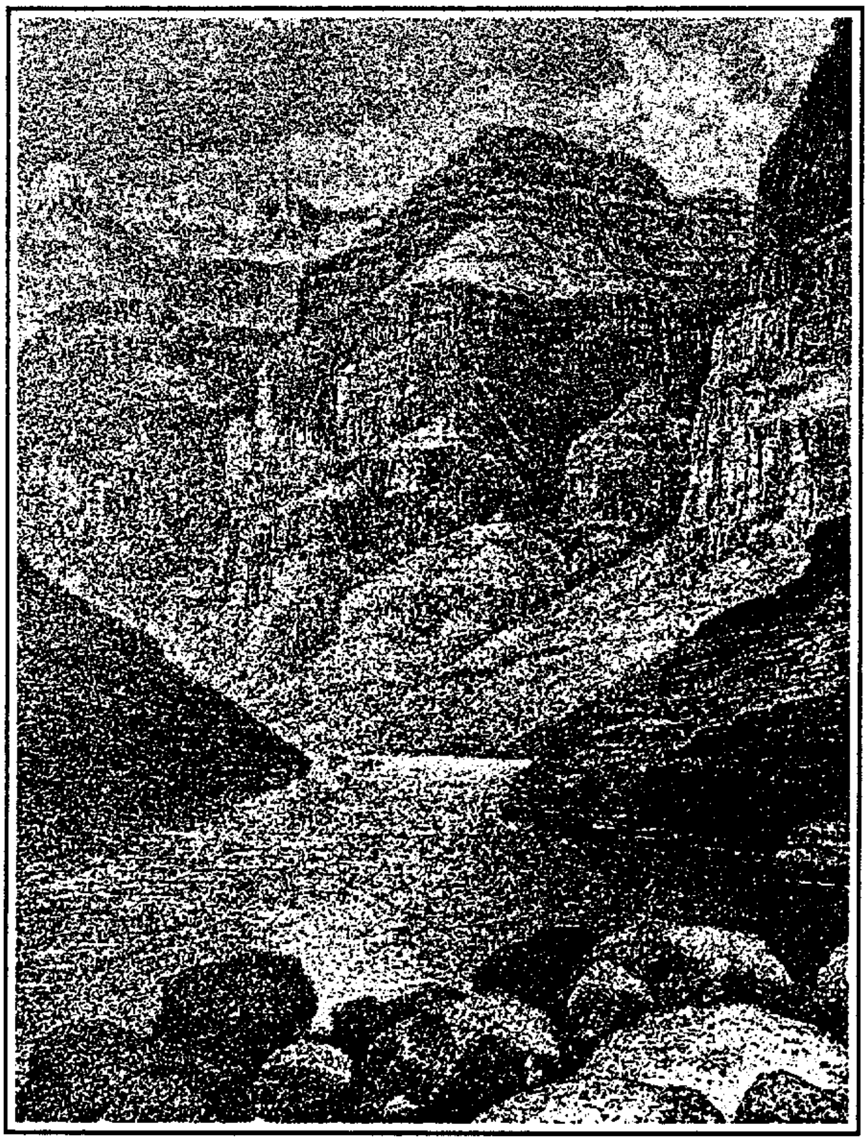
Life History and Ecology of the Humpback Chub (Gila cypha) in the Colorado River, Grand Canyon, Arizona

Supplement No. I:
Data Collection Plan



Bureau of Reclamation

BIO/WEST, Inc.

Glen Canyon Environmental Studies

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

GLEN CANYON ENVIRONMENTAL STUDIES

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Life History and Ecology of the Humpback Chub (*Gila cypha*) in the Colorado River, Grand Canyon, Arizona

Supplement No. I
Data Collection Plan

Richard A. Valdez
Lydia (Penny) Trinca

BIO/WEST, Inc.
1063 West 1400 North
Logan, UT 84321

Bureau of Reclamation
Upper Colorado River Region
Salt Lake City, UT 84147

Glen Canyon Environmental Studies
121 East Birch
Flagstaff, AZ 86002

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DATA COLLECTION PLAN

INTRODUCTION

This Data Collection Plan (Plan) was developed by BIO/WEST, Inc. (B/W) to provide a documentation of methodologies used to investigate the endangered humpback chub (Gila cypha) in the mainstem Colorado River, Grand Canyon, Arizona. This Plan replaces a preliminary Data Collection Plan (BIO/WEST Report No. TR-250-01) developed in January 1991, as part of the requirements of Bureau of Reclamation (Reclamation) Contract No. 0-CS-40-09110. This plan is one of six supplements to the final report entitled Characterization Of The Life History And Ecology Of The Humpback Chub (Gila Cypha) In The Colorado River, Grand Canyon, Arizona.

This Plan was developed in conjunction with Reclamation and Glen Canyon Environmental Studies (GCES). It was provided to all members of the B/W staff, as well as to the Aquatic Coordination Team (ACT), Arizona Game and Fish Department (AGF), U.S. Fish and Wildlife Service (Service), Arizona State University (ASU), Grand Canyon National Park, the Hopi Tribe, the Navajo Nation, and the Hualapai Tribe.

Description

This Plan describes the study area, study design, and methods for fish sampling, fish handling, radiotelemetry, habitat assessment, invertebrate drift, hydrology, water quality, and data management. Complete sets of data forms and data codes are included as appendices to provide details on data collection methods.

This Plan was designed for use as a scientific reference. It was developed primarily for fishery investigators in Grand Canyon to understand the approach and methods used by B/W. Administrators and other interested parties may also find this document helpful in understanding field methods and techniques employed by scientific investigators in Grand Canyon. A companion document, Supplement No. II: Evaluation of Sampling Design evaluates the sampling methods and fish injury.

Purpose and Objectives

The purpose of the investigation, as stated in the project contract, was to:

> "*Evaluate the ecological and limiting factors of all life stages of humpback chub in the mainstem Colorado River, Grand Canyon, and the effects of Glen Canyon Dam operations.*"

This investigation was designed to facilitate coordination and integration with other studies, describe physical, chemical, and biological components of the aquatic ecosystem in Grand Canyon; and to provide an understanding of principal factors that limit the endangered humpback chub. By itself, this investigation addressed only certain aspects of these components, and shared roles and responsibilities with other investigators. The specific study objectives for B/W were to determine the following factors for humpback chub in the mainstem Colorado River in Grand Canyon:

1. Distribution, abundance, and movement,
2. Survivorship of early life stages,
3. Reproductive capacity and success,
4. Resource use and availability (i.e., habitat, food),

5. Important biotic interactions with other species for all life stages, and
6. The life history schedule.

These objectives were developed by Reclamation to address Conservation Measures 5 and 7 of the Service's Biological Opinion on the operation of Glen Canyon Dam.

STUDY AREA

This investigation was conducted in a 364-km (226-mi) area of the Colorado River in Grand Canyon, from Lees Ferry (RM 0) to Diamond Creek (RM 226) (Fig. 1). The study area was divided into four study regions and 11 geomorphic reaches in order to approximate a uniform distribution of sampling. The four study regions included: (1) Region 0--Lees Ferry to Kwagunt Rapid (RM 0-56.0), (2) Region I--Kwagunt Rapid to Hance Rapid (RM 56.0-76.6), (3) Region II--Hance Rapid to below Havasu Creek (RM 76.6-160.0), and (4) Region III--below Havasu Creek to Diamond Creek (RM 160.0-226.0). Regions I, II, and III, were sampled from October 1990 through November 1993. Region 0 was sampled from January through November 1993 and extended the investigation upstream. A fifth region--Region IV (Diamond Creek to Pearce Ferry, RM 280)--was investigated by B/W as part of an aquatic resources study for the Hualapai Indian Tribe and GCES (Valdez 1993, 1994, 1995).

Reference landmarks along the river corridor were located to the nearest tenth (0.1) of a river mile (i.e., distance downstream from Lees Ferry along the center of the river) according to Belknap and Evans (1989), and sample sites were entered in a database to the nearest twentieth (0.05) of a river mile, where possible. It should be noted that Lees Ferry is 15.8 river miles downstream of Glen Canyon Dam, and river miles cited in this report are in reference to Lees Ferry and not Glen Canyon Dam.

STUDY DESIGN

Project Schedule

This study was initiated in September 1990 and was completed in September 1995 (Fig. 2). Project workshops were held in December of 1990, 1991, 1992, 1993, and 1994 to provide ongoing staff coordination, identify and resolve problems, update data collection status, and provide progress reports to Reclamation and GCES.

Field Trips

A total of 36 monthly field trips were conducted on the Colorado River in Grand Canyon, from Lees Ferry (RM 0) to Diamond Creek (RM 226), starting in October 1990 and ending in November 1993 (Fig. 2). Trips were conducted monthly, except for December 1991 and 1992. From October 1990 through November 1992, trip length alternated between 12 and 20 days, resulting in five 12-day trips each in 1991 and 1992 (February, April, June, August, October) and six 20-day trips (January, March, May, July, September, November). The schedule was modified in 1993 to include eight 16-day trips (January, February, March, April, June, August, October, November), and three 20-day trips (May, July, September). Launch dates and sampling locations were coordinated with AGF, when possible, to provide concurrent sampling and comparable data.

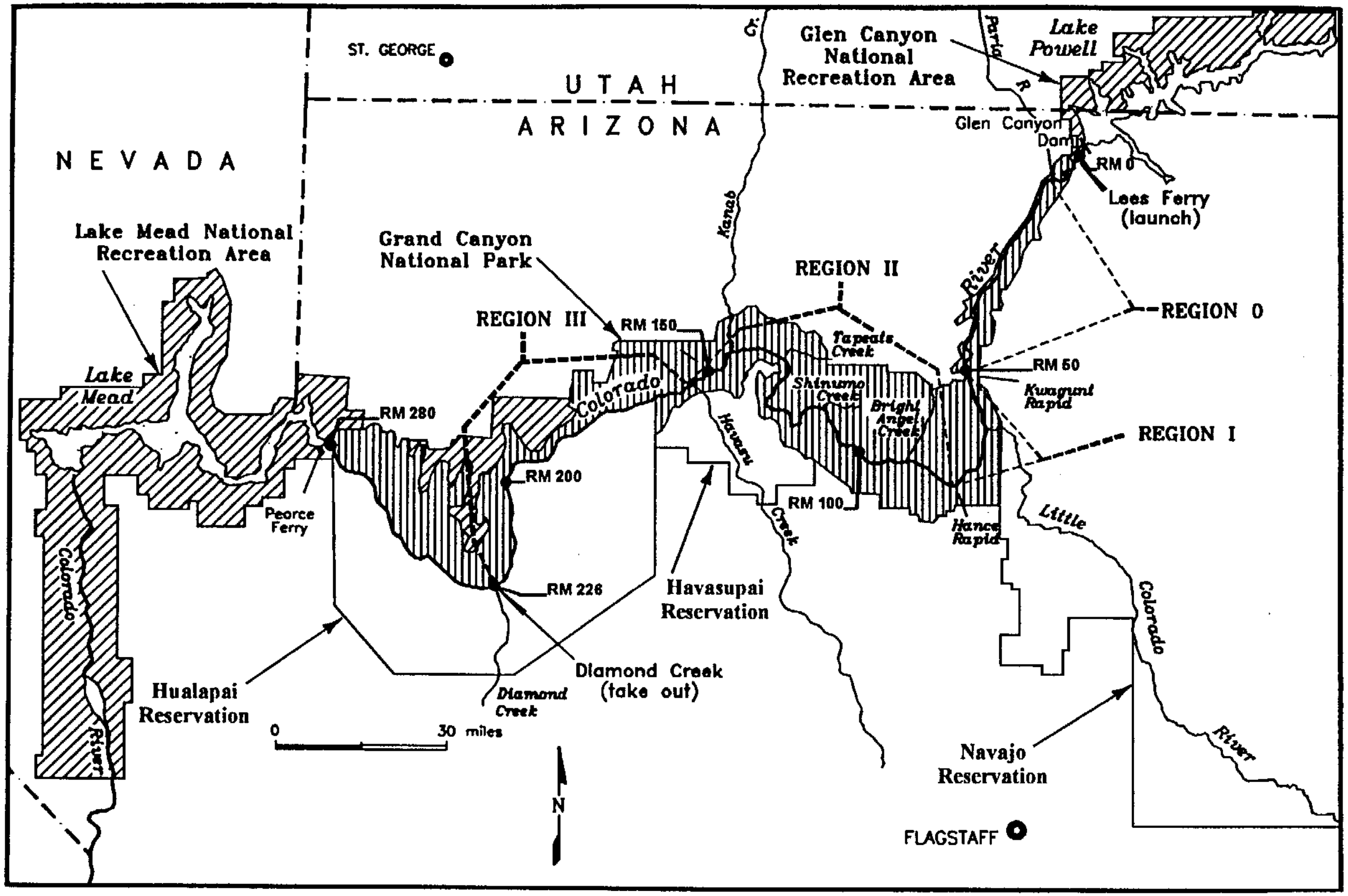

Fig. 1. BIO/WEST study area in Grand Canyon and four sample regions.

Tasks or Products	1990				1991												1992												1993												1994												1995								
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
Project Workshops				●												●												●												●												●									
Data Collection Plan				●													●												●												●									●										●	
12- Day Trips		○		○		○		○		○		○		○				○		○		○		○		○																																			
20- Day Trips			○		○		○		○		○		○		○		○		○		○		○		○		○						○		○		○																								
Special 18-Day Trip																																															○														
16- Day Trips																													○	○	○	○		○		○		○	○																						
Trip Reports		●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●								●														
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FINAL REPORT																																																													
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Final Report																																																													●

● Deliverable or Event
○ Field Trips

Fig. 2. BIO/WEST project schedule.

Twenty-day trips were conducted to assess composition and distribution of fish, monitor habitat availability and use, determine important biotic interactions between humpback chub and other fish species, and capture humpback chub for implanting radio transmitters. These trips included two field crews, one with six B/W and one ACT biologists sampling Region I, and one with four B/W and one ACT biologists sampling concurrently in Region II. The two crews jointly sampled Region III during the last 5 days of the trip, so that each of the three study regions was sampled with equal effort of about 10 team-days.

Field crews were established for each trip under the leadership of Project Leaders. Project Leaders were directly responsible to the Project Principal Investigator.

Twelve-day trips were conducted primarily to recontact previously radio-tagged adult humpback chub and monitor their movement and habitat use in Region I. These trips involved one field crew with six B/W and two ACT biologists. Fish were usually equipped with radio transmitters during 20-day trips, and tracked and monitored during 12-day trips from October 1990 through November 1992.

Sixteen-day trips were conducted from January through November 1993, when radiotelemetry was discontinued in Region I, and implemented in Region II, and when Region 0 was added to the sample area. The 16-day schedule allowed crews to allocate more time to radio tracking fish in Region II, while maintaining sampling frequency and intensity throughout the study area. The number of crews on 16-day trips alternated between one crew (February, April, June, August, October) and two crews (January, March, May, July, September, November), with number of personnel as described for 12-day and 20-day trips, respectively.

Reports

Trip reports were completed and submitted within 10 days of the completion of each of the 36 field trips and annual reports were completed at the end of 1990, 1991, and 1992. These reports were submitted to Reclamation and GCES, and distributed to cooperating agencies and interested individuals.

Sampling Design

A stratified random sampling design was implemented to approximate uniform spatial and temporal sampling of fish assemblages and associated physical, chemical, and biological components (Schreck and Moyle 1990). The four study regions (0-III) were longitudinally divided into 11 geomorphic reaches (Schmidt and Graf 1990), each with approximately uniform channel and shoreline characteristics. The 11 geomorphic reaches were subdivided into 34 sample strata that ranged from 3.2 to 19.5 km (2.0 to 12.1 mi) in length (Table 1). These strata were the base spatial sampling units, and were considered representative of the geomorphic reaches in which they occurred (Fig. 3). The five major tributary inflows in Region II (i.e., Bright Angel Creek, Shinumo Creek, Tapeats Creek, Kanab Creek, and Havasu Creek) were treated as individual stratum to be selected and sampled at least once seasonally in order to insure adequate temporal characterization of areas where fishes aggregated seasonally. Eight to 16 strata were randomly selected for sampling during each monthly trip. Selected strata were not eliminated from consideration for selection on subsequent trips.

Table 1. Lengths of sample strata within the 11 geomorphic reaches.

Study Region	Geomorphic Reach	Sample Strata	River Miles	Length km(mi)
0	1 - Permian Section	a. Paria - Badger Creek	1.0-8.0	11 .3 (7.0)
		b. Badger Creek - Soap Creek	8.0-11.3	5.3 (3.3)
	2 - Supai Gorge	c. Soap Creek - Sheer Wall	11.3-14.5	5.1 (3.2)
		d. Sheer Wall - House Rock	14.5-17.0	4.0 (2.5)
		e. House Rock - North Canyon	17.0-22.6	9.0 (5.6)
	3 - Redwall Gorge	f. North Canyon - Tiger Wash	22.6-26.5	6.3 (3.9)
		g. Tiger Wash - Vasey's	26.5-35.9	15.1 (9.4)
	4 - Lower Marble Canyon	h. Vasey's - President Harding Rapid	35.9-43.7	12.6 (7.8)
		I. President Harding Rapid - Nankoweep	43.7-52.0	13.4 (8.3)
		j. Nankoweep - Kwagunt	52.0-56.0	6.4 (4.0)
I	4 - Lower Marble Canyon	a. Kwagunt - LCR	56.0-61.5	8.9 (5.5)
	5 - Furnace Flats	b. LCR - Chuar Rapid	61.5-65.5	6.4 (4.0)
		c. Chuar Rapid - Unkar Rapid	65.5-72.5	11.3 (7.0)
		d. Unkar Rapid - RM 77.4	72.5-77.4	7.9 (4.9)
II	6 - Upper Granite Gorge	a. Hance Rapid - Cremation Canyon	77.4-86.5	14.6 (9.1)
		b*. Bright Angel Creek	86.5-89.0	4.0 (2.5)
		c. Pipe Creek - Crystal Rapid	89.0-98.0	14.5 (9.0)
		d. Crystal Rapid - Bass Rapid	98.0-107.8	15.8 (9.8)
		e*. Shinumo Creek	107.8-109.8	3.2 (2.0)
		f. 110-mile Rapid - RM 117.8	109.8-117.8	12.9 (8.0)
	7 - Aisles	g. Aisles	117.8-125.5	12.4 (7.7)
	8 - Middle Granite Gorge	h. RM 125.5 - Dubendorf SSR	125.5-131.7	9.8 (6.2)
		i*. Tapeats Creek	131.7-134.5	4.5 (2.8)
		j. 134 Mile Rapid - RM 140.0	134.5-139.9	8.7 (5.4)
	9 - Muav Gorge	k*. Kanab Creek	139.9-143.8	6.3 (3.9)
		l. Kanab Rapid - Sinyala Rapid	143.8-153.5	15.6 (9.7)
		m*. Havasu Creek	153.5-159.9	10.3 (6.4)
III	10 - Lower Canyon	a. RM 160 - RM 169.9	159.9-169.9	15.8 (9.8)
		b. RM 169.9 - Lava Falls	169.9-179.4	15.3 (9.5)
		c. Lava Falls - RM 189.1	179.4-189.1	15.6 (9.7)
		d. RM 189.1 - RM 200.0	189.1-200.0	17.5 (10.9)
		e. RM 200.0 - 209-Mile Rapid	200.0-208.9	14.3 (8.9)
		f. 209-Mile Rapid - 214 Mile Cr	208.9-213.9	8.0 (5.0)
	11 - Lower Granite Gorge	g. 214-Mile Cr - Diamond Creek	213.9-226.0	19.6 (12.1)

*Tributary strata

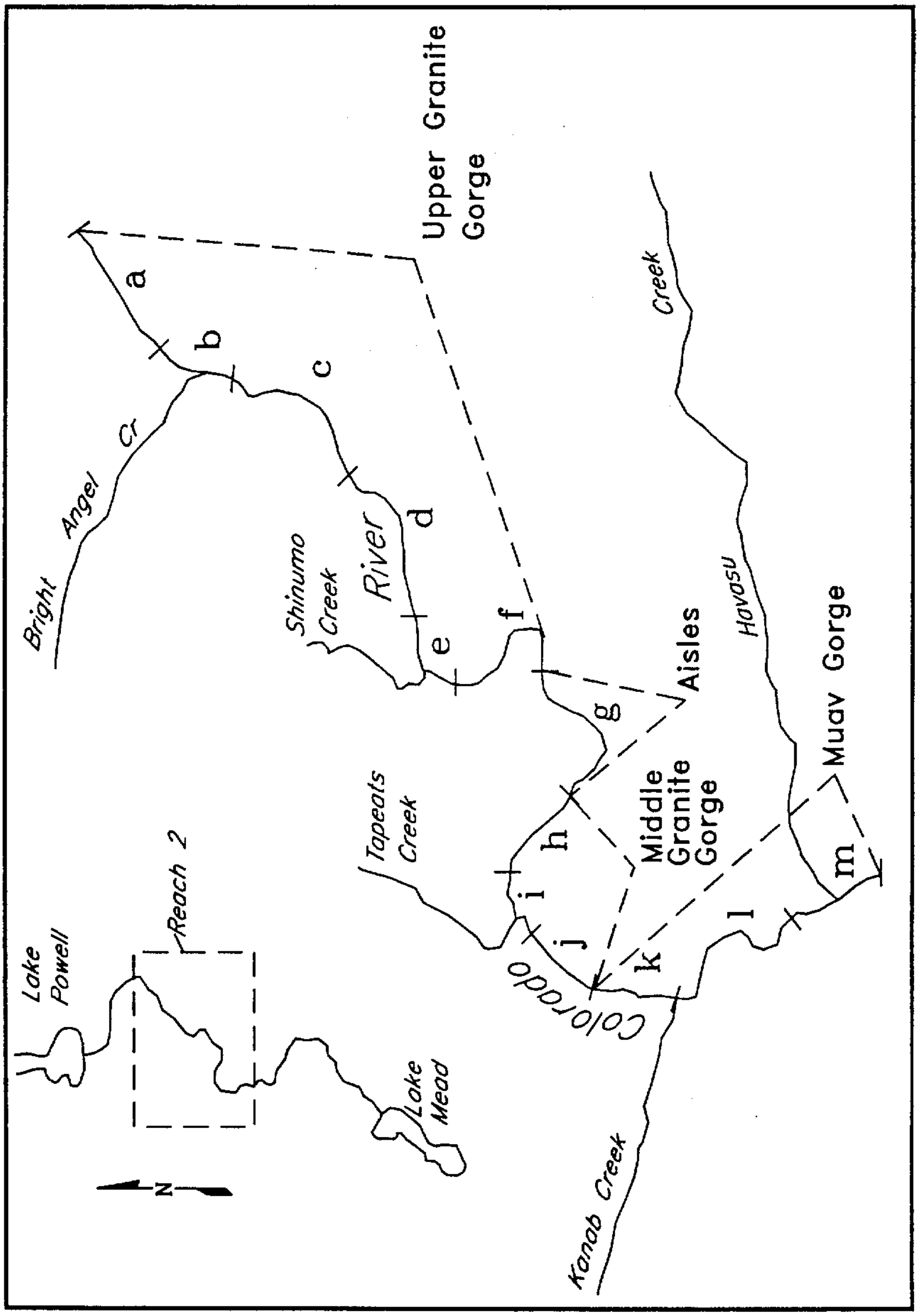


Fig. 3. Spatial stratified sampling design for Region II; a-m are sampling strata within geomorphic reaches, Upper Granite Gorge, Aisles, Middle Granite Gorge, and Muav Gorge.

The length of each sampling stratum was determined primarily by the distance of river between large rapids that was repeatedly accessible by research boats and location of temporary riverside camps for setting and retrieving sampling gear and tracking radio-tagged fish. Whitewater rapids too large or swift to ascend with small motorized research boats prevented repeated access to sample sites and frequently delineated stratum boundaries.

Sampling was conducted monthly and at different times of day and night to account for temporal variation (Fig. 4). Effort was partitioned by season to represent winter (December-February), spring (March-May), summer (June-August), and fall (September-November), and by time of day to represent night, dawn, day, and dusk. Since day length and photoperiod varied with season, a computer program (Sun and Moon Events Worksheet, Heizer Software, Inc., Palo Alto, CA) was used to appropriately adjust time blocks.

FISH SAMPLING METHODS

Equipment

Inflatable hypalon boats (Achilles Corp., Number 22 Daikyo-Cho, Shinjuku-Ku, Tokyo 160) were used for sampling and radio tracking. These small boats increased access to a greater variety of habitats than previously sampled, and enhanced scientific validity by allowing replication of data collection (Valdez et al. 1993). The sport utility SU-16 model (4.9 m long) was used primarily for electrofishing and the sport heavy-duty SH-170 model (5.2 m long) was used primarily for netting and radio tracking. The frames for these boats were designed for safety and functionality and were easily disassembled for transport on larger support rafts (10.0 m or 11.3 m long).

Standard safety equipment was provided with each boat including: (1) standard first aid kit, (2) 65-foot throw line, (3) throw able floatation device, (4) flip lines, (5) fire extinguisher, (6) extra life jacket, (7) spare paddles or oars, (8) life line, (9) bow line, (10) safety lanyard motor switch, (11) river rescue kit, (12) boat patch kit, (13) motor repair kit, (14) spare motor, propeller, and gas, and (15) Q-beam and battery.

Each electrofishing boat (SU-16) was designed to accommodate up to three biologists -- an operator and one or two netters. The boat was equipped with two subframes, including a front netting deck and rail, and a middle frame with dry compartments, a live well, and a 5-kw generator (Fig. 5). The SU-16 model boat had a load capacity of about 3,210 pounds, and the boat, frame, and outboard motor weighed about 1,200 pounds.

Each netting/radio tracking boat (SH-170) was designed to accommodate two or three biologists -- an operator and one or two biologists to perform various research tasks such as setting and retrieving fishing nets or radio tracking. The boat was equipped with a single frame with a live well, dry equipment storage compartments, radio tracking equipment, and a breakdown antenna extension boom (Fig. 6). The SH-170 model boat had a load capacity of 3,500 pounds and the boat, frame and outboard motor weighed about 800 pounds.

Only principal B/W biologists experienced in operating research vessels handled these boats during sampling activities. Maneuvering research vessels through rapids was done by boat operators with the qualifications outlined in the National Park Services Colorado River Management Plan (CRMP). All B/W biologists and personnel were familiar with and adhered to the CRMP regulations on river safety, experience, and boating restrictions. A Boat Operating and Safety Plan (BIO/WEST Report

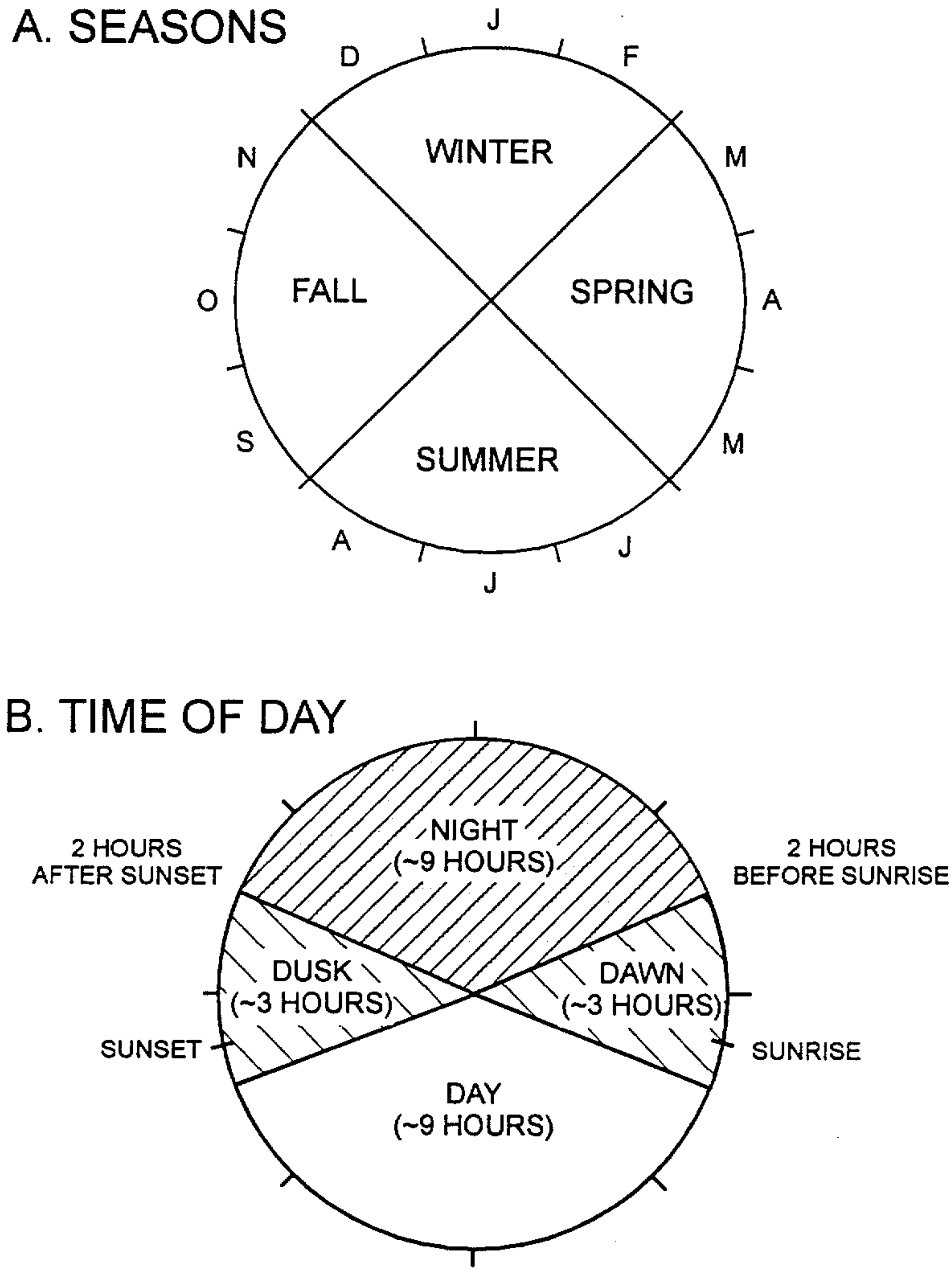


Fig. 4. Temporal stratified sampling design for seasons (A) and time of day (B).

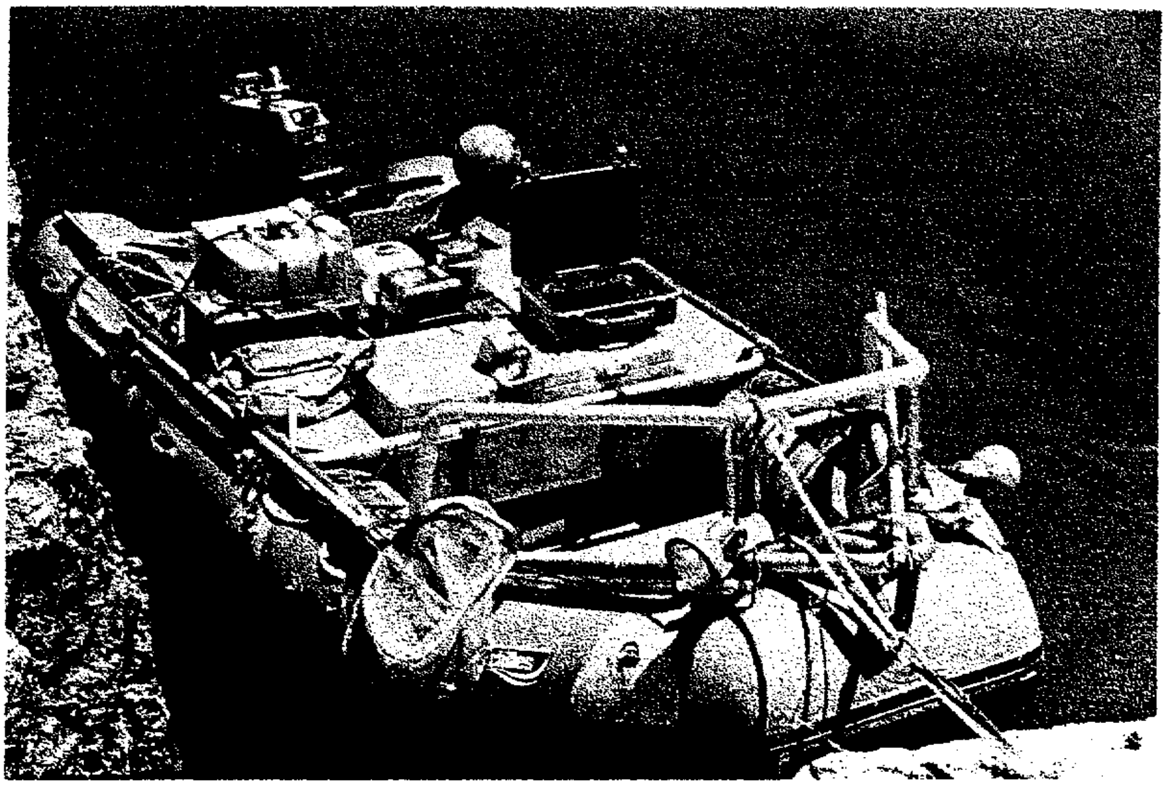
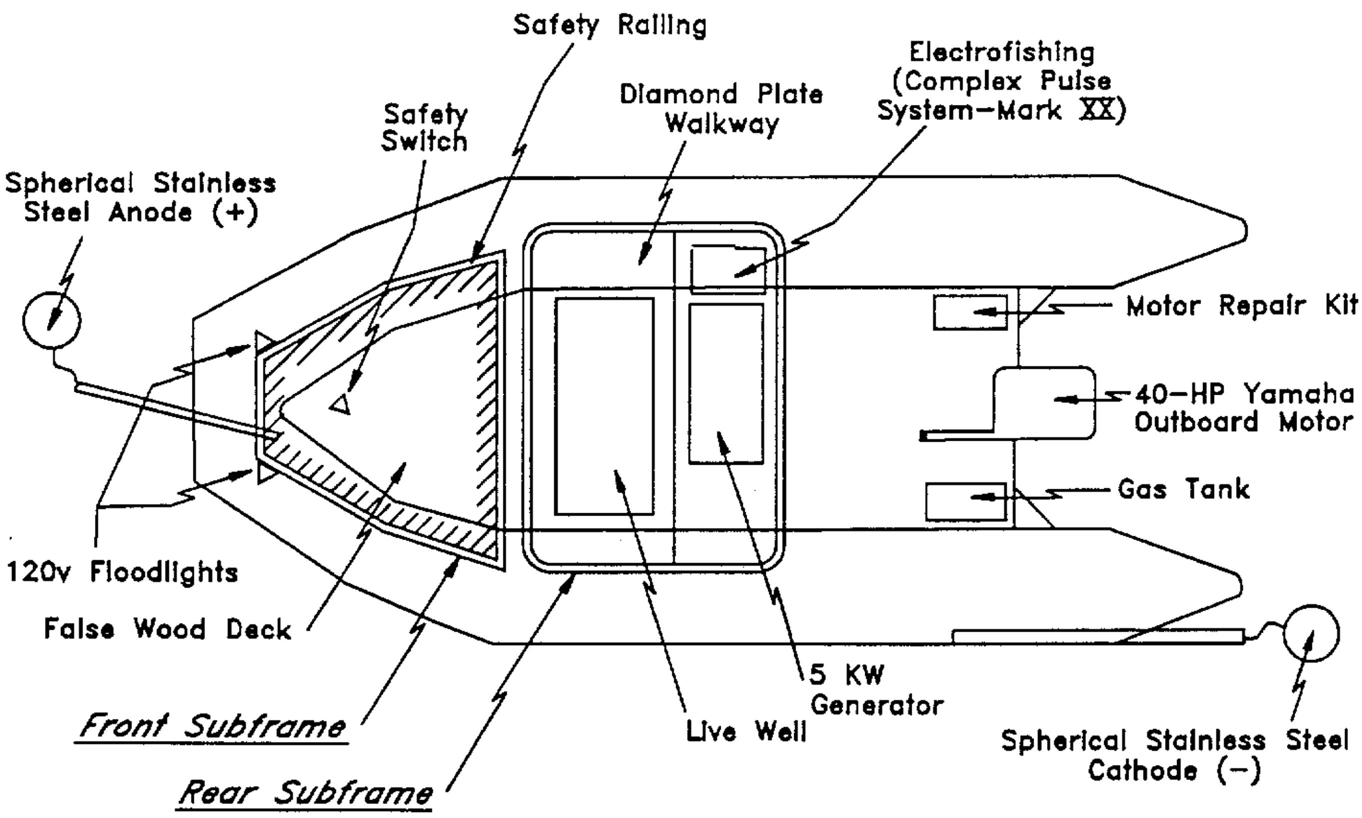


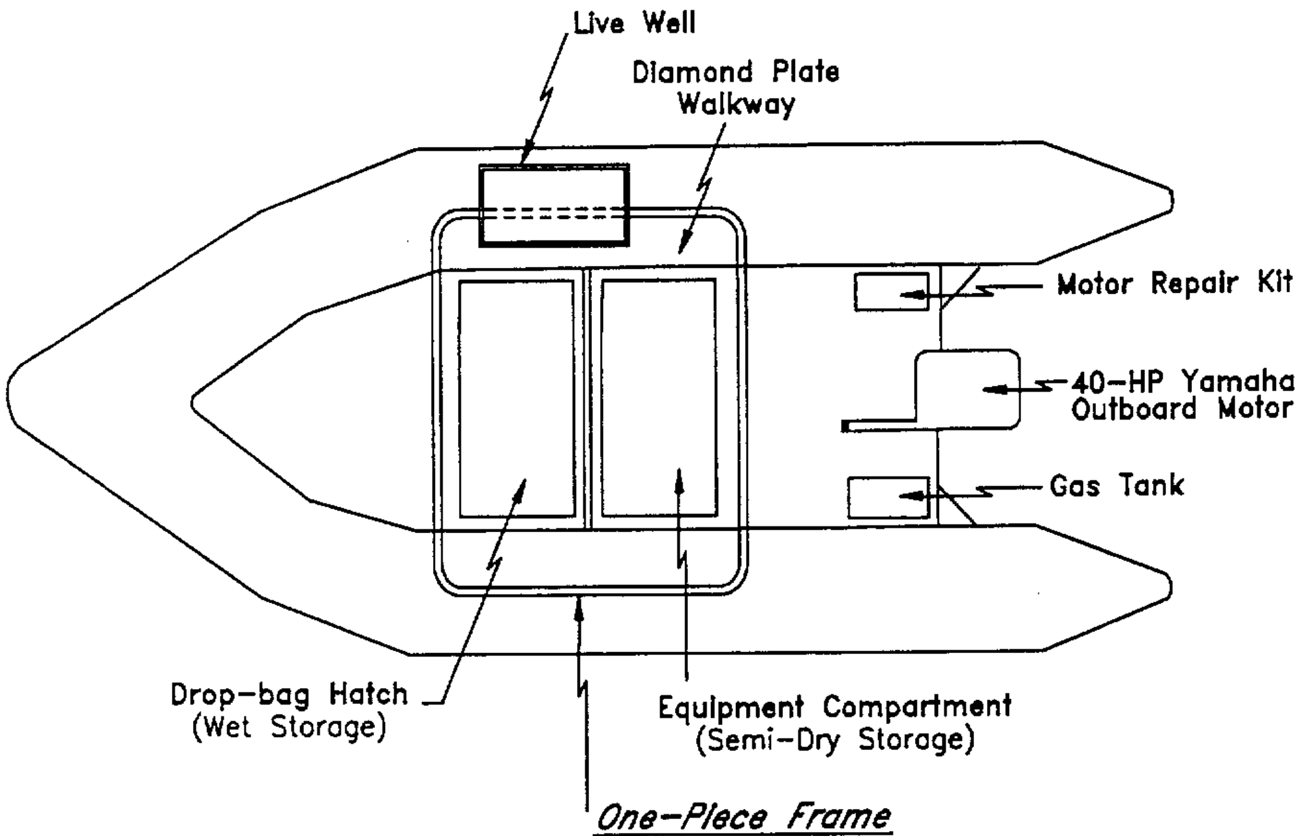
Photo of SU - 16



Frame Design for SU - 16

Fig. 5. Fishery research boat, Achilles SU-16 and frame design for electrofishing.

Photo of SH - 170



Frame Design for SH - 170

Fig 6. Fishery research boat, Achilles SH-170 and frame design used for radiotracking and netting.

No. TR 250-03) was developed by B/W to insure that all personnel were thoroughly familiar with the safety aspects of the project and that appropriate personnel were properly trained in boat operation.

Care for these boats and motors was essential to sampling the Colorado River in Grand Canyon and to accomplishing the objectives of this scientific investigation. Boat operators were always aware of onboard gas supplies to avoid running out of fuel. A regular check of each outboard motor was performed by boat operators, including oil level and condition of propeller and lower spindle. Outboard motors were allowed to warm up, especially during cold weather, and water pump outlet ports and impeller port were checked for continuous streams of water to insure that the engine coolant system was working. Outboard motors left on boats overnight were placed in a tilt position to keep the lower unit out of the water to prevent mud from settling in the water pump housing. Gas tanks were never run dry to prevent clogging outboard carburetors with residues. Gas tanks and outboard motors were not used as foot steps to prevent damage to handle or spout seals that could cause gasoline leaks and equipment and boat damage. Outboard motor problems were recorded on plastic tape and placed on the motor, and the Equipment Coordinator was advised of the problem. During hot summer months air was released from boat tubes periodically to prevent over pressurization and weakening of seams and patches.

The research boats were usually folded and loaded on larger support boats (33 or 37-ft S-rigs, or 23-ft snouts) for transport to and from riverside camps. Using larger support boats reduced boat activity in the canyon and minimized personal risk and damage to equipment in traversing large whitewater rapids. Support rafts were provided by OARS, a commercial river concessionaire from Flagstaff, Arizona, contracted by GCES to provide logistical support for research efforts in Grand Canyon.

Fish Capture Methods

Six basic gear types were used by B/W in the Colorado River in Grand Canyon to sample fish, including gill and trammel nets, hoop nets and minnow traps, electrofishing, seines, and angling. Data sheets were developed for categories of gear type to facilitate data entry and analysis. Samples of data sheets are presented in Appendix A. All B/W personnel were familiar with each data sheet and the codes and entries required for each data field. The accuracy and consistency of data were important to the value of this scientific investigation.

Nets

Gill Nets: Gill nets were the primary gear used to sample large-fish assemblages in deep shoreline habitats and to capture adult humpback chub for implanting radio transmitters. This gear type was used to gain information on fish distribution and abundance by area and time, as well as to assess general fish habitat use to augment radiotelemetry data. These gear types are commonly used to survey and monitor other populations of humpback chub in the Upper Colorado River Basin (Valdez and Clemmer 1982, McAda et al. 1994, U.S. Fish and Wildlife Service 1987).

Several net mesh sizes were selected to capture a variety of fish sizes including adults and juveniles. Numbers of fish captured by species from each net set were recorded for calculation of catch-per-unit effort (CPE) expressed as the number of fish per 100 feet of net per 10 hr.

Gill nets were 30.5 m long and 1.8 m deep, with 3.8 or 5.1 cm-square mesh (100 ft x 6 ft deep, 1.5 or 2-in mesh). Experimental gill nets were also used with four sections of 1.3, 2.5, 3.8, 5.1-cm mesh (0.5, 1, 1.5, and 2-in). Trammel nets were 22.9 m long and 1.8 m deep (75 ft x 6 ft), with three panels of netting--two outer walls of 12-in (30.5 cm) mesh and one inner panel of 1.3, 2.5, or 3.8-cm mesh (0.5, 1, or 1.5-in). Gill and trammel nets were made of double knotted #139 multifilament twine with 1.3-cm (0.5-in) diameter braided polyfoamcore float line and 0.8-cm (5/16-in) leadcore line. White, labeled mooring boat bumpers, 12.7 cm (5-in) in diameter and 45.7-cm (18-in) long, were tied to a line at the distal end of each net to facilitate relocation and retrieval and to alert boaters to submerged nets. Polypropylene mesh bags were filled with rocks and used as convenient net weights.

Gill nets were generally set from shorelines diagonal to the direction of the current. One end of the float line was anchored to the shore so that the end of the net was within 1 m of the shoreline (Fig. 7). A weight bag was attached to the shoreline end of the leadline to anchor the net in position and keep it extended. Experimental gill nets were set with the small mesh nearest the shore.

In areas with a strong current, nets were generally extended downstream, parallel to the current either along eddy lines, runs or pools. In areas with little or no current, nets were placed perpendicular to anticipated fish movements. A second weight was attached to the distal end of the net with a length of line that determined the net height above the river bottom. An extension line was then attached to the float line and the net was lowered into the water until the weight reached the bottom, at which time, the marker/float was attached with a bowline knot. Nets to be reset the next day in the same location were bagged and set on shore above the high water line.

Outboard engines were turned off and placed in the tilt position while nets were checked. The nets were pulled from the water by grabbing the marker float, pulling the distal net weight from the bottom and then hauling the net aboard the boat while slowly moving toward the shoreline attachment point. If the distal net weight became lodged on the bottom it was necessary to work from the shoreline in order to free the weight.

Fish were removed from each net as they were encountered with priority given to endangered species, native species, trout and other non-natives (in that order). If endangered fish were severely entangled, the mesh was cut to free the fish.

Fish were identified and counted as they were removed from the net and placed in a live well. Each fish was measured, weighed and appropriately processed before release. Nets were checked at least every 2 hr to minimize stress and reduce mortality of entangled fish. Nets damaged or clogged with the algae Cladophora or debris were removed and replaced with clean ones.

Trammel Nets: Trammel nets consisted of three panels of netting, two outer walls of large mesh and one inner panel of small mesh. The outer walls consisted of #139 multifilament twine netting with a 12-inch mesh. The inner panel consisted of either 1-inch or 1.5-inch mesh; these mesh sizes have been found most effective for capturing humpback chub with a minimum of damage. All inner panels were constructed of double knotted #139 nylon multifilament twine. Trammel nets were used in a similar manner to gill nets to characterize fish assemblages and document changes in fish distribution and abundance over time and with location. Trammel nets tended to be less stressful on the fish than gill nets because the middle panel of netting tended to form a bag around the fish rather than tightening around their gill opercles and impeding respiration. Trammel nets were also used in an active manner by floating them through areas of fish concentrations, such as in tributary mouths during spawning time. This technique worked best in areas of low current and smooth sand bottom to prevent tangling and tearing the nets on bottom debris. Catch rate (CPE) for trammel nets was expressed the same as for gill nets, i.e., number of fish per 100 feet of net per 10 hr.

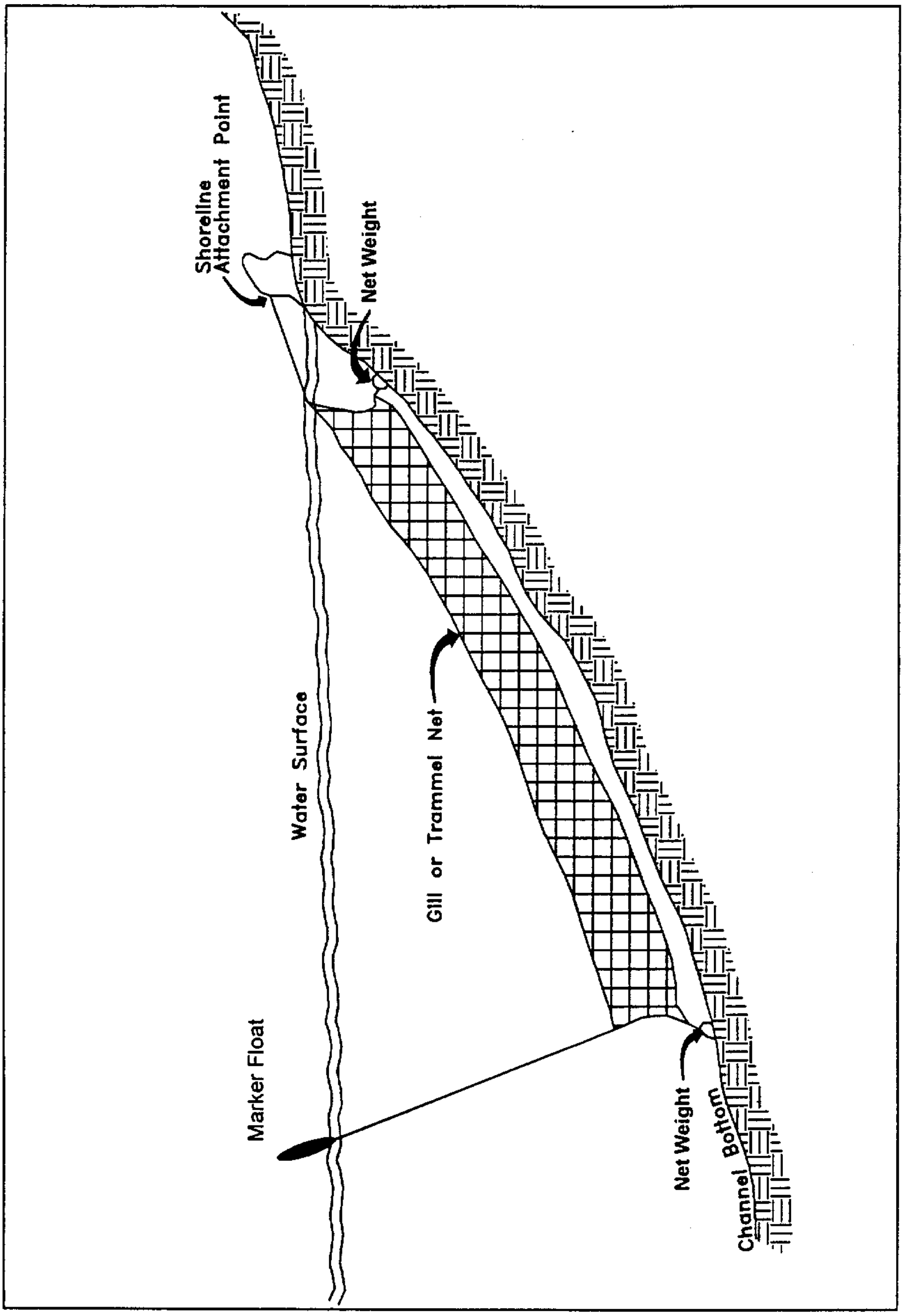


Fig. 7. Typical gill or trammel net set.

Traps

Hoop Nets: Three sizes of hoop nets were used in various velocity habitats including 0.6 m x 3.0 m x 1.3-cm (2 ft x 10 ft x 0.5-in), 0.9 m x 4.0 m x 2.5-cm (3 ft x 13 ft x 1-in), and 1.2 m x 4.9 m x 1.3-cm (4 ft x 16 ft x 0.5-in) (diameter x length x square mesh). Nets were typically located in tributary streams or their mouths. Two 7.6 m (25-ft) wings made of 2.5-cm (1-in) #15 knotless nylon were attached to the opening of the hoop nets. Hoop nets were set by anchoring the rear of the net with a length of rebar and orienting the mouth in a downstream direction to capture fish moving upstream (Fig. 8). Wings were anchored with rocks. Nets were checked at least every 8 hr to minimize stress and mortality to fish. Occasionally nets were set in the mouths of tributary streams when water in the mainstem was low. Catch rate (CPE) for hoop nets and minnow traps was expressed as number of fish per 100 hr.

Minnow Traps: Unbaited minnow traps were used to sample small fish in a variety of shoreline habitats. Minnow traps were standard Gee minnow traps; 44.5 cm (17.5 in) long, 22.9 cm (9 in) diameter, and constructed of galvanized wire and steel. Funneled openings were located at each end of the trap. Traps were placed on the bottom or suspended in the water column depending on conditions. Traps were also set in pods of five as sample repetitions for habitat types. Each trap was tethered to a secure anchor point and discretely flagged for easy relocation. A long length of cord was attached between the anchor point and the trap to prevent stranding with fluctuating water depths. Traps were checked at intervals of no longer than 24 hr (8-12 hr in Region I) to minimize stress and mortality to fish.

Electrofishing

Electrofishing was used to sample fishes along shorelines and to capture adult humpback chub for implanting radio transmitters. Each electrofishing effort was conducted within a distinct geomorphic shoreline type (i.e., alluvial fan, bedrock, cobble bar, sand bar, talus slope, vegetation) in order to evaluate habitat use and reduce variability in comparing catch rates between habitats and reaches, as well as between flow levels and over time. The number of fish captured by species in a discrete effort was recorded and related to time (seconds of electrofishing from internal system timer) for calculating CPE expressed as number of fish per 10 hr of effort.

Electrofishing was conducted from an Achilles SU-16 research boat capable of ascending small and medium-sized rapids for increased access to sample areas (Fig. 5). Each boat was designed to meet Occupational Safety and Health Administration (OSHA) safety standards with specialized features such as pressure safety switches, grounded wiring, insulated railing, separate line-channeling for circuits and lights, and rubber gloves, rubber boots, and fiberglass-lined dip nets for netters and boat handler. The system was powered by a 5,000-W Yamaha industrial grade generator (Model YG-500-D) or a Honda 5,000-W generator (Model EB 5000X), and routed through a Mark XX Complex Pulse System (CPS) developed by Coffelt Manufacturing (Flagstaff, AZ). Stainless steel spheres were used as electrodes with the anode (positive electrode) mounted on a boom projecting from the bow and the cathode (negative electrode) suspended from the stern. Anode and cathode were interchanged once every 45-60 min of electrofishing to clean the cathode surface by reversing the electroplating process.

During the 1990 and 1991 field trips, CPS output was set at a range of 300-350 V and 15-20 A, as recommended by Coffelt Manufacturing for electrofishing in the Colorado River below Glen Canyon Dam (N. Scharber, Coffelt Manufacturing, pers. comm.). In 1992, output was reduced to a range

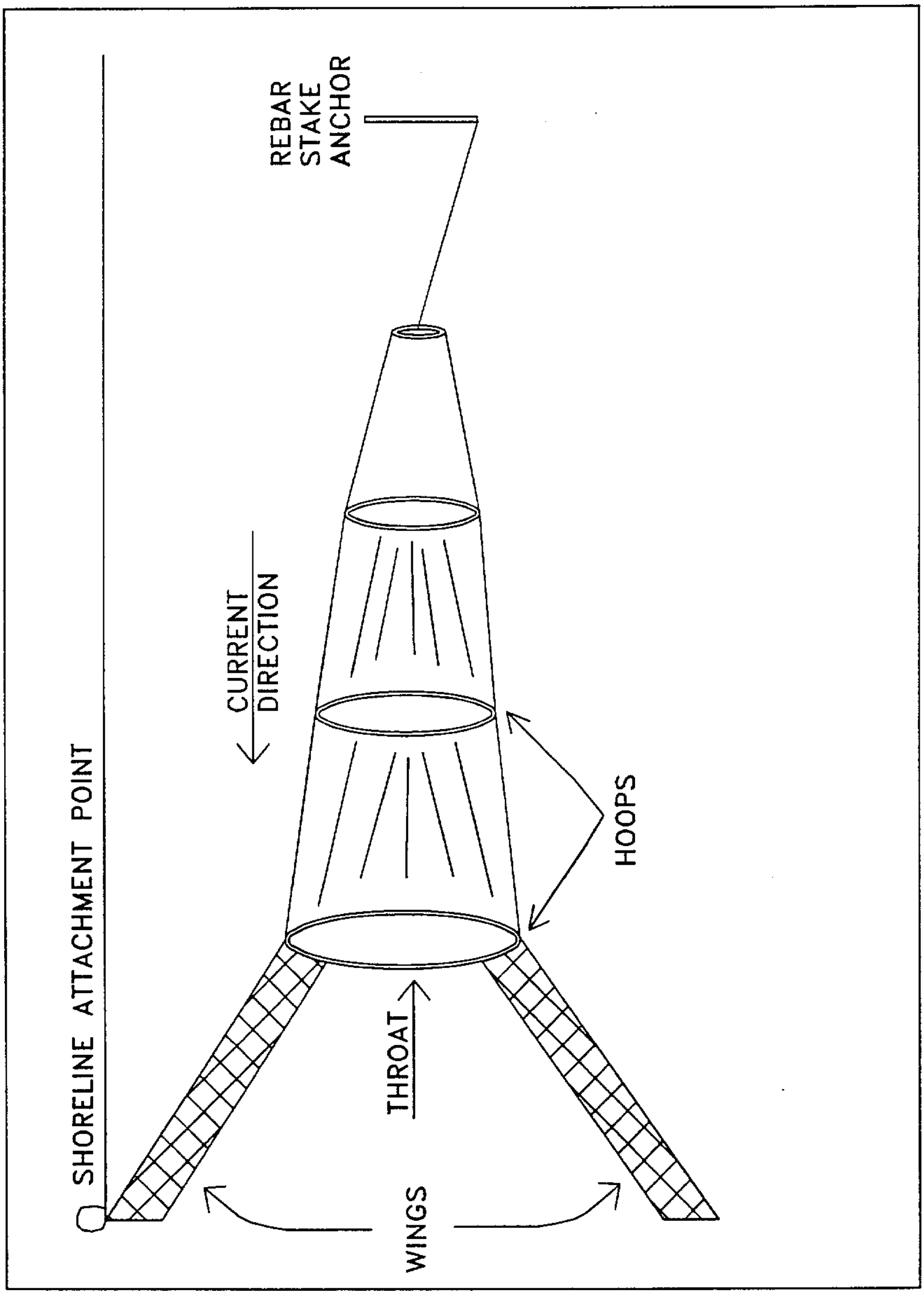


Fig. 8. Typical hoop net set.

of 200-250 V and 8-10 A after "bruise marks" were observed on trout under the higher settings. The lower settings seemed to reduce the incidence of these marks.

During electrofishing runs, one or two dip-netters were positioned in the bow of the boat to capture stunned fish. Crews also made "blind net sweeps" into turbid water in likely habitats such as pocket water behind boulders and along shorelines. Dip nets had an opening of 324 square inches (18"x18"), a bag depth of 24 inches, and were constructed of 0.25-inch knotless mesh. One netter was designated to operate a safety foot switch which had to be depressed for the system to be operational. The boat operator was also able to quickly shut off power at the CPS control unit. As fish were netted, they were placed into a live well located just behind the netters.

Electrofishing runs were generally made adjacent to the shoreline and in the direction of the current. The boat was maneuvered among shoreline cover to adequately sample areas used by fish. An electronic timer, built into the CPS, was used to keep track of time associated with each run. All fish captured during electrofishing were processed immediately upon completion of a run within a habitat type. Each fish was visually examined for evidence of injury associated with electrofishing. Bruises, spinal deformities, and prolonged lethargy were noted on data sheets. Target fish such as humpback chub and razorback sucker were processed immediately and released at their capture location. Nontarget fish were processed and released within 0.1 to 0.2 mile from the point of capture.

Nighttime electrofishing was conducted with the aid of two 150-W floodlights mounted on the safety railing at the bow of the boat. These 110-V lights were powered by the 5,000-W generator with the electrical lines isolated from the 220-V lines for increased safety. The operator also had access to a battery-operated 500,000 candlepower Q-beam spotlight to aid in night time navigation.

Seines

Seines were used to characterize assemblages of small fish in relatively shallow habitats (up to about 1.5 m in depth). Three sizes of seines were used, including 9.1 m x 1.2 m x 0.6-cm (30 ft x 4 ft x 0.25-in), 9.1 m x 1.5 m x 0.6-cm (30 ft x 5 ft x 0.25-in), and 3.0 m x 0.9 m x 0.3-cm (10 ft x 3 ft x 0.125-in) (length x height x square mesh). The float line was constructed of 0.8-cm (0.3125-in) braided polypropylene with hard foam floats at 45-cm (18-in) intervals. The bottom line was made of braided polypropylene line with lead sinkers at 15-cm (6-in) intervals.

Length and width of each seine haul were measured and three water depths were recorded; one at the deepest point of the haul, and one each midway between the deepest point and the nearest shore. Length and width of the habitat sampled were also recorded. Catch rate (CPE) for seine hauls was expressed as the number of fish per 100 square meters of area seined. Each sheltered habitat sampled was checked for longitudinal thermal gradients prior to seining. If significant temperature differences occurred, extreme care was taken to avoid subjecting fish to thermal shock during seining, holding, and release.

After each haul, the seine was held suspended in the water while endangered and native fishes were removed and placed into live wells (buckets). The seine was then beached and a second intensive search made. After all endangered and native fish were removed, the remainder of the fish were placed in a separate live well. Fish captured with seines were identified in the field and released live at the capture location. Specimens that could not be identified afield were preserved in formalin (3 - 5% concentration) and placed in an appropriately-labeled sample jar and noted on the data sheet. Incidental mortalities were also preserved and recorded . All preserved fish were returned to the B/W laboratories for further identification and processing. Specimens were transferred to the Service, AGF, or NPS as required by scientific collecting permits. Specimens of federally threatened or endangered species were transferred as soon as possible to AGF with accompanying letters of transfer.

Angling

Angling has been used as an effective method for capturing humpback chub in the Upper Colorado River Basin, Black Rocks, Westwater Canyon (Valdez et al. 1982), and in Yampa Canyon (Tyus and Karp 1989). Cheese balls, commercial salmon eggs, stink bait, grasshoppers, Mormon crickets (Tyus and Minckley 1988), and artificial flies have been used with varying success. Angling was not used extensively in Grand Canyon because of the relative high efficiency and low impact of other sampling methods and the time and commitment necessary for successful angling of this endangered species. However, angling was used to catch actively feeding rainbow trout for stomach analysis to assess predation on young-of-the-year (YOY) and juvenile humpback chub in the vicinity of the LCR inflow, where concentrations of young chubs were highest.

FISH HANDLING METHODS

Handling fish in the Grand Canyon required particular care and attention, primarily because endangered species were involved, and because the work was conducted in a national park where sampling activities were highly visible in the field and came under regular scrutiny from state and federal resource agencies and the public. A fish handling protocol was therefore essential to all fishery investigations in Grand Canyon. This section of the Plan describes fish handling techniques employed by B/W biologists in Grand Canyon. These techniques reflect considerable experience with riverine species from other parts of the Colorado River basin, and were refined to fit the logistical needs and conditions of the canyon. Every reasonable effort was made to minimize impacts associated with research on all fish species residing in Grand Canyon National Park, especially the endangered humpback chub and razorback sucker. All methods and procedures employed to capture, hold, anesthetize, and process fish reflect a concerted effort to avoid excessive stress to fish.

Transport and Holding

Captured fish were placed in live wells to minimize stress and enhance recovery. Live wells consisted of 127-L (120-qt) insulated coolers located on each boat, 1.3-L (5-gal) bail buckets carried by seining crews, and 1.2 m x 1.8 m x 1.3-cm mesh (4 ft x 6 ft, 0.5-in) holding pens placed in the river. Small fish were placed in buckets inside of live wells. The live well lid was kept closed during sampling and transport to prevent the fish from jumping out. For each sample effort, fresh river water was placed in each live well, and changed frequently (every 15 min) when holding time was prolonged or large numbers of fish were held. Fish showing signs of stress (e.g., increased or irregular respiration, loss of equilibrium, dramatic color change, reddened fins, excessive slime) were isolated in fresh water, carefully monitored, and treated with a salt solution to minimize electrolytic losses (Bulkley et al. 1982, Hattingh et al. 1975). Fish with extended lethargy or obvious injuries were appropriately treated (e.g., Betadine was applied to wounds) and each fish was released upon recovery. Parasitic copepods (Lernaea cyprinacea) were killed by compressing the body of the parasite between the thumb and forefinger to cause release of the cephalic horns, and the organism was wholly extracted. Dead fish were preserved in an appropriately labeled container and transferred to the ichthyology collection at Arizona State University. Incidental mortality of humpback chub from this investigation did not exceed 10 per year, the number allowed under B/W's federal collecting permit.

Fish Processing Procedures

A number of fish processing procedures were used during the course of this investigation. Some were initiated by the original study design, and modified or discontinued, while others were implemented as a result of specific data needs or at the request of the ACT (Fig. 9). From October 1990 through July 1991, all captured humpback chub were transported to a central processing station near camp and then returned to their capture location for release--a one-way distance of up to 6.4 km (4 mi). This protocol prolonged holding time and unnecessarily stressed the fish and was modified in August 1991, when humpback chub were processed and released near their capture location. Only adults destined for radio implant were transported to a central processing station. Humpback chub were measured for total length (TL), standard length (SL), and forked length (FL) in millimeters, weighed wet in grams, marked with a PIT (Passive Integrated Transponder) tag, and gender was determined From October 1990 through July 1991, the left aspect of every humpback chub 200 mm TL or longer was photographed (35-mm color slide and VHS video) on a white plastic board marked with a 1-cm wide grid pattern. Starting in August 1991, 35-mm photographs were taken of every tenth adult that was not a recapture and videography was discontinued. Primary rays of dorsal and anal fins were also counted for every tenth adult and ten morphometric dimensions were measured with venier calipers, accurate to the nearest 0.01 mm, including depth of nuchal hump, head length, snout length, distance between insertion of pelvic and pectoral fins, maximum body depth, caudal peduncle length, maximum caudal peduncle depth, minimum caudal peduncle depth, length of anal fin base, and length of dorsal fin base (Fig. 10).

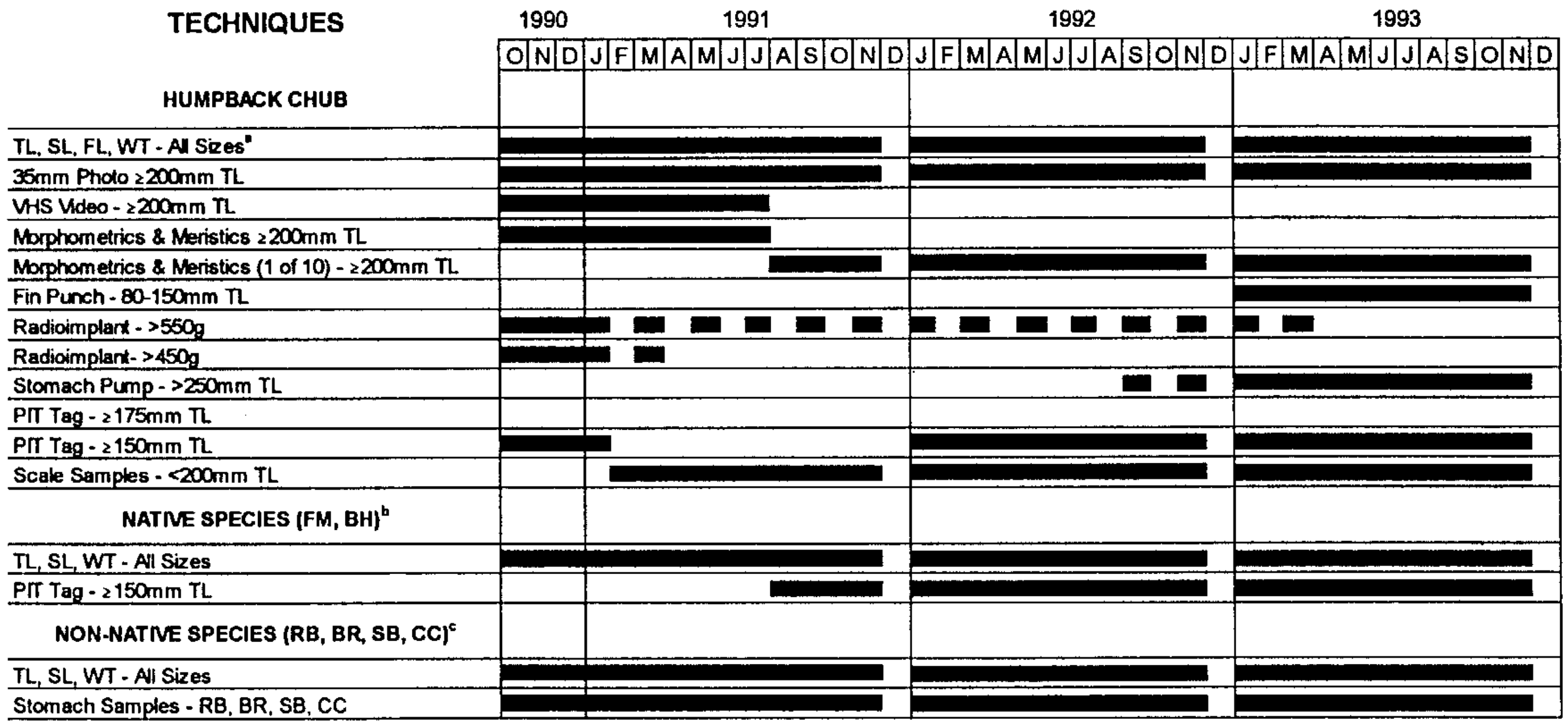
Selected adult humpback chub from Region I weighing more than 550 g were surgically equipped with 11-g radio transmitters from October 1990 through January 1991 and every other month through March 1993. Use of 9-g radio transmitters in fish 450-550 g was discontinued because of transmitter limitations. A nonlethal stomach pumping technique was implemented in September 1992, following evaluation of the technique (Wasowicz and Valdez 1994). Scales were taken from chub less than 200 mm TL to determine age and size at transition from the LCR to the mainstem.

Tissue core samples were taken for genetic analysis during October 1992 as part of the Gila Taxonomy Study of the Upper Colorado River Recovery Implementation Program (W. Starnes, Smithsonian Institute, pers. comm). Tissue cores were removed with a 3-mm biopsy punch from multiple locations including: fins and along the dorsal and peduncle musculature. Samples were preserved in liquid nitrogen and transferred to appropriate laboratories. Humpback chub sampled in this manner were noted on data sheets along with any other pertinent observations.

Other native species, including flannelmouth sucker, bluehead sucker, and speckled dace were measured for total and standard length (i.e., TL, SL-mm), weighed (g), and fish with total length greater than 150 mm TL were PIT-tagged starting in February 1991. Non-native species were also measured for total and standard length, weighed, examined for reproductive condition and gender, and released. All channel catfish, striped bass, and selected rainbow trout and brown trout were sacrificed for removal of stomachs. Gut contents were preserved in ethanol, placed in labeled Whirl-pack bags, and transported to Leibfried Environmental Services in Flagstaff, Arizona, for identification and quantification of food contents.

Stomach Analysis

Food habit studies generally require sacrificing many fish for stomach removal and examination. In systems with low fish numbers or with endangered fish, removal of fish can seriously deplete populations and lethal methods are generally not permitted. A nonlethal method of stomach pumping



[a] TL= total length, SL= standard length, FL= forked length, WT= weight

[b] FM= flannelmouth sucker, BH= bluehead sucker

[c] RB= rainbow trout, BR= brown trout, SB= striped bass, CC= channel catfish

Fig. 9. Schedule of fish processing procedures conducted by BIO/WEST.

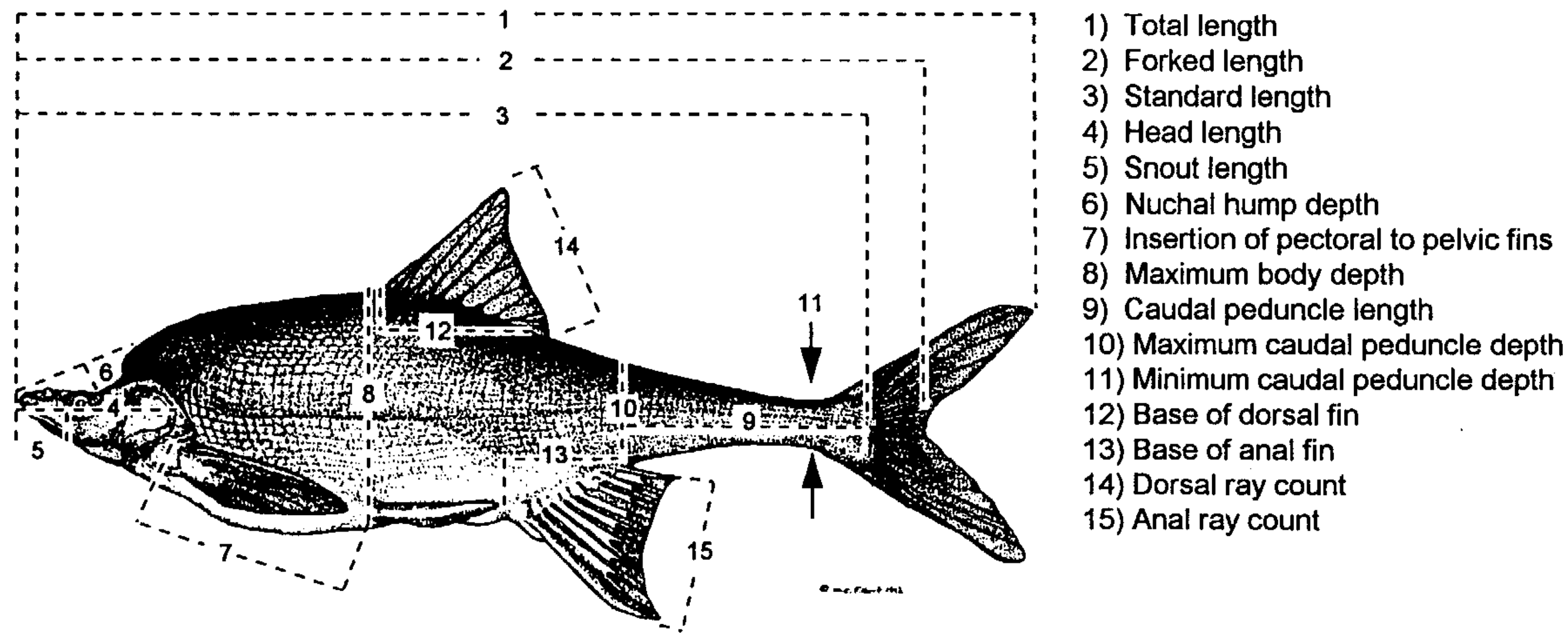


Fig. 10. Morphometrics and meristics recorded for adult humpback chub ≥200 mm TL.

was used to examine food habits of humpback chub in the mainstem Colorado River of Grand Canyon. Studies have shown that stomach pumping is an effective technique for evacuation gut contents without harming the fish. Fish species which have been effectively tested include a variety of salmonids, centrarchids, ictalurids, percids, and esocids (Meehan and Miller 1978, Swenson and Smith 1973, Seaburg and Moyle 1964). Stomach pumps have also been used successfully with roundtail chub in the Upper Colorado River Basin (R. Valdez, BIO/WEST, pers. comm.). In all cases, the removal of stomach contents with pumps was not injurious to the fish.

A non-lethal stomach pumping technique was developed and tested in 1992 by B/W for recovering gut contents of humpback chub in Grand Canyon (Wasowicz and Valdez 1994). Testing was conducted on surrogate roundtail chub (Gila robusta) and initiated with humpback chub in Grand Canyon in September 1992.

The stomach pump design (Fig. 11) was based on Gengerke's modification of the original Seaburg design (Gengerke et al 1973, Seaburg 1957). Flexible plastic tygon tubing was connected to both ends of a clean, hand-held, rubber bulb, commonly used as an in-line gasoline pump for outboard motors. Fish were mildly anesthetized with MS-222 (~100 mg/l), and the clear outlet tube inserted into the buccal cavity of the fish. A stream of water was pumped through the inlet tube and into the gut, flushing food items from the digestive tract through the vent, and into a collecting jar. Flexible tubing minimized the chance of damage to the esophagus and pharyngeal mill, and the hand-held rubber pump allowed for precision in dictating water flow and pressure. Different sized, interchangeable tubes were used for efficient flushing of various sized fish.

Gut contents were appropriately labeled and preserved in 75% ethyl alcohol solution. Samples were placed in a secure container and transferred to the laboratory at Leibfried Environmental Services in Flagstaff for sorting and identification.

Humpback chub were captured at various times of the day and night to ascertain feeding periodicity relative to flow, time of day, turbidity, and other riverine conditions. Peak feeding times were identified by examining the digestive stage of stomach contents.

All fish were held in a live well for a brief period after pumping to ensure recovery and to identify any anomalous characteristics such as previous marks (e.g., fin punches, fin clips, external fish tags), parasites, wounds, or deformities. Anomalies were recorded in detail on appropriate data sheets and photographed if relevant.

Marks

PIT Tags: A PIT tag (Passive Integrated Transponder) was injected into the subdominal cavity (Fig. 12) of each humpback chub 175 mm TL or greater. Starting in February 1991 minimum size of tagging was reduced to 150 mm TL. Each tag was a glass-encapsulated microchip12 mm long and 1.7 mm in diameter, that emitted a unique 10-digit alphanumeric identifier when activated with a specialized electromagnetic scanner. PIT tags were injected into the abdominal cavity of a fish just posterior to the pelvic fin (usually the left fin), using a large bore hypodermic needle which was cold sterilized with 95% ethyl alcohol after each use. PIT tags were injected only by trained personnel designated by the Principal Investigator or Project Leaders. Native and endangered fish were thoroughly scanned prior to tagging for the presence of a PIT tag from a previous capture. External tags (i.e., Carlin or Floy tags placed by other investigators) were removed from native fish and replaced with PIT tags, and both tag numbers were recorded in the database with corresponding

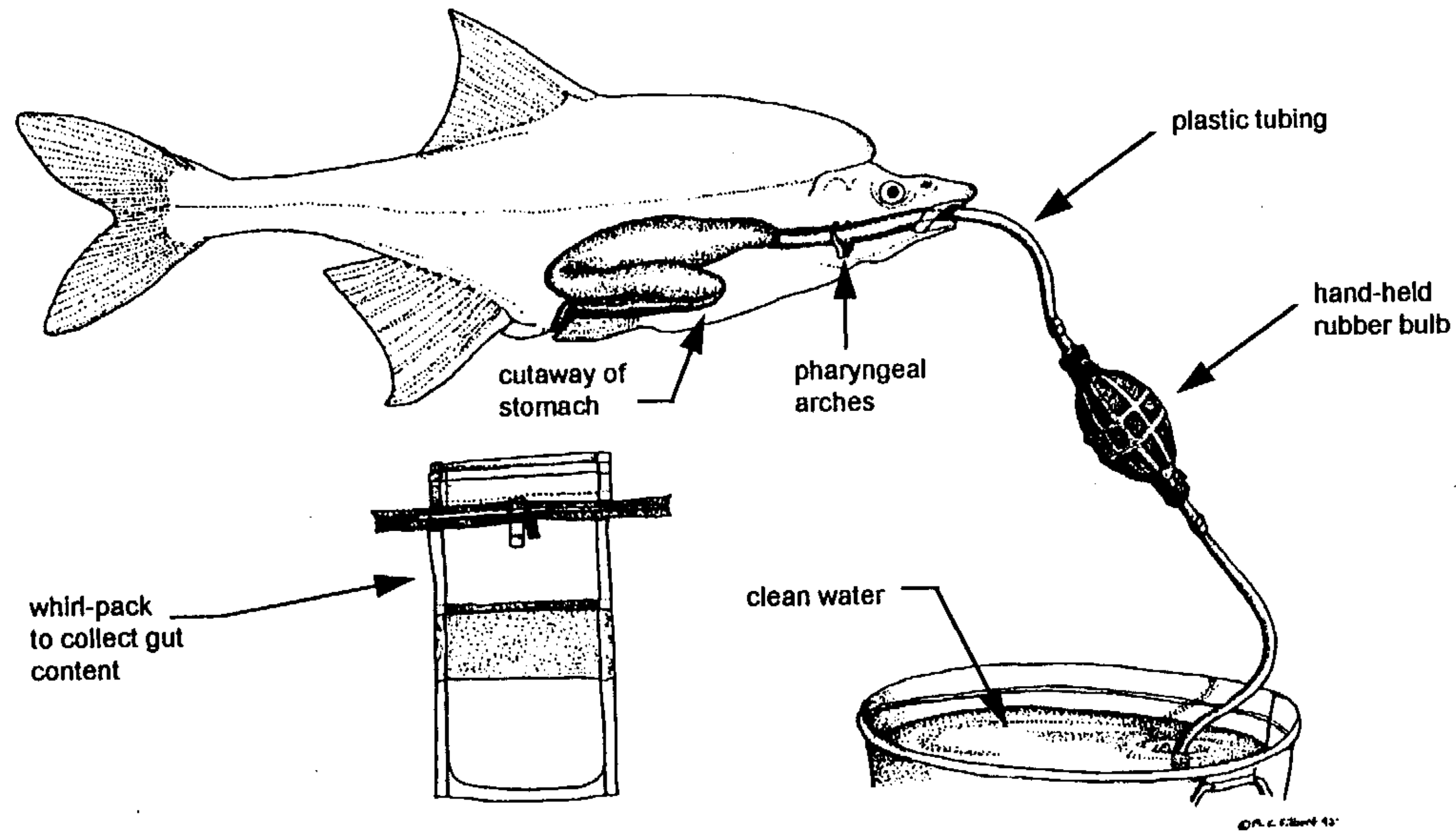


Fig. 11. Stomach pump used to recover gut contents of adult humpback chub.

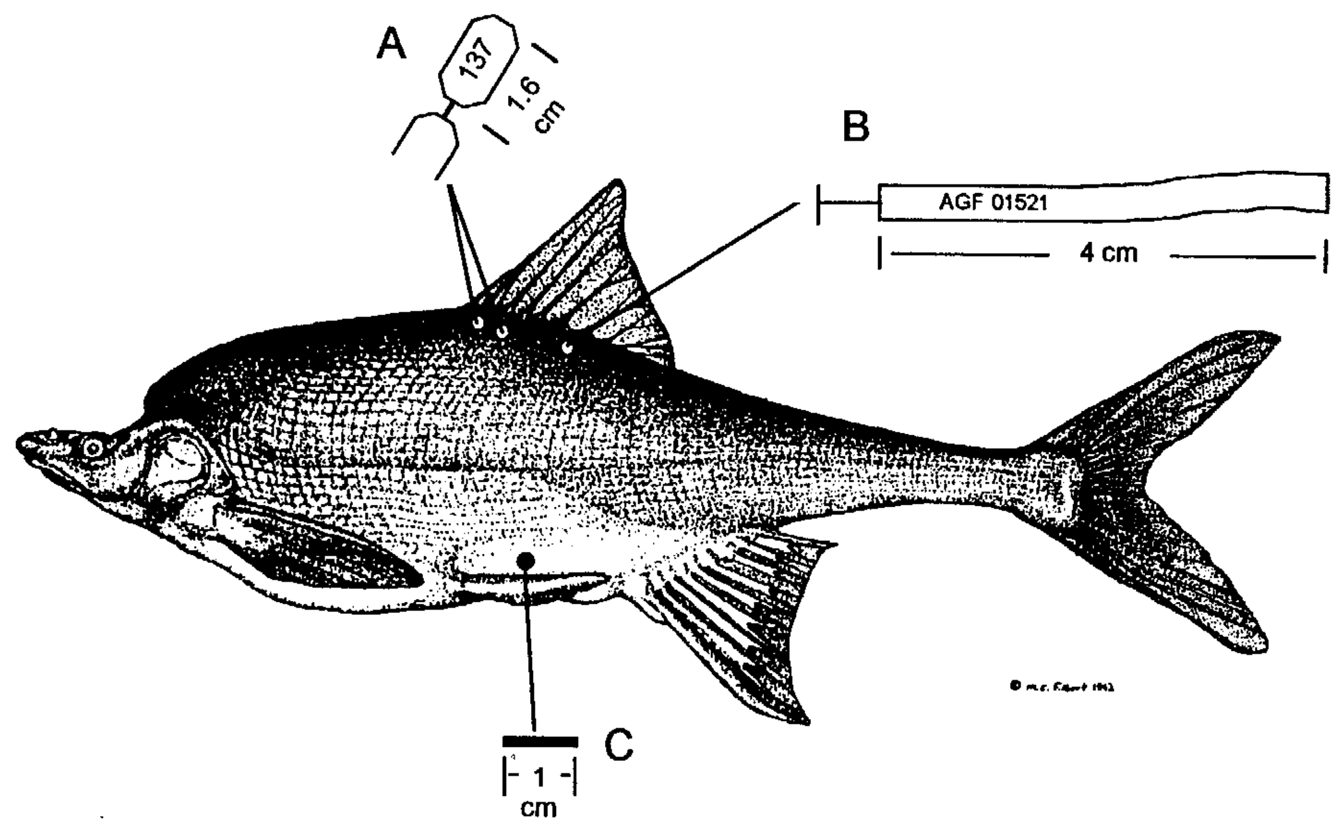


Fig. 12. Attachment sites for Carlin dangler tag (A) and Floy anchor tag (B) by previous investigations, and injection site for PIT tag (C) by this investigation.

information. These old tags were replaced at the request of the ACT because PIT tags were considered more reliable, with less chance of tag loss, and greater capacity and facility for information retrieval (Burdick and Hamman 1993).

Fin marks: Beginning in January 1993, juvenile humpback chub (range, 60-150 mm TL) were marked with temporary fin punches (Fig. 13) to track longitudinal dispersal. A 3-mm diameter biopsy needle was used to punch various fin combinations specific to river subreaches (Wydoski and Emery 1983).

The following fin punch combination was used by B/W and AGF for juveniles captures and released within respective subreaches of the mainstream Colorado River:

Fin Punch Combination	Location (Colorado River)
dorsal fin	Malagosa Canyon to Lava Canyon (RM 57.6-65.4)
lower caudal fin lobe	Lava Canyon to Hance Rapid (RM 65.4-76.6)
upper caudal fin lobe	Hance Rapid to Havasu Creek (RM 76.6-156.7)
dorsal fin plus upper caudal lobe	Havasu Creek to Diamond Creek (RM 156.7-225.7)

The following fin clip combination was used by ASU for juveniles captured and released at respective reaches of the LCR:

Fin Clip Combination	Location (LCR)
upper caudal lobe plus right pelvic fin	Chute Falls to Salt Trail Camp (RK 14.9-10.8)
upper caudal lobe plus left pelvic fin	Salt Trail Camp to Sipapu (RK 10.8-7.5)
lower caudal lobe plus right pelvic fin	Sipapu to Powell Canyon Camp (RK 7.5-3.0)
lower caudal lobe plus left pelvic fin	Powell Canyon Camp to Confluence (RK 3.0-0.0)

ASU removed the entire upper or lower gossamer portion of the caudal fin while avoiding injury to the peduncle and fin ray bases. The pelvic fins were removed at the base allowing the fin to regenerate but providing a longer-term mark.

Preservation of Incidental Mortalities

Humpback Chub

Humpback chub that died during sampling were handled in the following manner:

A. For humpback chub less than 150 mm TL, the following were recorded or performed:

1. Weight and length of fish (total, forked, standard),
2. A numbered Carlin tag was affixed to the lower jaw so it was clearly visible,
3. The fish was placed in a plastic bag with 95% ethyl alcohol (ketone-free solution provided by AGF), and
4. A waterproof tag was placed in the sample bag with the fish that had a field sample identification, species, fish length, weight, date, location of capture, and collector.

B. For humpback chub 150 mm total length or over, the following were recorded or performed:

1. Weight and length of fish (total, forked, standard),

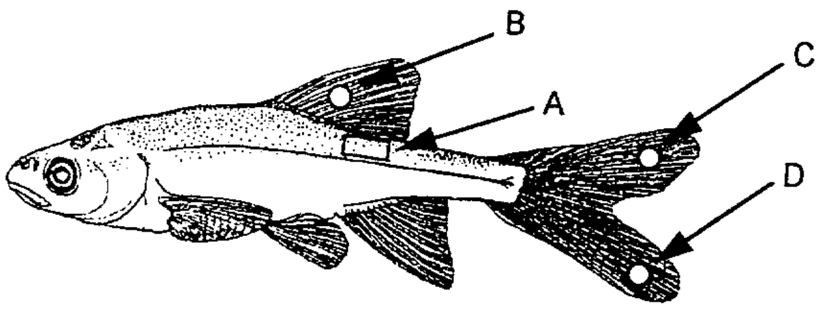


Fig. 13. Juvenile humpback chub with location of scale samples (A), and punches of dorsal fin (B), upper caudal fin lobe (C), and lower caudal lobe (D).

2. The fish was eviscerated and the stomach placed in 95% ethyl alcohol (stomach was not dissected),
3. The fish was skeletonized; i.e., filleted and removed the bulk of the flesh leaving the skeleton and head in tact.
4. A numbered Carlin tag was affixed to the jaw of the skeleton,
5. The dried skeleton was placed in a plastic bag with a label with field sample identification, species, fish length, weight, date, location of capture, and collector.

Native fish

All other native species that died during sampling (i.e., flannelmouth suckers, bluehead suckers, speckled dace) were preserved in 10% formalin for 48 hr then transferred to 95% ethyl alcohol. Appropriate data were recorded on data sheets and on sample bags. Specimens were kept in a secure place (e.g., ammo box) to prevent damage and to prevent theft by ravens.

At the end of a trip all specimens were transferred to a designated Project Leader who in turn transferred these to the AGF designee. All information associated with each fish (Carlin tag number, field sample identification, species, fish length, weight, date, location of capture, and collector) was then transferred to the B/W Principal Investigator, and a "letter of transfer" sent to the Service with copies to AGF, NPS, ASU, GCES, and Reclamation.

Non-native fish

Specimens of non-native fish that were returned to a laboratory for further examination were preserved in the following manner. Fish that were smaller than 75 mm TL were preserved in a 4 - 5% formalin solution, while fish larger than 75 mm TL were placed in a 10% formalin solution. All fish collected were placed in containers of adequate size to prevent distortion or damage during collection and transportation. Care was taken to not overcrowd specimens in containers. A small incision was made on the right side of the abdomen of all specimens greater than 150 mm in length to insure thorough preservation. All collections were labeled with the appropriate sample number, date, and river mile corresponding the information recorded on the data sheet. Labeling was done with permanent markers on the outside of the containers and in pencil on collection labels placed in the container with the fish.

RADIOTELEMETRY

Equipment

Transmitters

Two models of radio transmitters were used in this investigation. The ATS Model 1 BEI 10-18 weighed 9 g and was 3.8 cm long and 1.3 cm diameter. The Model 2 BEI 10-35 weighed 11 g and was 6.0 cm long and 1.3 cm diameter. Both models were oblong with an external antenna at one end that was about 25 cm long and 1.2 mm diameter.

Frequencies of 40.600 to 40.740 megahertz (MHZ) were used in Grand Canyon. These were separated by 10 kilohertz (KHz) intervals (i.e., 40.600, 40.610, 40.620, etc.) to distinguish individual transmitters. This 10 KHz separation yielded 15 different frequencies. The combination of 15 different frequencies and 3 pulse rates (40, 60, and 80 pulses per minute) allowed for a total of 45 unique signatures to identify individual fish. The same combination of frequency and pulse was reused following expiration of a transmitter. Transmitter longevity was a function of battery life. The manufacturer's estimated life for the 9-g transmitters was 50 days. The 11-g transmitters with 40 pulses per minute were expected to transmit for 120 days, those with 60 pulses per minute were expected to transmit for 100 days, and those with 80 pulses per minute were expected to transmit for 75 days. All transmitters were checked prior to implanting and immediately after release of the fish to insure that each transmitter was functional and that frequency and pulse rate were accurately recorded. Frequency and pulse sometimes varied from factory specifications because of temperature, battery age, and varying signal sensitivity from different receivers.

Yard et al. (1990) concluded from field tests with an ATS R2000 programmable receiver and directional Smith-Root loop antenna that signal reception from 9-g external-antenna transmitters was effective at a depth of 4.63 m at a horizontal distance of 48 m on the mainstem Colorado River in Grand Canyon. The same transmitter in the LCR was received at a depth of only 0.91 m at a horizontal distance of 48 m. Internal antenna transmitters weighing 13 g were simultaneously tested with signal reception in the mainstem of 3.96 m depth at 48 m distance, and in the LCR of 0.85 m depth at 48 m distance.

BIO/WEST tested signal reception (ATS R2000 receivers and Smith-Root loop antenna) depth of 11-g external-antenna transmitters used in this investigation and found an average depth extinction of 4.5 m at 50 m distance (three field trials of 4.5, 4.5, and 4.6 m). These results were similar to those reported by Yard et al. (1990). A specially developed internal-antenna transmitter (prototype: 13.2 g, 7.5 cm x 1.3 cm) was simultaneously tested to ascertain if the external antenna could be eliminated while maintaining the same transmisivity and battery life with a transmitter of approximately 13 g. Average signal depth extinction for the prototype was 3.2 m at 50 m distance (three field trials of 3.2, 3.2, and 3.2 m), or 29 % less than the 11-g external-antenna transmitter.

BIO/WEST also tested signal reception distance with an ATS R2000 receiver and a Larson-Kulrod omni-directional antenna and found that at a 1 m depth the signal from the 11-g external-antenna transmitter was received at a distance of 1,200 m, while that of the prototype was received at only 600 m, or 50 % of the distance. BIO/WEST concluded from these tests that the internal-antenna prototype was not suitable for its needs in the Grand Canyon, and continued using the 11-g external-antenna transmitters. Maximum reception distance for the 11-g transmitter with an ATS R2000 receiver and a loop directional antenna was about 500 m at a 1-m depth.

Radio transmitters were implanted without a wax coating following cold sterilization with 90% isopropyl alcohol. Beeswax has been used as a coating in earlier studies to provide an inert surface to minimize risk of rejection and expulsion (Tyus 1988). However, the manufacturers of the transmitters contend that the epoxy resin used to encase the electronic components is non-irritating and can be more effectively sterilized than beeswax (M. Shuster, ATS, pers. comm.). Beeswax would have added undesirable weight and bulk to the transmitter, which is critical with the small size of humpback chub.

Transmitter weight could not exceed 2% of fish weight (Bidgood 1980, Marty and Summerfelt 1990), hence 9-g transmitters were implanted only in fish weighing 450 g or more, and 11-g transmitters were implanted in fish weighing 550 g or more. Care was taken to select fish that were healthy and showed no signs of stress. Females were usually not implanted from March through May to prevent stress to these gravid fish and to eliminate the risk of transmitter expulsion from enlarging egg masses (Bidgood 1980, Marty and Summerfelt 1990).

Receivers

ATS Receiver: The ATS Model R2000 is a scanning-programmable receiver, used in this investigation to receive radio frequencies of 40 to 41 MHZ in omni-directional searching, directional triangulation, and in remote stations. This receiver was used because of its light weight, compactness, water resistant case, and compatibility with ATS radio transmitters. It was easy to use with nearly unlimited capacity to quickly and easily add or delete frequencies. The disadvantage of this unit was that it scanned single preprogrammed frequencies instead of multiple frequencies simultaneously. The unit had an optional scan rate setting of 2, 4, 8, 16, or 32 sec, or 1, 4, 8, or 16 min. If the unit had 10 preprogrammed frequencies set at 4-sec-intervals (time to scan a single frequency), all 10 frequencies were scanned in 40 sec or a given frequency was scanned every 36 sec. ATS receivers were normally used at the 4-sec scanning rate and all radiotelemetry searches and surveillences were conducted in a slow, methodical manner with observers using headsets to reduce the possibility of missing audible signals. The characteristic water-drop sound from radio transmitters was audible through the ATS R2000, and the unit had a visual signal strength meter. The ATS R2000 was portable with nickel-cadmium batteries that were rechargeable and replaceable in the field. Twelve-volt marine batteries were sometimes used as power sources when the battery pack was low, but these became cumbersome when tracking from shore.

Smith-Root Receivers: The Smith-Root SR-40 (Fig. 14) was also used for omni-directional searching. This model receiver was previously used to successfully track, via airplane and boat, Colorado squawfish (Ptychocheilus lucius) and razorback sucker (Xyrauchen texanus) in the Green River, Utah (Valdez and Masslich 1992). The SR-40 was preferred for aerial tracking because it simultaneously scanned multiple preprogrammed frequencies. This receiver emitted audible and visual contact signals. A bank with 10 red lights corresponding to preset frequencies enabled trackers to confirm audible with visual signals.

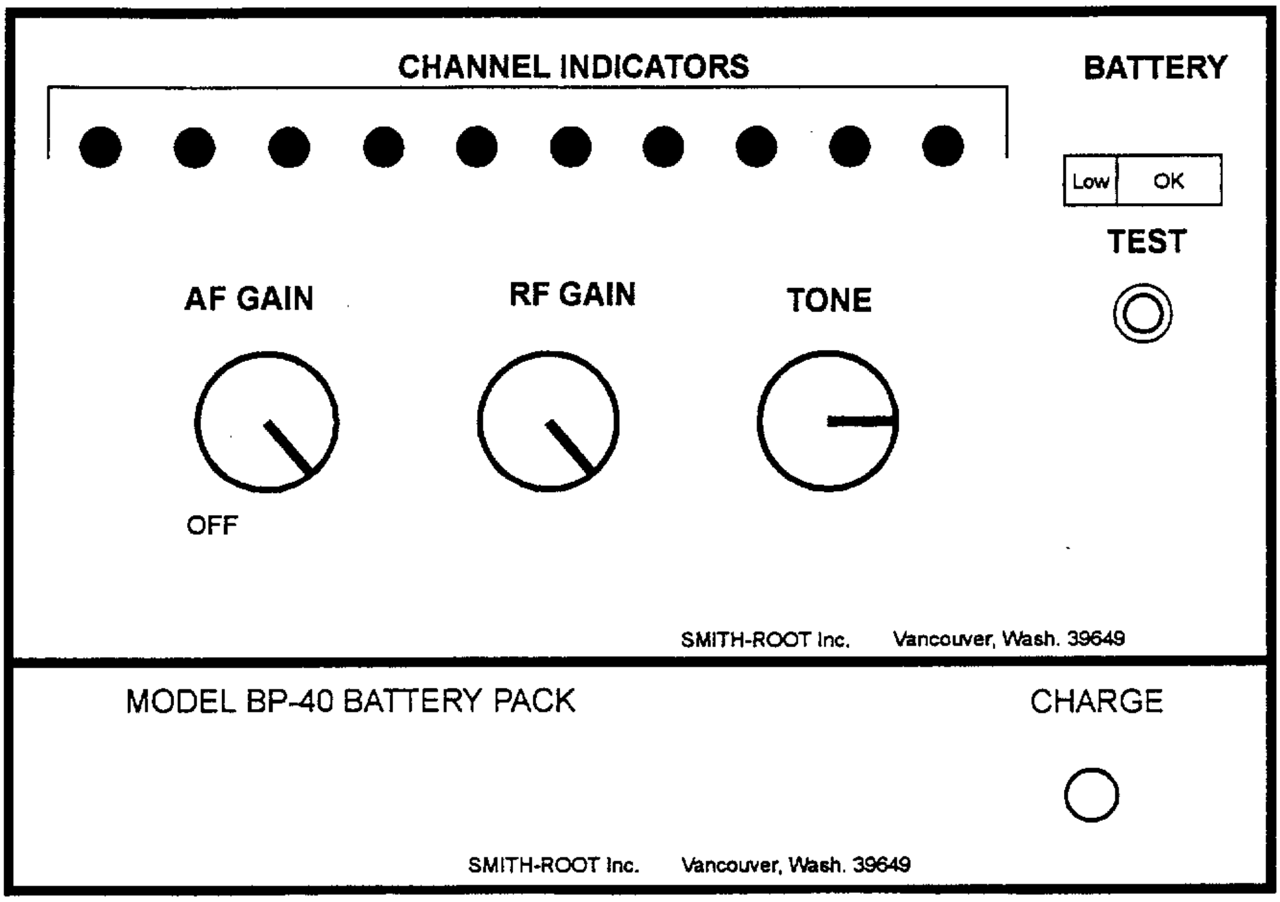
The disadvantage of the SR-40 was that it accommodated only 10 preprogrammed frequencies that were set by the manufacturer. Although it received signals from similar frequencies, it did not register weak signals from intermediate frequencies. Unique frequency/pulse combinations were difficult to distinguish with this unit, particularly when multiple frequencies were contacted (multiple audible and visual signals emit simultaneously), or when two or more fish occupied the same area with transmitters of similar frequency and pulse rate. Frequencies were also difficult to identify when fewer than three signal contacts occurred.

The Smith-Root RF-40 (Fig. 14) programmable receiver was used as a companion to the SR-40 in past investigations (Valdez and Masslich 1992), but the unit is no longer manufactured. The SR-40 was used as a backup to the ATS R2000, or the two units were used simultaneously to insure complete surveillance coverage. Although the battery pack for the SR-40 was separate from the receiver, keeping batteries charged was difficult with different users and various power drain schedules.

Antennas

Omni-directional Larsen-Kulrod whip antennas were used with ATS R2000 and SR-40 receivers for searching radio signals. Smith-Root loop antennas were used for locating signals by triangulation. Breakage and fraying of the external sheath of the coaxial cable at the handle base of the loop antenna and near the base plate of the whip antenna required frequent checking and periodic maintenance. All antennas were carefully checked before each use. Small breaks or frays in the coaxial cable weaken or voided signal strength and loss of contact with the grounding sheath of the coaxial cable deactivated one side of a directional antenna, causing large errors in triangulation.

Smith-RootRF-40



Smith-Root SR-40

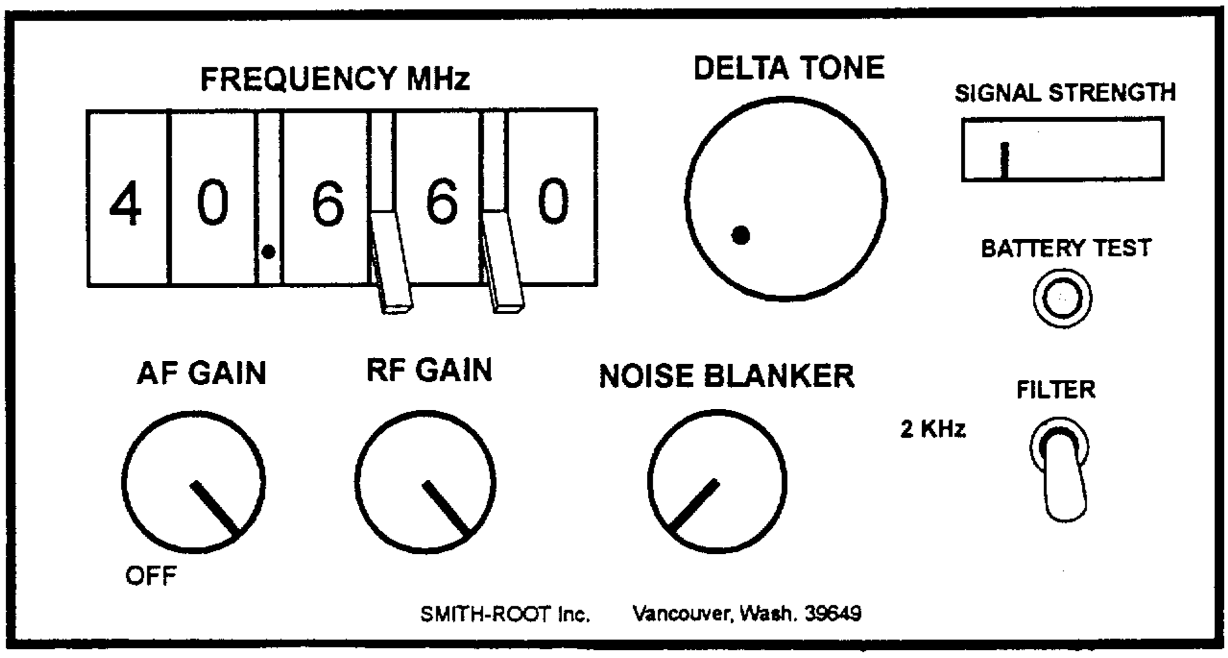


Fig. 14. Operational features of Smith-Root RF-40 (A) and SR-40 (B) radio receivers.

Remote Stations

Remote stations deployed for this investigation were established under the guidance of Grand Canyon National Park. Two remote telemetry stations were established in 1991 and 1992 near the mouth of the LCR to monitor movement of radio-tagged fish to and from the LCR (Fig. 15). One station (KLCR), located immediately upstream of the LCR confluence (RM 61.3) and on the east bank of the Colorado River, had a directional yagi antenna aimed across the river at the upper mouth of the LCR. The second station (KRSH) was located downstream of the LCR confluence (RM 62.1) on the west bank of the Colorado River with a directional yagi antenna aimed across the river in line with the shallowest point in the channel. The antennas were not aimed directly across the LCR because previous tests (Yard et al. 1990) showed signal impedance from high conductance during clear flows from that tributary. These stations were each equipped with a directional Proline low band yagi antenna (30 to 75 MHZ). These two stations operated February through August of 1991 and 1992 and were dismantled after 1992.

A third remote station (KILR) was deployed in mid-August of 1991 and operated through January 1992, about 1 km upstream of the LCR confluence on the east bank of the Colorado River. This station was equipped with an omni-directional Larsen-Kulrod whip antenna to monitor daily near-surface activity of radio-tagged fish from RM 59.9 to RM 61.3.

Two omnidirectional stations established in Middle Granite Gorge were operated February through September 1993 (KBNE, RM 126.1), and March through September 1993 (KMGG, RM 127.4).

Each remote station was equipped with an ATS Model R2000 receiver (data logger compatible) and a DCC-II Model R5041 data logger. Data were downloaded at the beginning and end of each field trip with a portable computer. The receiver and data logger were housed in locked weatherproof boxes to prevent damage from elements and vandalism. Each station was properly identified in case it was discovered by someone not familiar with the project. The weatherproof boxes and yagi or omnidirectional antennas were painted drab brown to camouflage the station and reduce visibility.

Problems with power supply and static surges associated with electrical storms were the main problems with remote stations in Grand Canyon. A solar powered recharger was incorporated into each station to resolve power problems, although lack of adequate solar radiation in the canyon during winter months resulted in lower power supply, and cold winter temperatures adversely affected battery efficiency. Grounding cables were used to minimize risk of static from electrical storms.

Radio tracking

Aerial Radio tracking

Aerial tracking was sometimes conducted prior to a field trip to locate radiotagged fish thought to be outside of routine tracking areas. Aerial tracking was conducted from a helicopter, at an altitude of 500 to 1,000 feet and speeds of up to 80 miles per hour (mph).

Two types of radio receivers were used for aerial tracking, a Model 2000 ATS programmable receiver and a Smith-Root SR-40 simultaneous scanning receiver. Each was attached to one of two Larsen-Kulrod omni-directional whip antennas mounted to the struts of the helicopter (Fig. 16). The antenna on the pilot's side was connected to the Model 2000 ATS receiver and the antenna on the passenger's side was connected to the SR-40 receiver. Output signals from both receivers were routed through a switch box to two sets of headphones, one for the tracker and one for the pilot.

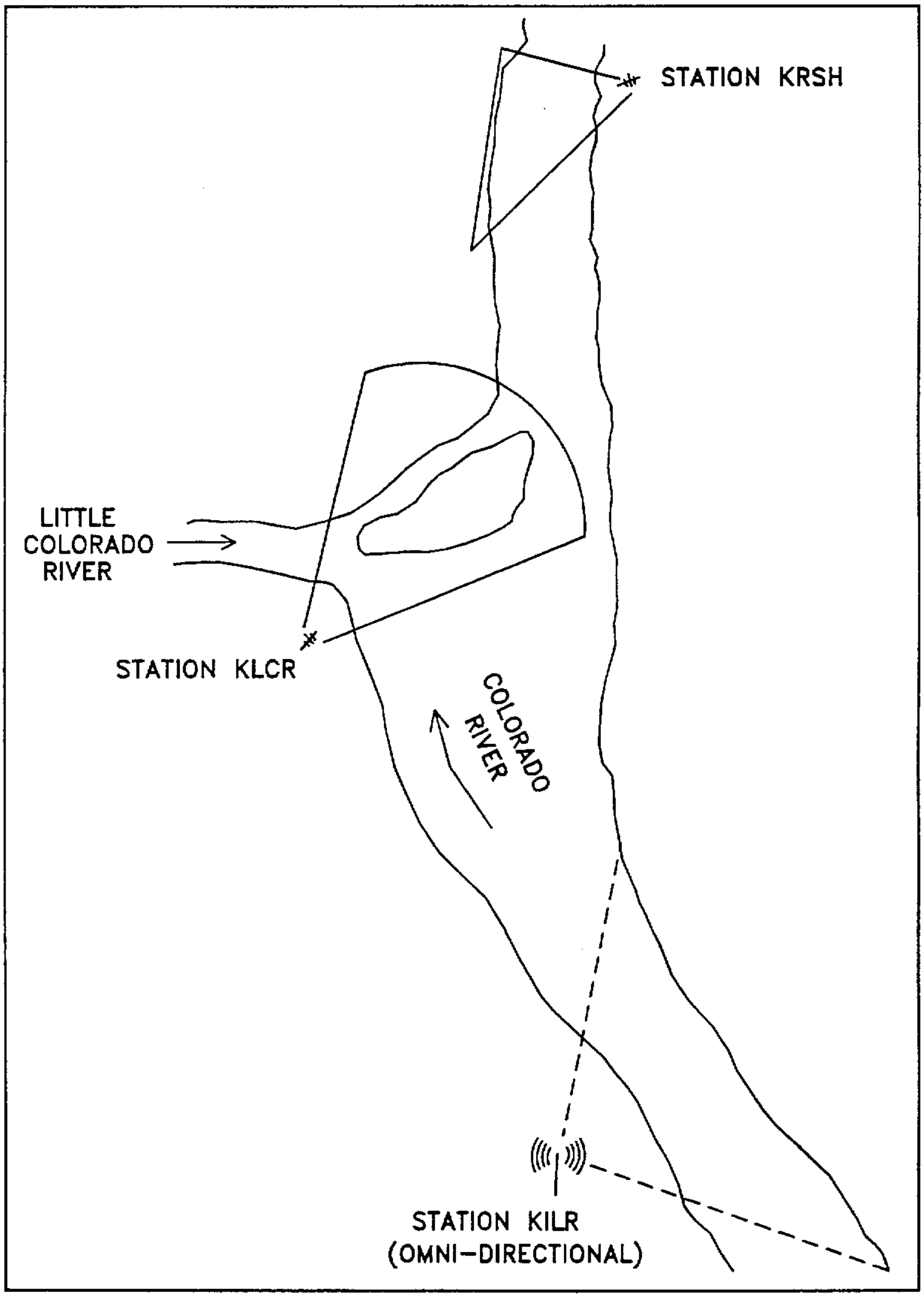


Fig. 15. Approximate receiving zones for three remote telemetry stations near the mouth of the Little Colorado River.

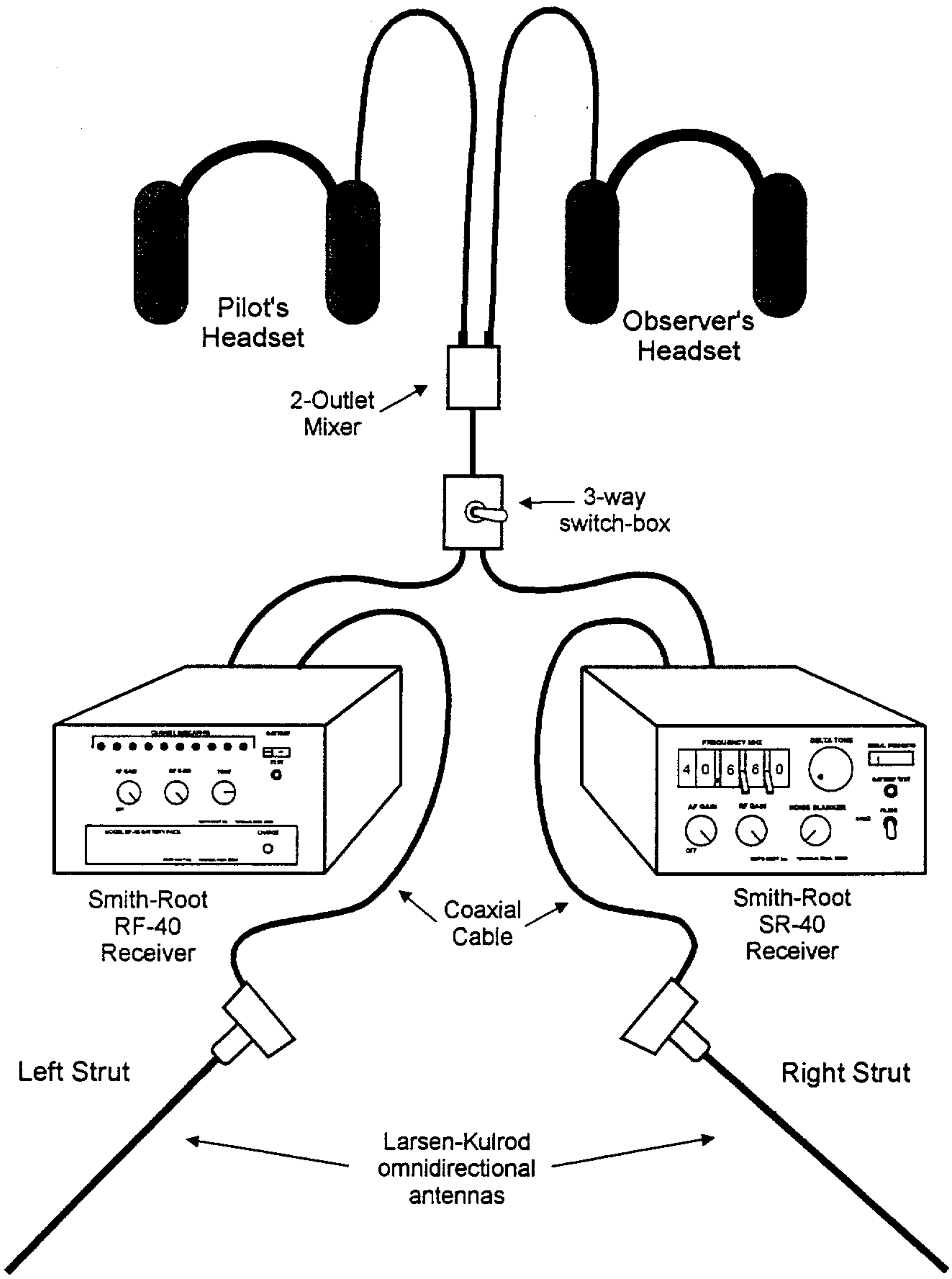


Fig. 16. Diagram of radio receivers, antennas, switches, and headsets used with aerial tracking of radio-tagged fish.

This enabled the tracker to switch back and forth between the two receiver outputs, and the signals were heard by both tracker and pilot to enhance coordination and quick course adjustments.

All active transmitter frequencies were programmed into the ATS Model R2000 receiver prior to each aerial tracking effort. A list of all frequencies and pulse rates for active transmitters, as well as last known locations of transmitters was made available to the tracker. Surveillance flights usually proceeded in a downstream direction for the entire length of the study area. Since the Smith-Root-40 had the capability to simultaneously scan all frequencies, the chance of missing signals was minimized and tracking speed was not as restricted as with cycling search receivers such as the ATS.

When a signal or signals were received by the SR-40, the pilot was asked to remain stationary or circle the area slowly in a counter clockwise rotation so that the pilot side, or programmable receiver antenna, was located on the inside of the rotation for constant signal reception. The tracker then tuned the programmable receiver to the most likely frequency in the area. The transmitter signal was identified when the signal from the scanning receiver matched the signal from the programmable receiver. The pulse rate of the transmitter was easily determined since only three highly separable rates were used--40, 60 or 80 pulses per minute. Fish location could be determined by listening to variation in signal strength with orientation of the antenna. Once a frequency had been confirmed, the fish location was plotted on a map for later transfer to the field crew. Most fish were located within 400 m of actual location. The aerial tracking continued until all transmitters were located or a reasonable search had been conducted. Aerial surveillances by helicopter were conducted three times, but discontinued because fidelity by radio-tagged fish to specific areas precluded the need for widespread searches.

Ground Radio Tracking

Surveillance: Surveillance radio tracking was conducted from research and logistic boats during downstream travel, beginning from Lees Ferry and continuing to the take out point for each trip. Radio receivers were stowed in water-proof boxes in whitewater sections, but remained accessible so that tracking efforts could continue once rapids had been negotiated. Tracking was conducted from more than one boat, if possible, to monitor both sides of the channel. Data were recorded on Form 5 of Appendix A.

Radio tracking was done with either the Smith-Root SR-40 scanner or the ATS Model R2000 programmable receiver using Larsen-Kulrod omni-directional whip antennas mounted on large metallic base plates such as cargo boxes. Contacts made from the larger S-rigs had to be confirmed and pinpointed later by using smaller research boats. If a radio contact was made from a support boat at a location where a return trip was considered impractical, the operator of the support boat was asked to make an effort to land the boat so that the location of the fish could be determined.

Multiple surveillance runs were made daily with the small research boats through the region of river occupied by radio-tagged fish. The purpose for this surveillance was to determine diel patterns of near-surface activity and long-range movements. Signal locations were marked on 1:2,400-scale aerial photographs, and a confidence level of 1 (high, <10 m), 2 (medium, 10-100 m) or 3 (low, 100-400 m) was assigned to each location as an index of observer confidence for resolution of location accuracy, i.e., triangulation was usually inaccurate at night, in proximity to canyon walls, during inclement weather, and with faint or inconsistent signals. Habitat type was recorded at each radio contact location, and water clarity was measured at least once daily with a Secchi disk, and beginning in March 1992, turbidity as NTUs was measured daily. Locations of implanted fish were plotted on mylar overlay maps and later digitized into a GIS system.

Observation: Individual radio-tagged adult humpback chub were observed for periods of 2 to 72 hr to characterize local movement and habitat use by season, time-of-day, turbidity, flow, ramping rate, and magnitude of flow change. Data were recorded on Form 4 of Appendix A. Local movement or activity was defined as movement within macrohabitats or habitat complexes, and was represented two-dimensionally as horizontal movement. Fish chosen for monitoring were not randomly selected because fish could not consistently be contacted in water deeper than about 4.5 m. Thus, fish were monitored when their radio signal was audible. When a fish was contacted, an attempt was made to determine its general location from the boat using an ATS Model R2000 receiver and a directional loop antenna. When the general location was established, the tracking boat was taken to the shore nearest the fish using care to not disturb the fish. An ATS Model R2000 programmable receiver and directional loop antenna were used from shore to triangulate the position of the fish in the channel.

A fish that would potentially be monitored for 2 hr was first observed for 30 min to accurately determine its position. If the fish was stationary, its location was triangulated and marked. The fish was then monitored for an additional 1.5 hr to determine habitat use. Triangulation locations were marked for all areas where the fish remained stationary for 15 min or more during the 1.5 hr monitoring period. If the fish was moving, its movements were monitored for an undetermined amount of time to ascertain if behavior or movement patterns were related to various factors including: 1) stage change, 2) local macrohabitats, or 3) other radio-tagged fish in the area. If the fish became stationary, it was monitored as described for a stationary fish.

Fish monitored for longer than 2 hr were carefully observed for habitat use and movements particularly during changes in flow stage. Each movement by a fish and each area occupied for longer than 15 min was mapped on a mylar overlay over a 1:2,400 scale photograph of the area, with sequential observations conducted every 0.25 hr. River stage, monitored on temporary bench marks with an abney level, was recorded for each observation for the fish. Generally, fish monitored for 24 hr were checked every 1 to 2 hr or more frequently if river stage was changing rapidly.

Variation in river stage was monitored with temporary staff gages surveyed to temporary bench marks (TBM). Temporary bench marks were established at strategic locations in the study area in order to relate fish movement and habitat use to river stage. Each TBM was surveyed into one of 50 permanent USGS bench marks at a latter date so that relative stage changes could be related to absolute changes and thus to specific flow releases from the dam. The temporary staff gages were employed only during field trips for radiotelemetry monitoring and habitat mapping. The temporary staff gages were placed as near as possible to the sample site (location of radio-tagged fish) or within an area to be mapped. Readings were taken from the temporary staff gage as needed.

A detailed hand drawn map or a detailed map using a mylar overlay on an aerial photograph (depending on photo availability) was prepared for each fish that was monitored. Distance and direction of all movements were recorded on the map and in the telemetry log relative to time and river stage. Locations and movements between subsequent locations were transferred to GIS files as a record of movement for comparison with channel bathymetry, macrohabitat, substrate type, temperature, and flow.

Observation periods were divided into blocks for analysis, each spawning time between consecutive locations. A given observation period was usually composed of many blocks, each representing a movement by fish under specific conditions. To standardize blocks for analysis, only those with elapsed time of 0.25-1.0 hr were used, and included 1,831 blocks (90% of total) with a total elapsed time of 962.8 hr. Detectable fish movement during a time block was defined as movement 5 m or greater, the approximate observer triangulation error. Proportion of movement (Pm) was used as an index of fish movement or activity and was calculated using the following equation.

$$P_m = BM/BT \quad \text{(Equation 1)}$$

where: P_m = proportion of movement,
BM = number of blocks with movement, and
BT = total number of blocks.

Categories of season, time-of-day, and turbidity were the same as described for surveillance. Mainstem flow in 0.5-hr intervals was determined from the Colorado River USGS gaging station (#9383100) just above the LCR confluence. Flow was classified as high (≥ 10,000 cfs) or low (< 10,000 cfs), with the dividing point close to the mean flow during observations (mean=10,874 cfs; range, 4,778 - 29,916 cfs). Absolute ramping rates were calculated from flow measurements nearest the start and end times of an observation period and were classified as high (≥ 300 cfs/hr) or low (< 300 cfs/hr). Ramping rates ranged from 0 to 8,833 cfs/hr and averaged 454 cfs/hr during observations. Periods of continuous 24-hr observations were used to evaluate fish movement under research and interim flow regimes, since flow changes typically cycled through 24 hr. Proportion of movement from 24-hr observations was also related to magnitude of flow change, i.e., the difference between high and low flows within a flow cycle.

Radiotelemetry in Middle Granite Gorge was used primarily for tracking movement and dispersal of adults from a small disjunct aggregation of humpback chub prior to the expected spawning period of April and May. The area was surveyed and radio-tagged fish were monitored in the same manner as described for the LCR inflow area.

At the conclusion of monitoring, habitat measurements were taken at all locations where the fish was stationary for at least 15 min. Habitat measurements taken at each point included depth, velocity, substrate, temperature, overhead cover, and lateral structure.

Remote Telemetry

Two directional remote telemetry stations were used to evaluate humpback chub use of the LCR confluence by identifying specific times in which radio-tagged fish were present (Fig. 15). Maximum antenna range was approximately 500 m, as determined by deploying test tags at a 1-m depth at increasing distances up- and downstream from each station. Upstream or downstream movement to and from these monitored areas was inferred from surveillance locations identified before and after contact by a station. Season and duration of use of the LCR confluence and specific timing of movements by adults between the mainstem and LCR were determined with this monitoring system.

Three omni-directional remote telemetry stations were deployed to assess near-surface activity of radio-tagged fish in the LCR inflow aggregation (KILR) and Middle Granite Gorge aggregation (KBON and KMGG). Although antenna ranges were not established for KBON or KMGG, effective ranges were assumed to be similar to KILR, or about 1,200 m. To permit comparisons with telemetry surveillance data, only remote telemetry data collected during field trips when turbidity data were collected were analyzed. Average proportion of radio contacts with remote telemetry (APRC) was also used as an index of near surface activity:

$$APRC = \sum(CO/CE)/n \quad \text{(Equation 2)}$$

where: APRC = average proportion of radio contacts,
CO = number of radio contacts within a specified time period,
CE = number of possible contacts within the same time period, and
n - number of time periods.

Average APRC was related to turbidity and time-of-day, but seasonal effects could not be evaluated because KILR was operated only during non-spawning periods and an appropriate spawning season could not be identified for the Middle Granite Gorge aggregation. Diel periods and turbidity levels were the same as defined for telemetry surveillance. APRC values were arcsin transformed (Sokal and Rohlf 1987) to normalize the data for statistical analysis.

Fish Handling Procedures for Radio implant

Fish captured for radio tagging were handled with particular care and attention to minimize stress in preparation for surgical implant. The fish were held in a separate live well for transportation to a central surgical station and constantly monitored for signs of stress. Surgical equipment was kept clean and available in a designated 10 ft x 20 ft tent to minimize preparation time. Two 80-qt coolers were used as live wells, one with anesthesia, and one with fresh river water for postsurgical recovery.

In the event that a candidate fish was captured some distance from a central surgical station, or the crew was unable to safely return to the station (e.g., low water), the fish was radio-implanted at a temporary field station close to the point of capture. Each research boat carried a full complement of surgical apparatus including surgical instruments, sterilizing agent and reservoirs, portable work tables, radio transmitters and receivers, and live wells.

Surgical Procedures

A surgical protocol was established from procedures developed by Valdez and Nilson (1982) and Kaeding et al. (1990) for humpback chub; Tyus (1982) for Colorado squawfish; and Valdez and Masslich (1989) for Colorado squawfish and razorback sucker.

Surgical implants were performed in an enclosed tent to minimize exposure to blowing sand and reduce the risk of infection. Two trained members of the B/W staff were designated with the primary responsibility of insuring that all aspects of surgical procedures were followed and monitored. The surgical procedures were practiced by these individuals so that a surgery could be completed within 6 min (first incision to last suture). Three people were involved with surgery--a surgeon, an assistant, and an anesthetist to administer anesthesia and monitor respiration of the fish. The principal surgeon was a former employee of Gore Laboratories with considerable experience in animal surgery and use of surgical materials used in this study.

Fish were selected for radio implant based on weight, condition, and location of capture. Prior to surgery, each fish was measured and weighed, and all surgical instruments were cold-sterilized with 90% isopropyl alcohol and allowed to air dry on a disposable sterile cloth. Two 5-gallon buckets were placed above the level of the surgical table, one with anesthetic solution and one with fresh river water. Each bucket was drained with a 5-foot length of tygon tubing allowing the anesthetist to alternately irrigate the gills of the fish with anesthetic or fresh water, according to the reaction of the fish. Small spring C-clamps were used to control flow through the tubing. Fish were mildly anesthetized with Finquel, a brand of tricaine methanesulfonate (MS-222), at a concentration of 100 mg/l for 2-4 min, or until fish lost equilibrium and rolled on its side in the holding tank, but continued moderate opercular movement (25-30 movements per minute). During surgery, gills were bathed with anesthetic at 50 mg/l, as needed, and then with fresh water about half way through the surgery to expedite post-surgical recovery.

Primary Incision: The fish was removed from the anesthetic bath by the anesthetist and placed on a surgical cradle. The surgeon then wiped the abdomen with a sterile saline swab and made a 2-3-cm long incision at one of two locations; abdominal midline or lateral to the midline. The midline incision was located on the belly about 2 cm anterior to the pelvic girdle along the linea alba (Fig. 17). The lateral incision was on the left side of the fish, midway between the pectoral and pelvic fins and about 1 cm lateral to the linea alba. The radio transmitter was inserted through the primary incision and positioned on the pelvic girdle with the antenna protruding through the abdominal wall, posterior to the pelvic girdle and anterior to the vent.

Incisions along the linea alba have been the standard procedure for most transmitter implants (Hart and Summerfelt 1975, Marty and Summerfelt 1986, Marty and Summerfelt 1990, Bidgood 1980, G. Klontz, Univ. of Idaho, pers. comm.). Midline incisions are conventionally used in abdominal surgeries in veterinarian practices because the linea alba is a fascial plane that is stronger than muscle fibers with little nerve and vascular tissue (Marty 1991; V. Seggern, W.L. Gore and Assoc., pers. comm.; and Cosgrove, Univ. of Calif., Davis). Studies show that properly-sutured midline incisions are nearly as strong as those of the lateral wall (Marty and Summerfelt 1990). Lateral incisions were used in the Upper Colorado River Basin on humpback chub (Valdez and Clemmer 1982, Kaeding et al. 1990) and Colorado squawfish and razorback suckers (Tyus 1988, Valdez and Masslich 1992). Lateral incisions were preferred in these species to reduce irritation of the suture line from visceral pressure, and lessen the likelihood of abrasion of sutures with the river bottom. Marty and Summerfelt (1986) noted that the ventral body wall thickened rapidly lateral to the midline, making surgery difficult with more lateral incisions. Incisions of the lateral body wall generally bleed more than incisions of the midline because the body wall is more vascularized. It is important to avoid bleeding because clots lead to the formation of adhesions (Rosin 1985) that are the first step in the process of transintestinal expulsion. Incision location was not mentioned as a factor of transmitter expulsion by Marty and Summerfelt (1990), but Tyus (1988) felt that incision site may have a bearing on transmitter expulsion.

Antenna Exit: A drawback of external-antenna transmitters is the need to expose the antenna to insure proper signal transmission. The point where the antenna protrudes from the body cavity can be an avenue for bacterial invasion. This area is often aggravated by the rotating action at the antenna caused by water currents. Many methods have been used for passing the external antenna through the body cavity. Winter et al. (1978) used a knitting needle to tunnel a cavity under the skin to an exit point. Ross and Kleiner (1982) used an eyed, curved rug needle sleeved with 0.5-cm diameter plastic tubing to pass the antenna the length of the abdomen and through the wall. Chart and Cranney (1991) used the same shielded needle technique to implant 86 hatchery-reared bonytail (Gila elegans) for release into the Green River, Utah. These techniques led to problems with possible damage to the peritoneum and vital organs, as well as possible bacterial contamination.

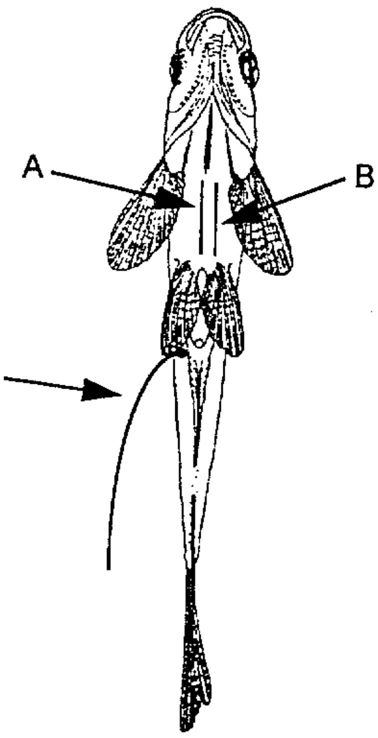


Fig. 17. Primary abdominal incision on midline (A) or lateral to the midline (B), and external antennae (C) of implanted radio transmitter in adult humpback chub.

Two techniques were used in this investigation to pass the transmitter antenna through the abdominal wall. One involved passing the antenna through a small incision with mosquito forceps and suturing anteriorly and posteriorly at the exit point. The second technique used a specially-designed "sleeved needle antenna guide" (SNAG) developed by B/W.

The SNAG consisted of a gently curved 20-cm long hollow stainless steel needle inside a 15-cm long hollow stainless steel sheath. The inside diameter of the inner needle was 0.06 inches (1.52 mm), which accommodated the antenna, with an outside diameter of 0.05 inches (1.27 mm). The sheathed needle was inserted in the primary incision and guided to a point posterior to the pelvic girdle where the needle was pushed through the abdominal cavity. The sheath was removed and the antenna threaded through the needle. The needle was pulled through the antenna exit leaving the antenna in place. This technique allowed for the peritoneal tissue to seal the antenna exit and reduced the risk of bacterial invasion. The antenna was pulled through the exit hole while guiding the radio transmitter through the primary incision to a position on the pelvic girdle. The trailing antenna was clipped in line with the end of the hypural plate of the fish to prevent fraying of the tail fin. When a fish was recaptured with a non-functioning radio transmitter, it was weighed and measured, and examined to document recovery or complications associated with radio implant procedures. Photographs were taken of the fish to document general condition, and of the primary incision and antenna exit to document rate and degree of healing or signs of necrosis. Protruding antennae from expired transmitters were cut approximately 1-2 cm from the body wall to remove frictional drag and reduce stress to the fish. Expired transmitters were not removed from fish.

Suture Material: Three to five sutures were required to properly close the primary incision. Two types of suture material were used; CV3 Gortex non-absorbable and 3-0 Maxon absorbable. CV3 Gortex was used on the first 31 fish implanted from October 1990 through March 1991. The 3-0 Maxon absorbable suture was used on 23 fish implanted from May through November 1991 and became the preferred suture material. The 3-0 Maxon is a polygluconate monofilament suture that was absorbable over long-term (G. Marty, Univ. of Calif, Davis, pers. comm.). Monofilament suture was less likely to wick water and bacteria into the abdominal cavity, as was possible with Gortex sutures. Long-term absorption (90 days) allowed the incision ample time to heal before the sutures dissolved, particularly in the 8 - 10°C temperatures of the Colorado River in Grand Canyon. A PH 26 curved needle was standard with each suture material. Other investigators have used 3-0 prolene sutures (Ethilon) with Colorado squawfish and razorback suckers (Tyus 1988, Valdez and Masslich 1992), humpback chub (Valdez and Nilson 1982, Kaeding et al. 1990), and bonytail (Chart and Cranney 1991).

The CV3 Gortex suture (developed by W.L. Gore and Associates) was originally selected because of its handling ease, excellent tensile strength, and incorporation by healing tissue. However, inflammation was noted around the sutures of the first six fish recaptured, indicating that the porosity of the suture allowed bacterial wicking from the unsterile river environment into the abdominal cavity (V. Seggern, W.L. Gore and Assoc., pers. comm.).

HABITAT ASSESSMENT

Riverine habitat was described by physical attributes of the river channel and resultant hydraulic characteristics within defined geomorphic regions. Habitat use by subadult (YOY and juveniles) and adult humpback chub in the Colorado River in Grand Canyon was determined by fish capture locations and radiotelemetry observations. Habitat selection was inferred through comparisons of habitat availability and use and life-history needs of humpback chub.

Habitat Descriptions and Availability

Since channel geomorphology and predominant shoreline geology are determined by successive rock layers encountered by the river, habitat descriptions were based on geologic formative processes reflected in channel width, channel depth, slope, and shoreline lithology. These change longitudinally and shape hydraulic characteristics, that in turn affect depth, velocity, substrate, and cover of fish habitat. These characteristics were identified at four levels of resolution (i.e., longitudinal geomorphic reaches, shoreline types, hydraulic units, and shoreline microhabitat measurements) containing descriptors consistent with those used by other investigators in the Colorado River Basin (Valdez and Wick 1983, Tyus 1984, Kaeding and Osmundson 1989, Harvey et al. 1993, Stanford 1994, Osmundson et al. 1995) and with an integrated description of resources in Grand Canyon (Werth et al. 1993).

The first level consisted of 11 geomorphic reaches consistent with the designations of Schmidt and Graf (1990), subsequent levels were embedded within each reach, i.e., eight shoreline types within each geomorphic reach, eight hydraulic units within each shoreline type, and four microhabitat parameters within each hydraulic unit (Fig. 18). A similar classification system was used by Anderson et al. (1986) to analyze aquatic habitat for low and high flows of the Colorado River in Grand Canyon from video imagery, and to provide a comparative data set.

Availability of habitat in select subreaches of the mainstem was determined from (1) maps with visual interpretations of macrohabitat and shoreline types, (2) channel bathymetry, (3) velocity isopleths, (4) temperature isopleths, (5) maps with visual interpretation of substrate types, and (6) shoreline fish microhabitat measurements. Map products (1) through (5) were incorporated into the GCES Geographic Information System (GIS) developed for resource monitoring of the Colorado River in Grand Canyon (Werth et al. 1993). Shoreline microhabitat measurements were integrated into a fisheries database and stored in dBASE IV. Each map product was referenced to an established control network for use as informational layers on the GIS. A multi-temporal, multi-accuracy GIS database was developed to accommodate the different data types and accuracies associated with these maps (Hougaard and Valdez 1994).

Level 1: Geomorphic Reaches

The 11 geomorphic reaches described by Schmidt and Graf (1990) were the basis for longitudinal comparisons of fish habitat. Major geologic units at river level, width to depth ratio, channel width, channel slope, and bed composition were described for each reach to provide a longitudinal characterization of fish macrohabitat. A more detailed analysis was conducted for two subreaches with the largest aggregations of humpback chub, the LCR Inflow (LCRI) and Middle Granite Gorge (MGG), and compared with a third subreach with few fish, in order to identify important geomorphic variables in determining reach selection. That analysis compared number of debris fans, slope, and average width to depth ratio. Water temperature was also considered because of the dominating influence of cold hypolimnetic releases from Glen Canyon Dam.

Level 2: Shoreline Types

Shoreline types were classified to reflect predominant formative shoreline geology, and included bedrock, cobble bars, debris fans, sand bars, and talus slopes (Table 2, Fig. 19); vegetated banks were identified as a sixth category because of their influence on fish distribution and abundance. Shoreline

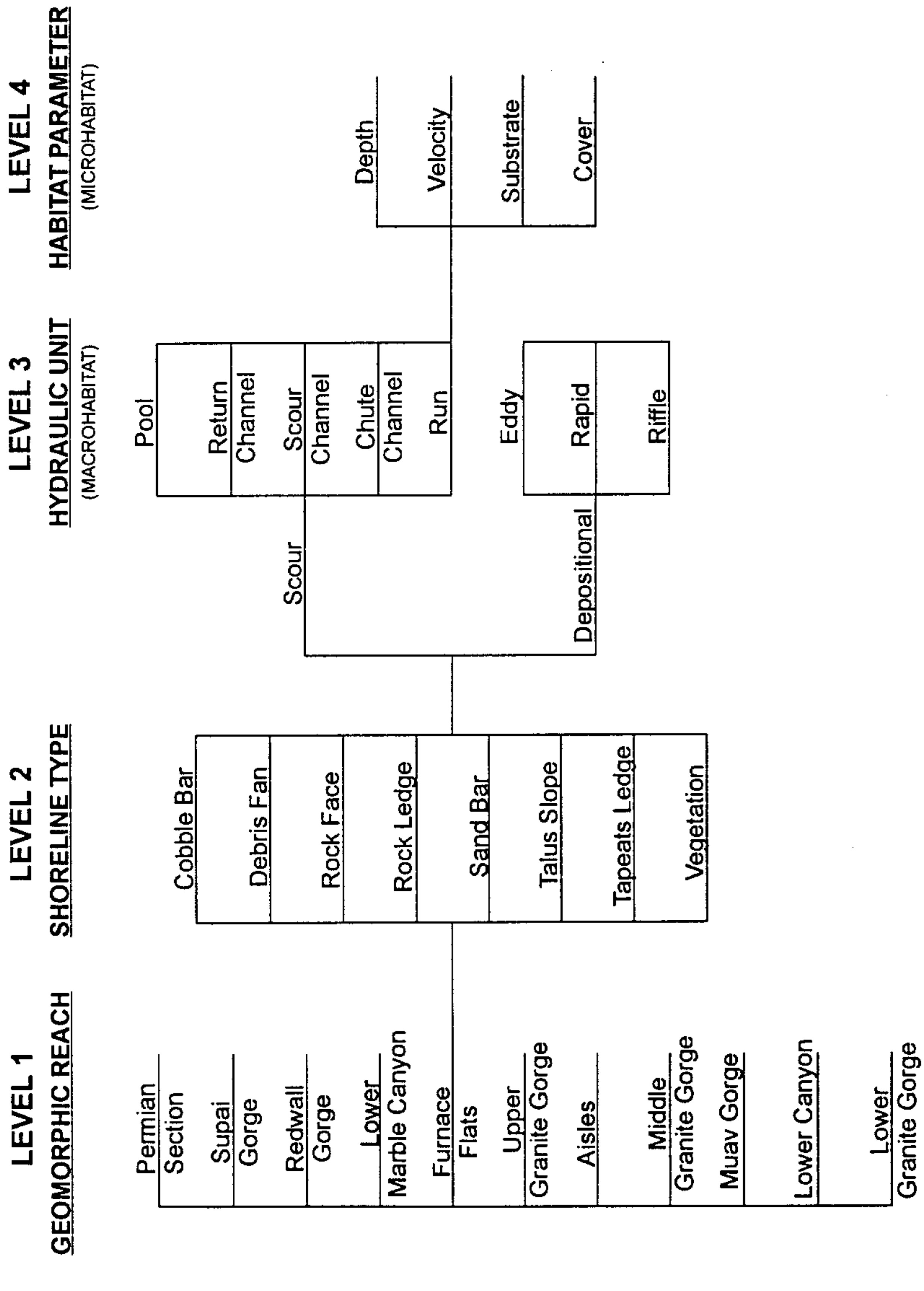


Fig. 18. Dendrogram of a classification system for fish habitat in the Colorado River, Grand Canyon.

Table 2. Shoreline types and definitions associated with fish habitat of the Colorado River in Grand Canyon.

SHORELINE TYPE	DEFINITION
Bedrock	Exposed underlying parental rock material.
Cobble Bar	Cobble transported and rounded by main channel activity, characteristically well worked and imbricated. May show embededness.
Debris Fan	Material transported from a tributary during flood events, primarily boulders and cobble rounded by transport processes. Material is often embedded, and the angle of repose is generally flatter than talus.
Sand Bar	Predominantly exposed sand.
Talus Slope	Unconsolidated colluvium, predominantly angular boulders, deposited by rockfalls or rockslides from canyon walls. Talus is characteristically not embedded, and has a steeper angle of repose than alluvial fans.
Vegetation	Inundated plant material, consisting of stems, leaves, and/or root wads.

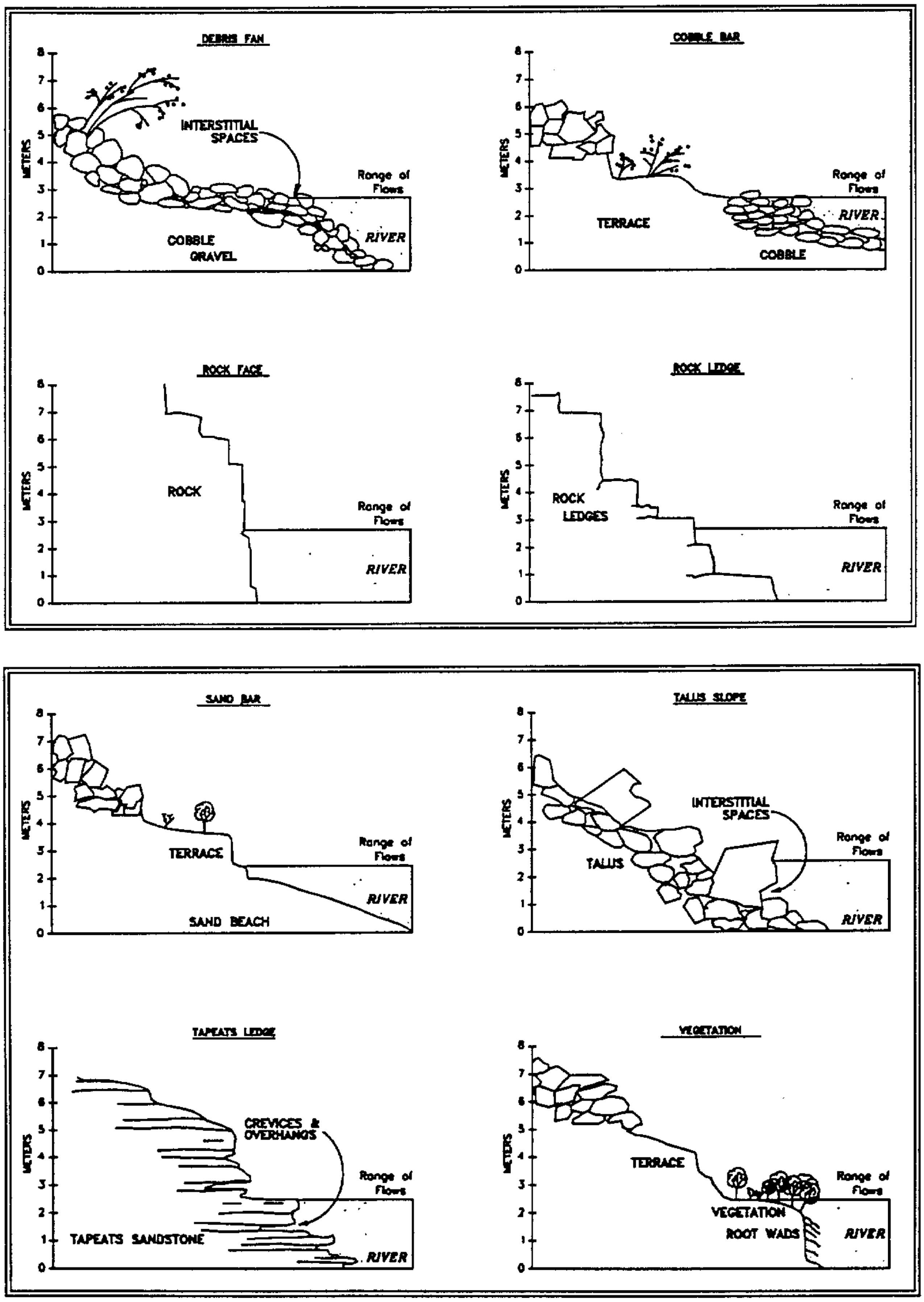


Fig. 19. Cross-sections of hypothetical shoreline types.

and macrohabitat types (see Level 3: Hydraulic Unit) were visually delineated at seven map sites and various flows, between RM 59.75 and RM 63.24, to determine changes in availability with fluctuating flows. This classification was similar to that used by Werth et al. (1993), except that rock ledge and rock face were combined into bedrock and alluvial fans were termed debris fans. This shoreline classification was designed to reflect geomorphic processes and transposition of material with the greatest influence on fish habitat. For example, cobble bars were composed of material rounded and embedded by river processes with limited spaces for fish shelter, while talus slopes consisted of irregular, angular boulders formed from shoreline rockfalls and slides, and providing interstitial spaces with low velocity.

Surface area of shoreline types and macrohabitat types were delineated irrespective of flow, from the LCR inflow (RM 61.3) to Hance Rapid (RM 76.4), to relate longitudinal shoreline geomorphology with occurrence and densities of juvenile humpback chub and with shoreline microhabitat measurements (Converse 1995).

Level 3: Hydraulic Units

Fish macrohabitat described the general area occupied by a fish and was classified on the basis of hydraulic units, including eddies, pools, rapids, return channels, riffles, and runs (Table 3, Fig. 20). Terms and definitions for macrohabitats were consistent with those adopted by the American Fisheries Society (Helm 1985), with elements of the GCES/GIS classification scheme for aquatic biology (Werth et al. 1993), and with common usage of terms throughout the Colorado River Basin (Tyus et al. 1982, Valdez et al. 1982, Maddux et al. 1987). These hydraulic units reflected areas of differential fish use distinguishable at the water's surface, so that changes in flow were reflected in changes in surface area, and thus effects of dam operations on fish macrohabitat.

Twenty-five habitat maps were developed for seven sites in the vicinity of the LCR (Fig. 21, Table 4) for determination of flow to habitat relationships. These sites were (1) ESPN, RM 60.8-61.0, (2) CAMP, RM 61.0-61.2, (3) LCRI, RM 61.2-61.5, (4) HOPI, RM 62.2-62.4, (5) SALT, RM 62.4-62.6, (6) WHAL, RM 62.6-62.9, and (7) WEEP, RM 63.9-64.2. Aerial photographs at a 1:1200 scale (1 cm = 12 m) were used as base maps to simultaneously delineate macrohabitats and shoreline types for a subreach of river about 400 m long at each site. Two to four maps were developed at each site for different flows during interim flow criteria in 1991 and 1992.

Maps were developed by the same observer using visual interpretations of macrohabitat margins and shoreline delineations from two or three established high shoreline vantage points. Binoculars were used to better define water levels, habitat interfaces, and shoreline types. All observations were made early and late in the day to minimize solar reflection and water surface disturbances from wind.

Habitat maps were rectified to orthophoto base maps for GCES/GIS monitoring site #5 (Werth et al. 1993), from the LCR to Cardenas (RM 61.3-72). Surface area of each macrohabitat type in square meters, and linear distance of each shoreline type in meters were determined from the GIS, and related to river flow at the midpoint of map development (habitat maps were developed in 35-60 min). A flow routing model described in HYDROLOGY was used to estimate flow at the site during each period of map development.

Table 3. Fish macrohabitat types and definitions for the Colorado River in Grand Canyon.

MACROHABITAT TYPE	DEFINITION
Eddy	A circular current of water, sometimes quite strong, diverging from and initially flowing contrary to the main current. It is usually formed at a point at which the flow passes some obstruction or on the inside of river bends (Helm 1985). In the Colorado River, an eddy forms in a channel expansion where flow separates from the bank, creating a zone of relatively weak recirculating current (Rubin et al. 1990). Bars accumulate at the weak points of flow where the current separates from the bank (separation point) and where flow reattaches to the bank (reattachment point). Increasingly restricted countercurrent behind the reattachment bar creates a recirculating eddy return channel.
Pool	A portion of the stream with reduced current velocity, often with water deeper than the surrounding areas, and which is frequently usable by fish for resting and cover (Helm 1985). In the Colorado River, a pool usually occurs in a deepened scour basin, and there may be small surface boils and upwellings.
Rapid	A relatively deep stream section with considerable surface agitation and swift current. Some waves may be present. Rocks and boulders may be exposed at all but high flows. Drops up to one meter (Helm 1985). In the Colorado River, rapids are whitewater, high velocity area caused by a constriction and drop in elevation. A rapid is deeper than a riffle, and has large, broken standing waves.
Return Channel	A topographic feature of a recirculating eddy that serves as the main pathway for upstream circulation, and forms a narrow channel (Rubin et al. 1990). When flows are below the crest of the reattachment bar, a sheltered body of water forms, bound on three sides by land with one opening to the river. A return channel is one type of backwater.
Riffle	A shallow rapids where the water flows swiftly over completely or partially submerged obstructions to produce surface agitations, but standing waves are absent (Helm 1985).
Run	An area of swiftly flowing water, without surface agitation or waves, which approximates uniform flow and in which the slope of the water surface is roughly parallel to the overall gradient of the stream reach (Helm 1985).

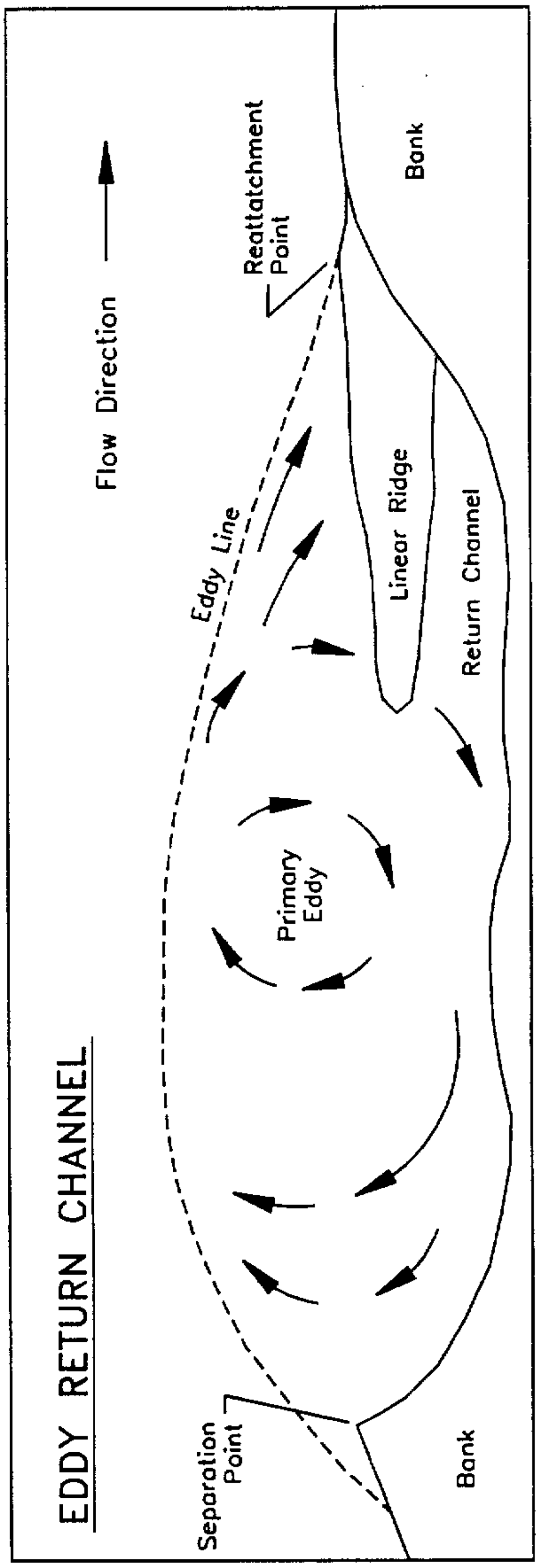


Fig. 20. Surface flow pattern of an eddy (adopted from Rubin et al. 1990).

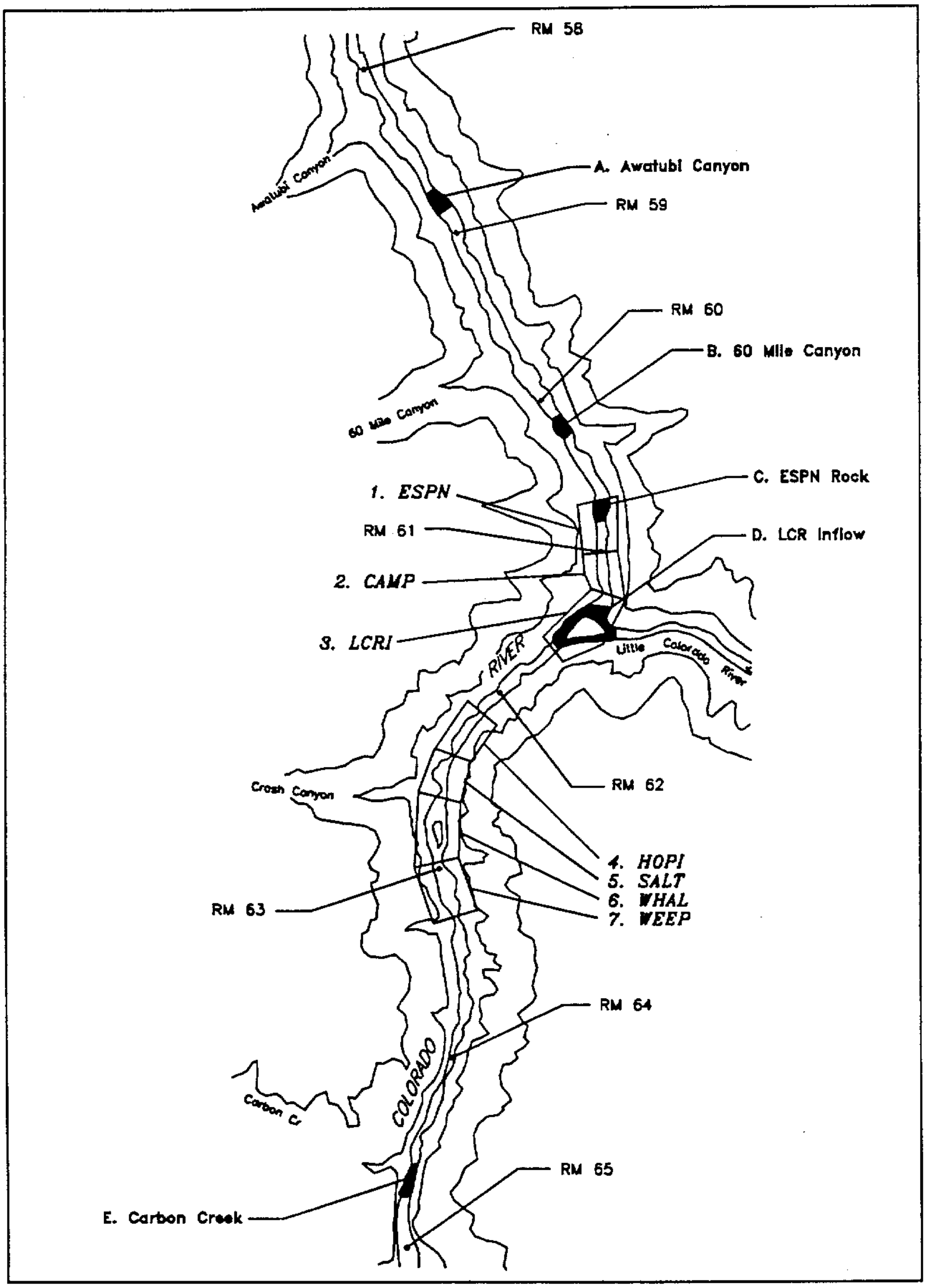


Fig. 21. Locations of five bathymetry map sites (A-E) and seven macrohabitat map sites (1-7) on the Colorado River in Grand Canyon. RM = river mile.

Table 4. Habitat map sites for the Colorado River in Grand Canyon with flows and dates in which maps were rendered.

Map Site	Flow Range	Midpoint	Date (time)
ESPN (RM 59.75-61.00)	5,318-5,467	5,385	May 19, 1991 (1300-1400)
	11,089-11,089	11,089	August 19, 1991 (1830-1856)
	14,792-15,502	14,920	May 22, 1991 (1130-1230)
	17,249-16,749	17,148	August 18, 1991 (0850-0920)
	12,378-12,016	12,085	June 17, 1992 (1130-1245)
CAMP (RM 61.00-61.25)	5,318-5,268	5,234	May 20, 1991 (0830-0930)
	11,297-11,237	11,250	August 19, 1991 (1730-1750)
	15,017-14,888	14,888	May 21, 1991 (1515-1630)
	17,651-17,249	17,500	August 18, 1991 (0800-0834)
	12,916-12,443	12,696	June 17, 1992 (1015-1100)
LCRI (RM 61.25-61.50)	5,335-5,451	5,400	May 19, 1991 (1000-1130)
	11,446-11,326	11,400	August 18, 1991 (1800-1830)
	14,856-14,984	14,920	May 21, 1991 (1330-1430)
	16,451-16,155	16,300	August 18, 1991 (1000-1032)
	8,000	8,000	May 30, 1993 (0630-0700)
HOPI (RM 62.20-62.40)	10,052-10,043	10,050	September 16, 1991 (1530-1618)
	16,122-15,762	16,000	August 20, 1991 (1030-1050)
	11,979-11,643	11,708	June 18, 1992 (1215-1250)
SALT (RM 62.40-62.60)	9,257-10,266	10,266	May 20, 1991 (1720-1815)
	10,043-10,057	10,054	September 16, 1991 (1415-1508)
	14,824-14,888	14,952	May 22, 1991 (0830-0930)
	14,920-14,600	14,500	August 20, 1991 (1200-1230)
WHAL (RM 62.60-63.00)	14,920-14,920	14,920	May 22, 1991 (1810-1900)
WEEP (RM 63.00-63.25)	10,033-10,023	10,030	September 16, 1991 (1630-1718)
	17,517-17,115	17,300	August 20, 1991 (0830-0850)
	8,500	5,500	May 29, 1993 (1500-1530)

Level 4: Habitat Parameters

Channel Bathymetry: Channel morphology was further described with bathymetry maps of five sites (Fig. 21), including (A) Awatubi Canyon, RM 58.5, (B) 60-Mile Canyon, RM 60.1, (C) ESPN Rock, RM 60.8, (D) Carbon Creek, RM 64.7, and (E) LCR Inflow, RM 61.3. The first four sites contained large recirculating eddy complexes regularly used by humpback chub. The LCR Inflow site was used as a staging area by prespawning adults.

A Super-Hydro bathymetric system was used to map underwater topography of the mainstem (F. Protiva, M. Gonzales, GCES, pers. comm.), and presented as two-dimensional isopleths or three-dimensional bathymetry enhanced with computer imagery. The system consisted of a shore station, located by coordinates with the aid of an Ashtech Global Positioning System (GPS), to track and send position information to a main computer located on a boat. The boat computer included a graphics screen to guide the helmsman along a pre-determined sampling pattern of transects set 10 m apart. Survey readings, including distance and angle, were taken with the aid of a prism on the traversing boat, and simultaneous to measurements of depth (using a Lowrance depth sonar) and velocity (using a Marsh-McBirney current meter). Data point collection interval for depth was adjustable, from once every 2 sec to 4 points/sec; e.g., over 10,000 points were collected to develop a bathymetric map for the LCR site (1.6 km distance of river). Elevational starting points for each map were based on a local coordinate system above the high water line in order to reliably reestablish control points and allow for future resurveys.

Field information was stored on the main computer and transferred to GCES for processing and plotting. Data processing included editing erroneous points, generating a database from surveyed points, visual reality check of data points, depth reductions to relative elevation, generation of a surface model, and orientation to established network coordinate points (Werth, et al. 1993). Bathymetric plots were generated with contour intervals of 0.5 m (consistent with GCES/GIS).

Velocity Isopleths: Velocity isopleths were also developed with the aid of the Super-Hydro for two sites (Fig. 21), including ESPN Rock (RM 60.8) and Carbon Creek (RM 64.7). Velocity was measured 1 m below the water surface with a Marsh-McBirney current meter, and recorded simultaneous to depth readings. Velocity was plotted with contour intervals of 0.1 m/sec. Although flow volume changed during these measurements, and multi-directional velocity shears were common in a single vertical transect, these isopleths provided a characterization of velocity magnitude, and distribution and location of high and low velocity zones, relative to channel morphology.

Temperature Isopleths: Thermal isopleths of the LCR inflow were developed from water temperature data collected with hand-held thermometers over a series of points located by a latice grid system. Data were collected May 16, 20, and 21, and July 21, 22, 23, 24, and 25, 1992, and assimilated by four mainstem flow ranges, including (1) 9,200-9,600 cfs, (2) 12,130-12,809 cfs, (3) 13,947-14,504 cfs, and (4) 17,470-17,798 cfs. A relationship of LCR temperature (at base flow of 230 cfs) to mainstem flow was established, and thermal gradients plotted at 2°C intervals, from 10°C to 24°C.

Substrate Maps: Substrate of the LCR inflow was also delineated with the aid of the Super-Hydro, simultaneous to development of bathymetry maps. Observers used the tracking boat or waded in shallow areas to classify substrate according to a modification of the Wentworth system (Table 5). Substrate was segregated as a separate layer of the GIS, and surficial area of each type determined in square meters.

Table 5. Modified Wentworth classification for substrate particle sizes (Cummins 1962).

Classification	Particle size range (mm)
Boulder	>256
Cobble (Rubble)	64 - 256
Pebble	32 - 64 16 - 32
Gravel	8 - 16 4 - 8 2 - 4
Very coarse sand	1 - 2
Coarse sand	0.5 - 1
Medium sand	0.25 - 0.5
Fine sand	0.125 - 0.25
Very fine sand	0.0625 - 0.125
Silt	0.0039 - 0.0625
Clay	<0.0039

Shoreline Microhabitat: Depth, velocity, substrate, and cover of shorelines commonly used by juvenile humpback chub were evaluated to describe habitat attributes and to determine relationships of flow to microhabitat. Parameters were measured and classified at three 1-m intervals from shore, along each of ten parallel transects. Depth was measured with a graduated staff, velocity with a Marsh-McBirney current meter, substrate was classified according to Table 5, and cover was classified as instream, lateral, and overhead (Helm 1985). Measurements were made at 84 sites at different flows to evaluate changes in available habitat components within sites and within shoreline types. These sites were also sampled with electrofishing to relate fish density to shoreline type and to evaluate effects of dam operations (i.e., fluctuating flows) on juvenile habitat.

Habitat Use

Radiotelemetry was identified by species experts as the most effective method for determining habitat used by the Colorado River endangered fishes (Valdez et al. 1990) and has been applied to humpback chub (Kaeding et al. 1990, Valdez and Nilson 1982, Valdez and Clemmer 1982), Colorado squawfish and razorback sucker (Tyus et al. 1982, Valdez and Masslich 1990), and bonytail (Chart and Cranney 1991). Habitat used by humpback chub and sympatric species in the mainstem was determined from radiotelemetry and capture information, and selection was determined from highest proportion of use. Radio-tagged adults (n=75) were located and observed as previously described (RADIOTELEMETRY-Observations) and habitat use was calculated as a percentage of radio contacts in respective macrohabitats, i.e., contact locations were mapped for each of two to four daily boat surveillances through the area occupied by radio-tagged fish. Efforts to measure microhabitat (depth, velocity, substrate, cover) of radio-tagged adults were abandoned because water depth, channel width, and high, multi-directional velocity shears precluded accurate measurements. Macrohabitat of juvenile and YOY humpback chub, and sympatric species, was determined from catch locations associated with electrofishing, nets, seines, minnow traps, and hoop nets. Capture locations of adults were used to supplement and confirm radiotelemetry data, since the latter are generally considered more reliable descriptors of fish habitat (Tyus 1982, Valdez et al. 1990).

Microhabitat of subadult humpback chub (<200 mm TL) was determined within shoreline types sampled with electrofishing (Table 2). Depth, velocity, substrate, and cover were determined from measurements taken along each of 10 parallel transects, as previously described in the Shoreline Microhabitat section. Individual capture locations were not used for microhabitat quantification because electrofishing displaced fish from microhabitat sites (Bovee 1986, Valdez et al. 1990), and sampling within specific shoreline types reduced variation of macrohabitat parameter measurements.

INVERTEBRATE DRIFT

The volume of material (i.e., detritus, macroinvertebrates) drifting in the river was determined for season, time of day, flow magnitude, ramp direction, habitat, and longitudinal location in order to relate drift material to dam operations and to food habits of fish.

Equipment

Drift nets were made of a rectangular tubular frame (30.48 cm x 45.72 cm) with a 3-m long net of 560 μm mesh, and a detachable catchment cup (Fig. 22). Nets were placed in pairs, one collecting surface drift (including neuston lager) and one collecting subsurface drift, and a Swoffer current meter was used to determine net-mouth current velocity at the beginning and end of each set, usually 15-20 min.

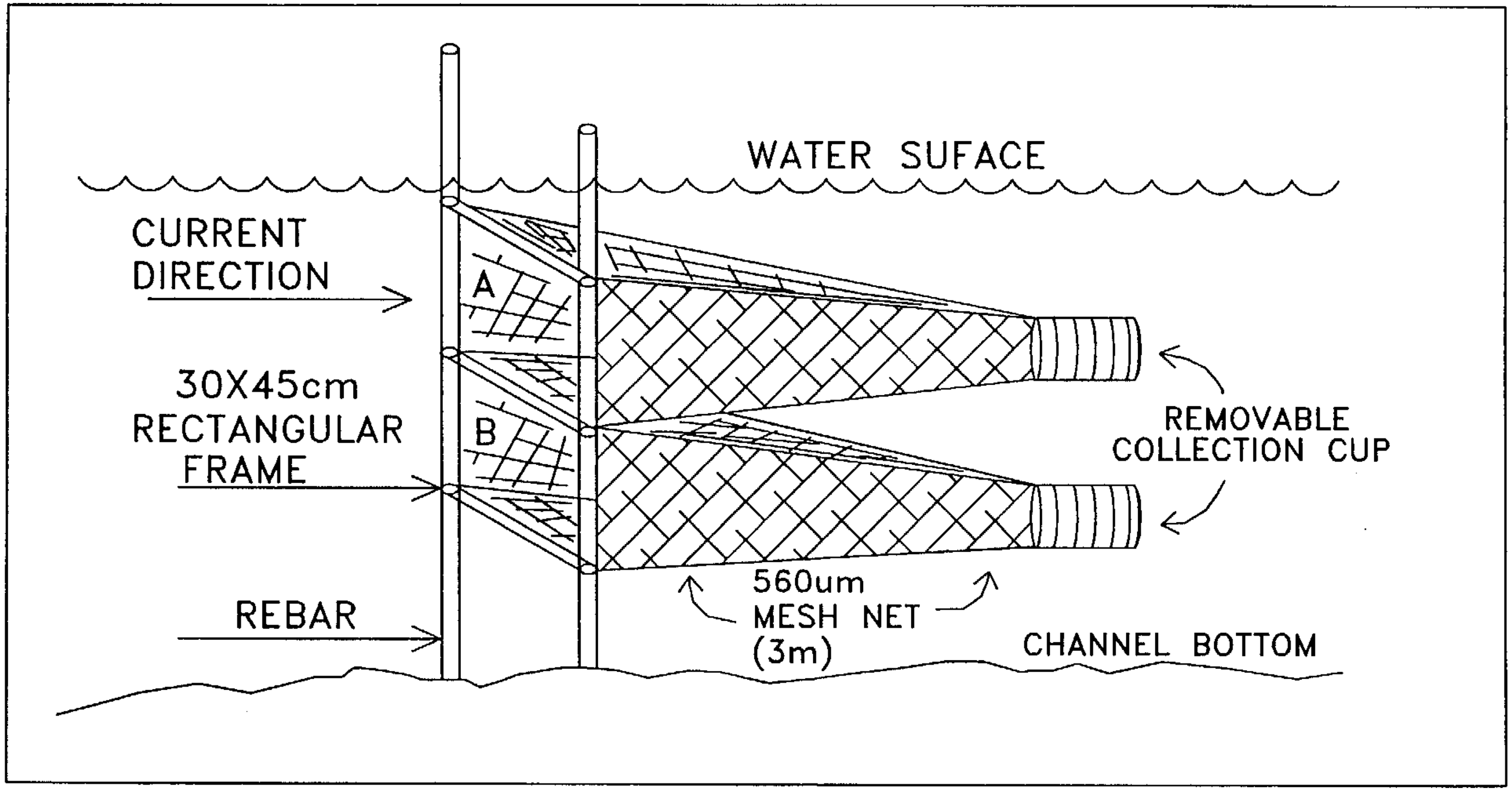


Fig. 22. Drift nets set in tandem to sample near-surface (A) and midwater (B).

Volume of water filtered through each net was calculated as:

$$VOL = W \cdot H \cdot V \qquad \text{(Equation 3)}$$

where: VOL = volume of water filtered in cubic meters per hr,
W = width of net opening (45.72 cm),
H = height of net opening (30.48 cm), and
V = average water velocity as meters per second at the net mouth, (start + end velocity)/2.

In 1991 and 1992, a permanent drift sampling site was established just upstream of the LCR (RM 61.2) to determine the effects of discharge, habitat, and time of day on drifting macroinvertebrates. Drift was sampled monthly to account for seasonal variation and to provide a long-term data set. Drift was also sampled longitudinally from the LCR (RM 61.2) to Diamond Creek (RM 226).

Analyses

The contents of each drift net was placed in appropriately-labeled whirl-pacs or Ziplock bags, preserved with 70% ethanol, and returned to a laboratory. Macroinvertebrates were sorted from detritus, identified, and counted by taxonomic family, genus, or species. Dry weight of remaining detritus (algae, woody debris, etc.) was measured. Sample drift density (macroinvertebrates/100 cubic meters water filtered), as reported by Allen and Russek (1985), was calculated as:

$$DD = \frac{N}{VOL} \times 100 \qquad \text{(Equation 4)}$$

where: DD = Sample drift density, as number of macroinvertebrates/100 m^3 of water filtered,
N = number of organisms per net hour, and
VOL = volume of water filtered in cubic meters per hour.

Data collected from drift samples were presented as volume in milliliters (ml) and number of organisms in 100 cubic meters of water filtered (orgs/100 m^3 wf). For algae, all results were presented as displacement volume (ml) in 100 cubic meters of water filtered. Analysis of drifting food items was based on the volume of material (i.e., algae, macroinvertebrates) drifting in the river by season, flow ramp direction (i.e., rising, falling, and steady flow), and region of the river in order to relate drift material to dam operations and to food habits of fish. Analysis of Variance (ANOVA) and Fisher's LSD were used to compare differences among seasons (spring, summer, and fall) and areas of fish groups (above LCR, below LCR, and MGG).

HYDROLOGY

Flow of the Colorado River and its tributaries in Grand Canyon was evaluated from stream gage records of the U.S. Geological Survey (USGS) (Table 6, Fig. 23). Earliest records for the Grand Canyon section of the Colorado River were available for Lees Ferry in 1895. Early records were typically based on single daily measurements, while most gaging stations today record streamflow at 15-min intervals.

A streamflow routing model (Goodwin 1995) was developed for this study to provide time and site-specific flow for correlation with radiotelemetry observations of adult humpback chub and collection of drift material. This flow routing model was based on the flood wave theory (Lazenby 1987), using the nearest stream gages for calibration. Stage-discharge relationships were derived from USGS stream gages for determination of flow from channel bathymetry.

Table 6. Stream gages used for hydrology analysis.

USGS Station Number	Station Name	Location[a]	Drainage Area (mi^2)	Period of Record (water years)
9380000	Colorado River at Lees Ferry, AZ	RM 0.0	111,800	1895-present
9383100	Colorado River above LCR, AZ	RM 61.2	N/A	Apr 1983-present
9402500	Colorado River near Grand Canyon, AZ	RM 87.4	~141,600	1925-present
9404120	Colorado River at National Canyon, AZ	RM 166.5	N/A	Apr 1983-present
9404200	Colorado River above Diamond Creek, AZ	RM 226.0	N/A	Apr 1983-present
9402000	Little Colorado River near Cameron, AZ	45 mi ups	26,459	1947-present
9402300	Little Colorado River near mouth, AZ	0.5 mi ups	26,964	1989-Jan 1993[bc]
9382000	Paria River at Lees Ferry, AZ	1.1 mi ups	1,410	1923-present
9403000	Bright Angel Creek near Grand Canyon, AZ	0.5 mi ups	101	1923-1974
9403780	Kanab Creek near Fredonia, AZ	31 mi ups	1,085	1963-1980

[a]RM = river miles downstream from Lees Ferry.
ups = distance upstream from Colorado River confluence.
[b]data inconsistent
[c]discharge based on stage elevations, periodically adjusted based on stream channel measures.

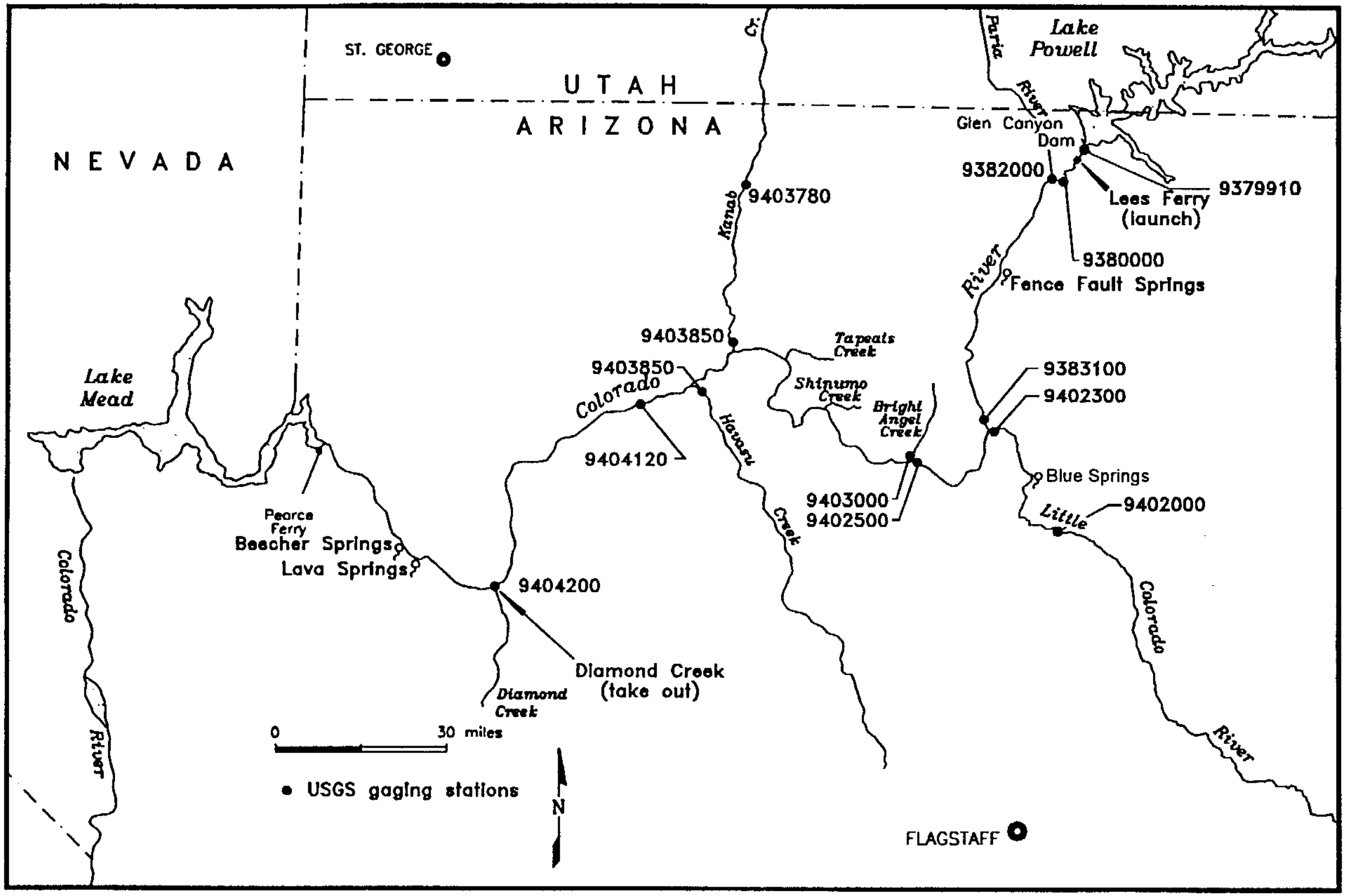


Fig. 23. Locations of stream gages used for hydrology analysis.

Mainstem Colorado River

Flow data for the Colorado River in Grand Canyon were obtained from five USGS stream gages (Fig. 23), identified by the following gage numbers and descriptions:

- ▸9380000 - at Lees Ferry, AZ
- ▸9383100 - above Little Colorado River, AZ
- ▸9402500 - near Grand Canyon, AZ
- ▸9404120 - at National Canyon, AZ
- ▸9404200 - above Diamond Creek, AZ

Historic records were available from the Lees Ferry gage (1895 to present) and from the Grand Canyon gage (1922 to present), but only intermittent records were available from above the LCR, at National Canyon, and above Diamond Creek (mid-1980s to present). Missing or aberrant discharge measurements were replaced using routed flow data from the Lees Ferry gage. Because USGS discontinued recording streamflow above the LCR in April 1993, GCES began collecting flow data in March 1993. A correlation was developed between the two records to adjust the GCES data and provide a consistent record.

Little Colorado River

Flow data for the LCR were obtained from the following two USGS stream gages (Fig. 23):

- ▸9402000 - near Cameron, AZ
- ▸9402300 - near mouth, AZ

The gage near Cameron has provided a historic record of flow for the LCR since 1947. However, the gage was located 72 km (45 mi) upstream of the confluence and did not record flow from Blue Springs (21 km upstream of the confluence), which was the major source of base flow for the LCR. The gage above the confluence with the mainstem was operated from 1987 to January 1993, when it was disabled by an unusually high flood. GCES measured stage at this location with a manometer pressure sensor starting in January 1993, but no correlation with discharge was made in time for this report.

Other Tributaries

Flow data for major tributaries in Grand Canyon, other than the LCR, were obtained from the following three USGS stream gages (Fig. 23):

- ▸9382000 - Paria River at Lees Ferry, AZ
- ▸9403000 - Bright Angel Creek near Grand Canyon, AZ
- ▸9403780 - Kanab Creek near Fredonia, AZ

Of seven major tributaries identified in the study region, only four had USGS gaging streamflow data--LCR, Paria River, Bright Angel Creek, and Kanab Creek. No USGS gages were located on Shinumo Creek, Tapeats Creek, or Havasu Creek. The gages on the Paria River and Bright Angel Creek were each located within 2 km (1.2 mi) of the mouth and were valuable for determining annual and seasonal inflow into the Colorado River. The Kanab Creek gage was located about 50 km (31 mi) upstream from the mouth and recorded general hydrology data.

WATER QUALITY

Water quality parameters, analyzed for the mainstem Colorado River, LCR, other tributaries, and special habitats (i.e., riverside springs, tributary inflows, shallow embayments, areas of local fish abundance), included temperature, turbidity, specific conductance, dissolved oxygen, and hydrogen ion concentration (pH). Water quality data were procured from three sources, including portable Hydrolab water quality instruments (Hydrolab Corp, Austin, TX), USGS stream gaging stations, and Ryan Tempmentors (Ryan Instruments, Redmond, WA) deployed and maintained by GCES. Water quality data were collected during monthly field trips to characterize local habitats and supplement other data. Water quality data were usually collected from the Hydrolab hourly for 10-20 days/month, and discontinuous between field trips, since instruments were not left in the field between trips. BIO/WEST used the following Hydrolab water quality instruments:

- ▸Surveyor 2: With Field Data Logger (Model 5100A)
- ▸Surveyor 2: Display Unit (Model: SVR2-SU)
- ▸Surveyor 3: 1100 Surveyor Data Logger (Model SVR3-DL)
- ▸DataSonde 2: (Model 2270 H)

Water temperature was recorded in degrees Celsius (°C), and turbidity (as light transmisivity) was recorded in nephelometric turbidity units (NTUs) with a Hach Model 2100P turbidimeter, and as depth of water clarity with a standard 20-cm diameter Secchi disk. Specific conductance was measured in μS, adjusted to 25°C. Dissolved oxygen was expressed as milligrams per liter (mg/l), and hydrogen ion concentration in pH units (0-14).

Hydrolab instruments were calibrated before and after each field trip. Water quality data were downloaded from data loggers using a laptop or desktop computer and Procomm Plus Version 1.1B communications program (Datastorm Technologies, Inc., Columbia, MO). Water quality parameters (except turbidity) were recorded at camp locations, sample sites, tributary inflows, and special habitats. Turbidity was measured daily at camp, or with dramatic changes, usually from tributary inflow.

Data from six mainstem gages and six tributary USGS gages were used to provide historic and present overviews of water quality in the mainstem Colorado River and its tributaries (Table 6, Fig. 23). Pre-dam water quality and sediment data were obtained from two mainstem gages (Colorado River at Lees Ferry and Colorado River near Grand Canyon, AZ) and three tributary gages (Paria River at Lees Ferry, LCR near Cameron, and Bright Angel Creek near Grand Canyon). Post-dam data were from gages on the Colorado River below Glen Canyon Dam, above the LCR, at National Canyon, and at Diamond Creek, which were installed in 1983, as part of GCES Phase I to evaluate sediment transport and provide data for a flow routing model. Post-dam data were also obtained from gages (mini-monitors) installed in 1989 on the lower LCR, Bright Angel Creek, Kanab Creek, and Havasu Creek. These mini-monitors recorded water temperature, DO, and conductivity, and included pressure transducers for use with flow-rating curves to yield stream discharge estimates.

Ryan Tempmentors were installed by GCES in several tributaries and mainstem locations to supplement USGS gaging data and to provide data for a temperature model for the Colorado River in Grand Canyon. Tempmentors were located in lower Nankoweap Creek, LCR, Shinumo Creek, Kanab Creek, Tapeats Creek, and Havasu Creek, as well as select locations on the mainstem, such as RM 127 (Middle Granite Gorge).

Methods for gathering water quality parameters were adjusted for particular locations and conditions in this investigation. Water quality parameters in the mainstem were measured with a Hydrolab DataSonde deployed from a 37-ft (11.3-m) raft at each temporary campsite. Parameters were recorded electronically at 1-hr intervals, and manual readings were recorded from a Hydrolab Surveyor 2, to supplement the electronic data in case of battery failure. Water temperature associated with fish and drift sampling was recorded with hand held thermometers, calibrated with a Surveyor 2 at the beginning of each trip. Water quality in the LCR was also recorded electronically at 15-min intervals with a Hydrolab DataSonde. DataSondes were deployed only when teams were in the vicinity--about 10 days/month--and temperature data were supplemented with Ryan Tempmentors and CR10 data loggers (Campbell Scientific, Inc., Logan, UT), and USGS ADAPs (Data Collection Platforms). Hydrolab Datasondes or Surveyors were also used to record water quality data in various tributary inflows, which were supplemented with data from Tempmentors or USGS gaging stations, to provide a continuous record of tributary temperature. Water quality parameters of special habitats were measured opportunistically with a Surveyor 2 and results recorded manually.

DATA MANAGEMENT

Rigorous data management procedures were implemented to insure data quality and accuracy. These procedures included: (1) project planning; (2) development of data forms, (3) staff training, (4) data collection in the field, (5) transfer of data forms, (6) data entry and analysis, and (7) reporting. Rigorous quality control checks were incorporated in the field and in the office. Procedures for data collection and management presented in this document were designed and implemented to maximize quality control during transition from field observation to final report.

Project Planning

The initial phase of project planning was the development of a study design, which was a collaborative effort by the Principal Investigator, field staff, data management staff, and agency representatives (Fig. 24). The study design dictated sampling strategy, data collection methods, and projected analyses. A stratified random sampling design was implemented to approximate uniform spatial and temporal sampling of fish assemblages and associated physical, chemical, and biological components. A number of sampling techniques were used to meet project objectives. Standard fishery assessment was done in a manner so that seasonal and longitudinal patterns could be evaluated distinctly from environmental variables such as flow. Data forms were designed for each sampling technique used (i.e., netting, electrofishing, trapping, etc).

Development of Data Forms

Data were recorded on 10 unique data forms (Appendix A). These data forms were developed to simplify and assure completeness of data collection in the field. Specific forms were developed for each sampling technique or group of similar techniques. Standard sampling techniques included netting and trapping (gill and trammel nets, hoop and minnow traps), electrofishing and seining. Data forms were also developed for telemetry observations, telemetry surveillance, fish meristics, water quality, juvenile habitat, river stage, and drift net samples.

Netting and trapping data (Form 1) were related to the location of the net or trap (header information) and information related to each specific sample unit or repetition (a Data Code Glossary is provided in Appendix B). Header information included sample type, gear, trip number, date, reach, and location in river miles and left or right side of the river channel, clipboard number, crew,

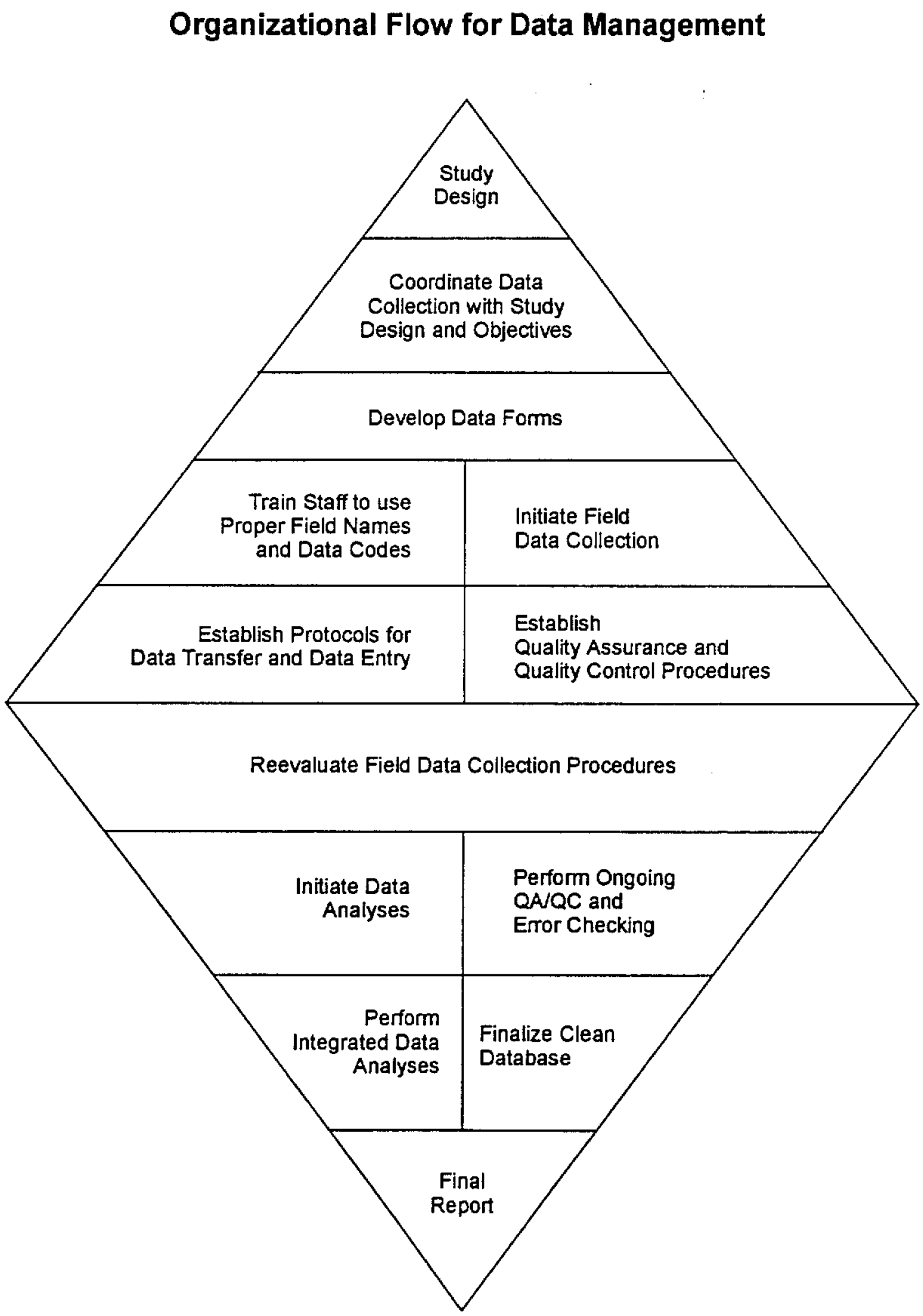


Fig. 24. Organizational flow for coordinating data management.

and habitat characteristics. The information associated with an individual sample event included a unique sample number, start and end times for each event, weather, air and water conditions during the sample time, and a summary of fish captured.

Electrofishing (Form 2) was conducted as runs within discrete habitat units. A single pass was conducted within a unit. Multiple passes were not performed so there was no need for separation of header and sample information. Sample type, number, trip, date, reach, clipboard, and crew were recorded, as well as information characterizing the habitat and sampling conditions. Voltage, amperage, run duration, turbidity, and lighting conditions all affected the performance of the equipment and crew, and hence catch rate.

Seining data (Form 3) included header and location information described previously and information to further characterize habitat. Habitat length, width, and depths were recorded along with temperature, substrate, sample length, and width. If seining was done in a tributary stream, the stream name was recorded and the sample location was described in terms of distance in meters upstream from the main river. A summary of fish captured during each sample effort was recorded on each Form (1-3) and individual fish characteristics such as total length, weight, gender, and any anomalous marks from sampling (e.g., bruising) were recorded on the reverse sides of the data forms.

Forms 4 and 5 were used for radiotelemetry. Telemetry observation data were recorded on Form 4 and included header and location information as for other sample types. The start and end times, observation mode, benchmark, and map key were also recorded and a fish information section was added for descriptions of the fish under observation and the radio signal received (PIT tag, radio size, frequency, and pulse rate). Telemetry observations were conducted on a single stationary fish, at 15 min intervals. Data recorded included time, habitat, distance moved from last observation, gage reading which indicated relative change of water stage, ambient light, turbidity, and weather condition.

Telemetry surveillance data were recorded on Form 5. A surveillance run was conducted several times daily to characterize locations of radio-tagged fish and hence habitat use over time. Header information was recorded and the range of locations surveyed for radio signals was noted. Time, location, river channel side, and the identification of the fish, frequency and pulse were recorded. Since radio signals could be obscured by surrounding features, a confidence level was added to each radio contact both on observation and surveillance forms.

Meristic data for humpback chub were recorded on Form 6. Data describing the specific morphology of each humpback chub captured were first recorded on a chub meristics data form, then also recorded on the sampling form corresponding to the collection gear. This duplication of effort greatly increased the accuracy of B/W's humpback chub database used for all analyses. The cross-check between file types allowed us an additional opportunity to verify catch numbers for a given sample or group of samples. Data recorded included the sample information by which the fish was captured, sample type, number, trip number, reach and clipboard, and general information and morphometric or meristic information on individual fish. General information included total length, forked length, standard length, weight, gender, and sexual maturity. Morphometric/meristic information included nuchal depth, caudal peduncle length (maximum and minimum caudal peduncle diameter), head length, snout length, dorsal and anal fin base length, body depth, and number of dorsal and anal fin rays.

Water Quality data were recorded on Form 7 initially, but were later transcribed into waterproof bound journals kept with the water analysis equipment as a backup for data logged electronically. Journals were removed at the end of each research trip, photocopied and returned to the equipment boxes. The data logger files were downloaded after each trip and re-formatted into dBASE files (see File List). Data recorded on Form 7 included location, river mile, date and time, weather, habitat characteristics such as water fluctuation, ambient temperature, and water quality parameters (dissolved oxygen, pH, conductivity, turbidity, Redox potential).

Form 8 was used to record information on habitat used by juvenile humpback chub. Header information was included with a detailed survey of a small reach of shoreline habitat. Location, including river mile and river channel side, was recorded along with shoreline type, general and specific habitat types, and local temporary bench marks. Depth, flow direction, velocity at 0.2, 0.6 and 0.8 of the depth, substrate, and cover were all recorded for up to 10 different transects at distances of 0.5 m, 1.5 m, and 2.5 m from the shoreline.

Stage level reference point location information was recorded on Form 9. Data such as reference point number, photo number, and river mile were recorded in the header information. Vertical distance from a reference point, initial date and time of measurement, and units of measurement were recorded along with instaneous stage and stage change over time.

Drift data were recorded on Form 10. Date, time, elapsed time, habitat, river location and stage, and velocity and net height were recorded in the header information. Later in the laboratory, information was added regarding contents of net samples. Organisms (identified to family), life stage, and dry weight were recorded.

Staff Training

Key field personnel were trained in proper procedures for completing all data forms. Each team had a waterproof copy of a Data Code Handbook with data forms (Appendix A) and data codes (Appendix B). This ensured adherence to B/W's defined data codes, yet provided flexibility by allowing new or unusual information to be incorporated in the COMMENT and DESCRIPTION fields. The adequacy of these data forms was discussed at Project Workshop meetings, held twice yearly. Changes to forms were evaluated by the staff and the Principal Investigator. Recommended changes were incorporated into the forms and the Data Code Handbook. This continual re-evaluation of data collection needs resulted in a database that accurately reflected field observations.

Data Collection in the Field

Each Project Leader was responsible for the security and accuracy of data collected in the field and for transfer of the data sheets to the Database Manager at B/W. Data forms were recorded in pencil on water-resistant bond paper and kept in numbered metal clipboards, reducing the amount of dirt and water on forms. Completed data forms were transferred to water tight containers located on the OARs support boats at the end of each work day. Each Project Leader checked the data forms daily for completeness and clarity and corrected any omissions or errors. Performing this step in the field was beneficial to recall certain events inadvertently deleted from the database. At the end of the sampling trip the Project Leader reviewed the data forms to ensure that the sequence of sample numbers was consecutive and that recorded data were legible and in the proper format. The data forms were hand-carried back to B/W and transferred to the Database Manager at the end of each trip.

Transfer of Data Forms

Data forms received by the Database Manager were organized sequentially by sample number or by river mile and photocopied. One copy of all data forms and other data media (i.e., mylar map overlays, slides, videotapes) was maintained in B/W's Logan office in a locked, fire-proof storage cabinet. A second copy was maintained at the office of Leibfried Environmental Services in Flagstaff, Arizona and a third copy was sent to the GCES office in Flagstaff. Data were entered into an electronic database from original data forms. Any changes to data recorded on forms was done in colored ink and initialed by the responsible individual. A tracking sheet (Fig. 25) accompanied the original data sheets in the Logan office, detailing the data management procedures that had been performed. Final copies of all working data files and the original data forms were stored in a fire-proof safe at B/W's Logan office.

Data Entry and Analysis

Data were entered into electronic files at the end of each trip (trip data files) by staff members familiar with the biological conditions encountered in Grand Canyon. This further increased the accuracy level of B/W's database since data were not only checked for accuracy against a written data form, but also against a set of probable conditions. BIO/WEST used dBASE IV to store and maintain data, and dBASE IV, SYSTAT, Number Cruncher, and EXCEL for data analysis. Error trapping programs were custom-designed to match each data form. These error trapping programs were used to check electronic data for omissions, duplication, incorrect data codes, and values outside a probable range. Error trapping programs were run for all data forms at the completion of entry after each field trip. The humpback chub meristics file was also printed in its entirety and each entry checked visually to eliminate errors. Humpback chub data such as PIT tag number, recapture status, and total length were cross checked against the fish collection file as an additional verification of data. After errors had been identified, a report was printed and errors were manually fixed. When a trip data file was error free it was appended to an aggregate file used for analyses. Summary reports of B/W's monthly findings were published in trip reports 15 days after the end of each field trip. These reports contained a printout of data of humpback chub captured (total length, PIT tag number, date, location, gender, sexual maturity, recapture status, and disposition upon release), and a draft summary of other species captured and effort expended.

Table 7 lists the specifications for the B/W databases (Aggregate data files); detail of the file structures is presented in Appendix C - Data File Structures.

Several datasets were incorporated into a GIS, including netting, electrofishing, seining, and trapping sample locations, habitat maps, hydraulic maps, bathymetry maps, velocity isopleths, substrate maps, and temperature maps. The GIS data are distinct and link to field-specific data. Some of the GIS information layers were developed by GCES, and those developed by B/W were digitized using Arc/CAD software on an IBM compatible personal computer. The files were maintained and further developed using Arc/INFO software on a Sun Sparcstation 2, and are compatible with the GCES GIS database. Table 8 lists the specifications for the B/W mainstem GIS database.

Other Data Media

Other types of data media used on this project included photographs and video footage of individual fish. This information was used in conjunction with meristic analyses, habitat photographs, aerial photographs, and photographs and video footage of sampling techniques. Habitat maps produced on mylar and fathometer tapes were also used in the collection of habitat information. Still photographs taken with slide film were stored in vinyl slide pages in three ring binders. These slide

MONTHLY DATA TRACKING SHEET

Date	Initials	
☐☐		Procure data sheets from crew leaders.
☐		Copy data sheets.
☐		Mail original drift net data sheets to invertebrate laboratory.
☐		Mail copies of data sheets to GCES and Bureau of Reclamation.
☐		File copies of data sheets in fireproof vault in office.
☐		Enter chub data.
☐		Summarize other data for trip report.
☐		Compare numbers from sampling sheets to chub numbers - error check.
☐		Generate chub data.
☐		Enter sampling and fish data.
☐		Run checking programs (NETCHK, ELECCHK, SEINCHK)
☐		Error check: visually check all single, sample_num, species, YOY, juv, adu, total fields
☐		Visually check every 10th entire record
☐		Do CHUBUPDT - correct errors - archive old files
☐		Do CHUBCHK
☐		Do FISHCOMB - correct errors - archive old files
☐		Do FISHCHK
☐		Do ELAPSED.PRG, review ###.ERR text file - visually check all records with elapse time >10 hr or <0.
☐		Do sample area calc. for seine file, visually check odd records.
☐		Do recapture update.
☐		Make aggregate files - archive all files.
☐		Do YOY etc, adjustments by running DOMAKE_AGE and AGEUPDT.
☐		Copy adjusted files back to network and archive.

Fig. 25. Sequence of data checks for monthly data tracking.

Table 7. Database specifications for BIO/WEST Humpback Chub Studies.

File Name	No. Records	Record Length	Size (bytes)	Anticipated No. Records	Description
NETTING.DBF	16,643	192	3,080,614	16,643	Netting and trapping sample data, Oct 1990 - Nov 1993
ELECTRO.DBF	4,612	182	850,018	4,612	Electrofishing sample data, Oct 1990 - Nov 1993
SEINE.DBF	958	217	202,814	958	Seining sample data, Oct 1990 - Nov 1993
CHUB.DBF	6,294	214	1,235,258	6,294	Humpback Chub morphometrics and meristics, Oct 1990 - Nov 1993
FISH.DBF	26,542	163	4,194,948	26,542	All fish capture data, Oct 1990 - Nov 1993
SURVEIL.DBF	1,600	111	290,626	1,600	Radiotelemetry surveillance, Oct 1990 - Nov 1992
OBSERV_H.DBF	260	206	29,854	260	Header for radiotelemetry observations, Oct 1990 - Nov 1992
OBSERV_M.DBF	2,025	149	302,975	2,025	Movement for radiotelemetry observations, Oct 1990 - Nov 1992
SCALES.DBF	157	133	22,099	157	Humpback Chub scale analyses, Oct 1990 - Nov 1993
JUVHAB.DBF	282	155	44,832	282	Juvenile habitat measurements, Oct 1990 - Nov 1993
DRIFT.DBF	570	218	125,030	570	Drift net sample analysis data, Oct 1990 - Nov 1993
FOOD.DBF	552	253	142,570	552	Stomach pumping analysis data, 1993
REMOTE.DBF	26,583	14	452,493	26,583	Remote radiotelemetry station data, Oct 1990 - Nov 1992
DATASOND.DBF	43,586	45	2,000,000	43,586	Datasonde water quality data, Oct 1990 - Nov 1993
SURVEYOR.DBF	5,161	51	265,000	5,161	Surveyor II water quality data, Oct 1990 - Nov 1993

Table 8. GIS database specifications for BIO/WEST humpback chub studies.

Dataset	No. Files	Anticipated Size (bytes)	Description
Sampling Locations	2	~1,000,000	Net, trap, and electrofishing locations
Surficial Habitat Maps	27	~100,000	Surficial hydraulic features outlined on aerial photos for four selected sites
Hydraulic Maps	2	~3,000,000	Current patterns and shoreline types mapped from LCR to Tanner
Bathymetric Maps	5	~12,000,000	Bathymetry for LCR confluence and RM 58.5, 60.1, 60.8, 64.7
Velocity isopleths	4	~2,000,000	Velocitiy isopleths for RM 58.5, 60.1, 60.8, 64.7
Substrate Maps	1	~45,000	Substrates outlined for LCR confluence
Temperature Maps	4	~190,000	Temperature isopleths for LCR confluence

pages were filed by content (i.e. chub, habitat, and technique), by year, trip, and date and stored in the B/W office. Video footage was filed similarly, though grouping of content types was not possible since the tape was continuous. Maps and aerial photographs were filed in map cases in alphabetical order.

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APPENDIX A - DATA FORMS

Form 1 - Netting and Trapping
Form 2 - Electrofishing
Form 3 - Seining
Form 4 - Telemetry Observations
Form 5 - Telemetry Surveillance
Form 6 - Chub Meristics
Form 7 - Water Quality
Form 8 - Juvenile Habitat
Form 9 - Stage Level
Form 10 - Drift Net

FORM 1

SET ______

BIO/WEST GRAND CANYON STUDY

(Colorado River Mainstem)

Netting and Trapping

Sample Type: _ Trip: 9 3 - _ _ Reach: _ CB #: _ Date: _ _ _ _ _ _ (YY MM DD) RM: _ _ _ . _ _ Gear: _ _

Hab1: _ _ Hab2: _ _ Hab3: _ _ Side: _ Profile (Y/N): _ Max Depth: _ _ . _ ft Sub1: _ _ Sub2: _ _

Fish Pres (Y/N): _ No. Bottles: _ Habitat Photo: Camera: _ _ Roll: _ _ Frame: _ _ - _ _ Crew: _ _ , _ _ , _ _

Comments: ______________________________

Sample #:	_ _ _	_ _ _	_ _ _	_ _ _	_ _ _	_ _ _
Start Date:	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
Start Time:	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
End Time:	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
End Date:	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
Ambient Light:	_ _	_ _	_ _	_ _	_ _	_ _
Weather:	_ _	_ _	_ _	_ _	_ _	_ _
Turbidity:	_	_	_	_	_	_
AirT(c):	_ _ . _	_ _ . _	_ _ . _	_ _ . _	_ _ . _	_ _ . _
McT:	_ _ . _	_ _ . _	_ _ . _	_ _ . _	_ _ . _	_ _ . _
HabT:	_ _ . _	_ _ . _	_ _ . _	_ _ . _	_ _ . _	_ _ . _
Fluctuations:	_ _	_ _	_ _	_ _	_ _	_ _

			SUMMARY			
SPECIES	Y J A	Y J A	Y J A	Y J A	Y J A	Y J A
HB	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --
FM	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --
BH	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --
RB	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --
BR	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --
CC	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --
CP	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --
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INDIVIDUAL FISH LENGTHS

Sample #	Species	TL	SL	WT	PIT Tag No.	Recap (Y/N)	Old Tag	P/V	Shore Y/N	Sex	Ripe	Disp	Rel. Loc.
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---	--	---	---	----	----------	-	------	-	-	-	--	--	---'-
---	--	---	---	----	----------	-	------	-	-	-	--	--	---'-
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---	--	---	---	----	----------	-	------	-	-	-	--	--	---'-
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[1]- Photo / [2]- Video

FORM 2

Page __ of __
RUN ______

BIO/WEST GRAND CANYON STUDY

(Colorado River Mainstem)

Electrofishing

Sample Type: E Sample No: _ _ _ Trip: 9 3 - _ _ Reach: _ CB #: _ Date: _ _ _ _ _ _ (YY MM DD)

Start RM: _ _ _ . _ _ End RM: _ _ _ . _ _ Start Time: _ _ _ _ End Time: _ _ _ _ Sec: _ _ _ _ _

Volts: _ _ _ Amps: _ _ . _ Amb Light: _ _ (SU, CL=cloudy PC, SH=shadow NI, ML=moonlight DD=dawn/dusk)

Hab1: _ _ Hab2: _ _ Hab3: _ _ Sub1: _ _ Sub2: _ _ AirT(c): _ _ . _ McT: _ _ . _ HabT: _ _ . _

Turbidity _ Weather: _ _ Fluctuations: _ _ Fish Pres (Y/N): _ No. Bottles: _

Crew: _ _ , _ _ , _ _

Comments: ____

____

SPECIES SUMMARY

Species	YOY	JUV	ADU	Total
H B	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
F M	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
B H	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
R B	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
B R	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
C C	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
C P	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
F H	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
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INDIVIDUAL FISH LENGTHS

Sample #	Species	TL	SL	WT	PIT Tag No.	Recap (Y/N)	Old Tag	P/V	Shore Y/N	Sex	Ripe	Disp	Rel. Loc.
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[1]- Photo / [2]- Video

BIO/WEST GRAND CANYON STUDY

(Colorado River Mainstem)

Seining

Sample Type: S Sample No: ___ Trip: 93-__ Reach: _ CB #: _ Date: ______ (YY MM DD)

RM: ___.__ Gear: __ Start Time: ____ Hab1: __ Hab2: __ Hab3: __

Sub1: __ Sub2: __ AirT(c): __._ McT: __._ HabT: __._ Quant Y/N: _ Subsamp Y/N: _

Ambient Light: __(SU=sunny CL=cloudy PC=partly cloudy SH=shadow NI=night ML=moonlight DD=dawn/dusk)

Weather: __ Turbidity: _ Fluctuation: __

Hab L: ___._m Hab W: ___._m Sa L: ___._m Sa W: ___._m

MaxDepth: __._ft D_1: __._ft D_2: __._ft Fish Pres (Y/N): _ No. Bottles: _

Habitat Photo: Camera: __ Roll: __ Frame: __ Crew: __,__,__

Comments: ______________________________

Species	LAR	YOY	JUV	ADU	Total
H B	____	____	____	____	____
F M	____	____	____	____	____
B H	____	____	____	____	____
R B	____	____	____	____	____
B R	____	____	____	____	____
C C	____	____	____	____	____
C P	____	____	____	____	____
F H	____	____	____	____	____
__	____	____	____	____	____
__	____	____	____	____	____
__	____	____	____	____	____

INDIVIDUAL FISH LENGTHS

Sample #	Species	TL	SL	WT	PIT Tag No.	Recap (Y/N)	Old Tag	P/V	Shore Y/N	Sex	Ripe	Disp	Rel. Loc.
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[1]- Photo / [2]- Video

FORM 4

Page _ of _

BIO/WEST GRAND CANYON STUDY

(Colorado River Mainstem)

Telemetry Observations

Sample No: _ _ _ Trip: _ _ Reach: _ CB #: _ Date: _ _ _ _ _ _

Start Time: _ _ _ _ End Time: _ _ _ _ River: _ _ RM: _ _ _ . _ Mode <Locate:_ 2H:_ 24H:_ Test Flow:_ Implant:_>

Habitat Map #: _ _ _ _ _ _ Benchmark: _ _ _ _ _ _ Confidence: _

Habitat Photo: Camera _ _ Roll: _ _ Frame: _ _-_ _ Crew: _ _, _ _, _ _

Fish Information

Species: H B PIT tag: _ _ _ _ _ _ _ _ _ _ TL: _ _ _ Wt.: _ _ _ _ Radiotag Size: _ _ g

Freq 1: 40._ _ _ Freq 2: 40._ _ _ Pulse 1 (#/min): _ _ Pulse 2: _ _ Surgeon: _ _

Time	RM	Hab	Distance Moved	Gage	Rel Stage	Abs. Stage	Ambient Light	Weather	Turbidity

COMMENTS

FORM 4, Page 2

Habitat Measurements:

Hab1: _ _ Hab2: _ _ Depth: _ _ ._m V 0.2: _ ._ m/s V 0.6: _ ._ m/s V 0.8: _ ._ m/s

V Bottom: _ ._ m/s AirT(c): _ _ _ McT: _ _ ._ HabT: _ _ ._ Sub1: _ _ Sub2: _ _

Cover: Over: _ _ Lat: _ _ In: _ _ Turb: _ DO: _ _ mg/l pH: _ ._ Cond: _ _ _ _ umhos/cm

---

Habitat Sketch:

BIO/WEST GRAND CANYON STUDY

(Colorado River Mainstem)

Telemetry Observations

Sample No: _ _ _ Trip: _ _ Reach: _ CB #: _ Date: _ _ _ _ _ _

PIT tag: _ _ _ _ _ _ _ _ _ _ Freq 2: 40._ _ _ Pulse 2: _ _

Time	RM	Hab	Distance Moved	Gage	Rel Stage	Abs. Stage	Ambient Light	Weather	Turbidity

COMMENTS

BIO/WEST GRAND CANYON STUDY

(Colorado River Mainstem)

Telemetry Surveillance

Sample No: __ __ __ Trip: __ __ Reach: __ CB#: __ <Aerial: __ Boat: __ Foot: __>

Date: __ __ __ __ __ __ Time: Start __ __ __ __ End __ __ __ __ RM __ __ __ . __ to __ __ __ . __
Y Y M M D D

Ambient Light: __ __ (SU=sunny CL=cloudy PC=partly cloudy SH=shadow NI=night ML=moonlight DD=dawn/dusk)

Weather __ __ Turbidity __ __ Sechi Disk __ __ m Fluctuations: __ __

Crew: __ __, __ __, __ __

Time	RM	Side	Frequency	Pulse	Confidence	Hab2	Cover

Form 6

BIO/WEST GRAND CANYON STUDY
Chub Meristics

PITTag No.: __________ DATE: __-__-__ SAMPLE #: _-____-___-_-_ TL (mm): ___ FL: ___ SL: ___ WT (g): ____

SEX: _ RIPE: __ P_1-P_2: __._ ND: __._ CPL: ___._ CPMD: __._ CPND: __._ HL: __._ SNL: __._ DFB: __._ AFB: __._ BD: ___._

D: __ A: __ RECAP: _ TAG: _____ DISP: __ CAM: __ ROLL: __ FRAME: __-__ VIDEO: __ RM RELEASE: ___._ RADIOTAG (Y/N): _

PITTag No.: __________ DATE: __-__-__ SAMPLE #: _-____-___-_-_ TL (mm): ___ FL: ___ SL: ___ WT (g): ____

SEX: _ RIPE: __ P_1-P_2: __._ ND: __._ CPL: ___._ CPMD: __._ CPND: __._ HL: __._ SNL: __._ DFB: __._ AFB: __._ BD: ___._

D: __ A: __ RECAP: _ TAG: _____ DISP: __ CAM: __ ROLL: __ FRAME: __-__ VIDEO: __ RM RELEASE: ___._ RADIOTAG (Y/N): _

PITTag No.: __________ DATE: __-__-__ SAMPLE #: _-____-___-_-_ TL (mm): ___ FL: ___ SL: ___ WT (g): ____

SEX: _ RIPE: __ P_1-P_2: __._ ND: __._ CPL: ___._ CPMD: __._ CPND: __._ HL: __._ SNL: __._ DFB: __._ AFB: __._ BD: ___._

D: __ A: __ RECAP: _ TAG: _____ DISP: __ CAM: __ ROLL: __ FRAME: __-__ VIDEO: __ RM RELEASE: ___._ RADIOTAG (Y/N): _

PITTag No.: __________ DATE: __-__-__ SAMPLE #: _-____-___-_-_ TL (mm): ___ FL: ___ SL: ___ WT (g): ____

SEX: _ RIPE: __ P_1-P_2: __._ ND: __._ CPL: ___._ CPMD: __._ CPND: __._ HL: __._ SNL: __._ DFB: __._ AFB: __._ BD: ___._

D: __ A: __ RECAP: _ TAG: _____ DISP: __ CAM: __ ROLL: __ FRAME: __-__ VIDEO: __ RM RELEASE: ___._ RADIOTAG (Y/N): _

PITTag No.: __________ DATE: __-__-__ SAMPLE #: _-____-___-_-_ TL (mm): ___ FL: ___ SL: ___ WT (g): ____

SEX: _ RIPE: __ P_1-P_2: __._ ND: __._ CPL: ___._ CPMD: __._ CPND: __._ HL: __._ SNL: __._ DFB: __._ AFB: __._ BD: ___._

D: __ A: __ RECAP: _ TAG: _____ DISP: __ CAM: __ ROLL: __ FRAME: __-__ VIDEO: __ RM RELEASE: ___._ RADIOTAG (Y/N): _

PITTag No.: __________ DATE: __-__-__ SAMPLE #: _-____-___-_-_ TL (mm): ___ FL: ___ SL: ___ WT (g): ____

SEX: _ RIPE: __ P_1-P_2: __._ ND: __._ CPL: ___._ CPMD: __._ CPND: __._ HL: __._ SNL: __._ DFB: __._ AFB: __._ BD: ___._

D: __ A: __ RECAP: _ TAG: _____ DISP: __ CAM: __ ROLL: __ FRAME: __-__ VIDEO: __ RM RELEASE: ___._ RADIOTAG (Y/N): _

PITTag No.: __________ DATE: __-__-__ SAMPLE #: _-____-___-_-_ TL (mm): ___ FL: ___ SL: ___ WT (g): ____

SEX: _ RIPE: __ P_1-P_2: __._ ND: __._ CPL: ___._ CPMD: __._ CPND: __._ HL: __._ SNL: __._ DFB: __._ AFB: __._ BD: ___._

D: __ A: __ RECAP: _ TAG: _____ DISP: __ CAM: __ ROLL: __ FRAME: __-__ VIDEO: __ RM RELEASE: ___._ RADIOTAG (Y/N): _

BIO/WEST GRAND CANYON STUDY

(Colorado River Mainstem)
Water Quality

Location: __ RM: ___._ (Mainstem) Date: ______ Time: ____ Weather: __

Fluctuation: __ Sechi Disc: __._ AirT(C): ___ McT: __._ HabT: __._

D.O.(mg/l): __._ pH _._ Cond. (umhos) _.___ Redox: ____
Comments:

Location: __ RM: ___._ (Mainstem) Date: ______ Time: ____ Weather: __

Fluctuation: __ Sechi Disc: __._ AirT(C): ___ McT: __._ HabT: __._

D.O.(mg/l): __._ pH _._ Cond. (umhos) _.___ Redox: ____
Comments:

Location: __ RM: ___._ (Mainstem) Date: ______ Time: ____ Weather: __

Fluctuation: __ Sechi Disc: __._ AirT(C): ___ McT: __._ HabT: __._

D.O.(mg/l): __._ pH _._ Cond. (umhos) _.___ Redox: ____
Comments:

Location: __ RM: ___._ (Mainstem) Date: ______ Time: ____ Weather: __

Fluctuation: __ Sechi Disc: __._ AirT(C): ___ McT: __._ HabT: __._

D.O.(mg/l): __._ pH _._ Cond. (umhos) _.___ Redox: ____
Comments:

FORM 8

JUVENILE HABITAT DATA SHEET

DATE __ __ __ __ __ __

SAMPLE NO. ______________ RMI __ __ __.__ __ RIVER RIGHT ____ LEFT ____

TBM ID ______________ STAGE (start) ___________ (end) ___________
TIME (start) ___________ (end) ___________

HAB1 ____ HAB2 ____
SHORELINE TYPE: TALUS _____ TAPEATS LEDGE _____ SAND BEACH _____ CLIFF _____
ALLUVIAL FAN ____ VEGETATION ____ OTHER ______________________________

RECORDERS: __________, __________, __________

TRAN SECT no.	DIST. from shore	DEPTH (feet)	FLOW DIR (+ or -)	VELOCITY (mps) (1)	VEL (2)	VEL (3)	SUBSTRATE (see codes)	LAT	COVER OV	IN
_1_	0.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_1_	1.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_1_	2.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_2_	0.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_2_	1.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_2_	2.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_3_	0.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_3_	1.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_3_	2.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_4_	0.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_4_	1.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_4_	2.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_5_	0.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_5_	1.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_5_	2.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_6_	0.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_6_	1.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_6_	2.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_7_	0.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_7_	1.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__
_7_	2.5 m	__.__	__	__.__	__.__	__.__	__/__	__	__	__

FORM 9

STAGE LEVEL REFERENCE POINT LOCATION

SHEET ____ OF ____

POINT NO:__.__ __ __ __   RIVER MILE:__ __ __.__   (LEFT/RIGHT)   PHOTO NO.___/___/____

LOCATION DISCRIPTION:

LOCATION SKETCH:

STAGE DISCHARGE MEASUREMENTS: DATE:________   TRANSMITTER FREQUENCIES: 40:______, 40:______, 40:_____

VERTICAL DISTANCE FROM REFERENCE POINT: _________
INITIAL DATE/TIME OF MEASUREMENT (- -) / (:)
UNITS OF MEASURE _________

DATE	TIME	STAGE A	STAGE B	STAGE C	STAGE D	STAGE E	RELATIVE CHANGE (+/-)
							0.00

FORM 10

DRIFT NET SAMPLES

Date: ______ Time: ____-____ Elapsed Time: _____ RM: _____ River Stage: ____

V_1: ____.____.____ V_2: ____.____.____ H_1: _____ H_2: _____ Habitat: __________

Description: ____

____

For Lab use only:

Black Fly	Midges	Gammarus	other	Misc.	% Clado.
adult: pupae: larvae: drwt:	adult: pupae: larvae: drwt:	mat: imm: drwt:	adult: imm: drwt:	terr: drwt:	 drwt:

Date: ______ Time: ____-____ Elapsed Time: _____ RM: _____ River Stage: ____

V_1: ____.____.____ V_2: ____.____.____ H_1: _____ H_2: _____ Habitat: __________

Description: ____

____

For Lab use only:

Black Fly	Midges	Gammarus	other	misc	% Clado
adult: pupae: larvae:	adult: Pupae: larvae:	mat: imm: drwt:	adult: imm: drwt:	terr: drwt:	 drwt:

Date: ______ Time: ____-____ Elapsed Time: _____ RM: _____ River Stage: ____

V_1: ____.____.____ V_2: ____.____.____ H_1: _____ H_2: _____ Habitat: __________

Description: ____

____

For Lab use only:

Black Fly	Midges	Gammarus	other	Misc.	% Clado.
adult: pupae: larvae: drwt:	adult: pupae: larvae: drwt:	mat: imm: drwt:	adult: imm: drwt:	terr: drwt:	 drwt:

APPENDIX B - DATA CODE GLOSSARY

DESCRIPTION OF FIELDS FOR DATA FORM 1, 2, 3
(Colorado River Mainstem)

Fish/Habitat Sampling

Field	Width	Type	Description
AirT	3	numeric	1-3 = air temperature in °C
Ambient Light	2	alphanumeric	2 = light conditions at time of sample SU = sunny CL = cloudy (> 50% cloud cover) PC = partly cloudy (< or= 50% cloud cover) SH = shadow NI = night ML = moonlight DD = dawn/dusk
Amps	4.1	decinumeric	1-4 = amperage level from Mark-XX
CB#	1	numeric	1 = clipboard #
Crew	6	alphanumeric	1-2 = principal crew member 3-4 = recorder 5-6 = assistant i.e. RV = Rich Valdez BM = Bill Masslich LC = Larry Crist
Date	6	numeric	1-2 = Year, 1992 = 92 3-4 = Month, June = 06 5-6 = Day of Month
D_1	3.1	decinumeric	1-3 = depth halfway to one side of backwater
D_2	3.1	decinumeric	1-3 = depth halfway to other side of backwater
Disposition	2	alphanumeric	2 = disposition of fish RA = returned alive (no radio implant) RI = radio implanted RR = returned with active radio transmitter RN = returned with non-active radio transmitter (removed external antennae but did not re-implant RS = returned alive with stomach contents removed

Field	Width	Type	Description
			DP = dead, preserved DR = dead, released (non-native fish) DS = dead, stomach contents preserved
Elapsed Time	4	numeric	1-4 = duration of net or trap sets recorded in tenths of hours i.e. 2.4 hr
End Time	4	numeric	1-4 = end of sample time
Fish Pres(Y/N)	1	alphanumeric	1 = were fish preserved Y = yes N = no
Fluctuations or Fluct.	2	alphanumeric	1-2 = Stage change between start time and end time RI = rising FA = falling SL = steady low SH = steady high
Gear	2	alphanumeric	1-2 = EL = electrofishing FR = frame net SA = 10'x3'x1/8" seine SB = 30'x4'x1/4" seine SG = 30'x5'x1/4" seine DL = larval fish drift net DR = invert drift net SU = surber AQ = aquarium net KS = kick screen TK = 75'x6'x1"x12" Trammel net TL = 75'x6'x1 1/2"x12" Trammel net TF = floated Trammel net TM = 50'x6'x1"x12" Trammel net TN = 50'x6'x1.5"x12" Trammel net TW = 75'x6'x1/2"x10" Trammel net TZ = TL with attached floats TY= TK with attached floats GM = 100'x6'x2" Gill net GP = 100'x6'x1 1/2" Gill net GX = experimental Gill net GZ = 60' experimental Gill net GY = 50'x6'x1.5" Gill net GF = floated Gill net

Field	Width	Type	Description
			MT = Minnow trap HL = Large hoop net (4' diam.) HM = Medium hoop net (4' diam.) HS = Small hoop net (2' diam.) AN = angling
Habitat Photo	(Compound Field)		
Camera	2	alphanumeric	1-2 = camera identifier 01 = B/W camera #1 02 = B/W camera #2 LC = Larry Crist's camera BL = Bill Leibfried's camera BM = Bill Masslich's camera
Roll	2	numeric	1-2 = photo roll number
Frame	4	numeric	1-4 = photo frame numbers
Hab1	2	alphanumeric	1-2 = general habitat MC = main channel TS = tributary stream SC = side channel
Hab2	2	alphanumeric	1-2 = specific habitat BA = backwater ED = eddy EM = embayment RI = riffle RU = run SH = shoreline PO = pool RC = return channel
Hab3	2	alphanumeric	1-2 = shoreline habitat TS = talus scree SW = shear wall LE = ledge BE = bedrock SI = silt SA = sand CO = cobble BO = boulder CB = cut bank VG = vegetation DF = debris flow

Field	Width	Type	Description
Hab L	5.1	decinumeric	1-5 = length of habitat seined
Hab W	5.1	decinumeric	1-5 = width of habitat seined
HabT	4.1	decinumeric	1-4 = temperature of habitat sampled
Hours	4.1	decinumeric	1-4 = hours gear set between checks
Max Depth	4.1	decinumeric	1-4 = maximum depth at gear location
McT	4.1	decinumeric	1-4 = main channel temperature

Field	Width	Type	Description
No. Bottles	1	numeric	1 = number of bottles with preserved fish
Old Tag	6	alphanumeric	1-6 = old tag number with color and size i.e. 003CSG for small green Carlin tag #003; 003FLY for yellow Floy tag #003 UCRP2 = upper caudal plus right pelvic clips UCLP2 = upper caudal plus left pelvic clips LCRP2 = lower caudal plus right plevic clips LCLP2 = lower caudal plus left pelvic clips LC = lower caudal punch UC = upper caudal punch DP = dorsal punch UCDP = upper caudal and dorsal punch
PIT Tag	10	alphanumeric	1-10 = unique number transmitted by PIT tag
P[1]	1	alphanumeric	1 = photo taken Y = yes N = no
Profile(Y/N)	1	alphanumeric	1 = cross section fathometer profile was taken Y = yes N = no
Quant Y/N	1	logical	1 = was sample done quantitativly
Reach	1	numeric	1 = Reach (0=above LCR, 1=LCR, 2=Granite Gorge, 3=Lower)
Recap(Y/N)	1	alphanumeric	1 = fish is a recapture Y = yes N = no
Rel. Loc.	4.1	decinumeric	1-4 = point of release of fish in RM to the nearest 0.05 mile below Lee's Ferry
Ripe	2	alphanumeric	2 = state of gonadal maturity of fish TU = tubercled only TC = tubercled and colored MI = running milt EG = expressible eggs SP = spent CO = colored only

Field	Width	Type	Description
RM	5.1	decinumeric	1-5 = miles downstream from Lees Ferry in 0.05 mile increments where possible
Sa L	4.1	decinumeric	1-4 = sample length (in meters)
Sa W	4.1	decinumeric	1-4 = sample width (in meters)
Sample No or Sample #	7	alphanumeric	1-3 = sequential sample no.
Sample Type	1	alphanumeric	1 = Sample type E = Electrofishing N = Gill/Trammel nets S = Seining T = Traps, i.e. hoop nets, minnow traps D = Drift netting A = Angling
Seconds	5	numeric	1-5 = total time from Mark-XX clock
Sex	1	alphanumeric	1 = gender of fish M = male F = female I = immature U = undetermined
Side	1	alphanumeric	1 = side of river channel where net or trap is anchored R = river right (looking downstream) L = river left (looking downstream)
SL	3	numeric	1-3 = standard length of fish
Species Code or Species	2	alphanumeric	1-2 = code for fish species HB = humpback chub SD = speckled dace CC = channel catfish FM = flannelmouth sucker BH = bluehead sucker RB = rainbow trout CP = carp BR = brown trout BK = brook trout RZ = razorback sucker FV = flannelmouth sucker variant

Field	Width	Type	Description
			PK = Plaines/Rio Grande killifish SB = striped bass FH = fat head minnow WE = walleye FR = flannelmouth x razorback sucker FZ = flannelmouth x razorback sucker SU = unidentified sucker YB = yellow bullhead BB = black bullhead
SPECIES SUMMARY (Compound Field) SEE LENGTH BREAKDOWN SHEET			
ADU	4	numeric	1-4 = number of adults caught
JUV	4	numeric	1-4 = number of juveniles caught
LAR	4	numeric	1-4 = number of larval caught
YOY	4	numeric	1-4 = number of YOY caught
Total	4	numeric	1-4 = total number caught by species
Start Date	6	numeric	1-6 = day a sample is begun
Start Time	4	numeric	1-4 = start of sample time 6am = 0600 6pm = 1800
Subsamp Y/N	1	logical	1 = was sein effort a subsample of habitat
Sub1	2	alphanumeric	1-2 = dominant substrate SI = silt SA = sand GR = gravel CO = cobble BO = boulder BE = bedrock OR = organics
Sub2	2	alphanumeric	1-2 = secondary substrate Same codes as Sub1
TL	3	numeric	1-3 = total length of fish in mm
Trip	2	Numeric	1-2 = Trip No. for year (0-12)

Field	Width	Type	Description
Turbidity or Turb	2	alphanumeric	1-2 = turbidity C = clear L = low >or= 0.5m secchi disk H = high turbidity <or= 0.5m secchi disk
V[1]	1	alphanumeric	1 = video footage taken Y = yes N = no
Volts	3	numeric	1-3 = voltage setting for Mark-XX
Weather	2	alphanumeric	1-2 = weather condition SU = sunny CS = clear skies (SU) CL = cloudy (>50% cloud cover) PC = partly cloudy (< or = 50% cloud cover) OV = overcast RA = raining SN = snow
WT	4	numeric	1-4 = weight of fish in grams

LIFE STAGE / LENGTH BREAKDOWN FOR FISH IN THE GRAND CANYON

SPECIES			LIFE STAGE DESIGNATION all lengths in mm TL		
Common Name	B/W Code	Scientific Name	Young of the Year Y-O-Y (mm TL)	Juvenile (mm TL)	Adult
Humpback chub	HB	Gila cypha	Dec-Apr 30: 100 May 30: 30 June 30: 40 July 30: 50 Aug 30: 60 Sept 30: 70 Oct 30: 80 Nov 30: 90	Dec-Apr 101-199 May 31-199 June 41-199 July 51-199 Aug 61-199 Sept 71-199 Oct 81-199 Nov 91-199	>=200
Flannelmouth sucker	FM	Catostomus latipinnis	<= 50	>50 - 199	>=200
Flannelmouth varient	FV		<= 50	>50 - 199	>=200
Flannelmouth x Razorback Hybrid	FR		<= 50	>50 - 199	>=200
Razorback sucker	RZ	Xyrauchen texanus	<= 50	>50 - 199	>=200
Bluehead sucker	BH	Catostomus discobolus	<= 50	>50 - 149	>=150
Speckled dace	SD	Rhynichthys osculus	<= 25		> 25
Rainbow trout	RB	Oncorhynchus mykiss	<= 75	> 75 - 199	>=200
Brown trout	BR	Salmo trutta	<= 75	> 75 - 199	>=200
Brook trout	BK	Salvelinus fontinalis	<= 75	> 75 - 199	>=200
Plains killifish	RK	Fundulus zebrinus	<= 25		> 25
Striped bass	SB	Morone saxatilis	<= 85	> 85 - 199	>=200
Walleye	WE	Stizostedion vitreum	<= 170	> 170 - 339	>=340
Common carp	CP	Cyprinus carpio	<= 75	> 75 - 199	>=200
Fathead minnow	FH	Pimiphales promelas	<= 25		> 25
Channel catfish	CC	Ictalurus punctatus	<= 60	> 60 - 199	>=200
Black bullhead	BB	Ameiurus melas	<= 50	> 50 - 199	>=200

DESCRIPTION OF FIELDS FOR DATA FORM 4 & 5
(Colorado River Mainstem)

Radiotelemetry

Field	Width	Type	Description
Abs. Stage	6	numeric	1-6 = absolute stage change from initial temporary staff gage reading
Aerial	1	alphanumeric	1 = radiotracking was done by aircraft Y = yes N = no
AirT	3	numeric	1-3 = air temperature in °C
Ambient Light	2	alphanumeric	2 = light conditions at time of sample SU = sunny CL = cloudy (> 50% cloud cover) PC = partly cloudy (< or= 50% cloud cover) SH = shadow NI = night ML = moonlight DD = dawn/dusk
Benchmark	6	alphanumeric	1-6 = unique code describing location of temporary stage benchmarks
Boat	1	alphanumeric	1 = radiotracking was done from boat Y = yes N = no
CB#	1	numeric	1 = clipboard #
Cond.	4	numeric	1-4 = conductance in umhos/cm
Confidence	1	numeric	1 = confidence rating on fish location 1 = high, excellent reception 2 = low, poor reception 3 = very low, don't use
Cover (Compound Field - fill out each)			
Over	2	alphanumeric	1-2 = overhead cover OB = overhanging bank SV = streamside vegetation NC = no cover

Field	Width	Type	Description
Lat	2	alphanumeric	1-2 = lateral cover VW = vertical rock well BO = boulders NC = no lateral cover
In	2	alphanumeric	1-2 = instream cover BO = boulder LG = log jam SS = sand shoal RJ = rock jetty NC = no instream cover
Crew	6	alphanumeric	1-2 = principal crew member 3-4 = recorder 5-6 = assistant i.e. RV = Rich Valdez BM = Bill Masslich LC = Larry Crist BL = Bill Leibfried
Date	6	numeric	1-2 = Year, 1992 = 92 3-4 = Month, June = 06 5-6 = Day of Month
Depth	4.1	decinumeric	1-4 = depth at gear location
Distance Moved	6	numeric	1-6 = distance moved by fish in meters since last observation
DO	2	numeric	1-2 = dissolved oxygen in mg/l
End Time	4	numeric	1-4 = end of sample time
Fluctuations or Fluct.	2	alphanumeric	1-2 = Stage change between start time and end time RI = rising FA = falling ST = steady
Frequency	3	numeric	1-3 = frequency of radiotag in field
Freq 1	3	numeric	1-3 = frequency of radiotag from manufacturer
Freq 2	3	numeric	1-3 = frequency of radiotag in field

Field	Width	Type	Description
Gage	6	numeric	1-6 = reading on temporary staff gage
Habitat Photo	(Compound Field)		
Camera	2	alphanumeric	1-2 = camera identifier 01 = B/W camera #1 02 = B/W camera #2 LC = Larry Crist's camera BL = Bill Leibfried's camera BM = Bill Masslich's camera
Roll	2	numeric	1-2 = photo roll number
Frame	4	numeric	1-4 = photo frame numbers
Hab1	2	alphanumeric	1-2 = general habitat MC = main channel TS = tributary stream SC = side channel
Hab2	2	alphanumeric	1-2 = specific habitat BA = backwater ED = eddy EM = embayment RI = riffle RU = run SH = shoreline PO = pool RC = return channel
Hab	2	alphanumeric	2 = specific habitat (Hab2) of fish being observed, same codes as Hab2
HabT	4.1	decinumeric	1-4 = temperature of habitat sampled
Habitat Map No.	6	alphanumeric map	1-6 = unique number corresponding to a habitat
McT	4.1	decinumeric	1-4 = main channel temperature
Mode (Compound field, check one)			
	2	alphanumeric	1-2 = sampling mode IM = implant LO = locate 2H = 2-hour 24 = 24-hour

Field	Width	Type	Description
			TF = test flow
pH	3.1	decinumeric	1-3 = pH
PIT Tag	10	alphanumeric	1-10 = unique number transmitted by PIT tag
Pulse	2	numeric	1-2 = pulse rate in field
Pulse 1	2	numeric	1-2 = pulse rate from manufacturer (#/min)
Pulse 2	2	numeric	1-2 = pulse rate in field
Radiotag Size	2	numeric	1-2 = weight specifications 09 = 9 grams 11 = 11 grams 16 = 16 grams
Reach	1	numeric	1 = Reach (0=above LCR, 1=LCR, 2=Granite Gorge, 3=Lower)
Rel. Stage	6	numeric	1-6 = relative stage change since last observation
River	2	alphanumeric	1-2 = location of radiotagged fish CO = Colorado River LC = Little Colorado HC = Havasu Creek
RM	5.1	decinumeric	1-5 = miles downstream from Lees Ferry
RM ___ to ___	4.1	numeric	1-4 = surveillance area, start RM to end RM
Sample No or Sample #	7	alphanumeric	1-3 = sequential sample no.
Secchi Disc	2	numeric	1-2 = depth to which sechi disc markings can be seen
Side	1	alphanumeric	1 = side of river channel where net or trap is anchored R = river right (looking downstream) L = river left (looking downstream)
Species	2	alphanumeric	1-2 = humpback chub
Start Time	4	numeric	1-4 = start of sample time

Field	Width	Type	Description
			6am = 0600 6pm = 1800
Sub1	2	alphanumeric	1-2 = dominant substrate SI = silt SA = sand GR = gravel CO = cobble BO = boulder BE = bedrock OR = organics
Sub2	2	alphanumeric	1-2 = secondary substrate
Surgeon	2	alphanumeric	2 = initials of team member that implanted radiotag
Time	4	numeric	4 = time of signal observation or attempt
TL	3	numeric	1-3 = total length of fish in mm
Trip	2	numeric	1-2 = Trip No. for year (0-12)
Turbidity or Turb	2	alphanumeric	1-2 = turbidity C = clear L = low> or = 0.5m secchi H = high turbidity < or = 0.5m secchi
V 0.2	3.1	decinumeric	1-3 = velocity at 0.2 depth at fish
V 0.6	3.1	decinumeric	1-3 = velocity at 0.6 depth at fish
V 0.8	3.1	decinumeric	1-3 = velocity at 0.8 depth at fish
V Bottom	3.1	decinumeric	1-3 = velocity at bottom at fish
Weather	2	alphanumeric	1-2 = weather condition SU = sunny CS = clear skies CL = cloudy (> 50% cloud cover) PC = partly cloudy (< or = 50% cloud cover) OV = overcast RA = raining SN = snow

DESCRIPTION OF FIELDS FOR DATA FORM 6
(Colorado River Mainstem)

See Chub Diagram for measurement locations

Chub Meristics

Field	Width	Type	Description
A -	2	numeric	number of anal fin rays
AFB -	2.1	decinumeric	anal fin base
BD -	3.1	decinumeric	maximum body depth
CAM -	2	alphanumeric	camera number
CPND -	2.1	decinumeric	caudal peduncle depth (minimum)
CPL -	3.1	decinumeric	caudal peduncle length
CPMD -	2.1	decinumeric	caudal peduncle depth (maximum)
D -	2	numeric	number of dorsal fin rays
Date -	6	numeric	1-2 = Year, 1992 = 92
			3-4 = Month, June = 06
			5-6 = Day of Month
DFB -	2.1	decinumeric	dorsal fin base
DISP -	2	alphanumeric	disposition
FL -	3	numeric	fork length
FRAME -	4	numeric	range of film frames
HL -	2.1	decinumeric	head length
ND -	2.1	decinumeric	nuchal depression
P_1-P_2 -	2.1	decinumeric	distance between the insertion of the pectoral and pelvic fins
PIT Tag No. -	10	alphanumeric	1-10 = unique number transmitted by PIT tag

Field	Width	Type	Description
WT	4	numeric	1-4 = weight of fish in grams

Field	Width	Type	Description
RADIOTAGGED -	1	alphanumeric	(Y or N)
RECAP -	1	alphanumeric	recapture (Y, N, or S for tag scar)
Ripe -	1	alphanumeric	running milt or expressing eggs, tuberculated or colored
RM RELEASE -	3.1	decinumeric	release point
ROLL -	2	numeric	film roll number
Sample # -	8	numeric	composite entry made up of Sample Type, Sample No, Trip, Reach, and CB#.
Sex -	1	alphanumeric	male, female, immature, or undetermined
SL -	3	numeric	standard length
SNL -	3.1	decinumeric	snout length
TAG -	6	alphanumeric	number and type of old external tag
TL -	3	numeric	total length
WT -	4	numeric	weight in grams

(Refer to other definition sheets for response options for similar fields)

DESCRIPTION OF FIELDS FOR DATA FORM 7
(Colorado River Mainstem)

Water Quality Sampling

Field	Width	Type	Description
AirT	3	numeric	1-3 = air temperature in °C
Cond.	4	numeric	1-4 = conductance in umhos/cm
Date	6	numeric	1-2 = Year, 1992 = 92 3-4 = Month, June = 06 5-6 = Day of Month
D.O	3.1	decinumeric	1-3 = dissolved oxygen in mg/L
Fluctuations or Fluct.	2	alphanumeric	1-2 = Stage change between start time and end time RI = rising FA = falling ST = steady
HabT	4.1	decinumeric	1-4 = temperature of habitat sampled
McT	4.1	decinumeric	1-4 = main channel temperature
pH	3.1	decinumeric	1-3 = pH
Redox	4	numeric	1-4 = redox potential of water
RM	5.1	decinumeric	1-5 = miles downstream from Lees Ferry
Sechi Disc	2	numeric	1-2 = depth to which sechi disc markings can be seen
Time	4	numeric	4 = time of observation
Weather	2	alphanumeric	1-2 = weather condition SU = sunny CS = clear skies CL = cloudy (> 50% cloud cover) PC = partly cloudy (< or = 50% cloud cover) OV = overcast RA = raining SN = snow

DESCRIPTION OF FIELDS FOR DATA FORM 8
(Colorado River Mainstem)

Juvenile Habitat

Field	Width	Type	Description
Cover	2	numeric	LA = lateral OV = overhead IN = instream
Date	6	numeric	1-2 = year, 1992 = 92 3-4 = month, June = 06 5-6 = day of month
Depth	4.1	decinumeric	water depth in feet
Dist.	3.1	decinumeric	0.5 m = 0.5 m from shore 1.5 m = 1.5 m from shore 2.5 m = 2.5 m from shore
FLOW	1	alphanumeric	+ = downstream flow - = upstream flow (eddy)
HAB1	2	alphanumeric	1-2 = general habitat MC = main channel TS = tributary stream SC = side channel
HAB2	2	alphanumeric	1-2 = specific habitat BA = backwater ED = eddy EM = embayment RI = riffle RU = run SH = shoreline PO = pool RC = return channel
HAB3	2	alphanumeric	1-2 = shoreline habitat TS = talus scree SW = shear wall LE = ledge BE = bedrock SI = silt SA = sand CO = cobble BO = boulder

Field	Width	Type	Description
			CB = cut bank VG = vegetation DF = debris flow
Recorders	6	alphanumeric	i.e. RV = Rich Valdez BM = Bill Masslich LC = Larry Crist BL = Bill Leibfried
River	1	numeric	Right = right bank, facing downstream Left = left bank, facing downstream
RMI	5.7	decinumeric	1-5 = miles downstream from Lees Ferry in 0.05 mile increments
Sample No.	3	alphanumeric	1-3 = sequential sample no
Shoreline type	2	alphanumeric	TA = talus TL = tapeats ledge SA = sand beach CL = cliff AF = alluvial fan VE = vegetation OT = other
Stage	4.1	decinumeric	river level from temporary bench mark to 0.1 cm
Time	4	numeric	time at start and end of river stage measurements
TBM ID	5.2	alpha-decinumeric	temporary bench mark identified as river mile and river left or right, e.g., 139.02L
Transect	1	numeric	1-10
Substrate	2	numeric	Dominant/Secondary SI = silt SA = sand GR = gravel CO = cobble BO = boulder BE = bedrock OR = organics

DESCRIPTION OF FIELDS FOR DATA FORM 9
(Colorado River Mainstem)

Stage Level Reference Point Locations

Field	Width	Type	Description
Date	6	numeric	1-2 = year, 1992 = 92 3-4 = month, June = 06 5-6 = day of month
Location Description		memo	written description of location of temporary bench mark
Initial date /time of measure	6/4	numeric	dates as above, time in military time
Location Sketch			Sketch of temporary bench mark location
Photo no.	6	alphanumeric	1-2 = camera number 3-4 = roll number 5-6 = frame number
Relative change	5.1	decinumeric	Total water level change in cm from initial start point
River Mile	5.1	decinumeric	1-5 = miles downstream from Lees Ferry in 0.5 mile increments
Stage	5.1	decinumeric	River level on different staff gages (A-E)
Transmitter Frequencies	3	numeric	Radiofrequency in kilohertz of radiotagged fish
Vertical Distance	3	numeric	Distance in meters from temporary bench mark to staff gage

DESCRIPTION OF FIELDS FOR DATA FORM 10
(Colorado River Mainstem)

Drift Net Samples

Field	Width	Type	Description
Date	6	numeric	1-2 = year, 1992 = 92 3-4 = month, June = 06 5-6 = day of month
Description	-	memo	description of sample contents
Elapsed Time	2	numeric	minutes of sample time
H_1	3.1	decinumeric	height of drift net at start of set
H_2	3.1	decinumeric	height of drift net at end of set
River stage	2	alphanumeric	RI = rising FA = falling ST = steady
RM	5.1	decinumeric	1-5 = miles downstream from Lees Ferry in 0.5 mile increments
V_1	3.1	decinumeric	water velocity at start of set at mouth of net
V_2	3.1	decinumeric	water velocity at end of set at mouth of net

APPENDIX C - DATA FILE STRUCTURES

File CHUB.DBF: Humpback chub morphometrics and meristics, Oct 1990-Nov 1993
File NET_MC.DBF: Netting and trapping sample data, Oct 1990-Nov 1993 (humpback chub
File ELEC_MC.DBF: Electrofishing sample data, Oct 1990-Nov 1993 (humpback chub)
File SEIN_MC.DBF: Seining sample data, Oct 1990-Nov 1993 (humpback chub)
File FISH_MC.DBF: All fish capture data, Oct 1990-Nov 1993 (humpback chub)
File SURVEIL.DBF: Radiotelemetry surveillance, Oct 1990-Nov 1992
File OBSERV_H.DBF: Header for radiotelemetry observations, Oct 1990-Nov 1992
File OBSERV_M.DBF: Movement for radiotelemetry observations, Oct 1990-Nov 1992
File REMOTE.DBF: Remote radiotelemetry station data, Oct 1990-Nov 1993
File DRIFT_MC.DBF: Drift net sample analysis data, Oct 1990-Nov 1993 (humpback chub)
File FOOD.DBF: Stomach pumping analysis data, 1993
File DSOND_MC.DBF: Datasonde water quality data, Oct 1990-Nov 1993 (humpback chub)
File SURV_MC.DBF: Surveyor II water quality data, Oct 1990-Nov 1993 (humpback chub)
File JUVHAB.DBF: Juvenile habitat measurments, Oct 1990-Nov 1993
File SCALES.DBF: Humpback chub scale analysis, Oct 1990-Nov 1993

Note: **Type**
C = character
N = numeric
L = logical

File: CHUB.DBF

Contents: Humpback chub morphometrics and meristics, Oct 1990-Nov 1993

Field	Type	Size	Dec	Description
PIT_TAG	C	10	0	PIT tag number
DATE	C	6	0	Date (year,month,day)
RIVER	C	2	0	River or tributary code
METER	N	4	0	Meters above tributary mouth (±20m)
TYPE	C	1	0	Type of sample
GEAR	C	2	0	Gear code
SAMPLE_NUM	C	3	0	Sample number
TRIP	C	5	0	Trip code
REACH	C	1	0	Mainstem Colorado River reach code
CLIPBOARD	C	1	0	Clipboard number
TL	N	3	0	Total length (mm)
FL	N	3	0	Fork length (mm)
SL	N	3	0	Standard length (mm)
WT	N	4	0	Weight (g), ±1g
SEX	C	1	0	Sex code
RIPE	C	3	0	Gonadal maturity code
P1_P2	N	4	1	Distance between insertions of pectoral and pelvic fins (mm)
ND	N	4	1	Nuchal depression depth (mm)
CPL	N	5	1	Caudal peduncle length (mm)
CPMAXD	N	4	1	Maximum caudal peduncle depth (mm)
CPMIND	N	4	1	Minimum caudal peduncle depth (mm)
HEAD_LN	N	4	1	Head length (mm)
SNOUT_LN	N	4	1	Snout length (mm)
DORSAL_FB	N	4	1	Dorsal fin base (mm)
ANAL_FB	N	4	1	Anal fin base (mm)
BODY_DEPTH	N	5	1	Body depth (mm)
DORSAL_RAY	N	2	0	Number of dorsal fin rays
ANAL_RAY	N	2	0	Number of anal fin rays
RECAPTURE	C	1	0	Recaptured fish
OLD_TAG	C	10	0	Old tag number if fish is recapture
DISP	C	2	0	Disposition code
CAMERA_NUM	C	2	0	Camera number
ROLL_NUM	C	2	0	Roll number
FRAME_NUM	C	5	0	Frame numbers
VIDEO_NUM	C	2	0	Video number
RM_CAPTURE	N	6	2	River mile of capture location (to 1/20 rm)
RM_RELEASE	N	6	2	River mile of release location (to 1/20 rm)
RADIO	C	1	0	Radio-tagged fish
COMMENTS	C	60	0	Comments

File: NET_MC.DBF
Contents: Netting and trapping sample data, Oct 1990-Nov 1993 (humpback chub)

Field	Type	Size	Dec	Description
TYPE	C	1	0	Type of sample
TRIP	C	5	0	Trip code
REACH	C	1	0	Mainstem Colorado River reach code
CLIPBOARD	C	1	0	Clipboard number
DATE	C	6	0	Date (year,month,day)
RIVER	C	2	0	River or tributary code
RM	N	6	2	River mile (to 1/20 rm)
METER	N	4	0	Meters above tributary mouth (±20m)
GEAR	C	2	0	Gear code
HAB1	C	2	0	General habitat
HAB2	C	2	0	Specific habitat
HAB3	C	2	0	Shoreline habitat
SIDE	C	1	0	Side of river looking downstream
PROFILE	C	1	0	Cross-section fathometer profile status
MAX_DEPTH	N	4	1	Maximum depth at gear location (m)
SUB1	C	2	0	Dominant substrate
SUB2	C	2	0	Secondary substrate
FISH_PRES	C	1	0	Fish or other materials preserved
NO_BOTTLES	N	1	0	Number of bottles with preserved materials
CAMERA_NUM	C	2	0	Camera number
PHOTO_ROLL	C	2	0	Roll number
FRAME_NUM	C	5	0	Frame numbers
CREW	C	8	0	Initials of crew members
SINGLE	C	1	0	Marks one of multiple records for a sample
SAMPLE_NUM	C	3	0	Sample number
TIME_SET	N	4	0	Net set time
TIME_PULL	N	4	0	Net pull time
END_DATE	C	6	0	Net pull date (year,month,day)
TIME_ELAPS	N	5	2	Elapsed time
LIGHT	C	2	0	Ambient light
WEATHER	C	2	0	Weather
TURBIDITY	C	2	0	Turbidity
TEMP_AIR	N	4	1	Air temperature (°C)
TEMP_MC	N	4	1	Main channel temperature (°C)
TEMP_HAB	N	4	1	Habitat temperature (°C)
FLUCT	C	2	0	River stage change
SPECIES	C	2	0	Fish species code
YOY	N	4	0	Number of young-of-year fish
JUV	N	4	0	Number of juvenile fish
ADU	N	4	0	Number of adult fish
TOTAL	N	4	0	Total number of fish
COMMENTS	C	0	0	Comments
MAP_ID_NUM	C	4	0	Unique net location ID to link with GIS

File: **ELEC_MC.DBF**
Contents: **Electrofishing sample data, Oct 1990-Nov 1993 (humpback chub)**

Field	Type	Size	Dec	Description
TYPE	C	1	0	Type of sample
SAMPLE_NUM	C	3	0	Sample number
TRIP	C	5	0	Trip code
REACH	C	1	0	Mainstem Colorado River reach code
CLIPBOARD	C	1	0	Clipboard
DATE	C	6	0	Date (year,month,day)
RIVER	C	2	0	River or tributary code
START_RM	N	6	2	River mile at start of sample (to 1/20 rm)
END_RM	N	6	2	River mile at end of sample (to 1/20 rm)
METER	N	4	0	Meters above tributary mouth (±20m)
TIME_START	N	4	0	Sample start time
TIME_END	N	4	0	Sample end time
SECONDS	N	5	0	Seconds electrofished
VOLTS	N	3	0	Voltage setting
AMPS	N	4	1	Amperage level
LIGHT	C	2	0	Ambient light
HAB1	C	2	0	General habitat
HAB2	C	2	0	Specific habitat
HAB3	C	2	0	Shoreline habitat
SUB1	C	2	0	Dominant substrate
SUB2	C	2	0	Secondary substrate
TEMP_AIR	N	4	1	Air temperature (°C)
TEMP_MC	N	4	1	Main channel temperature (°C)
TEMP_HAB	N	4	1	Habitat temperature (°C)
TURBIDITY	C	2	0	Turbidity
WEATHER	C	2	0	Weather
FLUCT	C	2	0	River stage change
FISH_PRES	C	1	0	Fish or other materials preserved
NO_BOTTLES	N	1	0	Number of bottles of preserved materials
CAMERA_NUM	C	2	0	Camera number
PHOTO_ROLL	C	2	0	Roll number
FRAME_NUM	C	5	0	Frame number
CREW	C	8	0	Initials of crew members
SINGLE	C	1	0	Marks one of multiple records for a sample
SPECIES	C	2	0	Fish species code
YOY	N	4	0	Number of young-of-year fish
JUV	N	4	0	Number of juvenile fish
ADU	N	4	0	Number of adult fish
TOTAL	N	4	0	Total number of fish
COMMENTS	C	60	0	Comments

File: **SEIN_MC.DBF**
Contents: **Seining sample data, Oct 1990-Nov 1993 (humpback chub)**

Field	Type	Size	Dec	Description
TYPE	C	1	0	Type of sample
SAMPLE_NUM	C	3	0	Sample number
TRIP	C	5	0	Trip code
REACH	C	1	0	Mainstem Colorado River reach code
CLIPBOARD	C	1	0	Clipboard number
DATE	C	6	0	Date (year,month,day)
RIVER	C	2	0	River or tributary code
RM	N	7	2	River mile (to 1/20 rm)
METER	N	4	0	Meters above tributary mouth (±20m)
GEAR	C	2	0	Gear code
TIME_START	N	4	0	Sample start time
HAB1	C	2	0	General habitat
HAB2	C	2	0	Specific habitat
HAB3	C	2	0	Shoreline habitat
SUB1	C	2	0	Dominant substrate
SUB2	C	2	0	Secondary substrate
TEMP_AIR	N	4	1	Air temperature (°C)
TEMP_MC	N	4	1	Main channel temperature (°C)
TEMP_HAB	N	4	1	Habitat temperature (°C)
QUANT	C	1	0	Quantitative seine haul
SUBSAMPL	C	1	0	Subsampled habitat
LIGHT	C	2	0	Ambient light
WEATHER	C	2	0	Weather
TURBIDITY	C	2	0	Turbidity
FLUCT	C	2	0	River stage change
HABL	N	5	1	Habitat length (m)
HABW	N	5	1	Habitat width (m)
SAMP_LN	N	5	1	Sample length (m)
SAMP_WID	N	5	1	Sample width (m)
SAMP_AREA	N	7	2	Sample area (m^2)
MAX_DEPTH	N	4	1	Maximum depth of habitat (ft)
DEPTH_1	N	4	1	Depth halfway between max and one side (ft)
DEPTH_2	N	4	1	Depth halfway between max and other side (ft)
FISH_PRES	C	1	0	Fish or other materials preserved
NO_BOTTLES	N	1	0	Number of bottles of preserved materials
CAMERA_NUM	C	2	0	Camera number
PHOTO_ROLL	C	2	0	Roll number
FRAME_NUM	C	5	0	Frame number
CREW	C	8	0	Initials of crew members
SINGLE	C	1	0	Marks one of multiple records for a sample
SPECIES	C	2	0	Fish species code
LAR	N	4	0	Number of larval fish
YOY	N	4	0	Number of young-of-year fish
JUV	N	4	0	Number of juvenile fish
ADU	N	4	0	Number of adult fish
TOTAL	N	4	0	Total number of fish
COMMENTS	C	60	0	Comments

File: **FISH_MC.DBF**
Contents: **All fish capture data, Oct 1990-Nov 1993 (humpback chub)**

Field	Type	Size	Dec	Description
TYPE	C	1	0	Type of sample
SAMPLE_NUM	C	3	0	Sample number
TRIP	C	5	0	Trip code
REACH	C	1	0	Mainstem Colorado River reach code
CLIPBOARD	C	1	0	Clipboard
DATE	C	6	0	Date (year,month,day)
GEAR	C	2	0	Gear code
HAB1	C	2	0	General habitat
HAB2	C	2	0	Specific habitat
HAB3	C	2	0	Shoreline habitat
SUB1	C	2	0	Dominant substrate
SUB2	C	2	0	Secondary substrate
SPECIES	C	2	0	Fish species code
TL	N	3	0	Total length (mm)
SL	N	3	0	Standard length (mm)
LB	N	2	0	Pounds
OZ	N	2	0	Ounces
WT	N	4	0	Weight (g), ±1g
PIT_TAG	C	10	0	PIT tag number
RECAPTURE	C	1	0	Recaptured fish
OLD_TAG	C	10	0	Old tag number if fish is recapture
PHOTO	C	1	0	Photographs taken
VIDEO	C	1	0	Video footage taken
SEX	C	1	0	Sex
RIPE	C	2	0	Gonadal maturity code
DISP	C	2	0	Disposition code
RIVER	C	2	0	River or tributary code
RM	N	6	2	River mile of capture location (to 1/20 rm)
METER	N	4	0	Meters above mouth of tributary (±20m)
RM_RELEASE	N	6	2	River mile of release location (to 1/20 rm)
COMMENTS	C	60	0	Comments

File: **SURVEIL.DBF**
Contents: **Radiotelemetry surveillance, Oct 1990-Nov 1992**

Field	Type	Size	Dec	Description
SAMPLE_NUM	C	3	0	Sample number
TRIP_NUM	C	2	0	Trip code
REACH	C	1	0	Mainstem Colorado River reach code
CLIPBOARD	C	1	0	Clipboard number
SINGLE	C	1	0	Marks one of multiple records for a sample
MODE	C	2	0	Type of surveillance
START_DATE	N	6	0	Date at start of surveillance (year,month,day)
START_TIME	N	4	0	Time at start of surveillance
END_DATE	N	6	0	Date at end of surveillance (year,month,day)
END_TIME	N	4	0	Time at end of surveillance
TIME_ELAPS	N	6	2	Time elapsed during surveillance
START_RMI	N	5	1	Starting river mile of surveillance (to 1/20 rm)
END_RMI	N	5	1	Ending river mile of surveillance (to 1/20 rm)
LIGHT	C	2	0	Ambient light
WEATHER	C	2	0	Weather code
TURBIDITY	C	1	0	Turbidity code
SECHI_DISK	N	4	2	Secchi depth (m)
NTU	N	6	1	Turbidity (NTU)
FLUCT	C	2	0	River stage change during surveillance
CREW	C	8	0	Initials of crew members
DATE	N	6	0	Date of individual fish contact (year,month,day)
TIME	N	4	0	Time of individual fish contact
RIVER	C	2	0	River or tributary code
RM	N	6	2	River mile (to 1/20 rm)
SIDE	C	1	0	Side of river looking downstream
FREQ	N	3	0	Tag frequency (40.XXX MHz)
PULSE	N	3	0	Tag pulse rate (pulses/minute)
CONFIDENCE	C	1	0	Observer confidence in location accuracy
HAB2	C	2	0	Specific habitat
COVER	C	2	0	Instream cover
PIT_TAG	C	10	0	PIT tag number
COMMENTS	C	75	0	Comments

File: OBSERV_H.DBF
Contents: Header for radiotelemetry observations, Oct 1990-Nov 1992

Field	Type	Size	Dec	Description
SAMPLE_NUM	C	3	0	Sample number
TRIP_NUM	C	2	0	Trip code
REACH	C	1	0	Mainstem Colorado River reach code
CLIPBOARD	C	1	0	Clipboard number
SINGLE	C	1	0	Marks one of multiple records for a sample
START_DATE	N	6	0	Date at start of observation (year,month,day)
START_TIME	N	4	0	Time at start of observation
END_DATE	N	6	0	Date at end of observation (year,month,day)
END_TIME	N	4	0	Time at end of observation
TIME_ELAPS	N	6	0	Time elapsed during observation
RIVER	C	2	0	River or tributary code
RM	N	6	2	River mile (to 1/20 rm)
MODE	C	2	0	Mode of observation
HAB_MAP_NO	C	10	0	Habitat map number
BENCHMARK	C	6	0	Temporary benchmark code
CONFIDENCE	N	1	0	Observer confidence in location accuracy
CAMERA_NUM	C	2	0	Camera number
PHOTO_ROLL	C	2	0	Roll number
FRAME_NUM	C	5	0	Frame numbers
CREW	C	8	0	Initials of crew members
PIT_TAG	C	10	0	PIT tag number
TL	N	3	0	Total length when implanted (mm)
WT	N	4	0	Weight when implanted (g), ±1g
SEX	C	1	0	Sex
TAG_SIZE	N	2	0	Weight of tag (g)
FREQ_1	N	3	0	Original tag frequency
FREQ_2	N	3	0	Strongest tag frequency observed
PULSE_1	N	2	0	Original tag pulse rate
PULSE_2	N	2	0	Tag pulse rate during observation
SURGEON	C	2	0	Initials of surgeon

File: OBSERV_M.DBF
Contents: Movement for radiotelemetry observations, Oct 1990-Nov 1992

Field	Type	Size	Dec	Description
SAMPLE_NUM	C	3	0	Sample number
TRIP	C	5	0	Trip code
REACH	C	1	0	Mainstem Colorado River reach code
CLIPBOARD	C	1	0	Clipboard number
SINGLE	C	1	0	Marks one of multiple records for a sample
PIT_TAG	C	10	0	PIT tag number
START_DATE	N	6	0	Date at start of observation block (year,month,day)
START_TIME	N	4	0	Time at start of observation block
START_RMI	N	6	2	River mile location at start of observation block (to 1/20 rm)
START_HAB	C	2	0	Specific habitat at start of observation block
START_GAGE	N	5	1	River stage at start of observation block
START_LITE	C	2	0	Ambient light at start of observation block
START_WEAT	C	2	0	Weather code at start of observation block
START_TURB	C	2	0	Turbidity code at start of observation block
END_DATE	N	6	0	Date at end of observation block (year,month,day)
END_TIME	N	4	0	Time at end of observation block
END_RMI	N	6	2	River mile location at end of observation block (to 1/20 rm)
END_HAB	C	2	0	Specific habitat at end of observation block
MOVEMENT	N	3	0	Movement during observation block (m)
END_GAGE	N	5	1	River stage at end of observation block
END_LITE	C	2	0	Ambient light at end of observation block
END_WEAT	C	2	0	Weather code at end of observation block
END_TURB	C	2	0	Turbidity code at end of observation block
TIME_ELAPS	N	6	2	Time elapsed during observation block
GAGE	N	6	1	River stage change during observation block (cm)
STAGE_RATE	N	7	2	Rate of river stage change (cm/hr)

File: REMOTE.DBF
Contents: Remote radiotelemetry station data, Oct 1990-Nov 1993

Field	Type	Size	Dec	Description
JUL_DATE	N	3	0	Julian date
TIME	N	4	0	Time
FREQ	N	3	0	Tag frequency (40.XXX MHz)
PULSE	N	3	0	Tag pulse rate (pulses/minute)

File: DRIFT_MC.DBF
Contents: Drift net sample analysis data, Oct 1990-Nov 1993 (humpback chub)

Field	Type	Size	Dec	Description
DATE	N	6	0	Date of sample (year,month,day)
TIME	N	4	0	Time of sample
RM	C	5	0	River mile (to 1/20 rm)
STAGE	C	2	0	River stage change
HAB	C	2	0	Habitat
DEPTH	C	3	0	Height of net above water surface (cm)
SIMADU	N	7	2	Number of adult simuliids
SIMPUP	N	7	2	Number of pupa simuliids
SIMLAR	N	7	2	Number of larval simuliids
CHIRADU	N	7	2	Number of adult chironomids
CHIRPUP	N	7	2	Number of pupa chironomids
CHIRLAR	N	7	2	Number of larval chironomids
GAMMADU	N	7	2	Number of adult gammarus (>7mm)
GAMMIMM	N	7	2	Number of immature gammarus (<7mm)
OTHER	N	7	2	Number of other aquatic invertebrates
TERR	N	7	2	Number of terrestrial insects
CLADDRWT	N	7	4	Cladophora dry weight (g)
CLADPER	N	2	0	Percent cladophora
LABVOL	N	3	0	Sample volume after preservation (ml)
FIELDVOL	N	3	0	Sample volume before preservation (ml)
REHYDVOL	N	3	0	Sample volume after rehydration in lab (ml)
CMH	N	7	2	Water filtered through net (Cubic meters per hour)
NOTES	C	100	0	Specific notes about sample

File: **FOOD.DBF**
Contents: **Stomach pumping analysis data, 1993**

Field	Type	Size	Dec	Description
TYPE	C	1	0	Type of sample
SAMPLE_NUM	C	3	0	Sample number
TRIP	C	5	0	Trip code
REACH	C	1	0	Mainstem Colorado River reach code
CLIPBOARD	C	1	0	Clipboard
DATE	N	6	0	Date of sample (year,month,day)
RIVER	C	2	0	River or tributary code
RM	N	5	1	River mile (to 1/20 rm)
SPECIES	C	3	0	Species of fish stomach pumped
AGE	C	2	0	Age of fish (adult or juvenile)
SEX	C	1	0	Sex
TL	N	3	0	Total length (mm)
SL	N	3	0	Standard length (mm)
LB	N	3	0	Weight in pounds
OZ	N	3	0	Weight in ounces
WT	N	4	0	Weight in grams
PIT_TAG	C	10	0	PIT tag number
GAMMADU	N	3	0	Number of adult gammarus (>7mm)
GAMMIMM	N	3	0	Number of immature gammarus (<7mm)
SIMADU	N	3	0	Number of adult simuliids
SIMLARV	N	3	0	Number of larval simuliids
SIMPUP	N	3	0	Number of pupa simuliids
CHIRADU	N	3	0	Number of adult chironomids
CHIRPUP	N	3	0	Number of pupa chironomids
CHIRLAR	N	3	0	Number of larval chironomids
ANNELID	N	3	0	Number of annelids
OTHER	N	3	0	Number of other aquatic insects
TERR	N	3	0	Number of terrestrial insects
CLADOVOL	N	3	0	Volume of cladophora (ml)
NEMOTODES	L	1	0	Presence of nematodes
TAPEWORMS	L	1	0	Presence of tapeworms
FISH	L	1	0	Presence of fish
MEMO	C	200	0	Details of sample

File: DSOND_MC.DBF
Contents: Datasonde water quality data, Oct 1990-Nov 1993 (humpback chub)

Field	Type	Size	Dec	Description
DATE	N	6	0	Date (year,month,day)
TIME	N	4	0	Military time
RIVER	C	2	0	River or tributary code
RM	N	6	2	River mile (to 1/20 rm)
TEMP	N	5	2	Temperature (°C)
PH	N	5	2	pH
COND	N	6	3	Conductivity
DO	N	5	2	Dissolved oxygen
BATT	N	5	2	Battery voltage

File: SURV_MC.DBF
Contents: Surveyor II water quality data, Oct 1990-Nov 1993 (humpback chub)

Field	Type	Size	Dec	Description
DATE	N	6	0	Date (year,month,day)
TIME	N	4	0	Military time
RIVER	C	2	0	River or tributary code
RM	N	6	2	River mile (to 1/20 rm)
TEMP	N	5	2	Temperature (°C)
PH	N	5	2	pH
TRUEDO	N	5	2	Dissolved oxygen
COND	N	6	3	Conductivity
ORP	N	6	3	Oxidation-reduction potential
BATT	N	5	2	Battery voltage

File: **JUVHAB.DBF**
Contents: **Juvenile habitat measurements, Oct 1990-Nov 1993**

Field	Type	Size	Dec	Description
SAMPLE_NUM	C	3	0	Sample number
TRIP	C	5	0	Trip code
REACH	C	1	0	Mainstem Colorado River reach code
DATE	N	6	0	Date (year,month,day)
RIVER	C	2	0	River or tributary code
RM	N	5	2	River mile (to 1/20 rm)
SIDE	C	1	0	Side of river looking downstream
TBM	C	8	0	Temporary benchmark location code
GAGE_BEG	N	4	0	River stage at beginning of sample
GAGE_END	N	4	0	River stage at end of sample
TIME_BEG	N	4	0	Time at start of sample
TIME_END	N	4	0	Time at end of sample
LC_MC_FLOW	N	5	0	Approximate discharge in cfs
SHORETYPE	C	15	0	Shoreline type
CREW	C	8	0	Initials of crew members
FISHPRESNT	C	1	0	Fish present
COMMENTS	C	20	0	Comments
TRAN_NUM	N	2	0	Transect number
DIST_05_DP	N	5	2	Depth 0.5 meters from shore (ft)
DIST_05_VL	N	5	2	Velocity at 0.6 depth, 0.5 meters from shore (ft/s)
DIST_05_S1	C	2	0	Dominant substrate 0.5 meters from shore
DIST_05_S2	C	2	0	Secondary substrate 0.5 meters from shore
DIST_10_DP	N	5	2	Depth 1.0 meter from shore (ft)
DIST_10_VL	N	5	2	Velocity at 0.6 depth, 1.0 meter from shore (ft/s)
DIST_10_S1	C	2	0	Dominant substrate 1.0 meter from shore
DIST_10_S2	C	2	0	Secondary substrate 1.0 meter from shore
DIST_15_DP	N	5	2	Depth 1.5 meters from shore (ft)
DIST_15_VL	N	5	2	Velocity at 0.6 depth, 1.5 meters from shore (ft/s)
DIST_15_S1	C	2	0	Dominant substrate 1.5 meters from shore
DIST_15_S2	C	2	0	Secondary substrate 1.5 meters from shore
DIST_25_DP	N	5	2	Depth 2.5 meters from shore (ft)
DIST_25_VL	N	5	2	Velocity at 0.6 depth, 2.5 meters from shore (ft/s)
DIST_25_S1	C	2	0	Dominant substrate 2.5 meters from shore
DIST_25_S2	C	2	0	Secondary substrate 2.5 meters from shore

File: SCALES.DBF
Contents: Humpback chub scale analysis, Oct 1990-Nov 1993

Field	Type	Size	Dec	Description
BOX	C	2	0	Box number of slide location
FISH_NO	C	2	0	Sequential fish number
SINGLE	C	1	0	Marks one of multiple scales per fish
SAMPLE_NO	C	8	0	Unique sample identifier
DATE	N	6	0	Date (year,month,day)
SPECIES	C	2	0	Fish species code
RIVER_MILE	N	6	2	Mainstem river mile (to 1/20 rm)
METERS	N	5	0	Meters from tributary mouth (for AGF scales)
TL	N	3	0	Total length (mm)
SL	N	3	0	Standard length (mm)
SCALE_RAD	N	4	1	Length from nucleus to scale margin (μm)
NO_CIRC	N	2	0	Total number of circuli
A1	N	4	1	First annulus from nucleus (μm)
NO_CIRC_A1	N	2	0	Number of circuli to first annulus
A2	N	4	1	Second annulus from nucleus (μm)
NO_CIRC_A2	N	2	0	Number of circuli to second annulus
A3	N	4	1	Third annulus from nucleus (μm)
NO_CIRC_A3	N	2	0	Number of circuli to third annulus
A4	N	4	1	Fourth annulus from nucleus (μm)
NO_CIRC_A4	N	2	0	Number of circuli to fourth annulus
A5	N	4	1	Fifth annulus from nucleus (μm)
NO_CIRC_A5	N	2	0	Number of circuli to fifth annulus
A6	N	4	1	Sixth annulus from nucleus (μm)
NO_CIRC_A6	N	2	0	Number of circuli to sixth annulus
X	N	4	1	Length from nucleus to transitional check (μm)
NO_CIRC_X	N	2	0	Number of circuli to transitional check
AGE	N	1	0	Age of fish when scale collected
YEAR_CLASS	N	4	0	Year fish was hatched
RELIABLE	C	1	0	Reliability of scale information
PCX	N	5	2	Proportional total length at trans. check
BCX	N	5	2	Back-calculated total length at trans. check (mm)
BC1	N	5	2	Back-calculated total length at first annulus (mm)
PC1	N	5	2	Proportional total length at first annulus
BC2	N	5	2	Back-calculated total length at second annulus (mm)
BC3	N	5	2	Back-calculated total length at third annulus (mm)
BC4	N	5	2	Back-calculated total length at fourth annulus (mm)
BC5	N	5	2	Back-calculated total length at fifth annulus (mm)
BC6	N	5	2	Back-calculated total length at sixth annulus (mm)