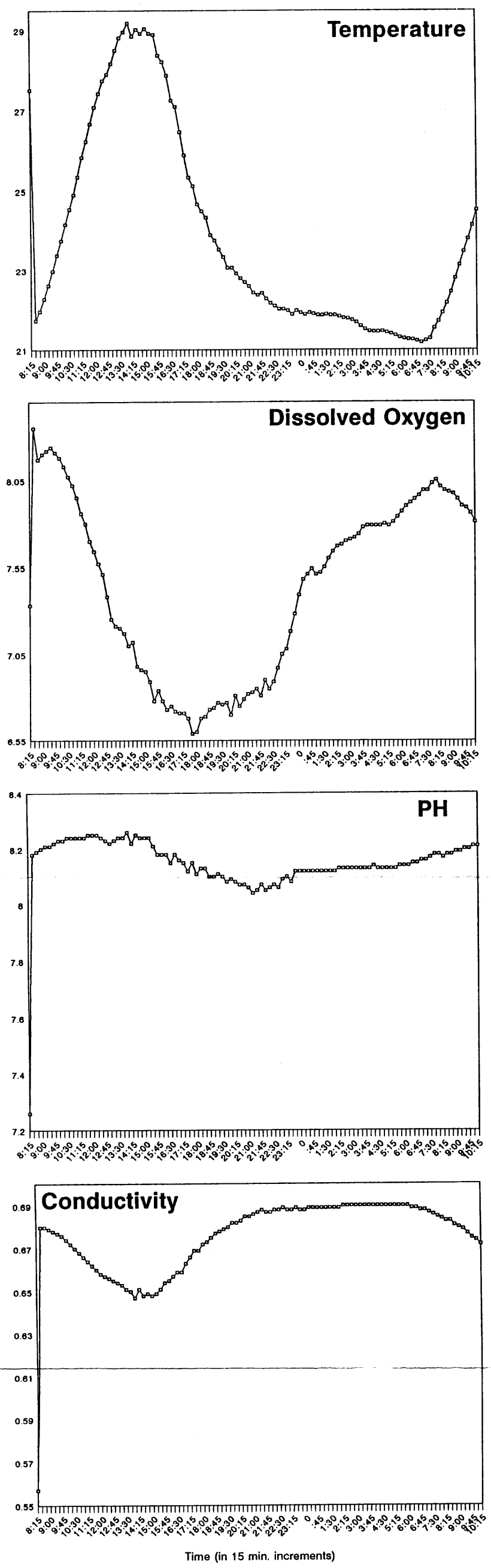

Figure 8. Water quality parameters from Spencer Creek recorded with a Hydrolab Datasonde on June 26-28 (0815-1015 hrs), 1992.

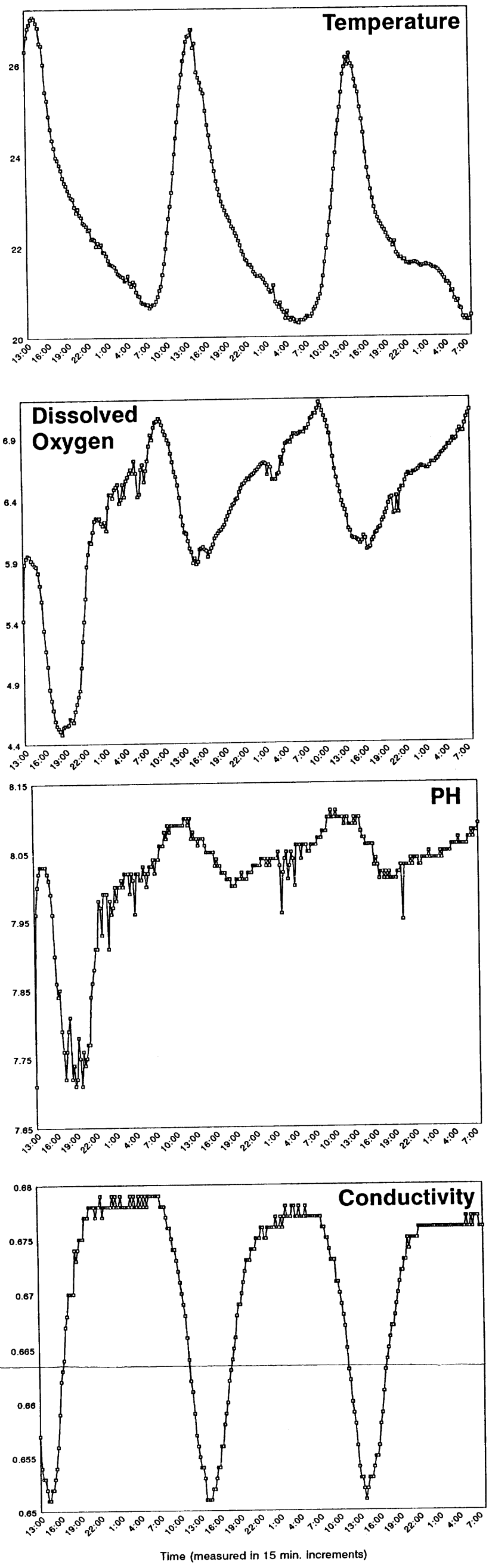

Figure 9. Water quality parameters from Spencer Creek recorded with a Hydrolab Datasonde on September 30-October 3 (1300-0700 hrs), 1992.

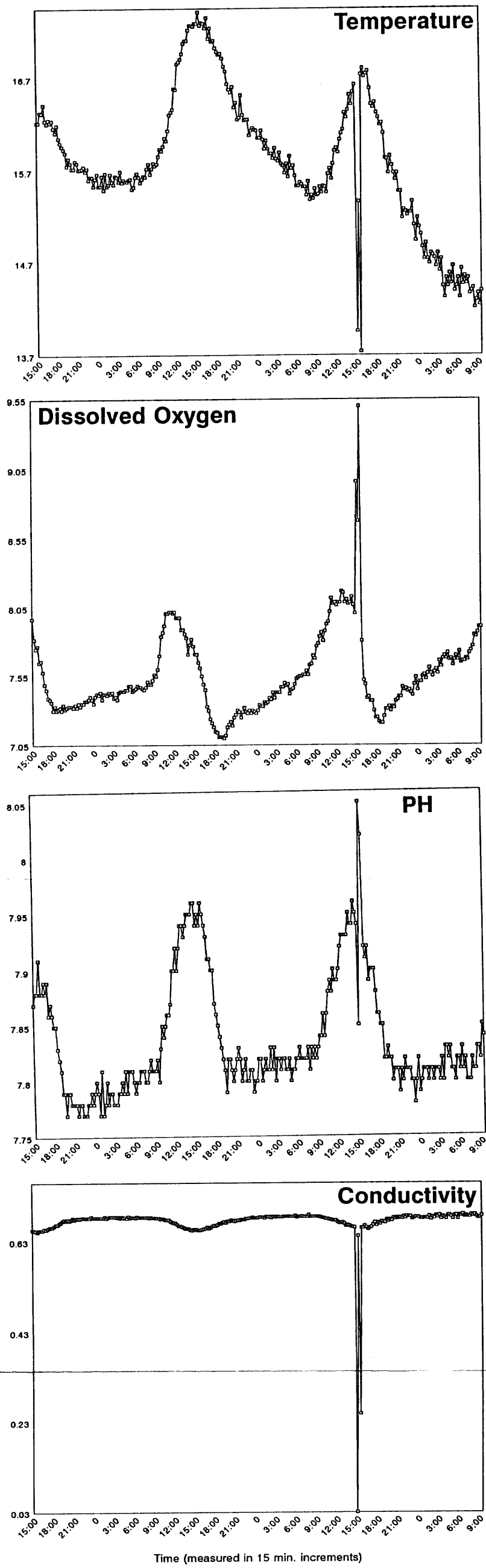

Figure 10. Water quality parameters from Spencer Creek recorded with a Hydrolab Datasonde on December 3-6 (1500-0900 hrs), 1992.

Mainstem water temperature information was also taken with dialstem thermometers during fish sampling. Minimum and maximum water temperatures at various mainstem locations show that in late June, the daily temperature in the steep canyon area above Quartermaster Canyon did not vary by more than 0.5°C (Table 16). Mainstem minimum and maximum temperature was 17.0°C at Travertine Canyon (RM 229.1), 17.5°C at Spencer Canyon (RM 246.0), and 18.0°C at Lost Creek (RM 249.8). Minimum and maximum water temperatures, respectively, were 18.0 and 19.5°C at Quartermaster Canyon (RM 259.8), 18.0 and 20.0°C at Grand Wash Cliffs, and 24.5 and 26.0°C at Pearce Ferry (RM 280.0). The significantly higher temperatures at Pearce Ferry were from the effect of lake impoundment. Longitudinal temperature change in June for the 47-mile riverine portion, from Travertine Canyon to Grand Wash Cliffs (RM 276.5), was 17.0 to 20.0°C, or about a 3°C increase. In September-October, mainstem water temperature ranged from 14.7°C near Spencer Canyon to 23.0°C near Pearce Ferry. Mainstem water temperatures in December remained cold throughout the reach, with a minimum of 8.6°C at Bridge Canyon and a maximum of 10.2°C near Pearce Ferry (Scorpion Island).

Table 16. Minimum and maximum water temperature recorded for the mainstem Colorado River and selected tributaries, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Location (River Mile)	Dates	Water Temperature	
		Min.	Max.
MAINSTEM COLORADO RIVER			
Travertine Canyon (RM 229.1)	Jun 25-26	17.5	17.0
Spencer Canyon (RM 246.0)	Jun 26-28	18.0	17.5
Lost Creek (RM 249.7)	Jun 28-30	18.5	18.0
Quartermaster Canyon (RM 259.8)	Jun 30-Jul 1	18.0	19.5
Grand Wash Cliffs (RM 276.0)	Jul 1-Jul 2	18.0	20.0
Pearce Ferry (RM 280.0)	Jul 1-Jul 2	24.5	26.0
Bridge Canyon (RM 235.0)	Sep 27-Sep 28	15.0	15.0
Spencer Canyon (RM 246.0)	Sep 29-Sep 30	14.7	17.5

Location (River Mile)	Dates	Water Temperature	
		Min.	Max.
Quartermaster Canyon (RM 259.8)	Oct 3-Oct 4	14.7	17.5
Travertine Cleft (RM 268.0)	Oct 5-Oct 6	15.0	17.0
Grand Wash Cliffs (RM 276.0)	Oct 7-Oct 8	15.0	15.0
Pearce Ferry (RM 280.0)	Oct 7-Oct 8	20.0	23.0
Bridge Canyon (RM 235.0)	Dec 1-Dec 3	8.6	8.6
Above Spencer Canyon RM 245.0)	Dec 3-Dec 6	9.3	9.7
Below Lost Creek (RM 249.7)	Dec 6-Dec 7	9.7	9.9
Burnt Spring Canyon (RM 259.7)	Dec 7-Dec 9	10.0	10.2
Braided Area (RM 267.5)	Dec 9-Dec 11	9.90	10.2
Scorpion Island (RM 277.5)	Dec 11-Dec 13	9.0	10.2
TRIBUTARIES			
Spencer Creek (RM 246.0)	Jun 26	28.5	29.0
Surprise Creek (RM 248.4)	Jun 29	26.5	26.5
Quartermaster Creek (259.8)	Jun 30	19.0	20.0

Changes In River Stage

Changes in river stage were monitored and recorded at six distinct locations during the three field trips (Table 17). Maximum recorded stage changes were 60 cm on June 27 (Fig. 11), 42 cm on October 1-2 (Fig. 12), and 56 cm on December 5-6 (Fig. 13). These changes occurred over 8-10 hour periods, and were attributed primarily to the operation of Glen Canyon Dam.

Table 17. Stage change of the Colorado River at sample sites, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

Sample Site (River Mile)	Observation Period Time (hours)	Max. Stage Change (cm)
	Trip No. 1	
Travertine Canyon (RM 229.1)	Jun 25 - 26 1030-0800 (21.5 hrs)	35[a]
Spencer Canyon (RM 246.0)	Jun 26 - 28 1230-1043 (46.2 hrs)	60
Lost Creek (RM 249.7)	Jun 28 - 30 1206-0744 (43.7 hrs)	54
Quartermaster (RM 259.8)	Jun 30 - July 1 1245-1339 (24.9 hrs)	19
	Trip No. 2	
Bridge Canyon (RM 234.9)	Sep 28 - 29 1130-0825 (20.7 hrs)	36
Spencer Canyon (RM 246.0)	Oct 1 - 2 1335-1717(27.7 hours)	42
Quartermaster (RM 259.8)	Oct 3 - 4 1607-0622(14.2 hours)	17
	Trip No. 3	
Bridge Canyon (RM 234.9)	Dec 2 - 3 1030-1010(23.7 hrs)	42
Spencer Canyon (RM 246.0)	Dec 5 - 6 0723-0825(25.0 hrs)	56
Below Lost Creek (RM 249.7)	Dec 6 - 7 1922-0646(6.6 hrs)	25
Burnt Spring (RM 259.3	Dec 8 -9 1203-1041(22.6 hrs)	38

[a] Staff gage located in surging eddy -- readings unreliable.

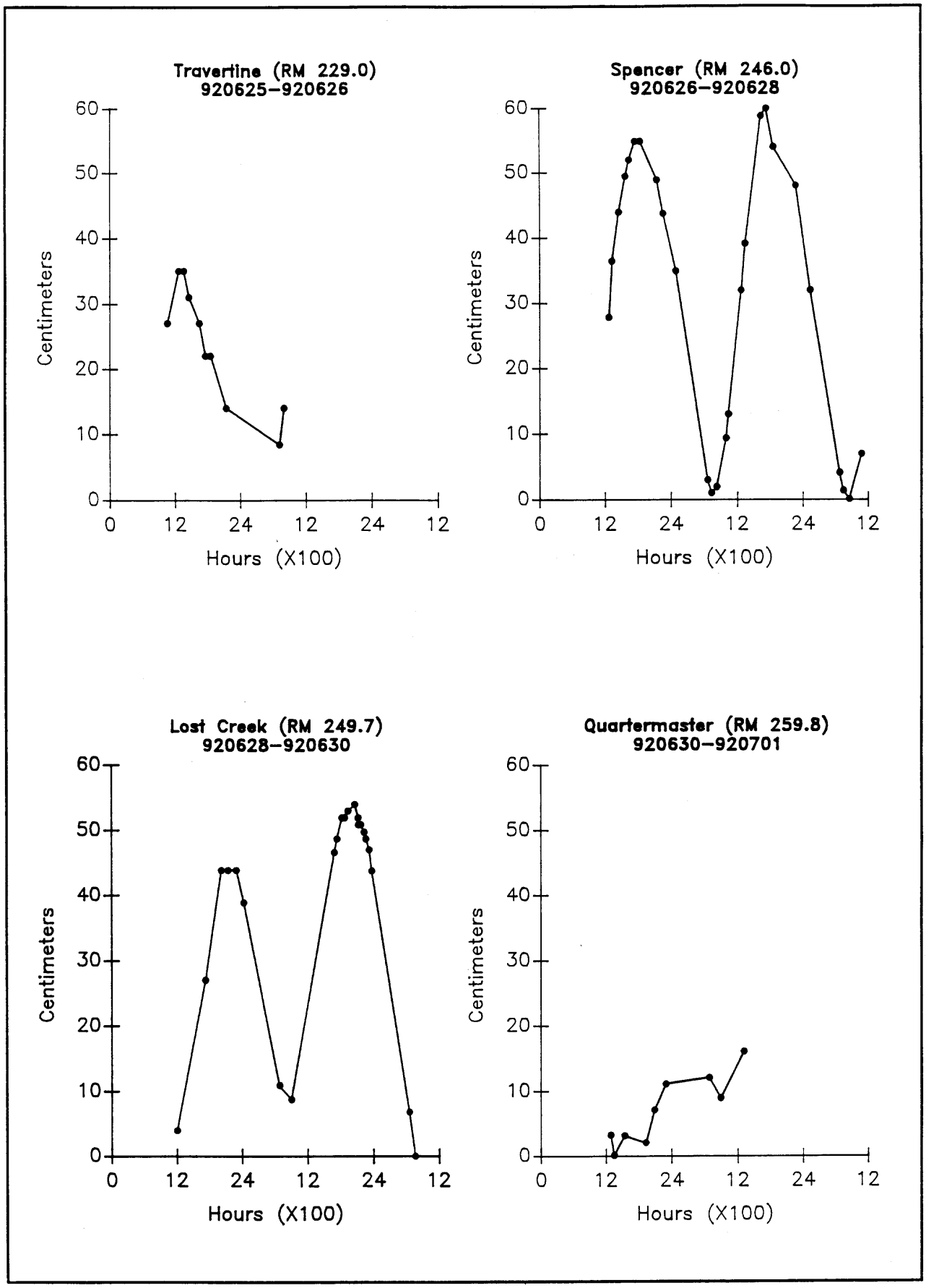

Figure 11. Relative changes in river stage recorded at four locations in Lower Grand Canyon and Lake Mead, Trip 1, 1992. (920625 = June 25, 1992)

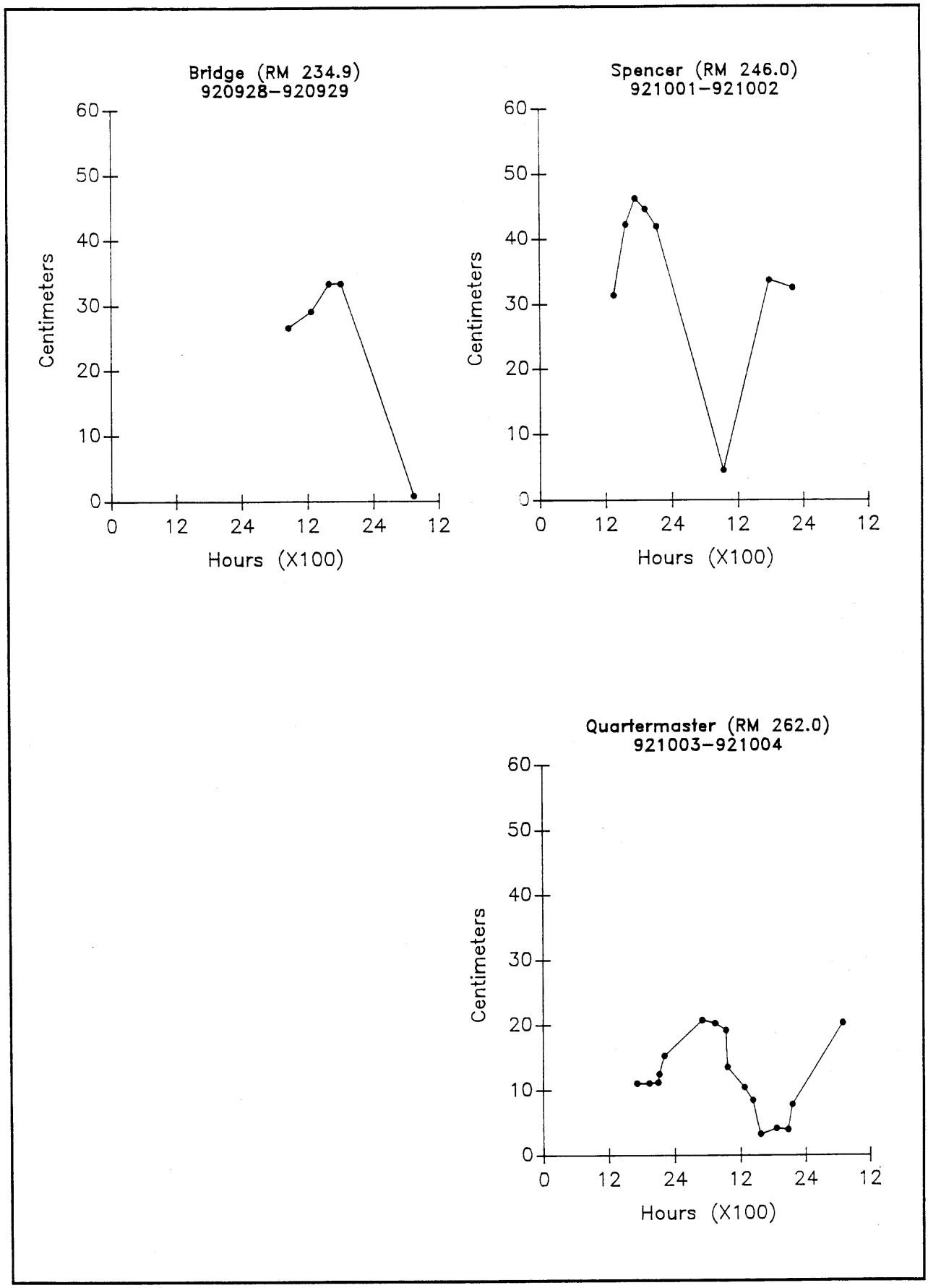

Figure 12. Relative changes in river stage recorded at three locations in Lower Grand Canyon and Lake Mead, Trip 2, 1992. (920928 = September 28, 1992)

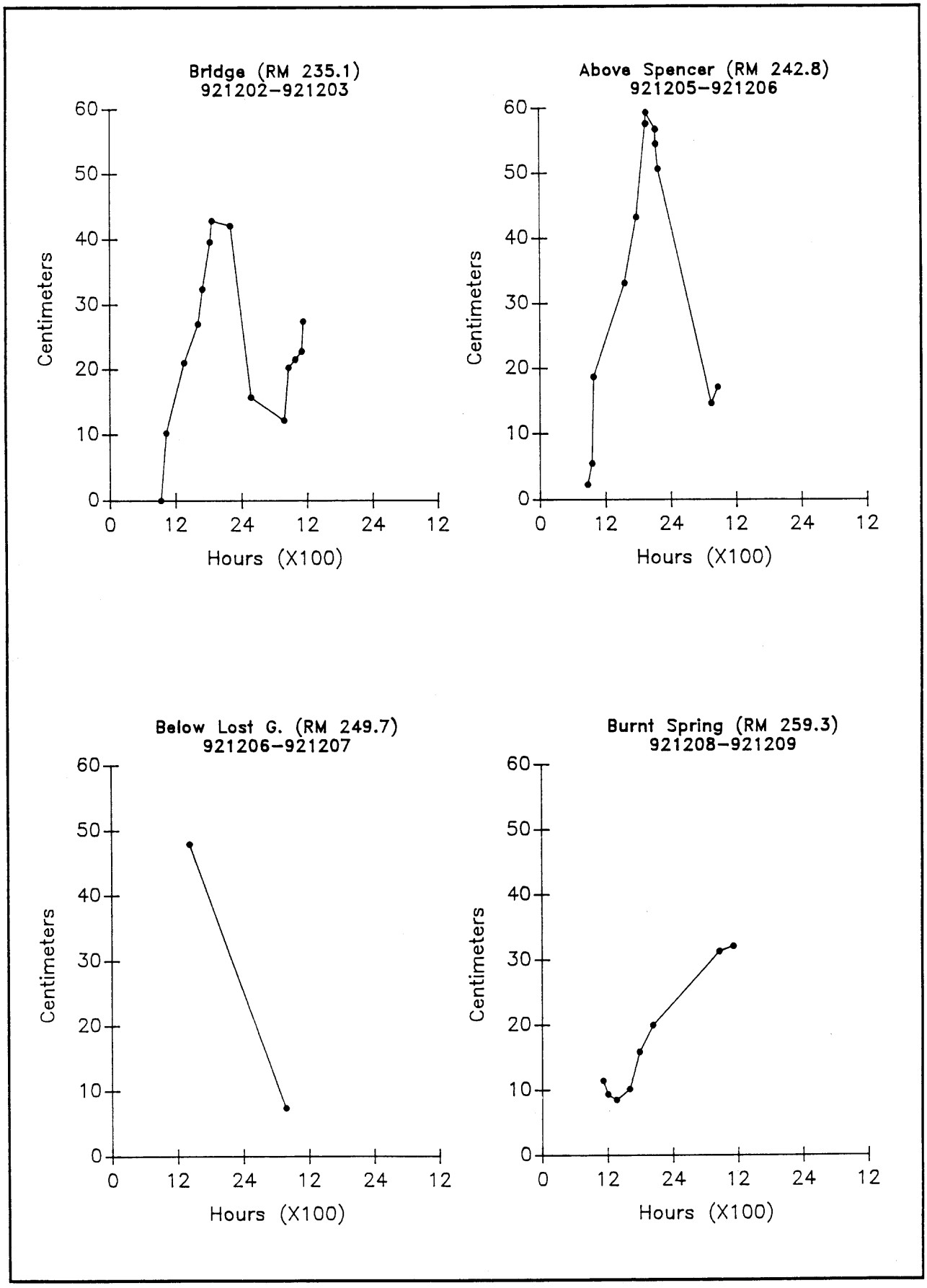

Figure 13. Relative changes in river stage recorded at four locations in Lower Grand Canyon and Lake Mead, Trip 3, 1992. (921202 = December 2, 1992)

DISCUSSION

The Hualapai Indian Reservation is bound on the north by 109 miles of the Colorado River in Grand Canyon, from RM 164.5 (near National Canyon) to RM 273.5 (near Emery Falls Canyon). This is the lowermost third of approximately 300 miles of river between Glen Canyon Dam and Lake Mead. This region of river supports significant aquatic resources and a potential that may be detrimentally or positively affected by dam operations.

Three field trips in 1992, from Diamond Creek (RM 226) to Pearce Ferry (RM 280), provided Hualapai and BIO/WEST biologists with the opportunity to begin to assess aquatic resources of the lower portion of the region. Continued studies in 1993, including 4 field trips, will allow a better opportunity to focus on specific areas, and particular aspects in order to describe the effects of interim flows. Results of the 1992 and 1993 investigations will be integrated with results of the upstream BIO/WEST studies, in order to provide a complete perspective of aquatic resources for the entire reservation boundary--National Canyon to Emery Falls Canyon.

The Colorado River, from Diamond Creek to Pearce Ferry, is the most dynamic reach of river between Glen Canyon Dam and Lake Mead. It represents the transition between the relatively steep gradient of Grand Canyon and the sediment-filled channel inundated by Lake Mead. At maximum lake elevation (1,221 feet), the Colorado River is inundated as far upstream as RM 235.5 (base of Bridge Canyon Rapid), or about 82% of the 54 miles from Diamond Creek to Pearce Ferry. Minimum lake elevation is approximately 1,157 feet. The varying seasonal and annual inundation of this lower reach of Grand Canyon enhances biological, physical, and chemical dynamics, and may sometimes result in high levels of productivity from nutrient deposits and upwellings.

This dynamic nature greatly complicates an objective evaluation of interim flows from Glen Canyon Dam, because measured variables, such as fish species composition and abundance, macroinvertebrate densities, and water quality parameters, may change dramatically in response to Lake Mead elevation and not necessarily interim flows. The dynamic nature of the area needs to be understood first in order to better isolate the effects of variables such as flow magnitude and ramping rates.

Although the study reach (Diamond Creek to Pearce Ferry), is 240 miles downstream of Glen Canyon Dam, magnitude and patterns of release from the dam directly and indirectly affect aquatic resources. Flow magnitude and ramping rates--although ameliorated with distance from the dam--affect river stage that in turn affects fish habitat and depth of inflow areas. A maximum of 60 cm (2 feet) vertical stage change was measured in June of 1992 in this study reach. The magnitude of this

change is sufficient to cause fish habitat changes in backwaters, shallow side channels, ledge shorelines, and tributary inflows.

Releases of cold hypolimnetic water from Glen Canyon Dam also effect river temperatures in this lower reach of Grand Canyon. At an estimated maximum warming rate of about 1 C for every 35 miles, water released at 10 C from Glen Canyon Dam is expected to warm to about 17 C in the study reach, 240 miles downstream of the dam. Temperature measured in June 1992 confirmed this longitudinal warming effect by recording 17 C near Diamond Creek.

The following is a discussion of findings in 1992 relative to each of the five study objectives. The discussion addresses effects of interim flows and findings to date, as well as proposed actions for 1993.

Distribution, Abundance, And Behavior Of Fish

The 1992 study established fish species composition, approximate distribution, and relative abundance for the study reach. The 1993 study will focus on specific areas such as tributary inflows, canyon habitats likely to contain native or endangered species, and influx of fish from Lake Mead.

Of 17 species of fish captured in the study reach in 1992, most were found in relatively small numbers, except for large aggregations of non-native cyprinids (red shiners, fathead minnows) and poecilids (mosquitofish) in the tributaries. Native flannelmouth sucker adults were few in number and found in the steep upper canyon as well as the alluvial lower area of the reach. Young flannelmouth suckers were found in tributaries, indicating that these were used as spawning or nursery areas, or both. Humpback chub, razorback sucker, and bluehead sucker were not found in the study reach in 1992. Native speckled dace were rare in the mainstem, but numerous in tributaries. The effect of interim flows on these native species can only be determined when the distribution and behavior of these fish in this reach are better understood with varying Lake Mead elevations. Interim flows affect depth of tributary inflows, and may impede access by adults to spawning sites.

Distribution, abundance, and behavior of non-native species may also be affected by interim flows, but have probably been determined largely by the cold releases from Glen Canyon Dam. Red shiners, although abundant in the tributaries (Surprise, Spencer, Lost, Quartermaster canyons) were found primarily near tributary inflows, but were not found upstream of Bridge Canyon. Since water temperature increased only 1 C in June, from Diamond Creek (RM 226) to Spencer Canyon (RM 246.0), it does not appear that cold water temperature restricted upstream dispersal of this species. Instead, the steeper gradient above Bridge Canyon provided few opportunities for quiet, sheltered habitat preferred by red shiners. Furthermore, the absence of deep, perennial tributary streams

upstream of Separation Canyon (RM 239.5) limits spawning and nursery opportunities provided further downstream by Surprise, Spencer, Lost, and Quartermaster canyons. Possibly, red shiners move upstream in a system like the Colorado River by establishing populations in tributaries from which individuals disperse to other potential spawning tributaries. This "tributary hopping" should have enabled the red shiner to access Travertine Canyon and Diamond Creek, but the species is absent from these streams. As an alternative to explain the upstream distribution of red shiners at Bridge Creek, this point on the river is the upstream-most area once inundated by Lake Mead. Perhaps this species accessed the area during the high lake elevations.

Other non-native species of interest are large predators such as striped bass and channel catfish. Striped bass are found in small numbers throughout Grand Canyon in July and August--presumably during spawning ascents from Lake Mead. The numbers in the Lake Mead inflow were small in 1992, indicating that the more substantial populations are located further into the lake. Channel catfish, however, were distributed throughout the canyon.

Distribution, Abundance, And Behavior Of Larvae and Juveniles

The only young native fish species captured were flannelmouth suckers. The majority of these fish were in tributaries, indicating that either the fish were spawned, hatched, and reared in these streams, or moved into these streams from nearby mainstem spawning sites.

The presence of four closely spaced, warm, perennial tributaries (Surprise, Spencer, Lost, Quartermaster canyons) in close proximity to Lake Mead may provide an opportunity to enhance populations of some of the native species--particularly the endangered razorback sucker. Specimens of small suckers from these tributaries will be closely examined--and collected if permitted by resource agencies--in order to ascertain the species identity of these young fish and determine the presence or absence of razorback suckers. These specimens, or tissues from larger fish, will have to be examined genetically (DNA analysis) to determine species identity.

In the case where young razorback suckers are found, there abundance and distribution will be determined, and limiting factors identified to enhance natural reproduction in the area. Augmentation with eggs or larvae from hatcheries will be assessed, and impacts on existing wild populations evaluated.

In the case where no young razorback suckers are found, the possibility of augmentation with eggs or larvae will be evaluated, considering habitat conditions, water quality, food resources, and sympatric species.

Reproduction, Food Habits, Habitat

Sample efforts in spring of 1993 will focus on identifying native fish spawning sites to determine the proportion of mainstem and tributary spawning. Although mainstem spawning is restricted throughout Grand Canyon by the cold hypolimnetic release, the Colorado River between Diamond Creek and Pearce Ferry is the warmest, and possibly most suitable for spawning by native species. Carcasses of adult flannelmouth suckers in Spencer Creek and the presence of small numbers of young suckers in Spencer and Surprise canyons is evidence of reproduction by flannelmouth suckers, and possibly razorback suckers.

The effect of interim flows on food habits of fishes cannot be determined without a thorough understanding of diet by species and life stage. Stomach samples are currently being processed to evaluate food habits, and drift samples are being sorted and analyzed to assess food availability, and the relationship of species composition and relative abundance to flow.

Environmental Conditions Of Tributary Mouths and Shorelines

The tributary inflows in the study reach (Surprise, Spencer, Lost, Quartermaster canyons) supported the highest abundances of fish, as reported from other tributaries further upstream, in Grand Canyon (Valdez et al. 1991, 1992). Fish are attracted to tributary inflows by an influx of food (aquatic and terrestrial macroinvertebrates) and warm water temperature. Clearly, these inflows experience the greatest physical, chemical, and biological changes, during fluctuating flows, of any other mainstem habitats. Maintaining the environmental integrity of these inflows by providing mainstem flows that promote species diversity and abundance is vital to ecosystem health.

Productivity And Algal Standing Crops

Productivity and algal standing crops are difficult to measure in a stochastic western river such as the Colorado. These parameters become even more difficult to assess in lake inflow regions such as the lower 45 miles of the study reach, which may be inundated by Lake Mead with water of different temperature, water quality, and nutrient levels than the inflowing Colorado River. These parameters are often too variable to allow comparison between areas and over time, but their measurement can provide a valuable perspective of trophic energetics and important aspects affected by river flows.

Algal standing crops will be determined for specific locations so that results can be meaningfully related to other aspects of the ecosystem, e.g., macroinvertebrate and diatom densities in areas important to fish such as tributary inflows.

RECOMMENDATIONS

The following are recommendations for the Hualapai Aquatic Resources Study for 1993:

1. Continue to survey the reach for fish composition, relative abundance, and behavioral aspects relative to interim flows and Lake Mead elevation.

2. Measure habitat parameters (depth, velocity, substrate) of shorelines, tributary inflows, side channels, and backwaters to ascertain effects of interim flows and Lake Mead elevations. Camera stations will be used to enhance visual monitoring of particularly tributary inflows and backwaters.

3. Quantitatively survey lower reaches of Spencer Canyon, Lost Creek, and Quartermaster Canyon to determine fish species composition, abundance, and distribution. Examine or collect specimens of young fish from these tributaries to determine presence or absence of native species. Survey the tributaries in spring to determine presence or absence of spawning by native fish.

4. Continue to document water quality, particularly of the Colorado River at inflows, of tributaries, and at the river-lake interface to qualitatively describe effect of lake level on temperature, dissolved oxygen, pH, conductivity, nutrient levels, and algal species.

5. Photograph and map tributary inflows in order to quantify fish habitat dynamics with river stage changes, including water depth, velocity, resting areas, and mixing zones.

6. Preserve specimens of fish parasites to ascertain the presence of the Asian tapeworm in this reach and species infected. Specimens should be taken from eviscerated fish such as channel catfish, carp, striped bass, as well as in whole fish such as red shiners, fathead minnows, mosquitofish, and plains killifish.

7. Coordinate the aquatic resource studies with concurrent studies of riparian habitats.

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APPENDIX A

Photo Documentation

Photo A-1. Aerial of 232 Mile Rapid, RM 232, sample stratum A, June 24, 1992.

Photo A-2. Aerial of Separation Canyon, RM 239.5, sample stratum B, June 24, 1992.

Photo A-3. Aerial of Spencer Canyon, RM 246.0, sample stratum B, June 24, 1992.

Photo A-4. Aerial of Surprise Canyon, RM 248.3, sample stratum B, June 24, 1992.

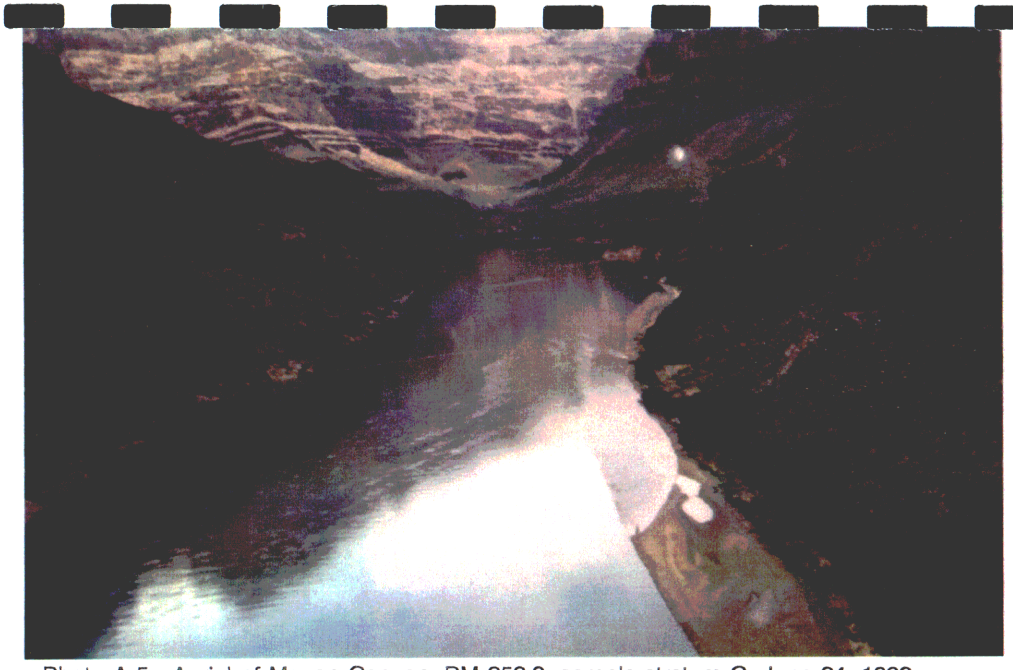

Photo A-5. Aerial of Maxon Canyon, RM 252.3, sample stratum C, June 24, 1992.

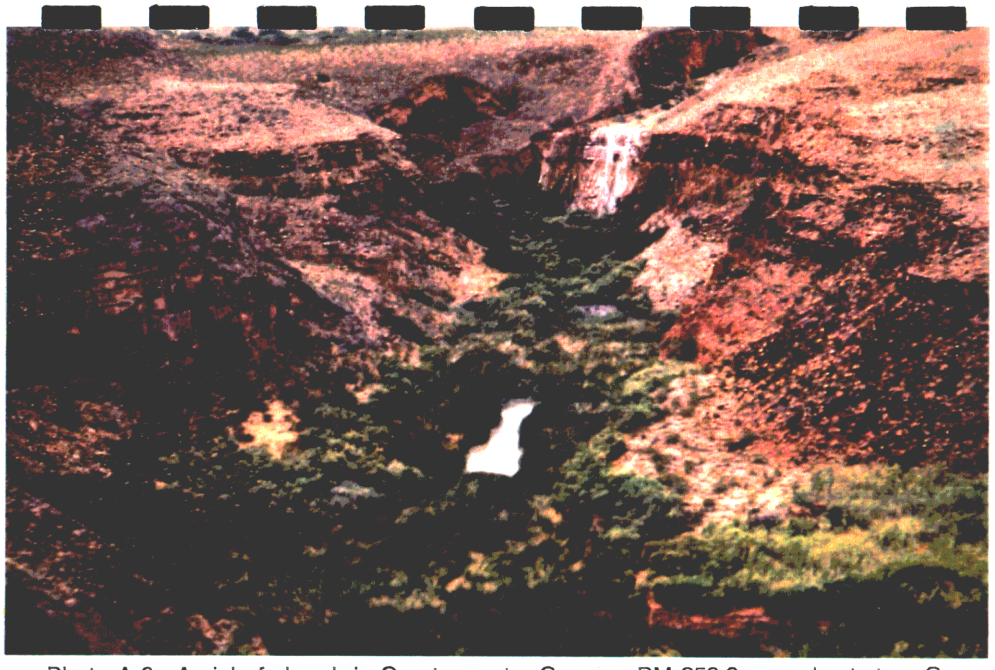

Photo A-6. Aerial of slough in Quartermaster Canyon, RM 259.8, sample stratum C, June 24, 1992.

Photo A-7. Aerial of braided channel at RM 268.5, sample stratum D, June 24, 1992.

Photo A-8. Aerial of Lake Mead Inflow near Grand Wash Cliffs, RM 276, June 24, 1992.

Photo A-9. Typical steep canyon walls in sample stratum A, RM 229.5, June 26, 1992.

Photo A-10. Spencer Creek outflow in sample stratum B, RM 246.0, June 27, 1992.

Photo A-11 Seine Surprise Canyon in sample stratum B, RM 248.3, June 28, 1992.

Photo A-12. Research boat in Lost Creek slough, RM 249.0, June 28, 1992.

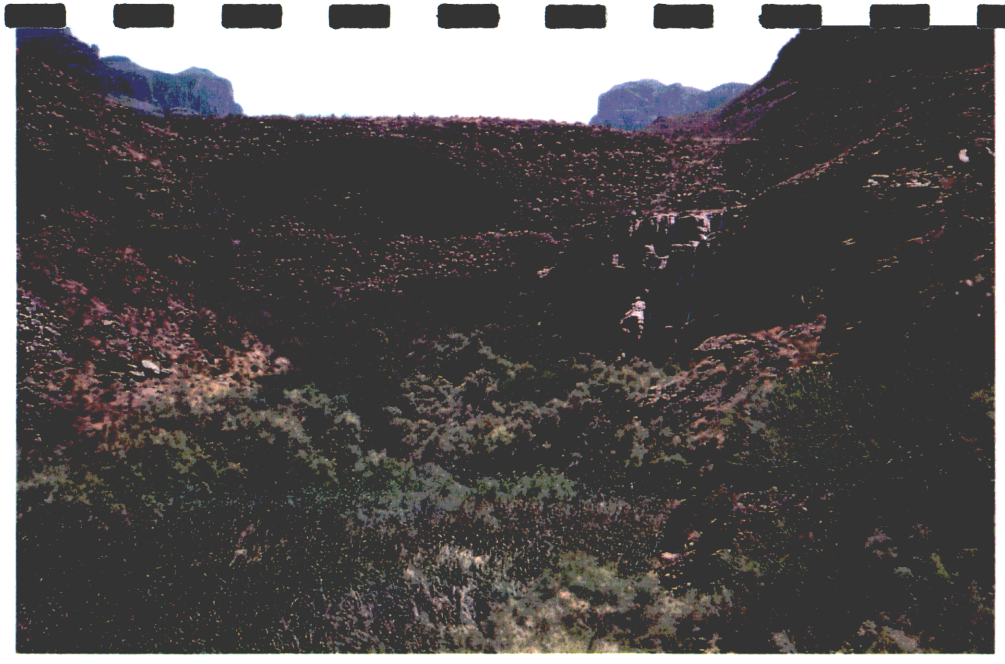

Photo A-13. Heavily vegetated slough in Quartermaster Canyon, RM 259.8, June 30, 1992.

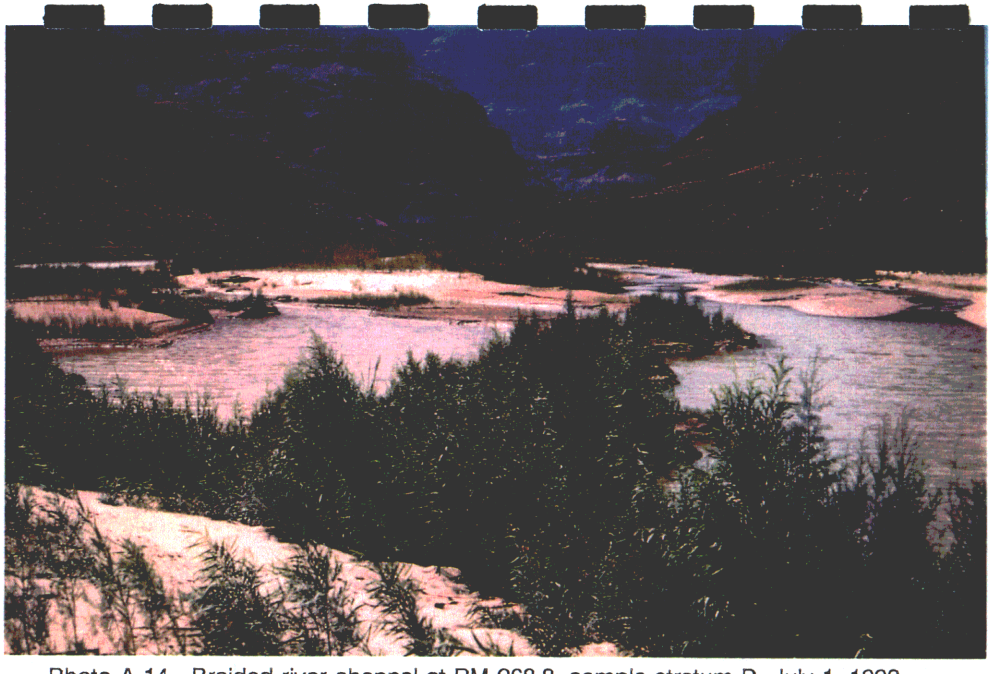

Photo A-14. Braided river channel at RM 268.8, sample stratum D, July 1, 1992.

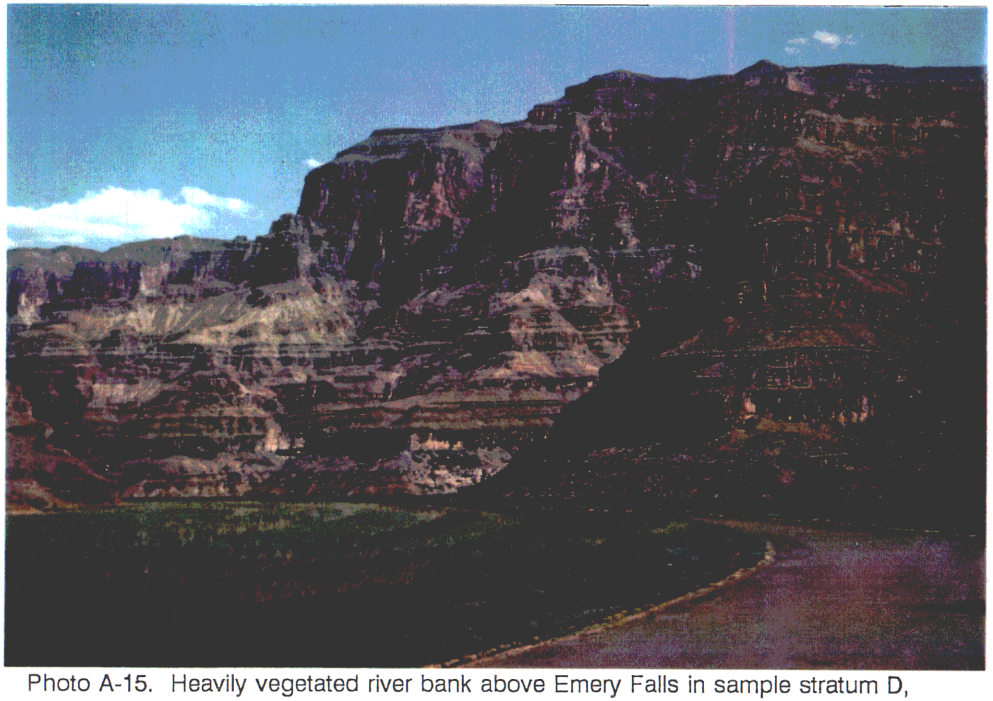

Photo A-15. Heavily vegetated river bank above Emery Falls in sample stratum D, RM 273.5, July 1, 1992.

Photo A-16. Heavily vegetated river bank near Grand Wash Cliffs (in background) in sample stratum D, RM 276, July 1, 1992.

Photo A-17. Electrofishing near Salt Creek in sample stratum C, RM 256.0, June 30, 1992. B. Dierker, C. Bravo, T. Magenty, M. Sampson.

Photo A-18. T. Magenty and M. Sampson check gill net near Travertine Canyon, June 25, 1992.

Photo A-19. C. Bravo checks trammel net, June 30, 1992.

Photo A-20. Hoop net in Lost Creek slough, June 28, 1992. R. Valdez, T. Magenty, C. Bravo.

Photo A-21. C. Bravo uses snorkel to survey fish in Spencer Creek, June 27, 1992.

Photo A-22. M. Sampson screens gravel for eggs in Spencer Creek, June 26, 1992.

Photo A-23. D. Freitas and R. Haley deploy Hydrolab Datasonde with datalogger in Spencer Creek, June 27, 1992.

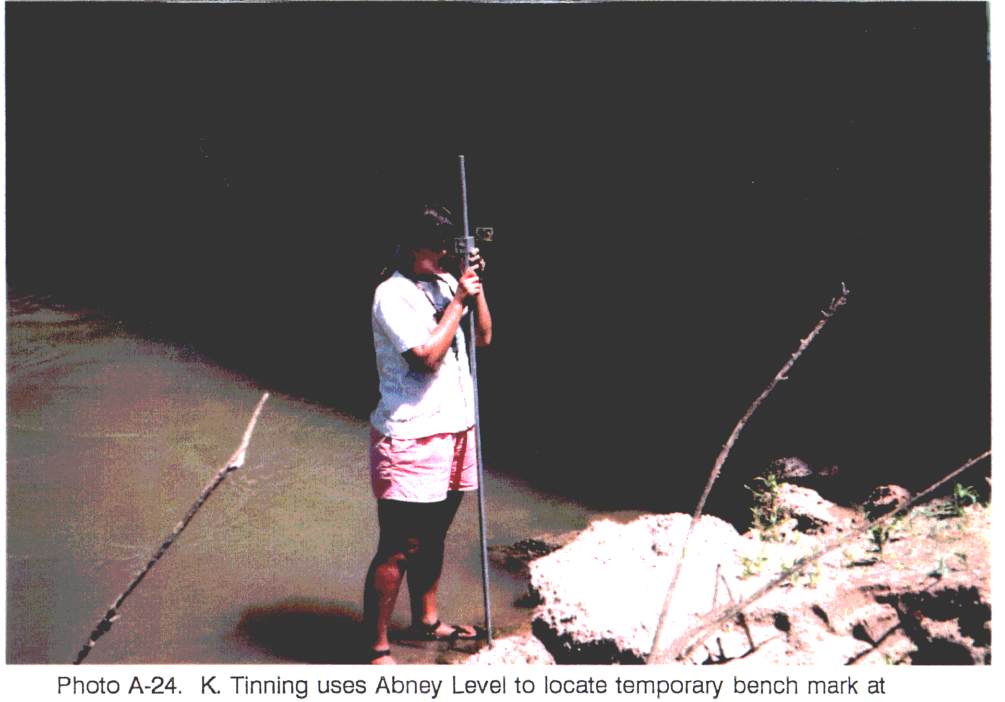

Photo A-24. K. Tinning uses Abney Level to locate temporary bench mark at Quartermaster Canyon, RM 259.8, June 30, 1992.

Photo A-25. Red shiner (Cyprinella lutrensis) from Spencer Creek, June 26, 1992.

Photo A-26. Male striped bass (Morone saxatilis) from Colorado River near Quartermaster Canyon, RM 259.8, June 30, 1992.

Photo A-27. Common carp (Cyprinus carpio), most common mainstem species captured.

Photo A-28. Fathead minnow (Pimephales promelas) from Surprise Canyon, RM 248.3, June 28, 1992.

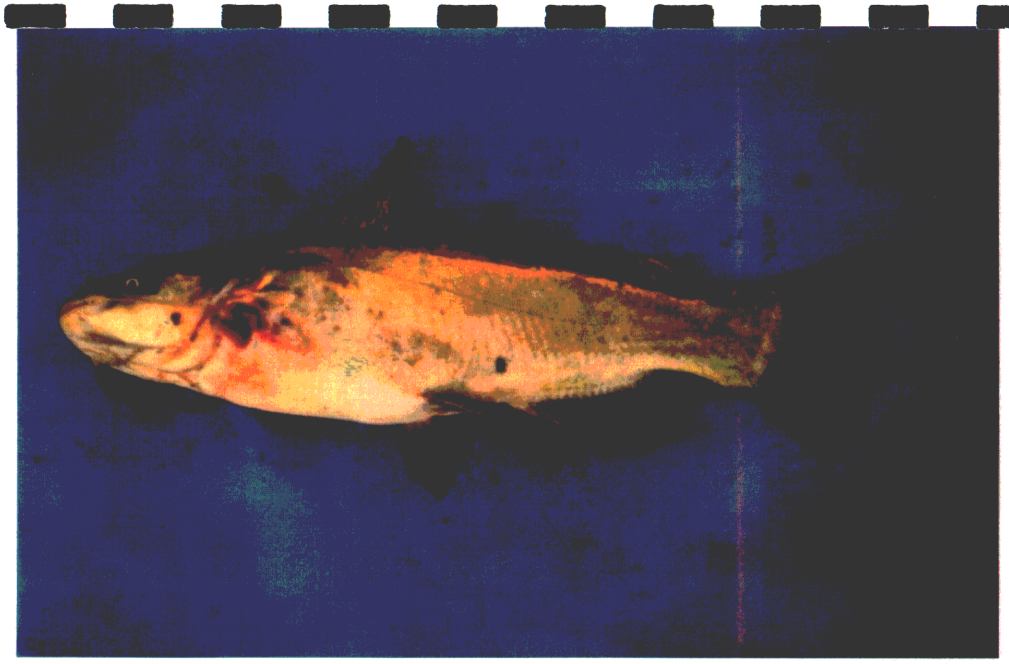

Photo A-29. Black bullhead (Ameiurus melas) from Lake Mead Inflow near Pearce Ferry, RM 280.0, July 2, 1992.

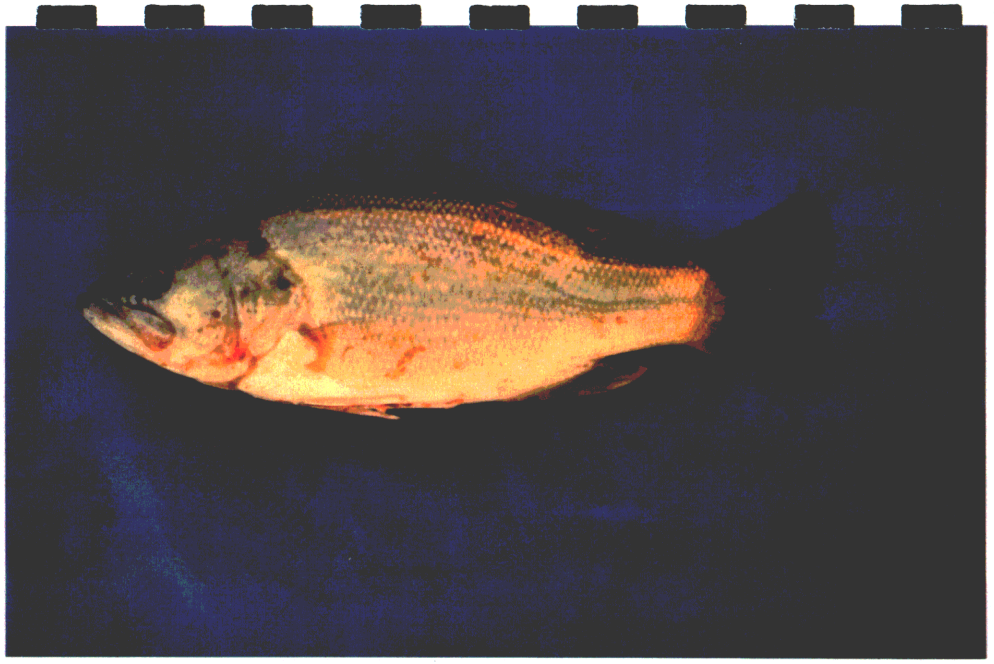

Photo A-30. Largemouth bass (Micropterus salmoides) from Lost Creek slough, RM 249.0, June 28, 1992.

Photo A-31. Flannelmouth sucker (Catostomus latipinnis) from Colorado River near Travertine Canyon, RM 229.0, June 25, 1992.

Photo A-32. Seine haul from Surprise Canyon with several hundred red shiners (Cyprinella lutrensis) and fathead minnows (pimephalis promelas), June 28, 1992.

Photo A-33. Bluegill (Lepomis macrochirus) and largemouth bass (Micropterus Salmiodes) seined near Scorpion Island, RM 278.5, October 4, 1992.

Photo A-34. Channel catfish (Ictalurus pernatatus) from near Spencer Canyon, RM 246.0, October 8, 1992.

Photo A-35. K. Tinning and M. Sampson seine Colorado River, October 1992.

Photo A-36. M. Sampson and W. Powskey with Hualapai Research Boat, October 1992.

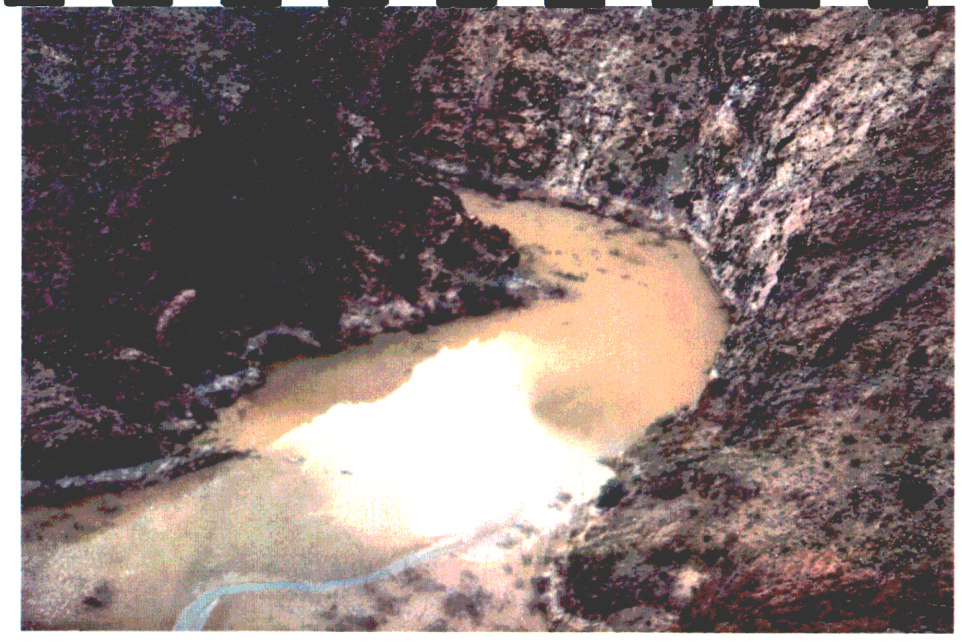

Photo A-37. Aerial of Lost Creek slough, RM 248.8, June 1992.

Photo A-38. Aerial of Diamond Creek, RM 225.8, June 1992.

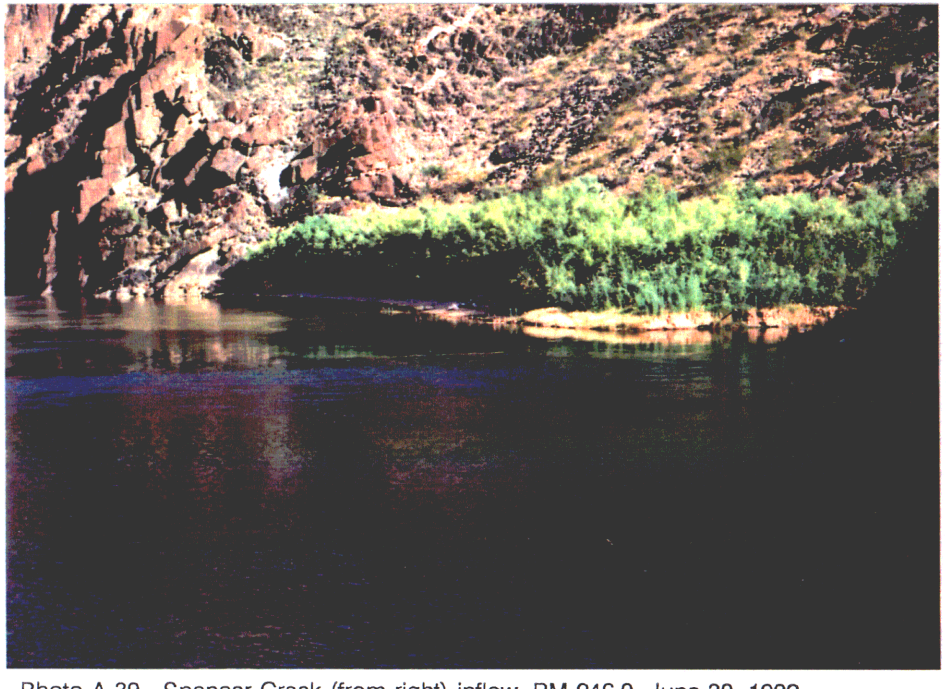

Photo A-39. Spencer Creek (from right) inflow, RM 246.0, June 30, 1992.

Photo A-40. E. Prats, W. Powskey seine large isolated pool near Scorpion Island, RM 278.5, October 5, 1992.