GLEN CANYON ENVIRONMENTAL SUDIES

PHASE II

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1. Executive Summary

The purpose of this report is to summarize progress by the Arizona Game and Fish Department (AGFD) in meeting the research objectives identified in Cooperative Agreement 9-FC-40-07940 between AGFD and the Bureau of Reclamation (BR). The information contained herein has primarily been collected in 1993, however, where appropriate, information from both Phase I and from the start of Phase II research are included. In that data presented are provisional and conclusions drawn from these data may change as additional data and analysis are incorporated, the reader is cautioned to contact the author prior to citing this report.

A primary objective of this research is to identify the impacts associated with different flow conditions on the aquatic conditions of Glen and Grand Canyons and select tributaries in these areas. Four specific research segments have been incorporated into the AGFD research program. Included are: ecosystem processes and lower trophic levels, native fish in the Colorado River, native fish in the Little Colorado River (LCR), and trout in the Lee's Ferry reach. Some of the key findings are identified in this Executive Summary.

Ecosystem Processes and Lower Trophic Levels

Gammarus density in benthos samples followed a seasonal cycle, peaking in the fall and reaching lowest levels in the spring. *Gammarus* densities at the 8,000 cfs flow level were significantly lower than those at the 5,000 cfs flow level were significantly lower than those at the 5,000 cfs flow level, as was periphyton biomass. De-watering and subsequent desiccation or freezing may have reduced both primary and secondary production in the Lee's Ferry reach. Preliminary analysis of size distribution of *Gammarus* suggested poor recruitment to sizes greater than 4 mm. Experiments were conducted to evaluate effects of exposure and desiccation on the nutritional quality of *Cladophora.*

Trout Studies

The age and growth structure of the Lee's Ferry trout population were modeled with length frequencies from 1984 - 1993 using the MULTIFAN approach. In terms of the estimated Von Bertalanffy growth coefficient (K), growth has decayed approximately 66%

from 1984 to 1992. Floy tag and coded wire tag returns appear to validate the MULTIFAN approach. Use of coded wire tags in hatchery stocked fish will greatly assist in future analysis of this fishery.

Native Fishes - Colorado River

Twenty-one river trips have been completed from March 1991 through November 1993. Data were collected for both fish and habitat parameters during these trips. In addition, zooplankton, benthos, and sediment samples were collected from both mainstem and backwater habitats. Humpback chub were abundant immediately below the mouth of the LCR during 1993. Floods in the LCR during January and February 1993 helped form many large backwaters between the mouth of the LCR and Upper Granite Gorge. Large numbers of young-of-the-year and juvenile humpback chub were collected from those backwaters during 1993. Very small chub were also collected from a backwater 20 miles upstream from the LCR and below a series of warm springs where mainstream spawning may be possible.

Native Fishes - Little Colorado River

Six fish species were captured during the spring monitoring period, four of which are endemic. Of these humpback chub and speckled dace were most abundant. Occurrence of native fish protolarvae indicated that all four native fishes had concentrated spawning periods from late April through mid-May. Occurrence of humpback chub larvae indicated that chub spawned into the beginning of June and probably into the beginning of July. Adult humpback chub in the LCR appeared to be largely sedentary, moving relatively short distances between recaptures. Results of larval fish longitudinal surveys support the hypothesis that decreasing spring flows and the accompanying increase in water temperature and decrease in turbidity may be environmental cues initiating spawning activity.

Temperature Tolerance of Humpback Chub and Colorado Squawfish

Early life stages of humpback chub and Colorado squawfish exposed to low temperature (10 C) lost equilibrium and mobility but did not die. Growth patterns of 6-9 day old humpback chub larvae reared at 10 C, 14 C, and 20 C averaged 10%, 37%, and 83% length gain, respectively over 30 days.

2. Ecosystem Processes and Lower Trophic Levels

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This chapter will present preliminary data and an update on the status of studies which are being conducted under Cooperative Agreement no. 9-FC-40-07940. The results from these studies will give us the opportunity to assess effects on the environment during interim flows. Because most of the data from the experiments are still being gathered, tabulated and analyzed results presented here are few. In addition, background information from other scientific sources are still being accumulated to assist in the interpretation of data.

OBJECTIVE 1.1. Evaluate the ecosystem-level processes that determine fish production in the Lee's Ferry tailwater. The processes of concern include primary production, nutrient uptake and regeneration, and transformation of organic matter between dissolved and particulate states. These processes are affected by dam/reservoir-mediated discharge regimes, water temperature and inflow chemistry.

METHODS

Estimates of particulate organic matter from Lake Powell fore-bay, Glen Canyon Dam draft tubes and the Colorado River at Lee's Ferry were taken monthly starting May 1993. Coarse particulate organic matter (CPOM) was sampled over 24 hour periods coincident with low, rising, high and falling flows of the daily hydrograph.

Lake Powell

Estimates of particulate organic matter from Lake Powell fore-bay were taken monthly starting April 1993. Hydrolab measurements were taken in the Lake Powell fore-bay prior to sampling for fine particulate organic matter (FPOM) (0.7μm - 1μm size fraction) to determine degree of stratification and positions of the epilimnion, metalimnion and hypolimnion. Measurements included dissolved oxygen, pH, specific conductance, temperature and oxidation-reduction potential. Measurements were taken every 1.5m for the first 60m, then every 3m to 90m. Two water samples each, from the surface, penstock depth and 75m were collected with a diaphragm pump and filtered through a 1mm mesh, into pre-cleaned 5 gal polypropylene carboys. Samples for FPOM biomass (g AFDW) and chlorophyll *a* were filtered from each of two 3l subsamples onto pre-weighed, pre-burned (AFDW) or unburned (chlorophyll a) glass fiber filter paper. Zooplankton were collected by filtering 100l of water through an 80 μm plankton net and preserving in 2.5% formalin.

Glen Canyon Dam

FPOM samples were collected from central draft tube sampling ports and passed through a 1μm mesh into pre-cleaned 5 gal polypropylene carboys and filtered as above. Hydrolab readings were taken immediately following collection of water aliquots.

Lee's Ferry

Hydrolab measurements were taken from the approximate midpoint of the river 1/4 mile above Lee's Ferry. Zooplankton were gathered by filtering 100l of river water through an 80μm plankton net and preserving in 2.5% formalin. FPOM samples were taken by pumping water from the river while traversing from one side to the other along a transect normal to the flow, while raising and lowering the pump intake. Water was passed through a 1mm mesh net to remove coarse particulate components and filtered as described for Lake Powell FPOM samples. CPOM was gathered by towing a metered net with a 0.5m diameter opening and 1mm mesh across the river while raising and lowering the net. Resulting material was sorted (e.g., *Cladophora*, terrestrial litter, *Gammarus*)and quantified by percent volume displacement. Algal material was dried and ashed for biomass estimation. Invertebrates were counted and preserved in 95% ethanol. *Gammarus* were sent to a contract laboratory for length measurements, egg enumeration and examination for parasites. Bulk samples of CPOM were dried, ground, subsampled and frozen and will be sent off for determination of Kjeldahl nitrogen (TKN), total phosphorus (Total P) and total organic carbon (TOC) as soon as a contract laboratory has been selected. Additional tests for percent C and percent N will be performed on initial samples to be able to compare our data with that of Angradi et al. (1992). Changing from measuring percent C to TOC and percent N to Kjeldahl nitrogen will better estimate the organic fraction of these elements in CPOM.

Additional CPOM samples were gathered according to the methods of Angradi et al. (1992) to permit comparison of data. CPOM collection methods were changed as a result of Miller tubes clogging with large clumps of CPOM. This clogging problem resulted in high variability in data (T. Angradi, pers. comm.).

Spring sampling

Hydrolab measurements for temperature, pH, dissolved o_2, conductivity and redox were taken monthly from six springs in Glen Canyon.

Laboratory procedures

Chlorophyll *a* levels and AFDW were measured in FPOM samples as follows. A saturated solution of $MgCO_3$ (100μl) was added to the final 200ml being filtered. Filters were placed into petri dishes, wrapped in foil and frozen until analyzed. Thawed samples (previously filtered) were homogenized in a hand-held glass homogenizer (20ml) in 20.0ml methanol. Contents were transferred to a 250ml beaker and the homogenizer rinsed with an additional 20.0ml methanol. The homogenate was boiled in a water bath (80° C) for 2 min. A 40.0ml aliquot was filtered (10-12 lb vacuum) into a 50ml graduated cylinder. Optical density of a 15ml aliquot was read at 480nm, 750nm, 666nm and again at 750nm against a methanol blank. The aliquot then was acidified with 122μl of 1N HCl, vortexed and optical density read at the above wavelengths after 90 sec (Tett et al 1975).

CPOM volume was made by placing the sample in a pan and separating algae and non-algae matter. Algal matter was then drained and placed in a 250 micron sieve over paper toweling, blotted gently and allowed to dry for 1 min. Algae and non-algae matter were then transferred to separate graduated cylinders containing either 300ml (algae) or 30ml (non-algae) tap water to determine volume displacement. Proportion of each type of matter was calculated relative to total volume displaced by both subsamples. AFDW of algae then was determined. Initial preservation of samples in 10% formalin prohibited direct determination of AFDW and dry weight; estimations were made for these samples based on results with fresh samples.

AFDW and dry weight were determined following standard procedures. Samples were dried at approximately 100° C for 24 hr, desiccated for 20 min minimum and ashed for 2 hr (500°-525° C). Samples were cooled, desiccated for an additional 20 min and weighed.

CURRENT STATUS

FPOM and CPOM samples and hydrolab data have been collected since May 1993. FPOM samples have been analyzed for biomass (AFDW) and chlorophyll a. These data are currently being entered into the computer and will be analyzed in the next few weeks. CPOM taxonomic samples have been analyzed and preserved, counted or ashed, and data are awaiting entry into the computer. CPOM samples for TKN, TOC and Total P have been collected, frozen and are being dried prior to sending to the contract laboratory for analysis. The Contract laboratory for the analysis of FPOM and CPOM (TKN, TOC and Total P) and nutrient samples has not been selected. Samples will be collected as soon as some necessary equipment has been received and a contract laboratory has been selected.

OBJECTIVE 1.2. The objective of work task 1.2 is to determine the impact that Glen Canyon Dam releases have on *Gammarus lacustris* and determine how those releases affect the overall productivity of the amphipod. An effort will be made to determine the sources of organic matter required for *Gammarus*. Autochthonous organic matter inputs will be measured and evaluated as related to *Gammarus lacustris* production.

METHODS

Gammarus productivity

Gammarus lacustris were sampled monthly with a Hess sampler (0.09 m^2) immediately below the 8000 and 5000 cfs river elevations. Samples were preserved with a 10% formaldehyde solution. Eight samples were collected at each elevation and at each of three sites: 14 mile bar, 4.1 mile bar (first sampled January 1993) and 3.5 mile bar. The 4.1 mile bar collection site was added because of its similarity to 14 mile bar in terms of substrate homogeneity. Flow velocity measurements were taken at the time of sampling. In the laboratory, benthos samples were rinsed in a 250μm sieve, contents were placed into a dissecting pan, and invertebrates were counted and preserved in 95% ethanol. Preserved *Gammarus* were sent to a contract laboratory for length measurements, egg enumeration and examination for parasites.

RESULTS

Gammarus density in benthos samples followed a seasonal cycle, peaking in the fall and reaching lowest levels in the spring (Figure 1.1). At the 5,000 cfs flow level, lowest densities occurred during March-April at the 3.5 mi and 14 mi sites. At 14 and 3.5 mi peak *Gammarus* numbers occurred during September and October (Fig. 1.2). Increasing densities from June through October probably reflect onset of the annual cycle of reproductive recruitment. Mean densities during each month at 3.5 mi were 11/2 to 2 times those observed at 14 mile.

While the annual pattern of densities at the 8,000 cfs flow level remained generally the same as at the 5,000 cfs level, numbers per square meter tended to be much lower (Fig. 1.1). At 14 mi, 8,000 cfs, densities essentially stabilized during August - January. Densities fell to minimum levels at 3.5 mi during Febuary - March. This tendency toward decline was also apparent during March and April at 14 mi. Generally, densities observed at the 8,000 cfs flow level at 3.5 mile ranged from 5-50% of values found for the 5,000 cfs level, and differences at 14 mi were comparable. *Gammarus* densities at the 4.1 mi 8,000 cfs level ranged from 20-60% of values found for the 5,000 cfs level(Figure 1.2). Data were not available from the 5,000 cfs flow level during December and January at 4.1 mi and also during January at 14 mi and 3.5 mi, due to high river flows.

Analyses revealed no significant correlation between mean monthly minimum flows and mean monthly *Gammarus* densities at either 5,000 cfs or 8,000 cfs flow levels at any site (Table 1.1, Figures 1.1 and 1.4). Future analysis will examine if duration of flow below the 8,000 cfs level on a monthly basis may be correlated with *Gammarus* density.

Table 1.1. Correlation coefficients comparing mean *Gammarus* density at 14 mile, 4.1 mile and 3.5 mile (5000 and 8000 cfs elevations) with mean minimum monthly flow.

	14 mile 5000 cfs	14 mile 8000 cfs	4.1 mile 5000 cfs	4.1 mile 8000 cfs	3.5 mile 5000 cfs	3.5 mile 8000 cfs
r	.01538	0.4008	0.8922	0.8150	-0.1786	.4529
n	11	12	3	5	11	12
P	0.652	0.197	0.298	0.093	0.599	0.139

Mean *Gammarus* densities (Table 1.2) were compared using a two way ANOVA with a log(x+1) transformation to correct for non-normality. Significant differences were found among river miles 14, 4.1 and 3.5 (DF 2, F=16.14, P<0.001) and between river elevations 5000 cfs and 8000 cfs (DF 1, F=303.8, P<0.001). Using the LSD comparison of multiple means, it was found that *Gammarus* densities at the 8,000 cfs flow level at all sites (14 mi, 4.1 mi and 3.5 mi) were significantly below those found at the 5,000 cfs flow level (P<0.05)). Also, densities at the 8,000 cfs flow level were significantly greater at 3.5 mile than at 14 mi and 4.1 mile as compared to 14 mile (P<0.05), but densities did not differ significantly between 4.1 mile and 3.5 mile (P>0.05). At the 5,000 cfs flow level, *Gammarus* density was significantly higher at 3.5 mile than at either 14 mile or 4.1 mile (P<0.05). However densities at river mile 14 and 4.1 mile were not significantly different (P>0.05).

Table 1.2. Mean (± 1SE) *Gammarus* densities at river miles 14, 4.1 and 3.5 at 5000 and 8000 cfs elevations.

ELEVATION	MILE 14	MILE 4.1	MILE 3.5
5000 CFS	3,645.9 ±281.7 n=82	1,929.1 ±186.8 n=24	6,196.5 ±537.0 n=87
8000 CFS	533.7 ±49.38 n=95	1,354.0 ±155.2 n=40	1,291.2 ±137.7 n=96

The smallest size class (1-3.99mm) of *Gammarus* varied from month to month at all sites and elevations (Figure 1.3). However increases in abundance for the 1-3.99mm size class did not transfer at any site or flow level to the next higher size class in the following months. Remaining size classes were fairly constant from month to month at 14 mile, less so at 3.5 mile. No statistical analyses have been performed on size classification data, but these data will be analyzed for the final report.

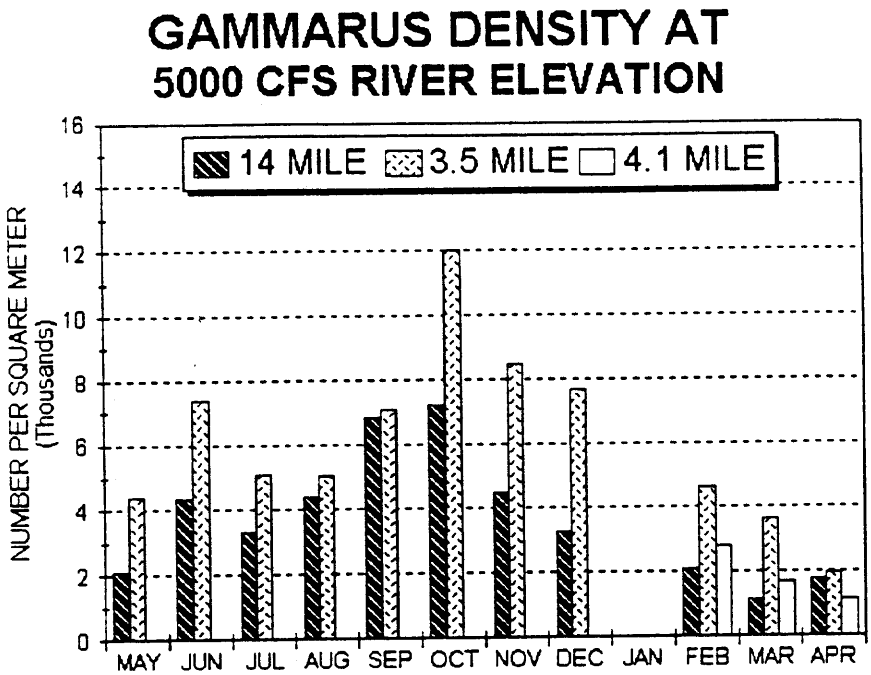
DISCUSSION

Although data on *Gammarus* size distribution are incomplete, the seasonal increase in density during summer months appears primarily due to recruitment of the smallest size class (1-3.99mm). However, *Gammarus* larger than 4mm had much less variability in numbers from month to month (Figure 1.3). These results may indicate reduced recruitment into the larger size classes. Small individuals could be lost due to predation, drift or stranding.

Preliminary data indicate that very few *Gammarus* were found in the drift. This may be due to sampling method. The current method does not effectively sample sides and bottom of the channel. Future sampling could include these areas if proper equipment were obtained. We plan to use existing trout gut data (yet to be analyzed) to evaluate *Gammarus* loss due to predation. We also plan to gather additional trout gut data, emphasizing collection of smaller individuals (which have been under-sampled in the past). Increasing numbers of small trout have been observed during the last winter (B. Persons pers. comm.), and predation by this group could explain differential loss of small *Gammarus*.

The significantly lower numbers of Gammarus at 8000 cfs (versus 5000 cfs) correspond to lower periphyton biomass (see section 1.5) at this elevation (Figures 1.2 & 1.5). Lower quantities were probably due to low flows from Glen Canyon Dam and subsequent de-watering of this elevation. This de-watering and subsequent desiccation or freezing may have reduced both primary and secondary production.

Data on size of maturation, clutch size and reproductive seasonality for *Gammarus* are still being analyzed by our contract laboratory and will be incorporated into the final report in December.



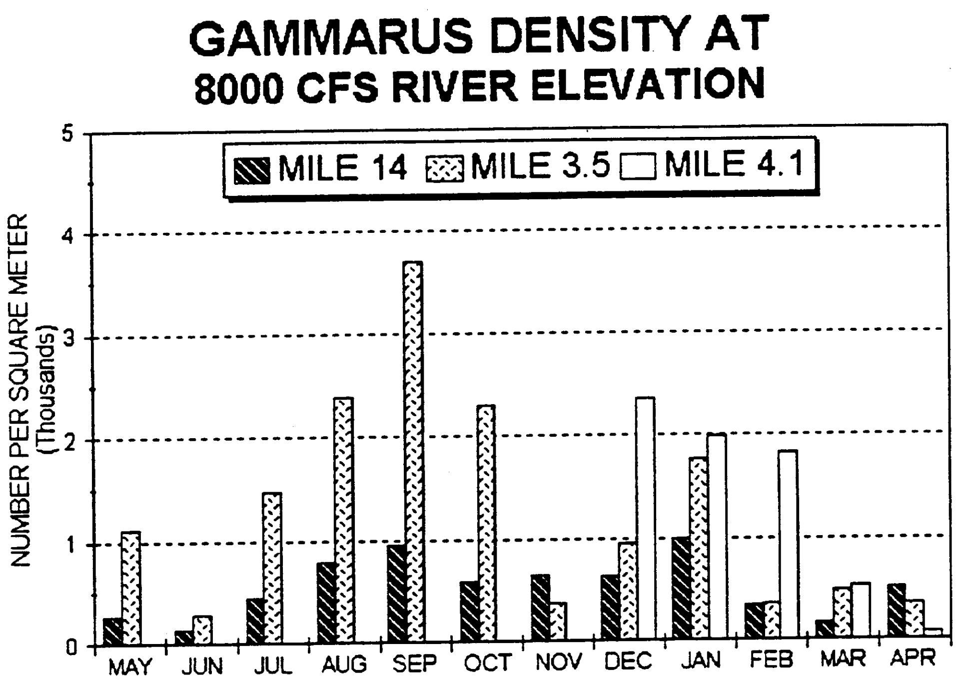


Figure 1.1. *Gammarus* density (number / m^2) at 5000 and 8000 cfs river elevations, river miles 14, 4.1 and 3.5, May 1992 - April 1993.

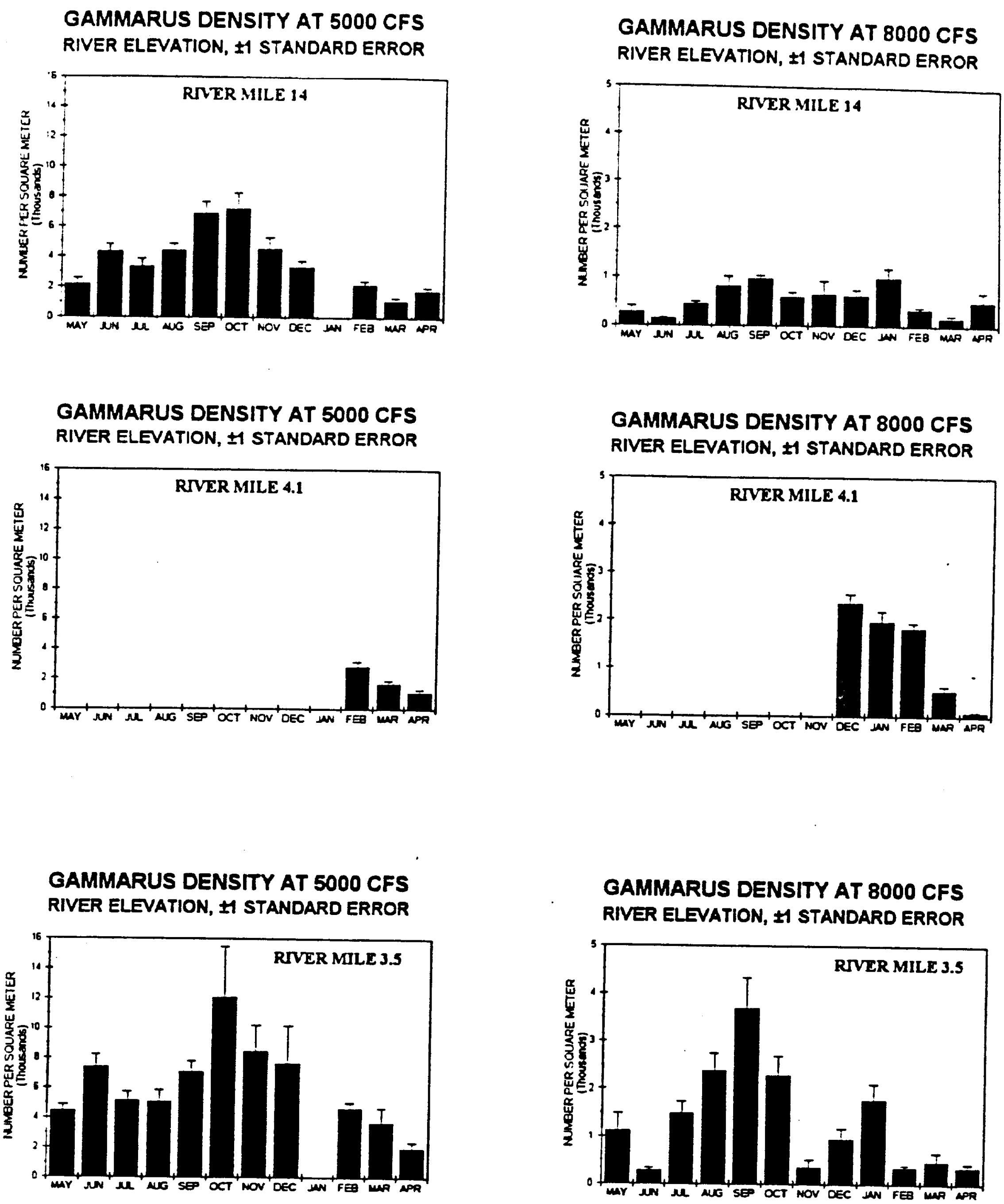


Figure 1.2. *Gammarus* density (number / m^2) at 5000 and 8000 cfs river elevations river miles 14, 4.1 and 3.5, May 1992 - April 1993.

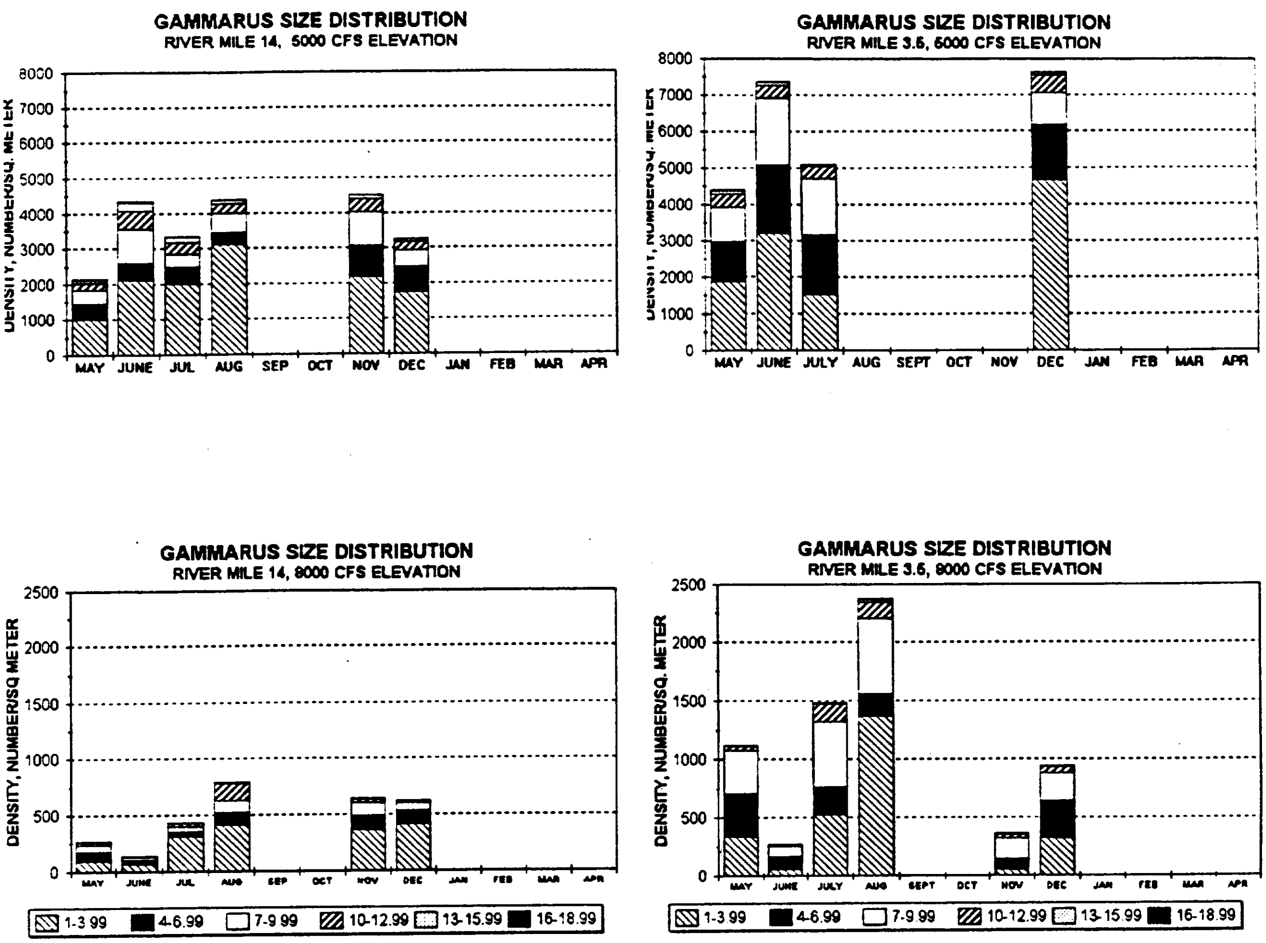


Figure 1.3. *Gammarus* size(mm) distribution at river miles 14 and 3.5, 5000 and 8000 cfs river elevation.

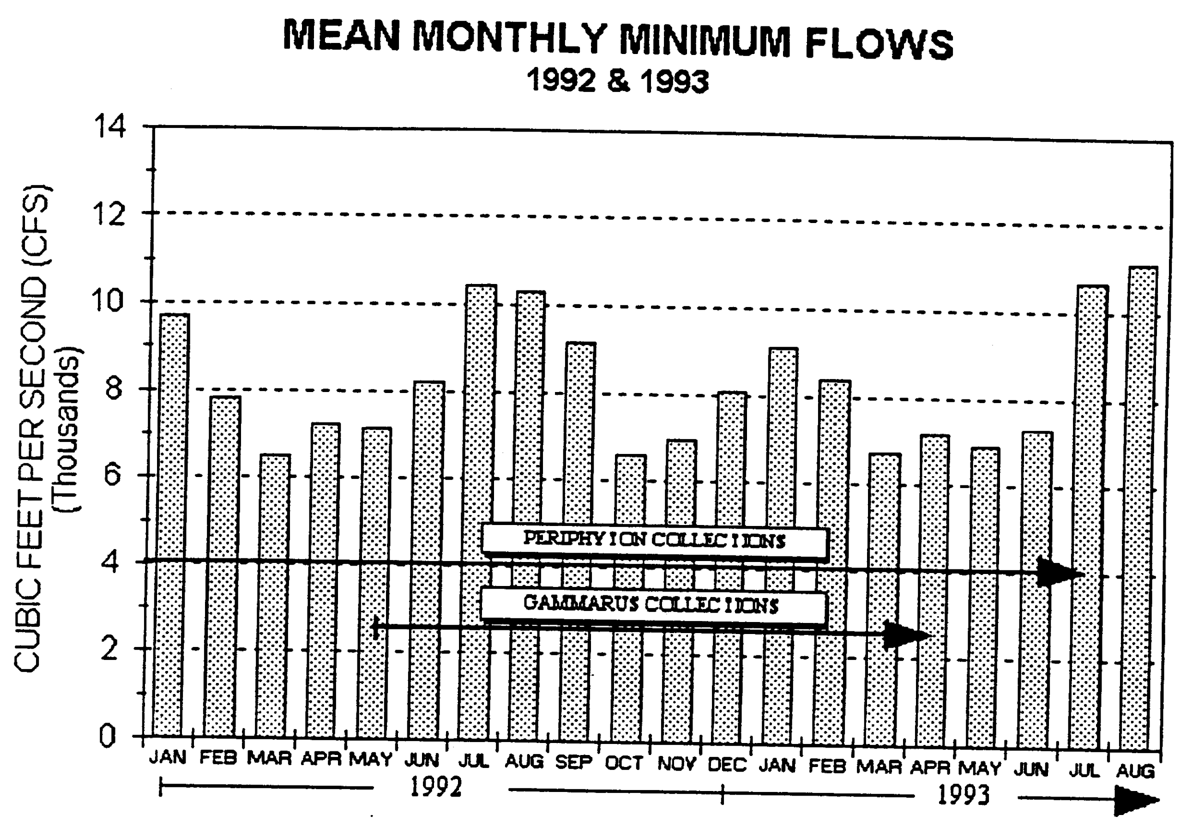


Figure 1.4. Mean monthly minimum flows from Glen Canyon Dam during years 1992 & 1993. Periphyton and *Gammarus* collection periods are indicated by arrows.

OBJECTIVE 1.3. Determine the effect of desiccation rates and time on the colonization and growth of *Cladophora glomerata* and its epiphytic diatoms. Experiments to determine the relationship of flow levels and community response are the overall objective.

METHODS

During April, artificial substrate sites were established at 4.1 mi, 9.0 mi and 14.0 mi above Lee's Ferry. At each site, 2 m transects were situated parallel to river flow at 5,000 cfs, 6,000 cfs, 7,000 cfs and 8,000 cfs flow levels. At each flow level, five sets of four native sandstone substrates (approximately 70mm x 70mm) were placed in the river, attached to an expanded metal base.

A second set of substrates was placed adjacent and parallel to the sandstone tiles to measure invertebrate colonization rates. Each unit consisted of five small (2 1/2 in maximum diameter), conical clay flower pots affixed to threaded rod. Pots were placed so that the open portion faced downstream.

Tile substrates were collected at four week intervals by removing one set of four from each location and placing them into watertight containers containing river water. The containers were placed into iced coolers and taken to the laboratory within four hours following collection. Two tiles from each set were analyzed for AFDW, chlorophyll *a* and pheophytin *a*, and the other two tiles were sent directly to Arizona State University for analyses of algal species composition.

Pot substrates were collected at four week intervals by carefully inserting them (while immersed) into cylindrical plastic containers. Both container and substrate were carefully rinsed into a 250 micron sieve, using a pressure spray and river water. Each substrate was sealed into a plastic bag, and sieve contents were rinsed into a plastic bottle. Formaldehyde solution (10%) was added in volume equal to that of river water in the bottle from rinsing. Samples were transported to the laboratory and analyzed immediately for invertebrate abundance and composition (genus level).

Tiles were analyzed for chlorophyll *a* and pheophytin *a* (Tett et al. 1975). Organic matter was scraped and brushed from each tile (surface only) and collected in a dissecting tray. Surfaces of tiles were washed into the tray with double distilled water (DDH_2O). Length and width of tile surface was recorded and pan contents transferred into a 250 ml graduated cylinder by washing with DDH_2O. Volume in the graduated cylinder was noted, and contents were transferred to a blender flask. The graduated cylinder then was brought to desired end volume with DDH_2O (based on sample size; e.g. 150ml), and contents were added to the blender and blended for 90 sec. A 10-30ml aliquot (based on visual assessment of relative chlorophyll content) was then transferred to a vacuum filtering system and filtered (10-12 lb vacuum, Whatman GF/F filter) following addition of 100μl of a saturated $MgCO_3$ solution. After filtration, filters were stored frozen in plastic containers wrapped in aluminum foil until analyzed further. Tile substrate samples on filter paper (previously filtered) were homogenized in a hand-held 20ml glass homogenizer in 20ml methanol. Contents were transferred to a 250 ml beaker and homogenizer rinsed with an additional 20ml methanol. The homogenate was boiled in a water bath (80° C) for 2 min, then filtered (10-12 vacuum) into a 50ml graduated cylinder. Optical density of a 15ml aliquot was read against a methanol blank at 480nm, 750nm, 666nm and again at 750nm. The aliquot then was acidified with 122μl of 1N HCl, vortexed and optical density read at the above wavelengths after 90 sec.

Aliquots of tile homogenate (see above) were filtered onto burned glass fiber filter paper and processed for AFDW. These determinations were made following standard procedures. Samples were dried at approximately 100° C for 24 hr, desiccated for 20+ min and ashed for 2 hr ((500°-525°C). Samples were cooled, desiccated for an additional 20 min, and weighed.

CURRENT STATUS

Tile chlorophyll a, AFDW and invertebrate data are being entered into the computer and will be analyzed as soon as possible. We are awaiting data on algal species composition from the contract lab and will begin analysis of these data as soon as they are received.

OBJECTIVE 1.4. Evaluate effects of exposure and desiccation on the nutritional quality of *Cladophora glomerata* and its associated epiphytes. The intent is to determine if exposure of *Cladophora* to desiccation will increase the nutrient quality due to breakdown of the algal mats.

METHODS

During July 11-13, 1993, a study was implemented to examine effects of desiccation and re-inundation on periphyton nutritional composition. Cobbles were collected randomly from below the 5,000 cfs flow level 14.0 mi above Lee's Ferry. They were transported immediately in coolers containing river water to a dock at Glen Canyon Dam and placed into a covered polyethylene tank. Water from the river was pumped continuously into the tank at a rate adequate to maintain water temperature in the tank equal to that of the river (8°-9° C) and water level approximately 6 in above surface of all organic matter.

Following an initial sampling,(using the periphyton procedure described below (see objective 1.5)) all rocks (except controls) were placed outside the tank and exposed to ambient conditions for 6 hr from 12:00 PM to 6:00 AM to simulate a period of exposure due to a low flow level. After exposure samples again were taken and all rocks returned to the tank. Rocks then were removed and sampled at intervals (15 min, 1 hr, 2 hr, 4 hr, 8 hr, 16 hr, 32 hr and 64 hr following desiccation) and immediately returned to the tank.

Controls (n=4, no desiccation) were sampled 0 hr, 2 hr, 8 hr, 32 hr and 64 hr after termination of desiccation. At each sampling period, 10 rocks were selected randomly, removed and sampled (n=10). Samples were placed on dry ice, taken immediately to the laboratory and held frozen for subsequent lyophilization and analyses for total protein, total carbohydrates, total lipids, AFDW and dry weight.

Total protein was determined using a modification of Lowry et al. (1951). Lyophilized samples (20.0g) were ground to powder in a ceramic mortar and pestle. A 20.0mg subsample was homogenized using hand-held glass homogenizer with teflon pestle attached to a fixed hand drill) in 5.0 ml DDH_2O. Duplicate 1.0ml aliquots were mixed in test tubes with 1.0ml 2N NaOH and placed in a water bath (60° C) for 60 min. A 0.5ml aliquot then was taken, mixed in a test tube with 5.0ml of alkaline copper solution (1.0ml 1% $CuSO_4$; 1.0ml 2% sodium tartrate; 98.0ml 2% Na_2CO_3) and vortexed. After 20 min at room temperature, 500 μl of 1N Folin's phenol reagent (Sigma Chemical Co.) were added, and test tubes were vortexed immediately, covered with parafilm and let stand (room temperature) for 30 min. Optical density was read at 660nm against appropriate reagent blanks. Standards were prepared using bovine serum albumin (BSA) and treated in the same manner as the samples. Total protein was calculated using a standard curve.

Total carbohydrates were determined by modifying the Scott and Melvin (1953) procedures. Samples were homogenized as described above, and duplicate 0.5ml aliquots were mixed with 2.5ml DDH_2O in clean test tubes. Test tubes were placed in an ice water bath, and 6.0ml of 0.2% anthrone (w/v, concentrated H_2S0_4) were added slowly. Test tubes were mixed by vortexing carefully. Once at room temperature, they were placed in a 90°C water bath for 16 min with marbles placed on top of the tubes to prevent spurting. Test tubes were removed from the water bath and immediately placed in an ice bath to cool to room temperature. A 5.0ml aliquot was transferred to a cuvette and optical density read against reagent blanks at 625 nm . Standards were prepared using glucose was used as the standard, and treated in the same manner as the samples. Total carbohydrates were calculated using a standard curve.

Lipids were extracted according to the method of Bligh and Dyer (1959) as modified by Mayzaud and Martin (1975). Two 20.0mg subsamples were taken from each sample and homogenized in 1.4ml of distilled water. A 1.2ml aliquot of the homogenate was transferred to a 15ml centrifuge tube; 3.0ml of methanol and 1.5ml of chloroform were added. The solution was vortexed for 1 min, then held at 5^0C for at least 10 min. After centrifugation for 5 min at 0^0C and 800g , the supernatant was carefully transferred to a clean centrifuge tube. An additional 1.5ml chloroform and 1.5ml distilled water were added and the solution vortexed for 15 sec. The tube was centrifuged again at 0^0C for 10 min at 800g, and the top phase was removed by aspiration. The lower phase was dried at 50^0C and the residue redissolved in 2.5ml chloroform.

Total lipids were determined using the method of Pande, et al. (1963). The extract (2.0ml) was transferred to the bottom of a clean test tube and the solvent removed by slow vacuum to prevent spurting. Then, 3.0ml 2% potassium dichromate (w/v) in 98% (w/v) sulfuric acid was added. The tube was then capped with a glass cap, placed in a boiling water bath for 15 min and cooled in running tap water. After cooling, 4.5ml distilled water was added and the solution mixed carefully and re-cooled. The solution was transferred to a cuvette and the optical density read against a reagent blank at 590 nm. A standard curve using palmitic acid was used to determine lipid content.

CURRENT STATUS

Samples are currently being analyzed for their protein, carbohydrate and lipid composition. This is expected to take another two weeks, at which time data will be analyzed.

OBJECTIVE 1.5. Provide for comparative data collection of the water chemistry and aquatic food base elements. This work will be concentrated in the immediate area above Glen Canyon Dam and in the tailwater section from Glen Canyon Dam to Lee's Ferry. The specific techniques will follow those established under GCES Phase II research program.

WATER CHEMISTRY PROPOSED METHODS

Once a contract laboratory has been secured water samples will be collected monthly from Lake Powell fore-bay surface and penstock depth, from Glen Canyon Dam draft tube ports and from the Colorado River below the dam at 14 mile bar, six major springs and Lee's Ferry .

Lake Powell

Hydrolab measurements will be taken in the Lake Powell fore-bay prior to sampling for nutrients to determine the degree of stratification and positions of the epilimnion, metalimnion and hypolimnion. Measurements will include dissolved oxygen, pH, specific conductance, temperature and oxidation-reduction potential. Measurements will be taken every 1.5m for the first 60m and then every 3m to 90m. Two water samples each, from the surface, penstock depth, and 75m will be taken. Water samples will be collected with a diaphragm pump and filtered through 1mm mesh into precleaned 5 gal polypropylene carboys. Zooplankton will be collected by filtering 100l of water through an 80 μm plankton net and preserving in 2.5% formalin. Samples are to be identified (to genus) and quantified in the laboratory. Samples for FPOM biomass and chlorophyll *a* (a measurement of phytoplankton abundance) will be filtered from each of two 3l subsamples onto pre-weighed and pre-burned glass fiber filter paper. Samples for nutrient analysis (NH_4, NO_2, NO_3, orthophosphate and silica) and DOC will be taken from 0.45μm filtrates of the lake water. Samples for TOC, Total P and TKN will be taken from 125ml subsamples of unfiltered lake water. Nutrient samples will be collected once a contract laboratory is selected, preserved immediately according to their specifications and sent for analysis.

Glen Canyon Dam

Samples from central drift tubes for FPOM, zooplankton and dissolved nutrients will be collected from central draft tube sampling ports and passed through a 1mm mesh. Hydrolab readings will be taken immediately following collection water aliquots.

Lee's Ferry and 14 mile bar

Hydrolab measurements will be taken from the approximate midpoint of the river at Lee's Ferry. Zooplankton will be gathered by filtering 100l of water through an 80μm plankton net and preserving the sample in 2.5% formalin. FPOM, chlorophyll *a* and nutrient samples will be taken from transects normal to flow by pumping water from the river using a diaphragm pump while raising and lowering the intake. The water will be handled as described for Lake Powell FPOM and nutrient samples.

Spring sampling

Six springs will be measured monthly using the hydrolab for temperature, pH, dissolved O_2, conductivity and redox. They will be sampled for nutrients as above when a contract has been awarded.

Laboratory procedures

Chlorophyll *a* samples will be processed as follows. A saturated $MgCO_3$ solution (100μl) will be added to the final 200ml being filtered. Filters will be placed into petri dishes, wrapped in foil and frozen until analyzed. Thawed samples (previously filtered) will be homogenized in a hand-held glass homogenizer (20ml) in 20ml methanol. Contents will be transferred to a 250ml beaker and homogenizer rinsed with an additional 20ml methanol. The homogenate will be boiled in a water bath (80° C) for 2 min and filtered (10-12 lb vacuum) into a 50ml graduated cylinder. Optical density of a 15ml aliquot will be read against a blank at 480nm, 750nm, 666nm and again at 750nm . The 15ml aliquot will be acidified with 122μl of 1N HCl, vortexed and optical density read at the above wavelengths after 90 sec (Tett et al. 1975).

Dry weight and AFDW will be determined following standard procedures. Samples will be dried at approximately 100° C for 24 hr, desiccated for 20 min and ashed for 2 hr ((500°-525° C), cooled, desiccated for an additional 20 min and weighed.

METHODS

PERIPHYTON BIOMASS

Periphyton samples were collected monthly 4.1 mi, 13.5 mi and 14.0 mi above Lee's Ferry. Cobbles were collected along pre-established 25 m transects corresponding to 5,000 cfs and 8,000 cfs flow levels. Samples (n=15) were taken from the top of each cobble (1-3 samples per cobble) by placing a small cylinder (4.12cm^2) on each rock surface. Organic matter within the cylinder was removed by cutting, scraping and rinsing (with river water) the material into plastic vials. Samples were placed on ice for transport and subsequently frozen prior to determining chlorophyll a, pheophytin a, dry weight and AFDW.

Periphyton samples were thawed immediately prior to analysis for chlorophyll a/pheophytin a (Tett et al 1975), placed directly on a standard glass GF/F filter, washed lightly with DDH$_2$O and filtered (10-12 lb vacuum). The filter with sample was placed into a blender flask and blended for 1 min in 200ml methanol. A 40ml aliquot then was boiled for 2 min in a water bath (80° C) and filtered (10-12 vacuum) into a 50ml graduated cylinder. Methanol was added to the filtered extract to a final volume of 40ml. Optical density of a 15ml aliquot was read against a blank at 480nm, 750nm, 666nm and again at 750nm. The aliquot then was acidified with 122μl of 1N HCl, vortexed and optical density read at the above wavelengths after 90 sec.

AFDW and dry weight were determined using standard methods. Samples were dried at approximately 100° C for 24 hr, desiccated for 20 min and ashed for 2 hr (500°-525° C). Samples were cooled, desiccated for an additional 20 min. and weighed.

RESULTS

Periphyton

No seasonal pattern of periphyton growth was apparent at any site or flow level (Figure 1.5). Mean periphyton biomass values at river miles 14 13.5 and 4.1 and at 5000 and 8000 cfs elevations were compared using a two way Anova with a log(x+1) transformation to correct for non-normality. Periphyton biomass was significantly higher at the 5,000 cfs flow level than at the 8,000 cfs flow level over all sites (DF=1, F=406.0 P<0.001). Significant differences were found among river miles 14, 13.5 and 4.1 (DF=2, F=79.7, P<0.001). Using the LSD comparison of multiple means it was found that biomass was significantly higher at 13.5 mile bar versus 4.1 mile bar, and 14 mile bar was significantly higher than either 13.5 mile bar or 4.1 mile bar (P<0.05).. However, greatest differences in periphyton biomass between flow levels occurred at 14 mi, and monthly deviations were substantial at all sites and both flow levels (Figure 1.5). No strong relationship seemed to exist between mean monthly minimum flows and periphyton biomass at either 5,000 cfs or 8,000 cfs flow levels (Figures 1.5 & 1.4). This relationship will be analyzed statistically in the final report.

Changes in periphyton chlorophyll *a* and total pigment were similar during April - August to those seen in periphyton biomass at 4.1 mi and 13.5 mi, 5,000 and 13.5 mi, 8,000 cfs flow levels (Figures 1.5 and 1.6). However, this relationship did not seem to occur at 14 mi or 4.1 mile 8,000 cfs. Proportion of chlorophyll *a* as percent of total pigment remained essentially stable at all sites during April-August, though some monthly fluctuations were apparent. Future analyses will examine mg chlorophyll *a* per gram of biomass at all three sites.

Total pigment and chlorophyll *a* levels at the 8,000 cfs flow level ranged from 20%-50% of those at the 5,000 cfs flow level (Figure 1.6). Exceptions occurred at 13.5 mi during April, when chlorophyll *a* and total pigment levels at 8,000 cfs flow level were 1.5 times those at the 5,000 cfs flow level and during July 1993 when they were essentially equal.

DISCUSSION

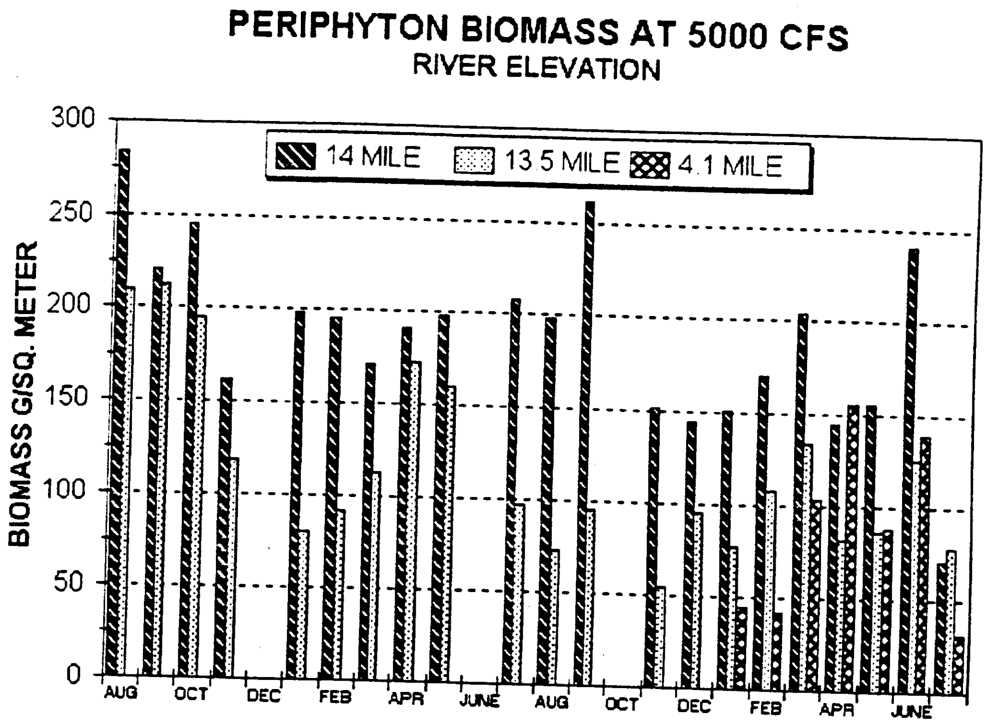
No seasonal pattern was noted for periphyton biomass at the 5,000 or 8,000 cfs elevation (Figure 1.5). Lack of a seasonal pattern at 5,000 cfs may have been due to minimum water levels being maintained above this level during interim flows. Therefore, the algal mat was not exposed to desiccation or freezing. Lack of a clear seasonal pattern in periphyton biomass at the 8000 cfs elevation may have resulted from multiple factors. For example, freezing temperatures one or two nights per month in January or February 1993 may have inflicted more damage than much longer and much more frequent periods of desiccation under milder conditions. In support of this possibility, biomass levels at 8000 cfs elevation were greatly reduced during January and February 1993 (Figure 1.5), when subfreezing nighttime temperatures occurred. Reduced biomass also seemed to occur at the same time flows were minimal during April, May and June 1993 (Figure 1.4). Further monitoring of periphyton, climatic conditions and flow levels may clarify their interrelationships.

Lower levels of chlorophyll *a* found at river mile 4.1 may have reflected greater abundance of diatoms as compared to filamentous green algae (Figure 1.6). Data concerning algal species composition (not yet received from contractor) will enhance interpretation of these reduced chlorophyll *a* levels, as will calculation of chlorophyll *a* per gram ash free dry weight, since diatoms contain less chlorophyll *a* per unit of ash free dry weight (Bold and Wain, 1978).

Similarity of changes in chlorophyll *a* levels and periphyton biomass indicate that periphyton contained a consistent percentage of algal material. Discrepancies, e.g. the July 1993 data at river mile 14, 8000 cfs elevation (Figures 1.5 & 1.6), probably were due to occasional occurrence of invertebrates in periphyton samples.

CURRENT STATUS

Sampling for nutrients from Lake Powell fore-bay, Glen Canyon Dam draft tubes and the colorado river at river mile 14 and Lee's Ferry will begin as soon as a contract with a laboratory has been established. We are currently sampling for FPOM chlorophyll *a* and zooplankton at all of these locations except river mile 14 as fulfillment of work task 1.1 (see above).



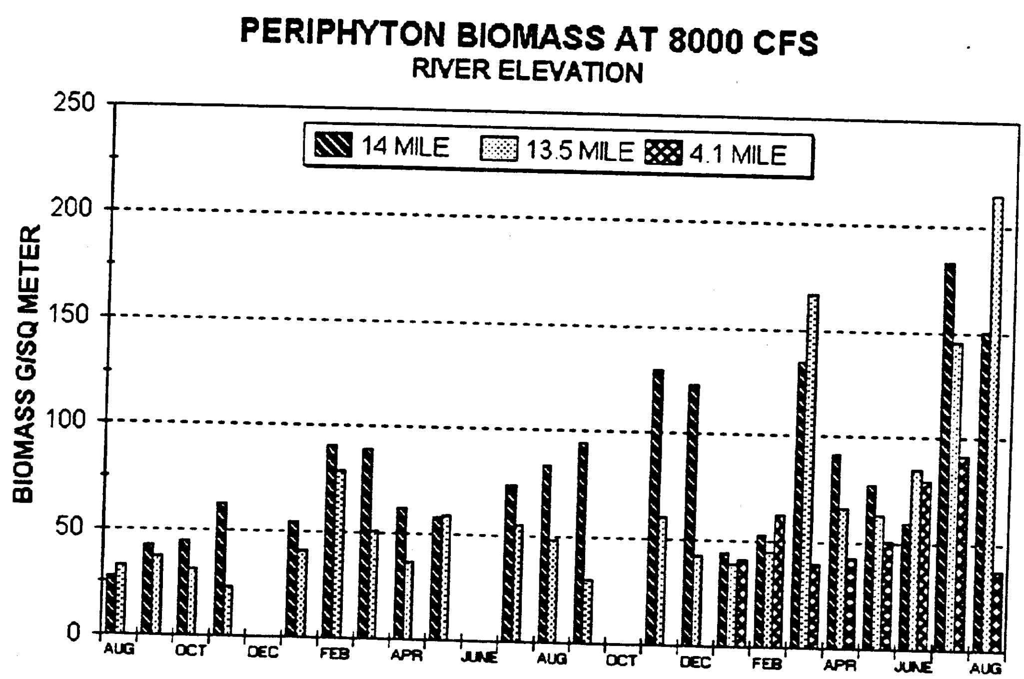


Figure 1.5. Periphyton biomass (g/m^2) at 5000 and 8000 cfs river elevation, river miles 14, 13.5 and 4.1, August 1991 - August 1993.

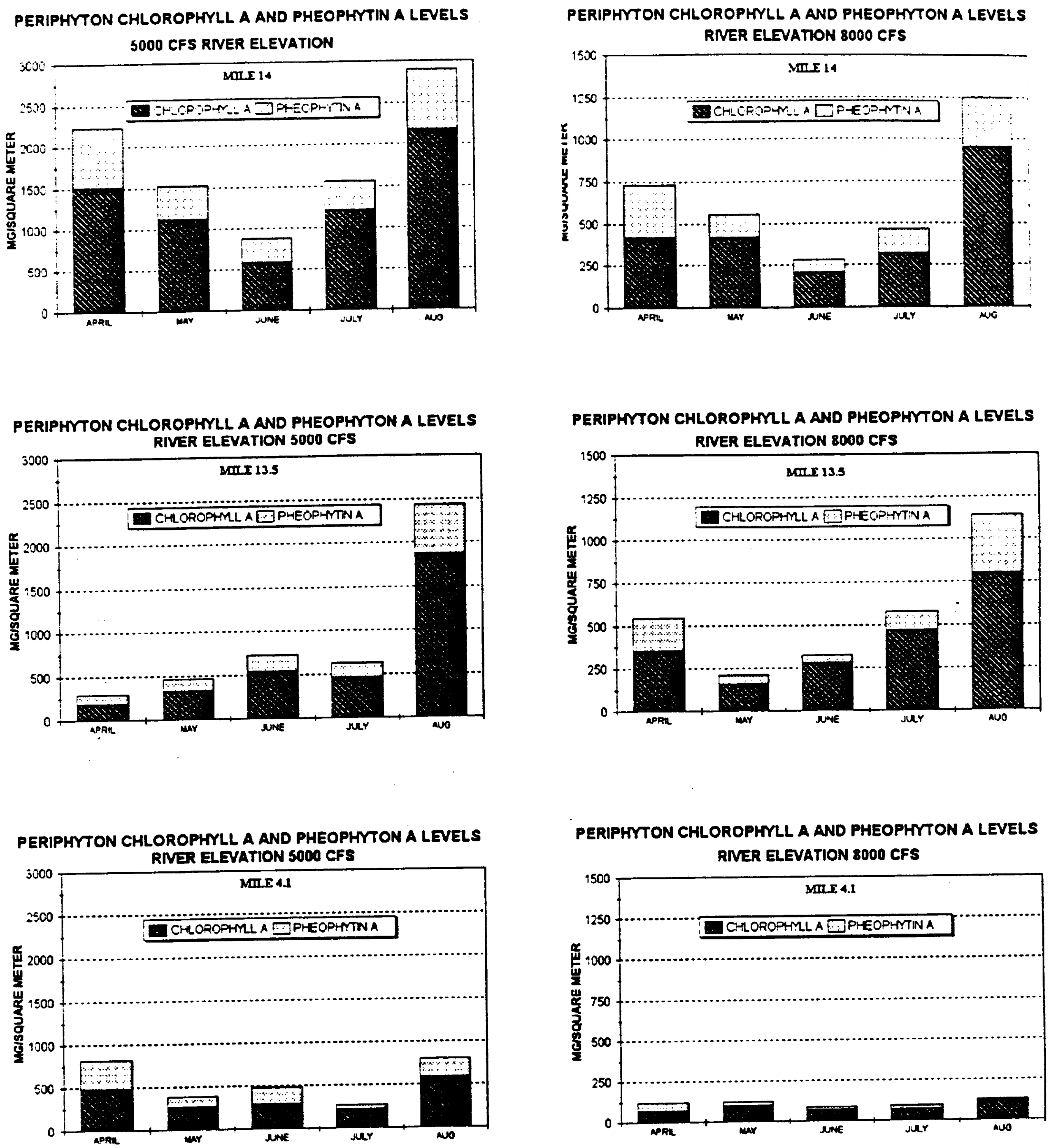


Figure 1.6. Periphyton chlorophyll *a* and pheophytin *a* concentrations (mg/m^2) at river miles 14, 13.5, and 4.1 and 5000 and 8000 cfs elevations.

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3. Rainbow Trout

M. K. Musyl

INTRODUCTION

The purpose of this draft report is to summarize initial results of the GCES trout project in fiscal year 1992-1993. Although prior reports have focused on year-to-year results, it is our intention to analyze some of the data available from 1984 to the present in an historical context. In particular, temporal trends in the length-at-age and growth of trout in Lee's Ferry can be better parameterized by examining a suitable time series of data.

As some of the results are preliminary and additional results and analyses are still pending, the results (and data) must be viewed as 'provisional'. Therefore, this draft report will attempt to accomplish three main objectives; i) present preliminary results to date (Appendix 2.1), ii) indicate which types of analyses are still pending and iii) outline prospective manuscripts for submission to peer reviewed journals. Lastly, it is also our intention to fashion the final report into a series of manuscripts that will address each of the main work tasks as outlined in the contractual agreement.

Work item 2.1 - Determine the potential loss of trout spawning, defined as areal loss of spawning bars and exposure of redds, at various flows in the reach of the Colorado River between Glen Canyon Dam and Lee's Ferry.

Previous reports have summarized many aspects of this work item (Angradi *et al.* 1992; Arizona Game & Fish Department [AGFD] 1993). Additional data and analyses will include the following:

1) Maps of spawning bars are currently being generated from past survey data by GIS personnel at AGFD. These maps will include contours at varying flow regimes.

Redd density data will also be calculated from these maps. Loss or gain of spawning habitat will be tested against fluctuating flows by regression analyses.

2) The potential feasibility of a regression model will be examined to forecast the relative abundance of trout by using redd density data, CPUE data and/or relative population estimates (see also item 2.2). This model will assume a strong relationship between redd density and relative abundance. However, an additional component in the model must be estimated to cover the impact of hatchery introductions.

Work item 2.2 - Determine the rate of stranding and mortality of naturally reproduced and stocked trout under different flow regimes in the Glen Canyon tailwater.

Background information for this task is presented elsewhere (Angradi *et al.* 1992; AGFD 1993). New information on the mortality of trout is presented in Appendix 2.1. Further analyses will include the following:

1) By regression analyses, the relationship between stranding and flow regimes will be estimated.

2) Relative population estimates (and hence mortality) can be estimated by careful analysis of mark-recapture data provided by externally tagged and coded wire tagged (CWT) trout for some locations in Lee's Ferry. Since 1984, personnel from AGFD have externally tagged approx. > 10,000 trout in Lee's Ferry. Preliminary analysis of some of these mark-recapture data suggest limited movement in trout with movements usually confined to river locations where trout were tagged. Due to the nature of previous tagging strategies, even and continuous coverage for some of the locations in Lee's Ferry was not implemented. As such, three general models of

relative population abundance will be calculated for trout in some locations from Lee's Ferry:

i) Single census methods. Since we are interested in a relative index, a simple Peterson model would suffice. However, as more information is gained on the survivability of hatchery trout (*e.g.* see Appendix 2.1), refinements to the model can be made (Ricker 1975).

ii) Multiple census methods. These methods (*e.g.* Schnabel & Schumacher-Eshmeyer) are extensions of the single census estimates. As the number of marked fish increases, the variance of the estimates decreases.

iii) Multiple recapture methods. This method, Jolly-Seber, is used when closed populations cannot be assumed (Ricker 1975).

iv) The estimates derived from i-iii will be used in the predictive model with redd density data (see 2.1, #2).

v) Mark-recapture summaries for trout tagged in Lee's Ferry will be presented in the final report. This summary will recount mark-recapture histories for trout tagged by external fluorescent dyes, fin clips, and by Floy and Carlen tags. Estimation of movement patterns will also be quantified by using these data.

Addendum to Work Item 2.2. Conduct a literature review of trout strains. This should include an assessment of the relationship between trout strains and their interaction with flows, growth, survivorship and movement.

This item has been completed (see AGFD 1993 for additional details).

Work item 2.3 - Determine the effects of fluctuating flows on age and growth relationships of stocked trout in the Glen Canyon Dam tailwater downstream of Lee's Ferry.

This work task is treated in Appendix 2.1 and background information is provided in previous reports. To quantify presumptive lengths-at-ages given in Appendix 2.1, bony structures (scales from "key" areas, otoliths, pre-opercle) will be re-examined from new specimens to verify (if possible) results from the MULTIFAN approach.

Work item 2.4 - Determine the behavioral responses of trout in the Glen Canyon Dam tailwater to different steady and fluctuating flow regimes.

Information concerning this work item is given in Angradi *et al.* (1992) and AGFD (1993). Additional analyses of mark-recapture data will allow estimation of movement patterns in relation to varied flow regimes.

Proposed manuscript titles:

1) "Technical demonstration of the MULTIFAN model to infer the population dynamics of a tailwater rainbow trout *Oncorhynchus mykiss* fishery: Glen Canyon Dam, Colorado River". (this draft manuscript is given in Appendix 2.1).

2) "Analysis of varying flow regimes from Glen Canyon Dam (Lake Powell) and their impact on a tailwater rainbow trout *Oncorhynchus mykiss* fishery at Lee's Ferry, Colorado River".

3) "Relative estimates of redd density, abundance and mortality of rainbow trout *Oncorhynchus mykiss* in a perturbed system: Glen Canyon Dam, Colorado River".

4) "Use of coded wire tagged hatchery rainbow trout *Oncorhynchus mykiss* to estimate their contribution to a tailwater trout fishery in Glen Canyon, Colorado River".

APPENDIX 2.1

Technical demonstration of the MULTIFAN model to infer the population dynamics of a tailwater rainbow trout *Oncorhynchus mykiss* fishery: Glen Canyon Dam, Colorado River

INTRODUCTION

Of the potential problems that face fisheries investigators, perhaps the most serious is the inability to assign correct age-classes to the cohorts that comprise the fishery. These inabilities may stem from artifactual flaws or may represent a true biological phenomenon. For instance, some cool-water and tropical fish species do not always leave discernable age marks or annuli on their bony structures or scales to signify spawning or seasonal growth. In addition, determining ages from length-frequency distributions can be problematical when cohorts are not readily apparent. Tagging studies may overcome this problem as cohorts can be tracked through time but this methodology poses special problems and added expense. As such, in situations where age cannot be determined from bony structures, sometimes the only information available is from length-at-catch data. Fortunately, statistical techniques have been developed to take advantage of such data (*e.g.* Bhattacharya's method, ELEFAN I, MULTIFAN, Shepard's SRLCA).

Such is the case of the tailwater rainbow trout *Oncorhynchus mykiss* fishery below Glen Canyon Dam (Lake Powell), Colorado River, Lee's Ferry. The fishery extends approximately 16 river miles (ca. 27 km) downstream from the tailwaters of the dam to Lee's Ferry, which is a major access point. Descriptions of the river corridor and physio-chemical parameters of this stretch are provided elsewhere (Persons *et al.* 1985; Maddux *et al.* 1987). Previous attempts to age rainbow trout with otoliths and scales proved unsuccessful, possibly due to the release of hypolimnial water from Lake Powell which remains relatively constant (8.4 to 10.4 C) throughout the year (Persons *et al.* 1985; Maddux *et al.* 1987).

When Glen Canyon Dam was filled in 1963, rainbow trout were stocked to take advantage of the newly created cold tailwater and provide a recreational fishery. Later in 1968, simultaneous introductions of the filamentous algae *Cladophora glomerata* and the amphipod *Gammarus lacustris* were envisaged to help bolster the food base of the introduced rainbow trout (Maddux *et al.* 1987). Hatchery supplementation of the fishery continues on a regular basis.

In the early part of the fishery, trout flourished in their newly created habitat and the fishery was managed as a "blue-ribbon" fishery for a number of years. However, in the late 1980s and early 1990s, the fishery declined. Reasons to account for the decline were speculative. However, the decline coincided with a change in dam operations and the appearance of emaciated trout in the system. Creel statistics indicate that the harvest and mean relative weight has steadily declined from 1977 to 1992 (AGFD 1993).

Virtually all of the emaciated trout were found to be infected by an endo-parasitic nematode, *Buldodacnitis ampullastoma* (Landye, *pers. comm.*). Since 1963, different strains of rainbow trout have been stocked in the fishery from outside origins (see Persons *et al.* 1985). It is reasonable to speculate that the parasite was an unwitting introduction from an *ex*-hatchery stock. For example, Hiscox & Brocksen (1973) investigated the effects of *B. ampullastoma* on the growth and mortality of a hatchery stock of rainbow trout. They indicated that this parasite was responsible for reduced growth rates in experimentally inoculated trout. Under conditions of starvation, infected trout had a 60% higher mortality than non-parasitized trout. Lastly, their experiments were conducted on the Kamloops strain of rainbow trout, a strain that has been stocked into Lee's Ferry.

Because the occurrence and etiology of the parasite was never quantified, these observational data do not provide an explanation for the overall impact of the parasite on trout growth and mortality. In general, the reasons for collapse of the fishery largely remains unknown. However, monitoring of the fishery commenced in 1984 and has continued to the present. In this paper, we analyze a time series of length-frequency data from 1984 to 1993 using the MULTIFAN approach. With this method, we were able to model the age and growth structure of the Lee's Ferry trout population.

METHODS

Description of MULTIFAN Model

MULTIFAN is a non-linear statistical procedure that can describe length-frequency data with a robust maximum likelihood procedure (Fournier *et al.* 1990, 1991; Tercerio *et al.* 1992). In situations where reliable biological information was obtained to verify the results of the MULTIFAN model (*e.g.* southern bluefin tuna *Thunnus maccoyii* [Fournier *et al.* 1990] and pandalid shrimp *Pandalus borealis* [Fournier *et al.* 1991]), the model gave very similar results. Part of the formulation behind the model is based on the fact that better parameter estimation (*e.g.* von Bertalanffy K, $L\infty$, Z, t_0) and number of significant age-classes can be obtained by simultaneously analyzing a time series of length-frequency data. The reader is encouraged to consult Fournier *et al.* (1990, 1991) for the mathematical formulation of the model.

Although it is beyond the scope of this paper to present the mathematical formulation behind the model, certain assumptions of the model will aid the reader in interpreting the model and results. Much of the following is taken from Fournier *et al.* The main biological assumptions of the model are:

1) lengths of trout in each age class are normally distributed around their mean length;
2) mean lengths at age lie on (or near) a von Bertalanffy growth curve (K); and
3) standard deviations of the actual lengths about the mean at age are a simple function of the mean length at age.

Several structural hypotheses and different number of age classes can be tested in the model. The best fit of the parameter estimates to a time series of length-frequency distributions are determined using X^2 tests. A X^2 test is used to determine a significant increase in the maximum value of the log-likelihood function using initial values of K with different age classes. The increase in the maximum value of the log-likelihood function is tabulated by adding each age class into the model. If the increase is significant, the next age-class is included in the model. The process is repeated until adding extra age classes does not lead to a significant increase in the maximum value of the log-likelihood function.

Significance of fits is determined in the following way. For example, if 2 fits are compared and one contains $r + 1$ parameters, under the hypothesis that the simpler model is the correct one (Occam's razor), then twice the difference between the value of the log-likelihood function will be asymptotically distributed as a X^2 random variable with r degrees of freedom. Again, the reader is encouraged to consult Fournier *et al.* for more details.

Two types of errors can be made in the tests of significance: accepting an extra age class in the model (type 1) or rejecting an extra age class when it is present (type 2). Fournier *et al.* reported that better estimates of K were obtained when the number of age classes in the model was over estimated rather than underestimated. As such, to reduce the probability of type 2 errors in estimation of age classes, the 0.90 level of the X^2 random variable was employed. For all other parameters, the 0.95 level was used.

In summary, the best fit of the model can be defined as:

1) it should not be possible to add any new parameters that produce a significant improvement in fit to the model and
2) it should not be possible to remove any parameters from the model without producing a significant degradation in fit.

Rainbow trout were collected by electrofishing from 1984 to 1993 in various locations from Lee's Ferry. In this period, the sampling strategy was either randomly stratified to represent a cross-section of different riverine habitats (*e.g.* cobble bars, runs, riffles, pools, sand bars) or was purely random. All lengths were taken as TL measured to the nearest mm.

RESULTS

For trout in Lee's Ferry, several different structural hypotheses were tested using the MULTIFAN approach. These models were based on biological information for rainbow trout summarized in Carlander (1969), from prior rainbow trout studies in Lee's Ferry (Persons *et al.* 1985; Maddux *et al.* 1987; Reger *et al.* 1988) and from results of coded wire tagged (CWT) hatchery introductions. From this information, it was decided to model from five to eleven different age classes with bounds placed on the first presumptive age class (L_1). In addition, varying K values and length dependent standard deviations (σ) were incorporated into the models. Given the fact that Lee's Ferry trout are from perennially cool-waters, slow growth and a mixture of age-classes was anticipated. A summary of the parameters estimated for each of the five to eleven age-class models is presented (Table 1).

Table 1. Summary of the parameters estimated in each model. A + or - indicated whether or not the corresponding parameter is estimated in the model.

	Model			
Parameter	1	2	3	4
L_1	+	+	+	+
K	+	+	-	-
σ	+	-	-	+

The time series of length-frequency data for trout was collected from 4/84 to 5/93 and are presented in five separate data sets each containing ten samples (odd numbered Figs. 1,3,5,7,9; even numbered Figs. 2,4,6,8, 10 correspond to the "blobs" display and von Bertalanffy growth curves for each of the five temporal data sets). As a reminder to the reader, strength in the procedure is increased by simultaneously analyzing a time series of data sets. Due to limitations of our particular version of MULTIFAN, only 10 length-frequency samples could be used to construct each of the five data sets. For this reason, eight samples from Data Set 4 were used to create the last data set (#5) which included data from two samples collected in 1993. Table 2 summaries the best parameter fits to each of the length-frequency data sets.

Table 2. Estimates from the best fits to data sets 1, 2, 3, 4, and 5. λ_1 is the average standard deviation and λ_2 is the ratio of the first to last standard deviation.

	Data set				
	1	2	3	4	5
log likelihood	11422.87	12297.88	13261.10	12512.23	12427.09†
estimated parameters	(45)	(45)	(85)	(44)	(45)†
df	367	361	237	408	431†
significant age classes	5	5	9	5	5†
$L\infty$	670.8	695.6	651.8	865.4	1219.0†
K	0.468	0.262	0.246	0.160	0.083†
λ_1	42.56	34.53	29.01	43.94	41.84†
λ_2	0.55	0.85	0.52	1.00	0.95†

†Convergence was never achieved in Data Set 5

Data Set 1

This time series of length frequency samples was collected between 4/84 and 12/85 and exhibited the highest estimated growth (*K*) in the data sets (Table 2; and Figs. 1 & 2).

Numerous modes were apparent in the length-frequency distribution in which model 1 gave the best fit with five age classes.

In the accompanying figures, dashed vertical lines are the estimated mean length at age, inner smooth curves are estimated numbers at age and the outer smooth curve is the estimated length-frequency distribution. Horizontal bars in the figures are bounds constrained on the mean length at age for the presumptive first mode or age-class. Samples are ordered in the data sets by year, month, and day. For example in Fig. 1 (Data Set 1), the first sample (#1 1/4/1) was collected on 4/84 and the last sample (#10 2/12/1) was collected on 12/85. The following figures are labelled using the same convention.

Data Set 2

This time series was collected between 2/86 and 12/89 and had the best fit with model 1 and five age classes. In the five data sets, only Data Set 2 exhibited good resolution of a 'first' mode with clear evidence of modal progression in the distributions (Table 2; Figs. 3 & 4).

Data Set 3

This time series was collected between 1/90 and 1/91. Best fit was estimated again by model 1 but with nine age classes instead of five as estimated in the previous two data sets (Table 2; Figs. 5 & 6). This data set was unusual because the apparently 'single mode' showed obvious negative growth in some instances (Figs. 5 & 6). In addition, there was virtually no indication of recruitment (taken here as obvious occurrence of smaller individuals) to the fishery.

Data Set 4

Rainbow trout in this time series were collected between 1/91 and 11/92. Best fit of the parameters was obtained by model 2 with five age classes (Table 2; Figs. 7 & 8). Here, in this data set (Fig. 7), two modes can be distinguished from 8/91 to 11/92. However, the skewness in the patterns of distributions is reversed from 5/92 to 8/92. Again, there is little evidence of gross modal progression and, in some instances, negative growth was apparent.

Data Set 5

Convergence in this data set was never achieved using any of the models. Since eight of the data samples were taken from Data Set 4, it seemed reasonable to use the parameters generated from that data set into the estimation of the parameters for Data Set 5 (Table 2; Figs. 9 & 10). The samples in Data Set 5 are nearly identical in their distributions from 8/92 to 5/93 (Fig. 9). As evidenced in Data Set 4 (Fig. 7), the apparent pattern of shifting skewness was preserved in the 1993 samples (*cf.* Figs. 7 & 9).

Growth Trends

In terms of the estimated von Bertalanffy growth coefficients (*K*) for the data sets (Table 2), growth has decayed approximately 66% from 1984 to 1992. Except for Data Set 4 (and 5), $L\infty$ (length at infinity or asymptotic length) remained relatively steady in the data sets (Table 2; see also the von Bertalanffy growth curves in Figs. 2, 4, 6, 8, 10).

To verify and compare the estimates for *K* and $L\infty$ in the MULTIFAN model, we analysed the growth of marked and recaptured Floy-tagged rainbow trout from 1984 to 1993 and converted lengths to ages using an assumed von Bertalanffy growth curve [FABENS2 program as reported in Sims (1985) and later modified by Kimura (1980)]. The results of this analyses and one other (Persons *et al.* 1985) are given in Table 3.

Table 3. Mark-Recapture studies of Lee's Ferry Trout from 1984 to 1993.

Mark-Recapture Year (*n*)	$L\infty$ (95% C.I.)	*K* (95% C.I.)
1984 to 1985 (32)	459 (401-517)	.0038 (.0002-.0074)
1986 to 1988 (51)	447 (421-473)	.0014 (.0006-.0022)
1989 to 1990 (120)†	40.4 (-344-424)	-.0001
1989 to 1990 (76)	348 (331-366)	-.0005
1990 to 1991 (69)	527 (481-573)	.0004 (.0003-.0005)
1992 to 1993 (32)	450 (423-468)	.0017 (.0012-.0022)

†1989 to 1990 data sets had to split up because case limits for the program was exceeded (*i.e.* $n > 120$; see Kimura and Sims for more details).
Persons *et al.* (1985) used a Walford plot and suggested a $L\infty$ of 580 mm and a *K* of 0.707 for eight specimens captured between 1984 to 1986.

The estimates of these data (Table 3) are not directly comparable to estimates derived from the MULTIFAN model since Floy-tagged trout were usually tagged at sizes greater than 250 mm. That is, these mark-recaptured specimens do not adequately estimate growth from t_0 to 250 mm and probably miss the main inflection of the von Bertalanffy growth curve. Never-the-less, the estimates of *K* for tagged specimens decay (55%) in a manner similar to the decay reported for *K* in the MULTIFAN approach (Table 2).

Monitoring the growth of CWT trout in Lee's Ferry commenced in 1992 with approximately 70,000 marked fingerlings stocked at a size of about 50 to 125 mm in May 1992 . The growth and relative survivability of this hatchery cohort are reported in Table 4.

Table 4. Mean total length of coded wire tagged hatchery rainbow trout. *S* is the relative survivability.

	viii.92	ix.92	iii.93	v.93
Mean TL	147 (± 24)	171 (± 37)	207 (± 49)	217 (± 53)
S	?	68%	73%	66%

Since it is apparent that hatchery trout can grow to a size of 270 mm in about 14 months (hatching date approx. 3/92), it was reasonable to place bounds on the first presumptive age class in the MULTIFAN model in about the same size range (*e.g.* see Figs. 1,3,5,7,9). As a general note, the model does not require an exact figure for the placement of bounds and does allow for some flexibility. It was decided to place bounds in this region to "tell" the model what size a one year old trout might attain in the fishery. However, this growth rate may not be true of resident-spawned trout (*e.g.* see Table 7). This constraint was necessary because most of the data sets do not contain a clearly resolved mode in this size range. And when younger fish are apparent in the distributions, most of these individuals (except for the 1993 samples) probably represent hatchery introductions. At this stage, there was no way to determine whether 'resident-natural' trout exhibit similar growth to hatchery introductions since spawning has been documented throughout the year in Lee's Ferry (Persons *et al.* 1985; Maddux *et al.* 1987). Probably after an initial heavy mortality, the relative survivability of the 1992 hatchery cohort appears to have remained constant (Table 4).

MORTALITY

In the absence of population estimates of Lee's Ferry rainbow trout, natural mortality (*M*) was estimated by using the growth parameters generated by MULTIFAN with Pauly's empirical formula. Holt (1962) suggested that *K* is related to water temperature whereas $L\infty$ is related to food availability and possibly other factors. Based on the data from 175 fish stocks, Pauly (1980) determined a linear relationship based on *M*, *K*, $L\infty$, and *T* (degrees centigrade) in the following relationship:

$$\ln M = -0.0152 - 0.279 (\ln L\infty) + 0.6543 (\ln K) + 0.463 (\ln T).$$

Table 5 shows values of *M* calculated by Pauly's formula for combinations of $L\infty$, *K*, and *T*. Since *M* is directly estimated from the MULTIFAN model, the reader is cautioned that these estimates, are, at best, only "qualified guesses" (Sparre & Venema 1992).

Table 5. Natural mortality calculated by Pauly's formula for various combinations of $L\infty$ and *K* with $T = 10°$ C)

$L\infty$	**K 0.001**	**.01**	**.1**	**.2**	**.4**	**.6**	**.8**	**1.0**
400	.006	.026	.12	.19	.30	.38	.46	.54
500	.006	.025	.11	.18	.28	.36	.44	.51
600	.005	.024	.11	.17	.26	.34	.41	.48
700	.005	.023	.10	.16	.25	.33	.40	.46
800	.005	.022	.098	.15	.24	.32	.38	.44
900	.005	.021	.095	.15	.24	.31	.37	.43
1000	.005	.020	.092	.15	.23	.30	.36	.42

Three generalizations can be made from the formula (Sparre & Venema 1992):

1) small fish have high natural mortalities;

2) fast growing species have high natural mortalities; and

3) the warmer the ambient water temperature the higher the natural mortality.

DISCUSSION

The overall interpretation of the MULTIFAN model suggests rainbow trout in Lee's Ferry exhibit slow growth and contain perhaps a mixture of 5+ age classes. This interpretation seems biologically reasonable. For example, the preferred stream temperature of rainbow trout is given as 12° to 19°C (Raleigh *et al.* 1984) which is warmer than the tailwaters of Glen Canyon Dam. Moreover, as suggested by Holt (1962), K is a function of ambient water temperatures. From this, slow growth of trout in Lee's Ferry would be predicted given the perennially cool-waters. Next, the estimated mean lengths-at-ages correspond favorably with rainbow trout found in other stream habitats (Tables 6 & 7). In addition, slow growth was also suggested for mark-recaptured trout in Lee's Ferry (Table 3). Whether or not these mark-recapture data are reliable is debatable given that the von Bertalanffy growth of smaller trout (*e.g.* < 250 mm) was never estimated. Never-the-less, these data appear to verify aspects of the MULTIFAN model.

Natural mortality estimates derived from Pauly's formula (Table 5) and survivability of hatchery trout (Table 4) appear to support the same general conclusion. That is, slow growth combined with low mortality would seem to suggest a population comprised of many age classes. Continued monitoring of CWT hatchery trout will help clarify aspects of this study in regard to mortality, growth and the number of age classes present in the population.

The MULTIFAN analysis of the length-frequency data sets suggested a different length-at-age pattern than that reported by Persons *et al.* (1985) and Reger *et al.* (1988) for

Lee's Ferry Trout (Table 6). In their analyses, both Persons *et al.* and Reger *et al.* used creel data in addition to electrofishing data and suggested relatively fast growth. However, they also visually estimated their length-at-age relationships from length-frequency distributions which can be highly inaccurate (Fournier *et al.*). For instance, it may be incorrect to assume that consecutive modes in a length-frequency distribution reflect dominant age classes unless the pattern conforms to von Bertalanffy growth. Analysis of the data from Persons *et al.* indicate that their suggested growth pattern did not conform to von Bertalanffy growth. As such, their interpretation of the data must be regarded with caution. MULTIFAN estimates at lengths-at-ages were more similar to those reported in the literature than either Persons *et al.* or Reger *et al.* (Table 7).

Table 6. Estimated mean lengths at age for Lee's Ferry rainbow trout. Data from Persons *et al.* (1985), Reger *et al.* (1988) and the MULTIFAN model.

	I	II	III	IV	V	VI	VII	VIII	IX
Persons *et al.* (1985)	378	470	564						
Reger *et al.* (1988)	254	378	470	564	635				
Data Set 1	84	250	407	506	567				
Data Set 2	80	222	331	414	479				
Data Set 3	184	286	366	428	476	515	544	568	586
Data Set 4	85	200	299	383	454				
Data Set 5	93	188	275	354	427				

Table 7. Mean lengths-at-age calculated for stream rainbow trout by examination of annuli. Code refers to references cited in Carlander (1969).

Code	Locality	*n*	I	II	III	IV	V	VI	VII
B155	MT, Prickly Pear C.	*860*	89	168	239	300	424		
K34	MT, Missouri R.	*478*	81	201	282	343	404	421	470
B145	WY, Firehole R.	*198*	135	234	328	396			
B145	WY, Madison R.	*125*	127	244	356	417			
17	ID, Snake R.	*80*	130	257	353	462	495		
H35	OR, Crater L.	*318*	84	190	292	391	442	452	
S234	UT, Fish L.	*530*	163	259	333	417	523	617	
H258	WY, Pathfinder L.	*n.a.*	122	307	447	523	597	640	
S275	MT, Flint C.	*64*	66	135	183	229			
T2, T3	NM Streams	*65*	86	155	206	257			
P55	MT, Budge's Stream	*98*	97	168	218	284			
P55	MT, elevation 6000'	*133*	79	155	239	305	335		
P55	MT, elevation 5000'	*76*	81	165	226	307	396		
P55	MT, elevation 4000'	*142*	86	188	292	368	437		
P159, M453	MT Streams	*5144*	84	170	251	323	363		
17	ID, hatchery	*40*	127	244	333	445			
C53	BC, kamloops	*6*	66	122	300	465	546	635	759
	Streams, 21 means	*10358*	99	196	282	353	445	523	569

Aside from the MULTIFAN analyses, the quantification of age (and growth) of trout in Lee's Ferry remains problematical. When sufficient data are collected from CWT trout for a number of years, reliable estimates probably can be determined for these trout. However, can we assume that hatchery fish and 'resident-natural' trout have the same growth rates? This assumption seems unlikely for a number of reasons. Firstly, 'resident-natural' trout have been documented to spawn throughout the year in the tailwaters of the dam. Whether this pattern is due largely to resident spawners or hatchery introductions is unknown. What is the survivability and contribution of the multiple cohorts to the fishery? Secondly, there is considerable debate whether this pattern of spawning is the result of different genetic strains that have been stocked in Lee's Ferry. Until the genetic make-up of the fishery is understood, the contribution of hatchery trout to the gene pool is largely anecdotal (Claussen & Philipp 1991). Hence, it may be impossible to determine growth of trout in Lee's Ferry until the genetic make-up and survivability of the cohorts are estimated.

The MULTIFAN procedure is only as good as the data that is fed into it. In our case, there were several vitiating factors to possibly compromise some parameter estimates of the model (*e.g.* impact of the nematode, fluctuating flows, different genetic strains and changing management regulations). Yet, the model appeared robust in that the general interpretation of the data seemed biologically reasonable with regard to the expected growth and age structure of rainbow trout in streams.

As mentioned, there were several corrupting factors in the study that could not be controlled. Firstly, hatchery fish may confound the model because they probably do not have the same growth and survivability of 'resident-natural' trout. Secondly, the technique of electrofishing (the primary collection technique) may be size selective in that smaller individuals seemed to be absent in much of the data. Thirdly, different management regulations may have had the greatest overall impact on the fishery. For example, virtually all of the length-frequency distributions since 1990 indicate that the majority of trout are piling up in the 406 to 558 mm protected slot limit (implemented in 1/90). It therefore seems logical to hypothesize that this regulation has artificially selected for slower growing individuals in the population.

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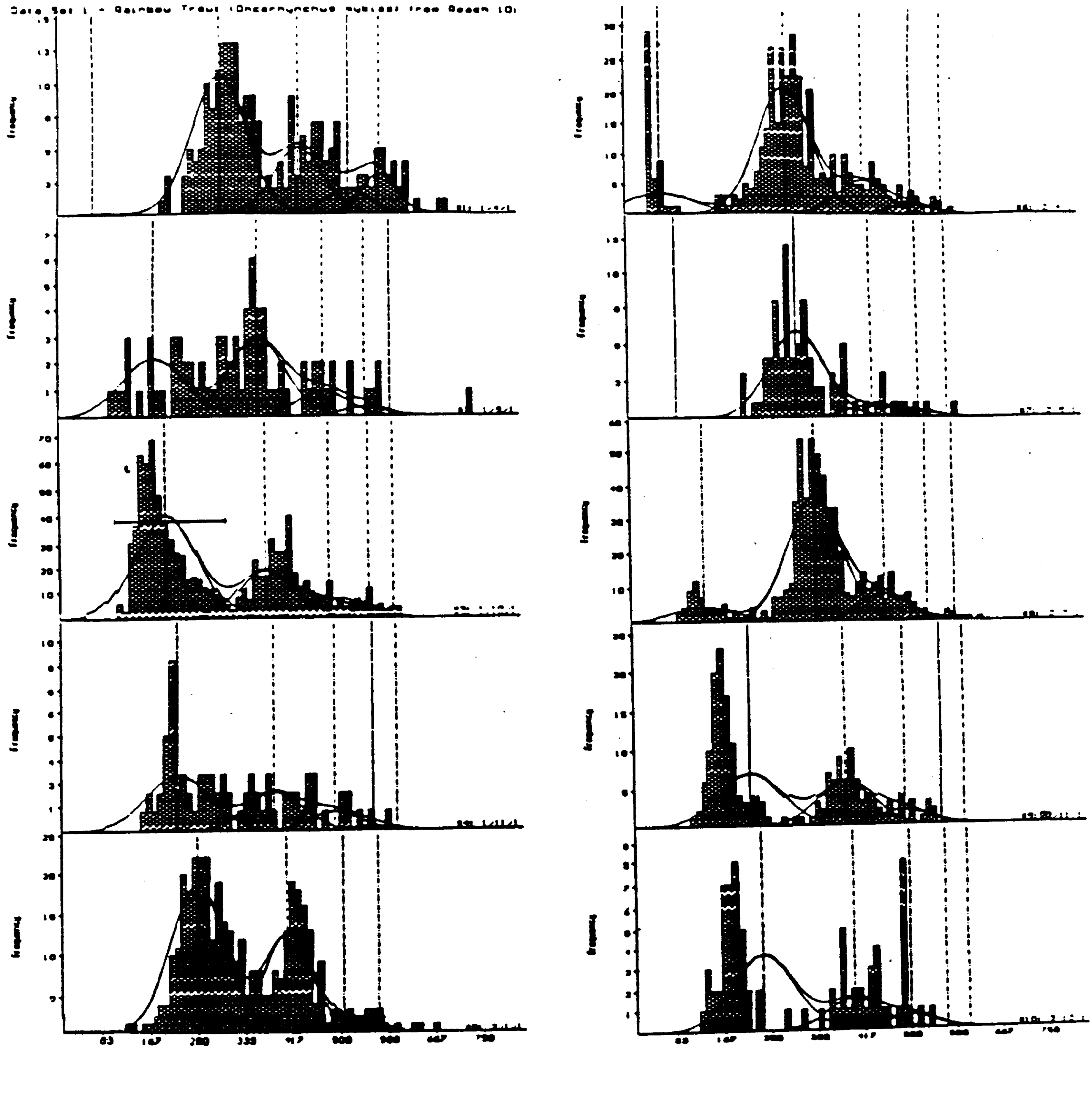
Figure 1 - Data Set 1



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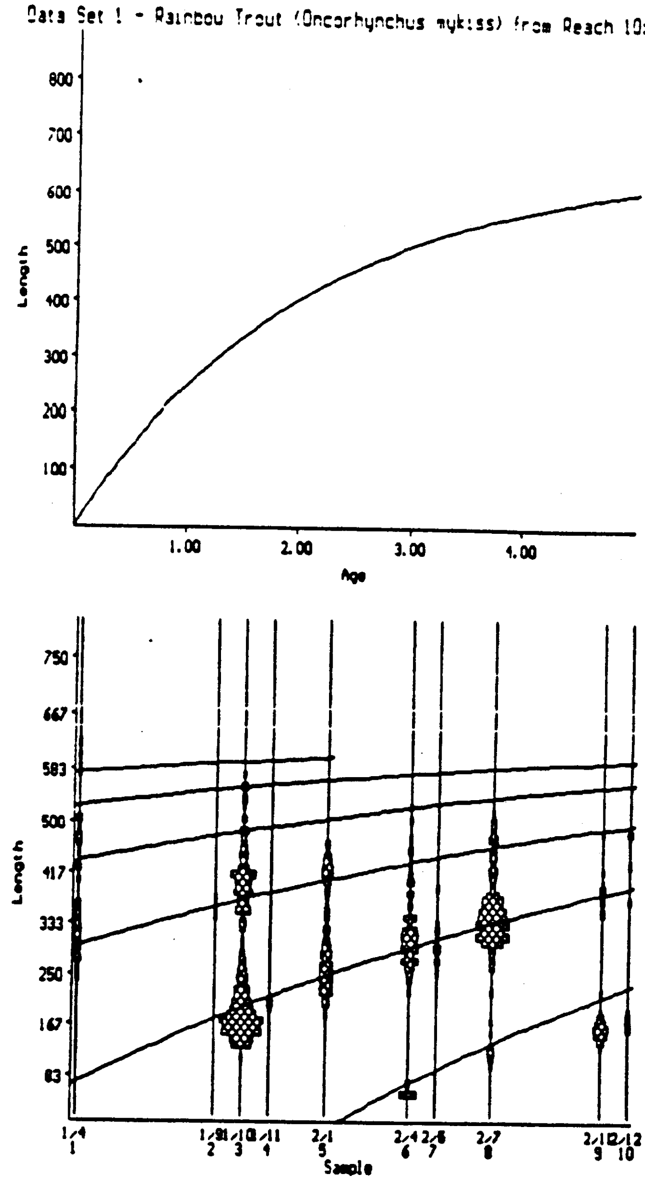

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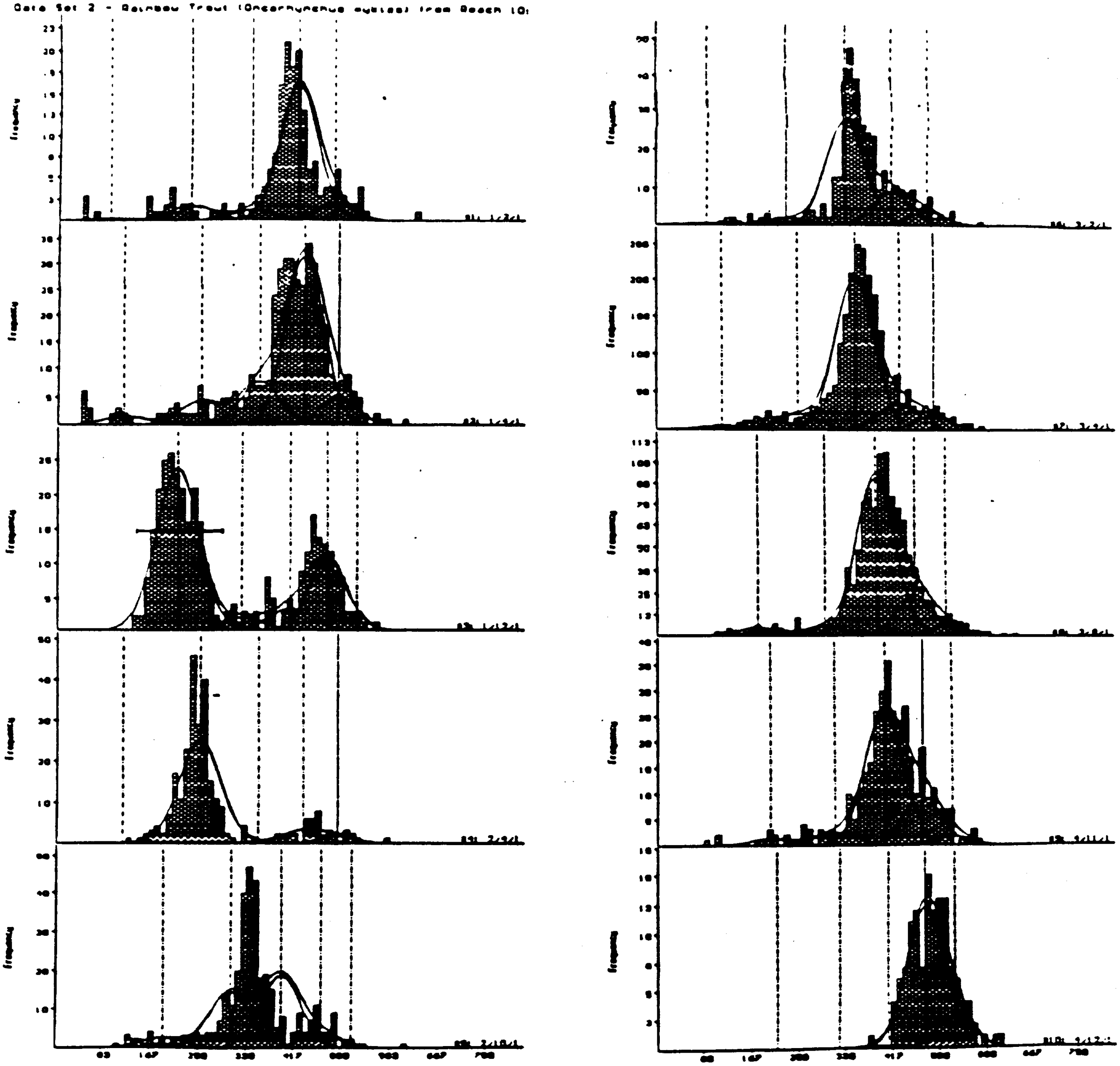

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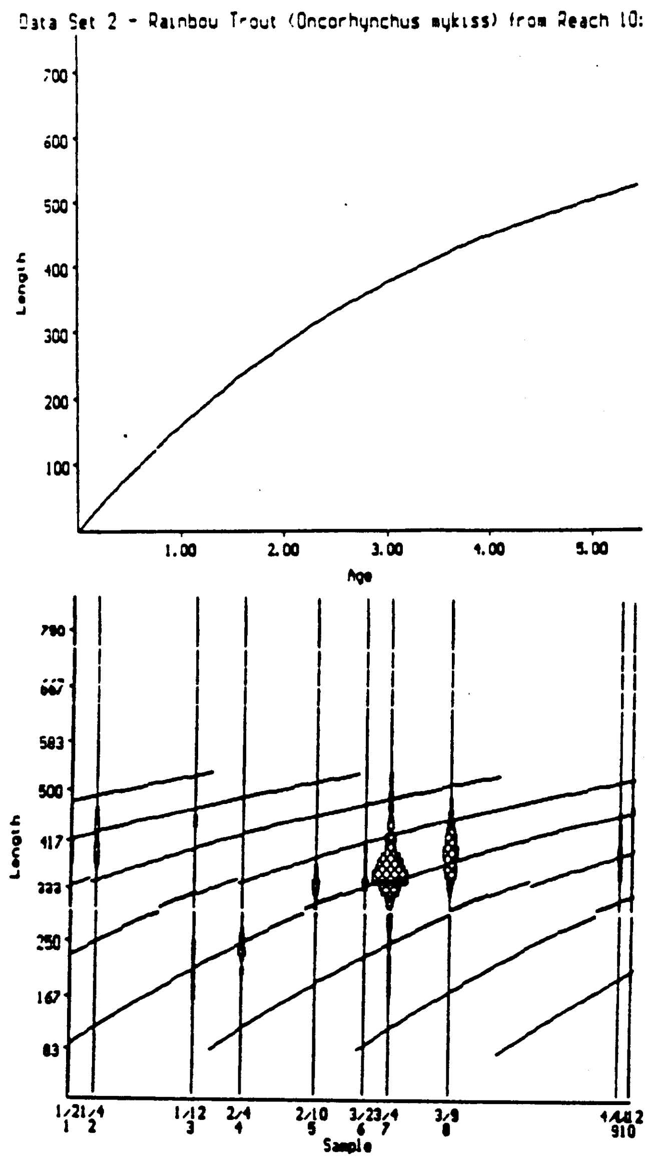

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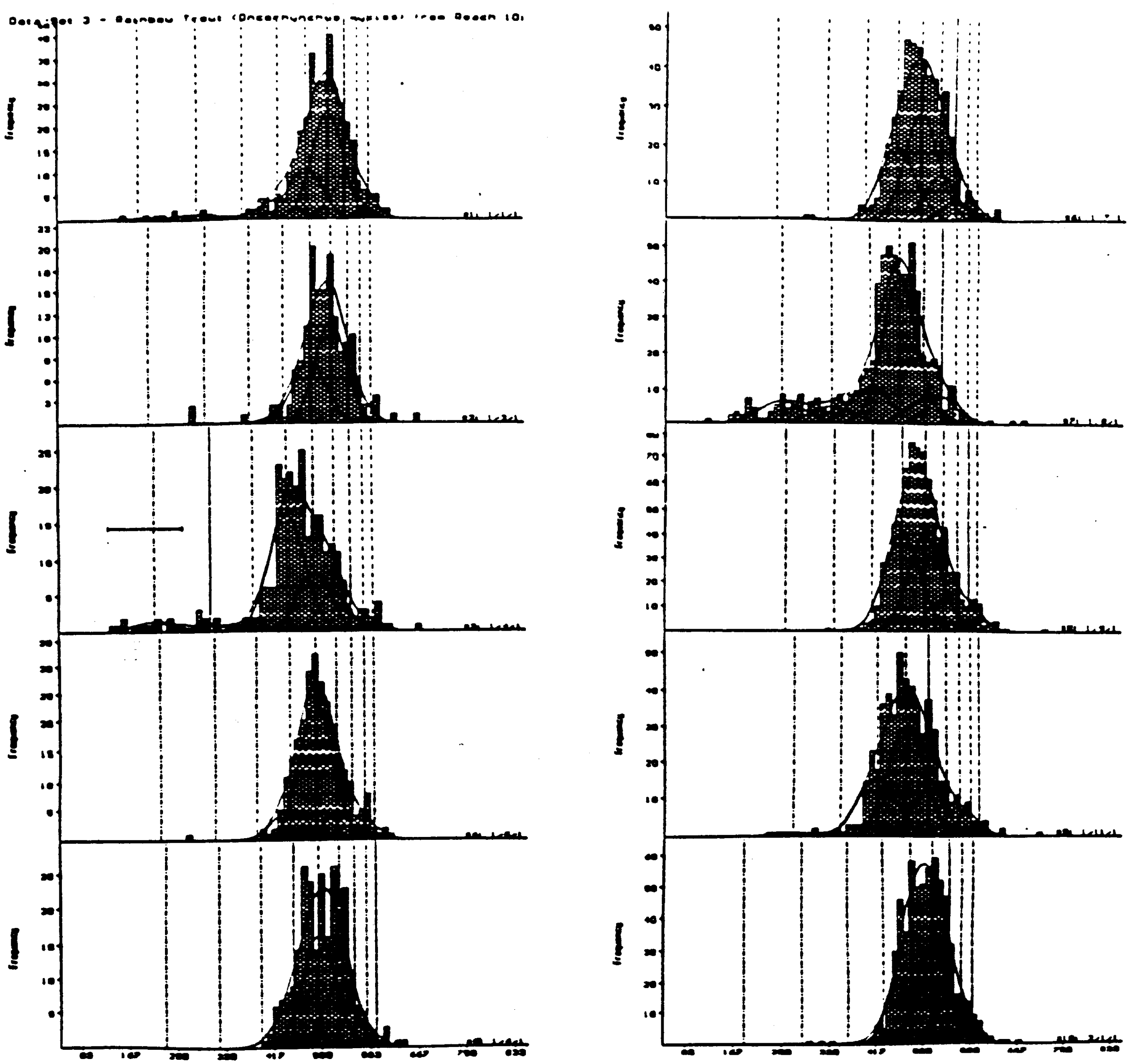

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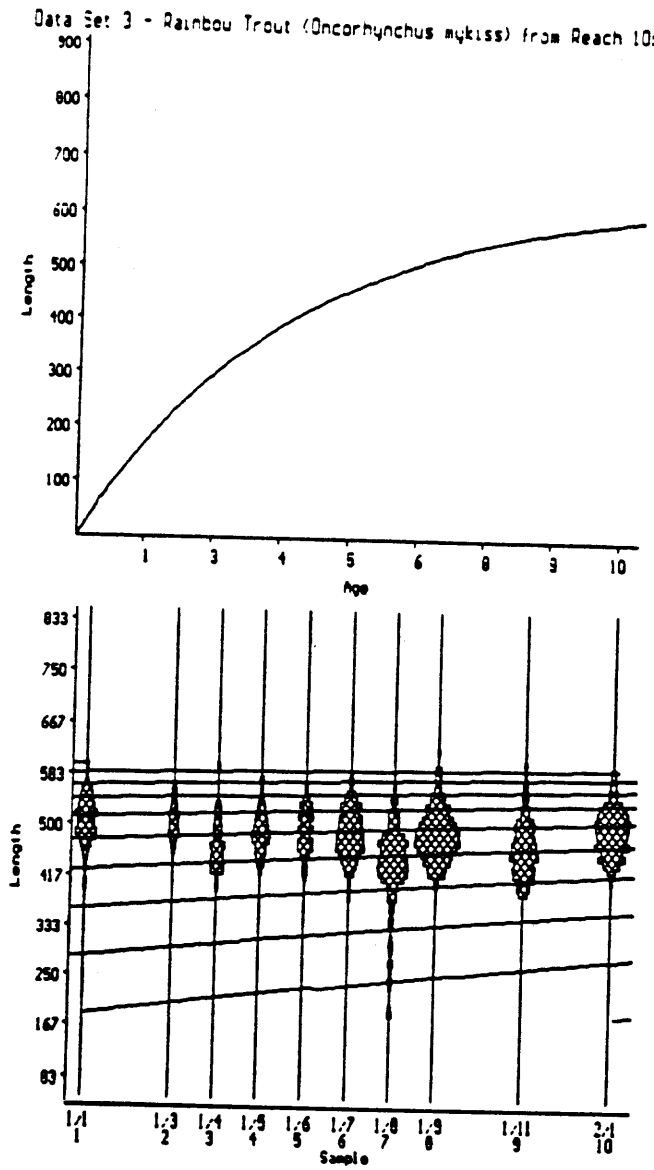

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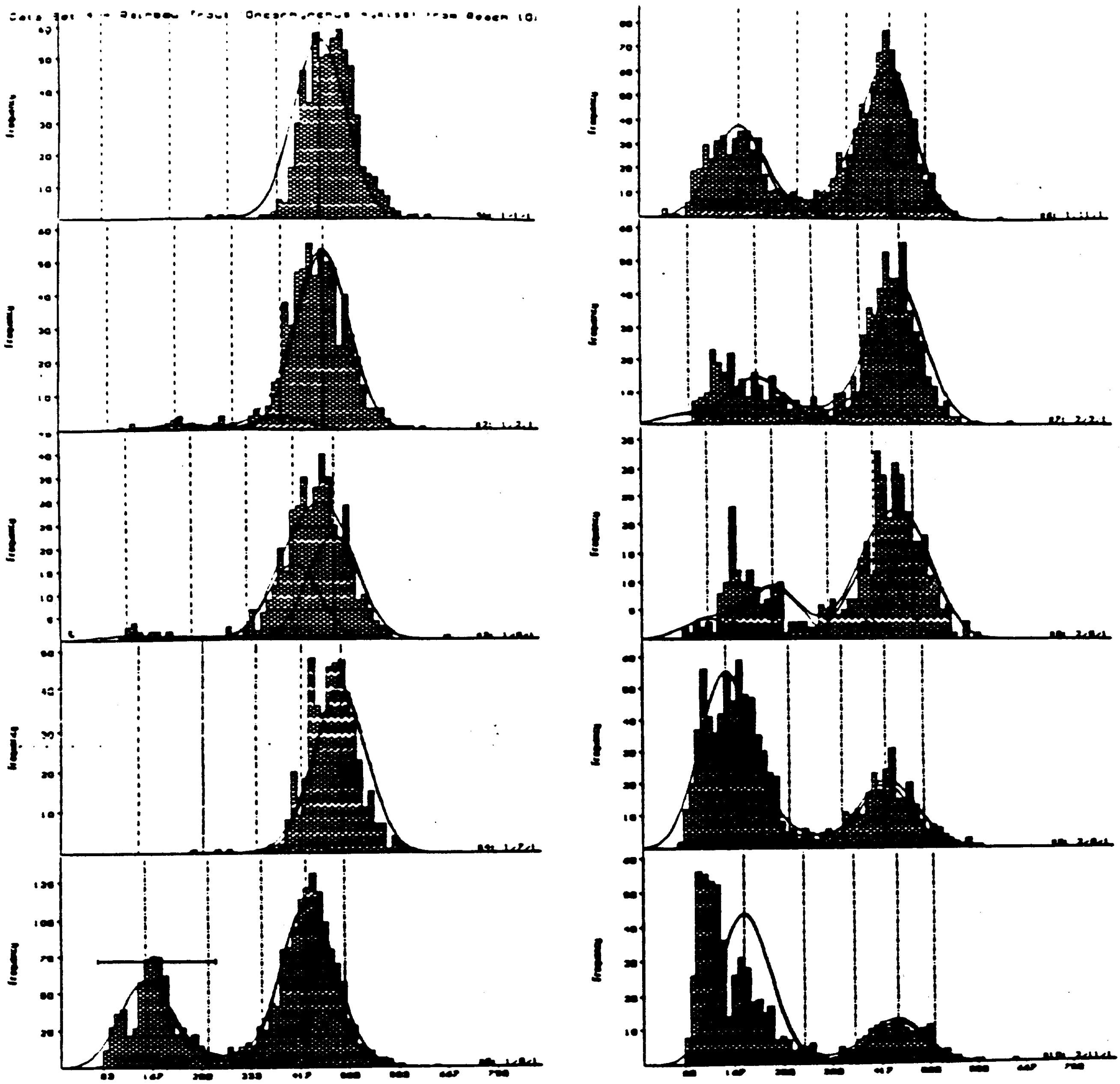


Figure 8 - Data Set 4

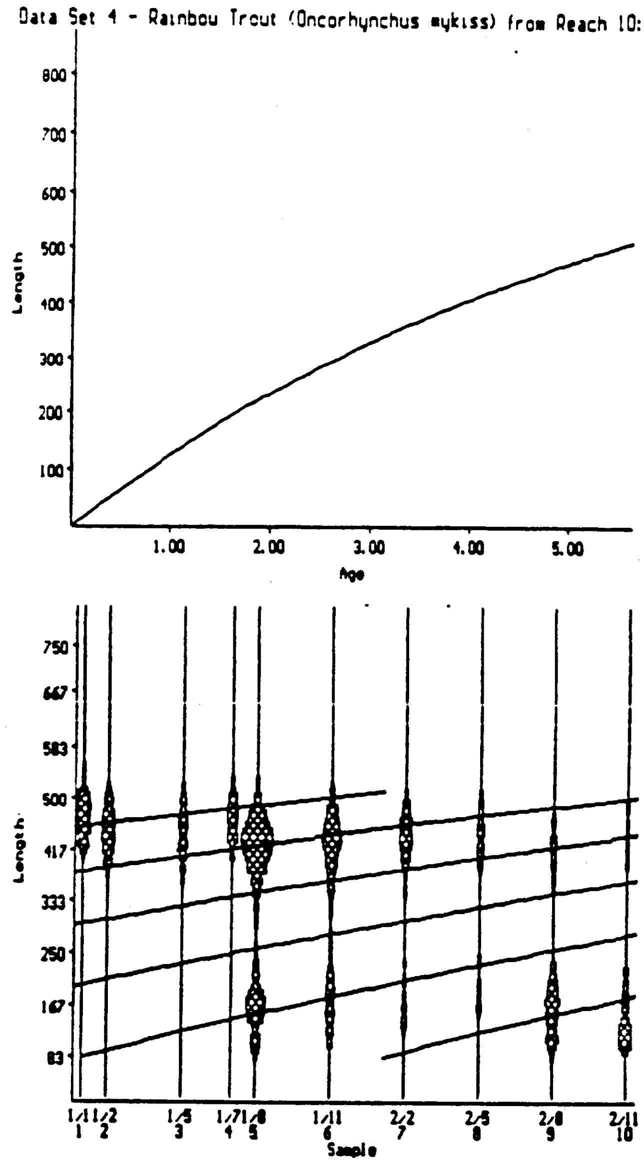


Figure 9 - Data Set 5

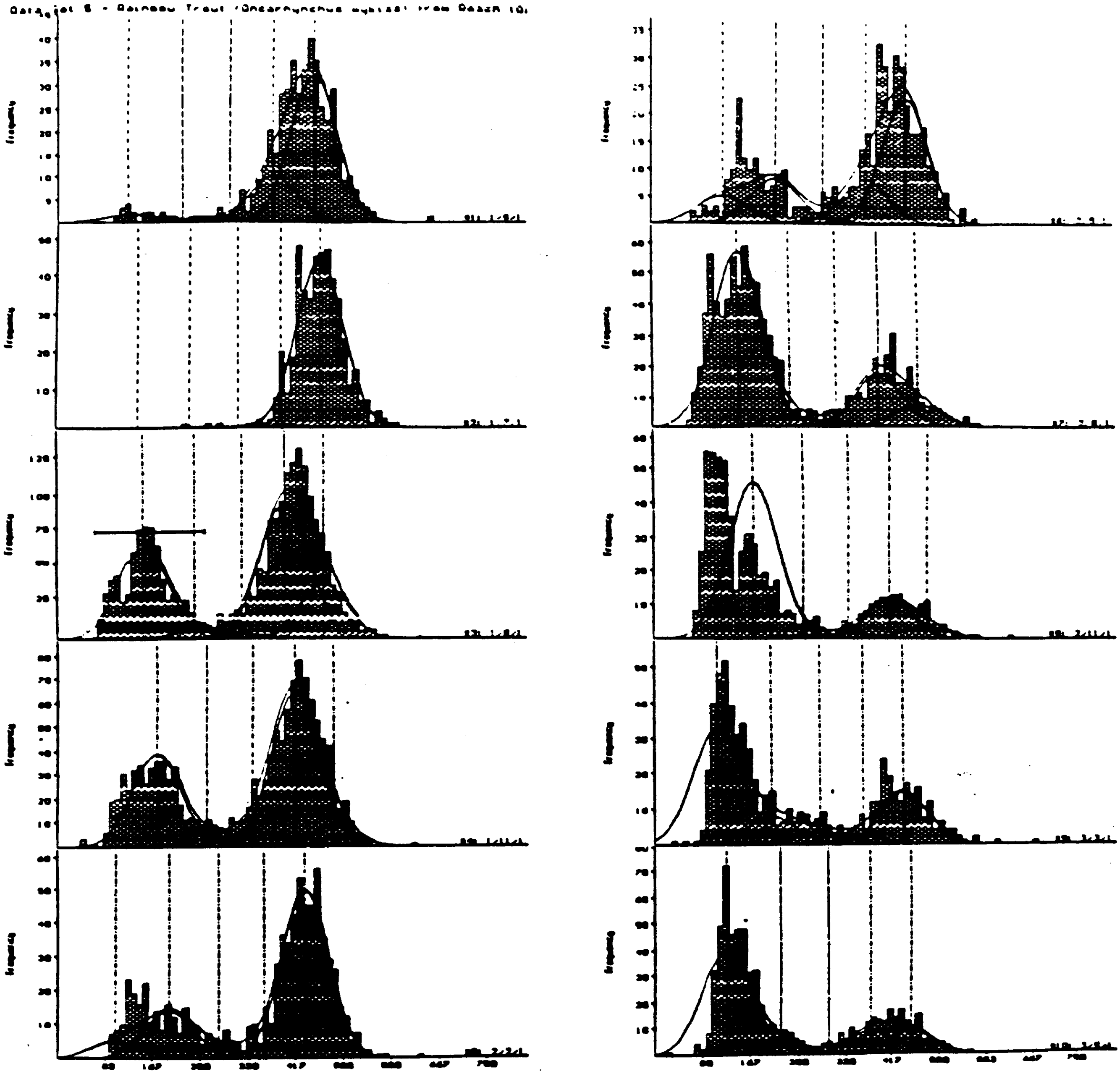
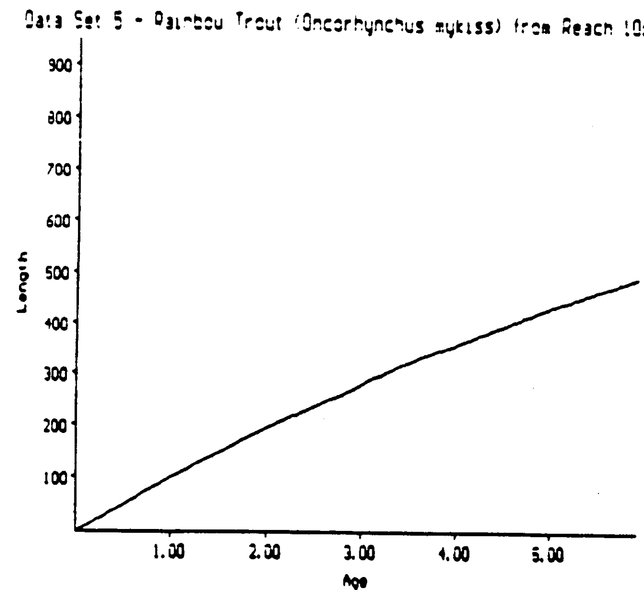
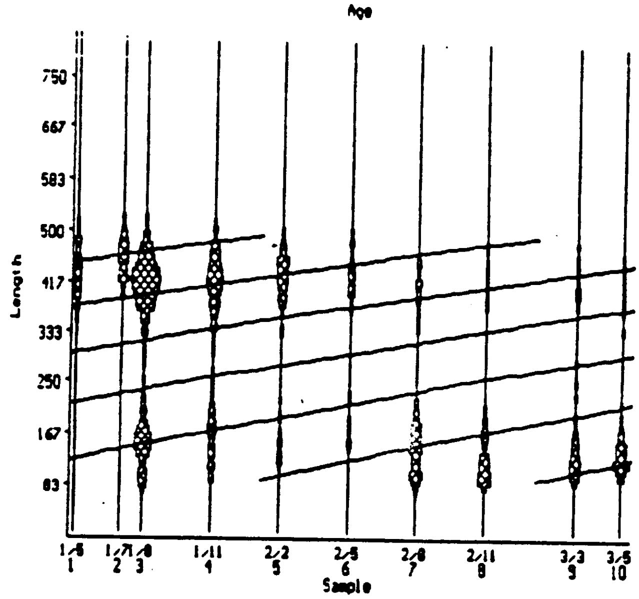


Figure 10 - Data Set 5





4. Mainstem Fish Studies

Tim Hoffnagle

The final 1993 river trip for the Mainstem Colorado River Native Fishes study was just completed but the data are not yet available for analysis. Therefore, this report will concentrate on methods and progress to date with summary statistics where available.

Objectives 4.4 and 4.6. Determine the environmental conditions at each tributary mouth and in the mainstem Colorado River. Determine the behavioral responses of larval to juvenile native fishes to changing environmental conditions in rearing habitats.

METHODS AND PROGRESS

Twenty-one river trips have been completed from March 1991 through November 1993. Three different sampling protocols were used to complete these objectives: Type A, Type B and Opportunistic sampling. Appendix 4.1 gives summarizes all of the sampling sites and the types of samples taken.

Opportunistic Sampling

Opportunistic sampling was conducted to obtain a quick, qualitative, point-in-time characterization of a site. These were largely sites where population estimates by depletion were not feasible, i.e. beach faces, side channels, tributaries and tributary mouths and deep backwaters. Fish were captured by a single pass through the site using either a straight or bag seine. The choice of gear depended on site size and topography. Dip nets and kick seines were used in locations where it was not practical to seine. Effort was recorded in m^2 seined (seines) or hours set (trap nets). Collected fish were identified and measured. Unidentified fishes were preserved in 10% buffered formalin or 95% buffered ethanol for later identification in the lab. At each site habitat type, depth, dominant substrate, water temperature, dissolved oxygen (percent saturation and mg · L^{-1}), conductivity, pH, turbidity, ambient light (shade, cloudy, sunny, night) and site dimensions were recorded.

Type A Sampling

Type A sampling is an intensive sample at a backwater site designed to assess fish population size under environmental conditions of river stage and velocity, depth, turbidity, temperature, pH, conductivity, ambient light, sediment and backwater size. Also, a plane table map was drawn of each site. Seine hauls, substrate and environmental parameter measurements were also taken in various habitat types in the main channel adjacent to the backwater.

Fish were captured by two methods in these samples: electrofishing and/or seining. First, block nets (3.25 mm mesh) were placed near the mouth of the backwater to prevent fish from escaping. The site was then electrofished using one or two hand-held probes powered by a Coffelt VVP pulsator and a 500 watt generator. Following electrofishing the site was seined using either straight or bag seines (3-10 m long, 1-1.5 m high), depending on site topography and size. Electrofishing and seining continued until no additional fish were captured. When very small fish (<25 mm) were present, the site was also seined using a 0.84 mm mesh larval seine. In the mainstream and mainstream eddy portion of the site fish were sampled in the same manner as described for opportunistic sampling, above.

Because of potential safety hazards and fish health problems associated with electrofishing it was discontinued during the April 1992 trip and seines were used exclusively for Type A sampling. Normally, each site was seined at least three times to improve the population estimate. However, in some sites each pass would disturb fine sediments making subsequent passes more difficult and stressful on the fish. In other sites (at certain times of the year) large numbers of larval or small juvenile fish were present. In these sites only two seine hauls were completed to prevent extensive sampling mortality.

Sites were mapped using an alidade and plane table to create an accurate map showing wetted perimeter, contour lines for 25 cm, 50 cm, 100 cm, 150 cm and 200 cm depths.

Plane table mapping allowed us to accurately measure the surface area and volume of the backwater and compare this site at different river stages. In this way we can see how backwaters change over time.

Water temperature and velocity were recorded at three evenly spaced locations along the axis of the backwater and in the main channel. Dissolved oxygen (percent saturation and mg/L) and turbidity (nephelometric turbidity units) were each measured at one location in each habitat type.

Benthos, plankton and sediment samples were collected from backwater and main channel sites prior to shocking or seining. Benthos samples were collected at two or three locations within each site using a Petite Ponar dredge. Plankton samples were taken by pouring 30 L of water through an 80 μm mesh plankton net. Volume of plankton samples was increased to 50 L in February 1992. Benthos and plankton samples were analyzed in the lab with all organisms being identified to the familial level. Sediment core samples were collected using a 50 cm^3 minicore sampler. Sediments were separated into sand and silt components with percent organic matter also being determined for earlier samples.

Type B Sampling

Type B samples were multi-day, intensive samples designed to assess changes in fish abundance and habitat use across varied flow and diel cycles at backwater and tributary mouth sites. At each Type B backwater and tributary sampling location, 30-50 minnow traps were deployed throughout the site. At backwater sites, traps were located in the mainstream, mainstream eddy, return channel eddy and backwater proper. At tributary mouths, traps were placed in the mainstream and up the tributary as far as the estimated high water zone. Traps were checked approximately four to five times per day. Whenever possible, trap checks took place during ascending, stable high, descending and stable low water stages over a three day period. During each trap check, current velocity, depth, water temperature and substrate type were recorded for each trap as well as the species and lengths of fish captured.

Benthos, sediment and plankton samples were collected as described above at 5-10 locations along a gradient of stage height ranging from locations that were continuously submerged throughout the three day period to those that were submerged only briefly. Sites were mapped using an ETM (Leitz or equivalent) supplied by GCES to accurately locate individual minnow traps and benthos sites and record topographic conditions. Two DataSondes (Hydrolab Corp.) were set to record pH, dissolved oxygen (percent saturation and mg/L), conductivity, water depth and temperature at 15-30 minute intervals. They were deployed at each site in both the mainstream and tributary or backwater. Some backwaters that were sampled intensively during early trips decreased in size during the period of the study (primarily because of deposition of fine sediments) and were replaced by other sites during subsequent trips. Clear Creek was also replaced by Crystal Creek because of the unsuitability of the Clear Creek area for camping.

Type B data were analyzed by ANOVA and multiway ANOVA with multiple comparisons by the Ryan-Einot-Gabriel-Welsch multiple F test (Day and Quinn 1989) at $\alpha = 0.05$.

RESULTS AND DISCUSSION

DataSondes

DataSondes were deployed in 67 locations during 20 trips. The resulting files require quite a bit of compilation and analyses of these data are not yet complete. However, preliminary results show that backwater temperatures fluctuate as the level of the river changes (Arizona Game and Fish 1993). As the river level drops there is less exchange between river and backwater. This allows the backwater to warm. As new water is brought into the backwater by rising river levels the backwater temperature decreases to that of the river.

The ability of backwaters to warm has been identified as being important in making backwaters suitable nursery and rearing areas for fishes in Grand Canyon (Maddux et al. 1987; Angradi et al. 1992). DataSonde data (temperature, dissolved oxygen, conductivity, pH) will be analyzed and compared with fish capture and other data (i.e. turbidity, sediments, benthos) in those sites. This may provide information on how the fish select backwaters to inhabit.

Type B Studies

During the seven trips in which Type B samples were collected, 3240 fish were captured in 6555 trap sets. The duration of each set averaged approximately 8 hours (range: 2-12 hours) and the mean CPUE was 0.494 fish/trap set or 0.062 fish/hour (Table 3.1). Speckled dace, fathead minnow and plains killifish comprised 62.2%, 16.9% and 13.3%, respectively, of the minnow trap catch in all habitats. In the mainstream 1103 trap sets caught 254 fish, a CPUE of 0.230 fish/trap set or 0.029 fish/hour. Speckled dace, fathead minnow and humpback chub comprised 78.0%, 11.4% and 3.5%, respectively, of the mainstream catch. In backwaters 607 fish were caught in 1791 trap sets, a CPUE of 0.339 fish/trap set or 0.042 fish/hour. Fathead minnow, speckled dace, flannelmouth sucker and humpback chub comprised 54.0%, 27.5%, 7.6% and 6.4% of the backwater catch. Tributaries caught more fish and had a higher CPUE, catching 2379 fish in 3661 trap sets, a CPUE of 0.650 fish/trap set or 0.081 fish/hour.

Overall, the number of fish caught in each trap set increased as temperature increased ($p=0.0001$) and velocity decreased ($p=0.0288$). No relationship was found for flow ($p=0.7843$) or depth ($p=0.3154$). No relationship between catch and any of these variables was found in backwaters ($p=0.2913$) or mainstream ($p=0.6004$) sites. However, in tributaries, increased fish catch was related to increased temperature ($p=0.0001$) and decreased velocity ($p=0.0452$). Catch of bluehead and flannelmouth suckers, fathead minnow and rainbow trout was not related to any environmental variables ($P \geq 0.1107$). However, humpback chub catch was related to increased depth ($p=0.0001$) and speckled dace catch was related to increased temperature ($p=0.0001$).

Bluehead sucker and rainbow trout showed no preference for habitat type (backwater, mainstem or tributary) ($p \geq 0.2359$). Flannelmouth sucker and fathead minnow preferred backwaters over mainstem or tributary habitats ($p=0.0001$). Alternatively, speckled dace and plains killifish were more common in tributaries than mainstem or backwater habitats ($p=0.0001$). Humpback chub preferred backwaters over mainstem habitats and mainstem over tributaries ($p=0.0001$).

Because of the small mesh and mouth openings the traps were obviously size selective. In addition, due to the passive nature of minnow traps it is likely that they were also selective for those species that sought shelter in the traps and against those that did not. Therefore, due to extremely low catches of fish (especially humpback chubs and bluehead and flannelmouth suckers) in backwaters by minnow traps, difficulty in securing traps to fixed locations and the large degree of disturbance impacted on backwater habitats while inspecting the traps, the use of minnow traps has been discontinued as a primary sampling technique. Seining (Type A sampling), which is active and less size selective was used during 1993 instead of minnow traps.

However, further analyses of the Type B data is still warranted and will continue. Analyses of benthos, sediment and plankton samples collected during Type B studies are not yet complete. These data will be correlated with fish collection and environmental data.

Sediments

Analysis of the sediment samples is nearly completed. These data will be correlated with benthos and fish data to see if substrate type (%sand and silt) affects the presence of benthic invertebrates and fishes.

Plankton

Analysis of the plankton samples is just beginning with 12 taxa having been found so far. Preliminary data from 1993 show that 10 taxa were found in backwaters and 11 taxa in mainstream samples. It also appears that the mainstream contains a greater total number of individuals and equal or greater numbers of individuals of each taxa when compared to backwaters. Preliminary data from examination of gut contents show that plankton appear to be the major food source of larval and juvenile native fishes. When sample analysis has been completed these data will be correlated with the fish, benthos, sediment and water quality data.

Benthos

Benthos samples have mostly been analyzed but all of the data have not yet been entered into the computer. A wide variety of invertebrates have been found with larger numbers (27 taxa) being found in backwater areas compared to mainstream (19 taxa) and tributaries (18 taxa). Although the tributaries had fewer taxa, they had significantly more numbers of individuals of 4 taxa, with backwaters having more numbers of only one taxa. These data will be correlated with sediment, water quality and fish data.

Fish

The several files of fish data have recently been combined and most of it is now accessible. Some summary statistics and information on locations of the fish during Trips 14-19, 1993 (caught by seining) in the river and their use of backwater and mainstream habitats will be reported here.

Backwater habitats are important sites for larval and juvenile fishes (Arizona Game and Fish 1993). Speckled dace was the most ubiquitous species caught in backwater habitats, comprising 9.2%-48.5% of the catch in any reach. Flannelmouth sucker was also common in backwaters throughout the river comprising no less than 8.3% of the catch in any reach and would be more common if unidentified (larval) suckers are included. Fathead minnow (0.5% - 21.0%) and rainbow trout (0.02% - 16.2%) were the most common exotic species captured in backwaters. Rainbow trout were most common in the colder and, generally, clearer water of Reach 20 with number decreasing further down river. Fathead minnow had the opposite pattern, being most common below the Little Colorado River (LCR) in Reaches 30, 40 and 50.

Speckled dace (48.5%) and flannelmouth sucker (32.5%) were the most common species in Reach 20 [Lee's Ferry (RM 0) to the LCR (RM 61.5)] backwaters. Humpback chub (33.3%) were the most common species in Reach 30 [LCR to Bright Angel Creek (RM 87.62)] backwaters. In Reach 40 [Bright Angel Creek to National Canyon (RM 166.4)] backwaters bluehead sucker (35.7%) were most common. Speckled dace (33.8%) and bluehead sucker (24.6%) were the most common species in Reach 50 [National Canyon to Diamond Creek (RM 225.6)] backwaters. Between reaches, bluehead sucker (66.5%), flannelmouth sucker (52.4%) and speckled dace (67.9%) were most commonly caught in Reach 50. Humpback chub were most commonly caught in Reach 30 (87.6%).

There was no relationship between CPUE in backwaters vs. water temperature, substrate, depth, turbidity nor ambient light for any native fishes ($p \geq 0.5140$). Therefore, as also seen in the Type B data, it appears that native fishes select backwater areas without relation to the measured water quality parameters. This may indicate that backwaters are selected as sources of cover (shallow areas to avoid large predators), feeding areas or reduced velocity or increased temperature as compared to the mainstream. Preliminary examination of Trip 21 data show that backwaters were colder than the mainstem and catch was dramatically lower than on Trip 20. Humpback chubs caught in backwaters during night samples were significantly larger than those caught during day samples ($p=0.0152$), indicating that larger chubs move into these areas during the night.

Nearshore mainstream habitats were also sampled by seining and can be compared with backwaters. In the mainstream, no relationship was found for CPUE vs. the environmental parameters for either bluehead suckers or speckled dace. Flannelmouth sucker CPUE was positively influenced by turbidity ($p=0.0001$) and negatively influenced by conductivity ($p=0.0205$) and depth ($p=0.0458$). There was a positive relationship between humpback chub CPUE and turbidity ($p=0.0039$) and temperature ($p=0.0003$).

The number of native fish captured in the mainstream depended largely on the reach sampled. One flannelmouth sucker and two speckled dace were the only native fishes captured in Reach 20. The bulk of the captures here (82.4%) were rainbow trout. Humpback chubs were the most common species (64.9%) captured in Reach 30. Bluehead sucker (46.0%) and speckled dace 30.4% were the most common species captured in Reach 40. Flannelmouth sucker (36.3%) and speckled dace (31.5%) were the most common species in Reach 50 with fathead minnow (18.6%) and bluehead sucker (12.5%) also being common.

Humpback chubs were found almost exclusively below the LCR where there is a large known spawning area. However, very small juvenile chubs have also been found 20 miles upstream from the LCR (below a series of warm springs where mainstream spawning may be possible) and at RM 204, indicating that there may be spawning occurring in these areas as well. Bluehead suckers were also found below the LCR as well as below Shinumo, Kanab and Havasu creeks. Neither larval nor juvenile flannelmouth suckers were found immediately below the Paria River, although large numbers of adults congregate there. However, they do appear at about RM 40, below the warm springs. Flannelmouth suckers were also found below the LCR, Bright Angel Creek and Havasu Creek, where spawning is likely. Overall, it appears that juvenile native fishes were most commonly found in or near known spawning areas for those species and, generally, don't appear to be displaced too far down river.

Speckled dace captured in tributaries were significantly larger ($p<0.0001$) than those caught in mainstream or backwater habitats (Figure 3.2). Bluehead (Figure 3.3) and flannelmouth (Figure 3.4) suckers caught in tributaries were also significantly larger ($p<0.0001$) than those caught in either mainstream or backwaters. Those caught in backwaters were significantly smaller ($p<0.0001$) than those caught in the mainstream. Humpback chub (Figure 3.5) were significantly larger in the mainstream ($p<0.0001$) than those caught in tributaries (LCR) or backwaters.

A number of small humpback chubs and bluehead and flannelmouth suckers, were preserved for examination of otoliths and stomach contents. Preliminary results of the stomach contents of these fish show that they are all feeding, largely, upon planktonic invertebrates.

Relationships between benthos and plankton vs. these environmental parameters and fish concentrations will be examined and may be enlightening.

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Table 4.1. Minimum, maximum and total number of fish caught of each species and CPUE for Type B samples.

Species	Minimum Caught	Maximum Caught	Total Caught	CPUE (# fish/trap set)
Backwaters (N - 1791 Trap Sets)				
Bluehead Sucker	0	1	4	0.00223
Brook Trout	0	0	0	0.00000
Brown Trout	0	0	0	0.00000
Channel Catfish	0	0	0	0.00000
Common Carp	0	1	2	0.00112
Fathead Minnow	0	20	328	0.18314
Flannelmouth Sucker	0	1	46	0.02568
Humpback Chub	0	1	39	0.02178
Plains Killifish	0	1	4	0.00223
Rainbow Trout	0	1	1	0.00056
Speckled Dace	0	3	167	0.09324
Unidentified Sucker	0	1	16	0.00893
Total	0		607	0.33892
Mainstream (N = 1103 Trap Sets)				
Bluehead Sucker	0	1	5	0.00453
Brook Trout	0	0	0	0.00000
Brown Trout	0	1	1	0.00091
Channel Catfish	0	0	0	0.00000
Common Carp	0	0	0	0.00000
Fathead Minnow	0	1	29	0.02629
Flannelmouth Sucker	0	1	5	0.00453
Humpback Chub	0	1	9	0.00816
Plains Killifish	0	1	3	0.00272
Rainbow Trout	0	1	4	0.00363
Speckled Dace	0	10	198	0.17951
Unidentified Sucker	0	0	0	0.00000
Total			254	0.23028

Table 4.1. (cont'd) Minimum, maximum and total number of fish caught of each species and CPUE for Type B samples.

Species	Minimum Caught	Maximum Caught	Total Caught	CPUE (# fish/trap set)
Tributaries (N = 3661 Trap Sets)				
Bluehead Sucker	0	30	70	0.01912
Brook Trout	0	1	1	0.00027
Brown Trout	0	1	2	0.00055
Channel Catfish	0	1	1	0.00027
Common Carp	0	0	0	0.00000
Fathead Minnow	0	4	189	0.05163
Flannelmouth Sucker	0	1	21	0.00574
Humpback Chub	0	0	0	0.00000
Plains Killifish	0	20	423	0.11554
Rainbow Trout	0	1	19	0.00519
Speckled Dace	0	53	1651	0.45097
Unidentified Sucker	0	1	2	0.00055
Total			2379	0.64982
All Habitats (N - 6555 Trap Sets)				
Bluehead Sucker	0	30	79	0.01205
Brook Trout	0	1	1	0.00015
Brown Trout	0	1	3	0.00046
Channel Catfish	0	1	1	0.00015
Common Carp	0	1	2	0.00031
Fathead Minnow	0	20	546	0.08330
Flannelmouth Sucker	0	1	72	0.01098
Humpback Chub	0	1	48	0.00732
Plains Killifish	0	20	430	0.06560
Rainbow Trout	0	1	24	0.00366
Speckled Dace	0	53	2016	0.30755
Unidentified Sucker	0	1	18	0.00275
Total			3240	0.49428

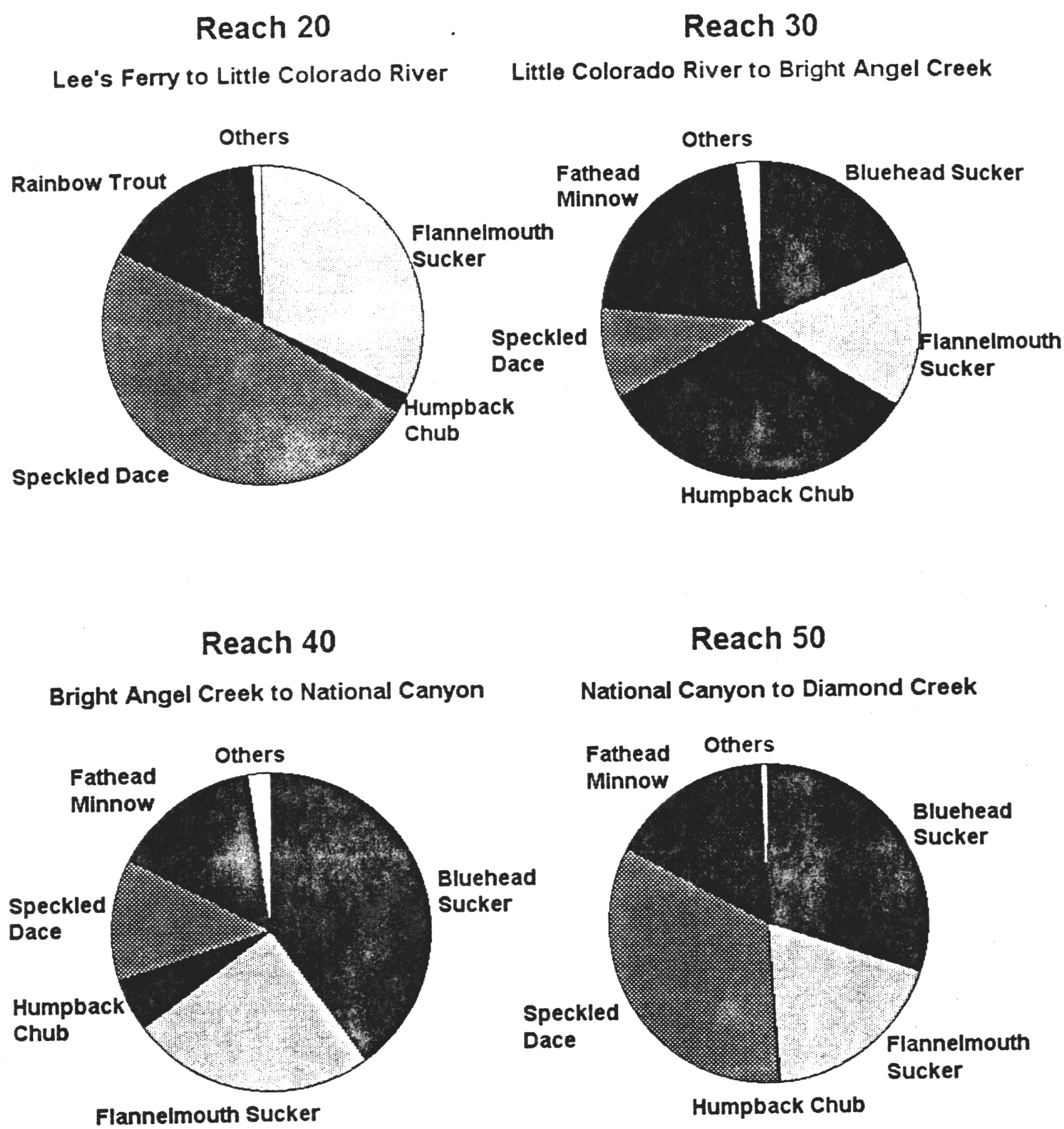

Figure 4.1. Percent composition of species captured in backwater samples, Colorado River, Grand Canyon, during Trips 14-19, February - August 1993.

Table 3.2. Number and percentage of fish captured in backwater and mainstem habitats in Reaches 20, 30, 40 and 50, Colorado River, Grand Canyon, February - August 1993.

Species	Reach 20 N	Reach 20 %	Reach 30 N	Reach 30 %	Reach 40 N	Reach 40 %	Reach 50 N	Reach 50 %
Backwater								
Native								
Bluehead Sucker	1	0.13	383	10.44	225	35.71	1207	24.57
Flannelmouth Sucker	246	32.45	304	8.29	138	21.90	756	15.39
Humpback Chub	15	1.98	1221	33.30	34	5.40	10	0.20
Speckled Dace	368	48.55	339	9.24	78	12.38	1660	33.79
Unidentified Suckers	0	0.00	568	15.49	47	7.46	450	9.16
Exotic								
Channel Catfish	0	0.00	1	0.03	0	0.00	3	0.06
Carp	1	0.13	14	0.38	3	0.48	9	0.18
Fathead Minnow	4	0.53	771	21.03	95	15.08	812	16.53
Plains Killifish	0	0.00	2	0.05	1	0.16	4	0.08
Rainbow Trout	123	16.23	64	1.75	9	1.43	1	0.02
Total	758	100	3667	100	630	100	4912	100
Mainstream								
Native								
Bluehead Sucker	0	0.00	5	10.44	109	45.99	37	12.54
Flannelmouth Sucker	1	5.88	2	0.45	16	6.75	107	36.27
Humpback Chub	0	0.00	286	64.85	2	0.84	0	0.00
Speckled Dace	2	11.76	33	7.48	72	30.38	93	31.53
Unidentified Suckers	0	0.00	0	0.00	11	4.64	0	0.00
Exotic								
Brook Trout	0	0.00	1	0.23	0	0.00	0	0.00
Brown Trout	0	0.00	0	0.00	1	0.42	0	0.00
Channel Catfish	0	0.00	0	0.00	0	0.00	1	0.34
Carp	0	0.00	0	0.00	3	1.27	0	0.00
Fathead Minnow	0	0.00	84	19.05	7	2.95	55	18.64
Plains Killifish	0	0.00	0	0.00	0	0.00	1	0.34
Rainbow Trout	14	82.35	30	6.80	16	6.75	0	0.00
Striped Bass	0	0.00	0	0.00	0	0.00	1	0.34
Total	17	100	441	100	237	100	295	100

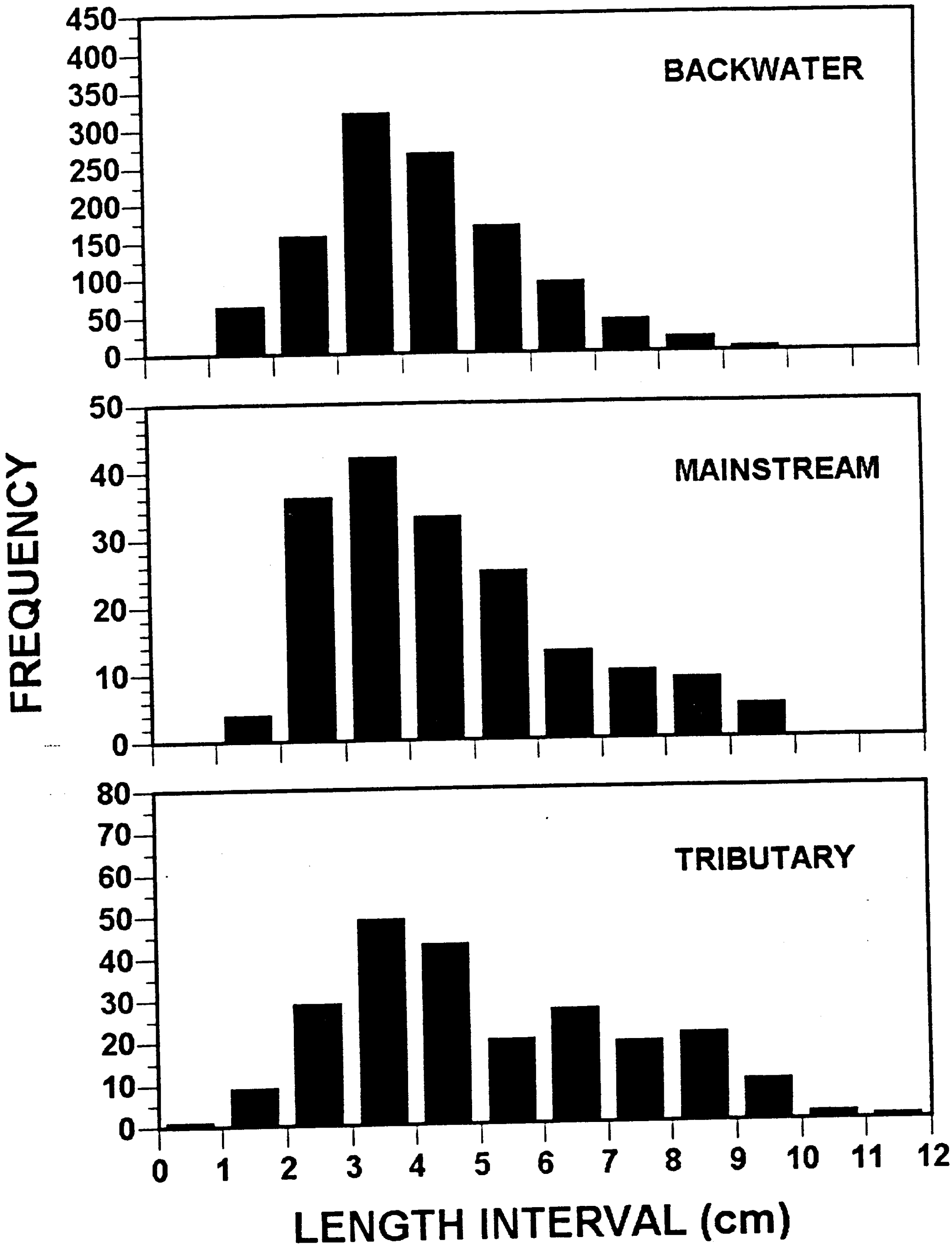

Figure 4.2. Length frequency of speckled dace (*Rhinichthys osculus*) captured in backwater, mainstream and tributary habitats in the Colorado River, Grand Canyon from March 1991 - August 1993.

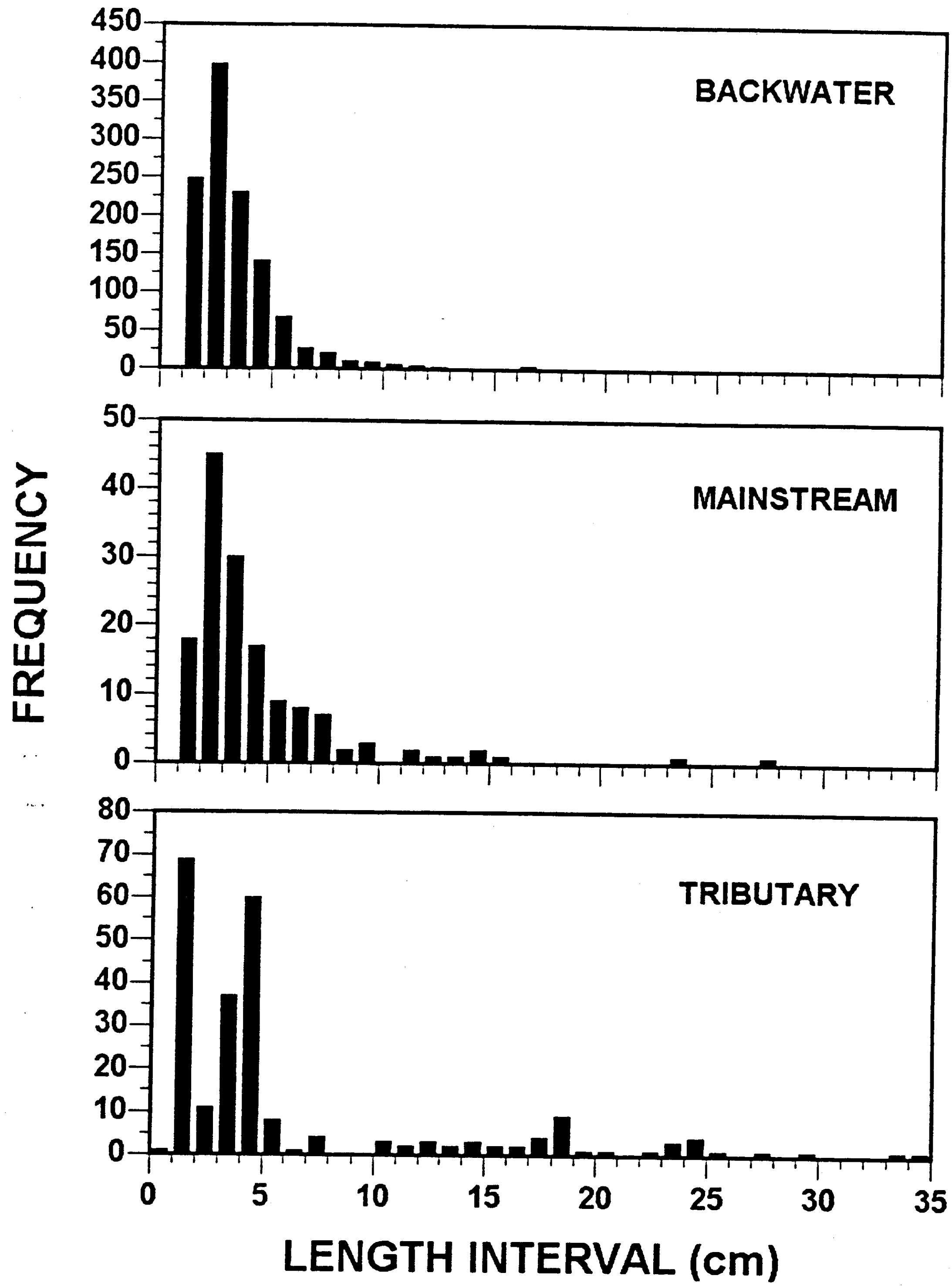

Figure 4.3. Length frequency of bluehead sucker (*Catostomus discobolus*) captured in backwater, mainstream and tributary habitats in the Colorado River, Grand Canyon from March 1991 - August 1993.

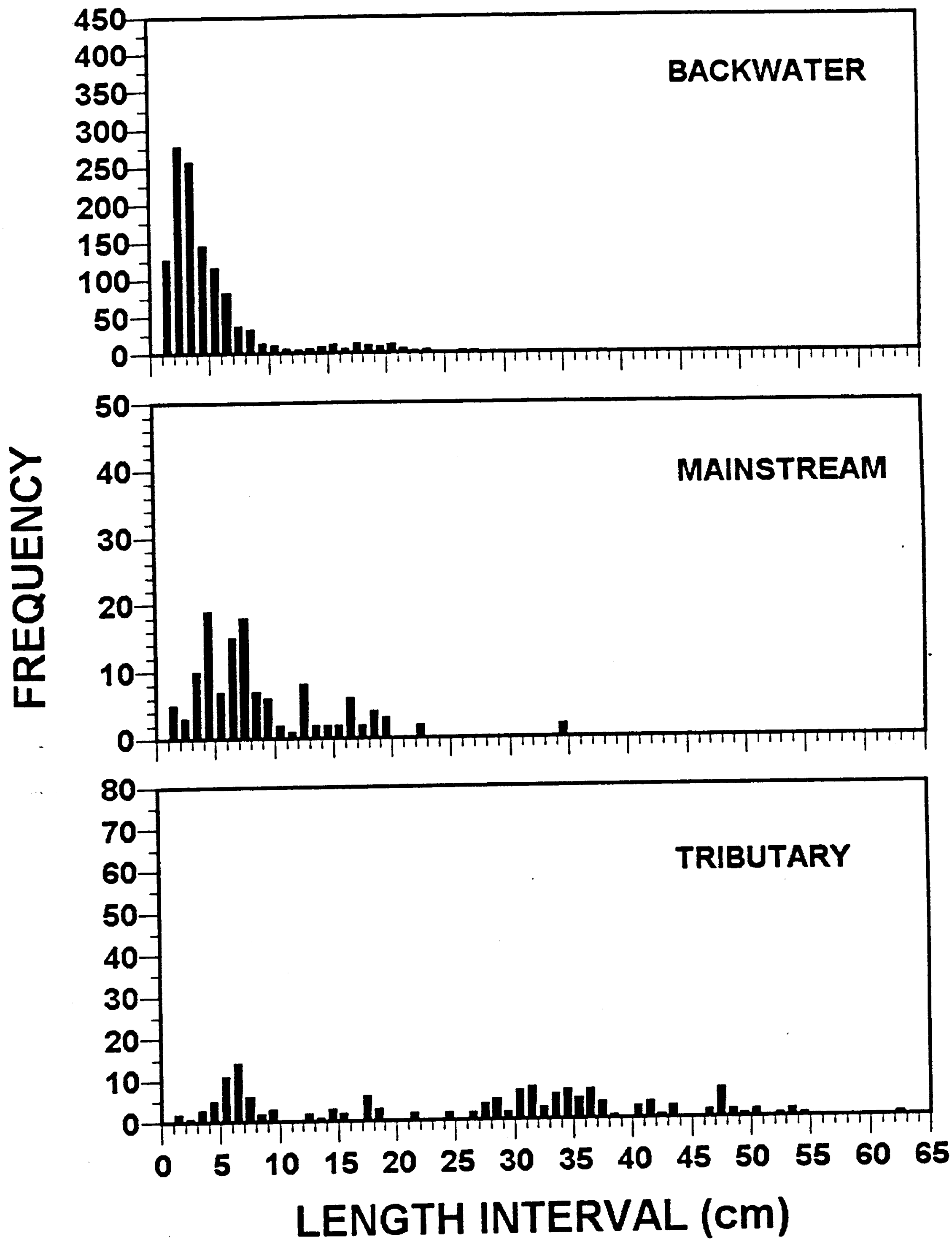

Figure 4.4. Length frequency of flannelmouth sucker (*Catostomus latipinnis*) captured in backwater, mainstream and tributary habitats in the Colorado River, Grand Canyon from March 1991 - August 1993.

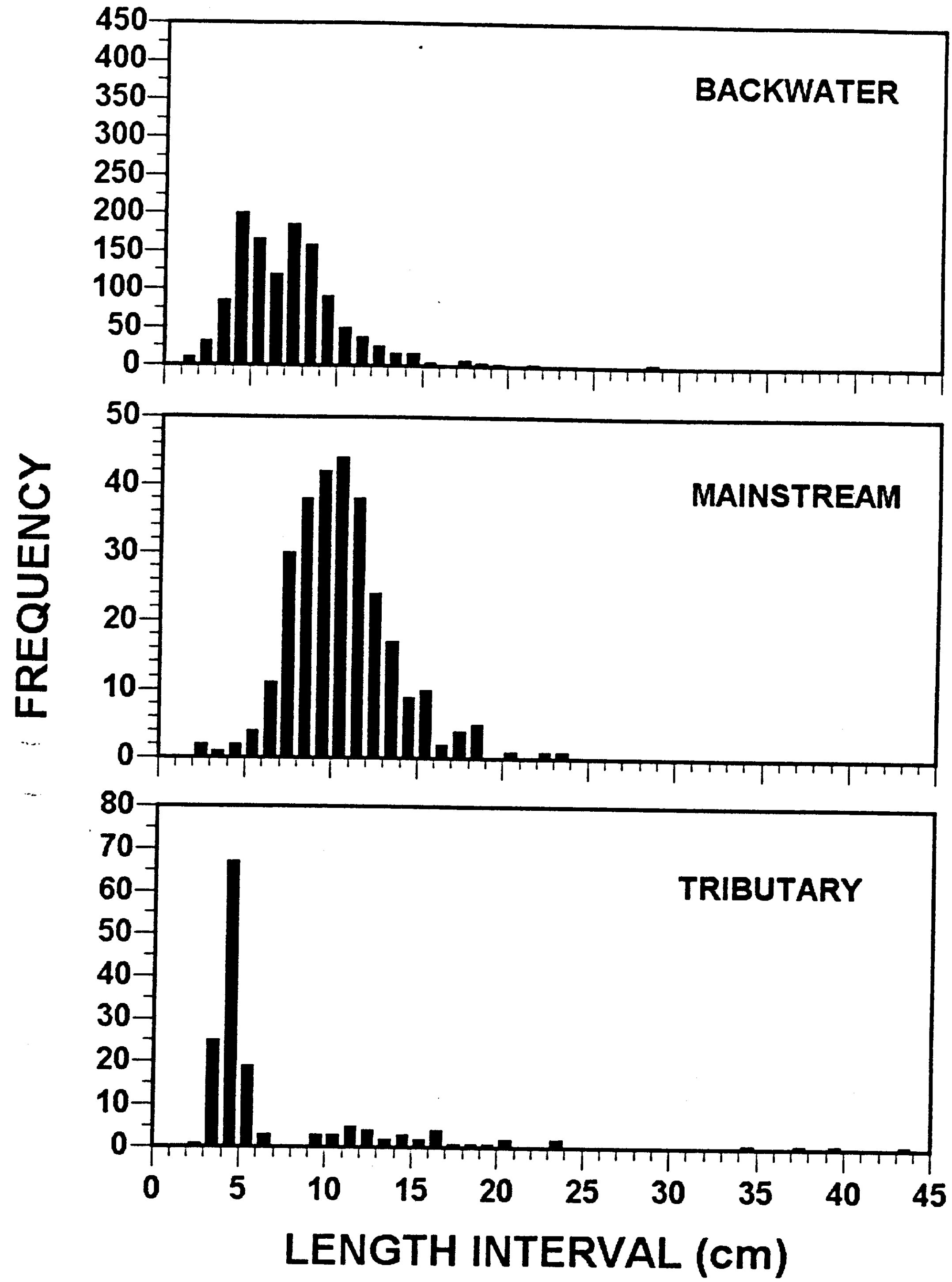

Figure 4.5. Length frequency of humpback chub (*Gila cypha*) captured in backwater, mainstream and tributary habitats in the Colorado River, Grand Canyon from March 1991 - August 1993.

APPENDIX 4.1

Appendix 4.1. Catalogue of samples collected, March 1991 - August 1993. Table values indicate the number of each type of sample collected. Column headings are abbreviated as:

Rch	Reach code (Maddux et al. 1987): 10 Glen Canyon Dam to Lee's Ferry (RM 0) 11 Paria River (RM 0.9) 20 Lee's Ferry to Little Colorado River (RM 61.5) 21 Nankoweap Creek (RM 52.2) 22 Little Colorado River (RM 61.5) 30 Little Colorado River to Bright Angel Creek (RM 87.62) 31 Clear Creek (RM 84.03) 32 Bright Angel Creek (RM 87.62) 40 Bright Angel Creek to National Canyon (RM 166.4) 401 Pipe Creek (RM 88.95) 41 Crystal Creek (RM 98.04) 42 Shinumo Creek (RM 108.60) 402 Elves Chasm (RM 116.50) 403 Stone Creek (RM 131.80) 43 Tapeats Creek (RM 133.83) 44 Deer Creek (RM 136.25) 45 Kanab Creek (RM 143.50) 404 Olo Canyon (RM 145.5) 46 Havasu Creek (RM 156.93) 47 Diamond Creek (RM 225.6) 50 National Canyon to Diamond Creek (RM 225.6)
Flo Cod	Flow code estimated on the river: SH = Steady High SL = Steady Low DC = Descending AC = Ascending
Flow CFS	Estimated flow in cfs
Typ A	Type A samples
Typ B	Type B samples
Ang lng	Angling sampling
Opp	Opportunistic samples
Son de	DataSonde deployments
Ben ths	Benthos samples
Sed	Sediment samples
Chl	Chlorophyll samples
Pkn	Plankton samples
Tot Map	ETM total station maps
Pla Map	Plane table maps
Vis cer	Viscera collections
Drift	Drift samples
A -2nd-	Modified Type A samples
Fish Coll	Total number of fish collected

Trip 1

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
30101	3	03/28/91 15:43	45.00 L	20		.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	0
30102	3	03/28/91 16:53	47.00 R	20		.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	0
30103	4	03/29/91 11:56	51.50 L	20		.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	0
30104	21	03/31/91 09:43	60.10 R	20		.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	0
30107	16	04/02/91 08:15	65.50 L	30		.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	0
30106	3	04/02/91 10:55	64.56 R	30		.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	1
30105	2	04/02/91 11:25	63.45 L	30		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30108	2	04/02/91 15:05	66.80 L	30		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30109	3	04/02/91 15:40	67.90 L	30		.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	1
30110	3	04/02/91 16:20	68.10 L	30		.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	2
30112	2	04/04/91 11:08	86.98 R	30		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30114	4	04/04/91 14:34	88.52 L	40		.	.	.	.	4	.	.	.	.	4	.	.	.	.	.	1
30115	5	04/06/91 09:22	110.80 R	40		.	.	.	.	5	.	5	5	.	.	.	.	.	.	.	0
30116	2	04/06/91 12:10	115.40 L	40		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30117	3	04/06/91 14:38	122.01 R	40		.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	1
30118	3	04/06/91 15:05	122.55 L	40		.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	1
30119	1	04/08/91 14:33	147.80 L	40		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30120	1	04/09/91 10:11	164.90 R	40		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30124	29	04/09/91 13:50	165.24 R	40		.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	1
30122	4	04/09/91 15:00	165.00 L	40		.	.	.	.	4	.	4	4	.	4	.	.	.	.	.	1
30125	1	04/09/91 16:30	166.40 R	40		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
30134	1	04/09/91 17:00	167.00 L	50		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30123	2	04/10/91 08:35	165.24 R	40		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30121	1	04/10/91 09:25	165.00 L	40		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30129	4	04/10/91 10:42	165.88 R	40		.	.	.	.	4	.	4	4	.	4	.	.	.	.	.	1
30127	1	04/10/91 16:20	165.49 R	40		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30128	1	04/10/91 16:30	165.67 R	40		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30130	1	04/10/91 16:40	166.00 R	40		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30131	1	04/10/91 17:00	166.20 R	40		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30132	1	04/10/91 17:05	166.40 R	40		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30126	1	04/10/91 17:40	165.41 R	40		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30133	2	04/11/91 08:45	166.85 L	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30135	2	04/11/91 09:30	167.21 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30136	2	04/11/91 09:45	167.53 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
30137	2	04/11/91 09:55	167.58 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30138	2	04/11/91 10:17	168.15 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30139	1	04/11/91 10:30	170.30 R	50		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30140	2	04/11/91 10:40	170.57 L	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30141	2	04/11/91 10:55	171.56 L	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30142	2	04/11/91 11:30	172.80 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30143	1	04/11/91 11:52	173.50 R	50		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30144	2	04/11/91 12:10	174.10 L	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30145	2	04/11/91 12:10	175.20 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30147	2	04/11/91 13:10	177.43 L	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30146	2	04/11/91 13:22	176.52 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	3
30148	2	04/11/91 15:10	183.80 L	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30149	2	04/11/91 15:20	184.04 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30151	2	04/11/91 15:30	186.00 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30150	2	04/11/91 15:39	185.55 L	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30152	2	04/11/91 16:00	187.43 L	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30153	1	04/11/91 16:45	189.54 R	50		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30154	1	04/12/91 08:55	191.20 R	50		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30161	16	04/12/91 08:55	192.33 R	50		.	.	1	.	.	1	3	3	.	3	.	.	.	.	.	3
30155	2	04/12/91 09:30	191.60 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30156	2	04/12/91 09:45	191.80 L	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30157	2	04/12/91 10:05	192.00 L	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30158	2	04/12/91 10:40	192.10 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30159	2	04/12/91 11:15	192.20 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30160	1	04/12/91 11:35	192.50 L	50		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30162	4	04/12/91 13:50	193.91 L	50		.	.	.	.	4	.	3	4	.	4	.	.	.	.	.	1
30163	2	04/12/91 15:05	193.85 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
30164	1	04/12/91 16:00	194.50 L	50		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30165	2	04/13/91 08:50	196.00 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30166	2	04/13/91 09:20	196.60 L	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	5

Trip 1 (cont'd)

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
30167	1	04/13/91 11:03	209.00 R	50		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
30168	2	04/13/91 11:40	209.50 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30169	2	04/13/91 11:55	212.60 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30170	2	04/13/91 13:00	213.90 L	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30171	2	04/13/91 14:15	220.00 R	50		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30172	1	04/13/91 15:00	221.50 L	50		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
Sum	215						.	5	.	133	1	19	20	.	19	.	.	.	.	.	59

Trip 2

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
30201	4	05/08/91 08:39	32.90 L	20		.	.	.	.	4	.	4	4	.	4	.	.	.	.	.	2
30202	3	05/08/91 11:09	37.32 R	20		.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	0
30203	3	05/08/91 11:50	37.36 L	20		.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	0
30204	2	05/08/91 12:00	39.88 L	20		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30205	2	05/08/91 12:54	45.00 L	20		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30206	4	05/08/91 14:47	48.78 L	20		.	.	.	.	4	.	4	4	.	4	.	.	.	.	.	0
30207	3	05/08/91 15:00	49.34 L	20		.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	1
30208	5	05/08/91 16:00	50.12 L	20		.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	0
30210	4	05/08/91 16:21	50.70 L	20		.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	0
30209	2	05/08/91 16:54	50.45 L	20		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30211	2	05/09/91 08:56	54.00 R	20		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30212	3	05/09/91 09:50	54.60 R	20		.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	0
30213	30	05/09/91 17:58	60.71 R	20		.	.	2	.	.	1	2	2	.	2	1	.	.	.	.	0
30214	30	05/09/91 18:48	60.85 L	20		.	.	2	.	.	1	2	2	.	2	1	.	.	.	.	0
30219	2	05/10/91 09:25	63.75 L	30		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
30216	2	05/10/91 11:40	61.49 R	20		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30217	2	05/10/91 12:34	61.50 R	20		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
30215	2	05/10/91 13:45	61.48 R	20		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30218	2	05/10/91 14:23	61.51 R	20		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30220	3	05/11/91 13:20	65.70 L	30		.	.	.	.	3	.	3	3	.	3	.	.	.	.	.	1
30221	2	05/11/91 13:35	68.10 L	30		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30222	3	05/11/91 16:38	68.39 R	30		.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	1
30224	4	05/12/91 13:45	71.12 R	30		.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	0
30223	3	05/12/91 14:05	70.30 L	30		.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	2
30226	2	05/12/91 15:57	72.25 L	30		.	.	.	.	2	.	2	2	.	2	.	.	.	.	.	0
30225	32	05/13/91 14:23	71.12 L	30		.	.	2	.	3	.	3	3	.	2	1	.	.	.	.	1
30227	2	05/14/91 10:06	81.07 R	30		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30229	1	05/14/91 11:00	84.03 R	30		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30295	2	05/15/91 .: .	87.62 R	32		.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
30235	10	05/16/91 08:33	122.55 R	40		.	.	1	.	2	.	3	3	.	3	.	.	.	.	.	1
30230	1	05/16/91 10:00	111.00 L	40		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30231	3	05/16/91 10:30	114.32 R	40		.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	0
30233	1	05/16/91 13:30	122.20 R	40		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30232	32	05/16/91 17:30	122.01 R	40		.	.	2	.	.	.	.	.	.	.	1	.	.	.	.	0
30234	1	05/16/91 17:46	122.55 L	40		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30236	2	05/17/91 15:14	122.55 L	40		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30237	2	05/18/91 10:52	126.20 L	40		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30238	2	05/18/91 11:00	126.85 R	40	SL	5000	.	.	.	2	.	2	2	.	2	.	.	.	.	.	0
30239	3	05/18/91 16:34	136.70 L	40	SL	5000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	0
30240	2	05/18/91 18:02	142.00 L	40	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30241	2	05/19/91 10:45	145.00 L	40	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30242	2	05/19/91 14:00	159.00 R	40	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30243	2	05/19/91 14:19	159.10 L	40	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30244	2	05/19/91 14:40	163.20 R	40	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30245	3	05/19/91 15:22	165.49 R	40	SL	5000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	0
30248	2	05/20/91 10:00	167.71 R	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30247	3	05/20/91 10:06	167.67 R	50	SL	5000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	1
30249	3	05/20/91 10:20	168.15 R	50	SL	5000	.	.	.	3	.	3	3	.	3	.	.	.	.	.	2
30250	2	05/20/91 11:35	169.00 R	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30252	2	05/20/91 12:00	170.98 R	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30253	2	05/20/91 13:10	171.12 R	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30251	2	05/20/91 13:19	171.56 L	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1

Trip 2 (cont'd)

					Flo	Flow	Typ	Typ	Ang	Son	Ben					Tot	Pla	Vis	Dri	-A-	Fish	
Study	Sites	Date--Time	Mile		Rch	Cod	CFS	A	B	lng	Opp	de	ths	Sed	Chl	Pkn	Map	Map	cer	ft	2nd	Coll
30254	2	05/20/91 13:55	172.62	L	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30256	2	05/20/91 14:30	173.63	L	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30257	2	05/20/91 14:50	173.82	R	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30255	39	05/20/91 16:00	173.00	R	50	SL	5000	.	2	.	1	1	3	3	.	3	1	.	.	.	.	2
30246	2	05/21/91 09:47	167.53	R	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30258	2	05/21/91 10:50	176.07	R	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30259	2	05/21/91 11:05	176.52	R	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30260	2	05/21/91 11:30	176.96	R	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30261	2	05/21/91 11:50	177.50	R	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30262	2	05/21/91 13:35	180.00	R	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30263	2	05/21/91 14:17	182.52	R	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30264	2	05/21/91 14:50	182.83	R	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30267	2	05/21/91 15:45	189.00	L	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30272	2	05/21/91 16:21	194.02	L	50	SL	5000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30269	23	05/22/91 08:20	193.91	L	50	SH	15000	.	1	.	1	1	3	3	.	3	1	.	.	.	.	4
30270	20	05/22/91 09:37	193.95	R	50	SH	15000	.	1	.	1	1	3	3	.	3	1	.	.	.	.	2
30268	2	05/22/91 14:42	192.00	R	50	SH	15000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30266	2	05/22/91 15:40	188.73	L	50	SH	15000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30265	2	05/22/91 16:06	188.40	R	50	SH	15000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30271	2	05/23/91 11:17	193.85	R	50	SH	15000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	4
30281	1	05/23/91 12:00	202.30		50	SH	15000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
30273	3	05/23/91 14:00	196.50	R	50	SH	15000	.	.	.	3	.	3	3	.	3	.	.	.	.	.	3
30274	2	05/23/91 13:55	195.57	R	50	SH	15000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30275	1	05/23/91 14:11	195.70	R	50	SH	15000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30277	1	05/23/91 14:32	198.10	R	50	SH	15000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30276	1	05/23/91 14:49	198.00	R	50	SH	15000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30278	1	05/23/91 15:17	199.40	R	50	SH	15000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30279	1	05/23/91 15:32	200.20	R	50	SH	15000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
30282	1	05/23/91 15:57	202.40	R	50	SH	15000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
30280	38	05/23/91 17:00	201.06	R	50	SH	15000	.	2	.	.	2	2	2	.	2	1	.	.	.	.	3
30283	2	05/24/91 09:50	202.90	R	50	SH	15000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
30284	2	05/24/91 10:13	203.00	L	50	SH	15000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
30285	3	05/24/91 10:46	204.00	R	50	SH	15000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	2
30286	2	05/24/91 11:17	204.30	L	50	SH	15000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30287	2	05/24/91 12:09	204.50	L	50	SH	15000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30288	2	05/24/91 12:32	204.70	R	50	SH	15000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30289	2	05/25/91 10:05	207.80	L	50	SH	15000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30290	2	05/25/91 10:55	210.80	L	50	SH	15000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
30292	1	05/25/91 11:11	213.50	L	50	SH	15000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
30291	2	05/25/91 11:15	211.40	R	50	SH	15000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30293	1	05/25/91 13:00	216.60	R	50	SH	15000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30294	2	05/25/91 14:15	219.40	R	50	SH	15000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
Sum	436							.	15	.	188	9	42	42	.	41	8	.	.	.	.	78

Trip 3

						Flo	Flow	Typ	Typ	Ang		Son	Ben				Tot	Pla	Vis	Dri	-A-	Fish
Study	Sites	Date--Time	Mile		Rch	Cod	CFS	A	B	lng	Opp	de	ths	Sed	Chl	Pkn	Map	Map	cer	ft	2nd	Coll
30301	2	07/07/91 10:09	26.03	L	20	SL	10000	1	.	.	.	.	1	1	.	1	.	1	.	.	1	1
30302	2	07/07/91 10:30	26.03	L	20	SL	10000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
30303	2	07/08/91 08:15	39.24	R	20	SL	10000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	0
30304	2	07/08/91 10:01	41.50	R	20	SL	10000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30305	2	07/08/91 13:29	44.00	L	20	SL	10000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30306	2	07/08/91 13:29	44.00	L	20	SL	10000	1	.	.	.	.	1	1	.	1	.	2	.	.	1	1
30307	2	07/09/91 08:48	51.14	L	20	DC	22000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30308	2	07/09/91 11:30	55.00	L	20	DC	20000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30309	2	07/09/91 14:00	55.00	R	20	DC	15000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30310	2	07/10/91 12:20	66.70	R	30	DC	20000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	0
30311	2	07/10/91 14:30	68.50	L	30	DC	15000	1	.	.	.	.	1	1	.	2	.	2	.	.	1	1
30312	2	07/14/91 14:42	118.50	R	40	SL	5000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30313	2	07/14/91 16:30	119.40	R	40	SL	5000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	2
30314	2	07/15/91 08:38	120.30	R	40	SL	5000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30315	2	07/18/91 08:26	167.53	R	50	SL	10000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30316	2	07/18/91 09:30	169.00	R	50	SL	10000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	2
30317	2	07/18/91 11:40	176.08	L	50	SL	10000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	0

Trip 3 (cont'd)

Study	Sites	Date--Time	Mile		Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Tot Pkn	Pla Map	Vis Map	Dri cer	-A- ft	Fish 2nd	Coll
30318	2	07/18/91 14:43	179.00	L	50	SL	10000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	0
30319	2	07/19/91 08:32	186.00	L	50	DC	11000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
30320	2	07/19/91 10:40	193.85	R	50	SL	10000	1	.	.	.	.	2	2	.	2	.	.	.	.	1	2
30328	1	07/10/91 11:45	64.30	L	20		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30321	2	07/19/91 11:40	193.95	R	50	SL	10000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	3
30322	2	07/20/91 07:45	193.91	L	50	DC	22000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30323	2	07/20/91 11:30	196.50	R	50	DC	18000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	2
30324	2	07/20/91 13:51	201.06	R	50	DC	18000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30325	1	07/11/91 10:00	71.12	L	30		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30326	1	07/16/91 15:00	156.93	L	46	AC	10000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30327	4	07/16/91 08:55	143.50	R	45		.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	2
30329	1	07/14/91 08:00	108.60	R	42		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
30338	1	07/09/91 17:15	61.50	L	22		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
30330	1	07/13/91 18:00	108.60	R	42		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30331	1	07/12/91 19:00	108.60	R	42		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30332	1	07/13/91 08:05	108.60	R	42		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30333	1	07/13/91 19:00	108.60	R	42		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30334	1	07/13/91 17:00	108.60	R	42		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30335	2	07/13/91 00:00	108.60	R	42		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
30336	1	07/06/91 19:30	18.00	L	30		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30337	1	07/10/91 09:20	61.50	L	22		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
Sum	66							24	.	.	18	.	45	45	.	46	.	41	.	.	24	43

Trip 4

Study	Sites	Date--Time	Mile		Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
30401	2	09/11/91 08:25	33.27	L	20	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	0
30402	2	09/11/91 10:40	37.32	R	20	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30403	2	09/11/91 13:50	41.13	R	20	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30404	3	09/11/91 16:00	44.27	L	20	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30405	3	09/12/91 08:30	54.80	R	20	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30406	3	09/12/91 10:25	55.50	R	20	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	2
30407	2	09/12/91 13:00	55.60	R	20	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30408	1	09/12/91 18:33	61.50	L	22		.	.	.	1	.	.	.	.	.	.	.	.	6	.	.	1
30409	1	09/13/91 09:12	64.30	R	30	DC	.	.	.	.	1	.	.	.	.	.	.	.	2	.	1	1
30410	1	09/13/91 09:38	64.80	R	30	DC	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	1
30411	2	09/13/91 10:25	68.10	L	30	DC	.	1	.	.	.	.	2	2	.	2	.	2	3	.	1	5
30412	1	09/13/91 13:09	70.19	L	30	DC	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	1
30413	2	09/13/91 14:27	72.03	R	30	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	5
30414	1	09/14/91 13:03	92.62	R	30	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30415	1	09/14/91 14:30	98.04	R	41	DC	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	2
30416	1	09/14/91 17:00	108.50	R	42	DC	17000	.	.	.	1	.	.	.	.	.	.	.	.	.	1	2
30417	2	09/15/91 10:36	117.40	R	40	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30418	2	09/15/91 11:50	118.10	R	40	AC	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	1
30419	2	09/15/91 13:00	119.13	R	40	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30420	2	09/15/91 14:33	120.30	L	40	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30421	2	09/16/91 07:56	122.01	R	40	SL	10000	1	.	.	.	.	2	2	.	2	.	2	.	.	.	2
30422	3	09/16/91 09:51	122.55	L	40	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30423	2	09/16/91 11:10	123.42	R	40	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30424	2	09/16/91 12:10	124.20	R	40	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30425	3	09/16/91 13:40	125.61	R	40	AC	15000	1	.	.	.	.	2	2	.	2	.	1	.	.	.	1
30426	2	09/16/91 14:27	127.00	R	40	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30427	1	09/17/91 08:40	133.70	R	43		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30428	1	09/17/91 10:40	136.30	R	44		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30429	2	09/17/91 11:37	137.30	R	40	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30430	2	09/17/91 14:36	145.00	L	40	AC	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	1
30431	2	09/17/91 14:55	145.60	L	40	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30432	2	09/18/91 10:40	160.70	L	40	SL	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	1
30433	2	09/18/91 11:35	164.70	L	40	SL	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	0
30434	2	09/18/91 13:20	166.85	L	50	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30435	2	09/18/91 14:10	166.86	R	50	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30436	2	09/18/91 15:40	167.40	R	50	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30437	3	09/19/91 09:14	170.30	R	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1

Trip 4 (cont'd)

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
30438	2	09/19/91 12:36	172.39 L	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30439	3	09/19/91 13:24	173.63 L	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30440	3	09/19/91 14:20	174.10 L	50	DC	.	1	.	.	.	.	2	2	.	2	.	4	.	.	.	1
30441	2	09/19/91 15:29	174.90 R	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30442	2	09/19/91 17:00	177.90 R	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30443	1	09/20/91 10:00	181.18 L	50	DC	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	0
30444	2	09/20/91 10:35	181.51 L	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30445	2	09/20/91 13:05	182.37 R	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	1	.	.	2
30446	2	09/20/91 14:07	182.52 R	50	SL	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	0
30447	3	09/20/91 14:57	182.82 L	50	SL	.	1	.	.	.	.	2	2	.	2	.	2	2	.	.	1
30448	1	09/20/91 14:57	182.83 L	50	SL	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30449	2	09/20/91 16:30	182.83 R	50	SL	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30450	2	09/21/91 09:00	185.55 L	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30451	2	09/21/91 10:10	187.12 R	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	3
30452	2	09/21/91 13:15	189.04 R	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	3
30453	2	09/21/91 14:45	190.25 L	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30454	2	09/21/91 16:30	191.95 L	50	SL	.	1	.	.	.	.	2	2	.	2	.	2	3	.	1	1
30455	1	09/21/91 18:17	191.76 L	50	SL	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	0
30456	2	09/22/91 08:31	193.91 L	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30457	2	09/22/91 09:40	193.95 R	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	2
30458	2	09/22/91 11:14	193.85 R	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	2
30459	2	09/22/91 13:50	195.37 L	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30460	2	09/22/91 14:50	195.57 R	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30461	2	09/23/91 08:27	199.58 R	50	SH	16000	.	.	.	1	.	.	.	.	.	.	.	.	.	2	1
30462	2	09/23/91 09:07	201.06 R	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30463	2	09/23/91 11:00	204.30 L	50	DC	15000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30464	2	09/23/91 11:57	208.40 L	50	DC	12000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30465	2	09/23/91 15:25	212.73 R	50	DC	10000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30466	2	09/24/91 08:10	214.13 R	50	SL	8000	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30467	2	09/24/91 10:13	215.50 L	50	AC	8000	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30468	2	09/24/91 11:22	216.15 L	50	AC	10000	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30469	2	09/24/91 13:00	218.10 L	50	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
30470	2	09/24/91 14:10	218.95 L	50	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	.	1
Sum	137						55	.	1	13	.	110	110	.	110	.	111	20	.	39	83

Trip 5

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
30501	440	11/03/91 15:05	64.60 R	30		.	.	1	.	.	.	10	10	.	10	1	.	.	.	.	1
30502	236	11/07/91 10:45	84.03 R	31		.	.	1	.	.	.	3	3	.	8	1	.	.	.	.	0
30503	410	11/09/91 18:00	108.60 R	42		.	.	1	.	.	.	6	10	.	10	1	.	.	.	.	6
30504	408	11/13/91 16:00	143.50 R	45		.	.	1	.	.	.	10	10	.	10	1	.	.	.	.	3
30505	419	11/16/91 16:30	193.95 R	50		.	.	1	.	.	.	10	10	.	10	1	.	.	.	.	1
Sum	1913						.	5	.	.	.	39	43	.	48	5	.	.	.	.	11

Trip 6

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
30600	1	01/06/92 12:00	31.65 R	20	DC	10000	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
30601	3	01/07/92 10:00	52.20 R	21	DC	10000	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
30602	2	01/07/92 14:41	54.60 R	20	SL	8000	.	.	.	.	.	4	.	2	.	.	.	.	.	1	0
30603	2	01/08/92 12:14	68.10 L	30	SH	13000	.	.	.	.	.	4	.	2	.	.	.	.	.	1	1
30604	2	01/08/92 14:35	71.12 L	30	SH	13000	.	.	.	.	.	.	.	.	.	.	.	.	.	1	0
30605	2	01/09/92 10:50	72.03 R	30	SH	10000	.	.	.	.	.	4	.	2	.	.	.	.	.	1	1
30608	0	01/09/92 13:30	84.03 R	31		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
30606	3	01/10/92 13:00	87.62 R	32	SH	11000	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
30607	5	01/11/92 10:10	88.95 L	401	AC	10000	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
30609	3	01/11/92 14:11	95.00 L	40	SH	10000	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
30610	3	01/12/92 09:30	108.60 R	42	AC	10000	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
30611	3	01/12/92 13:45	116.50 L	402	SH	12000	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
30612	3	01/13/92 10:55	131.80 R	403	DC	8000	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
30613	2	01/13/92 13:26	133.83 R	43	SL	7500	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
30614	4	01/14/92 09:40	136.25 R	44	DC	8000	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1

Trip 6 (cont'd)

Study	Sites	Date--Time	Mile	Flo Rch	Flow Cod	Typ CFS	Typ A	Ang B	lng	Son Opp	Ben de	ths	Sed	Chl	Tot Pkn	Pla Map	Vis Map	Dri cer	-A- ft	Fish 2nd	Coll
30615	2	01/14/92 14:16	143.50 R	45	AC	10000	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
30616	3	01/15/92 10:00	147.80 L	40	DC	12000	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
30617	2	01/15/92 13:15	153.17 L	40	AC	13000	.	.	.	.	.	2	4	.	2	.	2	.	.	1	1
30618	2	01/16/92 10:30	166.62 L	50	AC	10000	.	.	.	.	.	2	4	.	2	.	2	.	.	1	0
30619	2	01/16/92 11:30	167.21 R	50	AC	11000	.	.	.	.	.	2	4	.	2	.	2	.	.	1	1
30620	2	01/16/92 13:15	168.71 R	50	DC	10000	.	.	.	.	.	2	4	.	2	.	2	.	.	1	1
30621	3	01/17/92 10:00	182.63 L	50	AC	11000	.	.	.	.	.	2	6	.	3	.	2	.	.	2	1
30622	2	01/17/92 11:35	187.53 R	50	DC	10000	.	.	.	.	.	2	4	.	2	.	2	.	.	1	2
30623	2	01/17/92 13:30	191.41 L	50	DC	10000	.	.	.	.	.	2	4	.	2	.	2	.	.	1	2
30624	2	01/17/92 14:35	192.40 R	50	DC	9000	.	.	.	.	.	2	4	.	2	.	2	.	.	1	1
30625	2	01/18/92 09:40	204.30 L	50	SH	15000	.	.	.	.	.	2	4	.	2	.	2	.	.	1	1
30626	1	01/18/92 11:00	207.70 R	50	SH	15000	.	.	.	.	.	1	2	.	1	.	2	.	.	.	1
30627	1	01/18/92 13:00	211.53 L	50	DC	15000	.	.	.	.	.	2	4	.	2	.	2	.	.	1	0
Sum	64						.	.	.	.	.	33	44	6	22	.	22	.	.	15	20

Trip 7

Study	Sites	Date--Time	Mile	Flo Rch	Flow Cod	Typ CFS	Typ A	Ang B	lng	Son Opp	Ben de	ths	Sed	Chl	Tot Pkn	Pla Map	Vis Map	Dri cer	-A- ft	Fish 2nd	Coll
30701	328	02/19/92 15:00	68.10 L	30	DC	10000	.	.	.	.	.	10	10	.	10	.	.	.	.	.	0
30702	419	02/22/92 17:30	98.04 R	41		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
30703	321	02/25/92 16:00	108.60 R	42		.	.	.	.	.	.	5	3	.	.	.	.	.	.	.	0
30704	371	02/28/92 15:00	143.50 R	45		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
30705	138	03/03/92 18:00	201.06 R	50		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Sum	1577						.	.	.	.	.	15	13	.	10	.	.	.	.	.	

Trip 8

Study	Sites	Date--Time	Mile	Flo Rch	Flow Cod	Typ CFS	Typ A	Ang B	lng	Son Opp	Ben de	ths	Sed	Chl	Tot Pkn	Pla Map	Vis Map	Dri cer	-A- ft	Fish 2nd	Coll
30801	2	04/13/92 10:05	38.95 L	20	SL	8000	1	.	.	.	.	2	2	1	2	.	2	.	.	1	1
30802	2	04/13/92 13:55	39.88 L	20	SL	8000	1	.	.	.	.	2	2	1	2	.	2	.	.	1	1
30803	9	04/14/92 08:00	52.20 R	21	SL	5	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
30804	2	04/14/92 10:48	54.40 R	20	SH	10000	1	.	.	.	.	2	2	1	2	.	2	.	.	1	1
30805	2	04/14/92 12:29	55.50 R	20	SH	10000	1	.	.	.	.	2	2	1	2	.	2	.	.	1	1
30800	1	04/14/92 18:20	61.50 L	22	DC	2000	.	.	1	1	.	.	.	.	.	.	.	.	.	.	1
30806	2	04/15/92 08:57	64.50 L	30	AC	10000	1	.	.	.	.	2	2	1	2	.	2	.	.	1	6
30807	2	04/15/92 11:06	68.10 L	30	AC	10000	1	.	.	.	.	2	2	1	2	.	2	.	.	1	2
30808	1	04/15/92 14:05	72.25 L	30	AC	10000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
30809	1	04/15/92 15:25	76.65 L	30	DC	10000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
30810	8	04/16/92 10:05	84.03 R	31	SH	12	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
30811	1	04/16/92 13:36	87.62 R	32	SH	20000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30812	5	04/17/92 14:25	98.04 R	41	SH	12000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30813	3	04/18/92 08:30	108.60 L	42		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30814	2	04/18/92 13:00	122.01 R	40	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30815	2	04/18/92 16:50	133.83 R	43	SH	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30816	2	04/19/92 08:30	136.25 R	44	SL	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
30817	2	04/19/92 11:15	138.50 L	40	SL	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30818	2	04/20/92 08:30	161.50 R	40	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30819	2	04/20/92 12:00	163.86 L	40	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30820	2	04/20/92 12:00	166.85 L	50	SL	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30821	2	04/20/92 12:00	166.85 L	50	SL	.	1	.	.	.	.	1	1	.	2	.	2	.	.	1	1
30822	2	04/20/92 13:00	167.20 R	50	SL	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30823	2	04/20/92 14:50	168.70 R	50	SL	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30824	2	04/20/92 16:37	172.70 L	50	SL	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30825	2	04/21/92 09:45	181.30 L	50	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30826	2	04/21/92 11:15	182.83 R	50	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30827	2	04/21/92 12:45	183.20 L	50	AC	.	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
30828	2	04/21/92 14:00	187.20 R	50	AC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30829	2	04/22/92 09:00	189.40 R	50	SH	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30830	2	04/22/92 09:00	189.40 R	50	SH	.	1	.	.	.	.	1	1	.	1	.	2	.	.	1	1
30831	2	04/22/92 13:30	191.55 R	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30832	2	04/22/92 14:45	192.00 L	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30833	2	04/22/92 15:40	192.45 R	50	DC	.	1	.	.	.	.	2	2	.	2	.	2	.	.	1	1
30834	2	04/23/92 08:45	196.75 R	50	SH	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0

30835	2	04/23/92 10:00	200.48 L	50	SH	.	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
30836	2	04/23/92 11:20	201.06 R	50	SH	.	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
30837	2	04/23/92 14:00	202.75 L	50	SH	.	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
30838	2	04/23/92 16:15	204.12 R	50	SH	.	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
30839	2	04/23/92 17:10	204.11 R	50	SH	.	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
30840	2	04/24/92 08:45	207.40 L	50	SH	.	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
30841	2	04/24/92 10:30	210.80 L	50	SH	.	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
30842	2	04/25/92 10:00	225.00 R	50	AC	.	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
Sum	99						32	.	1	11	.	62	62	6	63	.	55	.	.	32	46

Trip 9

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
30901	405	05/22/92 15:00	68.10 L	30	DC	10000	.	18	.	.	2	7	7	.	7	.	.	.	17	.	2
30902	399	05/25/92 16:41	98.04 R	41	SL	8000	.	18	.	.	2	3	3	.	.	2	.	.	8	.	4
30903	385	05/28/92 14:30	108.60 R	42	AC	10000	.	17	.	.	2	2	2	.	.	1	.	.	2	.	12
30904	349	05/31/92 16:00	143.50 R	45	SL	7000	.	16	.	.	2	6	6	.	.	1	.	.	1	.	11
30905	204	06/04/92 18:00	201.06 R	50	AC	7000	.	9	.	.	2	6	6	.	.	1	.	.	4	.	1
Sum	1742						.	78	.	.	10	24	24	.	7	5	.	.	32	.	30

Trip 10

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
31001	1	06/22/92 12:00	29.02 R	20	SL	6000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31002	2	06/22/92 13:13	30.40 R	20	AC	6000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31003	2	06/22/92 15:36	32.90 L	20	AC	7000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	11
31004	1	06/22/92 15:36	32.90 L	20	AC	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	6
31005	2	06/23/92 10:53	44.27 L	20	DC	10000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	9
31006	2	06/23/92 14:36	54.60 R	20	DC	9000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	9
31007	2	06/24/92 09:15	64.50 L	30	AC	12000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	65
31008	2	06/24/92 12:22	68.10 L	30	AC	17000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	57
31009	2	06/24/92 14:39	72.25 L	30	SH	17000	1	.	.	.	.	.	.	.	.	.	.	.	.	.	60
31010	1	06/25/92 07:50	88.95 L	401	SL	2	.	.	.	1	.	.	.	.	.	.	.	.	.	.	50
31011	1	06/25/92 08:50	87.62 R	32	SL	20	.	.	.	1	.	.	.	.	.	.	.	.	.	1	1
31012	2	06/25/92 12:00	95.00 L	40	SL	1	.	.	.	2	.	.	.	.	.	.	.	.	.	.	23
31013	1	06/25/92 12:55	98.04 R	41	SL	5	.	.	.	1	.	.	.	.	.	.	.	.	.	.	7
31014	1	06/25/92 15:00	108.60 R	42	SL	10	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31015	2	06/26/92 09:00	117.40 R	40	AC	10000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	54
31016	2	06/26/92 10:40	119.13 R	40	AC	11000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	43
31017	2	06/26/92 13:24	122.01 R	40	AC	12000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	150
31018	1	06/26/92 14:55	122.55 L	40	AC	14000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	12
31019	2	06/27/92 10:35	138.50 L	40	AC	10000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31020	2	06/27/92 13:12	143.50 R	45	AC	13000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	3
31026	1	06/27/92 19:00	156.93 L	46	AC	15000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
31021	2	06/28/92 09:20	163.86 L	40	DC	11000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	124
31022	2	06/28/92 11:40	166.23 L	40	DC	10000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	78
31023	2	06/28/92 14:08	167.21 R	50	DC	9000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	74
31024	2	06/28/92 15:24	167.40 L	50	DC	8000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	21
31025	2	06/28/92 16:40	167.40 R	50	AC	9000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	20
31027	2	06/29/92 08:33	171.12 R	50	DC	13000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	23
31028	1	06/29/92 10:00	176.45 R	50	DC	13000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	9
31029	3	06/29/92 13:00	182.82 L	50	DC	10000	1	.	.	.	.	2	2	.	2	.	1	.	.	2	30
31030	2	06/29/92 15:09	187.53 R	50	DC	8500	1	.	.	.	.	2	2	.	2	.	1	.	.	1	80
31031	1	06/30/92 09:30	190.10 L	50	DC	12000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31032	2	06/30/92 10:15	189.04 R	50	DC	12000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	11
31033	2	06/30/92 13:06	190.76 R	50	DC	11000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	52
31034	2	06/30/92 15:12	192.33 R	50	DC	10000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	139
31035	2	07/01/92 08:41	193.85 R	50	SH	16000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	203
31036	2	07/01/92 10:50	197.69 L	50	DC	15000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	281
31037	2	07/01/92 13:27	201.06 R	50	DC	14000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	289
31038	2	07/02/92 10:06	211.22 L	50	SH	16000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	26
Sum	67						26	.	.	14	.	50	50	.	50	.	25	.	.	27	2027

Trip 11

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
31101	193	08/06/92 17:00	68.10 L	30	dc	11000	.	8	.	.	2	4	4	.	5	1	.	.	4	.	3
31102	134	08/09/92 16:00	98.04 R	41	DC	19000	.	6	.	.	2	1	1	.	2	1	.	.	2	.	13
31103	263	08/11/92 13:00	108.60 R	42	SH	19000	.	12	.	.	2	3	3	.	4	2	.	.	2	.	10
31104	147	08/14/92 17:00	143.50 R	45	DC	18000	.	7	.	.	2	3	4	.	4	1	.	.	.	.	3
31105	239	08/17/92 17:00	201.06 R	50	DC	11000	.	11	.	.	2	5	5	.	5	1	.	.	.	.	3
Sum	976						.	44	.	.	10	16	17	.	20	6	.	.	8	.	32

Trip 12

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
31201	2	09/14/92 13:00	2.41 L	20	AC	15000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31202	2	09/15/92 13:15	44.27 L	20	DC	9000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31203	2	09/16/92 09:00	50.70 L	20	SL	15000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31204	2	09/16/92 11:12	54.60 R	20	SL	15000	1	.	.	.	.	.	.	.	.	.	.	.	.	1	1
31205	2	09/16/92 13:10	55.40 R	20	SL	15000	.	.	.	2	.	.	.	.	.	.	1	.	.	.	1
31206	2	09/17/92 08:25	58.30 R	20	DC	14000	1	.	.	.	.	2	2	.	2	.	1	.	.	.	1
31207	2	09/17/92 10:08	58.68 L	20	DC	14000	1	.	.	.	.	2	2	.	2	.	1	.	.	.	1
31208	2	09/17/92 12:50	62.12 R	30	DC	12000	1	.	.	.	.	2	2	.	2	.	1	.	.	.	3
31209	2	09/19/92 09:30	119.13 R	40	DC	12000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	2
31210	2	09/19/92 13:00	122.01 R	40	DC	14000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31211	1	09/19/92 14:30	122.00 R	40	AC	14000	1	.	.	.	.	1	1	.	1	.	1	.	.	1	1
31212	2	09/19/92 16:09	117.40 R	40	DC	17000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31213	1	09/20/92 09:30	121.20 L	40	SL	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31214	1	09/20/92 10:30	121.70 L	40	SL	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31215	1	09/20/92 10:30	122.01 R	40	SL	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31216	1	09/20/92 11:15	122.80 R	40	SL	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31217	1	09/20/92 12:02	125.78 L	40	SL	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31218	1	09/21/92 13:30	137.16 L	40	SL	8000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31219	1	09/21/92 15:30	140.70 L	40	SL	7000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31220	2	09/22/92 11:30	161.63 L	40	SL	7000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31221	2	09/22/92 13:50	164.76 L	40	SL	7000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31222	2	09/23/92 09:00	168.75 R	50	SL	7000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31223	2	09/23/92 11:05	172.15 L	50	SL	7000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31224	2	09/23/92 13:35	176.68 L	50	SL	7000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31225	2	09/23/92 15:00	176.80 R	50	SL	7000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31226	2	09/24/92 09:00	182.83 L	50	DC	17000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31227	2	09/24/92 11:00	186.00 R	50	DC	15000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31228	2	09/24/92 11:55	187.85 R	50	DC	15000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31229	2	09/24/92 14:00	190.76 R	50	DC	14000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31230	1	09/24/92 15:50	192.33 R	50	DC	14000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31231	2	09/25/92 08:25	193.85 R	50	DC	14000	1	.	.	1	.	2	2	.	2	.	1	.	.	1	1
31232	1	09/25/92 08:25	198.03 L	50	DC	14000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31233	1	09/25/92 10:00	200.48 L	50	DC	14000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31234	2	09/25/92 11:00	200.80 R	50	DC	14000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
31235	2	09/25/92 13:00	201.06 R	50	DC	13000	1	.	.	.	.	2	2	.	2	.	1	.	.	1	1
Sum	59						26	.	.	11	.	49	49	.	49	.	26	.	.	23	38

Trip 13

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
31301	4	10/25/92 11:00	55.40 R	20	AC	6500	.	.	.	.	.	12	12	.	4	.	.	.	.	.	0
31302	78	10/25/92 16:00	64.60 R	30	DC	9000	.	3	.	.	1	.	.	.	.	.	.	.	.	.	1
31304	1	10/26/92 16:00	64.70 L	30	DC	8000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
31303	60	10/27/92 11:00	64.70 L	30	AC	11000	.	3	.	.	1	.	.	.	.	.	.	.	.	.	5
31305	1	10/27/92 17:00	64.70 L	30	DC	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31306	1	10/28/92 16:00	64.60 R	30	DC	8000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31307	1	10/28/92 16:30	64.70 L	30	DC	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31308	1	10/28/92 16:45	64.70 L	30	DC	6500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31309	1	10/28/92 17:00	64.70 L	30	DC	6500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31310	163	10/30/92 17:50	108.60 R	42	SH	9000	.	8	.	.	2	.	.	.	.	.	1	.	.	.	5
31311	9	11/02/92 13:00	119.10 R	40	SL	5000	.	.	.	1	.	9	9	.	6	.	.	.	.	.	1

31312	139	11/03/92 17:00	122.01 R	40	AC	6000	.	6	.	.	2	.	.	.	.	.	1	.	.	.	1
31315	1	11/04/92 17:00	122.01 R	40	AC	10000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31314	1	11/05/92 17:00	143.50 L	45	AC	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31313	174	11/06/92 09:00	143.50 L	45	DC	7000	.	8	.	.	2	.	.	.	.	.	1	.	.	.	2
31316	1	11/08/92 15:00	143.50 L	45	AC	6000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
31317	1	11/08/92 15:30	143.50 L	45	AC	6000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31318	1	11/08/92 16:00	143.50 R	45	AC	6000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31319	1	11/09/92 12:00	156.93 L	46	SL	25	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31320	3	11/10/92 08:00	201.06 R	50	DC	7000	.	.	.	.	.	9	9	.	3	.	.	.	.	.	0
Sum	642						.	28	.	13	8	30	30	.	13	.	3	.	.	.	29

<u>Trip 14</u>

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
31401	1	02/15/93 11:20	.90 R	11	AC	10000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31402	1	02/15/93 11:40	2.41 L	20	AC	10500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
31403	1	02/15/93 16:45	20.73 R	20	AC	14000	.	.	.	.	1	.	.	.	.	.	.	.	.	.	0
31404	1	02/16/93 10:00	32.90 L	20	DC	10000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	4
31405	4	02/16/93 12:10	44.27 L	20	DC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	7
31406	3	02/16/93 17:00	55.37 L	20	DC	9000	.	.	.	3	1	.	.	.	.	.	.	.	.	.	0
31407	8	02/16/93 18:00	55.50 R	20	DC	9000	.	.	.	8	.	12	12	.	4	.	.	.	.	.	1
31408	2	02/17/93 13:00	58.23 R	20	DC	12000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31409	2	02/17/93 14:00	58.70 L	20	DC	12000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31410	1	02/17/93 18:00	61.03 L	20	DC	9000	.	.	.	.	1	.	.	.	.	.	.	.	.	.	0
31412	1	02/17/93 20:00	58.23 R	20	DC	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31413	2	02/18/93 12:00	62.10 R	30	DC	15000	1	.	.	.	.	9	9	.	3	.	1	1	.	.	9
31414	3	02/18/93 14:30	62.75 R	30	DC	12000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	14
31411	3	02/18/93 15:30	62.55 R	30	DC	10000	.	.	.	3	1	.	.	.	.	.	1	.	.	.	0
31415	3	02/19/93 11:00	63.08 L	30	DC	15000	1	.	.	.	.	12	12	.	4	.	1	.	.	.	81
31416	2	02/19/93 12:00	63.18 L	30	DC	14000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	71
31417	1	02/20/93 11:30	63.85 R	30	DC	18000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31418	1	02/20/93 11:50	63.85 R	30	DC	18000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
31419	3	02/20/93 12:30	63.90 L	30	DC	18000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	9
31420	1	02/20/93 14:50	64.17 L	30	DC	18000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
31421	1	02/20/93 14:55	64.18 L	30	DC	18000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31422	1	02/20/93 15:10	64.78 L	30	DC	18000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	4
31423	1	02/20/93 15:45	68.10 L	30	DC	18000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31424	1	02/20/93 15:45	68.10 L	30	DC	18000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	15
31425	1	02/21/93 10:08	72.05 R	30	DC	19000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31426	1	02/21/93 10:15	72.05 R	30	DC	19000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31427	3	02/21/93 10:20	72.05 R	30	DC	19000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	16
31428	2	02/21/93 11:00	72.32 L	30	DC	19000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	27
31429	3	02/21/93 12:00	73.65 R	30	DC	19000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	10
31430	1	02/21/93 14:00	81.07 R	30	DC	19000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31431	3	02/22/93 15:00	108.60 R	42	AC	25000	.	.	.	3	2	.	.	.	.	.	.	.	.	.	56
31432	1	02/23/93 11:00	114.32 R	40	AC	25000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31433	1	02/23/93 12:30	117.40 R	40	AC	25000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31434	1	02/23/93 12:45	119.40 R	40	AC	25000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31436	1	02/23/93 13:10	120.05 R	40	AC	25000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
31437	1	02/23/93 13:50	120.50 L	40	AC	25000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31438	1	02/23/93 14:45	122.02 R	40	AC	25000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31439	3	02/23/93 14:50	122.00 R	40	AC	25000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	2
31440	2	02/23/93 15:00	122.25 L	40	AC	25000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
31441	1	02/24/93 10:15	122.61 L	40	AC	26000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
31442	1	02/24/93 10:15	122.60 L	40	AC	26000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	0
31443	2	02/24/93 11:30	127.55 R	40	AC	28000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31444	5	02/24/93 14:00	143.50 R	45	SH	30000	.	.	.	5	.	.	.	.	.	.	.	.	.	.	25
31445	3	02/25/93 10:00	143.50 R	45	DC	25000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	2
31446	3	02/25/93 10:40	145.50 L	404	DC	25000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	3
31447	1	02/25/93 13:20	160.87 R	40	SH	25000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	6
31448	1	02/25/93 14:30	161.80 L	40	SH	25000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31449	1	02/25/93 14:40	156.90 R	40	SH	25000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31450	1	02/25/93 14:45	163.30 R	40	SH	25000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
31451	1	02/25/93 15:15	164.44 R	40	SH	25000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31452	2	02/26/93 10:54	181.00 R	50	DC	18000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31453	1	02/26/93 11:15	182.37 R	50	DC	18000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1

31454	2	02/26/93 11:40	182.83 L	50	DC	18000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31455	3	02/26/93 12:50	185.40 R	50	DC	18000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	0
31456	4	02/26/93 16:00	193.85 R	50	SH	18000	.	.	.	4	2	.	.	.	.	.	.	.	.	.	4
31457	1	02/28/93 10:30	194.13 L	50	AC	18000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	7
31458	4	02/28/93 11:20	201.06 R	50	AC	18000	1	.	.	.	.	12	12	.	3	.	1	.	.	.	5
31459	2	02/28/93 14:00	200.80 R	50	DC	18000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	29
31460	2	02/28/93 14:45	214.17 R	50	DC	18000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
Sum	114						9	.	.	89	8	45	45	.	14	.	10	1	.	.	428

Trip 15

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
31501	4	03/12/93 13:50	3.30 L	20	AC	11000	.	.	.	4	.	.	.	.	.	.	.	.	.	.	32
31502	2	03/12/93 14:45	4.80 L	20	AC	11000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	16
31503	2	03/13/93 12:35	32.90 L	20	DC	7000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	35
31504	3	03/14/93 10:20	55.40 R	20	DC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	8
31505	3	03/14/93 12:00	58.23 R	20	DC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	2
31506	22	03/14/93 16:50	61.50 L	22	DC	8000	.	.	.	22	.	.	.	.	.	.	.	.	.	.	19
31507	1	03/16/93 10:30	61.50 L	22	DC	10000	.	.	.	1	2	.	.	.	.	.	.	.	.	.	1
31508	2	03/16/93 13:00	61.54 R	30	DC	9000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	5
31509	1	03/16/93 13:15	61.80 R	30	DC	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31510	2	03/16/93 13:30	61.92 L	30	DC	9000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	8
31511	1	03/16/93 14:00	62.10 R	30	DC	8500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31512	1	03/16/93 14:15	62.30 R	30	DC	8500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
31513	1	03/16/93 14:30	62.32 R	30	DC	8000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
31514	2	03/16/93 15:15	62.55 R	30	DC	8000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	2
31515	1	03/17/93 13:00	63.08 L	30	DC	10000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	26
31516	2	03/17/93 13:30	63.18 L	30	DC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	15
31517	4	03/17/93 14:30	65.25 L	30	DC	8500	1	.	.	.	.	.	.	.	.	.	1	.	.	.	71
31518	2	03/18/93 10:00	64.12 L	30	AC	11000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	5
31519	2	03/18/93 10:40	63.08 L	30	AC	11000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	6
31520	2	03/18/93 11:00	63.18 L	30	AC	11000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	12
31521	2	03/18/93 12:00	63.88 L	30	DC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	56
31522	4	03/18/93 17:15	64.65 R	30	DC	9000	.	.	.	4	.	.	.	.	.	.	.	.	.	.	41
31528	2	03/19/93 09:00	65.65 L	30	AC	11000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	12
31529	1	03/19/93 09:36	66.20 L	30	AC	11000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31530	1	03/19/93 09:55	66.75 L	30	AC	11000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31523	4	03/19/93 10:00	68.10 L	30	AC	11000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	16
31531	2	03/19/93 10:30	68.45 R	30	AC	11000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
31526	1	03/19/93 11:00	69.10 R	30	DC	11000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31532	1	03/19/93 11:05	69.00 L	30	AC	11000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31533	4	03/19/93 11:55	69.58 R	30	DC	11000	.	.	.	4	.	.	.	.	.	.	.	.	.	.	5
31534	1	03/19/93 12:30	69.75 L	30	DC	11000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31524	3	03/19/93 13:00	72.03 R	30	DC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	22
31527	2	03/19/93 13:00	73.65 R	30	DC	10000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31535	3	03/19/93 14:30	72.30 L	30	DC	10000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	30
31525	2	03/19/93 15:45	74.46 R	30	DC	9000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	35
31536	1	03/20/93 09:00	74.46 R	30	AC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	25
31537	4	03/20/93 17:00	108.60 R	42	DC	12000	.	.	.	4	.	.	.	.	.	.	.	.	.	.	8
31539	2	03/21/93 11:00	118.78 R	40	AC	8000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31538	2	03/21/93 11:30	119.13 R	40	AC	8000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	7
31540	3	03/21/93 11:30	122.01 R	40	AC	8000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	3
31541	2	03/21/93 13:30	120.47 L	40	AC	8000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	5
31542	6	03/22/93 16:00	143.50 R	45	SL	8000	.	.	.	6	.	.	.	.	.	.	.	.	.	.	22
31543	2	03/23/93 10:00	155.73 L	40	SL	7000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31544	2	03/23/93 11:50	159.47 R	40	SL	7000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31545	1	03/23/93 12:00	163.60 L	40	SL	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31546	2	03/23/93 12:30	164.70 L	40	SL	7000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	3
31547	2	03/23/93 13:00	165.12 R	40	SL	7000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	57
31548	2	03/23/93 14:00	166.86 R	50	SL	7000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31549	1	03/23/93 14:30	168.71 R	50	SL	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	26
31550	1	03/23/93 15:00	172.15 L	50	SL	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	8
31551	1	03/23/93 15:40	176.52 R	50	SL	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
31552	2	03/24/93 10:00	182.37 R	50	DC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	7
31553	2	03/24/93 11:40	182.83 L	50	DC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	2
31554	3	03/24/93 15:10	192.45 R	50	DC	8000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	31
31555	3	03/25/93 09:00	194.13 L	50	DC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	51

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
31556	3	03/25/93 10:20	195.92 R	50	DC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	28
31557	3	03/25/93 13:00	201.06 R	50	DC	9000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	16
31558	3	03/25/93 14:30	204.00 R	50	DC	9000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	45
31559	2	03/26/93 09:15	215.72 R	50	DC	11000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	11
31560	2	03/26/93 10:25	214.13 R	50	DC	11000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	3
Sum	150						21	.	.	97	2	.	.	.	.	.	21	.	.	.	851

Trip 16

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
31601	4	04/09/93 13:30	2.41 L	20	AC	9000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	13
31602	2	04/10/93 10:10	32.90 L	20	DC	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	36
31603	2	04/10/93 11:40	44.27 L	20	DC	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	50
31604	2	04/10/93 14:00	55.50 R	20	DC	7000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31605	1	04/10/93 15:00	58.23 R	20	DC	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31606	2	04/10/93 15:45	60.10 R	20	DC	7000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
31607	1	04/11/93 08:00	58.68 L	20	AC	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31608	6	04/11/93 13:00	61.50 L	22	DC	7000	.	.	.	6	.	.	.	.	.	.	.	.	.	.	19
31609	2	04/11/93 19:45	60.10 R	20	DC	6000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
31610	1	04/12/93 09:15	61.54 R	20	SL	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
31611	3	04/12/93 09:30	61.95 L	30	SL	7000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	3
31612	1	04/12/93 10:00	62.25 R	30	SL	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
31613	1	04/12/93 10:30	62.55 R	30	SL	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	17
31614	3	04/12/93 11:00	62.72 L	30	SL	7000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	10
31615	2	04/12/93 11:30	63.08 L	30	SL	7000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	27
31616	2	04/12/93 13:00	63.18 L	30	SL	7000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	26
31617	3	04/12/93 13:40	63.62 L	30	SL	7000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	43
31618	3	04/12/93 14:50	64.60 R	30	SL	7000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	21
31619	3	04/13/93 09:20	61.50 L	22	AC	12000	.	.	.	3	.	.	.	.	.	.	.	1	.	.	5
31620	1	04/13/93 10:30	61.51 L	30	AC	12000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
31621	2	04/13/93 10:50	61.50 L	30	AC	12000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
31622	4	04/13/93 12:20	62.55 R	30	DC	12000	1	.	.	.	.	.	.	.	.	.	.	.	.	.	44
31623	4	04/13/93 14:20	63.18 L	30	DC	12000	1	.	.	.	.	.	.	.	.	.	.	.	.	.	64
31624	2	04/13/93 15:40	63.08 L	30	DC	9000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	26
31625	1	04/13/93 17:00	63.08 L	30	DC	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	120
31626	4	04/14/93 10:30	63.62 L	30	DC	11000	1	.	.	.	.	.	.	.	.	.	.	.	.	.	13
31627	3	04/14/93 12:50	64.60 R	30	DC	10000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	9
31628	3	04/14/93 13:50	65.25 L	30	DC	9000	1	.	.	.	.	.	.	.	.	.	.	.	.	.	9
31629	5	04/14/93 16:30	62.25 R	30	DC	9000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	5
31630	1	04/16/93 10:20	68.10 L	30	DC	10000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	4
31631	2	04/16/93 10:30	68.42 R	30	DC	10000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
31632	3	04/16/93 11:20	72.03 R	30	DC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	25
31633	2	04/16/93 13:30	74.46 R	30	DC	9000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	24
31634	3	04/18/93 08:00	108.60 R	42	DC	12000	.	.	.	3	2	.	.	.	.	.	.	2	.	.	6
31635	2	04/18/93 10:50	117.86 L	40	AC	7000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	10
31636	2	04/18/93 12:00	119.15 R	40	AC	7000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	9
31637	2	04/18/93 14:00	120.47 L	40	DC	7000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	
31638	4	04/19/93 08:30	122.01 R	40	DC	7000	.	.	.	4	.	.	.	.	.	.	.	.	.	.	2
31639	2	04/19/93 09:15	122.55 L	40	DC	7000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	0
31640	1	04/19/93 11:00	125.65 R	40	DC	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31641	1	04/19/93 14:00	131.90 R	40	DC	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31642	1	04/21/93 08:00	133.62 R	40	DC	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31643	2	04/21/93 13:30	136.50 L	40	DC	8000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31644	1	04/21/93 14:00	137.12 L	40	AC	8000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31645	6	04/21/93 15:45	143.50 R	45	AC	9000	.	.	.	6	2	.	.	.	.	.	.	.	.	.	71
31646	1	04/21/93 15:45	143.50 R	40	AC	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31647	1	04/22/93 07:00	143.50 R	45	DC	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	22
31648	1	04/22/93 07:00	143.50 R	40	DC	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31649	1	04/22/93 16:00	156.93 L	46	AC	9000	.	.	.	1	2	.	.	.	.	.	.	.	.	.	3
31650	2	04/23/93 09:10	164.80 L	40	DC	9000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	29
31651	1	04/23/93 11:40	173.10 R	50	DC	8000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31652	2	04/23/93 15:45	191.42 L	50	DC	7000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	39
31653	2	04/23/93 16:45	192.42 R	50	DC	7000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	210
31654	2	04/24/93 09:25	192.42 R	50	DC	11000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	148
31655	2	04/24/93 12:15	201.06 R	50	DC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	124
Sum	123						16	.	.	76	6	.	.	.	.	.	12	3	.	.	1312

Trip 17

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
31701	4	05/14/93 13:00	2.41 L	20	AC	15000	.	.	.	4	.	.	.	.	.	.	.	.	.	.	19
31702	2	05/14/93 14:10	3.30 L	20	AC	16000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
31703	1	05/14/93 14:30	3.18 L	20	AC	16000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
31704	2	05/15/93 13:00	32.90 L	20	DC	7000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	57
31705	2	05/15/93 15:45	44.27 L	20	DC	7000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	35
31706	2	05/16/93 09:30	55.50 R	20	DC	7000	.	.	.	2	.	12	12	.	4	.	.	.	.	.	3
31707	4	05/16/93 13:10	58.23 R	20	DC	7000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1
31708	2	05/16/93 14:10	60.10 R	20	DC	7000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	12
31709	2	05/17/93 08:50	60.10 R	20	DC	7000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	8
31710	4	05/17/93 11:22	62.25 R	30	AC	7500	1	.	.	.	.	.	.	.	.	.	1	.	.	.	73
31711	2	05/17/93 14:45	62.55 R	30	DC	7000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	50
31712	4	05/18/93 08:20	62.55 R	30	AC	13000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	19
31713	2	05/18/93 10:45	63.08 L	30	AC	13000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	7
31714	3	05/18/93 11:00	63.18 L	30	AC	13000	1	.	.	.	.	12	12	.	4	.	1	1	.	.	49
31716	4	05/18/93 11:30	62.50 R	30	DC	9000	.	.	.	4	.	.	.	.	.	.	.	.	.	.	5
31718	1	05/18/93 14:00	63.18 L	30	DC	10000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	4
31717	2	05/18/93 15:30	62.55 R	30	DC	8000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
31719	4	05/19/93 08:30	62.50 R	30	DC	12000	.	.	.	4	.	.	.	.	.	.	.	.	.	.	2
31715	2	05/19/93 09:30	63.62 L	30	AC	13000	1	.	.	.	2	12	12	.	4	.	1	.	.	.	68
31720	5	05/19/93 14:00	65.25 L	30	DC	9000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	124
31721	3	05/20/93 08:40	64.12 L	30	DC	9000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	15
31722	2	05/20/93 10:40	64.35 L	30	DC	9000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	10
31723	4	05/20/93 16:20	64.60 R	30	DC	8000	.	.	.	4	.	.	.	.	.	.	.	.	.	.	30
31724	4	05/21/93 08:45	68.10 L	30	DC	11000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	32
31725	2	05/21/93 10:28	68.39 R	30	DC	11000	1	.	.	.	.	.	.	.	.	.	.	.	.	.	39
31726	1	05/21/93 12:40	69.48 R	30	DC	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31727	2	05/21/93 13:30	72.03 R	30	DC	9000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	62
31728	3	05/21/93 14:45	72.30 L	30	DC	9000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	22
31729	1	05/22/93 08:00	74.46 R	30	AC	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	6
31731	3	05/23/93 08:40	108.58 L	40	DC	7500	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
31730	2	05/23/93 08:45	108.60 R	42	DC	7500	.	.	.	2	2	.	.	.	.	.	.	.	.	.	2
31732	3	05/23/93 13:08	117.40 R	40	AC	7000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	10
31733	3	05/23/93 14:10	119.13 R	40	AC	8000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	4
31734	1	05/24/93 09:30	119.13 R	40	AC	10000	.	.	.	1	2	.	.	.	.	.	.	.	.	.	1
31735	1	05/24/93 09:40	118.78 R	40	AC	10000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31736	3	05/24/93 14:00	120.47 L	40	AC	7500	1	.	.	.	.	.	.	.	.	.	1	.	.	.	7
31737	3	05/24/93 15:11	121.17 L	40	AC	8000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	12
31738	1	05/25/93 08:00	119.13 R	40	DC	7500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31739	1	05/25/93 08:00	118.78 R	40	DC	7500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31740	2	05/25/93 12:20	137.12 L	40	AC	8500	1	.	.	.	.	.	.	.	.	.	1	.	.	.	9
31741	3	05/26/93 08:00	143.50 R	45	AC	7000	.	.	.	3	2	.	.	.	.	.	.	.	.	.	25
31742	1	05/26/93 08:50	143.50 R	40	AC	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31747	1	05/26/93 11:00	143.50 R	45	AC	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	21
31743	1	05/27/93 07:30	156.93 L	46	DC	8000	.	.	.	1	2	.	.	.	.	.	.	.	.	.	70
31744	2	05/27/93 10:00	164.80 L	40	DC	8000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	27
31745	2	05/27/93 11:15	167.21 R	50	DC	7500	1	.	.	.	.	.	.	.	.	.	1	.	.	.	24
31746	2	05/27/93 13:50	176.52 R	50	DC	7500	.	.	.	2	.	.	.	.	.	.	.	.	.	.	206
31748	1	05/28/93 08:45	189.40 R	50	DC	10000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	30
31749	2	05/28/93 10:00	191.92 R	50	DC	10000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	35
31750	4	05/28/93 11:15	192.40 R	50	DC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	401
31751	2	05/29/93 09:45	201.06 R	50	DC	12000	1	.	.	.	.	9	9	.	3	.	1	.	.	.	146
31752	1	05/29/93 12:45	204.05 R	50	DC	12000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	45
31753	2	05/29/93 12:45	204.00 R	50	DC	12000	1	.	.	.	.	.	.	.	.	1	1	.	.	.	1152
Sum	123						17	.	.	71	10	45	45	.	15	1	16	1	.	.	2986

Trip 18

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fish Coll
31801	4	06/13/93 12:40	44.27 L	20	DC	7500	1	.	.	.	.	.	.	.	.	.	1	.	.	.	201
31802	2	06/13/93 16:40	55.50 R	20	DC	7000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	3
31803	3	06/14/93 08:30	58.23 R	20	AC	9000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	26
31804	3	06/14/93 10:20	60.10 R	20	AC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	11

31805	4	06/14/93 13:00	63.18 L	30	DC	9000	1	.	.	.	1	.	.	.	.	.	1	.	.	.	892
31806	1	06/14/93 22:00	60.10 R	30	DC	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	15
31807	3	06/15/93 09:00	63.18 L	30	DC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	7
31808	2	06/15/93 13:30	62.25 R	30	DC	9000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	15
31809	1	06/15/93 21:00	62.25 R	30	DC	7500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	35
31811	4	06/16/93 08:00	63.62 L	30	DC	12000	1	.	.	.	1	.	.	.	.	.	1	.	.	.	75
31810	1	06/16/93 13:00	65.25 L	30	DC	9000	.	.	.	.	.	.	.	.	.	.	1	.	.	.	0
31812	1	06/16/93 14:00	62.55 R	30	DC	8000	.	.	.	.	.	.	.	.	.	.	1	.	.	.	0
31813	1	06/16/93 21:00	63.62 L	30	DC	7500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
31814	1	06/16/93 21:30	65.25 L	30	DC	7000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	169
31815	1	06/17/93 09:30	65.25 L	30	DC	12000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	328
31816	2	06/17/93 11:20	72.03 R	30	DC	11000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	85
31817	1	06/18/93 03:00	97.90 L	40	DC	8000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	119
31818	1	06/19/93 10:00	98.04 R	41	AC	10000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	16
31819	1	06/20/93 06:30	108.60 R	42	AC	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
31820	2	06/20/93 14:00	119.13 R	40	AC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	91
31821	1	06/21/93 05:15	119.13 R	40	DC	8000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	14
31822	2	06/21/93 08:20	120.47 L	40	DC	7500	1	.	.	.	.	.	.	.	.	.	1	.	.	.	2
31823	3	06/21/93 16:30	138.93 R	40	AC	9000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	2
31824	2	06/22/93 06:45	143.50 R	45	DC	9000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	37
31825	2	06/23/93 07:30	156.93 L	46	DC	8000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	118
31826	2	06/23/93 11:10	161.63 L	40	DC	7500	1	.	.	.	.	.	.	.	.	.	1	.	.	.	12
31827	2	06/23/93 13:30	164.44 R	40	DC	7500	1	.	.	.	.	.	.	.	.	.	1	.	.	.	94
31828	2	06/23/93 15:00	165.24 R	40	DC	7500	1	.	.	.	.	.	.	.	.	.	1	.	.	.	0
31829	2	06/24/93 11:00	164.80 L	40	DC	12000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	124
31830	3	06/25/93 15:15	187.53 R	50	DC	12000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	234
31831	4	06/26/93 09:00	192.40 R	50	DC	12000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	495
31832	4	06/26/93 13:50	193.85 R	50	DC	10000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	749
31833	1	06/27/93 09:15	201.06 R	50	DC	12000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	141
Sum	69						15	.	.	27	2	.	.	.	.	.	17	.	.	.	4116

Trip 19

Fish Study	Sites	Date--Time	Mile	Rch	Cod	Flo CFS	Flow A	Typ B	Typ lng	Ang Opp	de	Son ths	Ben Sed	Chl	Pkn	Map	Tot Map	Pla cer	Vis ft	Dri 2nd	-A- Coll
31901	2	07/22/93 11:27	2.41 L	20	AC	16000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31902	1	07/23/93 08:13	32.90 L	20	DC	11000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31903	3	07/23/93 12:50	44.27 L	20	DC	11000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	16
31904	1	07/23/93 15:57	44.77 L	20	DC	11000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31905	4	07/24/93 09:17	55.50 R	20	DC	18000	.	.	.	1	.	12	12	.	4	.	.	.	.	.	0
31906	2	07/24/93 15:00	60.10 R	20	DC	15000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	0
31907	1	07/24/93 20:30	60.10 R	20	DC	11000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31908	1	07/25/93 06:00	60.50 L	22	AC	17000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31909	1	07/25/93 13:49	60.45 L	22	DC	13000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
31910	1	07/25/93 14:00	60.50 L	22	DC	13000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	44
31911	4	07/25/93 16:30	63.18 L	30	DC	12000	.	.	.	.	.	12	12	.	4	.	.	.	.	.	0
31912	1	07/25/93 20:00	62.25 R	30	DC	11000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	10
31913	1	07/26/93 06:30	60.50 L	22	AC	14000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31914	3	07/26/93 09:00	63.18 L	30	AC	15000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	55
31915	3	07/26/93 09:00	63.08 L	30	AC	15000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	1
31916	2	07/26/93 14:10	62.25 R	30	DC	13000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	1
31917	2	07/26/93 20:40	63.18 L	30	DC	11000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31918	1	07/27/93 10:00	60.45 L	22	DC	17000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31919	2	07/27/93 10:30	60.50 L	22	DC	17000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
31920	2	07/27/93 16:30	65.25 L	30	DC	12000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	11
31921	1	07/27/93 18:25	64.60 R	30	DC	11500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31922	3	07/28/93 08:30	65.25 L	30	DC	18000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	39
31923	1	07/28/93 14:00	68.39 R	30	DC	16000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	13
31924	1	07/28/93 16:30	72.30 L	30	DC	14000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1024
31925	2	07/29/93 09:00	74.46 R	30	DC	16000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	3
31926	1	07/29/93 11:20	81.07 R	30	DC	16000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31927	1	07/31/93 08:20	108.60 R	40	AC	17000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31923	1	07/31/93 11:00	114.25 L	40	AC	18500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31929	2	07/31/93 14:20	118.10 R	40	AC	19000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31930	2	07/31/93 15:10	120.30 L	40	DC	18000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	1
31931	1	07/31/93 16:20	120.05 R	40	DC	17000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0

31932	2	08/01/93 07:30	119.13 R	40	DC	12000	1	.	.	.	.	6	6	.	2	.	1	.	.	.	0
31933	1	08/01/93 08:45	120.47 L	40	AC	13000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31934	2	08/01/93 09:50	122.30 L	40	AC	14000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31935	2	08/01/93 12:00	122.55 L	40	AC	16000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31936	1	08/01/93 14:50	137.12 L	40	DC	17000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31937	1	08/01/93 16:00	143.50 R	45	DC	16000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
31938	1	08/02/93 07:30	143.50 R	45	DC	11000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
31939	1	08/03/93 08:00	156.93 L	46	DC	12000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31940	2	08/03/93 10:30	164.44 R	40	DC	12000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31941	1	08/03/93 11:00	164.80 L	40	DC	12000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31942	1	08/03/93 11:30	165.75 R	40	DC	12000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31943	2	08/03/93 12:00	166.85 L	50	DC	11000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	7
31944	2	08/03/93 13:30	168.75 R	50	DC	11000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
31945	1	08/03/93 14:05	169.53 R	50	DC	11000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2
31946	2	08/04/93 08:00	182.83 L	50	DC	16000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	1
31947	2	08/04/93 11:00	192.40 R	50	DC	14500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
31948	4	08/04/93 13:15	193.85 R	50	DC	13000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	55
31950	2	08/04/93 15:43	192.40 R	50	DC	12000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	15
31949	3	08/04/93 16:30	201.06 R	50	DC	11000	.	.	.	2	.	9	9	.	3	.	.	.	.	.	8
31951	3	08/05/93 08:30	201.06 R	50	DC	16000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	7
31952	3	08/05/93 10:30	204.07 R	50	DC	15000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	0
31953	2	08/05/93 11:00	204.37 L	50	DC	15000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	32
31954	1	08/05/93 14:30	220.26 R	50	DC	15000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	7
Sum	96						12	.	.	58	.	39	39	.	13	.	12	.	.	.	1365

Trip 20

Study	Sites	Date--Time	Mile	Rch	Flo Cod	Flow CFS	Typ A	Typ B	Ang lng	Opp	Son de	Ben ths	Sed	Chl	Pkn	Tot Map	Pla Map	Vis cer	Dri ft	-A- 2nd	Fsh Coll
32001	3	09/04/93 12:00	2.41 L	20	AC	12000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	11
32002	3	09/05/93 07:00	30.48 R	20	DC	13000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	0
32003	1	09/05/93 09:20	32.90 L	20	DC	12000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	4
32004	1	09/05/93 09:40	32.05 R	20	DC	12000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
32005	3	09/05/93 12:00	44.27 L	20	DC	12000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	97
32006	2	09/05/93 15:30	45.43 L	20	DC	11000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	0
32007	4	09/06/93 08:45	58.23 R	20	DC	11000	.	.	.	4	.	.	.	.	.	.	.	.	.	.	84
32008	2	09/06/93 10:00	60.10 R	20	DC	11000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	10
32009	1	09/06/93 12:30	63.08 L	30	DC	10900	.	.	.	1	.	.	.	.	.	.	.	.	.	.	174
32010	2	09/06/93 14:25	61.50 L	22	DC	10800	.	.	.	2	1	.	.	.	.	.	.	.	.	.	317
32011	1	09/06/93 16:00	61.50 L	30	DC	10500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	12
32012	1	09/06/93 16:15	61.50 L	20	DC	10000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	11
32013	1	09/06/93 18:40	60.10 R	20	DC	9000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
32014	1	09/07/93 08:30	60.10 R	20	AC	12000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
32015	1	09/07/93 09:42	61.54 R	30	DC	14000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	33
32016	1	09/07/93 10:15	61.80 R	30	DC	13500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	8
32017	2	09/07/93 10:50	61.95 L	30	DC	13000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	90
32018	2	09/07/93 12:30	62.10 R	30	DC	12500	.	.	.	2	.	.	.	.	.	.	.	.	.	.	181
32019	2	09/07/93 13:11	62.25 R	30	DC	12000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	287
32020	2	09/07/93 15:31	62.75 R	30	DC	11500	1	.	.	.	.	.	.	.	.	.	1	.	.	.	221
32021	1	09/08/93 08:30	61.50 L	22	AC	14000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	11
32022	2	09/08/93 10:00	63.18 L	30	DC	14000	1	.	.	.	.	.	.	.	.	.	.	.	.	.	169
32024	3	09/08/93 13:00	65.25 L	30	DC	12000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	572
32025	1	09/09/93 09:00	65.70 L	30	AC	14500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	5
32026	2	09/09/93 09:40	68.10 L	30	AC	14500	.	.	.	2	.	.	.	.	.	.	.	.	.	.	61
32027	1	09/09/93 10:20	68.39 R	30	DC	14500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	472
32028	3	09/09/93 14:30	72.30 L	30	DC	12000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	188
32029	2	09/10/93 08:15	74.46 R	30	AC	14500	1	.	.	.	.	.	.	.	.	.	1	.	.	.	269
32030	1	09/10/93 10:00	74.47 R	30	AC	14500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	62
32031	1	09/10/93 11:00	75.90 R	30	DC	14500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	3
32032	1	09/10/93 13:15	81.17 L	30	DC	13000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	32
32033	2	09/10/93 18:00	87.45 R	30	DC	10000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	18
32034	3	09/11/93 06:00	87.62 R	32	DC	10000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	1
32035	2	09/12/93 07:30	108.60 R	42	DC	8500	.	.	.	2	.	.	.	.	.	.	.	.	.	.	134
32036	3	09/12/93 11:00	117.40 R	40	AC	9000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	79
32037	3	09/12/93 13:00	119.13 R	40	AC	9500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	13
32038	2	09/12/93 15:00	119.55 L	40	AC	10500	.	.	.	2	.	.	.	.	.	.	.	.	.	.	4
32039	2	09/13/93 08:19	120.47 L	40	DC	8000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	29

32040	2	09/13/93	10:35	122.01	R	40	DC	8000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
32041	2	09/13/93	11:30	122.55	L	40	DC	8000	.	.	.	2	.	.	.	.	.	.	.	.	.	.	17
32042	1	09/13/93	13:40	126.85	R	40	DC	7500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
32043	2	09/13/93	16:30	137.12	L	40	DC	7500	.	.	.	2	.	.	.	.	.	.	.	.	.	.	11
32044	2	09/14/93	09:00	143.50	R	40	DC	7500	.	.	.	2	.	.	.	.	.	.	.	.	.	.	5
32045	1	09/14/93	09:15	143.50	R	45	DC	7500	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0
32046	1	09/15/93	07:45	156.93	L	46	DC	12000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	8
32047	1	09/15/93	08:45	160.83	L	40	DC	12000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	5
32048	1	09/15/93	09:45	164.80	L	40	DC	11000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	13
32049	2	09/15/93	10:10	168.75	R	50	DC	10000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	37
32050	3	09/15/93	13:40	182.37	R	50	DC	9000	.	.	.	3	.	.	.	.	.	.	.	.	.	.	9
32051	2	09/15/93	15:10	192.42	R	50	DC	9000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	516
32052	2	09/16/93	08:00	193.85	R	50	DC	13000	1	.	.	.	.	.	.	.	.	.	1	.	.	.	164
32053	1	09/16/93	11:00	201.06	R	50	DC	13000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	49
32054	1	09/16/93	11:40	203.80	R	50	DC	12000	.	.	.	1	.	.	.	.	.	.	.	.	.	.	75
Sum	95								11	.	.	68	1	.	.	.	.	.	10	.	.	.	4577
Sum	8763								264	175	2	887	67	663	678	12	540	25	381	25	40	160	18131

5. Native Fishes - Little Colorado River

Anthony T. Robinson, Robert E. Forrest,
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INTRODUCTION

This chapter summarizes AGFD research on humpback chub (*Gila cypha*) and other native fishes in the Little Colorado River (LCR) of the Grand Canyon, Arizona, for the period of January through October 1993. The main focus of research was on larval and early juvenile stages of native fishes; their distributions, movements, habitat use, diets and behaviors. We also continued to track the growth and population of the 1992 cohort through their first year of life. AGFD completed standardized hoop net monitoring of the adult and subadult humpback chub population in the LCR during April-May 1993. We also completed research of longitudinal water quality patterns and initiated longitudinal algal standing crop studies. Fish and invertebrate drift studies results from 1991 and 1992 research are presented in greater detail than in previous reports (Angradi et al. 1992; Clarkson and Robinson 1993). Discharge data were obtained from the USGS station on the Little Colorado River near Cameron, Arizona.

Objective 3.1. Continue the AGFD monitoring and research program for native fishes of the Colorado River and its tributaries in the Grand Canyon.

Methods and Progress

The methods used to fulfill this objective were presented in detail by Hendrickson and Kubly (1990). Hoop nets (2-3 m long, 6.4 mm mesh, 1.0 m diameter of the largest hoop) were deployed at 13 standardized locations in the lower 1200 m during the May annual monitoring period (Hendrickson and Kubly 1990). Additional nets were also placed in the vicinity of Salt Trail Camp, river kilometer (RKM) 10.5 (10.5 km above the mouth), in April and May during humpback chub (*Gila cypha*) egg-take attempts (see Objective 3.3). Nets were run as soon as possible after sunrise and in the late afternoon before sunset, and lengths ($\pm$1 mm) and weights ($\pm$1 g) of captured fishes were recorded. Native species longer than 150 mm were injected with passive integrated transponders (PIT tags) prior to release. A limited amount of seining and dip netting was also conducted within this time period.

Results and Discussion

Six species of fish were captured during the May monitoring period, two of which were non-natives (rainbow trout, *Oncorhynchus mykiss* and fathead minnow *Pimephales promelas*; Table 4.1). All six species were captured by hoop nets, however only bluehead sucker (*Catostomus discobolus*), speckled dace (*Rhinichthys osculus*), and humpback chub were captured by seine. All four native species and fathead minnows were captured by dip net. No plains killifish (*Fundulus zebrinus*) or channel catfish (*Ictalurus punctatus*) were captured as in previous years (Clarkson and Robinson 1993). The mean catch rate of humpback chub collected by hoop net in May 1993 was 0.6 individuals per net per 12 hours, which is comparable to the 1991 and 1992 hoop net catch rates (Clarkson and Robinson 1993). Regression analysis revealed a negative relationship ($p=0.0123$, $R^2=.15$) between mean daily hoop net catch rates for humpback chub and mean daily flow ($F=6.89$, $p=0.0123$, $R^2=.15$); catch rate increased with decreasing flows (see Figure 4.1 for a graphic representation of flows in the Little Colorado River during 1993), a similar result to that reported for 1987, 1988, and 1991 (Robinson and Clarkson 1992). The negative relationship between catch rates and flows during the spring may indicate that decreasing flows and the accompanying increase in water temperature and decrease in turbidity may be environmental cues initiating spawning activity, or that the fish simply become more active with decreasing flows. The seine catch rate for humpback chub in May was 0.4 fish per 100 m^2.

The modified Schnaebel method (Ricker, 1975) was used to calculate a population estimate of humpback chub > 150 mm TL. A population estimate of 755 (95% C.I.=517-1210) was calculated for the May monitoring period in the lower 1200 m of the Little Colorado River. This estimate is greater than that calculated for either 1990 or 1992 (Clarkson and Robinson 1993). The population estimate is probably a better indicator of population trends than an actual estimator of population size. A correlation of population size with study year (1987-1993) was negative ($r=-0.73$, $p=.032$), indicating a decrease in the humpback chub population since monitoring began.

Humpback chub appear to be largely sedentary in the LCR, moving relatively short distances between captures, however two individuals recaptured in 1993 had moved over 10 km (10160 and 10118 m), nearly the entire section of the river inhabited by humpback chub (the lower 14 km). Distances moved by individual humpback chub between captures in 1993 were similar to results from previous years (Clarkson and Robinson 1993). In the lower 1200 m during May monitoring, mean distance moved upstream was 323 m, mean distance moved downstream was 124 m and the mean absolute distance moved was 133 m. The mean number of days at large between captures for the lower 1200 m during the month of May was 8.16 days. If humpback chub captures from Salt Trail camp (RKM 10.5) and if March and April captures are included in the analysis, then the mean distances moved were: upstream = 200 m, downstream = 1385 m, and absolute = 767 m; and the mean days at large was 8.7.

Objective 3.2. Determine if the reproductive activity of native fishes is temporally or spatially segregated. Determine the timing and duration of reproductive activity for different species as related to physical conditions. Determine if early life stages segregate themselves within habitats. Determine if early life stages drift in the tributaries. Determine if early life stages feed selectively on available drift and/or benthic sources.

Methods and Progress

Methods used to fulfill this objective were described in detail by Clarkson and Robinson (1993). Eleven longitudinal surveys to quantify temporal and spatial distributions of larval native fishes in the LCR were completed in 1993 between April and August. Habitat availability and larval habitat use measurements were recorded for the entire length of the river downstream from Atomizer Falls. Micro-habitat use of all near-shore habitat types within four 100 m reaches was also measured; habitat occupied by larvae was measured for depth, current velocity and substrate at cell midpoints using a 20 cm grid system (400 cm^2 grids) of 6 grids from May through August. In addition, fish abundance and distribution, water temperature, algal and zooplankton densities, and habitat cover features were estimated for each grid.

Larval traps similar to the design of Culp and Glozier (1989) and drift nets were used to determine the mechanisms of longitudinal dispersal of larval fishes. Three larval traps were emplaced in each selected occupied and unoccupied peripheral pool or shoreline margin habitat; one at the point of inflow (facing upstream), and two at the point of outflow (one facing upstream and another facing downstream). Capture of larvae in downstream facing traps will indicate active movement of larvae into near-shore habitats, capture of larvae in the inflow upstream facing trap could be the result of either active or passive movements of larvae, capture of larvae in the upstream facing outflow traps will indicate that larvae move out of near-shore habitats. Larval traps were deployed May through August, drift nets were deployed January through July. Traps were run at 6-h intervals encompassing a 24-h period.

Standard drift nets (3 m long, 0.25 m^2 opening , 750 μm mesh net, and 500 μm mesh bucket) were used to characterize the patterns of dispersal of larval fishes. Three drift nets were placed across the river, two near-shore and one midchannel. At depths of < 0.5 m drift nets were set in contact with the bottom, at depths > 0.5 m nets were set immediately below the surface of the water. Drift nets were run at the same intervals as the larval traps. Drift samples were analyzed in the laboratory for presence of larval fish.

Drift samples were also analyzed for invertebrate composition, to determine the potential food resources for the native fishes; young-of-year native fish in the LCR have been reported to feed in the water column and on the water surface (Clarkson and Robinson 1993), which suggests that fishes are feeding on drift. In order to determine any diel periodicity in diet, 50 larval fish were collected by dip net, over one 24-h period, at the same time that the larval traps and drift nets were run. Stomachs were analyzed in the laboratory. Time bound focal animal behavioral observations (Altman 1974) were conducted opportunistically on larval native fishes. Detailed statistical analyses of the habitat availability, habitat use, larval fish movements, diet periodicity, and behavioral data are in progress.

Results and Discussion

Larval Fish Longitudinal Surveys

Larval native fish distribution varied temporally and spatially in the LCR from April through July. No larval fish were found during the first survey, April 6-8. Larval flannelmouth suckers, bluehead suckers, and speckled dace were first encountered on April

30 as protolarvae and mesolarvae. Larval humpback chub were first encountered on May 1 as protolarvae and mesolarvae. Protolarvae of all species were encountered in the greatest numbers in May (Figure 4.2); this indicates that all four species had concentrated spawning periods from late April through mid-May. The temporal occurrence of native fish protolarvae (Figure 4.2) and mesolarvae (Figure 4.3) also indicates that humpback chub spawned into the beginning of June and probably into the beginning of July; speckled dace spawned into the beginning of June; bluehead sucker spawned until the beginning of July; and flannelmouth sucker spawned until mid-June. The appearance of protolarvae coincides with decreasing spring runoff flows (Figure 4.1); a result similar to that in 1992 (Clarkson and Robinson 1993). These results support the hypothesis that decreasing spring flows and the accompanying increase in water temperature and decrease in turbidity (personal observations) may be environmental cues initiating spawning activity. However, humpback chub are known to spawn even during years of no spring runoff (Robinson and Clarkson 1992).

The longitudinal distribution of protolarval native fishes varied among species (Figure 4.2). Protolarval humpback chub were encountered most frequently between RKM 2 and 6 and between RKM 7 and 13.5. Humpback chub may spawn in or slightly upstream from these two reaches. If protolarvae were completely at the mercy of the current, it is likely that their longitudinal distribution would quickly become uniform downstream from the hatching point. If protolarvae do attempt to swim towards the shoreline and suitable rearing habitat or if they can maintain a shoreline location once the current has deposited them there, then a more clumped longitudinal distribution of protolarvae would be expected. Speckled dace protolarvae also exhibited a longitudinal distribution with two aggregations, one between RKM 2 and 3 and the other between RKM 8 and 13. Bluehead sucker protolarvae were found relatively uniformly below RKM 13.5, almost the entire length of the river below Atomizer Falls. This may indicate that either blueheads spawn the whole length of the river or they spawn in the upper reaches and the protolarvae are more subject to drift than the native cyprinid species. Flannelmouth sucker protolarvae were distributed similarly to bluehead suckers, but the vast majority were found downstream from RKM 12.

Longitudinal distributions of the late larval stages also varied between the four native fish species. Mesolarvae of all four native fish species were distributed relatively uniformly along the length of the river (Figure 4.3). This distribution indicates that suitable rearing habitat was available the entire length of the river. Compared with mesolarvae, metalarvae (Figure 4.4) of the two sucker species were relatively scarce. This result suggests that the metalarvae of the sucker species are either migrating to deeper areas not sampled during the longitudinal survey or they are being transported out of the Little Colorado River into the mainstem (larval bluehead and flannelmouth suckers were collected in drift nets; see below). Humpback chub metalarvae were distributed relatively evenly between RKM 1 and 12; suitable habitat for metalarval humpback chub is likely concentrated in this reach. Metalarval speckled dace occur throughout the length of the river surveyed (below Atomizer Falls).

Larval Fish Movements

Results of larval trap data have yet to be statistically analyzed. However, larval fish of all four native species were captured in downstream facing traps, indicating that larvae can actively move into shoreline habitats. Larvae of all four species were also captured in pool outflow, upstream facing traps, indicating that larvae are moving out of near-shore habitats.

Analysis of drift samples collected is still in progress. All drifts collected from 1991 have been analyzed for fish and eggs. For 1992, only drifts collected during the first week of each month have been analyzed. All of the drifts collected during 1993 in the vicinity of each camp have been analyzed; 178 drifts collected near the confluence (300 m above the mouth) have yet to be analyzed. The remainder of 1992 samples and all of 1993 samples should be analyzed by January 1994.

Drift of larval fishes in the Little Colorado River has varied from 1991 through 1993 (Tables 4.2 through 4.4). All native larval fish (humpback chub, flannelmouth sucker *Catostomus latipinnis*, bluehead sucker, and speckled dace) were collected in drift nets at both Salt Trail (RKM 10.5) and Boulder (RKM 2) camps. Fish eggs (not identified to species), unidentified larval fish (fish to damaged to identify) and unidentified suckers (i.e., flannelmouth or bluehead suckers) were also observed in the drift. In 1991 all native fish larvae drifted primarily in the spring and early summer; one protolarvae and one mesolarvae bluehead sucker were also recovered from a November sample. In 1992 humpback chub larvae drifted in the spring and early summer, speckled dace larvae drifted in the summer, and flannnelmouth sucker larvae drifted in December. However, very few fish were collected in drift nets during 1992. The high flows during the spring and the flooding events during late May and early June may possibly have had deleterious effects on the reproductive success and larval survival of the native fish species. The patterns of larval drift in 1993 were similar to those of 1991. All of the native fish larvae drift primarily in the spring and early summer. Fish eggs were collected in drift nets April through June in 1993. Egg occurrence coincided with decreasing flow levels; river discharge levels decreased to base flow in May and remained at that level through July. In 1992 eggs were occurred in drift throughout the year, but primarily from April through June; peak densities were reached in April coinciding with decreasing spring runoff levels. In 1991 eggs were collected in drift nets primarily in spring (when sampling began) and a few in the fall and early winter. These drift analysis results suggest a primary late spring-early summer spawning period for all of the native fish species, and limited spawning throughout the rest year for the sucker species, a conclusion similar to that drawn from the longitudinal survey results. Flow levels may affect initiation of spawning, however additional analysis and research is needed to support or contradict this hypothesis.

Exotic larval fishes were rarely found in drift samples. Channel catfish larvae drifted in the Little Colorado River in June and July 1991, July 1992 and in May 1993. Common carp larvae drifted in May and June 1993, and fathead minnow larvae drifted in May 1993.

Food Selectivity

Invertebrate drift densities, which may be potential food resources available to young-of-year native fishes, vary between months and between years. Monthly densities of invertebrates in drift samples are presented in Tables 4.5 (1991) and 4.6 (1992). Invertebrate taxa diversities were greatest in May, June, and October in 1991, and in May and June in 1992. These peaks in diversities corresponded to peaks in larval fish presence in 1991 (Angradi et al. 1992; see length frequency results from the Little Colorado River, Chapter 4) and 1992 (Clarkson and Robinson 1993; see longitudinal survey results, Chapter 4). Some analyses of food selectivity were presented in Clarkson and Robinson (1993), but more detailed analyses have yet to be done.

Objective 3.3. Provide for the propagation of native fishes of the Colorado River in Grand Canyon for use in laboratory or hatchery based studies necessary to satisfy the needs of the Section 7 Conservation Measures.

See Appendix 5.1 for a report on propagation techniques for humpback chub.

Objective 3.7. Determine the age structure and growth rates of native fishes of the Colorado River in Grand Canyon. Relate these life history features to hydrologic and thermal conditions experienced by the fishes during their growth to present size.

Methods

Otolith Analysis

Detailed methods describing otolith analysis were presented by Hendrickson (1993).

Length-Frequency Analysis

Frequency distributions of total lengths of the four native fish species caught by seine and dip net were constructed for all months of collection.

Results and Discussion

Otolith Analysis

Dr. Dean Hendrickson of the University of Texas, Austin is currently analyzing humpback chub otoliths, and Dr. Richard Radtke of the University of Hawaii is currently analyzing speckled dace, flannelmouth sucker and bluehead sucker otolith samples.

Length-Frequency Analyses

Length-frequency distributions of putative YOY humpback chub, bluehead sucker and flannelmouth sucker were completely segregated from larger size classes (Figures 4.5-4.7), thus mean lengths could be accurately compared among months. Length frequency distributions of YOY speckled dace were completely segregated only from April through June (Figure 4.8), and thus mean length could be accurately compared among these 3 months only.

Growth of the 1993 cohort varied among the native fish species (Figures 4.5-4.8 and Table 4.7). Mean length increased from May to June by 77% for humpback chub, 50% for speckled dace, 19% for bluehead sucker, and 33% for flannelmouth sucker. Mean length of humpback chub larvae increased by 83% during the first 30 days following swim-up (5-7 days old) at 20 C in laboratory conditions (Lupher and Clarkson, Appendix 4.1). The growth rate of humpback chub in the LCR during 1993 compared to that observed in laboratory conditions suggests that the environmental conditions during the late spring and early summer were near optimal. The LCR attained base flow on May 26 (zero flows recorded at the USGS Cameron gauging station), however the river had attained its characteristic blue color by May 11. In addition water temperatures ranged from 17 to 20.4 C by May 7 (see Appendix 1). The physical environmental conditions during May and June likely caused an increase in primary and secondary production, thus resulting in high growth rates of humpback chub.

Objective 3.8. Compare otolith edge chemistry of native fishes collect in tributary and mainstem habitats for use in growth and movement analysis.

Dr. Dean Hendrickson of the University of Texas, Austin is currently analyzing humpback chub otoliths.

Objective 3.9. Determine the extent to which limnological factors, with emphasis on water chemistry and aquatic productivity, potentially limit the distribution and abundance of native fishes in the Little Colorado River and other tributaries which might serve as streams for augmentation of humpback chub in Grand Canyon.

Methods

Inflatable kayak trips from Blue Spring (21 km above the mouth) to the LCR mouth were taken during each season of the year to characterize longitudinal variations in water chemistry and algal periphyton and invertebrate standing crop. Six fixed sites, at roughly 21, 20, 15, 10, 5, and .6 km above the mouth were sampled.

Water chemistry was sampled at all six sampling sites and at several additional spring sites. Water temperature, conductivity, pH, and dissolved oxygen were measured with a Hydrolab Surveyor 3 datalogger and H2O transmitter. A Hach Model AL-36 digital titrator kit was used to measure alkalinity (brom-cresol green-methyl red endpoint, sulfuric acid titrant) and carbon dioxide (phenolphthalein endpoint, sodium hydroxide titrant). Nitrate-nitrite nitrogen (cadmium reduction method) and soluble reactive phosphate (ascorbic acid method) were measured using a Hach DREL 2000 spectrophotometer. Turbidity measurements were taken using a Milton Roy Spectronic Mini-20 nephelometer.

Periphyton and invertebrate standing crop samples were collected at 20, 15, 10, 5, and 0.6 km above the mouth during the spring and summer 1993. Periphyton standing crop samples were collected from two broad substrate categories: fine substrates = clay, silt and sand; and large coarse substrates = 64-256 mm (cobble). Within each sampling area three perpendicular-to-flow transects were established in each substrate category. Samples were collected at four points along each transect at the distance from shore where the depths of 10, 30, 50, and 90 cm were first encountered. Samples were collected from fine substrates using a mini-core sediment sampler (4.15 cm^2 cross sectional area). During the spring 1993 trip, one 5 cc sample was collected at each sampling point. During the summer 1993 trip three 5 cc samples were collected from each point and pooled into one sample in order to increase the amount of chlorophyll for analysis. Samples were collected from coarse substrates using a perimon sampler (Angradi et al. 1992). Algae was scraped and collected from an area of 4.15 cm^2 (spring 1993) or 12.45 cm^2 (summer 1993). All periphyton standing crop samples were wrapped in aluminum foil, frozen on dry ice and kept frozen in the dark until laboratory chlorophyll analysis could be performed.

Chlorophyll content of the periphyton standing crop samples was determined by a methanol extraction technique similar to Tett et al. (1975). Each sample was thawed immediately before analysis, placed on a glass fiber filter and water was then removed by vacuum. The sample and filter was then homogenized in a blender with 200 ml of methanol, and a 40 ml subsample was drawn off. The subsample was boiled in a hot water bath for two minutes and the chlorophyll was then extracted by vacuum through a glass fiber filter. The chlorophyll extract was brought to a volume of 40 ml with methanol, transferred to a cuvette and placed into a Spectronic 401 Milton Roy spectrophotometer. Absorbencies were recorded at 480, 750, 666, and again at 750 nm. The sample was then acidified with 122 μl of 1 N HCL and the absorbencies recorded at 750, 666, and again at 750 nm.

Periphyton species composition samples were collected opportunistically at all six sites and at several additional spring sites during the fall 1991 and winter 1992 trips. Samples were preserved in 5% Formalin. Samples collected during the October 1991 trip were sent to Dr. Milton Summerfeld of Arizona State University, Tempe, for species identification and enumeration.

Invertebrate samples were collected using a Hess Sampler, at the five sites mentioned above, during the spring and summer 1993 water quality trips. Within each sampling area one perpendicular-to-flow transect was established in each substrate category. Three samples were collected per transect at .5, 1, and 2 m from shore. Samples were preserved in 10% Formalin. Species composition and standing crop (ash free dry weight = AFDW) were determined in the laboratory. Additional invertebrate species composition samples were collected opportunistically during the fall 1991 and winter 1992 trips, but have not yet been analyzed.

Invertebrate standing crop was also estimated by analyzing drift samples for invertebrate composition and standing crop. Methods used to collect drift samples (see Objective 3.2) were presented in detail by Clarkson and Robinson (1993). Drift samples collected during the first week of each month from May 1991 through April 1993 were analyzed for invertebrate species content. Large volume drifts were sub-sampled (usually one quarter of the sample was removed for analysis) to decrease the duration of the analysis. All invertebrates were removed from each sample (or subsample), identified to taxonomic family and enumerated. All invertebrates, of each unique taxa, were then dried, and burned to determine ash free dry weight (AFDW).

Results and Discussion

Spring (early June 1993) and summer (early August) sampling trips were conducted in 1993; one trip from each season of the year has now been completed. Longitudinal patterns in water chemistry parameters were fairly consistent across the seasons (Figure 4.9). All of the water chemistry parameters change sharply in magnitude from Blue Spring (RKM 21) to RKM 20. These initial changes in magnitude are likely due to shifts in chemical equilibria upon the water's contact with the atmosphere after it empties from the spring. The focal point of change in the longitudinal pattern of water chemistry parameters is Atomizer Falls (RKM 14.5). Carbon dioxide concentration decreases from Blue Spring downstream, however the rate of decrease was the greatest in the first kilometer below Blue Spring. The waters emanating from Blue Spring are supersaturated with carbon dioxide and slightly acidic (Johnson and Sanderson 1968). Much of the carbon dioxide is quickly lost to the atmosphere as the chemical equilibria shift. In the reach from RKM 20 to RKM 15 the carbon dioxide levels become relatively stable. The mechanical action of Atomizer Falls (RKM 14.5) and other rapids and falls in the two kilometers immediately downstream may cause large amounts of carbon dioxide to be lost to the atmosphere, resulting in large amounts of calcium carbonate precipitate as is evident from the increase in turbidity below the falls complex. The rapid deposition of calcium carbonate probably also causes the rapid drop in alkalinity observed immediately below Atomizer Falls. The pH concentrations exhibited a pattern opposite to that of carbon dioxide, the greatest rate of increase was observed above Atomizer Falls. Dissolved oxygen concentrations and conductivity increased from Blue Spring to Atomizer, after which the values remain fairly constant.

Nutrient levels and longitudinal patterns (Figure 4.9) were comparable to other southwest desert streams (Grimm et al. 1981). No trend was evident in phosphate levels, however measurements of this parameter were questionable in June 1993 possibly due to aged reagents. Nitrate levels decrease from RKM 20 to the mouth.

Algae samples collected during June and August 1993 trips have been analyzed for chlorophyll *a* content, however only the June data have been statistically analyzed to date. Mean chlorophyll *a* levels during early June 1993 in the Little Colorado River below Atomizer Falls ranged from 106 to 194 mg/m^2 on coarse substrates, and from 21 to 104 mg/m^2 on fine substrates. The biomass levels (chlorophyll *a* content) on coarse substrates were similar to levels reported in the mainstem Colorado River at 13.5 and 14 mile bars (Angradi et al. 1992). Regression analysis revealed that algal biomass, as estimated by chlorophyll *a* concentrations, sampled from fine substrates decreased significantly ($p<.001$, $R^2=.23$) from RKM 20 to RKM 0.6 (Figure 4.10). Based on the longitudinal patterns of carbon dioxide concentrations, this result is expected, since carbon dioxide levels are known to influence primary productivity in periphytic algae (Minckley and Tindall 1963, McIntire and Phinney 1965, Wiegert and Fraleigh 1972). In addition turbidity levels generally increase from Blue Spring to the mouth; a decrease in primary productivity with increasing turbidity could be expected. Regression analysis also reveled that km above the mouth (T=3.17, p=.003), flow (T=-2.54, p=.015) and distance from shore collected (T=4.65, p=.0001) were significant factors affecting chlorophyll *a* concentrations collected from fine substrates; depth had no significant effect (overall equation, F=12.03; df=4, 39; p=.0001).

Levels of chlorophyll *a* extracted from periphyton collected from coarse substrates did not differ significantly among sampling sites (p<.1, Figure 4.10). However, the mean chlorophyll *a* concentrations were greatest at RKM 15 (376.36 mg/m^2) and decreased towards the mouth. Mean chlorophyll content at RKM 20 was 172.72 mg/m^2. When chlorophyll *a* values from RKM 20 were deleted from the analysis the regression was still not significant (p=.074, R^2=.16). The low levels of chlorophyll *a* found at RKM 20 may have been influenced by the abundance of algae-grazing caddisflies, *Hydropsyche* spp (Slack 1936; Jones 1950; Mecom 1972; Fuller and Mackay 1980; Dudley et al. 1986) and mayflies, *Baetis* spp (Chapman and Demory 1963; Gray and Ward 1979; Brown 1961; Edmonds 1984, Day 1956). Simple linear regression analysis revealed that abundance of *Hydropsyche* and *Baetis* on stones decreased significantly from RKM 20 to the mouth (*Hydropsyche* R^2=.585, p=.022; *Baetis* R^2=.622, p=.013). Greater numbers of algae-grazing invertebrates could result in reduced algal biomass at the RKM 20 sampling site (Gregory 1983, Lamberti and Resh 1983, Hart 1985, Vaughn 1986). Algae-grazing invertebrates from fine substrates did not significantly differ in abundances longitudinally. Further analysis of benthic samples collected may lend additional support to this hypothesis.

Abundances of several invertebrate taxa differed among sampling sites. Abundances of chironomidae, hydropsychidae, and baetidae collected from cobble decreased longitudinally from RKM 20 to the mouth (chironomidae R^2=.523, p=.045; significance values for hydropsychidae: *Hydropsyche* and baetidae: *Baetis* were given above). Abundance of invertebrates collected from fine substrates did not vary significantly longitudinally.

Native fishes are not distributed equally in the lower 21 km of the Little Colorado River. Of the four native fish species found in the Little Colorado River in the Grand Canyon only speckled dace are found in the reach upstream from Atomizer Falls. Speckled dace are relatively abundant (E.D. Creef and A.T. Robinson, personal observations) and are known to spawn above Atomizer Falls. However, it is not known if speckled dace dispersed into this reach from upstream or downstream movements. There are at least four factors that could limit the distributions of native fishes in the Little Colorado River: (1) the 8 ft vertical drop at Chute Falls (part of the Atomizer Falls complex) is a physical barrier; (2) the water chemistry above the Atomizer complex is not conducive to fish habitation; (3) not enough food resources are available above the Atomizer complex to support fish populations; and (4) suitable habitat is not available above Atomizer Falls. It is possible that Atomizer Falls is a physical barrier to upstream movement of fishes. However, it is likely that during high stage flooding events the vertical barrier would be all but eliminated.

Longitudinal patterns of selected water quality parameters are similar across seasons. However, at each sampling point, the values of most water quality parameter vary across seasons. The water chemistry levels below Atomizer Falls in one season are often similar to levels above Atomizer in another season. For instance, carbon dioxide levels at RKM 10 in January 1992 are greater than levels at RKM 20 and RKM 15 for the other three trips. Alkalinity is the only water quality parameter in which all values across the seasons below Atomizer Falls are less than all values above. Therefore, of the water quality parameters measured, alkalinity is the only factor likely to discourage native fishes from moving into the reach above Atomizer Falls. Food resources do not appear to be a factor limiting the distribution of fishes above Atomizer Falls, since invertebrate densities such as chironomids were greater above Atomizer than below and other known invertebrate food items (Clarkson and Robinson 1993) such as ostracods and empididae did not vary longitudinally in distribution. Mean ranges of substrate types, flows, and depths in the reach above Atomizer Falls overlap greatly with the reaches downstream to Sipapu (RKM 7.5; Gorman et al. 1993). Since all four native fish species inhabit the reach below Atomizer Falls, the data of Gorman et al (1993) indicate that similar habitat for native fishes is available upstream from Atomizer Falls.

Objective 3.10. Performance of the thermal tolerance tests on the young-of-the-year humpback chub.

See Appendix 4.1 for a report on thermal tolerances of humpback chub and Colorado squawfish.

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TABLE 5.1. Relative abundances (percent) of species caught in the three gear types during the May monitoring period, Little Colorado River, 1993.

SPECIES	HOOP NETS	SEINES	DIP NETS
Rainbow trout	0.2	0	0
Fathead minnow	0.1	0	0.1
Humpback chub	43.7	7.7	19.2
Speckled dace	46.2	38.5	27.6
Bluehead sucker	3.8	7.7	35.7
Flannelmouth sucker	4.5	0	10.6
Unidentified	1.4	46.2	6.8

TABLE 5.2. Frequencies of occurrence (percent) of eggs and larval fish in drift samples, Little Colorado River, 1991 through 1992. N is the total number of samples analyzed.

Category		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	N	--	--	(3)	--	(54)	(118)	(11)	(10)	(3)	(19)	(10)	(16)
Eggs		--	--	0	--	22.2	32.2	0	10.0	0	42.0	20.0	12.5
Humpback chub		--	--	0	--	0	11.0	0	0	0	0	0	0
Speckled dace		--	--	0	--	1.9	8.5	45.5	10.0	0	0	0	0
Bluehead sucker		--	--	0	--	0	7.6	18.2	0	0	5.3	10.0	0
Flannelmouth sucker		--	--	0	--	3.7	5.1	9.1	10.0	0	0	0	0
Channel catfish		--	--	0	--	0	1.7	9.1	0	0	0	0	0
Unidentified sucker		--	--	0	--	0	2.5	9.1	0	0	0	0	0
Unidentified larvae		--	--	0	--	3.7	8.5	18.2	0	0	15.8	0	0
1992	N	(8)	(16)	(12)	(25)	(140)	(104)	(18)	(18)	(14)	(16)	(16)	(16)
Eggs		12.5	18.8	8.3	32.0	20.0	11.5	11.1	0	0	31.3	0	31.3
Humpback chub		0	0	0	4.0	0.7	2.9	0	0	0	0	0	0
Speckled dace		0	0	0	0	0	0	5.6	0	0	0	0	0
Bluehead sucker		0	0	0	0	0	1.0	0	0	0	0	0	0
Flannelmouth sucker		0	0	0	0	0	0	0	0	0	0	0	6.3
Channel catfish		0	0	0	0	0	0	27.8	0	0	0	0	0
Unidentified sucker		0	0	0	0	0	1.0	0	0	0	0	0	0
Unidentified larvae		0	0	0	0	0.7	0	0	0	0	0	0	0
Unidentified larvae		0	0	0	0	20.6	7.8	0	--	--	--	--	--

TABLE 5.3. Frequencies of occurrence (percent) of eggs and larval fish in drift samples, Little Colorado River, 1993. N is the total number of samples analyzed.

Category		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	N	(13)	(8)	(12)	(25)	(194)	(191)	(24)	--	--	--	--	--
Eggs		0	0	0	15.4	37.2	15.8	0	--	--	--	--	--
Humpback chub		0	0	0	0	44.8	10.3	4.2	--	--	--	--	--
Speckled dace		0	0	0	0	55.1	26.7	8.3	--	--	--	--	--
Bluehead sucker		0	0	0	0	32.5	22.5	4.2	--	--	--	--	--
Flannelmouth sucker		0	0	0	12.0	11.8	7.8	0	--	--	--	--	--
Channel catfish		0	0	0	0	0.5	0	0	--	--	--	--	--
Fathead minnow		0	0	0	0	3.6	0	0	--	--	--	--	--
Common carp		0	0	0	0	3.6	0.5	0	--	--	--	--	--
Unidentified sucker		0	0	0	0	1.0	2.1	0	--	--	--	--	--
Unidentified larvae		0	0	0	0	20.6	7.8	0	--	--	--	--	--

TABLE 5.4. Monthly mean densities of eggs (not identified to species) and larval fish in drift samples, Little Colorado River, 1991 through 1992. Densities are mean numbers of individuals per 1000 m^3. N is the number of samples used to compute densities; drift samples with fish or eggs absent were included in the calculation.

Category		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	N	--	--	(3)	--	(38)	(106)	(11)	(10)	(1)	(17)	(5)	(16)
Eggs		--	--	0	--	18.30	5.38	0	0.10	0	1.32	0.45	0.65
Humpback chub		--	--	0	--	0	1.03	0	0	0	0	0	0
Speckled dace		--	--	0	--	0.01	0.72	30.19	0.97	0	0	0	0
Bluehead sucker		--	--	0	--	0	0.81	0.30	0	0	0	0.44	0
Flannelmouth sucker		--	--	0	--	0.20	0.77	0.18	0.49	0	0	0	0
Channel catfish		--	--	0	--	0	0.05	0.06	0	0	0	0	0
Unidentified sucker		--	--	0	--	0	0.05	0.06	0	0	0	0	0
Unidentified larvae		--	--	0	--	0.72	0.60	0.21	0	0	0.43	0	0
Total fish		--	--	0	--	0.93	4.03	31.01	1.46	0	0.43	0.44	0
1992	N	(8)	(14)	(0)	(21)	(105)	(97)	(18)	(18)	(14)	(16)	(16)	(16)
Eggs		0.71	10.60	--	150.46	26.35	1.55	34.54	0	0	4.91	0	2.03
Humpback chub		0	0	--	0.97	0.34	0.53	0	0	0	0	0	0
Speckled dace		0	0	--	0	0	0	1.03	0	0	0	0	0
Bluehead sucker		0	0	--	0	0	0.10	0	0	0	0	0	0
Flannelmouth sucker		0	0	--	0	0	0	0	0	0	0	0	0.08
Channel catfish		0	0	--	0	0	0	4.06	0	0	0	0	0
Unidentified sucker		0	0	--	0	0	0.05	0	0	0	0	0	0
Total fish		0	0	--	0.97	0.33	0.68	5.09	0	0	0	0	0.08

TABLE 5.5. Monthly mean densities of invertebrates in drift samples, Little Colorado River, 1991. Densities are mean numbers of individuals per 1000 m^3. No invertebrates were found in drift samples collected in March (N=3).

TAXA	May (N=14)	Jun (N=37)	Jul (N=10)	Aug (N=3)	Sep (N=1)	Oct (N=11)	Nov (N=5)	Dec (N=15)
Misc. Diptera	142.82	59.90	20.65	10.58	1904.76	45.17	5.28	20.36
Chironomidae	596.18	1381.47	139.05	392.11	190.48	549.03	119.01	185.09
Ceratopogonidae	80.76	44.73	19.45	42.25	571.43	98.73	8.42	5.09
Empididae	73.15	103.83	17.59	117.05	0	115.78	8.82	19.70
Sciaridae	0.68	8.30	0.42	0	0	9.87	0	4.52
Simulidae	107.52	2.89	0	0	0	3.62	0	0
Misc. Homoptera	48.66	7.45	3.42	0	380.95	2.09	0	0
Aphidae	62.17	157.41	16.57	254.97	0	395.41	132.68	52.36
Cicadellidae	21.15	30.69	1.53	0	190.48	13.00	2.61	0
Psyllidae	48.49	99.27	0	0	0	1.82	0.87	0
Misc. Ephemeroptera	170.04	40.52	2.80	0	0	530.63	9.64	519.06
Baetidae	0	18.77	0	0	0	172.60	26.36	110.80
Misc. Hymenoptera	40.27	29.46	5.81	7.05	0	8.68	1.74	0.73
Chalcidoidea	15.69	57.99	6.02	6.17	0	60.46	0	0
Formicidae	25.51	25.10	2.40	0.81	190.48	15.28	0	2.52
Hemiptera	11.38	54.63	3.11	6.98	190.48	10.42	1.74	4.48
Misc. Trichoptera	1.84	6.13	0.79	0	0	4.96	0.87	0.72
Hydropsychidae	150.30	24.91	0.54	0.81	190.48	16.62	2.21	9.68
Hydroptillidae	7.94	6.01	0.53	0	0	28.38	2.67	5.33
Coleoptera	16.21	28.43	3.42	9.70	190.48	4.42	0	0.90
Thysanoptera	0	18.68	8.62	26.38	0	6.61	0	0
Megaloptera	2.35	4.49	0	0.81	0	1.70	0	0
Odonata	2.35	0.95	0	0	0	0.67	0	0
Collembola	0	5.77	0	0.81	0	0	0	0
Other insects	20.32	18.46	1.10	0	1333.33	1.02	0	0
Arachnida	20.46	8.28	0.42	0	0	3.38	0.46	0
Mollusca	1.38	12.50	0.42	0.81	0	11.05	4.36	12.20
Other invertebrates	21.13	3.15	0	7.78	571.43	4.67	0	0
Total	1688.74	2260.21	254.67	885.05	5904.76	2124.08	327.75	953.53

TABLE 5.6. Monthly mean densities of invertebrates in drift samples, Little Colorado River, 1992. Densities are mean numbers of individuals per 1000 m^3. Densities could not be calculated for March due to missing flow data.

TAXA	Jan (N=8)	Feb (N=14)	Apr (N=9)	May (N=27)	Jun (N=28)	Jul (N=16)	Aug (N=18)	Sep (N=14)	Oct (N=15)	Nov (N=15)	Dec (N=16)
Misc. Diptera	0	49.64	314.96	803.69	9.65	564.15	43.04	287.91	19.48	2209.36	1.49
Chironomidae	2.85	249.13	629.69	507.79	31.61	2152.98	59.09	185.41	1.77	994.72	20.13
Ceratopogonidae	0	52.91	5.01	28.42	16.36	309.15	2.71	19.95	0.43	177.78	0.66
Empididae	0	56.59	300.28	134.92	19.12	212.67	2.71	0	2.26	0	1.17
Sciaridae	0	0	0	0	9.05	0	3.96	0	1.73	0	0.74
Simulidae	0	0	20.91	64.11	20.30	1.02	0	0	0.79	219.03	3.47
Misc. Homoptera	0	0	25.40	5.07	0.39	0	0	79.37	0.49	51.53	0
Aphidae	0	0	96.75	499.36	49.39	79.67	10.15	0	4.59	466.06	73.89
Cicadellidae	0	23.81	5.01	417.76	11.42	443.89	5.32	0	0	0	0.51
Psyllidae	0	15.87	42.59	3.89	0.39	0.74	0	0	0.79	0	0
Misc. Ephemeroptera	0	12.91	0	20.11	10.20	223.42	13.92	0	0	0	5.82
Baetidae	31.81	298.09	2.50	20.96	26.76	113.95	20.01	56.69	1.60	0	126.98
Misc. Hymenoptera	2.85	0	41.12	800.95	16.15	16.34	0	92.50	1.58	64.65	0.11
Chalcidoidea	0	0	18.40	20.36	1.41	0	3.61	0	0	45.58	0
Formicidae	0	52.28	269.36	101.87	43.56	545.05	39.62	234.15	4.86	268.38	0.33
Hemiptera	0	23.81	0	67.57	19.98	236.93	0	102.37	0.67	282.34	0.74
Misc. Trichoptera	0	0	0	387.32	0	0.57	27.64	54.42	4.30	0	0
Hydropsychidae	16.62	26.46	0	18.76	217.59	615.15	70.84	466.15	20.97	0	25.04
Hydroptillidae	0	12.91	0	0.59	0	0.25	5.19	0	2.81	214.71	0.49
Coleoptera	1.42	55.30	0	438.10	12.18	564.70	7.91	57.72	5.60	407.85	3.18
Thysanoptera	0	0	0	681.29	1.84	0	0	0	0	50.79	0

TABLE 5.6. Continued...

TAXA	Jan (N=8)	Feb (N=14)	Apr (N=9)	May (N=27)	Jun (N=28)	Jul (N=16)	Aug (N=18)	Sep (N=14)	Oct (N=15)	Nov (N=15)	Dec (N=16)
Megaloptera	0	0	0	148.87	0	9.76	0	13.14	0.79	45.58	0.41
Odonata	0	12.91	269.36	1.18	1.61	0	3.83	0	0.49	0	0.68
Collembola	0	0	0	0	1.01	0	0	0	0	0	0
Other insects	0	0	0	4.76	2.81	221.08	3.93	0	67.91	96.38	0.79
Arachnida	2.85	0	0	102.45	16.83	9.64	1.60	69.77	0.47	602.90	0.36
Mollusca	0	232.26	0	0	0	1.17	0	0	0	0	0.71
Other invertebrates	0	155.05	0	387.32	0.66	0	0	0	3.74	279.35	0
Total	58.40	1329.94	2041.34	5667.45	540.28	6322.30	325.08	1718.55	148.14	6477.00	267.70

TABLE 5.7. Monthly mean lengths (mm) of YOY native fishes, Little Colorado River, 1993.

Month		Humpback chub	Speckled dace	Bluehead sucker	Flannelmouth sucker
April	mean	--	10.3	11.7	13.0
	S.D.	--	2.66	1.29	2.65
	n	--	6	12	3
May	mean	12.9	12.4	13.1	14.7
	S.D.	3.94	4.22	2.68	3.78
	n	206	296	384	113
June	mean	22.8	18.5	15.7	19.6
	S.D.	5.61	6.56	5.11	5.62
	n	181	366	307	79
July	mean	36.7	32.1	34.3	25.6
	S.D.	9.82	9.11	11.90	10.43
	n	211	196	185	21
August	mean	43.8	34.1	41.8	38.6
	S.D.	7.81	6.23	7.56	6.66
	n	60	66	146	3

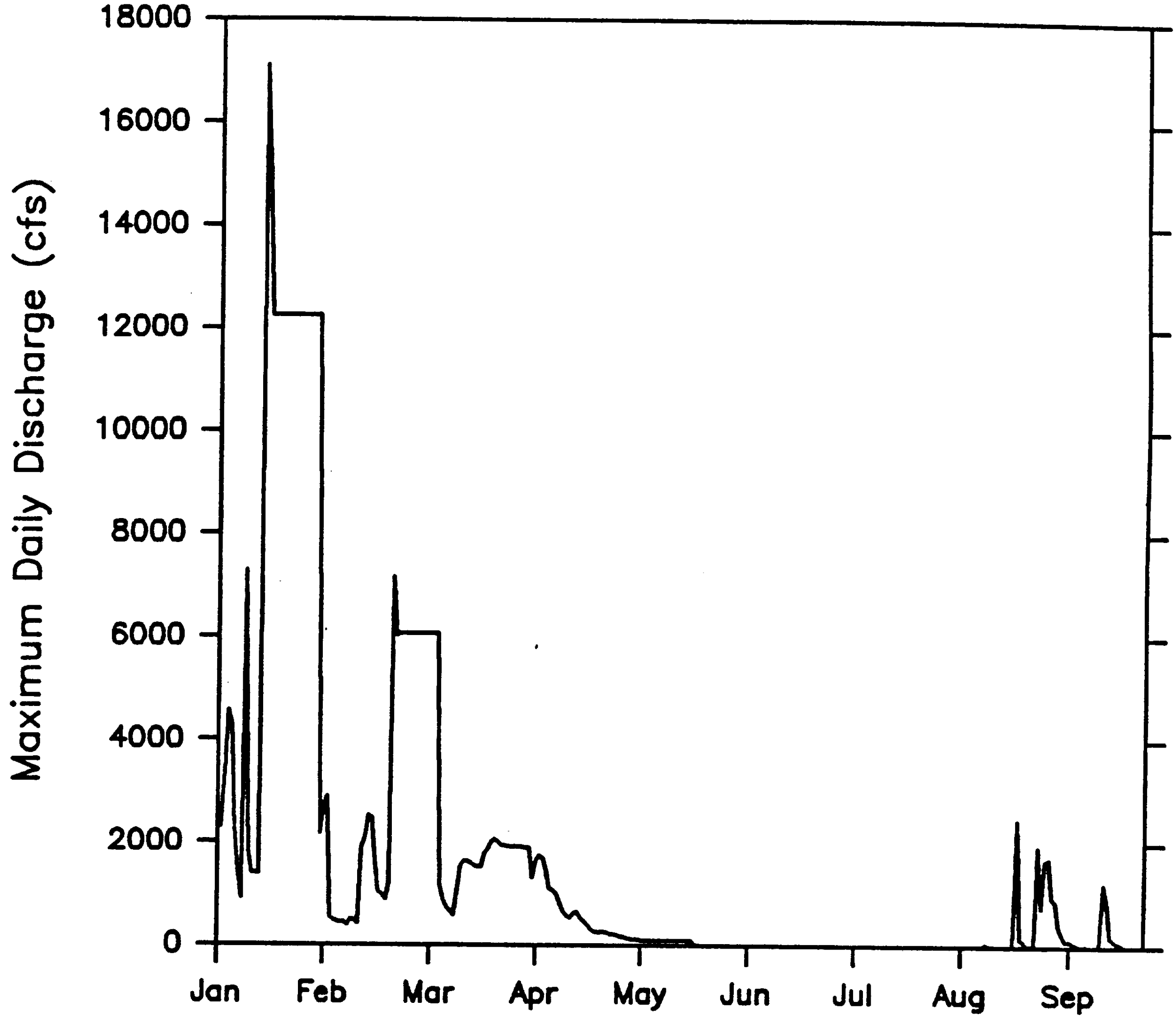

FIGURE 5.1. Maximum daily discharge (cfs) of the Little Colorado River near Cameron, AZ, January through mid-September 1993.

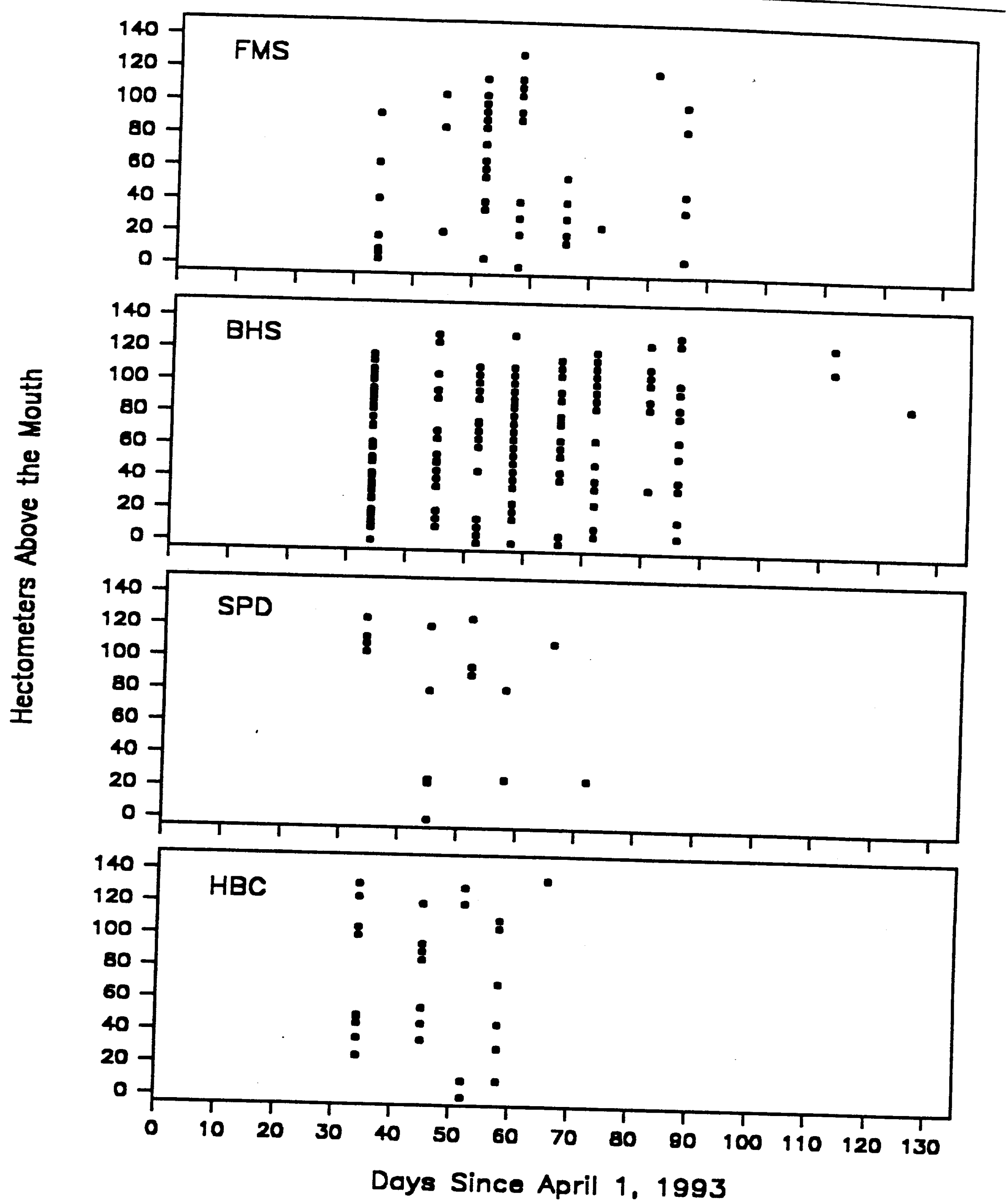

FIGURE 5.2. Longitudinal and temporal distributions of protolarvae, Little Colorado River, 1993. Larval occurrence data from the longitudinal surveys are shown for the final day of each survey (8, 34, 45, 52, 58, 66, 72, 81, 86, 112, and 125 days past April 1). FMS = flannelmouth sucker, BHS = bluehead sucker, SPD = speckled dace, HBC = humpback chub.

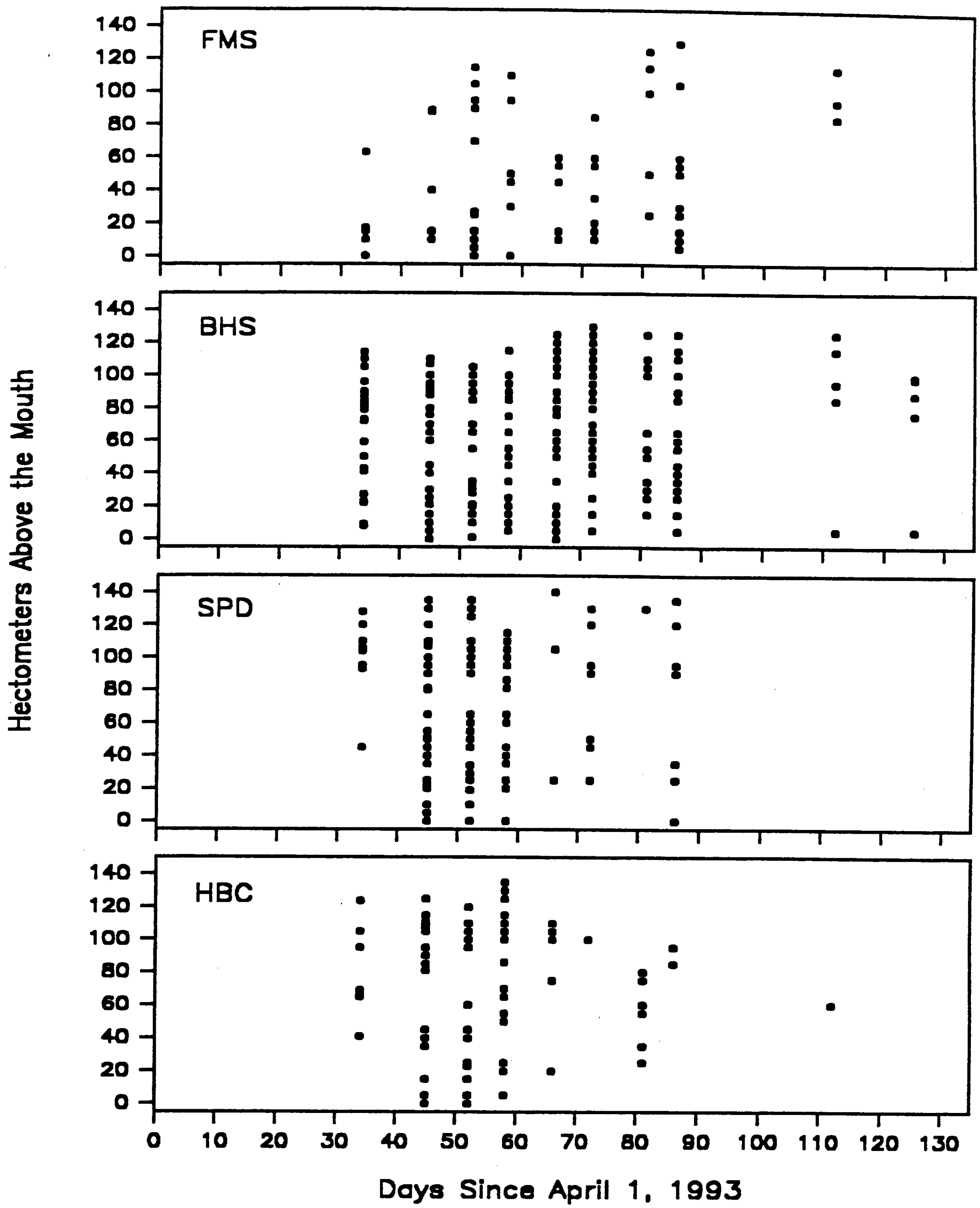

FIGURE 5.3. Longitudinal and temporal distributions of mesolarvae, Little Colorado River, 1993. Larval occurrence data from the longitudinal surveys are shown for the final day of each survey (8, 34, 45, 52, 58, 66, 72, 81, 86, 112, and 125 days past April 1). FMS = flannelmouth sucker, BHS = bluehead sucker, SPD = speckled dace, HBC = humpback chub.

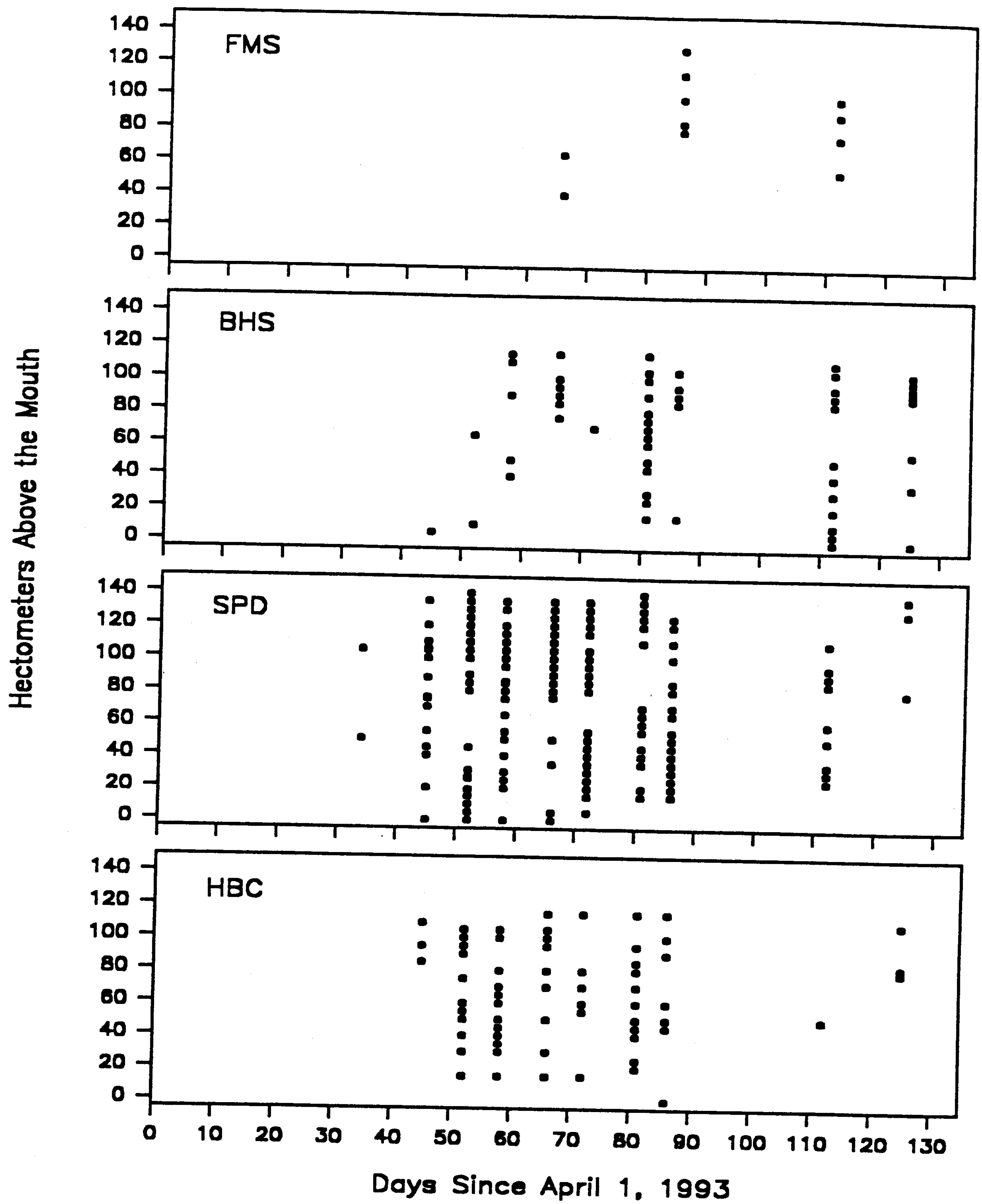

FIGURE 5.4. Longitudinal and temporal distributions of metalarvae, Little Colorado River, 1993. Larval occurrence data from the longitudinal surveys are shown for the final day of each survey (8, 34, 45, 52, 58, 66, 72, 81, 86, 112, and 125 days past April 1). FMS = flannelmouth sucker, BHS = bluehead sucker, SPD = speckled dace, HBC = humpback chub.

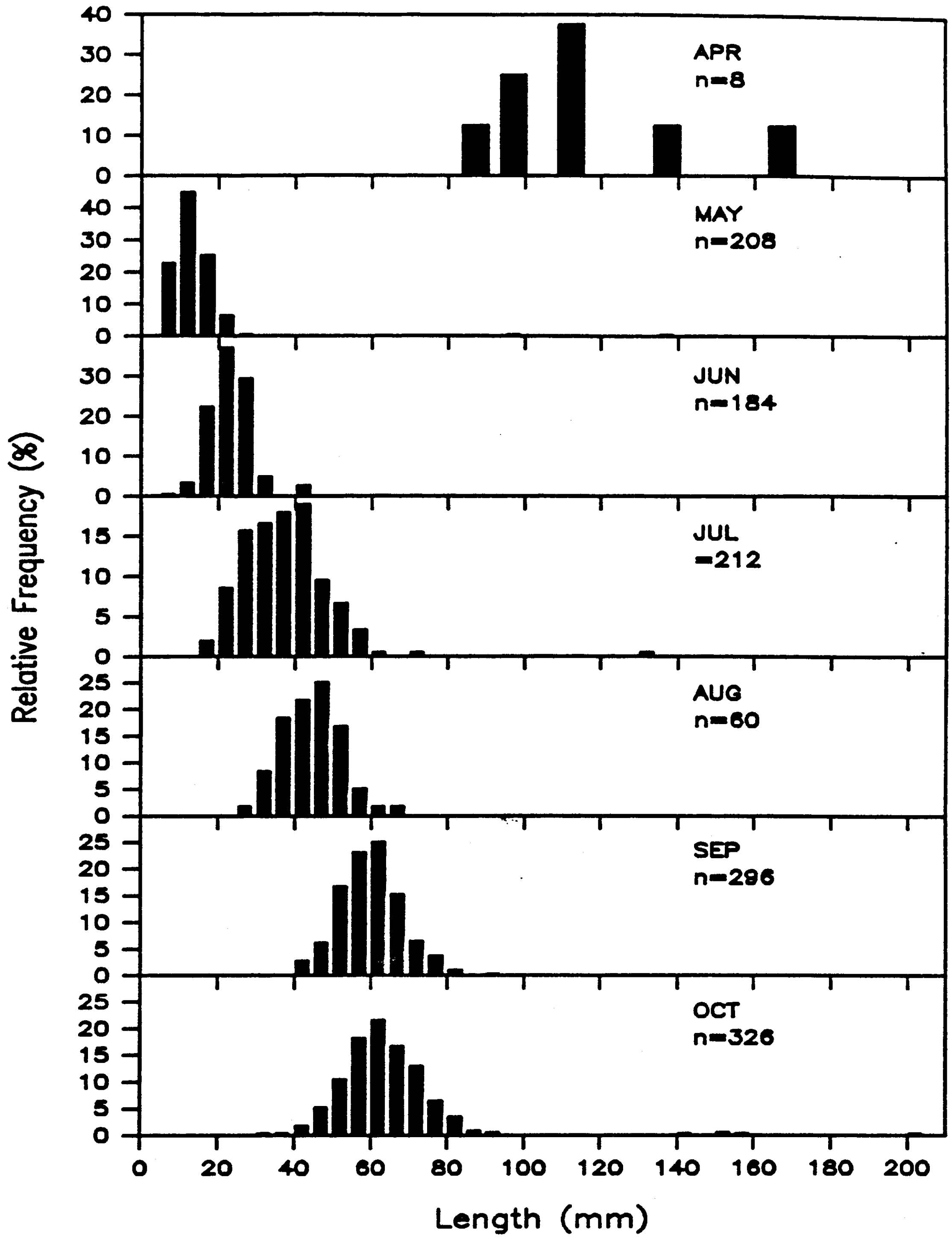

FIGURE 5.5. Length-frequency distributions for putative age-0 and age-1 humpback chub collected by seine and dip net in the Little Colorado River, April-August 1993. No fish were captured in January or March and no sampling was conducted in February.

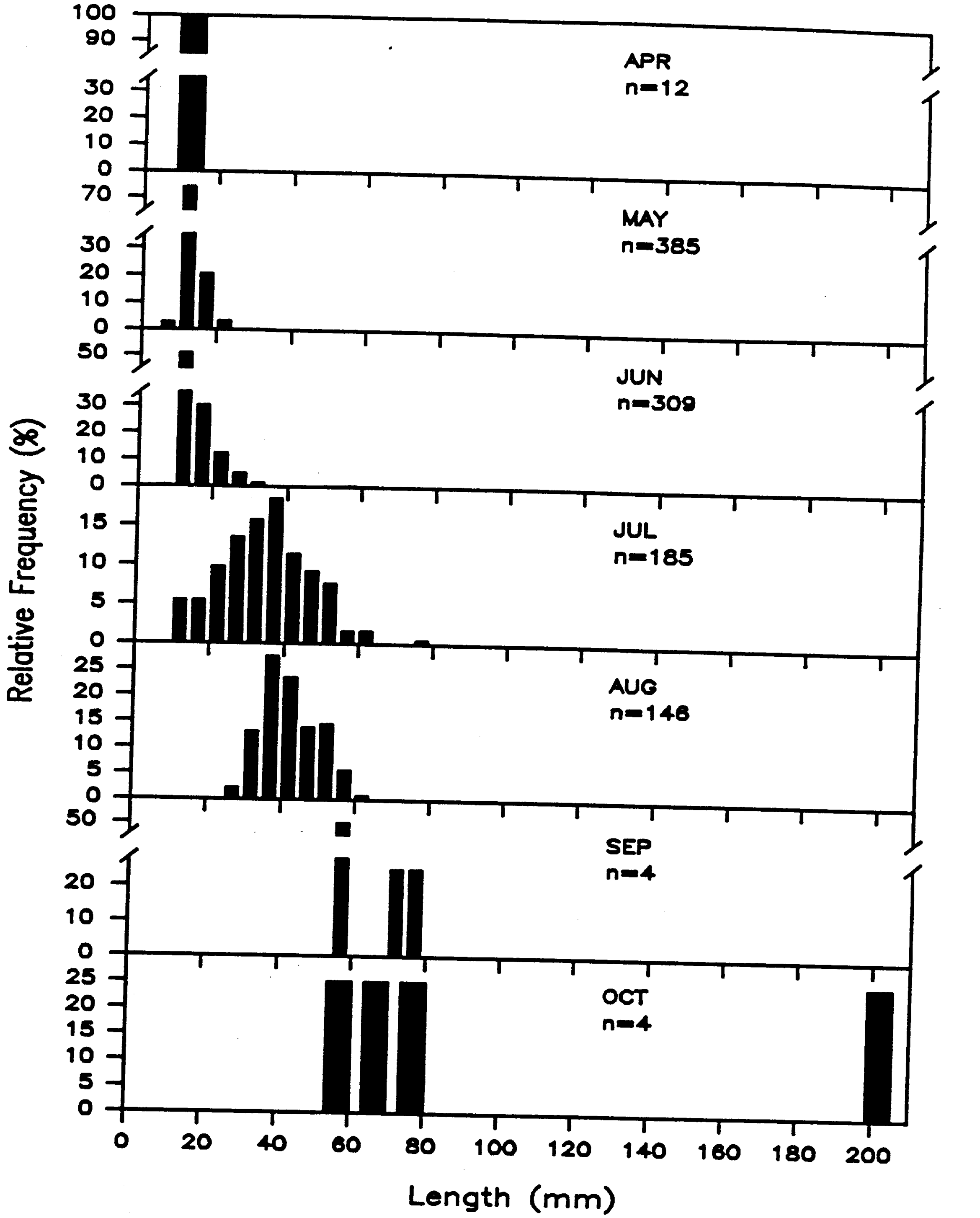

FIGURE 5.6. Length-frequency distributions for putative age-0 and age-1 bluehead sucker collected by seine and dip net in the Little Colorado River, March-August 1993. No fish were captured in January or March and no sampling was conducted in February.

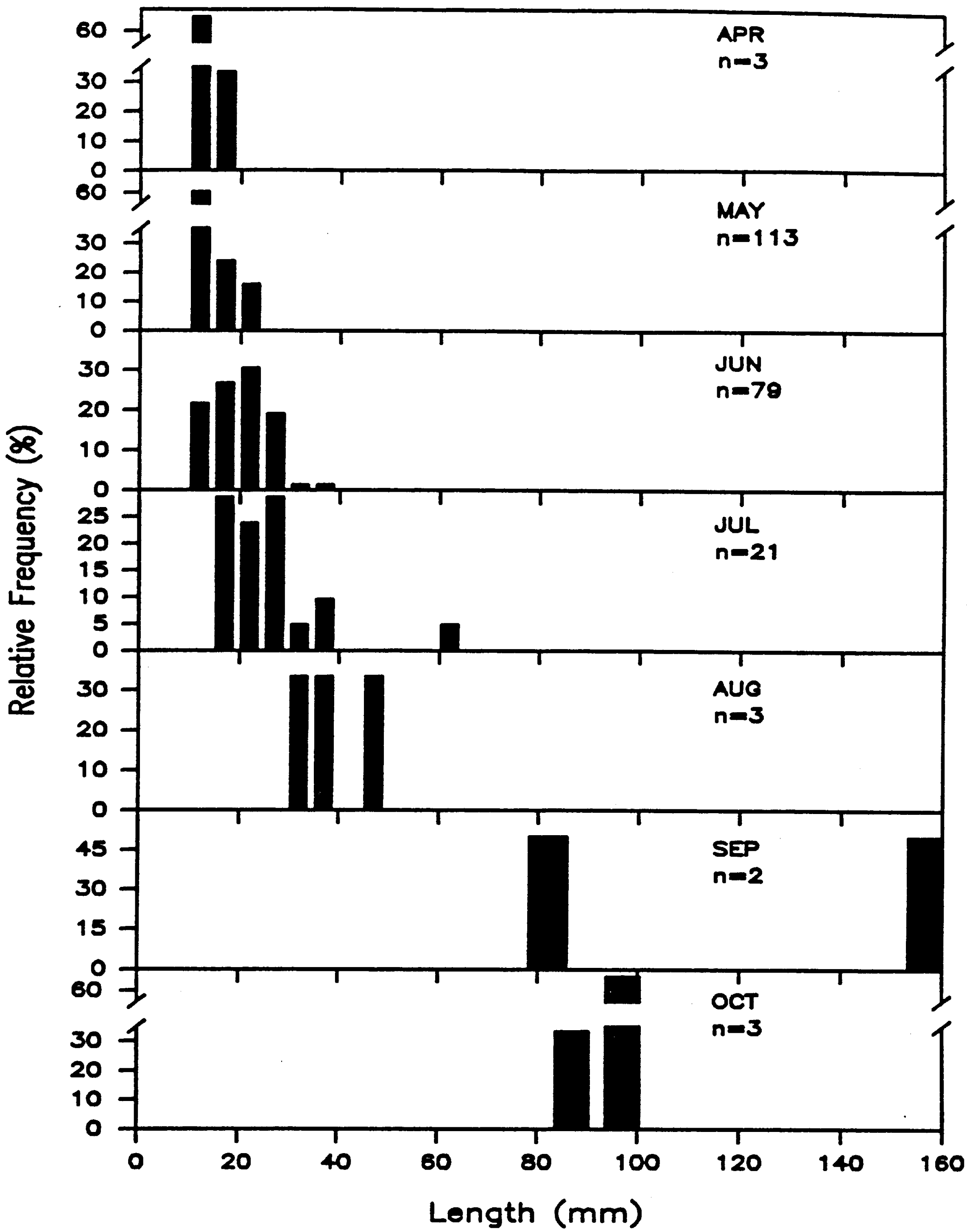

FIGURE 5.7. Length-frequency distributions for putative age-0 flannelmouth sucker collected by seine and dip net in the Little Colorado River, March-August 1993. No fish were captured in January or March and no sampling was conducted in February.

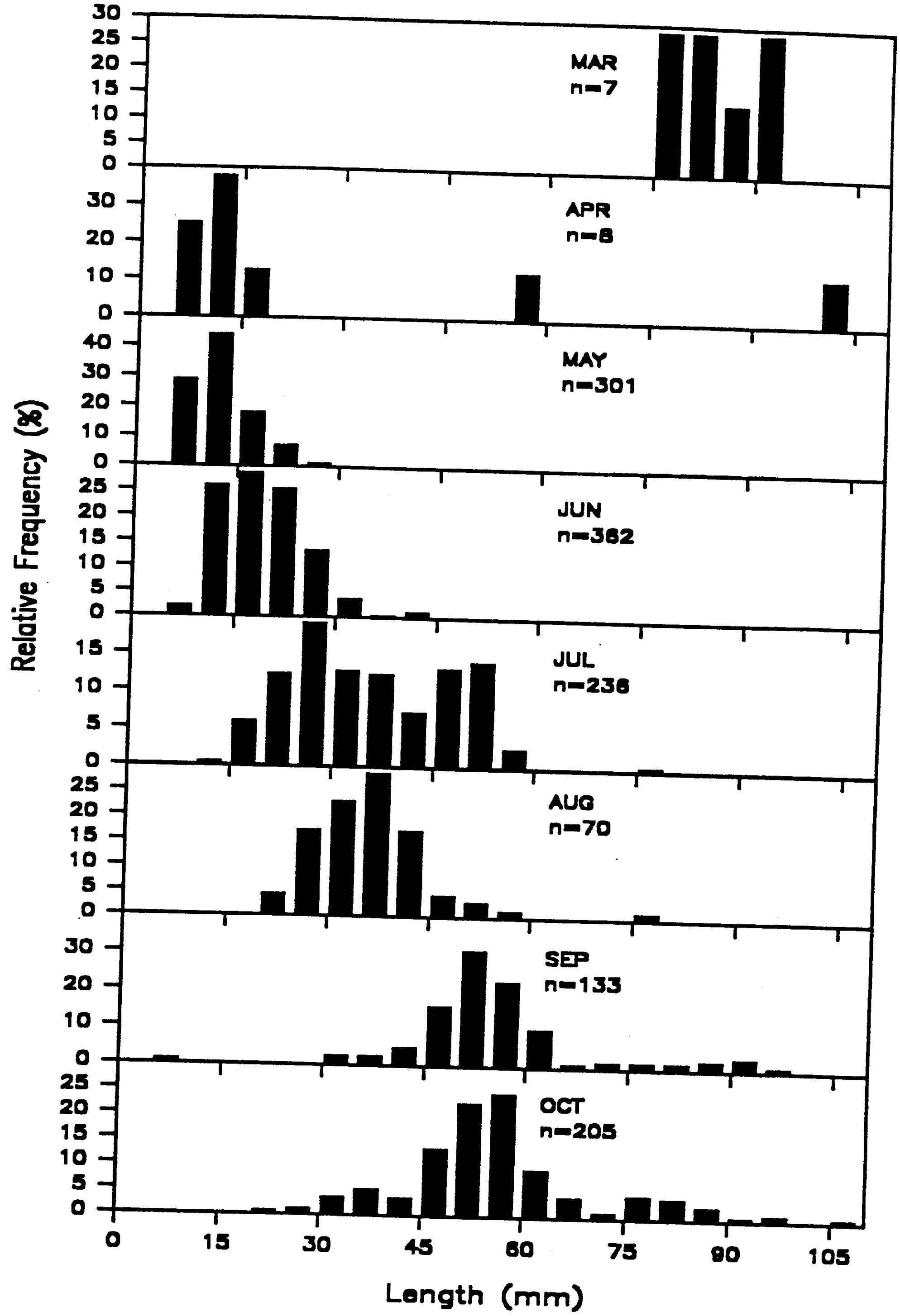

FIGURE 5.8. Length-frequency distributions for putative age-0 and age-1 speckled dace collected by seine and dip net in the Little Colorado River, March-August 1993. No fish were captured in January and no sampling was conducted in February.

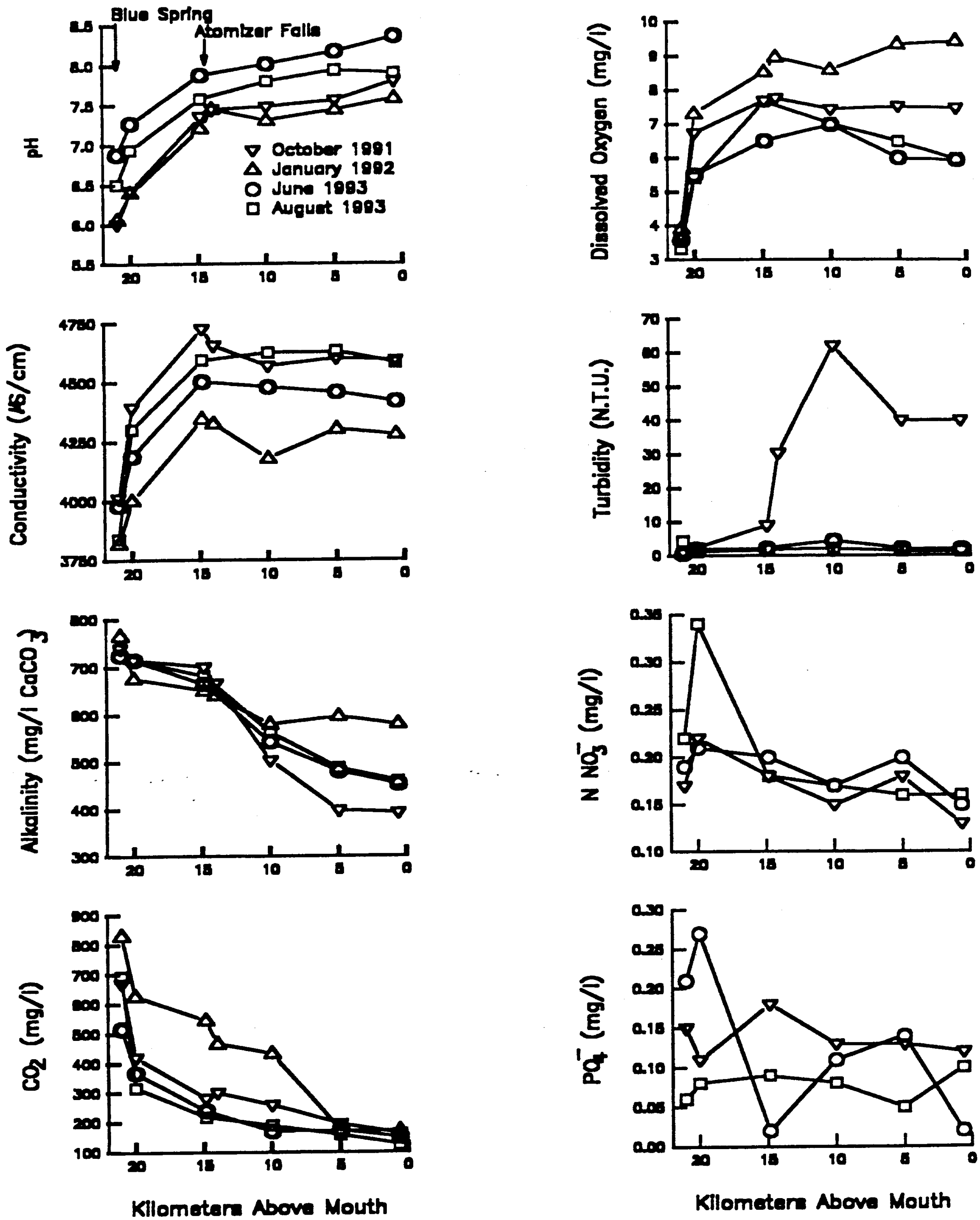

FIGURE 5.9. Longitudinal patterns of selected water quality parameters from the Little Colorado River, October 1991 through August 1993.

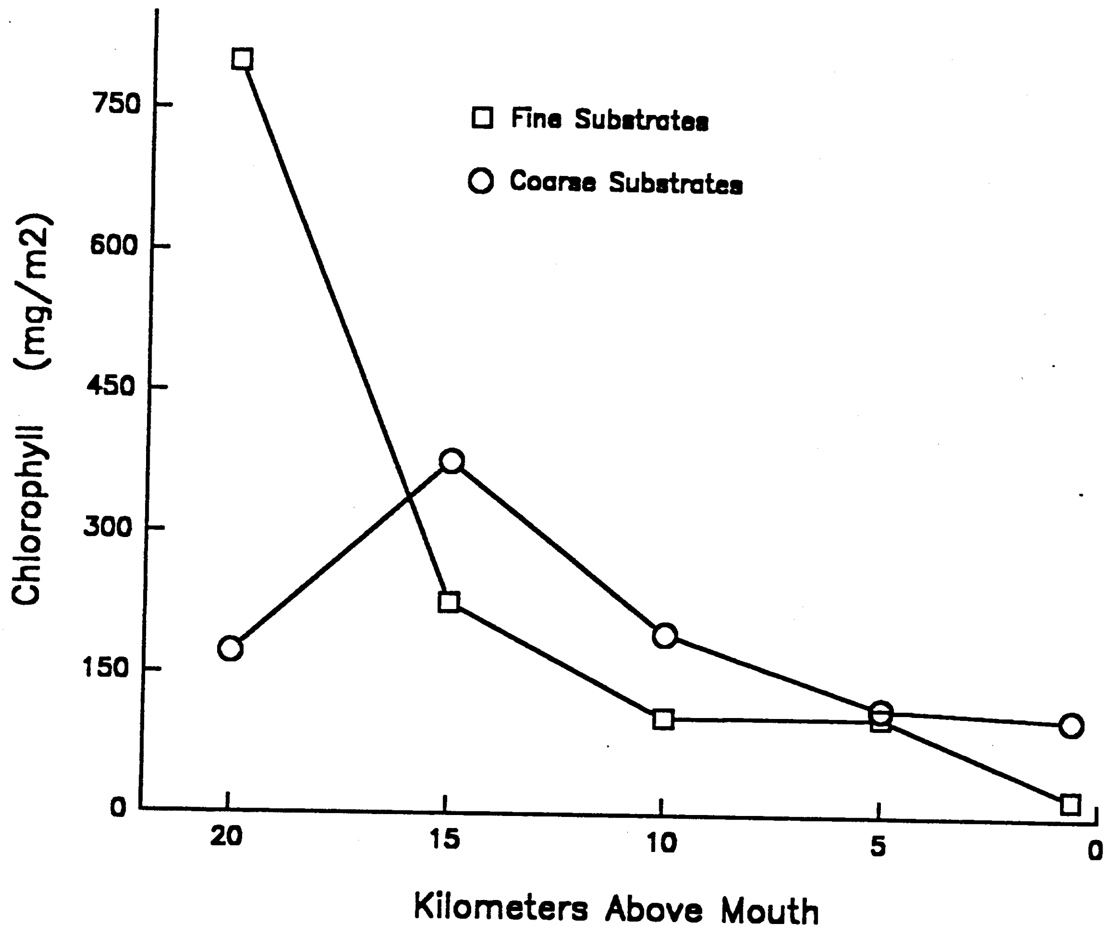

FIGURE 5.10. Longitudinal patterns of chlorophyll *a* concentrations extracted from algal samples collected from coarse and fine substrates, Little Colorado River, June 1993.

Temperature Tolerance of Humpback Chub (*Gila cypha*) and Colorado Squawfish (*Ptychocheilus lucius*), With a Description of Culture Methods for Humpback Chub

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Abstract--The closure of Glen Canyon Dam near the head of Grand Canyon, Arizona, in 1963 resulted in a depression of spring-summer downstream water temperatures. Post-dam temperatures likely have precluded successful mainstem reproduction of most native species due to mortality during incubation. In addition, movements of early life stage fishes from the Little Colorado River, a major undammed tributary used for spawning and rearing, to the Colorado River mainstem across a large thermal gradient have been surmised to negatively affect survival and growth. We exposed early life stages of endangered humpback chub (*Gila cypha*) and Colorado squawfish (*Ptychocheilus lucius*) to several temperatures to examine effects on survival and growth in the laboratory. All eggs were incubated at 18.6°C and moved to 20°C at swimup for a minimum of 24 h. When transferred from 20°C to 10°C for 4 h, 5-7 d old humpback chub larvae lost equilibrium and mobility for 90 min, but recovered. Same age humpback chub larvae became lethargic but did not lose equilibrium when transferred from 20°C to 12°C, and no behavioral effects were observed when moved to 14°C. Similar cold shock experiments with 11-13 d chub larvae affected only the 10°C group, which lost equilibrium for 15 min before recovering. No mortality was observed under any treatment during the 4 h observation period. Growth patterns of 6-8 d humpback chub larvae reared at 10°C, 14°C, and 20°C averaged 10%, 37%, and 83% length gain, respectively, and 28%, 195%, and 951% weight gain, over 30 d. Overall patterns of growth of 13-15 d humpback chub and Colorado squawfish larvae and 39-41 d chub post-larvae reared at these temperatures were similar. Results suggest that detrimental effects of reduced growth on individuals and populations of native fishes in Grand Canyon can be ameliorated through modification of Colorado River seasonal and daily hydrological patterns. We also recommend consideration of thermal modification of discharges from Glen Canyon Dam.

The Colorado River system in Grand Canyon, Arizona, supports the largest population of the endangered humpback chub, *Gila cypha*, of the seven remaining population centers of this species (USFWS 1990). Although the species historically occurred downstream in the Colorado River below present-day Hoover Dam (Miller 1955), the Grand Canyon population is the last remaining in the Lower Colorado River Basin. Closure of Glen Canyon Dam in 1963 effected profound physical changes to the Colorado River downstream (Carothers et al. 1980, Maddux et al. 1987). These alterations proved detrimental to the native fish fauna (Holden and Stalnaker 1975, Suttkus et al. 1976, Kaeding and Zimmerman 1983, Angradi et al. 1992, and others). Colorado squawfish (*Ptychocheilus lucius*), and bonytail (*G. elegans*) and roundtail chubs (*G. robusta*) were soon extirpated from the Colorado River in Grand Canyon, and the continued presence of razorback sucker (*Xyrauchen texanus*), humpback chub, and other native fishes is threatened (*op cit*, Nelson 1978, Minckley 1991, and others).

In reference to the life history of humpback chub and other native species, the most notable alteration of the Colorado River resulting from the closure of Glen Canyon Dam was a depression of spring-summer water temperatures. This feature likely has precluded successful mainstem reproduction due to mortality during incubation (Kaeding and Zimmerman 1983, Marsh 1985). Presently the Little Colorado River (LCR), a perennial tributary to the Colorado River in Grand Canyon, serves as the only known site of reproduction and recruitment for humpback chub (Kaeding and Zimmerman 1983, Maddux et al. 1987, Valdez et al. 1992). Known (AGFD unpublished data) and suspected (Kaeding and Zimmerman 1983, Angradi et al. 1992, AGFD 1993) movements of early life stage humpback chub from the LCR to the Colorado River mainstem across a large thermal gradient has been surmised to negatively affect survival and growth (Angradi et al. 1992). These and other effects on the life histories of native fishes in the Colorado Basin resulting from rearing in cold temperatures were noted by McAda and Wydoski (1983), Kaeding and Osmundson (1988), and Thompson et al. (1991). Actual effects in Grand Canyon, however, have been poorly studied.

The objectives of this study were to obtain humpback chub reproductive products from the LCR in order to rear larvae and juveniles for use in laboratory experiments to examine effects of temperature on aspects of survival and growth. In addition, we conducted similar experiments with Colorado squawfish larvae obtained from hatchery broodstock for comparisons with humpback chub.

Previously, adult humpback chub were collected from the LCR and from the Colorado River at Black Rocks, held in captivity for one year or more, spawned by hormone-induced gonadal maturation, and reproductive products used for culture and incubation experiments (Hamman 1982, Marsh 1985). Fertilized ova of humpback chub were also collected from a field spawning effort involving the Black Rocks, Colorado, population, transported to Dexter National Fish Hatchery, and successfully reared (Valdez and Valdez-Gonzales 1991). However, three field spawning attempts of the LCR population resulted in no live larvae (Minckley 1989, Raisanen et al. 1991, Angradi et al. 1992). Thus, an additional goal of the present study was to attempt to determine the cause(s) of previous failures. Methods used for culturing humpback chub are presented here.

METHODS

Spawning and Incubation

Humpback chub used in temperature experiments were obtained from manually stripped reproductive products of wild fish from the LCR. Spawning and incubation equipment was set up near Salt Trail Canyon, 10.5 km above the confluence with the Colorado River. Ten 6.4 mm mesh hoop nets were set in the immediate vicinity of Salt Trail Canyon, and were checked for presence of fish at least twice per day from April 26 to May 8, 1993. Humpback chub that exhibited secondary sexual characteristics were transported in 19 L buckets equipped with battery powered aerators to 1.2 m X 1.2 m X 1.2 m, 6.4 mm mesh live cars set in a backwater at the Salt Trail Canyon site. Fish were checked for presence of passive integrated transponders (PIT), and unmarked fish were injected intraperitoneally with PIT tags.

Female chub were tested for ripeness by applying pressure along their flanks (Ingram 1985). Females that did not readily express eggs were injected with 4 mg/kg body weight of acetone-dried carp pituitary (10 mg/cc) decanted from previously prepared solution in sterile water held in an ice chest. Males not expressing sperm were also injected in the same manner. Unripe females were injected daily for up to 3 d (Hamman 1982, Marsh 1985).

When ripe, ova from one female and milt from two or three males were stripped manually into a plastic bowl at a shaded spawning table. The area around the vent was dried with clean paper towels to prevent contamination by blood, skin mucus, or water (Piper et al. 1982). The egg/sperm mixture was stirred continuously with a clean feather for 10 min. Sperm diluent (pH stabilizer) and bentonite (egg clumping preventative) were not utilized, as they were suspected agents in previous field culture failures. Eggs were then poured into an egg basket constructed of 500 μm mesh nylon screen attached to a flotation frame in a cooler of desilted LCR water for water hardening (1-2 h). After spawning, fish were returned to the LCR near the point of capture.

After water hardening, eggs (on their flotation screens) were transferred to 19 L buckets (containing desilted LCR water) floating in the LCR by means of a styrofoam collar. Battery powered aerators provided necessary turbulence as well as oxygen to the eggs. The incubation buckets were shaded with a styrofoam lid.

A small lot of eggs was incubated in an instream hatching box set up in an area of low velocity in the LCR. This apparatus was comprised of a PVC pipe frame, sealed for flotation, and surrounded with 500 μm mesh nylon screen and a styrofoam lid. A Heath tray was suspended inside to hold the eggs, inclined 30° into the current to provide aeration (Hamman 1982).

Temperature, conductivity, dissolved oxygen and pH in the LCR during the field spawning procedures were monitored hourly with a Hydrolab Surveyor 3 data logger and H20 sonde. Turbidity was measured periodically with a Baush and Lomb Spectronic Mini-20 nephelometer. Water quality within hatching buckets was also measured periodically with these instruments.

After 1-3 d of onsite incubation, eggs were airlifted by helicopter to Bubbling Ponds Hatchery. They were double-bagged in 4 mil plastic bags filled 1/3 with desilted LCR water and 2/3 pure oxygen, and crated in insulated styrofoam egg shipping containers.

Upon arrival at Bubbling Ponds, bags of eggs were placed in Bubbling Ponds water for temperature and chemical acclimation. Ten per cent of the LCR water volume was exchanged with Bubbling Ponds water every ten minutes for 90 minutes. The eggs (still adhered to the nylon screens) were then transferred to Heath tray incubators. Water flow rates in the Heath tray apparatus was adjusted to preclude movement of eggs. Eggs were treated with 1,667 ppm formalin in a 15 min drip daily for control of aquatic fungi (*Saprolengiales*) (Schreck and Fitzpatrick, 1991).

Heath trays were checked 4 times daily for larvae. Larvae were removed with a pipette and placed in shallow troughs of through-flowing 18.6°C water until swimup. Larval baskets were placed under each Heath rack at the outflow to catch any larvae otherwise missed (Dupree and Huner 1984).

Zooplankton collected from hatchery ponds, *Artemia salina* larvae hatched from cysts, and Bio-Kyowa B-250 were fed to larvae approaching first-feeding stage. Later (in 2-4 weeks), larvae were fed a diet of commercial trout feed of progressively larger sizes as needed.

Temperature Experiments

Eighteen 10 gal aquaria were individually supplied with recirculating Bubbling Ponds water inside a temperature-controlled room. Two Aquanetics 1/4 hp chiller system packs (Model No. CSP-3) were individually connected to each of 2 sets of six aquaria. The third set of six aquaria were supplied with ambient 20°C recirculated water. The chiller system packs were equipped with mechanical, biological, and chemical filters, and 1,900 lph pumps. A separate, identical pump and filter system handled the 20°C set of tanks. A 14:10 h light-dark photoperiod, approximating the springtime day length, was provided with illumination from wide spectrum fluorescent lights.

In an attempt to simulate conditions experienced by fishes entering the Colorado River mainstem from the LCR, thermal shock experiments were conducted on 5-7 d old (swimup stage) and 11-13 d humpback chub larvae. Water temperature was first gradually increased from 18.6°C (incubation temperature) to 20°C, and larvae were allowed to acclimate for a minimum of 24 h. Three replicates of 20 fish each were then transferred separately to tanks at 10°C, 12°C, and 14°C ±0.5°C. Three replicate control groups were handled in like manner but transferred to 20 ±0.5°C tanks. Fish were observed for 4 h under each treatment.

Tolerance of humpback chub and Colorado squawfish to temperatures approximating those of the Colorado River in Grand Canyon was examined by comparing growth rates among treatment and control temperatures. Following incubation at 18.6°C and acclimation to 20°C after swimup, fishes were transferred to aquaria maintained at 10.0°C, 14.0°C, and 20.0°C ±0.5°C. Experimental groups consisted of: 1) 6-8 d humpback chub reared for 30 d; 2) 13-15 d humpback chub reared for 24 d; 3) 39-41 d humpback chub reared for 93 d, and; 4) 13-15 d Colorado squawfish reared for 92 d. Two aquaria of 56 individuals each were maintained for each temperature for groups 1 and 2, three aquaria of 10 individuals were maintained for each temperature for group 3, and three aquaria of 50 individuals were maintained for each temperature for group 4.

All larval fish were fed Bio-kyowa B-250, *Artemia salina*, and zooplankton *ad libitum* at 0600, 0900, 1200, 1500, and 1700 hrs. Older fish were fed commercial trout feed. Waste feed and excrement were siphoned from all tank bottoms every other day. Dissolved oxygen was monitored daily with a YSI meter and maintained at 90-100% saturation. Ammonia (NH_3-N), Nitrite (NO_2-N) and Nitrate (NO_3-N) nitrogen were monitored with Chemetrics titration kits to assess the effectiveness of the chemical (zeolite) and biological filters. Adjustments were made to maintain ammonia at <0.1 ppm, nitrite <0.1 ppm, and nitrate <4 ppm. pH was maintained at 8-9.

Approximately every 7 d, study individuals from groups 1 and 2 were anesthetized in a solution of 125 ppm MS-222, placed on blotter paper for 5 s, and weighed to the nearest 0.0001 g on a Mettler H80 balance. Total lengths were determined to the nearest 0.1 mm with a micro grid. Group 3 fish lengths and weights were measured at 14 d intervals with a micro grid and an OHaus CT200 electronic balance (to ±0.01 g). Five fish were sacrificed from each aquarium from group 4 fish every 15 d for length (as above) and weight (±0.0001 g) measurements.

Treatment of the protozoan parasite *Ichthyobodo necatrix* (costiasis) was with formalin at 25 ppm for 24 h, followed by Chloramine T the next day at 9 ppm for 1 h. Prophylactic treatments to older fishes (groups 3 and 4) were made every 7 d by adding 2 ppm 5% methylene blue solution. Nine ppm Chloramine T was added every 30 d, and flushed after 1 h.

RESULTS

Spawning and Incubation

A total of 75 humpback chub >200 mm TL (32 females, 43 males) was captured and held in live cars for spawning and propagation efforts on the LCR from 26 April-7 May, 1993. Twenty-eight females >250 mm were injected intraperitoneally with carp pituitary on 1-3 consecutive days, and 11 males were similarly treated. One female that was ripe at the time of capture was stripped of approximately 200 eggs and released. Three additional females 250 mm or less in length were released without injection. Thirty-two males were ripe at the time of capture. No mortalities were observed resulting from the propagation procedures.

Approximately 2,800 eggs were manually stripped from 10 hormone-injected females; four females expressed eggs on two consecutive days. Since bentonite was not added to the egg/sperm mixture, eggs were adhesive to each other and to screens of the hatching trays, preventing precise determination of numbers. Siltation on eggs in the instream hatching box (~200 eggs) was excessive and the apparatus was discontinued after the first trial. Egg development within aerated 19 L buckets with desilted LCR water appeared normal.

Turbidity of the LCR on 26 April was 282 NTU, and slowly declined to 89 NTU by 7 May. Turbidity within hatching buckets of desilted LCR water was 12 NTU. Maximum temperature of the LCR during this period was 20.4°C and the minimum was 17.0°C. Temperatures in hatching buckets fluctuated approximately 1°C greater in both directions than those in the LCR. Dissolved oxygen in the LCR ranged between 6.3 and 8.2 mg/l and 76.5-97.6% saturation; full saturation was maintained within aerated hatching buckets. Conductivity in the river increased from near 2800 μS on April 26 to 3800 μS on May 7, with similar levels maintained in buckets. pH fluctuated between 7.7-8.2 in the LCR, with hatching bucket values similar.

At Bubbling Ponds Hatchery following transport from the LCR, approximately 500 eggs appeared damaged or broken. The approximately 200 eggs that were covered with silt succumbed, 1,000 others were killed by fungus, and 1,100 hatched. Hatching took place on day 6 (25%), day 7 (50%), and was completed 8 d post-fertilization. Temperature, pH, and conductivity of incubation water were nearly constant at 18.6°C, 7.6, and 365 μS, respectively. Dissolved oxygen levels fluctuated between 4.3 and 7.3 mg/l.

Temperature Experiments

All 5-7 d humpback chub larvae transferred from 20°C to 10°C immediately entered "cold coma", a condition characterized by an inability to maintain equilibrium and position in the water column. Fish drifted in the current until settling to the bottom of the tank. They remained immobile for approximately 90 min. Over the next 60 min they regained their ability to swim in the water column but appeared lethargic compared to the control groups at 20°C. Observations of heart rate in these fish indicated that rates slowed from 100-120 beats/min at 20°C to 30-40 beats/min at 10°C. Larvae transferred from 20°C to 12°C became lethargic but did not lose their ability to remain in the water column. No behavioral effects were noted for 5-7 d larvae transferred from 20°C to 14°C.

Eleven to thirteen day old humpback chub larvae transferred from 20°C to 10°C also entered cold coma, but regained normal behavior after 15 min. All other temperature treatment groups at this age exhibited no obvious adverse behavioral effects. No mortalities for either age group occurred during the 4 h observation periods.

Replicate groups of 6-8 d humpback chub larvae transferred from 20°C to 10°C for determination of growth effects gained 10% in length and 28% in weight over 30 d (Table 1, Figure 1). These values compared to 37% and 195% length and weight gains over 30 d at 14°C, and 83% and 951%, respectively, at 20°C. Weight gains failed to keep pace with increases in length at 10°C, and fish appeared emaciated. Based on nonoverlap of 95%

confidence intervals (Figure 1), the differences in length and weight after 30 d were significantly different among all combinations of the three temperatures.

Similar experiments with 13-15 d humpback chub larvae produced like results, although differences in length and weight at 10°C and 14°C were not significant (Table 1, Figure 2). These results suggest that growth rates of older fish were less affected by the coldest temperature.

Tolerance experiments with 39-41 d humpback chub demonstrated that temperature effects on growth were significant to juvenile life stages as well (Table 1, Figure 3). Mean length at 20°C was twice the mean length at 10°C after 93 d, and 1.3 times the mean length at 14°C. Mean weight at 20°C was nearly eight times greater than at 10°C, and more than twice the weight at 14°C. These growth trends were also evident with Colorado squawfish based on 92 d temperature treatments on 14 d larvae (Table 2, Figure 4). Final length at 20°C was three times greater than at 10°C, and twice as great at 14°C, while weight gains at 20°C were 42 times greater than final weight at 10°C, and 5.7 times greater than 14°C. The relatively static growth between day 42 and day 59 (Figure 4) was a result of an outbreak of costiasis. Black and Bulkley (1985) reported that length and weight gains of yearling Colorado squawfish over 84 d were approximately three times greater at 20°C than at 15°C.

DISCUSSION

As earlier stated, we failed in previous attempts to propagate eggs from humpback chub in the field. We are unable to definitively determine reasons for previous failures based on comparisons with successful procedures utilized in 1993, but we suspect that use of commercial bentonite clay (to prevent clumping of eggs following fertilization) in earlier efforts was a possible factor. Complex adsorption interactions between differently charged clay particle types (i.e. bentonite and LCR clays) on the surfaces of eggs may have interfered with the fertilization process or oxygen uptake by eggs. Low suspended sediment loads (i.e. clay) typical of hatchery waters presumably allows successful use of bentonite in fish culture facilities. Because of the low number of eggs collected in 1993, we were unable to compare propagation results with and without bentonite treatments. This potential avenue of failure requires additional investigation. We consider other differences in methods among trials minor, and insufficient to account for total failures of early attempts.

Although similar numbers of fish were handled, approximately an order of magnitude fewer eggs were obtained in 1993 compared with 1992 field propagation efforts (Hines 1993, Clarkson and Robinson 1993). This illustrates the tremendous logistical difficulties involved with field propagation efforts at remote sites such as the LCR, especially with experimental procedures on endangered fishes. Annual variability of water discharge, water temperature, fish catchability, and reproductive condition of fishes combine to render such operations unreliable and expensive. We recommend that further attempts at field propagation of Grand Canyon native fishes be abandoned in favor of hatchery culture, except for experimental purposes. A genetic breeding program could then be generated, culture methods further refined, and prophylactic treatments and schedules developed. Progeny from hatchery brood stock can then be dependably available for experimental purposes or for reintroductions, and adults can serve as refugia individuals in the event of catastrophe in the wild.

Our experimental study design attempted to simulate temperature conditions experienced by native fishes within the Grand Canyon riverine system. Spawning and early development of native fishes occurs in the LCR and other warmwater Grand Canyon tributaries at temperatures near 20°C. At various stages within their life histories, fish may enter the mainstem Colorado River, where temperatures typically are 10-12°C. It is likely that some individuals of some species enter the mainstem as larvae through entrainment or active drift (Angradi et al. 1992), while others are flushed during summer floods as early juveniles (AGFD 1993, Hendrickson 1993). Mixing between warm tributary water and cold mainstem water may occur for some distance downstream, which we attempted to approximate with our experimental 14°C temperature.

Assuming no temperature amelioration through mixing of tributary and mainstem waters, our results indicate that 5-7 d and 13-15 d larval humpback chub that enter the mainstem Colorado River at temperatures near 10°C from the LCR will immediately enter cold shock for 15-90 min. Similar cold shock experiments conducted on 14 d Colorado squawfish by Berry (1986) indicated that mortality and cold coma occurred with temperature changes from 22°C to 7°C over 5 min, and that some cold coma occurred, activity levels were reduced, and other behavioral modifications noted with changes from 22°C to 12°C. Our experiments on 5-7 d humpback chub larvae moved from 20°C to 12°C also noted behavioral differences (lethargy) compared to controls, but no effects were noted with older larvae at 12°C, nor with any group at 14°C. Several researchers determined that temperature effects were lessened with slower rates of temperature change (Speakman and Kenkel 1972, Griffith 1978, Burton et al. 1979, Berry 1986) and with older fish (Pitkow 1960, Nickum 1966, Berry 1986).

The effects of entering cold shock in the Colorado River are potentially severe. Rates of predation may be increased (Coutant et al. 1974), physical damage and death may occur from abrasion against the substrate or entrainment in extreme current velocities and turbulence, or fish may be buried if they settle on the substrate. Muscle performance is likely reduced (Webb 1993).

Juveniles that enter the mainstem, and larvae that survive the immediate effects of cold coma or do not experience cold coma, are subject to greatly reduced growth rates. It is likely that growth rates in the wild (Colorado River) are even poorer than our results suggest when competition and other environmental stresses are considered. Effects of reduced growth rates include increased early-life mortality and decreased survival to sexual maturity (Kaeding and Osmundson 1988), reduced condition, lipid stores, and size that result in elevated overwinter mortality for young-of-year fishes (Thompson et al. 1991), lowered egg production by adults (McAda and Wydoski 1983), and other less studied effects (Kaeding et al. 1986).

These findings indicate that benefits are accrued to individual fish and populations by remaining in Colorado River warmwater tributaries as long as possible. We recommend that the historic pattern of high springtime discharges in the Colorado River be simulated through releases from Glen Canyon Dam. This flow pattern will impound tributary mouths and form slow velocity, warm, and productive refugia for rearing of early life stage, tributary-spawned native fishes, and potentially reduce losses to the mainstem. In addition, we advise a reduction in fluctuations of daily flows in the Colorado River to allow greater warming of backwaters and potentially other low velocity mainstem native fish rearing areas. Finally, we advocate that thermal modification of dam releases be considered to reduce detrimental effects of low temperatures on native fishes in Grand Canyon.

TABLE 1. Initial (day 0) and final length-weight statistics of pooled replicate data for temperature tolerance experiments with variable aged humpback chub reared at three different temperatures.

Initial age: 6-8 d post-hatching

			Length			Weight		
Day	°C	n	Mean	SD	Range	Mean	SD	Range
0	20	20	9.5	0.3	9.3-9.8	3.9	0.5	3.5-4.5
30	10	10	10.5	0.4	10.0-11.0	5.0	0.7	3.6-6.0
30	14	21	13.0	0.6	12.0-14.0	11.5	3.1	8.0-16.0
30	20	13	17.4	1.8	15.0-21.0	41.0	14.0	23.0-73.8
Initial age: 13-15 d post-hatching								
0	20	20	11.2	0.6	11.0-12.0	5.0	0.7	4.5-6.0
24	10	60	14.1	0.8	11.0-15.0	18.4	4.2	6.5-24.9
24	14	30	14.3	3.7	13.5-17.6	20.9	4.6	13.5-27.4
24	20	30	19.7	1.1	18.0-22.0	57.2	13.8	36.0-84.4
Initial age: 39-41 d post-hatching								
0	20	15	20.9	1.4	19-23	84.8	22.5	54-126
93	10	24	26.0	1.7	24-29	145.4	27.8	100-200
93	14	28	34.8	1.7	32-38	327.5	44.8	260-410
93	20	25	51.9	4.3	46-60	1136.0	216.5	850-1510

TABLE 2. Initial (day 0) and final length-weight statistics of pooled replicate data for temperature tolerance experiments with 13-15 d post-hatching Colorado squawfish reared at three different temperatures.

			Length			Weight		
Day	°C	n	Mean	SD	Range	Mean	SD	Range
0	20	10	10.0	0.5	9.0-11.0	4.5	0.4	4.1-4.9
92	10	21	11.7	0.6	11.0-13.0	7.7	1.0	5.0-8.9
92	14	30	20.0	0.4	19.5-21.0	44.1	4.3	36.6-53.5
92	20	25	36.3	2.4	32.0-40.0	329.3	69.4	170.0-440.0

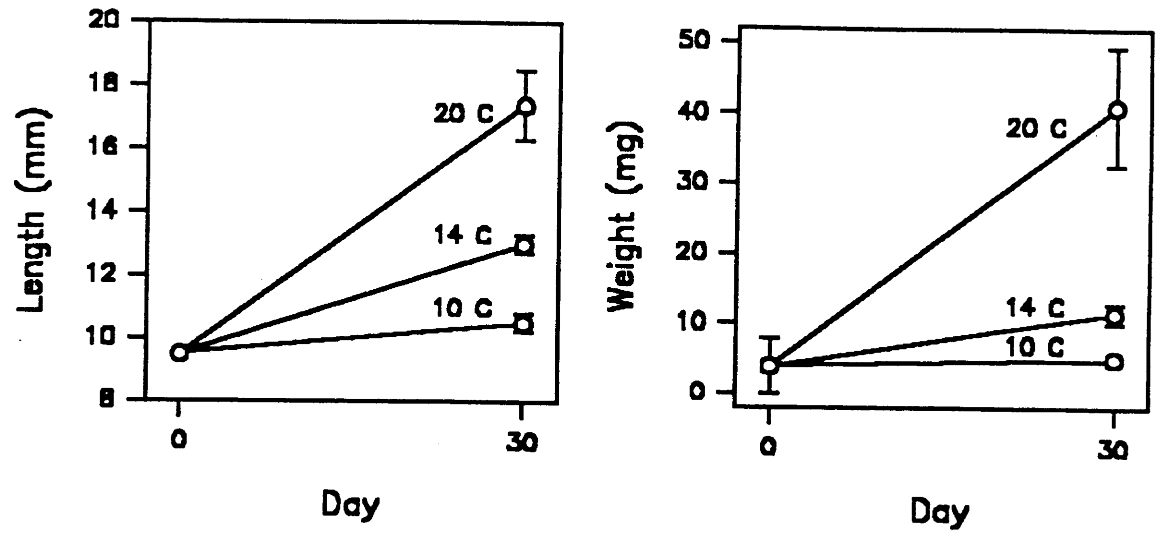

FIGURE 1. Initial and 30 d lengths and weights of humpback chub transferred from 20°C tanks as 6-8 d old larvae to 10°C, 14°C, and 20°C (control) tanks. Circles represent means and vertical bars represent 95% confidence limits of pooled replicate data.

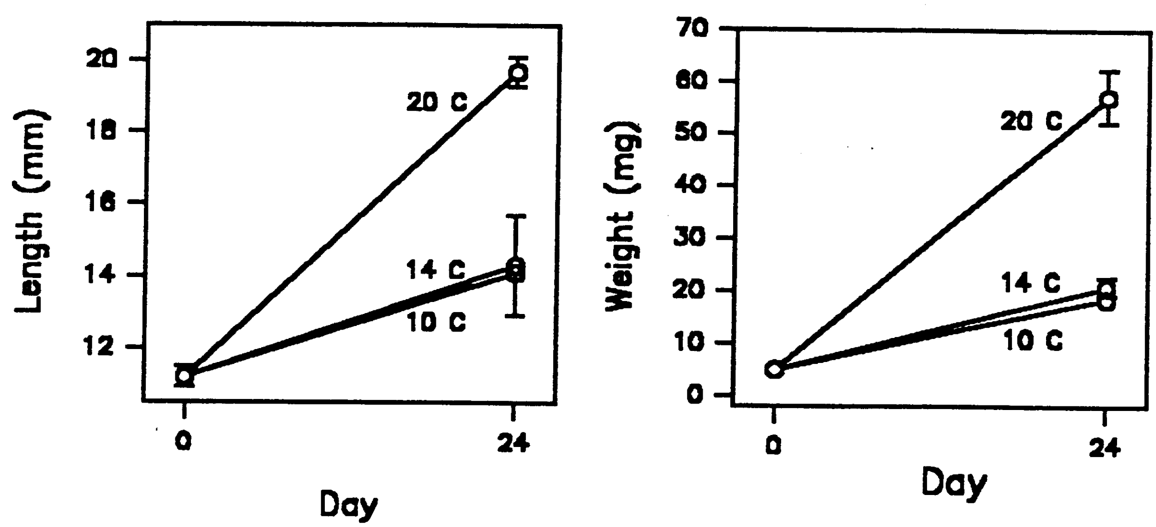

FIGURE 2. Initial and 24 d lengths and weights of humpback chub transferred from 20°C tanks as 13-15 d old larvae to 10°C, 14°C, and 20°C (control) tanks. Circles represent means and vertical bars represent 95% confidence limits of pooled replicate data.

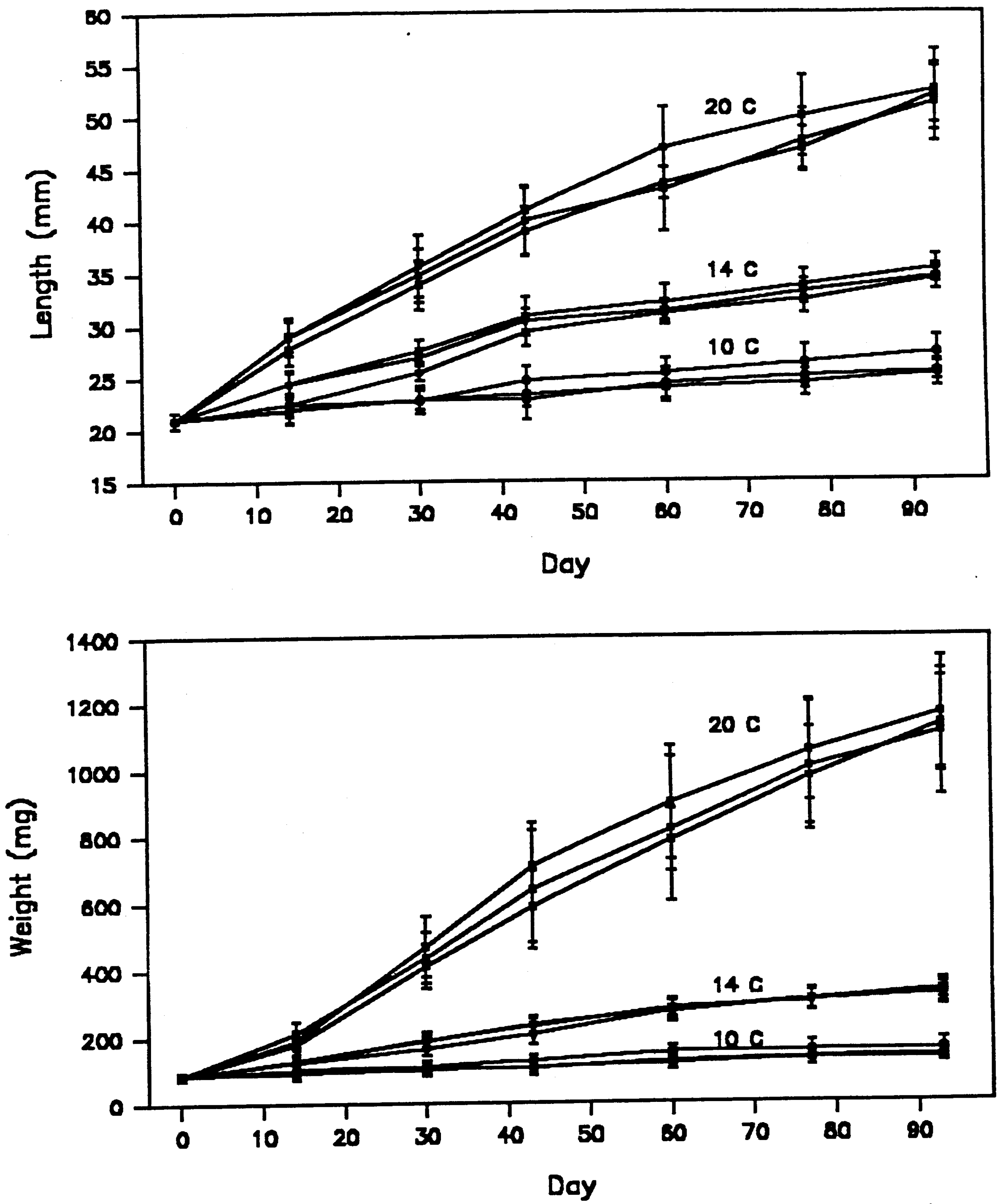

FIGURE 3. Mean lengths and weights of replicate groups of humpback chub transferred from 20°C tanks as 39-41 d old juveniles to 10°C (circles), 14°C (triangles), and 20°C (squares; control) tanks over 93 d. Vertical bars represent 95% confidence limits.

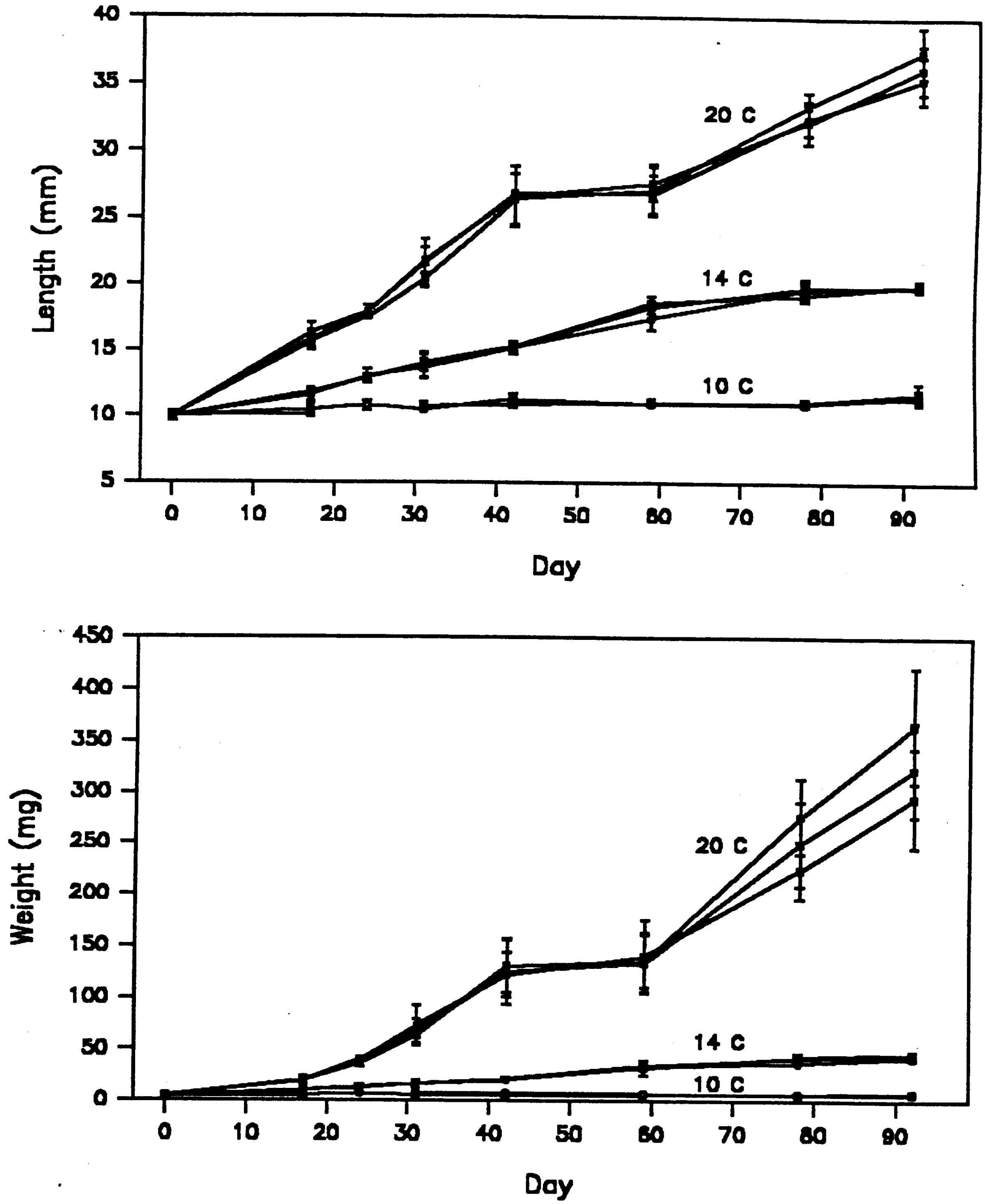

FIGURE 4. Mean lengths and weights of replicate groups of Colorado squawfish transferred from 20°C tanks as 14 d old larvae to 10°C (circles), 14°C (triangles), and 20°C (squares; control) tanks over 92 d. Vertical bars represent 95% confidence limits.

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