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 - 1993

PRELIMINARY DRAFT

BIO/WEST, Inc.

Resource Management and Problem Solving Services

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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 in May of 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. Seven research trips were conducted from June 1992 to December 1993 to sample fishes, macroinvertebrates, and water quality, and to monitor variability in river stage associated with flow changes. The 60-mile reach of river was divided longitudinally into four geomorphic 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 characterized by 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 in the Colorado River as well as the following tributaries: Diamond Creek, Travertine Falls Creek, Spencer Creek, Surprise Canyon, Lost Creek, and Quartermaster Canyon. Fish were collected with seven primary gear types including electrofishing, gill nets, trammel nets, hoop nets, minnow traps, seines, and angling. Nineteen species of fish were captured representing 10 families. Only four of these species, humpback chub (Gila cypha), speckled dace (Rhinichthys osculus), flannelmouth sucker (Catostomus latipinnis), and bluehead sucker (Catostomus discobolus), are native to the Colorado River Basin. Carp and channel catfish were the most common species in the Colorado River, whereas red shiners, fathead minnows, and mosquitofish were most common in tributaries. Plains killifish were found in local aggregations in tributaries. Striped bass, largemouth bass, green sunfish, black crappie, bluegill, threadfin shad, and walleye were lake species that were found in small numbers in tributaries or sheltered riverine habitats. The endangered species, razorback sucker (Xyrauchen texanus), Colorado squawfish (Ptychocheilus lucius), and bonytail (Gila elegans), were not seen or captured.

Benthic and drifting macroinvertebrates were sampled in the Colorado River and the tributaries mentioned above. Benthos were collected from rocky substrates in tributaries with Hess and Surber samplers, and an Ekman dredge was used in the mainstem where the substrate usually consisted of sand or silt. Drift volume of macroinvertebrates was greatest during descending flows, with no distinct seasonal patterns identified, with chironomids, simulids, and Gammarus most abundant. Densities of

drifting macroinvertebrates in Spencer Creek were 40 to 200 times those of the mainstem Colorado River.

Conductivity, water temperature, pH, and dissolved oxygen concentrations were measured in the mainstem and in some tributaries with a constant recording Hydrolab Surveyor II or Datasonde with datalogger. Turbidity was measured in the mainstem with a secchi disk. Long-term variation in temperature was monitored at two locations in the Colorado River and in Spencer Creek with thermographs (Ryan TempMentor). Mainstem temperature varied from about 8.5 C in December to about 20 C in September. Temperature of Spencer Creek varied from about 14 C in December to about 29 C in June.

River stage changes were recorded during each sampling trip. Maximum vertical change in river stage was about 90 cm in 48 hours. Most daily stage changes in narrow canyon reaches were 40 to 60 cm, and 20-30 cm in more alluvial reaches.

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 braided area between Dry Canyon (RM 264) and Pearce Ferry (RM 280) has suitable habitat for razorback suckers. The only humpback chub captured during this study was near Salt Creek, and may indicate an additional area of suitable habitat. The presence of young flannelmouth sucker in Spencer Canyon and Surprise Canyon indicates that these tributaries could be suitable spawning and rearing sites for razorback suckers. Spencer Canyon may also be a suitable site for introducing young razorback suckers 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 (Figure 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. In addition to the results obtained below Diamond Creek, we also report fish population information for the Colorado River from the northeastern boundary of the Hualapai Indian Reservation (near National Canyon - RM 165.0) to Diamond Creek. All data for the portion of the river from National Canyon to Diamond Creek were derived from other research conducted by BIO/WEST (Valdez et al. 1991, Valdez and Hugentobler 1992) in Grand Canyon.

Before impoundment by Glen Canyon Dam in 1963, the mainstem Colorado River 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 Grand Canyon, and humpback chub and razorback sucker are federally endangered species. The abundance and distribution of flannelmouth sucker, bluehead sucker, and speckled dace have also been diminished in the region. Alterations of the natural flow regime, reduced water temperature, and altered water quality are believed to play a major role in the current status of these fish.

Patterns and magnitude of flow in the Colorado River through Grand Canyon are largely regulated by Glen Canyon Dam, although spring runoff and periodic rain storms may increase tributary inflow sufficiently to influence 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. Daily changes cannot exceed 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 during high volume months (July, August, September). Ramping rates are not to exceed increases of 8,000 cfs over 4 hours for a maximum of 2,500 cfs per hour, and decreases of 1,500 cfs per hour.

Interim flow criteria were implemented in August 1991 to minimize damage to the Grand Canyon ecosystem that had resulted from previous Glen Canyon Dam 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 that 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 Glen Canyon Environmental Studies (GCES) Phase I and Phase II. This investigation extended the lower boundary of the study area 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 methods used in this investigation were consistent with those employed in 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 included seven sampling trips in 1992 and 1993. Quarterly reports, that provided a brief summary of results, were submitted for each of these sampling trips. This Annual Report provides detailed analyses and interpretation of data collected during 1993 and an integration with data collected in 1992. Results from this study are also integrated with results of research conducted by BIO/WEST in Reach 3 under the Phase II GCES investigation.

Representatives of the Hualapai Tribe provided the primary leadership for this investigation with technical support from BIO/WEST, and logistical support and coordination provided by GCES. The investigation was conducted in cooperation with the National Park Service and the U.S. Fish and Wildlife Service, and funding was provided by the HWMD and the Bureau of Reclamation (USBOR) as part of the GCES Interim Flows Monitoring Program. River logistics were provided by OARS, a commercial river concessionaire.

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. This phase characterized the ichthyofauna of the Colorado River from the eastern boundary of the Hualapai Reservation (RM 165) to below Pearce Ferry (RM 286), with emphasis on the mainstem and tributaries downstream of Diamond Creek (RM 226).
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. This phase characterized distribution and abundance in the Colorado River from the eastern boundary of the Hualapai Reservation (RM 165) to below Pearce Ferry (RM 286), with emphasis on the mainstem and tributaries downstream of Diamond Creek (RM 226).
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. This phase characterized reproduction, food habits, and patterns of habitat use in the Colorado River and selected tributaries from National Canyon to below Pearce Ferry.
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. This phase characterized taxa composition and distribution of drifting and benthic macroinvertebrates (food base), algae, and macrophytes in the Colorado River from Diamond Creek to below Pearce Ferry.

TRIP SCHEDULE AND PERSONNEL

Seven sampling trips were conducted during this study: three in 1992 (June-July, September-October, December), and four in 1993 (March-April, May-June, September-October, December) (Table 1). 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. Sampling locations were selected so that sampling effort was evenly distributed throughout the study area to provide a thorough characterization of aquatic resources. Camp sites were established to provide convenient access to sampling sites with minimal activity in the vicinity of recreational boaters. We frequently camped at or near tributaries (Travertine Canyon, Travertine Falls, Spencer Canyon, Surprise Canyon, Lost Creek, Quartermaster Canyon) to facilitate sampling of tributaries and inflows.

A total of 41 people participated in the seven field trips (Table A-1). A typical crew included three BIO/WEST biologist/boat handlers, three HWMD representatives, and two OARS river guides.

STUDY REACH

GRAND CANYON STUDY REACHES

The study reach included 60 miles of the Colorado River and selected tributaries from Diamond Creek (RM 226) to below Pearce Ferry (RM 286) (Figure 1). In addition, data from the BIO/WEST fishery investigation conducted in Grand Canyon from 1990 through 1993 (Valdez et al. 1991, 1992; Valdez and Hugentobler 1993, Valdez 1994) are provided for the section of river from National Canyon (RM 165) to Diamond Creek. Inclusion of these data allowed us to characterize the fish community along the entire northern boundary of the Hualapai Reservation (i.e., National Canyon to the vicinity of Emery Falls [RM 273.5]).

The area from Diamond Creek to Pearce Ferry was designated Reach 4 as a continuation of the BIO/WEST studies conducted further upstream (Table 2). The section of river from National Canyon to Diamond Creek is included in Reach 3. The study reaches for this investigation in 1992 were 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 geomorphic strata that reflected different fish habitat complexes and gradients (Table 2; Figure 2): Stratum A--13 miles from Diamond Creek (RM 226.1) 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).

The canyon in Stratum A was narrow, and the river was characterized by swift, deep runs and large recurrent eddies. The shoreline was composed mostly of vertical cliffs and talus, with few sand beaches. Gradient was approximately 10 feet per mile (0.19%). Tributaries in this stratum include 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 also characterized by a narrow canyon. However, the river was more gradual than in Stratum A with a gradient of about 3.5 feet per mile (0.07%) and slower runs and eddies. This stratum contained sedimentary lake deposits at most side canyons and tributaries that had accumulated in the past when the level of Lake Mead had risen to Separation Canyon. 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 by a wide canyon with continuous sedimentary lake deposits, heavily vegetated with coyote willow (Salix exiqua), Goodding willow (S. 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 only 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 (Baccharis?), tamarisk, cattails (Typha sp.) and rushes (Juncus torreyi). The shoreline was dominated by vegetated sand and 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. A small intermittent tributary was at Emery Falls Canyon (RM 274.3).

METHODS

Sampling was conducted from base camps shown in Table 1. 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. However, sampling intensity varied among tributaries according to their relative importance to the Colorado River ecosystem. In general, tributaries that appeared to have suitable fish habitat, especially for native species, were targeted. Therefore, Spencer Creek followed by Surprise Creek were sampled more intensively than other tributaries. As mentioned previously, all fisheries results presented for the mainstem from National Canyon to Diamond Creek were derived from other research conducted by BIO/WEST, Inc (Valdez et al. 1992, Valdez and Hugentobler 1993, Valdez 1994).

FISH SAMPLING METHODS

Fish were sampled with seven principal gear types, including electrofishing, gill nets, trammel nets, hoop nets, minnow traps, seines, and angling.

Electrofishing

In the mainstem Colorado River, 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.

Electrofishing in tributaries was conducted primarily with a Coffelt backpack electro-shocker (model BP-1C); in a few instances elevated river stage allowed sampling of Lost and Spencer Creeks to be conducted with the electrofishing boat. The backpack unit was typically operated within a range of 100 volts/8 amps to 150 volts/12 amps, depending on specific conductance of the water being sampled. In Spencer and Surprise Creeks backpack electrofishing was conducted in the inflow region to characterize species composition and relative abundance. All samples were timed so that catch rates could be compared among sampling trips and tributaries.

Additional electrofishing was conducted in Spencer Creek during trips 5, 6, and 7 to more thoroughly characterize fish populations. Population estimates were conducted to assess fish density (number/100 m^2) and to develop comprehensive species composition and relative abundance information. A multiple-pass removal technique was employed to derive population estimates at two locations: the inflow region (Site 1) and 0.75 miles (Site 2) upstream of the confluence with the mainstem. Site 1 was about 30 m long with an average width of about 5 m, and Site 2 was approximately 46 m long and 11 m wide (Site 2 received only a single-pass during sampling trip 5). To preclude the escape of fish from the area being sampled, block nets were set at both upstream and downstream ends of each site. Electrofishing was initiated at the downstream end of the site and proceeded to the upstream block-net. This process was repeated three times, and fish captured on different passes were stored in separate containers.

Further sampling was undertaken in Spencer Creek to evaluate the effect of distance from the Colorado River on the ichthyofauna, and to determine if non-native species were more abundant near the inflow. Sampling was conducted above the upstream population estimate site (Site 2) at approximately 0.5 mile intervals. Sampling was terminated about 2.5 miles above the inflow. Samples were taken so that catch rate could be compared among locations.

Netting

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. Most gill nets were 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, 4, and 5 to sample lacustrine and low-velocity riverine habitats. Experimental gill nets with 20-foot panels of 0.5, 1.0, 1.5, 2.0, and 2.5-inch mesh were also employed occasionally.

Trammel and gill 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 at least 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. Trammel and gill nets were cleaned by allowing them to dry on sand beaches, and brushing the mesh to dislodge the dried algae.

Seining

Seines were used in backwaters, tributaries, tributary mouths, along shorelines, and in shallow runs to sample small fish in these habitats. Three types of seines were used: 10 ft x 3 ft with 1/8 inch delta mesh, 30 ft x 4 ft with 1/4-inch delta mesh; and 30 ft x 5 ft with 1/4-inch delta mesh.

Trapping and Angling

Hoop nets with 3-foot diameter hoops were set overnight in side channels, backwaters, tributary mouths, and in the Lake Mead inflow region. 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 also checked about every 12 hours. Angling was used to capture large predators (i.e., game fish). Both artificial lures and hooks baited with red shiners were used.

Snorkeling

Snorkeling was conducted 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 fish without disturbing them.

Processing of Fish in the Field

All fish captured were held in live wells, and weighed and measured. Samples containing large numbers of individuals were subsampled, and only the first 100 individuals of a given species were weighed and measured, and the remained counted and released. Native and game species were measured by total length (TL) and standard length (SL), while all other species were measured by total length.

Native species greater than 150 mm TL were marked with PIT (Passive Integrated Transponder) tags, and released near the location of capture. PIT tags were injected into the peritoneal cavity with a sterile hypodermic needle designed for this purpose (Burdick et al. 1992).

MACROINVERTEBRATES

Benthic Macroinvertebrate Sampling

Benthic macroinvertebrates were sampled in the Colorado River and selected tributaries. Benthos were collected from rocky substrates in tributaries with Hess and Surber samplers, and an Ekman dredge was used in the mainstem where the substrate usually consisted of sand or silt. Although samples were collected in all tributaries, the majority were collected in Spencer Creek. In general, three samples were collected at each fish sampling site (multiple-pass) during Trips 5 through 7. In addition, sets of up to five Hess samples were taken at the Spencer Creek inflow during various trips.

Each invertebrate sample was placed in a labeled Ziploc bag or whirl-pack and preserved in 70 percent ethanol. All samples were returned to the laboratory where they are currently being sorted.

Drift Sampling

Drift was collected in the mainstem Colorado River at several camp sites. Samples were collected during the ascending and descending limbs of the hydrograph, as well as during steady flow to evaluate the influence of flow changes on drift. The metal-framed nets were attached to steel rods driven into the substrate. Nets were 10 ft long with an aperture area of 12 x 18 in and a mesh size of 560 μm. Screw-on PVC cups were attached to the end of the nets to facilitate removal of the sample. Samples were taken with two drift nets, one positioned on the water surface and the other in the water column (subsurface). Water velocity was measured at the mouth of each drift net with a Marsh-McBirney electronic current meter. Measurements were taken at the beginning and end of each sample and averaged to determine water velocity during the sampling interval. Each drift sample was placed in a labeled quart-sized plastic Ziploc bag and preserved in 90 percent ethanol. Drift samples were returned to the laboratory where they were sorted, dried, and analyzed.

WATER QUALITY PARAMETERS

Conductivity, water temperature, pH, and dissolved oxygen concentrations were measured in the mainstem Colorado River with a constant recording Hydrolab Surveyor II (Table A-2). The instrument was deployed at each camp site from the 33-foot S-rig support raft. Water quality parameters were measured over the entire period in which a particular camp was occupied. Turbidity was also measured from the support raft with a secchi disk (Table A-3). Finally, long-term variation in temperature was monitored at two locations in the Colorado River with thermographs (Ryan

TempMentor). In addition to field measurements, data from USGS records (Diamond Creek Gauge #XXX) were used to describe water quality conditions in the mainstem Colorado River, and evaluate the measurements made by the Hydrolab.

A Hydrolab Datasonde with datalogger was used in Spencer Creek to record conductivity, water temperature, pH, and dissolved oxygen concentration in this tributary. The unit was deployed in the inflow region, but placed far enough upstream so that measurements would not be influenced by mainstem dynamics. Long-term variation in temperature was also monitored in Spencer Creek with with a thermograph.

FLOW AND 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 related to a temporary bench mark (TBM) that will be surveyed later to determine actual elevation changes in river stage and river flow. A total of nine temporary bench marks were established during the course of the study (Table 3). Each TBM was designated by a 1-cm diameter dot of yellow enamel paint on a vertical rock face above the high water line. Descriptions and photographs of the TBMs were taken to allow reoccupation of these sites.

Flow measurements based on USGS records (Diamond Creek Gauge #XXX) were summarized for the entire two-year study period. In addition, magnitude and variation in flow were also described, in more detail, on a trip-by-trip basis. These records will eventually be compared to stage changes (as well as true altitude changes) to ascertain the relationship between releases from Glen Canyon Dam and magnitude of water level fluctuation in the lower Grand Canyon.

DISTRIBUTION OF FISH SAMPLING EFFORT

The majority of fish sampling in the mainstem Colorado River from Diamond Creek (RM 226) to below Pearce Ferry (RM 286) consisted of boat-electrofishing and trammel netting (Table 4). These two methods accounted for 30 and 53 percent of total effort, respectively. Although a range of complementary methods were employed on all trips, the frequency with which a particular sampling procedure was used varied among trips.

Sampling effort in the Colorado River also varied with river mile (Table 5). Sampling intensity was greatest in sample Stratum B (RM 240-250) and least in Stratum A. Sampling intensity in a given strata is a reflection of the amount of time spent in a section of river (Table 1). In general, more time was spent in the vicinity of tributaries (especially Spencer Creek). This allowed us to maximize our overall effort by sampling the mainstem during crepuscular periods and tributaries during the day.

Access to sampling locations from adjacent camp sites was restricted only from the Travertine Canyon site, because of the difficulty in up-running 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.

Sampling effort varied considerably among tributaries (Table 6). As mentioned previously, sampling effort was allocated primarily to larger tributaries, primarily Spencer and Surprise Creeks, with greater fisheries potential. Primary methods employed in tributaries were backpack electrofishing, seining, and minnow trapping. Tributary sampling increased over time as the focus of the study shifted from the mainstem to tributaries.

Sampling intensity in Lake Mead (below Emery Falls) also increased as the study progressed, with the maximum effort during Trip 4. Trammel and gill nets were the primary gear types used in the Lake, including 300 ft gill nets which were rarely used in the mainstem Colorado River.

DATA ANALYSIS

Fish Abundance

Catch-per-effort (CPE) statistics were developed to evaluate spatial variability (by river mile) in the abundance of flannelmouth sucker (Catostomus latipinnis), striped bass (Morone saxatilis), and channel catfish (Ictalurus punctatus) in the mainstem Colorado River. Because CPE values account for variation in sampling intensity, they more accurately reflect true patterns of fish distribution. We selected the three species listed above because of their importance (native and game species) and because their abundance was great enough to calculate meaningful CPE statistics. CPE statistics were derived for netting and boat electrofishing, the two primary sampling methods for the mainstem.

Catch-per-effort values were calculated for each sample (i.e., one trammel net set) and averaged for all samples by river mile. Results for netting are presented as number of fish/100 ft of net/100 hours of sampling, and for electrofishing results are presented as number of fish/10 hr of sampling.

Fish-population estimates for Spencer Creek were calculated with MicroFish 3.0 software (Van Deventer and Platts 1989). This program was designed to process electrofishing data obtained by the multiple-pass removal method. The program is based on a catch-per-effort removal model developed by Moran (1951) and Zippin (1956, 1958). The following assumptions are associated with this approach: effort is constant over the sampling period, the population is closed, probability of capture is equal for all individual fish and remains constant from sample to sample. We met the first two assumptions by applying relatively equal effort on each electrofishing pass and blocking the stream to prevent fish from moving in and out of the sample section. However, fish capture probability was at least partially a function of fish size.

Population estimate data were converted to density estimates (number/100 m^2) by dividing fish numbers by the area sampled. This probably provides the most meaningful value upon which to base seasonal and spatial comparisons in Spencer Creek.

<u>Macroinvertebrates</u>

Drift density was calculated for each set of samples with the following formula:

$$\text{sample drift density} = \frac{\text{number per net-hour}}{m^3 \text{ filtered per net-hour}} \times 100$$

as described by Allan and Russek (1985). Drift density estimates were then averaged and categorized according to whether samples were collected during rising, falling, or steady flow. Data were also partitioned by surface and subsurface drift categories.

Benthic invertebrate density (number/m^2) is currently being calculated. However, these data are currently incomplete and will be provided at a later date. Benthic densities will be evaluated on a seasonal and spatial basis, with emphasis on Spencer Creek.

RESULTS

FISH POPULATIONS

<u>Fish Species Composition And Relative Abundance</u>

A total of 19 different fish species representing 10 families were captured in Reach 4 over the period of the study (Table 7). Native fish species were quite uncommon, representing only about seven percent of the total catch. The only endangered species encountered over the duration of the study was a single humpback chub captured during Trip 6 at RM 253.2. Other native species captured during the study include flannelmouth sucker, bluehead sucker, and speckled dace; speckled dace is the only native species that could be considered common in the study reach.

The 161 flannelmouth suckers captured included 24 (15%) young-of-year (YOY), 106 (66%) juveniles, and 31 (19%) adults (Table A-4). Most (>99%) speckled dace were adults; only two YOY individuals were captured. Both the humpback chub (329 mm) and bluehead sucker (249 mm) were adults. During the entire study only one PIT-tagged fish, a flannelmouth sucker, was recaptured (Table 8). This individual was recaptured at the location (RM 230.7) where it was originally marked, suggesting that it remained in the same section of river for at least two months. According to length and weight measurements, this flannelmouth sucker had increased in length (3 mm) and weight (24 g) from October to December.

Nonnative species accounted for more than 90 percent of the fish collected during the study (Table 7). The most abundant species in the Reach 4 was red shiner (61%) followed by fathead minnow (19%). Common carp, channel catfish, and striped bass were the predominant large species captured throughout the reach. All life-stages of common carp were encountered but the majority (84%) were adults; 103 (9%) YOY and 86 (7%) juveniles were collected. The majority of striped bass (96%) and all but one channel catfish were adults.

Striped bass, found in the mainstem during June, 1992 were primarily small males with pink, maturing gonadal sacs, indicating the fish were 2 to 3 weeks from spawning. During Trip 5 a large number of carp were in spawning condition, especially those captured in Spencer Creek. Red shiner were also apparently spawning in tributaries at this time. 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, because this species of cestode is generally specific to members of the family Cyprinidae.

Fish Species Distribution

Mainstem Colorado River: Reach 4

Fish abundance and species composition varied throughout Reach 4 (Table 9). Total number captured was greatest in substrata 5 (245-249.9) and 9 (265-269.9). In both cases red shiner accounted for more than half of the fish captured. The presence of a number of tributaries in substratum 5 likely accounts for red shiner abundance. It is less apparent why red shiner abundance was high in substratum 9. The large number of fish in substratum 5 is also an artifact of the high sampling intensity associated with this section of river.

Only three species (flannelmouth sucker, channel catfish, and carp) were found in all sampling substrata. As expected, the abundance of lentic species, primarily centrarchids and threadfin shad, increased with proximity to Lake Mead. Although red shiners dominated the mainstem ichthyofauna, they were found only downstream of Bridge Canyon Rapid (RM 235.2) during this investigation. From that point downstream red shiner accounted for 54 percent of fish captured in the mainstem. The same pattern was observed for fathead minnow. Only native species (flannelmouth sucker, bluehead sucker, speckled dace) or large, highly mobile species (striped bass, channel catfish, common carp) were captured above Bridge Canyon Rapid.

Catch-per-effort calculations based on netting and electrofishing suggest that channel catfish abundance decreased with proximity to Lake Mead (Figures 3, 4). This pattern is due mostly to the large number of this species captured during May-June, 1993 (Trip 5) (Table 7). On subsequent trips many fewer catfish were encountered. We are uncertain whether these catfish had migrated upstream from Lake Mead, or if changes in habitat use made them more susceptible to sampling gear at that time. If the former is true, CPE calculations may only describe mainstem conditions during part of the year. Catch-per-effort calculations for striped bass indicate the opposite pattern: striped bass abundance is greater near the lake. Because this species originates in Lake Mead these results are intuitively reasonable. The CPE statistics for electrofishing also suggest that flannelmouth sucker abundance declined with increasing distance downstream. However, netting results show that this species was still relatively abundant at river miles 259 and 274.

Comparison Of Reaches 3 and 4

The ichthyofauna above Diamond Creek was quite different from that in Reach 4 (Table 10). Total catch above Diamond Creek was much lower than downstream during 1992 through 1993. Because effort was comparable Reach 3 and 4, fish abundance appears to be considerably lower upstream of Diamond Creek.

Native species accounted for a much larger proportion of the fish community upstream of Diamond Creek; native species account for 61 and 7 percent of the total catch above and below Diamond Creek, respectively. Flannelmouth sucker and speckled dace were considerably less abundant in the main channel below Diamond Creek, and bluehead sucker that occur continuously from National Canyon to Diamond Creek, were nearly absent (1 captured) in Reach 4.

The majority of the observed difference in fish abundance between Reach 3 and 4 is due to increased occurrence of red shiner, carp, and channel catfish starting at Bridge Canyon Rapid. In addition, lentic fish species (i.e., centrarchids, mosquitofish, threadfin shad) that occur below Bridge Canyon, especially near Lake Mead, are not present in Reach 3.

Tributaries

Fish abundance and species composition varied greatly among tributaries (Table 11). In tributaries above Bridge Canyon Rapid (RM 235.2) only speckled dace were collected. However, in the remaining tributaries nonnative species dominated the ichthyofauna. In Spencer Creek, red shiner accounted for more than two thirds of the fish captured. However, native species were also relatively abundant; 904 speckled dace and 72 flannelmouth sucker were captured over the duration of the study. Surprise Creek was much more heavily dominated by nonnative species than Spencer

Creek; red shiner and fathead minnow accounted for 98 percent of the fish captured. Much of the observed difference in fish species composition is a reflection of habitat differences between these two streams. Spencer Creek is a high-gradient, riffle-dominated system that is ideal for speckled dace. In contrast, Surprise Creek (at least near the inflow) is constituted by large slow pools interspersed with small runs. Habitat conditions in this stream may favor the introduced species. No native species were encountered in Lost Creek or Quartermaster Canyon. Red shiner, carp, and mosquitofish were the predominant species in these streams. The presence of mosquitofish, carp, and largemouth bass all indicate that these streams are slow-flowing and characterized by more lentic conditions.

It appears that fish abundance in Spencer Creek, and to a lesser extent Surprise Creek, increased over the period of the study. There were some changes in fish species composition and abundance, but much of the apparent increase is the result of greater sampling effort on later trips.

In general, fish encountered in tributaries were small relative to members of the same species captured in the mainstem. Table 12 provides a comparison of average lengths of flannelmouth sucker, channel catfish, common carp, and striped bass. In general, mean length of catfish and striped bass captured in tributaries was less than in the mainstem. Mean length of flannelmouth sucker was consistently lower in tributaries than in the mainstem; this species apparently uses Spencer and Surprise Creeks for spawning and rearing. In contrast, average length of common carp was often greater in tributaries. However, average length values from tributaries are often based on small sample sizes and may not accurately reflect true differences.

Population Estimates

Results of population estimates conducted in Spencer Creek show that fish density and species composition varied considerably among sampling trips (Figure 5). At Site 1 (immediately above the inflow), the density of red shiner and speckled dace increased greatly from May to October. In December the density of red shiner was still high, although speckled dace were less common. Fathead minnow were present for the first time in December. In contrast, common carp, channel catfish, and flannelmouth sucker were captured in May but not in October and December (flannelmouth sucker were captured by seining in the Spencer Creek inflow region in October). A more detailed breakdown of population estimate results is contained in Tables A-5a through A-5e.

At the upstream site (Site 2-0.75 mi upstream) population estimates were conducted in October and December (Figure 5). Results were similar to those derived at Site 1; fish abundance was high in October and declined slightly by December. However, actual fish densities were greater at the upstream site. Flannelmouth sucker and fathead minnow, not encountered at Site 1 during October, were present upstream. Although no population estimate was conducted at Site 2 during May, a single electrofishing pass produced common carp, and a large number of channel catfish. In addition, red shiner and speckled dace abundance were much lower in May than during subsequent months. Overall, similar trends in fish abundance and species composition were observed at both Sites 1 and 2.

The observed changes in the ichthyofauna of Spencer Creek were probably related to a number of factors. Changes in the abundance of larger species like common carp and channel catfish were probably behavioral, whereas changes in the density of smaller species (likely residents) may have been the result of physical disturbance.

High density of common carp during May was likely the result of seasonal migration patterns. Most carp collected in Spencer Creek were ripe adults, and may have moved into the tributary to spawn. By the October trip these fish had completed spawning and moved out of Spencer Creek. Channel catfish abundance was high throughout the mainstem as well as Spencer Creek during May. The absence of these fish during subsequent trips also suggests a migratory pattern. However, catfish collected were not in apparent spawning condition.

Changes in the abundance of smaller species may have been related to flash-flood activity that occurred in winter of 1992. Flooding intensity was so great that the majority of riparian vegetation in the inflow region was uprooted and the stream channel was reconfigured. Observations of channel conditions in late May and June still indicated that the streambed was unstable: bedload was excessive and very little algae was present on rocks. Flooding may have displaced smaller species into the mainstem (smaller species were relatively uncommon in May). However, as time passed and the stream channel stabilized, these species may have been able to recolonize the stream.

There was an inverse relationship between the abundance of small and large species. However, it is unlikely that the presence of the large fish was responsible for the absence of the smaller species. Although the larger fish, primarily channel catfish, were undoubtedly preying on the smaller species, predator load was probably not sufficient to reduce the number of small fish to the extent observed. This is especially true because of the abundant instream cover available to small fish in Spencer Creek.

Spatial variation in Spencer Creek indicates that nonnative fish may have had difficulty migrating past high velocity areas in the stream. Figure 6 shows fish species composition as a function of distance from the mainstem Colorado River. Species composition at the inflow and 0.75 miles upstream are from the population estimates conducted at Sites 1 and 2 in December. The data shown for further upstream (>1.25 mi) are the result of backpack electrofishing and seining conducted during October and December.

Although nonnative species were common in lower Spencer Creek, only speckled dace were found further upstream. The lack of nonnative species upstream appears to be the result of a migration barrier. The potential barrier consists of a deep, high-velocity (>6.0 ft/s) chute formed where a large boulder has fallen into the channel and formed a constriction.

Efficiency Of Sampling Gear

Boat-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 (Table A-4). Boat-electrofishing was also effective at capturing small fishes such as red shiners, fathead minnows, and mosquitofish occupying the river margins. 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 seining, backpack shocking, and minnow literaturetrapping were all effective in tributaries. Angling with live bait proved to be an effective method for catching striped bass and channel catfish in the mainstem.

MACROINVERTEBRATE DRIFT

Invertebrates found in the drift belonged to two classes: Insecta and Crustacea (Table 13). The predominant insects were chironomids and simuliids, although other aquatic forms did comprise a large portion of the drift during some months. The amphipod (Crustacea), Gammarus lacustris, which is very common further upriver (especially near Glen Canyon Dam) accounted for only a small proportion of the drift during all seasons. The relative abundance of terrestrial insects varied considerably from season to season.

Total drift density varied among sampling trips, but no strong seasonal pattern was apparent based on our results. During 1992, it appeared that drift was greatest during early summer and lowest during winter. However, total drift density was quite high in December, 1993. Only the pattern observed in 1992 is typical for temperate North America: as immature aquatic insects develop and approach emergence drift density increases. As expected, terrestrial invertebrates were abundant in the warmer months and uncommon during winter.

The discrepancy between drift patterns in the Grand Canyon and those usually observed in temperate streams and rivers may be linked to invertebrate species composition. In most lotic systems a large number of the taxa are univoltine (one generation per year). In contrast, a large portion of the invertebrates in the mainstem Colorado River are polyvoltine (mainly Chironomidae) and undergo complete life-cycles a number of times during the year. During December of 1993, sampling may have intercepted a short-term burst in drift density associated with a particular generation of chironomids. On the other hand, our results are based on relatively few samples that may not have been sufficient to accurately characterize seasonal changes in drift.

During May and June of 1993 drift density was much greater in Spencer Creek than in the mainstem (Table 13). No Gammarus were found and terrestrial insects represented a much smaller proportion of the total drift. In general, drift density values observed in the mainstem are low in comparison to reported values for streams and rivers in temperate North America, whereas observed density in Spencer Creek is high (Table 14). The abundance of invertebrate prey in Spencer Creek (and undoubtedly in other tributaries) is probably one of the main factors accounting for the high densities of fish observed in these streams.

Average values of subsurface drift density indicate that drift was greatest when flow was decreasing and lowest when river stage was increasing (Table 15). Drift densities associated with steady flow were intermediate between those associated with changing river level. The same pattern was observed for surface samples. In addition, average values of subsurface drift always exceeded those of surface drift.

Research has shown that an initial pulse in drift density results from both flow increases (catastrophic drift) and flow decreases (behavioral drift) (e.g., White and Wade 1980; Irvine 1985). However, after the initial change drift density is inversely related to flow; increased flow dilutes the drift produced by the benthic community. This relationship may explain the low drift density associated with higher flow in the mainstem Colorado River. However, based on the small number of samples that we collected, it is difficult to know whether or not we have accurately characterized the relationship of drift to flow change.

WATER QUALITY

Mainstem Colorado River

Turbidity was relatively high in the mainstem throughout the study period. Secchi disk measurements ranged from X in Y to X in Y with an average value of X.

(We can complete this section when we get our information from Craig).

Tributaries

The continuous recording Datasonde in Spencer Creek revealed strong diel pulses in temperature and dissolved oxygen for June 26-28 (Figure 7a) and September 30 - October 3 (Figure 7b). 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 1500 hr, and lowest readings about 0700 hr. Diel water temperature in September-October varied from about 20.5°C at 0700 hr to about 26.5°C at 1600 hr, 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 (Figure 7c). Highest readings were observed about 1600 hr, and lowest readings occurred between midnight and 2100 hr.

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.

RIVER STAGE AND FLOW

(We can relate stage to flow after we get information from Craig regarding mainstem flows).

Changes in river stage were monitored and recorded at the following six general locations in the mainstem during this study: Travertine Falls (RM 229.0-230.5), Bridge Canyon (RM 234.9-235.2), Above Spencer Creek (Rm 242.3-242.8), Burnt Spring (259.3), at the location where the humpback chub was captured (RM 253.2), Spencer Creek (RM 245.4-246.0), Lost Creek (RM 249.7), and Quartermaster Canyon (RM 259.8-262.0) (Figure 8). Maximum recorded stage change was about 90 cm recorded near Spencer Creek from 2 to 4 October, 1993. This change in stage occurred over a 48-hour period. Average stage change at most other locations was about 40-60 cm, and occurred over a shorter interval. However, at downstream locations (i.e., Burnt Spring and Quartermaster Canyon) average stage change was about 20-30 cm. The effect of changes in flow was apparently ameliorated to some degree by the presence of Lake Mead in these downstream locations (> RM 259.0).

DISCUSSION

*****NOTE: UPDATED DISCUSSION TO BE PROVIDED LATER

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.

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 and 90 cm (3 feet) in 1993 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 1992 and 1993 confirmed this longitudinal warming effect by recording 17 C near Diamond Creek.

The following is a discussion of findings in 1993 relative to each of the five study objectives, and integrated with 1992 results.

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, AND 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.

LITERATURE CITED

Allan, J.D., and E. Russek. 1985. The quantification of stream drift. Canadian Journal of Fisheries and Aquatic Sciences 42:210-215.

Angradi, T.R., R.W. Clarkson, D.A. Kinsloving, D.M. Kubly and S.A. Morgensen. 1992. Glen Canyon Dam and the Colorado River: responses of the aquatic biota to dam operations. Prepared for the Bureau of Reclamation, Upper Colorado Region, Glen Canyon Environmental Studies, Flagstaff, AZ. Cooperative Agreement No. 9-FC-40-07940. Arizona Game and Fish Department, Phoenix, AZ. 155 pages.

Armitage, P. D. 1977. Invertebrate drift in the regulated River Tees, and an unregulated tributary Maize Beck, below Cow Green dam. Freshwater Biology 7:167-183.

Brooker, M.P., and R.J. Hemsworth. 1978. The effect of the release of an artificial discharge of water on invertebrate drift in the River Wye, Wales. Hydrobiologia 59:155-163.

Carothers, S.W. and C.O. Minckley. 1978. A survey of the fishes, aquatic invertebrates, and aquatic plants of the Colorado River and selected tributaries from Lee's Ferry (Mile 0) to Separation Rapids (Mile 240). Quarterly progress report submitted to the U.S. Bureau of Reclamation by the Museum of Northern Arizona, Contract No. 7-07-30-Z0026.

Cowell, B. C., and W. C. Carew. 1976. Seasonal and diel periodicity in the drift of aquatic insects in a subtropical Florida stream. Freshwater Biology 6:587-594.

Eckblad, J. W., C. S. Volden, and L. S. Weilgart. 1984. Allochthonous drift from backwaters to the main channel of the Mississippi River. The American Midland Naturalist 111:16-22.

Irvine, J. R. 1985. Effects of successive flow perturbations on stream invertebrates. Canadian Journal of Fisheries and Aquatic Sciences 42:1922-1927.

LaPerriere, J. D. 1983. Alkalinity, discharge, average velocity, and invertebrate drift concentration in subarctic Alaskan streams. Journal of Freshwater Ecology 2:141-151.

McCall, T. 1979. Fishery investigation of Lake Mead, Arizona-Nevada, from Separation Rapids to Boulder Canyon, 1978-79. Final Report to U.S. Department of Interior, Water and Power Resources Service, Contract No. 8-07-30-X0025. Arizona Game and Fish Department, Kingman, AZ. 197 pp.

Minshall, G.W., and P.V. Winger. 1968. The effect of reduction in stream flow on invertebrate drift. Ecology 49:580-582.

Moran, P.A.P. 1951. A mathematics theory of animal trapping. Biometrika 38:307-311.

Perry, S. A., and W. B. Perry. 1986. Effects of experimental flow regulation on invertebrate drift and stranding in the Flathead and Kootenai Rivers, Montana, USA. Hydrobiologia 134:171-182.

Stoneburner, and L. A. Smock. 1979. Seasonal fluctuations of macroinvertebrate drift in a South Carolina piedmont stream. Hydrobiologia 63:49-56.

Valdez, R.A., W.J. Masslich, W.C. Leibfried. 1991. Characterization of the life history and ecology of the humpback chub (Gila cypha) in the Grand Canyon. Annual report to Bureau of Reclamation, Contract No. 0-CS-40-09110. BIO/WEST Report No. TR-250-02. 74 pp.

Valdez, R.A., W.J. Masslich, W.C. Leibfried. 1992. Characterization of the life history and ecology of the humpback chub (Gila cypha) in the Grand Canyon. Annual report to Bureau of Reclamation, Contract No. 0-CS-40-09110. BIO/WEST Report No. TR-250-04. 222 pp.

White, R. G., and D. T. Wade. 1980. A study of fish and aquatic macroinvertebrate fauna in the South Fork Boise River below Anderson Ranch Dam with emphasis on effects of fluctuating flows. College of Forestry, Wildlife, and Range Sciences, University of Idaho, Technical Completion Report 14-06-100-9220, Moscow.

U.S. Department of Interior. 1988. Glen Canyon Environmental Studies Final Report. Bureau of Reclamation, Upper Colorado Region, Salt Lake City, 84 pp + Appendices (NTIS No. PB88-183348/AS).

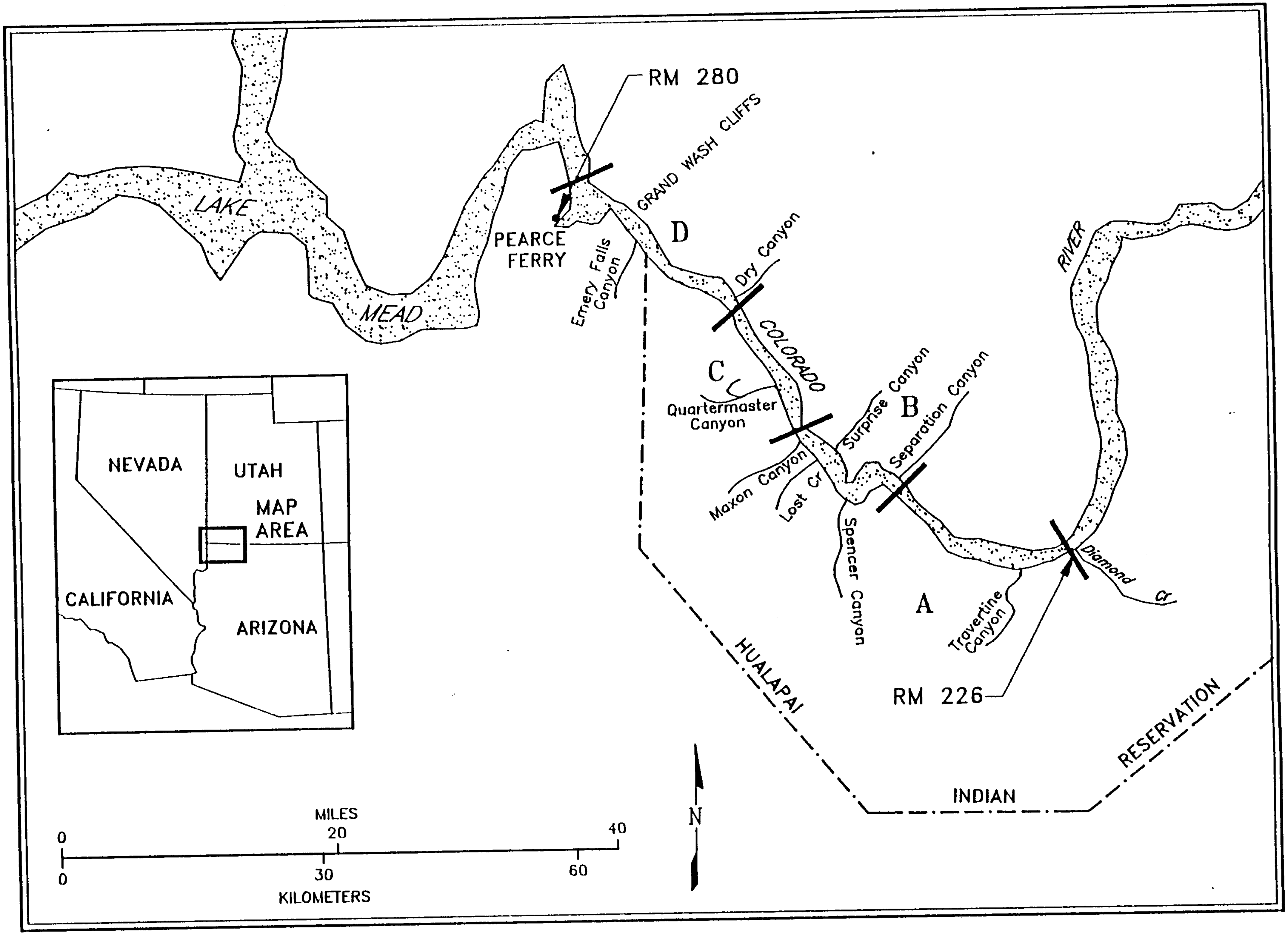
Van Deventer, J.S., and W.S. Platts. 1989. Microcomputer software system for generating population statistics from electrofishing data-user's guide for Microfish 3.0. General Technical Report INT-254, USDA Forest Service, Intermountain Research Station, Ogden, Utah.

Zimmer, D. W. 1976. Observations of invertebrate drift in the Skunk River, Iowa. Proceedings of the Iowa Academy of Science 82:175-178.

Zippin, C. 1956. An evaluation of the removal method of estimating animal populations. Biometrics 12:163-189.

Zippin, C. 1958. The removal method of population estimation. Journal of Wildlife Management 22:82-90.

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



RM 280
GRAND WASH CLIFFS
LAKE
MEAD
PEARCE FERRY
Emery Falls Canyon
D
Dry Canyon
COLORADO
RIVER
C
Quartermaster Canyon
Surprise Canyon
B
Separation Canyon
Maxon Canyon
Lost Cr
Spencer Canyon
A
Travertine Canyon
Diamond Cr
RM 226
HUALAPAI
INDIAN
RESERVATION
N
NEVADA
UTAH
MAP AREA
CALIFORNIA
ARIZONA
MILES
0
20
40
0
30
60
KILOMETERS

Figure 2. Cross-section of study reach 4 of the Colorado River from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992-1993.

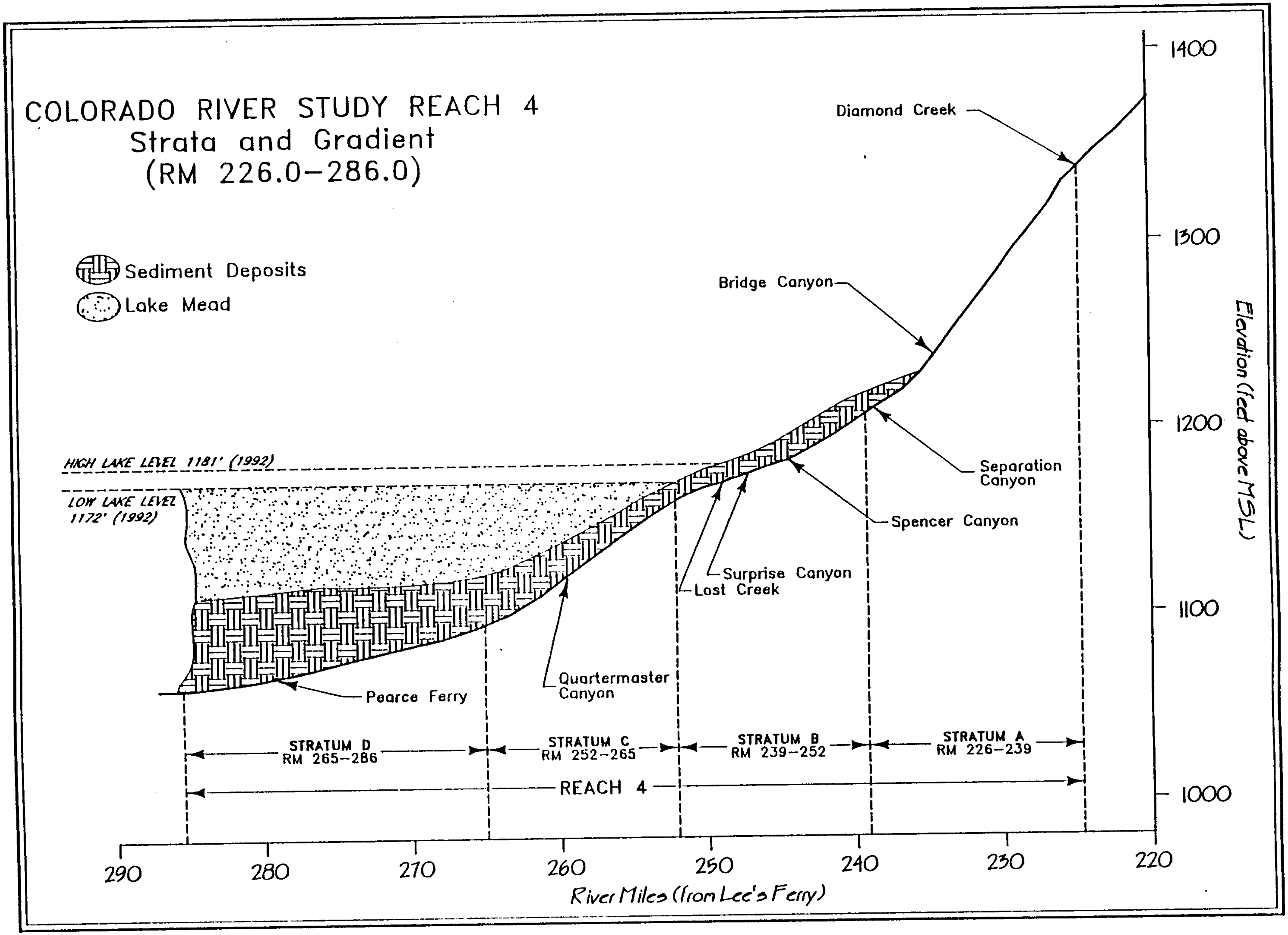
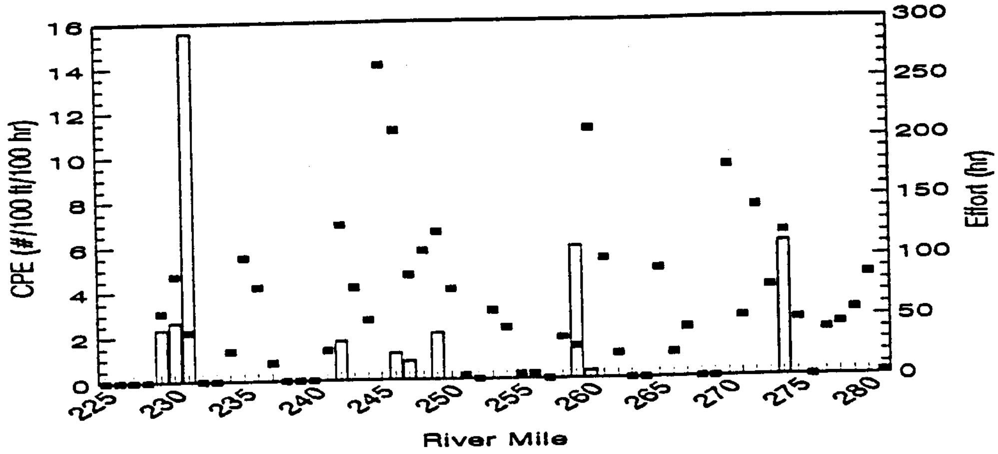
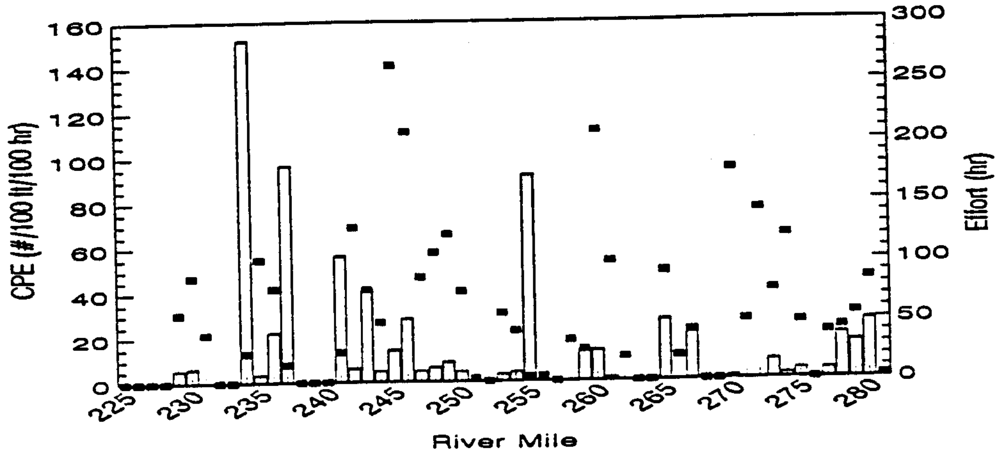

COLORADO RIVER STUDY REACH 4
Strata and Gradient
(RM 226.0–286.0)
Sediment Deposits
Lake Mead
Diamond Creek
Bridge Canyon
Separation Canyon
Spencer Canyon
Surprise Canyon
Lost Creek
Quartermaster Canyon
Pearce Ferry
HIGH LAKE LEVEL 1181' (1992)
LOW LAKE LEVEL 1172' (1992)
STRATUM D RM 265–286
STRATUM C RM 252–265
STRATUM B RM 239–252
STRATUM A RM 226–239
REACH 4
1400
1300
1200
1100
1000
Elevation (feet above MSL)
290
280
270
260
250
240
230
220
River Miles (from Lee's Ferry)

Figure 3. Catch-per-effort (total netting) for flannelmouth sucker (top), channel catfish (middle), and striped bass (bottom) from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992-1993. Bars represent CPE and points represent effort.


CPE (#/100 ft/100 hr)
Effort (hr)
River Mile


CPE (#/100 ft/100 hr)
Effort (hr)
River Mile

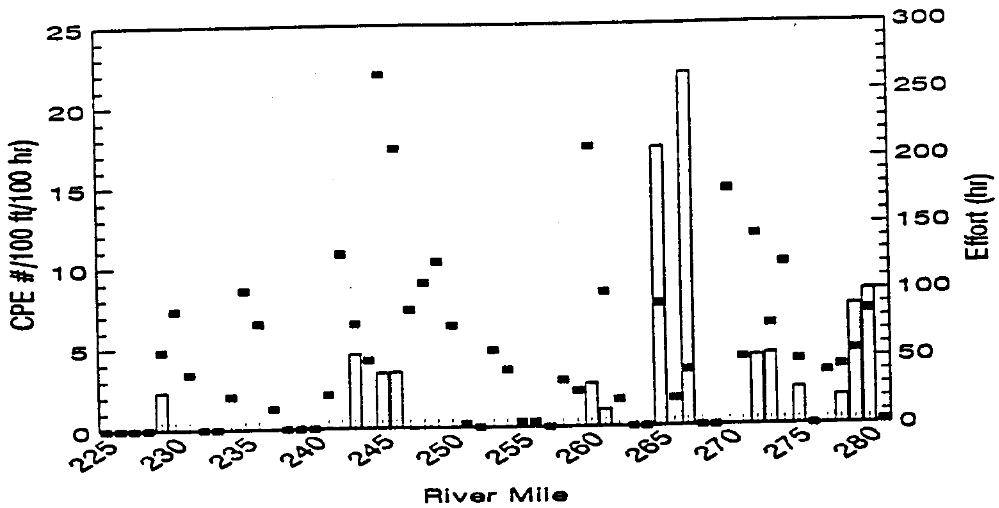
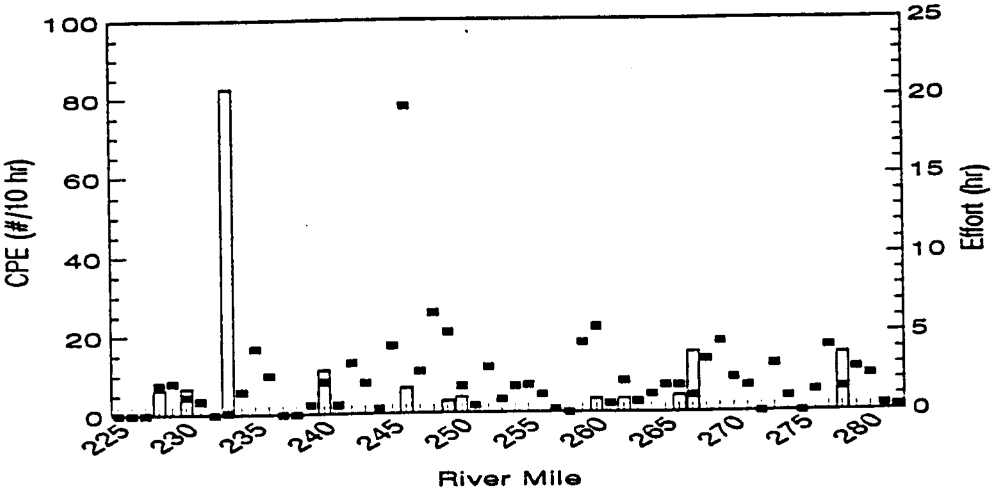
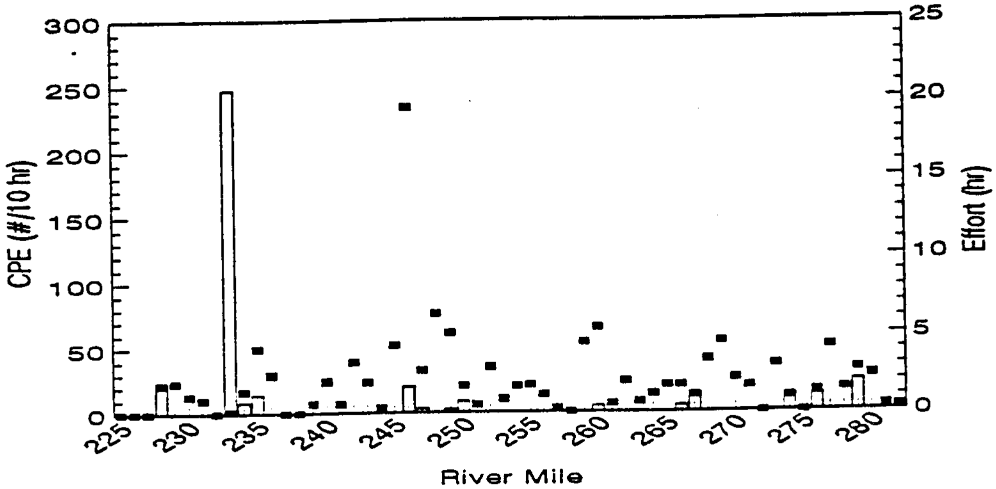

CPE #/100 ft/100 hr)
Effort (hr)
River Mile

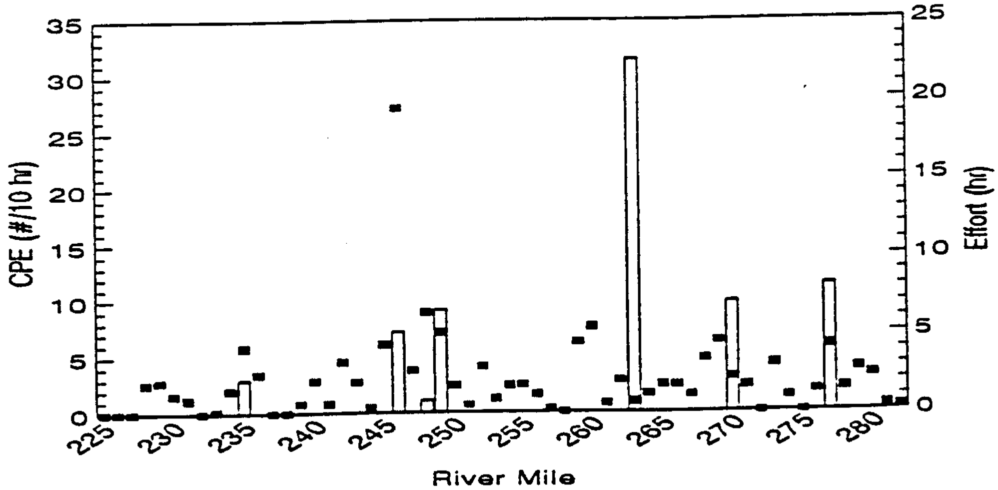
Figure 4. Catch-per-effort (electrofishing) for flannelmouth sucker (top), channel catfish (middle), and striped bass (bottom) from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992-1993. Bars represent CPE and points represent effort.



CPE (#/10 hr)
Effort (hr)
River Mile

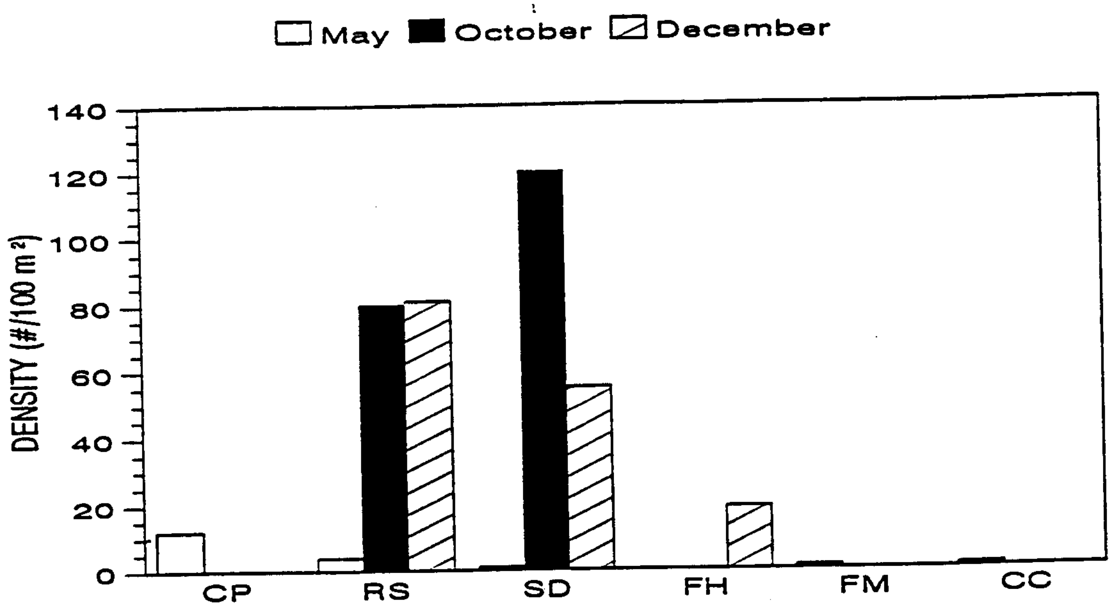


CPE (#/10 hr)
Effort (hr)
River Mile



CPE (#/10 hr)
Effort (hr)
River Mile

Figure 5. Fish density estimates for Site 1 (top) and Site 2 (bottom) in Spencer Creek, 1993.


May
October
December
140
120
100
80
60
40
20
0
DENSITY (#/100 m²)
CP
RS
SD
FH
FM
CC

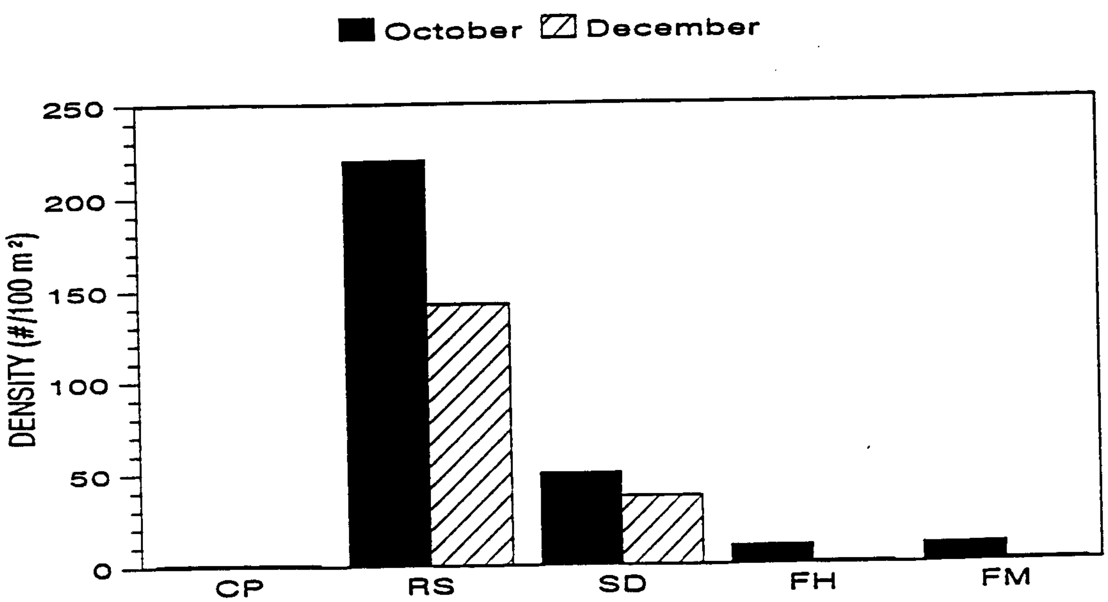

October
December
250
200
150
100
50
0
DENSITY (#/100 m²)
CP
RS
SD
FH
FM

Figure 6. Percent composition of fish community at three locations in Spencer Creek. Results are based on results of population estimates conducted at Sites 1 (inflow) and 2 (0.75 mi) and seining conducted upstream from these sites (>1.25 mi).

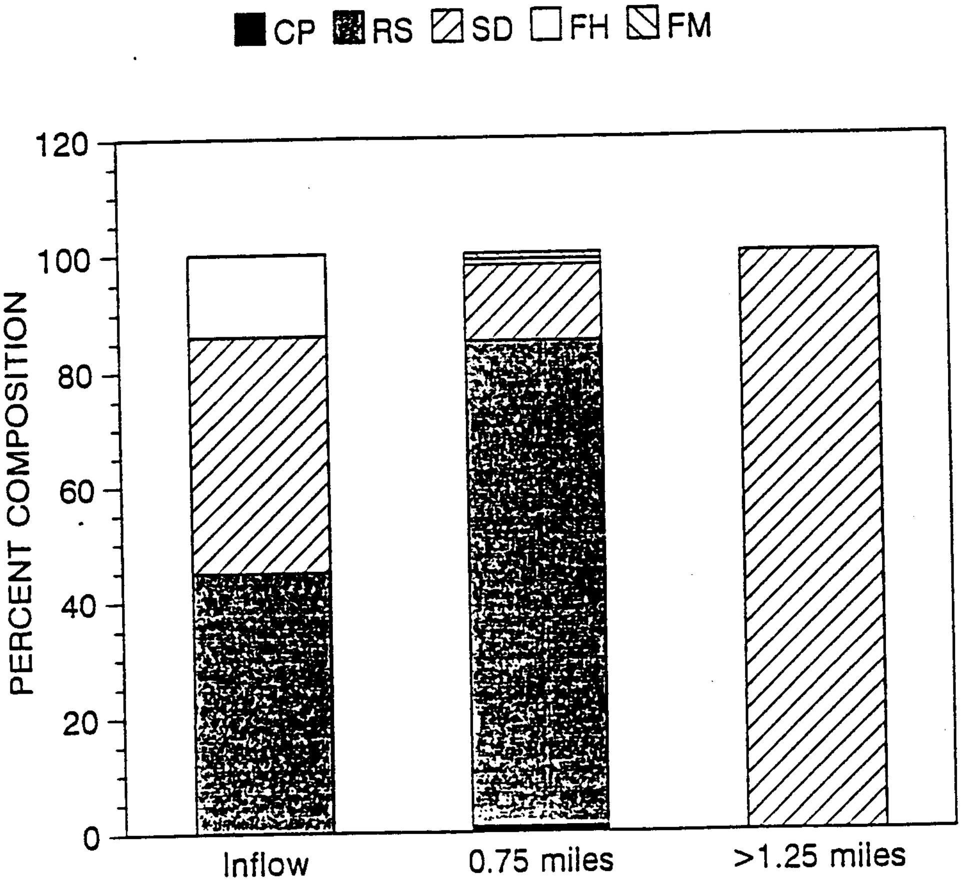
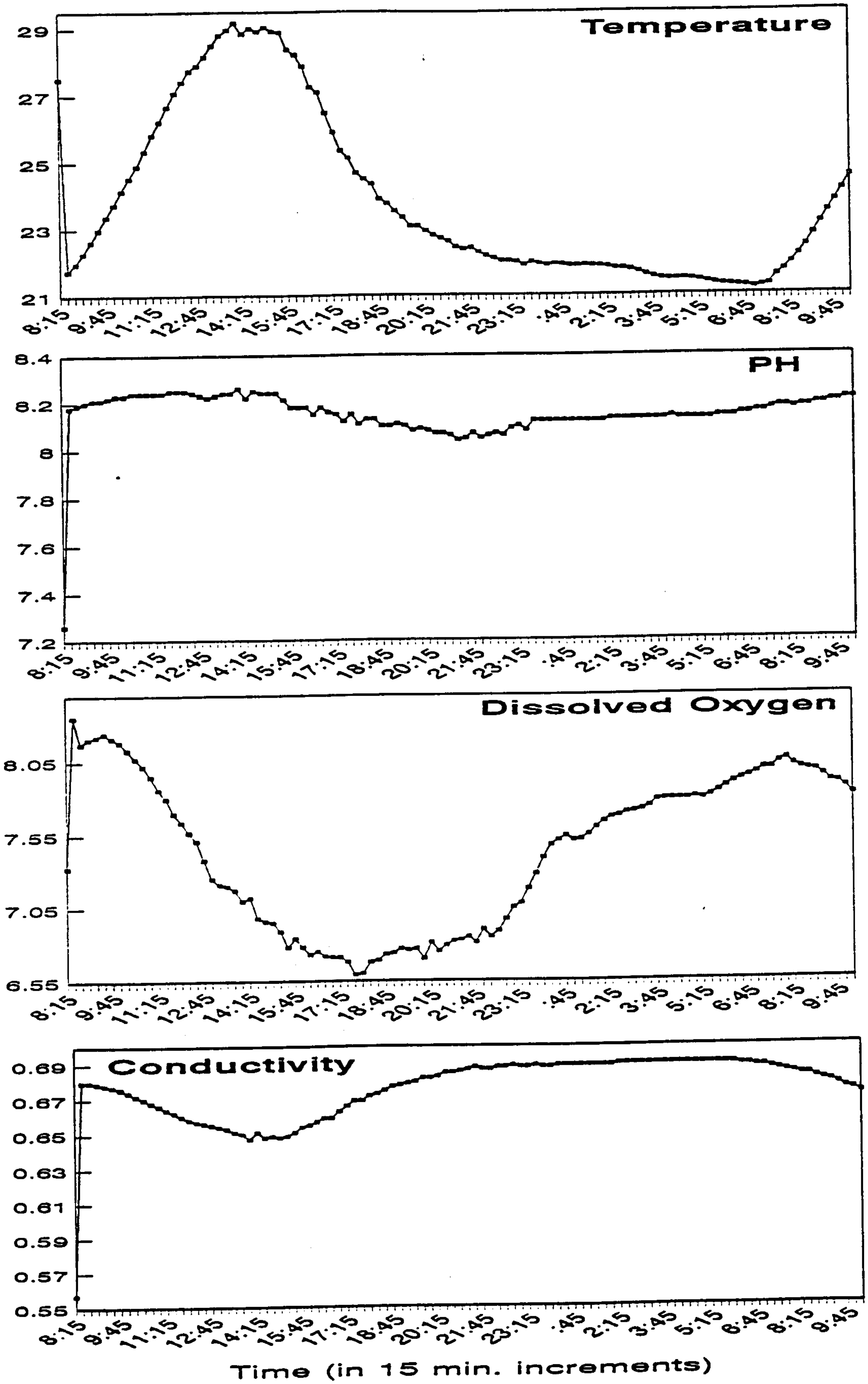
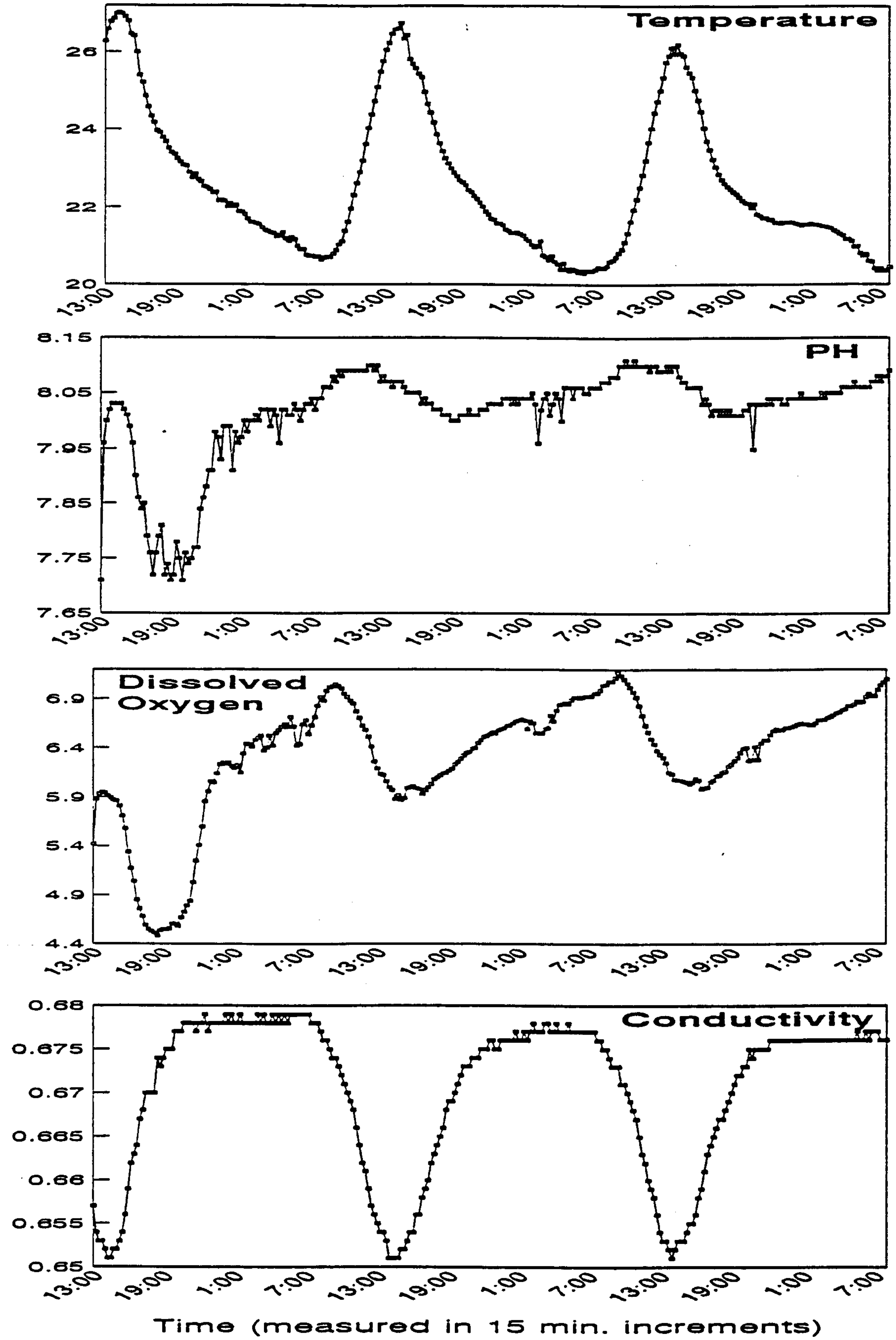

CP
RS
SD
FH
FM
PERCENT COMPOSITION
120
100
80
60
40
20
0
Inflow
0.75 miles
>1.25 miles

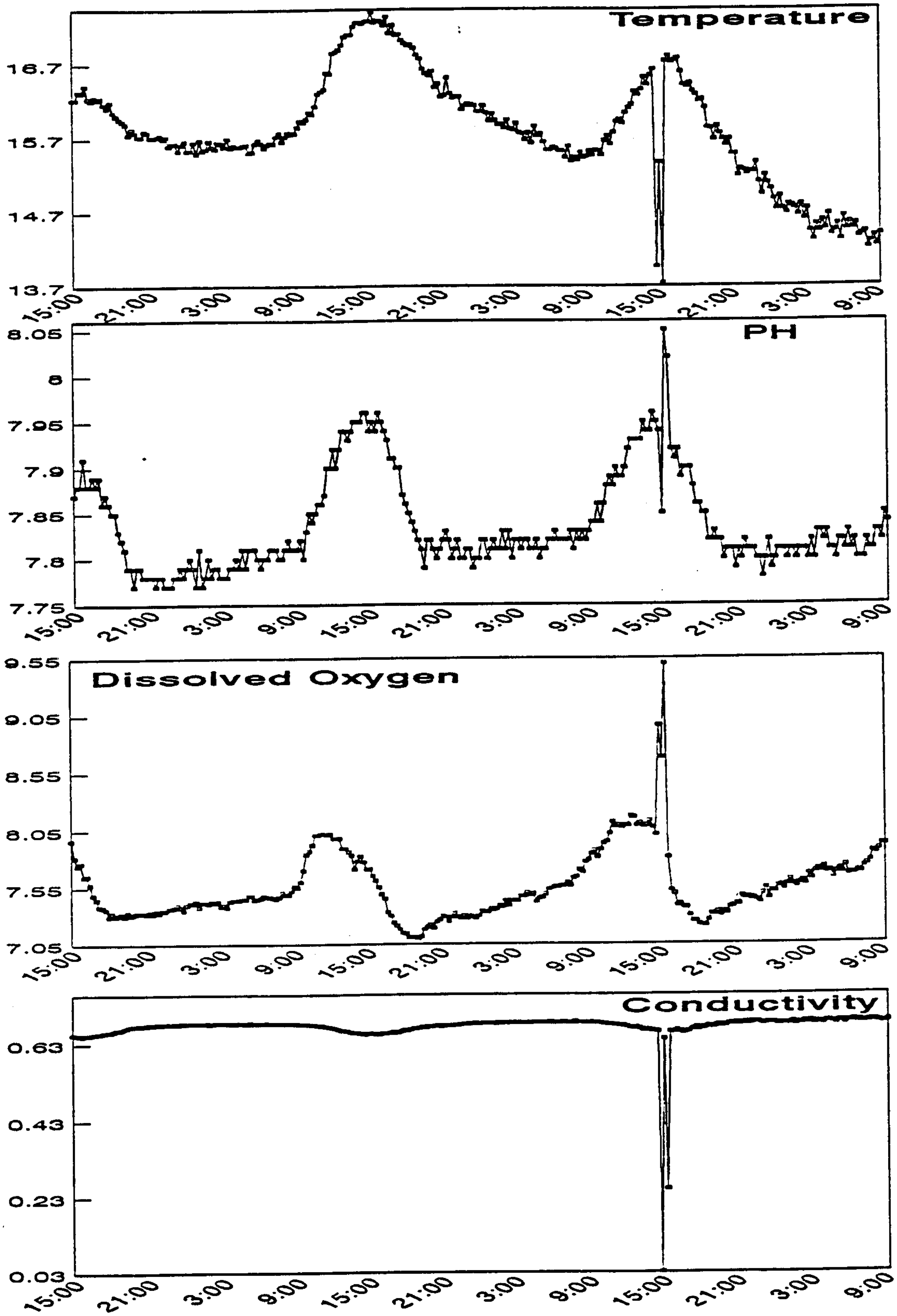
Figure 7a. Water quality parameters from Spencer Creek recorded with a Hydrolab Datasonde on 26-28 June (0815-1015 hrs), 1992.

Figure 7b. Water quality parameters from Spencer Creek recorded with a Hydrolab Datasonde on 30 September-3 October (1300-0700 hrs), 1992.

Figure 7c. Water quality parameters from Spencer Creek recorded with a Hydrolab Datasonde on 3-6 December (1500-0900 hrs), 1992.

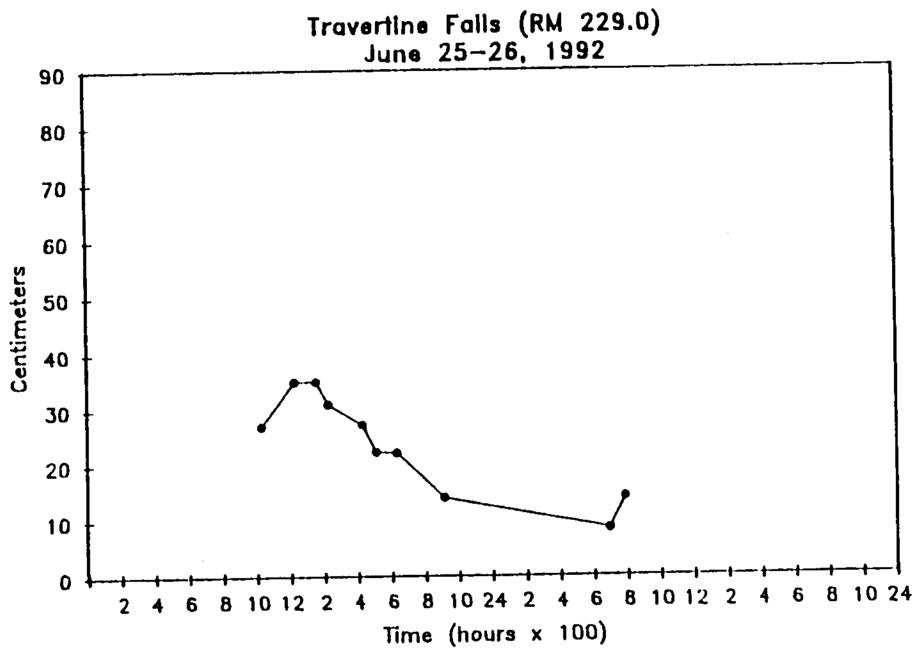

Temperature
29
27
25
23
21
PH
8.4
8.2
8
7.8
7.6
7.4
7.2
Dissolved Oxygen
8.05
7.55
7.05
6.55
Conductivity
0.69
0.67
0.65
0.63
0.61
0.59
0.57
0.55
8:15 9:45 11:15 12:45 14:15 15:45 17:15 18:45 20:15 21:45 23:15 :45 2:15 3:45 5:15 6:45 8:15 9:45
Time (in 15 min. increments)

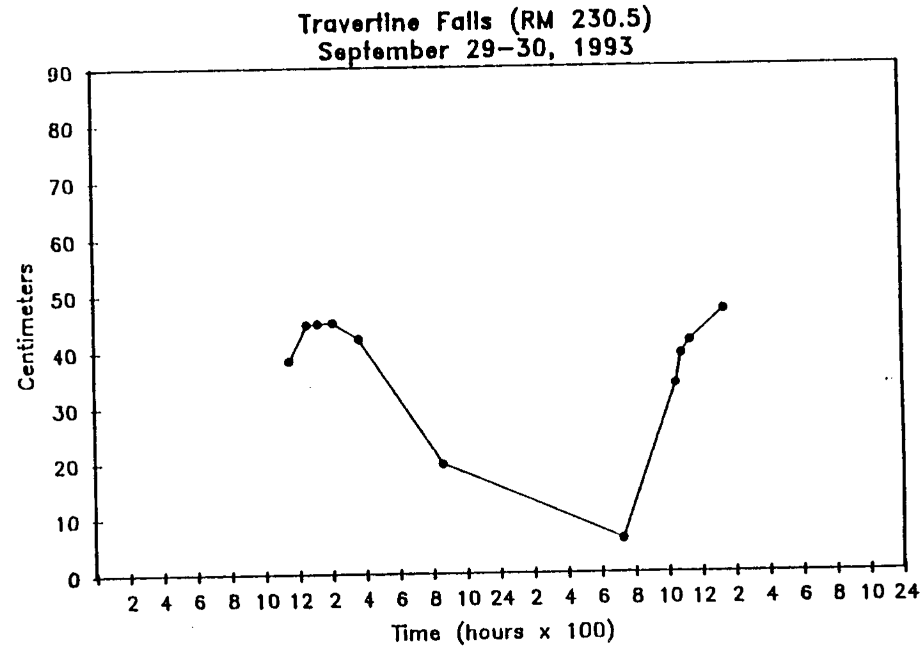

Temperature
26
24
22
20
PH
8.15
8.05
7.95
7.85
7.75
7.65
Dissolved Oxygen
6.9
6.4
5.9
5.4
4.9
4.4
Conductivity
0.68
0.675
0.67
0.665
0.66
0.655
0.65
13:00
19:00
1:00
7:00
13:00
19:00
1:00
7:00
13:00
19:00
1:00
7:00
Time (measured in 15 min. increments)



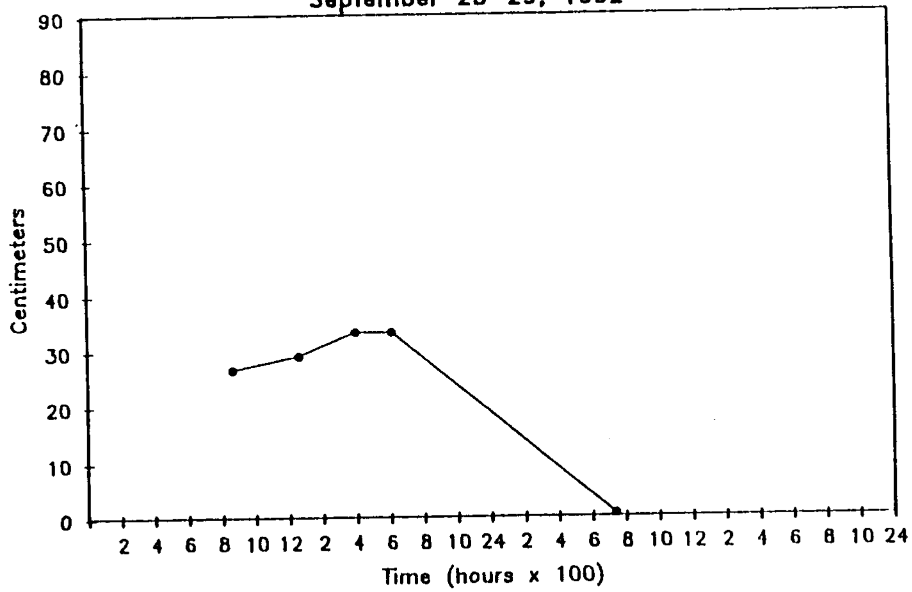
Time (measured in 15 min. increments)

Figure 8a-8e. Relative changes in river stage recorded at various locations in the mainstem Colorado River during 1992-1993.

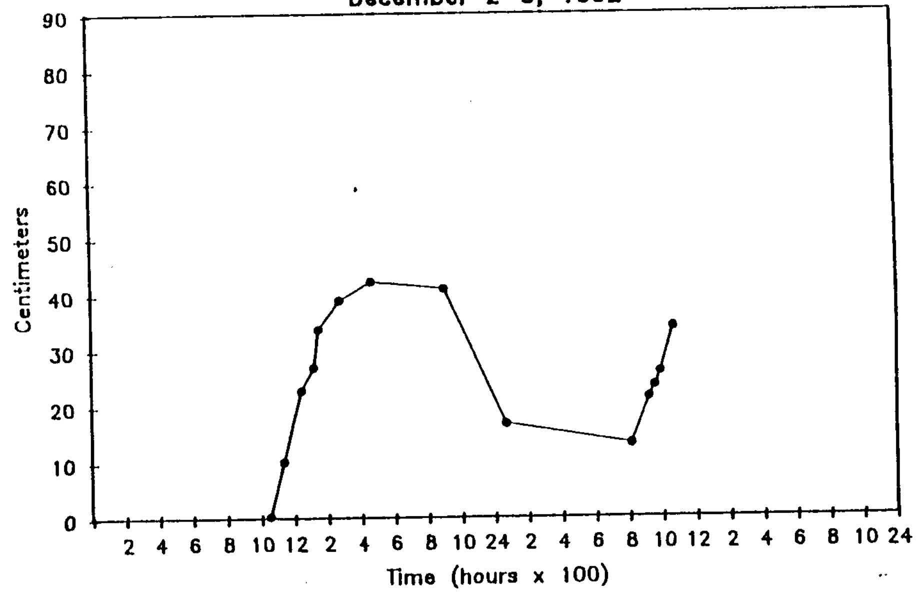

Travertine Falls (RM 229.0)
June 25-26, 1992
Centimeters
0
10
20
30
40
50
60
70
80
90
2 4 6 8 10 12 2 4 6 8 10 24 2 4 6 8 10 12 2 4 6 8 10 24
Time (hours x 100)


Travertine Falls (RM 230.5)
September 29-30, 1993
Centimeters
0
10
20
30
40
50
60
70
80
90
2 4 6 8 10 12 2 4 6 8 10 24 2 4 6 8 10 12 2 4 6 8 10 24
Time (hours x 100)

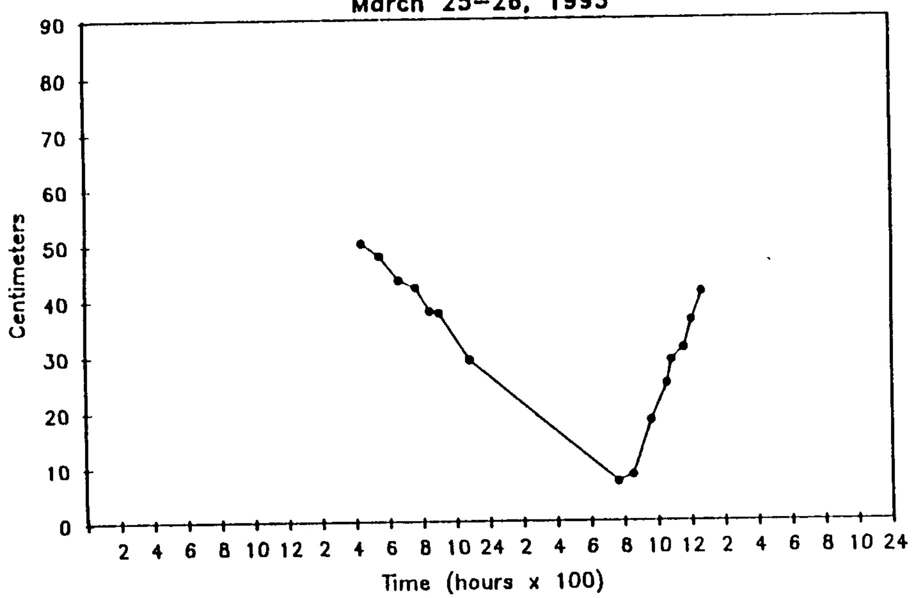
Bridge Cyn (RM 234.9)
September 28-29, 1992



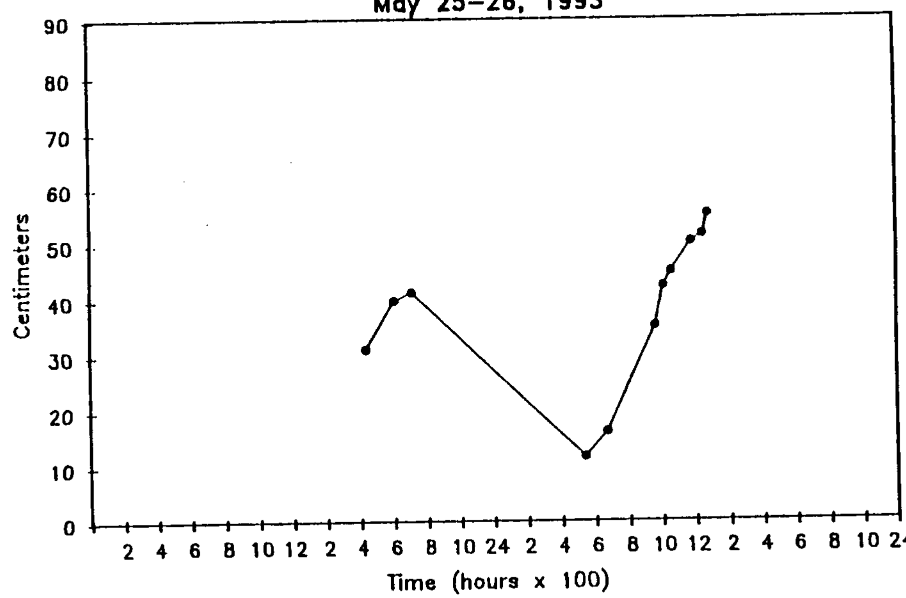
Bridge Cyn (RM 235.1)
December 2-3, 1992



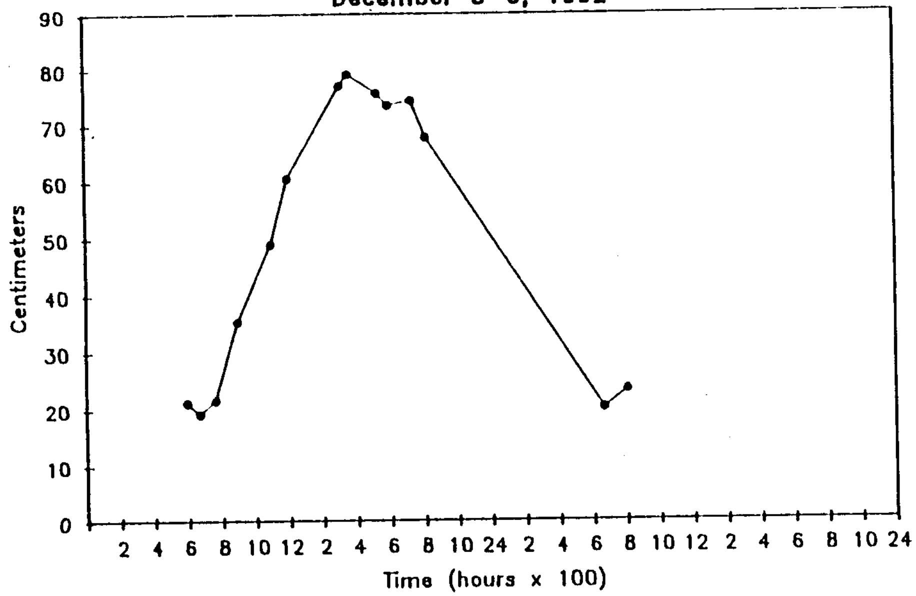
Upper Bridge Cyn (RM 235.2)
March 25-26, 1993



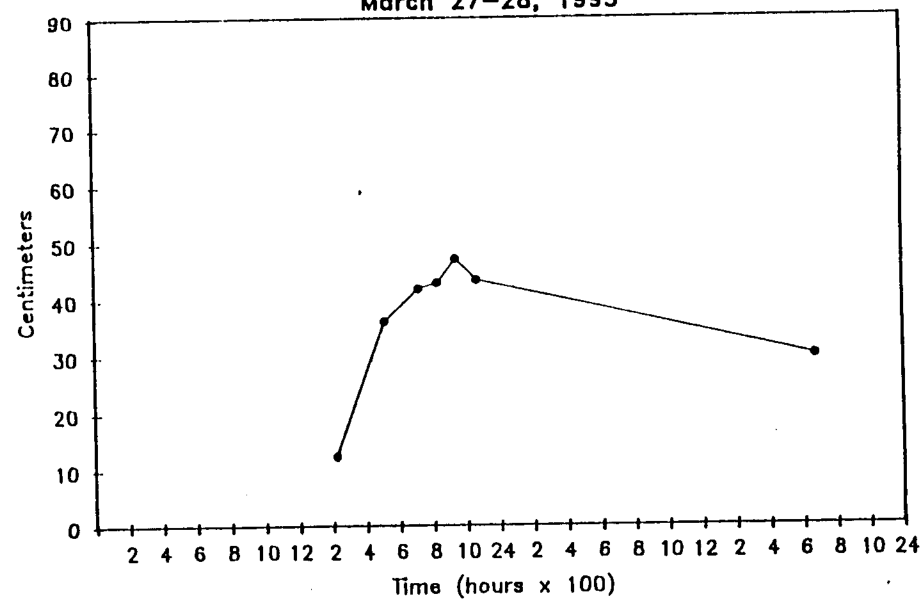
Bridge Cyn (RM 235.1)
May 25-26, 1993



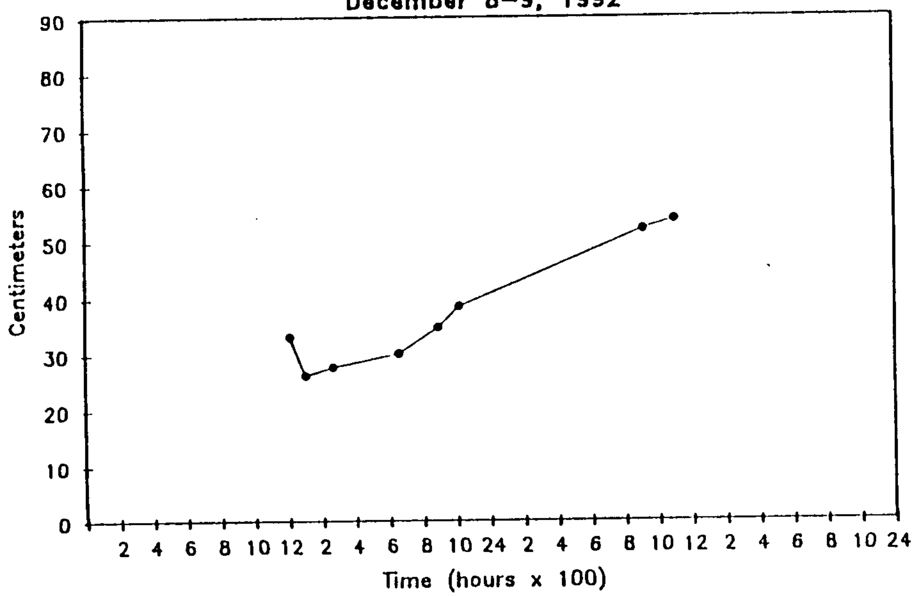
Above Spencer (RM 242.8)
December 5-6, 1992



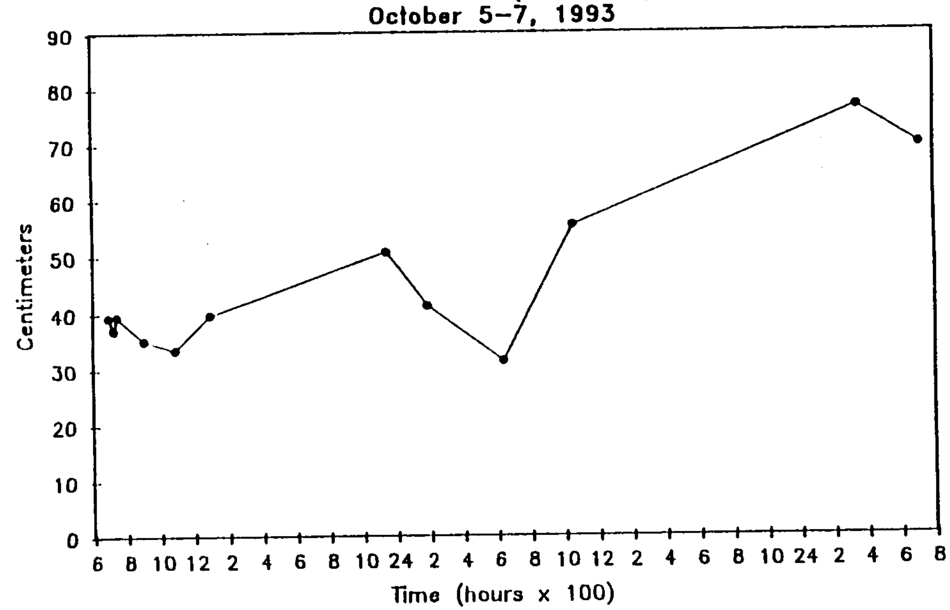
Above Spencer (RM 242.3)
March 27-28, 1993



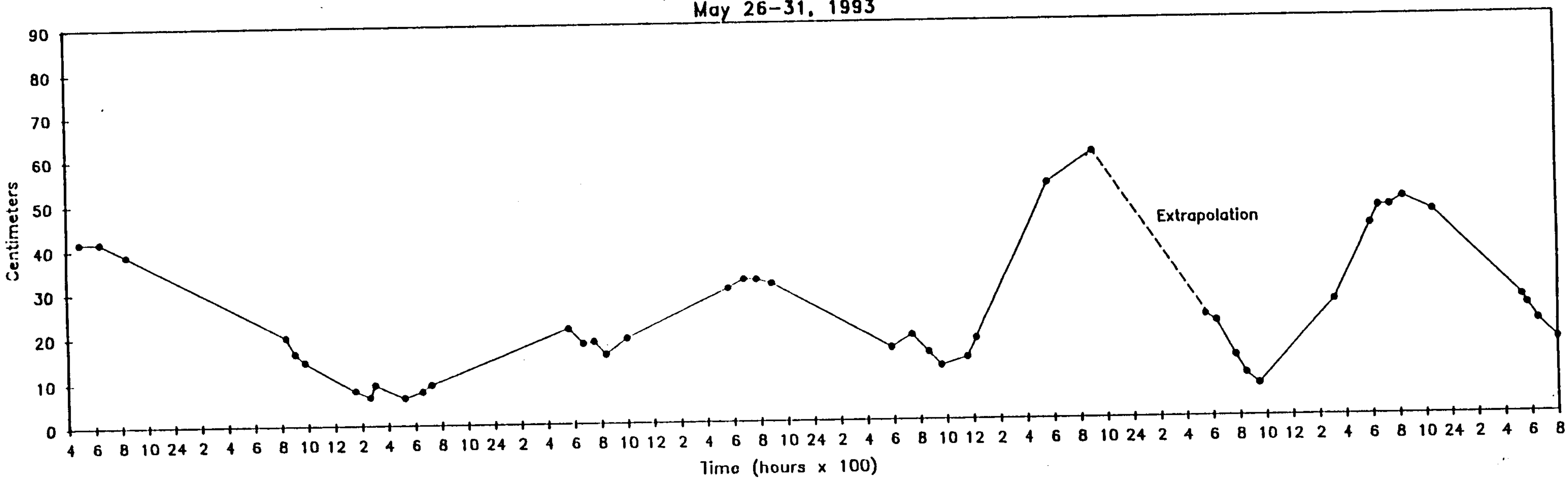
Burnt Spring (RM 259.3)
December 8-9, 1992



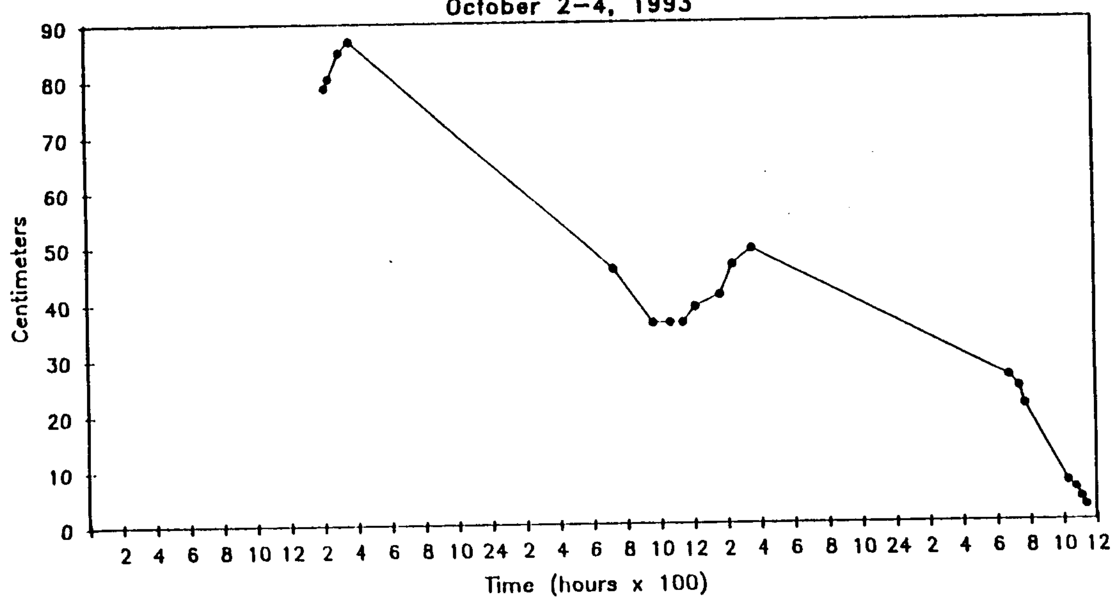
"Chub Staff" (RM 253.2)
October 5-7, 1993



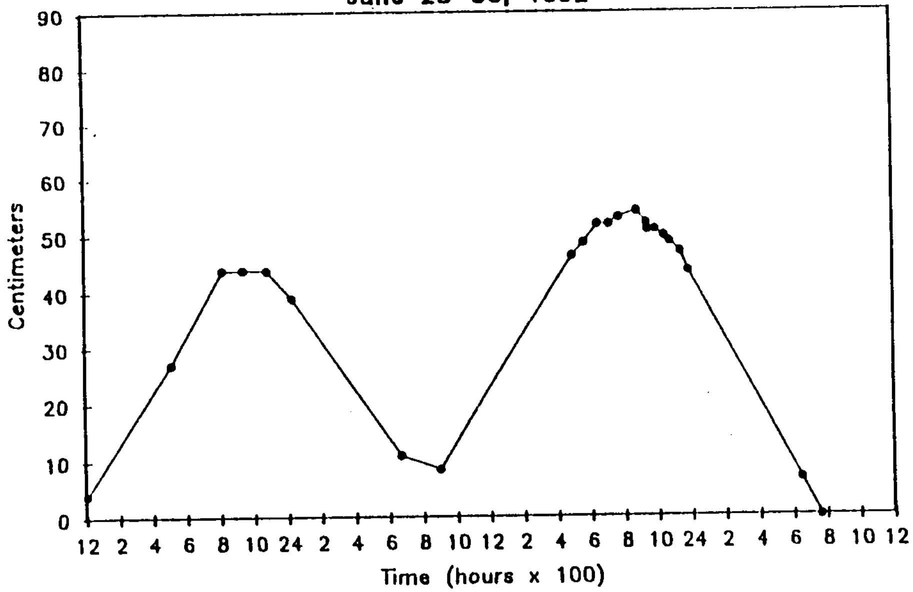
Spencer Creek (RM 245.4)
May 26-31, 1993



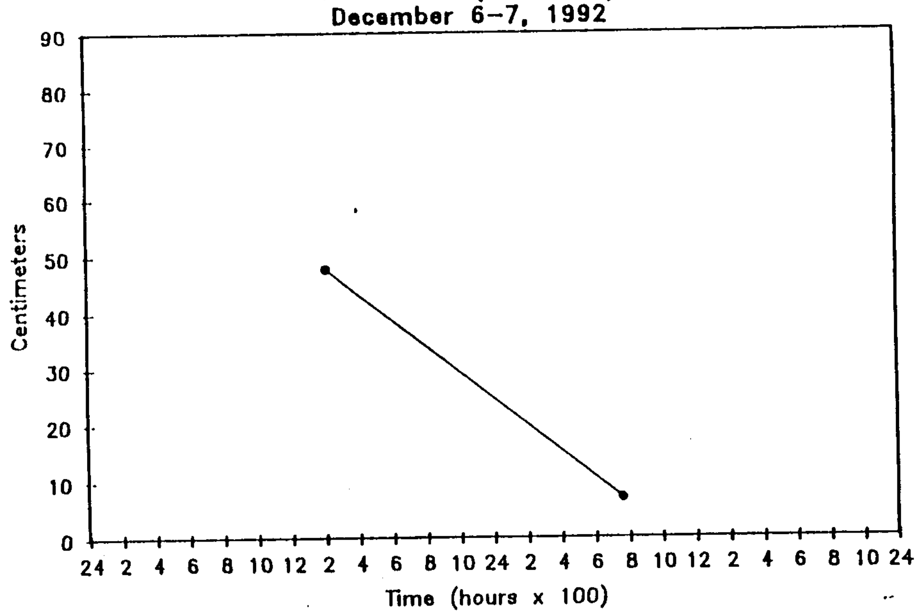
Spencer Creek (RM 246.0)
October 2-4, 1993



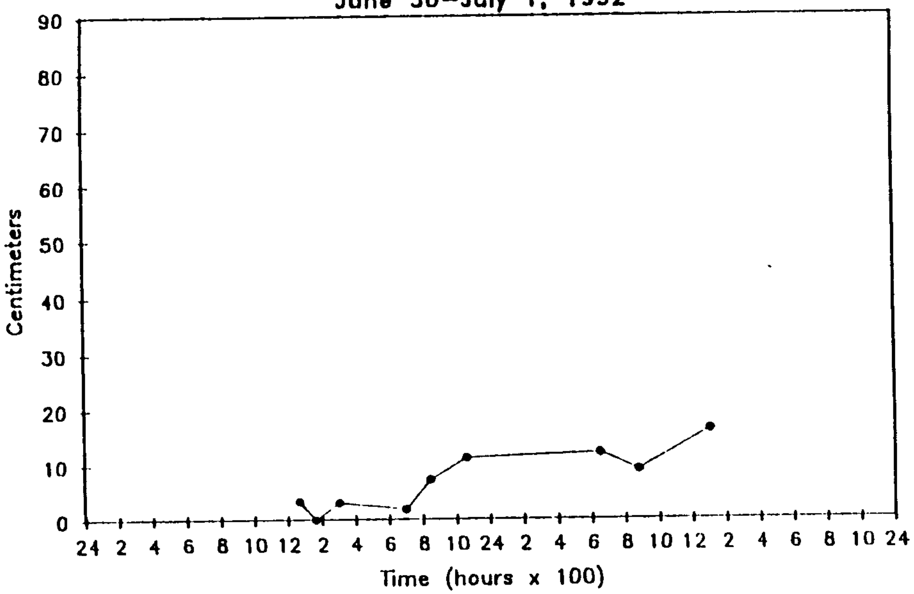
Lost Creek (RM 249.7)
June 28-30, 1992



Lost Creek (RM 249.7)
December 6-7, 1992



Quartermaster (RM 259.8)
June 30-July 1, 1992



Quartermaster (RM 262.0)
October 3-4, 1992

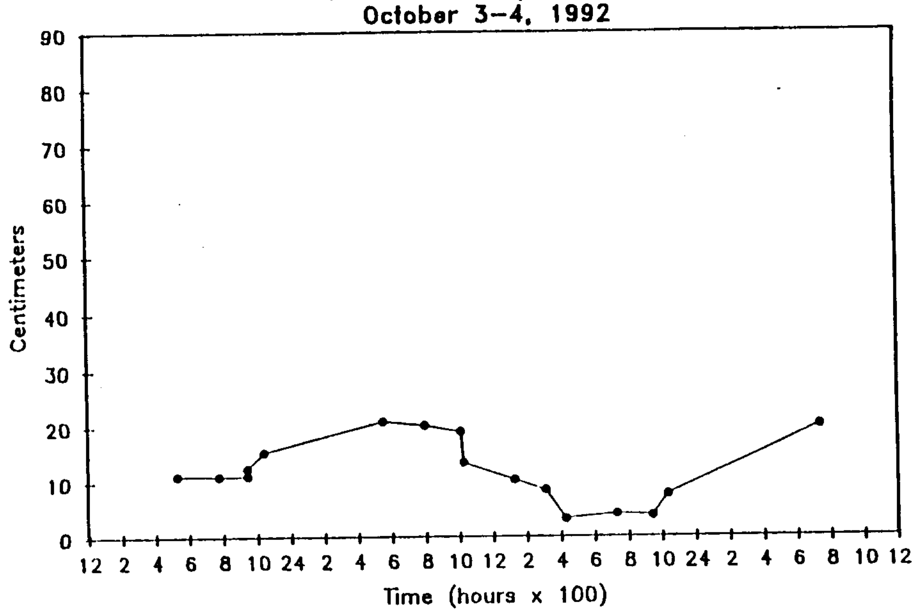


Table 1. Dates, camp sites and sample locations for three trips on the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992.

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)
	Trip No. 4 (March 25 - April 6, 1993)	
March 25-26	Bridge Canyon (RM 235.2)	Bridge Canyon Area (RM 233.8-235.2)
March 26-April 1	Above Spencer Creek (RM 242.2)	Above Spencer Creek to below Lost Creek (RM 241.8 to 250.2) including Spencer Creek (RM 246.0), Surprise Creek (RM 248.2), Lost Creek (RM 248.9)
April 1-2	Burnt Canyon (RM 259.5)	Burnt Canyon to below Quartermaster Canyon (RM 259.5 to 261.1)
April 2-5	RM 268.1 (above former Braided area)	RM 268.1 to 276.6
April 5-6	Pearce Ferry (RM 280)	RM 274.3 to 280.0
	Trip No. 5 (May 25 - June 6, 1993)	
May 25-26	Bridge Canyon (RM 235.2)	Bridge Canyon Area (RM 233.8-235.2)

Table 1. Continued.

Date	Camp Site	Sample Locations
May 26-31	Above Spencer Creek (RM 245.2)	Above Spencer Creek to below Lost Creek (RM 241.8 to 250.2) including Spencer Creek (RM 246.0), Surprise Creek (RM 248.2), Lost Creek (RM 248.9)
May 31-June 1	Below Burnt Spring Canyon (RM 259.5)	RM 259 - RM 262
June 1-3	RM 265.0	RM 264 - RM 268
June 3-6	Scorpion Island	RM 276 - RM 282 (9approx.) 2 net sets below Pearce Ferry
	Trip No. 6 (September 28 - October 10, 1993)	
Sept 28-30	Travertine Falls (RM 230.5)	RM 227.5 - 230.7
Sept 30-Oct 4	Above Spencer Creek (RM 245.2)	RM 242.5 - 249.1 including Spencr Creek (RM 246), Surprise Creek (RM 248.40, and the mouth of Lost Creek (RM 248.I4)
Oct 4-7	Above Salt Creek (RM 253.9)	RM 252.9 - 260 including the mouth of Quartermaster Creek (RM 259.9)
Oct 7-9	Scorpion Island (RM 279)	RM 273 - 278.5
Oct 9-10	Pearce Ferry (RM 280)	Derig
	Trip No. 7 (December 1 - 13, 1993)	
Dec 1-4	Travertine Falls (RM 230.5)	RM 228.5 - 230.7
Dec 4-9	Spencer Creek (RM 246.0)	RM 242.5 - 249.1 including Spencer Creek (RM 246), Surprise Creek (RM 248.4), the mouth of Lost Creek 9RM 248.9) and above Salt Creek (RM 253.2)
Dec 9-11	Near Bat Caves (RM 266)	RM 259.9 including mouth of Quartermaster Creek and main channel from RM 264.5 - 267
Dec 11-13	Scorpion Island (RM 279)	RM 274.7 - 279 including Lake Mead.

Table 2. Longitudinal sample strata in the Colorado River from the eastern boundary of the Hualapai Reservation (RM 165.0) to below Pearce Ferry (RM 286), 1992-1993.

Reach	Geomorphic Strata	Sample Substrata	River Miles	Length (mi)
3	Lower Canyon	a. RM 165-RM 169.9	165.0-169.9	4.9
		b. RM 170.0-Lava Falls	170.0-179.4	9.5
		c. Lava Falls-RM 189.1	179.5-189.1	9.6
		d. RM 189.2-RM 200.0	189.2-200.0	10.8
		e. RM 200.1-209-Mile Rapid	200.1-208.9	8.8
		f. 209-Mile Rapid-214-Mile Creek	209.0-213.9	4.9
	Lower Granite Gorge	g. 214-Mile Creek-Diamond Creek	214.0-226.0	12.0
4	Below Diamond Creek	a. Diamond Creek-RM 239.0	226.1-239.0	12.9
		b. Rm 239.1-Maxon Canyon	239.1-252.0	12.9
		c. Maxon Canyon-Dry Canyon	252.1-265.0	12.9
		d. Dry Canyon-Below Pearce Ferry (RM 286)	265.1-286.0	20.9

Table 3. Locations and descriptions of temporary bench marks (TBM) established on the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286).

TBM Number[a]	Date	Description
		Trip No. 1 (1992)
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 249.0 (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 (1992)
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 (1992)
L 235.1 (Above Bridge Canyon)	Dec 2	Upstream of Bridge Canyon Rapid beach, on shear wall near fanged rock-upper end of beach.
		Trip No. 5 (1993)
R 245.4 (Above Spencer Canyon)	May 26	On shear wall at upper end of beach.
		Trip No. 6 (1993)
L 230.5 (Travertine Falls)	Sep 29	Under rock overhang is depression in rock at upstream end of boat eddy, just above rapid.
R 253.2	Oct 5	Downstream portion of small sand beach about 20' above river, where cliff meets gentle slope, under small overhang facing river.

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

Table 4. Fish sampling equipment, codes, descriptions, and number of samples per trip from the Colorado River from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992-1993.

	Number of Samples							
Sampling Equipment Code - Description	Trip 1	Trip 2	Trip 3	Trip 4	Trip 5	Trip 6	Trip 7	Totals
Electrofishing								
EL - 220-v DC (Coffelt CPS)	40	110	39	48	114	38	42	431
Gill Nets								
GM - 100'x6'x2"	6	7	8	8	-	-	-	29
GP - 100'x6'x1.5"	14	12	5	4	23	-	-	58
GX - 100'x6'experimental gill net with 20' panels of 0.5, 1.0, 2.0, 2.5" mesh	11	4	10	12	-	-	-	37
GS - 300'x6'x2"	-	-	4	-	6	-	-	10
Trammel Nets								
TK - 75'x6'x1"x12"	15	31	49	80	18	23	-	216
TL - 75'x6'x1.5"x12"	46	38	41	59	29	31	29	273
TM - 50'x6'x1"x12"	4	-	16	9	57	26	44	156
TN - 50'x6'x1.5"x12"	3	33	16	34	22	15	38	161
TW - 75'x6'x0.5"x12"	-	-	-	5	3	-	-	8
Hoop Nets								
HM - 3' diameter (medium)	1	-	-	-	-	-	-	1
HS - 2' diameter (small)	-	5	-	-	-	1	-	6
Minnow Traps								
MT - commercial minnow traps	9	12	-	10	-	4	11	46
Seines								
SA - 10'x3'x1/8" seine	5	1	-	4	11	13	-	34
SB - 30'x4'x1/4" seine	-	16	32	-	-	-	-	48

Table 4. Continued.

Sampling Equipment Code - Description	Number of Samples							
	Trip 1	Trip 2	Trip 3	Trip 4	Trip 5	Trip 6	Trip 7	Totals
SG - 30'x5'x1/4" seine	-	14	-	-	-	-	-	14
Angling								
AN - angling with artificial or live bait	2	-	-	-	-	-	-	2

Table 5. Distribution of sampling efforts by gear types in the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992-93.

Sample Strata	River Mile[b]	Gear Type[a]																	
		EL	GM	GP	GX	GS	TK	TL	TM	TN	TW	HM	HS	MT	SA	SB	SG	AN	Totals
A	225-230	9	-	3	4	-	4	20	1	-	-	1	-	9	2	-	-	-	53
	230-235	27	3	-	-	-	10	32	24	21	-	-	-	-	-	-	-	-	117
	235-240	24	-	-	-	-	9	18	-	3	-	-	-	8	-	3	-	-	65
B	240-245	32	-	9	2	-	32	32	26	31	-	-	-	-	-	2	-	-	166
	245-250	106	5	10	-	-	67	75	29	41	3	-	3	11	10	15	5	2	382
C	250-255	25	-	-	-	-	10	16	7	13	-	-	-	-	4	4	-	-	79
	255-260	47	3	-	4	-	6	8	9	3	-	-	-	-	8	10	-	-	98
	260-265	33	-	15	3	-	18	19	17	7	-	-	-	-	1	2	-	-	115
D	265-270	48	4	8	-	-	6	14	20	3	-	-	2	3	9	-	5	-	122
	270-275	17	3	4	7	-	30	12	15	18	-	-	-	1	-	12	-	-	119
	275-280	33	3	2	5	4	2	2	2	-	-	-	-	-	-	-	4	-	57
	280-285	30	8	7	12	6	22	25	6	21	5	-	1	14	-	-	-	-	157
Totals:		431	29	58	37	10	216	273	156	161	8	1	6	46	34	48	14	2	1,530

[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 National Recreation Area Boundary	RM 276.6
Lost Creek	RM 248.9	Pearce Ferry	RM 280.0
Salt Creek	RM 255.5		
Burnt Spring Canyon	RM 259.5		

Table 6. Fish sampling equipment, codes, descriptions, and number of samples per trip from the tributaries and Lake Mead, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992-1993.

Sampling Equipment	Code - Description	Number of Samples							
		Trip 1	Trip 2	Trip 3	Trip 4	Trip 5	Trip 6	Trip 7	Totals
Diamond Creek (RM 226.0)									
	SA - 10'x3'x1/8" seine	-	-	-	-	-	4	4	8
Travertine Falls Creek (RM 230.4)									
	DN - Dip net	-	-	-	-	-	1	-	1
Spencer Creek (RM 246.0)									
	EL - 220-v DC (Coffelt CPS)	-	1	-	-	-	-	-	1
	BP - Backpack EL (Coffelt BP1C)	-	-	3	4	2	6	2	17
	HM - 3' diameter (medium)	2	-	-	-	-	-	-	2
	MT - commercial minnow traps	-	6	-	24	9	14	16	69
	SA - 10'x3'x1/8" seine	3	-	-	-	3	4	4	14
	SB - 30'x4x1/4" seine	-	5	1	-	-	-	-	6
Surprise Canyon (RM 248.4)									
	BP - Backpack EL (Coffelt BP-1C)	-	-	-	2	2	-	-	4
	HM - 3' diameter (medium)	-	-	1	-	-	-	-	1
	HS - 2' diameter (small)	-	-	2	-	-	-	-	2
	MT - commercial minnow traps	-	4	3	6	3	10	4	30
	SA - 10'x3'x1/8" seine	3	-	-	-	2	3	2	10
	SB - 30'x4x1/4" seine	-	1	4	-	-	-	-	5
Lost Creek (RM 248.9)									
	EL - 220-v DC (Coffelt CPS)	2	-	-	-	-	-	-	2
	HM - 3' diameter (medium)	1	-	-	-	-	-	-	1

Table 6. Continued.

Sampling Equipment	Code - Description	Number of Samples							
		Trip 1	Trip 2	Trip 3	Trip 4	Trip 5	Trip 6	Trip 7	Totals
	HS - 2' diameter (small)	-	-	-	2	1	-	-	3
	MT - commercial minnow traps	4	-	-	8	5	-	-	17
	SG - 300'x6'x2"	-	1	-	-	-	-	-	1
Quartermaster Canyon (RM 259.8)									
	HM - 3' diameter (medium)	1	-	-	-	-	-	-	1
	MT - commercial minnow traps	-	4	-	-	-	-	-	4
	SA - 10'x3'x1/8" seine	1	-	-	-	-	-	-	1

Table 7. 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), 1992-1993.

Family Common Name (Code)	Scientific Name	Number Captured								
		Trip 1	Trip 2	Trip 3	Trip 4	Trip 5	Trip 6	Trip 7	Totals	Percent
CYPRINIDAE (minnows)										
red shiner (RS)	Cyprinella lutrensis	1,473	1,226	888	220	1,239	2,615	3,075	10,736	61
fathead minnow (FH)	Pimephales promelas	1,572	203	486	24	27	187	863	3,362	19
humpback chub (HB)	Gila cypha	0	0	0	0	0	1	0	1	<1
common carp (CP)	Cyprinus carpio	119	171	120	351	359	25	19	1,164	7
speckled dace (SD)	Rhinichthys osculus	1	37	9	14	15	519	419	1,014	6
CATOSTOMIDAE (suckers)										
flannelmouth sucker (FM)	Catostomus latipinnis	16	33	14	4	28	58	8	161	1
bluehead sucker (BH)	Catostomus discobolus	0	0	0	0	0	1	0	1	<1
PERCICHTHYIDAE (temperate basses)										
striped bass (SB)	Morone saxatilis	13	0	3	3	42	2	4	67	<1
SALMONIDAE (trout)										
rainbow trout (RB)	Oncorhynchus mykiss	0	0	0	1	3	0	0	4	<1
ICTALURIDAE (catfishes, bullheads)										
channel catfish (CC)	Ictalurus punctatus	45	21	21	46	176	8	7	324	2
black bullhead (BB)	Ameiurus melas	2	0	0	0	0	0	0	2	<1
PERCIDAE (perches)									0	
walleye (WE)	Stizostedion vitreum	1	0	1	0	0	0	0	2	<1
CYPRINODONTIDAE (killifishes)										
plains killifish (PK)	Fundulus zebrinus	5	1	28	0	1	9	5	49	<1
POECILIIDAE (livebearers)									0	
mosquitofish (GA)	Gambusia affinis	76	40	26	0	105	4	0	251	1

Table 7. Continued.

Family Common Name (Code)	Scientific Name	Number Captured								
		Trip 1	Trip 2	Trip 3	Trip 4	Trip 5	Trip 6	Trip 7	Totals	Percent
CENTRARCHIDAE (sunfishes)										
largemouth bass (LM)	Micropterus salmoides	6	22	0	0	3	0	9	40	<1
green sunfish (GS)	Lepomis cyanellus	0	1	2	2	4	0	0	9	<1
black crappie (BC)	Pomoxis nigromaculatus	1	1	0	0	0	1	2	4	<1
bluegill (BG)	Lepomis macrochirus	0	37	0	0	1	1	0	39	<1
CLUPEIDAE (shads)										
threadfin shad (TS)	Dorosoma petenense	13	297	0	0	4	0	6	320	2
Totals		3,343	2,090	1,598	665	2,007	3,431	4,418	17,551	-

Table 8. Summary of PIT-tagging information for trips 1-7, 1992-93.

Date	Species	PIT-tag	TL (mm)	WT (g)	Sex	Recap	RM
920624	FM	7F7F3E524F	420	623	M	N	229.2
920627	FM	7F7F287E72	360	0 –	M	N	246.1
921003	FM	7F7F143B74	367	375	U	N	260.3
921004	FM	7F7F1F1322	329	314	M	N	259.8
921204	FM	7F7F480E49	322	260	F	N	246.9
921205	FM	7F7F284128	282	163	U	N	242.2
921207	FM	7F7F264F09	361	382	F	N	258.8
930321	FM	7F7F480106	-	106	-	N	245.5
930526	FM	7F0C5C1D5C	332	381	U	N	233.4
930530	FM	7F7F480366	397	567	U	N	246.1
930531	FM	7F7F22006C	221	137	U	N	260.0
930601	FM	7F7B081724	387	519	M	N	266.6
930929	FM	1F1E2B1107	294	206	M	N	230.5
930929	BH	1F20031B23	249	161	U	N	229.0
930929	FM	1F1E2D3264	380	481	F	N	227.7
930929	FM	1F1F5B7077	387	491	F	N	230.7
930930	FM	1F200E7241	228	108	M	N	230.5
931001	HB	1F1F74212D	329	293	F	N	253.2
931008	FM	1F0C701F46	410	639	F	N	274.0
931009	FM	1F0F642747	346	363	F	N	273.8
931204	FM	1F1F5B7077	390	515	F	Y	230.7
931211	FM	1F200C5065	412	679	F	N	274.4

Table 9. Number and percentage fish species composition in 12 sampling substrata of the mainstem Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1993.

Substrata River Mile	Fish Species Codes[a]																			
	RS	FH	CP	SD	HB	FM	SB	BH	RB	BB	CC	WE	PK	GA	LM	GS	BC	BG	TS	Total
225-229.9			8 (32)	7 (28)		2 (8)	1 (4)	1 (4)			6 (24)									25
230-234.9			160 (80)			6 (3)	1 (1)				31 (16)									198
235-239.9	81 (48)	2 (1)	54 (32)	7 (4)		1 (<1)					23 (14)	1 (<1)								169
240-244.9	49 (23)		121 (58)			1 (<1)	2 (1)				35 (17)				1 (<1)				1 (<1)	210
245-249.9	692 (71)	18 (2)	144 (15)	3 (<1)		15 (2)	22 (2)				70 (7)	1 (<1)	4 (<1)	5 (1)	1 (<1)				1 (<1)	976
250-254.9	101 (75)	9 (7)	16 (12)		1 (1)	1 (1)					4 (3)			3 (2)						135
255-259.9	246 (72)	6 (2)	38 (11)	1 (<1)		5 (1)	1 (<1)				7 (2)		1 (<1)	24 (7)	2 (1)		1 (<1)		12 (3)	344
260-264.9	201 (71)	4 (1)	40 (14)	2 (1)		2 (1)	6 (2)				22 (8)			4 (1)		2 (1)			2 (1)	285
265-269.9	621 (57)	175 (16)	90 (8)	34 (3)		19 (2)	10 (1)		3 (<1)		16 (1)			106 (10)		2 (<1)			6 (1)	1,082
270-274.9	70 (50)	4 (3)	47 (34)			5 (4)	4 (3)				7 (5)			2 (1)			1 (1)			140
275-279.9	199 (46)	1 (<1)	47 (11)			1 (<1)	3 (1)				16 (4)			33 (8)	8 (2)			37 (9)	90 (21)	435
280-284.9	11 (3)		149 (34)			2 (<1)	15 (3)			2 (<1)	22 (5)				23 (5)	3 (1)	3 (1)	2 (<1)	208 (47)	440
Total	2,271 (51)	219 (5)	914 (21)	54 (1)	1 (<1)	60 (1)	65 (1)	1 (<1)	3 (<1)	2 (<1)	259 (6)	2 (<1)	5 (<1)	177 (4)	35 (1)	7 (<1)	5 (<1)	39 (1)	320 (7)	4,439

[a] See table 7 for fish species codes.

Table 10. Comparison of number and percent composition in geomorphic strata from National Canyon (RM 165) to Pearce Ferry (RM 286).

Strata River Mile	Fish Species Codes[a]																						
	RS	FH	CP	SD	HB	FM	FV	BH	SU	SB	BR	RB	BB	CC	WE	PK	GA	LM	GS	BC	BG	TS	Total
165-169.9		6 (13)	23 (49)	1 (2)		7 (15)		3 (6)				6 (13)		1 (2)									47
170-179.4		1 (2)	33 (55)	3 (5)		10 (17)	1 (2)	3 (5)			2 (3)	7 (12)											60
175-189.1		14 (3)	96 (23)	131 (32)	2 (<1)	99 (24)		57 (14)	3 (1)	1 (<1)	1 (<1)	8 (2)		1 (<1)		1 (<1)							414
189.2-200.0		38 (18)	29 (14)	109 (51)	1 (<1)	9 (4)		16 (8)	3 (1)		2 (1)	1 (<1)		1 (<1)		5 (2)							214
200.1-208.9		4 (3)	32 (26)	60 (49)		7 (6)		7 (6)	9 (7)					2 (2)		2 (2)							123
209-213.9		1 (2)	24 (57)			4 (10)		2 (5)		1 (2)		1 (2)		9 (21)									42
214-226		6 (3)	68 (31)	84 (39)		28 (13)		9 (4)		3 (1)		5 (2)		14 (6)									217
226-238.9	30 (9)	1 (<1)	216 (66)	8 (2)		8 (2)		1 (<1)		2 (1)				60 (18)	1 (<1)								327
239-251.9	831 (64)	19 (1)	276 (21)	9 (1)		18 (1)				24 (2)				107 (8)	1 (<1)	4 (<1)	6 (<1)	2 (<1)				2 (<1)	1,299
252-264.9	509 (71)	19 (3)	89 (12)	3 (<1)	1 (<1)	7 (1)				7 (1)				31 (4)		1 (<1)	30 (4)	2 (<1)	2 (<1)	1 (<1)		14 (2)	716
265-286	901 (43)	180 (9)	333 (16)	34 (2)		27 (1)				32 (2)		3 (<1)	2 (<1)	61 (3)			141 (7)	31 (1)	5 (<1)	4 (<1)	39 (2)	304 (4)	2,097
	2271 (41)	289 (5)	1219 (22)	442 (8)	4 (<1)	224 (4)	1 (<1)	98 (2)	15 (<1)	70 (1)	5 (<1)	31 (1)	2 (<1)	287 (5)	2 (<1)	13 (<1)	177 (3)	35 (1)	7 (<1)	5 (<1)	39 (1)	320 (6)	5,556

[a] See table 7 for fish species codes.

Table 11. Number and percentage fish species composition in tributaries of the Colorado River, from Diamond Creek (RM 226) to below Pearce Ferry (RM 286), 1992-1993.

Tributary/Fish Species	Sampling trip							Total	Percent
	1	2	3	4	5	6	7		
Diamond Creek (RM 226.0)									
Speckled dace	-	-	-	-	-	1	34	35	100
Travertine Falls Creek (RM 230.4)									
Speckled dace	-	-	-	-	-	5	-	5	100
Spencer Creek (RM 246.0)									
Red shiner	491	35	105	55	151	1,406	1,125	3,368	71
Fathead minnow	0	0	23	3	0	26	110	162	3
Common carp	0	2	0	24	114	3	3	146	3
Speckled dace	0	2	6	12	7	498	379	904	19
Flannelmouth sucker	12	3	0	1	8	45	3	72	2
Rainbow trout	0	0	0	1	0	0	0	1	<1
Channel catfish	0	0	0	5	55	0	0	60	1
Plains killifish	4	0	5	0	0	5	0	14	<1
Surprise Canyon (RM 248.4)									
Red shiner	701	60	647	38	391	1,164	1,872	4,873	61
Fathead minnow	1,571	33	459	21	17	152	727	2,980	37
Common carp	1	21	41	2	2	0	0	67	1
Speckled dace	0	0	3	2	0	8	3	16	<1
Flannelmouth sucker	2	0	8	0	12	7	0	29	<1
Plains killifish	0	0	23	0	1	4	1	29	<1
Green sunfish	0	0	2	0	0	0	0	2	<1

Table 11. Continued.

Tributary/Fish Species	Sampling trip							Total	Percent
	1	2	3	4	5	6	7		
Surprise Canyon continued (RM 248.4)									
Mosquitofish	0	0	24	0	0	0	0	24	<1
Lost Creek (RM 248.9)									
Red shiner	29	1	-	24	1	-	-	55	51
Fathead minnow	1	0	-	0	0	-	-	1	1
Common carp	23	0	-	14	0	-	-	37	34
Channel catfish	1	0	-	4	0	-	-	5	5
Striped bass	2	0	-	0	0	-	-	2	2
Mosquitofish	5	0	-	0	0	-	-	5	5
Largemouth bass	3	0	-	0	0	-	-	3	3
Quartermaster Canyon (RM 259.8)									
Red shiner	167	2	-	-	-	-	-	169	78
Plains killifish	1	0	-	-	-	-	-	1	<1
Mosquitofish	45	0	-	-	-	-	-	45	21
Largemouth bass	2	0	-	-	-	-	-	2	<1
	3,061	159	1,346	206	759	3,324	4,257	13,112	

ɔle 12. Mean length (± 1 SD) of flannelmouth sucker, striped bass, channel catfish, and common carp by trip in the Colorado River m Diamond Creek (RM 226) to below Pearce Ferry (RM 286) and tributaries, 1992-1993.

pecies	Trip 1	Trip 2	Trip 3	Trip 4	Trip 5	Trip 6	Trip 7
ıain Channel							
Common Carp							
TL (mm)	403 (±114)	323 (±156)	481 (±46)	-	256 (±227)	385 (±89)	235 (±133)
N	87	145	79	-	27	12	10
WT (g)	980 (±515)	1161 (±523)	1440 (±575)	-	1522 (±924)	837 (±460)	340 (±458)
N	82	83	79	-	14	12	10
Flannelmouth sucker							
TL (mm)	390 (±30)	83 (±72)	237 (±97)	227	203 (±136)	341 (±62)	302 (±119)
N	2	30	6	1	8	6	5
WT (g)	623	345 (±31)	153 (±134)	106	192 (±235)	381 (±180)	356 (±269)
N	1	2	6	1	8	6	5
Striped bass							
TL (mm)	440 (±108)	-	266 (±4)	-	395 (±94)	503	452 (±75)
N	8	-	3	-	34	1	4
WT (g)	796 (±352)	-	189 (±13)	-	561 (±431)	1019	672 (±410)
N	8	-	3	-	32	1	4
Channel catfish							
TL (mm)	341 (±70)	297 (±47)	313 (±51)	290 (±42)	310 (±53)	354 (±51)	309 (±35)
N	36	21	21	32	105	8	5
WT (g)	356 (±214)	201 (±112)	283 (±149)	210 (±128)	289 (±168)	388 (±287)	215 (±91)
N	36	20	21	32	104	8	5
Tributaries							
Common carp							
TL (mm)	419 (±58)	288 (±168)	-	-	-	389 (±138)	499 (±25)
N	22	3	-	-	-	4	3
WT (g)	906 (±503)	708 (±29)	-	-	-	2915 (±3970)	-
N	20	2	-	-	-	4	-
Flannelmouth sucker							
TL (mm)	-	-	69 (±9)	65	59 (±22)	113 (±28)	160 (±27)
N	-	-	8	1	20	47	3
WT (g)	-	-	-	1	2 (±4)	14 (±9)	31 (±17)
N	-	-	-	1	19	37	2

Table 12. Continued.

ecies	Trip 1	Trip 2	Trip 3	Trip 4	Trip 5	Trip 6	Trip 7
Striped bass							
TL (mm)	187 (±4)	-	-	-	-	-	-
N	2	-	-	-	-	-	-
WT (g)	85	-	-	-	-	-	-
N	1	-	-	-	-	-	-
Channel catfish							
TL (mm)	248	-	-	319 (±79)	290 (±53)	-	-
N	1	-	-	9	28	-	-
WT (g)	142	-	-	241 (±146)	199 (±83)	-	-
N	1	-	-	4	23	-	-

Table 13. Mean macroinvertebrate drift densities (number/100 m^3), by season, in the Colorado River between Diamond Creek (RM 226) and Pearce Ferry (RM 286), and in Spencer Creek during 1992-1993.

Season	Chironomidae			Simuliidae			Gammarus		Other	Terrestrial	Total
	L	P	A	L	P	A	A	I			
Main Channel											
1992											
May-Jun	18.2	12.0	18.9	26.7	5.4	6.7	0.0	0.5	4.4	33.6	126.4
Sep-Oct	0.0	2.1	2.1	2.1	0.7	2.1	0.3	1.1	0.9	16.7	28.1
Dec	0.4	0.2	3.4	4.8	0.0	1.1	0.0	0.2	0.2	2.7	13.0
1993											
Mar-Apr	12.0	6.5	6.7	3.0	0.0	1.0	0.0	0.0	0.0	41.9	71.1
May-Jun	27.4	22.7	27.8	11.3	1.5	2.0	0.0	0.0	12.6	50.8	156.1
Sep-Oct	41.8	18.4	28.8	8.3	3.0	1.5	0.0	3.0	118.4	138.3	361.5
Dec	68.0	7.4	40.6	37.2	0.0	3.3	0.0	0.0	26.8	6.8	190.1
Spencer Creek											
1993											
May-Jun	2,332.8	3,571.3	271.6	2,219.1	366.9	8.0	0.0	0.0	5,143.3	701.4	14,614.4

Table 14. **Maximum drift densities (#/100 m^3) from some regulated and unregulated rivers in North America and Great Britian.**

Drift Density	Reference	
Regulated		
110	Eckblad et al (1984)	Mississippi R.
253	Brooker and Hemsworth (1978)	Great Br.
993	Perry and Perry (1986)	~~Flathead~~ & Kootenai R.
1,440	Armitage (1977)	Great Br.
157,620	Perry and Perry (1986)	Flathead R.
Unregulated		
43	LaPerriere (1983)	Alaska
49	Cowell and Carew (1976)	Florida
160	Stoneburner and Smock (1979)	S. Carolina
164	Zimmer (1976)	Skunk R., Iowa
730	Armitage (1977)	Great Br.
6,900	Minshall and Winger (1968)	Wisconsin

Table 15. Mean macroinvertebrate drift densities (number/100 m³) relative to changes in flow in the Colorado River between Diamond Creek (RM 226) and Pearce Ferry (RM 286), 1992-1993.

		River Stage					
		Steady		Rising		Falling	
Date		Surface	Subsurface	Surface	Subsurface	Surface	Subsurface
1992							
Trip 1	(27 Jun)	-	-	170.3	120.0	93.9	60.7
	(29 Jun)	-	-	112.0	107.7	150.0	276.4
	(30 Jun)	-	-	58.0	110.0	-	-
Trip 2	(28 Sep)	94.2	52.6	5.7	27.1	-	-
	(2 Oct)	-	-	2.0	2.8	-	-
	(4 Oct)	-	-	-	-	25.2	26.6
	(5 Oct)	-	-	26.0	17.3	-	-
Trip 3	(2 Dec)	-	-	22.0	30.0	-	-
	(5 Dec)	-	-	10.5	13.3	10.0	14.0
	(8 Dec)	9.3	2.7	6.0	6.0	-	-
1993							
Trip 4	(28 Mar)	-	-	105.0	106.0	-	-
	(2 Apr)	41.3	34.5	-	-	-	-
Trip 5	(29 May)	-	-	-	-	93.0	167.3
	(1 Jun)	64.0	222.3	-	-	-	-
Trip 6	(4 Oct)	-	-	-	-	-	391.5
	(7 Oct)	-	-	-	331.3	-	-
Trip 7	(8 Dec)	-	203.2	-	-	-	-
Average		**52.2**	**103.1**	**51.8**	**79.2**	**74.4**	**156.1**

APPENDIX A

Project Personnel

Table A-1. Personnel participating in 1992-1993 field trips.

Name	Trip	Agency, Address, Phone Numbers
Richard Valdez	1, 7	BIO/WEST, Inc., 1063 W. 1400 N., Logan, UT 84321 (801)752-4202
Gloria Hardwick	4, 5, 6, 7	BIO/WEST, Inc., 1840 W. Kaibab Ln. Suite 100, Flagstaff, AZ 86001 (602)774-8069
Randall Filbert	5, 6, 7	BIO/WEST, Inc., 1063 W. 1400 N., Logan, UT 84321 (801)752-4202
Kirsten Tinning	1, 2, 3, 4	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
Teresa Yates	3, 4, 6, 7	BIO/WEST, Inc., 1840 W. Kaibab Ln. Suite 100, Flagstaff, AZ 86001 (602)774-8069
Alyssa Reischauer	2	BIO/WEST, Inc., 1840 W. Kaibab Ln. Suite 100, Flagstaff, AZ 86001 (602)774-8069
Bill Leibfried	5, 7	BIO/WEST, Inc., 1840 W. Kaibab Ln. Suite 100, Flagstaff, AZ 86001 (602)774-8069
Alan Kinsolving	2	Aquatics International, 575 Lake Mary Road, Flagstaff, AZ 86001 (602)774-9428
Clay Bravo	1, 4	Hualapai Wildlife Management Department, P.O. Box 300, 947 Rodeo Way, Peach Spring, AZ 86434 (602)769-2254
Morris Sampson	1, 2, 3, 4, 5, 6, 7	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, 6	Hualapai Wildlife Management Department, P.O. Box 300, 947 Rodeo Way, Peach Spring, AZ 86434 (602)769-2254
Soloise Powski	5	Hualapai Wildlife Management Department, P.O. Box 300, 947 Rodeo Way, Peach Spring, AZ 86434 (602)769-2254
Ben Zimmerman	3, 4, 5, 7	Hualapai Wildlife Management Department, P.O. Box 300, 947 Rodeo Way, Peach Spring, AZ 86434 (602)769-2254
Jerry Cook	2, 4	Hualapai Wildlife Management Department, P.O. Box 300, 947 Rodeo Way, Peach Spring, AZ 86434 (602)769-2254
Alvin Dashee	6	Hualapai Wildlife Management Department, P.O. Box 300, 947 Rodeo Way, Peach Spring, AZ 86434 (602)769-2254
Stan Dashee	7	Hualapai Wildlife Management Department, P.O. Box 300, 947 Rodeo Way, Peach Spring, AZ 86434 (602)769-2254
Wallace Wilson	7	Hualapai Wildlife Management Department, P.O. Box 300, 947 Rodeo Way, Peach Spring, AZ 86434 (602)769-2254

Name	Trip	Agency, Address, Phone Numbers
Johnny Matuck	6	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
Debra Bills	5	U.S. Fish and Wildlife Service
Stuart Reeder	3, 7	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Lars Neimi	1, 5	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Steve Bledsoe	3, 7	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, 5	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Allistair Bleifuss	4	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Ann Cassidy	4	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Tony Anderson	4, 5	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Kelly Johnson	5	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Curtis (Whale) Hansen	6	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Bob Grusy	6	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Elizabeth Fuller	6, 7	OARS, P.O. Box 1969, Flagstaff, AZ 86002 (602)774-0526
Valerie Saylor	4	GCES, P.O. Box 22459, Flagstaff, AZ 86002 (602)556-7868

Table A-2. Locations and times of water quality measurement[a] using a Hydrolab Surveyor II, Hydrolab Datasonde with datalogger, and Secchi disk, 1992-1993.

Sample Site (River Mile)	Observation Period (Dates) Time (Hours)
Hydrolab Surveyor II	
Travertine Canyon (RM 229.1)	Jun 25-Jun 26, 1992 1030-0800 (21.5 hrs)
Spencer Canyon (RM 246.0)	Jun 26-Jun 28, 1992 1230-1043 (46.2 hrs)
Lost Creek (RM 249.7)	Jun 28-Jun 30, 1992 1206-0744 (43.7 hrs)
Quartermaster (RM 259.8)	Jun 30-Jul 1, 1992 1245-1339 (24.9 hrs)
Colorado River at Spencer Canyon[b]	Dec 1-Dec 4, 1992 2008-0639(58.5 hrs)
RM 255.2	Mar 25-Mar 26, 1993 1624-1227
RM 242.2	Mar 26-Mar 30, 1993 1637-0849
Surprise Canyon	Mar 30-Mar 30, 1993 1003-1607
Lost Creek	Mar 31-Mar 31, 1993 1100-1801
Burnt	Apr 1-Apr 2, 1993 1630-0907
RM 268.1 above Braided	Apr 2-Apr 5, 1993 1440-0704
Lake Mead	Apr 5-Apr 5, 1993 1139-1815
RM 234.9 - Bridge Canyon	May 25-May 26, 1993 2009-1225
RM 245.6 above Spencer	May 26-May 31, 1993 1718-0759
RM 259.5 across from Burnt	May 31-Jun 1, 1993 1535-0820
RM 265.0 below Dry Canyon	Jun 1-Jun 3, 1993 1724-0706
RM 279.5 behind Scorpion	Jun 3-Jun 5, 1993 1729-1739
RM 230.5 - Travertine Falls	Sep 29-Sep 30, 1993 1124-1258
RM 245 above Spencer	Sep 30-Oct 2, 1993 1958-0938

Table A-2. Continued

Sample Site (River Mile)	Observation Period (Dates) Time (Hours)
RM 246.0 - Spencer Creek	Oct 2-Oct 4, 1993 1111-1148
RM 253.9 below Spencer	Oct 4-Oct 7, 1993 1656-0835
RM 279.0 behind Scorpion	Oct 7-Oct 9, 1993 1800-0951
RM 230.5 - Travertine Falls	Dec 2-Dec 4, 1993 0925-1203
RM 216.0 - Spencer Creek	Dec 4-Dec 9, 1993 1538-1143
RM 266.0	Dec 9-Dec 10, 1993 1601-1417
RM 279.0 behind Scorpion	Dec 11-Dec 12, 1993 1432-1637
<u>Hydrolab Datasonde w/Datalogger</u>	
Spencer Creek (100 m above outflow)[b]	Jun 26-Jun 28, 1992 0815-1015(26 hrs)
Spencer Creek (100 m above outflow)[b]	Sep 30-Oct 3, 1992 1300-0800(66 hrs)
Spencer Creek (100 m above outflow)[b]	Dec 3-Dec 6, 1992 1500-0930(66.5 hrs)
Lost Creek (200 m above outflow)	Jun 29-Jun 30, 1992 0900-0900 (24 hrs)
RM 235.2 - Bridge Canyon	Mar 25-Mar 26, 1993 1603-1241
RM 242.2	Mar 26-Mar 27, 1993 1658-1309
RM 242.2	Mar 28 - Mar 29, 1993 1517-1320
RM 246 - Spencer Creek	Mar 29-Mar 31, 1993 ?-0933
RM 249 - Lost Creek	Mar 31-Apr 1, 1993 1245-1140
Burnt Creek	Apr 1-Apr 2, 1993 1630-0905
RM 268.1	Apr 2-Apr 5, 1993 1438-0920
RM 236.5 - Bridge Canyon	May 25-May 26, 1993 1702-1230
RM 245.7	May 26-May 30, 1993 1715-0920

Table A-2. Continued

Sample Site (River Mile)	Observation Period (Dates) Time (Hours)
RM 249.0	May 30-May 31, 1993 ?-1015
RM 230.5	Dec 1-Dec 4, 1993 1643-0947
Spencer Creek	Dec 4-Dec 9, 1993 1300-1120
RM 266.0	Dec 9-Dec 11, 1993 1535-0919

[a] Water quality parameters included temperature, pH, dissolved oxygen, conductivity

Table A-3. Turbidity measurements (Secchi disk readings) taken in the mainstem Colorado River between Diamond Creek (RM 226) and Pearce Ferry (RM 286), 1992-1993.

Sample Site (River Mile)	Date/time of Observation	Secchi disk readings (m)
235.2	Mar 25, 1993 1624	~~0.025~~ .03
235.2	Mar 26, 1993 1014	0.03
242.2	Mar 27, 1993 1159	~~0.025~~ .03
242.2	Mar 28, 1993 1523	0.04
242.2	Mar 29, 1993 0937	0.04
259.5	Apr 1, 1993 1630	0.04
268.1	Apr 2, 1993 1440	0.06
268.1	Apr 4, 1993 1445	0.57
234.9	May 26, 1993 0823	0.25
245.6	May 27, 1993 1648	0.25
245.6	May 28, 1993 0804	0.30
245.6	May 28, 1993 1038	0.30
245.6	May 29, 1993 1617	0.50
265.0	Jun 2, 1993 0806	0.60
265.0	Jun 2, 1993 1001	0.60
265.0	Jun 2, 1993 1541	0.50
230.5	Sep 29, 1993 1124	0.30
230.5	Sep 30, 1993 1013	0.42
245.0	Oct 1, 1993 1720	0.70
245.0	Oct 2, 1993 0938	0.90

Sample Site (River Mile)	Date/time of Observation	Secchi disk readings (m)
279.0	Oct 7, 1993 1001	0.55
230.5	Dec 2, 1993 0925	0.50
230.5	Dec 4, 1993 0921	0.07
246.0	Dec 8, 1993 1344	0.40
246.0	Dec 9, 1993 1143	0.40
246.0	Dec 10, 1993 1417	0.40

Table A-4. 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), 1992-1993.

Gear Types[a]	Life Stage[b]	Fish Species Codes[c]																		
		RS	FH	HB	CP	SD	FM	BH	SB	RB	CC	BB	WE	PK	GA	LM	GS	BC	BG	TS
EL	Y	29	0	0	10	0	0	0	0	0	0	0	0	0	20	9	0	2	0	23
	J	146	1	0	56	0	8	0	2	0	0	0	0	0	0	19	4	0	0	0
	A	1169	32	0	490	20	6	1	16	0	34	0	0	1	27	5	3	2	0	205
	T	1344	33	0	556	20	14	1	18	0	34	0	0	1	47	33	7	4	0	228
BP	Y	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	J	6	1	0	0	0	42	0	0	1	0	0	0	0	0	0	0	0	0	0
	A	1802	90	0	145	474	0	0	0	0	60	0	0	5	0	0	0	0	0	0
	T	1808	92	0	145	474	42	0	0	1	60	0	0	5	0	0	0	0	0	0
GM	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	J	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	A	0	0	0	8	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
	T	0	0	0	8	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
GP	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	J	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	A	0	0	0	15	0	0	0	9	0	13	0	0	0	0	0	0	0	0	0
	T	0	0	0	15	0	0	0	9	0	13	0	0	0	0	0	0	0	0	0
GS	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	J	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	A	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GX	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	J	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	A	0	0	0	0	0	0	0	1	0	8	0	0	0	0	0	0	0	0	0

Table A-4. Continued.

Gear Types[a]	Life Stage[b]	Fish Species Codes[c]																		
		RS	FH	HB	CP	SD	FM	BH	SB	RB	CC	BB	WE	PK	GA	LM	GS	BC	BG	TS
	T	0	0	0	0	0	0	0	1	0	8	0	0	0	0	0	0	0	0	0
TK	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	J	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	A	0	0	0	100	0	5	0	3	0	61	0	0	0	0	0	0	0	0	0
	T	0	0	0	100	0	5	0	3	0	61	0	0	0	0	0	0	0	0	0
TL	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	J	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	A	0	0	1	98	0	5	0	6	2	55	0	1	0	0	0	0	0	0	0
	T	0	0	1	98	0	5	0	6	2	55	0	1	0	0	0	0	0	0	0
TM	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	J	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	A	0	0	0	21	0	4	0	20	1	61	1	0	0	0	1	0	1	0	1
	T	0	0	0	21	0	4	0	20	1	61	2	0	0	0	1	0	1	0	1
TN	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	J	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	A	0	0	0	64	0	3	0	5	0	21	0	0	0	0	0	0	0	2	0
	T	0	0	0	64	0	3	0	5	0	21	0	0	0	0	0	0	0	2	0
TZ	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	J	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	A	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HM	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	J	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	A	157	0	0	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	T	158	0	0	4	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0

Table A-4. Continued

Gear Types[a]	Life Stage[b]	Fish Species Codes[c]																		
		RS	FH	HB	CP	SD	FM	BH	SB	RB	CC	BB	WE	PK	GA	LM	GS	BC	BG	TS
HS	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	J	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	A	1	0	0	15	0	0	0	0	0	6	0	0	0	0	0	0	0	0	1
	T	1	0	0	15	0	0	0	0	0	7	0	0	0	0	0	0	0	0	1
MT	Y	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	J	32	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
	A	449	112	0	3	176	0	0	0	0	0	0	0	10	0	0	0	0	0	0
	T	481	114	0	5	176	4	0	0	0	0	0	0	10	0	0	0	0	0	0
SA	Y	162	12	0	60	1	18	0	0	0	0	0	0	0	22	2	0	0	0	0
	J	562	541	0	0	1	19	0	0	0	0	0	0	4	18	0	0	0	0	0
	A	4897	1906	0	0	305	7	0	0	0	0	0	0	6	135	0	0	0	0	0
	T	5621	2459	0	60	307	44	0	0	0	0	0	0	10	175	2	0	0	0	0
SB	Y	0	0	0	31	0	6	0	0	0	0	0	0	0	0	0	2	0	0	0
	J	262	105	0	29	0	15	0	0	0	0	0	0	4	4	0	0	0	0	0
	A	592	393	0	0	9	1	0	0	0	0	0	0	19	22	0	0	0	0	0
	T	854	498	0	60	9	22	0	0	0	0	0	0	23	26	0	2	0	0	0
SG	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0
	J	17	0	0	1	0	18	0	0	0	0	0	0	0	0	4	0	0	11	0
	A	452	166	0	1	23	0	0	0	0	0	0	0	0	2	0	0	0	4	90
	T	469	166	0	2	23	18	0	0	0	0	0	0	0	2	4	0	0	37	90
AN	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	J	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	A	0	0	0	0	0	0	0	3	0	4	0	0	0	0	0	0	0	0	0
	T	0	0	0	0	0	0	0	3	0	4	0	0	0	0	0	0	0	0	0

Table A-4. Continued.

Gear Types[a]	Life Stage[b]	Fish Species Codes[c]																		
		RS	FH	HB	CP	SD	FM	BH	SB	RB	CC	BB	WE	PK	GA	LM	GS	BC	BG	TS
DN	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	J	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	A	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS		10,736	3,362	1	1,164	1,014	161	1	67	4	324	2	2	49	251	40	9	5	39	320

[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

Table A-5a. Results of the multiple-pass population estimate conducted at Site 1 (near confluence with main channel) in Spencer Creek, May, 1993.

Fish species	Number captured	Percent of sample	Population estimate (95% CI)	Estimated number/100 m^2	Mean length (mm) ± (1 SD)
Common carp (Cyprinus carpio)	60	65	61 (60,64)	12	403 ± (93)
Red shiner (Cyprinella lutrensis)	20	22	24 (20,35)	4	64 ± (10)
Speckled dace (Rhinichthys osculus)	5	5	5 (5,7)	1	55 ± (9)
Flannelmouth sucker (Catostomus latipinnis)	5	5	6 (5,15)	1	80 ± (26)
Channel catfish (Ictalurus punctatus)	3	3	3 (3,8)	1	301 ± (79)
Total	93	-	100 (93,109)	20	-

Table A-5b. Results of the multiple-pass population estimate conducted at Site 1 (near confluence with main channel) in Spencer Creek, October, 1993.

Fish species	Number captured	Percent of sample	Population estimate (95% CI)	Estimated number/100 m^2	Mean length (mm) ± (1 SD)
Red shiner (Cyprinella lutrensis)	115	41	116 (115,119)	80	55 ± (8)
Speckled dace (Rhinichthys osculus)	163	59	190 (167,213)	120	57 ± (7)
Total	278	-	296 (282,310)	190	-

Table A-5c. Results of the multiple-pass population estimate conducted at Site 1 (near confluence with main channel) in Spencer Creek, December, 1993.

Fish species	Number captured	Percent of sample	Population estimate (95% CI)	Estimated number/100 m^2	Mean length (mm) ± (1 SD)
Red shiner (Cyprinella lutrensis)	71	45	122 (71,202)	81	44 ± (10)
Speckled dace (Rhinichthys osculus)	64	41	82 (64,107)	55	62 ± (8)
Fathead minnow (Pimephales promelas)	22	14	29 (22,47)	19	46 ± (11)
Total	157	-	235 (162,308)	157	-

Table A-5d. Results of the multiple-pass population estimate conducted at Site 2 (0.75 mi upstream of confluence with main channel) in Spencer Creek, October, 1993.

Fish species	Number captured	Percent of sample	Population estimate (95% CI)	Estimated number/100 m^2	Mean length (mm) ± (1 SD)
Common carp (Cyprinus carpio)	4	<1	4 (4,6)	<1	389 ± (159)
Red shiner (Cyprinella lutrensis)	1,042	77	1100 (1077,1123)	220	59 ± (8)
Speckled dace (Rhinichthys osculus)	251	18	260 (252,268)	50	62 ± (7)
Fathead minnow (Pimephales promelas)	25	2	25 (25,25)	10	59 ± (7)
Flannelmouth sucker (Catostomus latipinnis)	40	3	40 (40,41)	10	123 ± (24)
Total	1362	-	1426 (1403,1449)	290	-

Table A-5e. Results of the multiple-pass population estimate conducted at Site 2 (0.75 mi upstream of confluence with main channel) in Spencer Creek, December, 1993.

Fish species	Number captured	Percent of sample	Population estimate (95% CI)	Estimated number/100 m^2	Mean length (mm) ± (1 SD)
Common carp (Cyprinus carpio)	3	<1	3 (3,3)	1	499 ± (30)
Red shiner (Cyprinella lutrensis)	710	86	721 (713,729)	142	47 ± (12)
Speckled dace (Rhinichthys osculus)	106	13	186 (106,290)	37	70 ± (6)
Fathead minnow (Pimephales promelas)	3	<1	3 (3,3)	1	47 ± (12)
Flannelmouth sucker (Catostomus latipinnis)	3	<1	5 (3,32)	1	160 ± (33)
Total	825	-	851 (837,865)	168	-