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BIO/WEST, Inc.

Resource Management and Problem Solving Services

Report No. TR 250-01
BIO/WEST, Inc.

CHARACTERIZATION OF THE LIFE HISTORY AND ECOLOGY OF THE HUMPBACK CHUB IN THE GRAND CANYON

DATA COLLECTION PLAN

Submitted To

Bureau of Reclamation
Upper Colorado Region
Salt Lake City, Utah

Submitted By

BIO/WEST, Inc.
1063 W. 1400 N.
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TABLE OF CONTENTS

INTRODUCTION

This Data Collection Plan was developed by BIO/WEST, Inc. as part of the requirements of Reclamation Contract No. 0-CS-40-09110, entitled *Characterization of the Life History and Ecology of the Humpback Chub in the Grand Canyon*. The background and scope of work for this investigation are described in the contract. The purpose of this data collection plan is to detail the sample design, methods, schedules, work activities, logistics, and data collection for this investigation.

This Data Collection Plan contains two appendices. Appendix A is the **Fish Handling Protocol** which provides the specific detail of our plans for handling all fish captured during this study. Appendix B is the **Database Management Protocol** which describes the manner in which the data are to be collected, entered, stored, and analyzed.

OBJECTIVES

The purpose of this investigation is:

To Conduct In Cooperation With The Service And AGF, Ecological Studies To Determine The Relationship Between Operations Of Glen Canyon Dam And The Ecology And Life History Requirements Of The Endangered Humpback Chub Population In Grand Canyon.

This 4-year investigation will focus on the collection of life history needs of the humpback chub, including habitat use and availability, in the mainstem reaches of the Grand Canyon. This mainstem investigation will be conducted while the U.S. Fish and Wildlife Service (Service), Arizona Game and Fish Department (AGF), and Arizona State University (ASU) in cooperation with the Navajo Nation are investigating aspects of the ecology of the humpback chub in the Little Colorado River (LCR) and other tributaries in the Grand Canyon. The objectives of the combined humpback chub investigations are as follows:

Objective 1: **To determine the ecological and limiting factors of all life stages of humpback chub in the mainstem Colorado River, Grand Canyon, and the effects of the Glen Canyon Dam operations on the humpback chub.**

- **1A:** **Determine resource availability and resource use (habitat, water quality, food, etc.) of humpback chub in the mainstem Colorado River.**
- **1B:** **Determine the reproductive capacity and success of humpback chub in the mainstem Colorado River.**
- **1C:** **Determine the survivorship of early stages of the humpback chub in the mainstem Colorado River.**
- **1D:** **Determine the distribution, abundance and movement of the humpback chub in the mainstem Colorado River, and effects of dam operations on the movement and distribution of humpback chub.**
- **1E:** **Determine important biotic interactions with other species for all life stages of humpback chub.**

Objective 2: **Determine the life history schedule for the Grand Canyon humpback chub population.**

- **2A:** **Develop or modify an existing population model from empirical data collected during the study for use in analyses of reproductive success, recruitment and survivorship.**

BIO/WEST's research will be partitioned into two major efforts. The primary effort will focus on the collection of life history information and habitat use of humpback chub within two intensive sampling reaches (LCR Reach (1) and Havasu Creek Reach (3)) using radiotelemetry and other gear types. The second effort will be comprised of a distributional survey and habitat data collection in the intervening reach of the mainstem Colorado River referred to as Granite Gorge Reach (2). Data collection will take full advantage of scheduled research flows (predetermined releases from Glen Canyon Dam) to determine the effects of dam operation on habitat conditions in the Grand Canyon. The use of radiotelemetry in study reaches other than the LCR Reach will be curtailed until the presence of humpback chub in the other reaches is established and the effectiveness of radiotelemetry is evaluated.

STUDY AREA

This investigation will be conducted in a 170-mile region of the Grand Canyon from Kwagunt Rapid (RM 56) to Diamond Creek (RM 226) (Figure 1). This region will be divided into three reaches, including (1) The Upper Reach from Kwagunt Rapid (RM 56) to Red Canyon (RM 76.5), (2) The Middle Reach or Granite Gorge from Red Canyon (RM 76.5) to Havasu Creek (RM 156), and (3) The Lower Reach from Havasu Creek (RM 156) to Diamond Creek (RM 226). Sampling will be concentrated in the confluence area of major tributaries where humpback chub have been collected in cooperation with the Service and AGF.

The Upper Reach (LCR Reach)

This 20.5-mile (33 km) reach will be sampled extensively with the use of radiotelemetry, electrofishing gear, experimental gill nets, trammel nets, hoop nets, minnow traps, and seines. All available habitats will be sampled, including runs, eddies, pools, backwaters, side channels, and slackwaters. Physical and chemical parameters will be measured to characterize the habitat used by humpback chub and the effect of Glen Canyon Dam operations. Since the LCR empties into the upper 5 miles of this reach

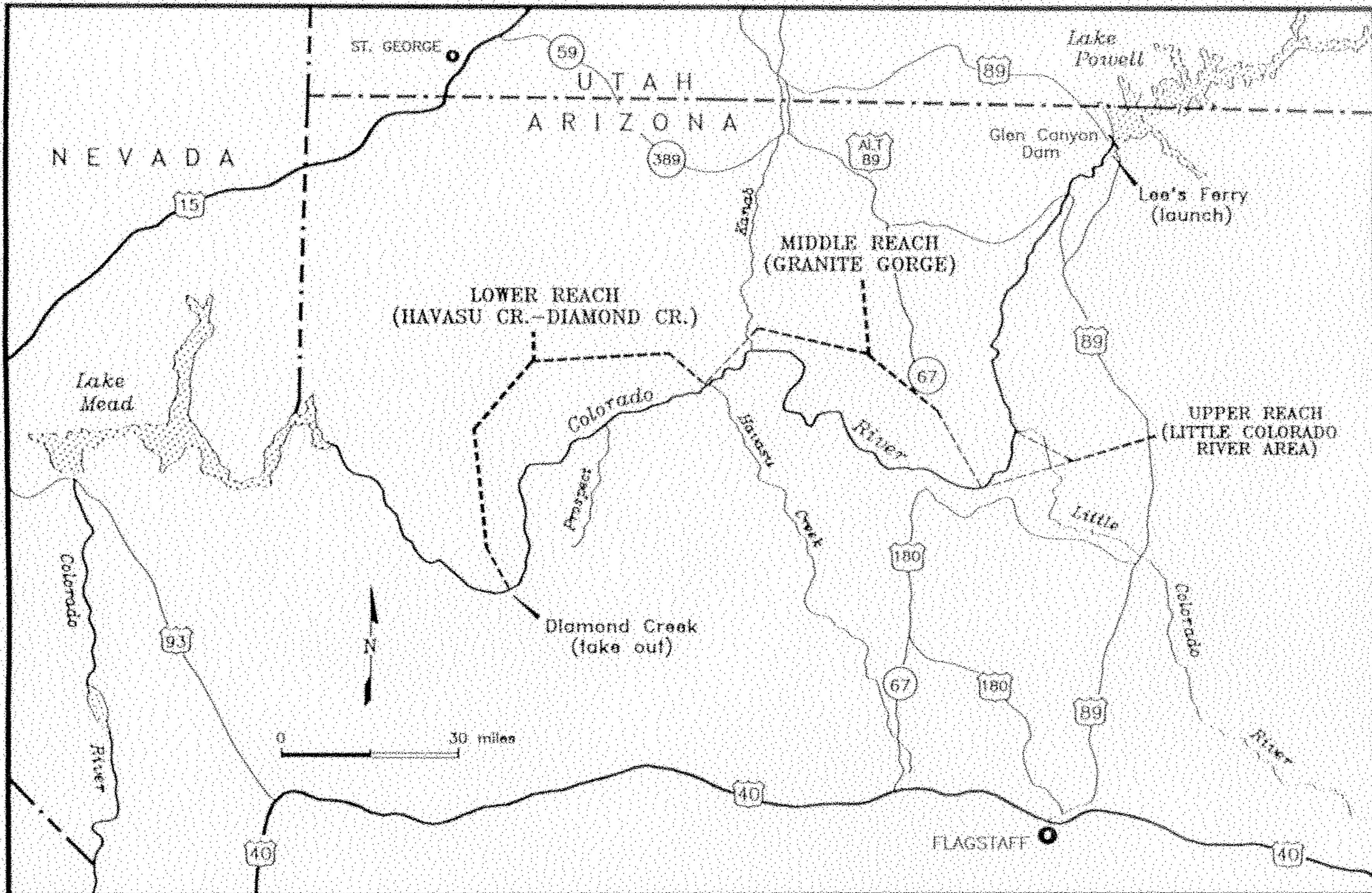

Figure 1. General study area for humpback chub study in the Grand Canyon, showing the three study reaches.

(RM 61), a concerted effort will be made to coordinate our efforts with those of AGF and the Service to assess the movement of fish between the LCR and the mainstem Colorado River.

The Middle Reach (Granite Gorge Reach)

This 79.5-mile (129 km) reach contains steep, rocky shoreline habitats typical of areas occupied by humpback chub in the Upper Colorado River Basin. The primary purpose for sampling this reach is to extend known information on the distribution of the humpback chub, its abundance by age class, habitat use, and changes in habitat availability, where possible. This Middle Reach will be quantitatively sampled with the use of gill and trammel nets, electrofishing gear, seines, and minnow traps. Radiotelemetry will not be conducted in this reach unless large numbers of adult humpback chub are encountered, and the scope of work is modified in conference with the ACT.

This Middle Reach will be divided into five longitudinal strata to enable us to sample the reach as thoroughly as possible. We recognize that this reach contains numerous large rapids which could easily influence sample site selection. We also recognize that this reach contains different geomorphological areas that dictate fish habitat. The initial categorization of the geomorphology of the Grand Canyon by Howard and Dolan (1981) has been further differentiated into eleven (11) morphologically distinct areas by Jack Schmidt (1988). We plan to use a portion of this classification of the Colorado River between Glen Canyon Dam and Diamond Creek to establish general fish habitat categories: (1) wide valleys with freely meandering channel, (2) valleys of intermediate width, (3) narrow valleys in fractured igneous and metamorphic rocks, and (4) narrow valleys in massive limestone. In order to avoid bias and to insure sampling all major habitat types, we plan to establish several strata (3-5) for random selection for each sample trip. The approximate bounds of these strata are as follows:

1. Red Canyon (RM 76.5) to Horn Creek (RM 90)
2. Horn Creek (RM 90) to Waltenberg Rapid (RM 112)
3. Waltenberg Rapid (RM 112) to Deubendorff Rapid (RM 132)
4. Deubendorff Rapid (RM 132) to Kanab Creek (RM 143.5)
5. Kanab Creek (RM 143.5) to Havasu Creek (RM 156)

The Lower Reach

Sampling in this 69-mile (112 km) reach will be conducted in the same manner as in The Upper Reach, except for the exclusion of radiotelemetry. The primary sampling program shall be to collect information on distribution of humpback chub, abundance by age class, habitat use, and changes in habitat availability with changes in flow or discharge. Use of radiotelemetry in this reach will depend on the number of adult humpback chub captured and will be determined in conference with the ACT.

SAMPLE SCHEDULE

Life history data for all life stages of humpback chub in the mainstem Colorado River will be collected on a seasonal basis. This information is critical for determining habitat use by season, its availability as affected by discharge changes, and possible preference by species. Field trips will be conducted on a monthly basis to accomplish seasonal sampling. The schedule shall consist of twelve field trips per year including six 20-day trips and six 10-day trips (Table 1). Trips will be conducted monthly alternating between 20-days and 10-days in duration. A total of 39 trips (twenty 20-day trips and nineteen 10-day trips) will be conducted between October 1, 1990 and December 31, 1993. The following is a brief description of each type of trip and an outline of daily activities.

Twenty Day Trips

The purpose of the 20-day trips is to capture humpback chub for radio-implant, monitor habitat use and changes with flow, assess limiting factors, and determine important biotic interactions with other fish species. The 20-day trips will involve two field teams (Figure 2) each with a designated Project Leader with extensive riverine fishery experience. Team 1 will have 6 B/W and 1 ACT biologists and will work at the confluence of the LCR (The Upper Reach) while Team 2, with 4 B/W and 1 ACT biologist, works in Granite Gorge (The Middle Reach). After about 10 days of sampling at each location, the teams will meet below Havasu Creek. Team 2 will continue to sample from Havasu Creek to Lava Falls for the last 5 days, while Team 1 proceeds to sample from Lava Falls to Diamond Creek. Team 1 will have three 16-foot sportboats (1 electrofishing and 2 netting/tracking), and Team 2 will have two 16-foot sportboats (1 electrofishing and 1 netting). B/W will provide 1 electrofishing and 3 netting/tracking boats and Reclamation will provide 1 electrofishing boat. All 5 research boats will be rolled and loaded on 37-foot S-rigs. One S-rig and 1 J-rig (snout boat) will accompany each of the two teams.

Table 1. Tentative Trip Schedule; Grand Canyon Project.

	1990		1991		1992		1993	
	10-D	20-D	10-D	20-D	10-D	20-D	10-D	20-D
January				X		X		X
February			X		X		X	
March				X		X		X
April			X		X		X	
May				X		X		X
June			X		X		X	
July				X		X		X
August			X		X		X	
September				X		X		X
October	X		X		X		X	
November		X		X		X		X
December	X		X		X		X	
Total	**2**	**1**	**6**	**6**	**6**	**6**	**6**	**6**
B/W People per Trip	**6**	**10**	**6**	**10**	**6**	**10**	**6**	**10**
Total Person Trips	**6**	**20**	**36**	**60**	**36**	**60**	**36**	**60**

TWENTY DAY TRIPS

Personnel: 10 B/W + 2 BOR
Boats: 2 Electrofishing + 3 Netting/Tracking Sportboats; 2 37–foot S–rigs + 2 Snouts

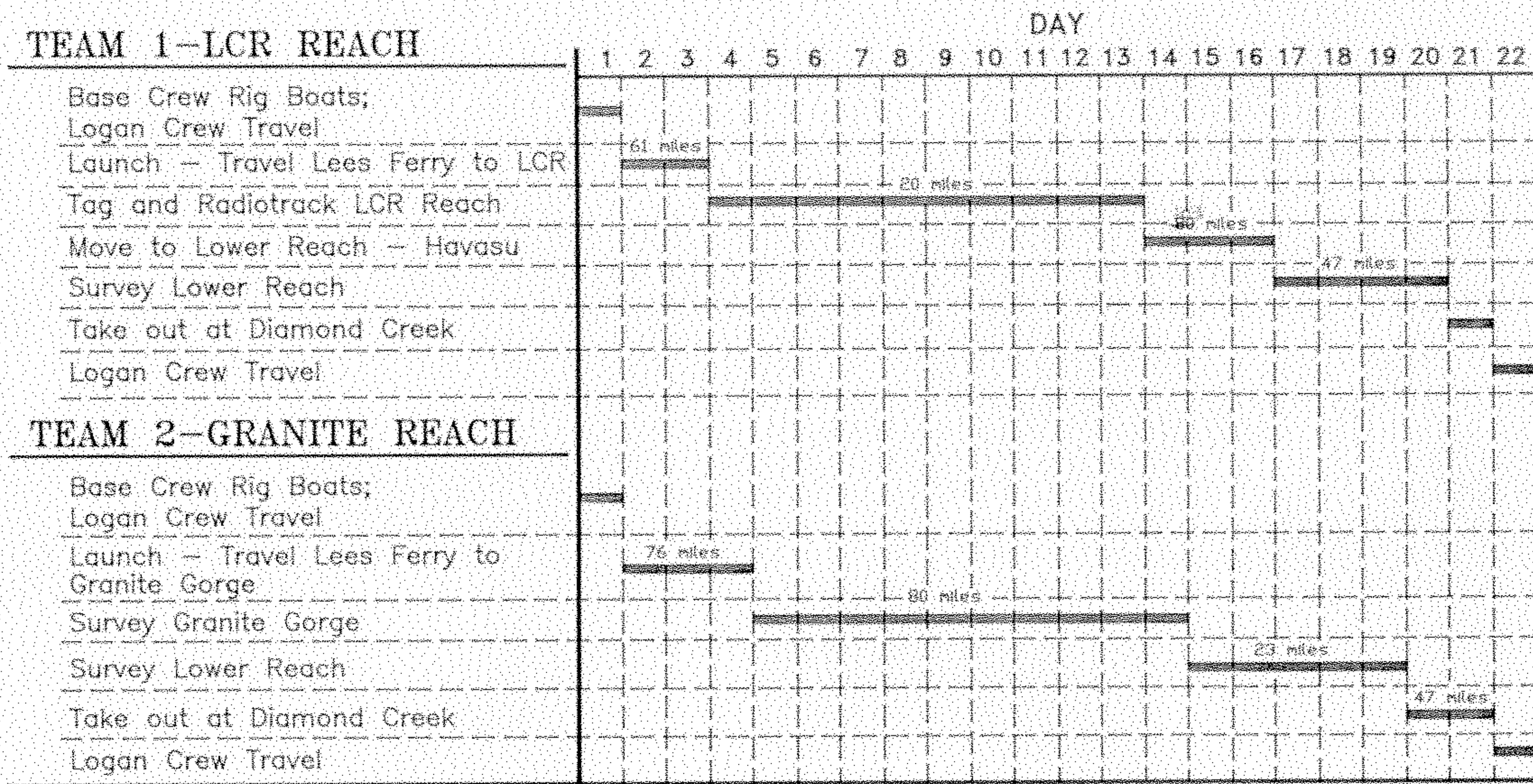

Figure 2. BIO/WEST's sample schedule for 20 day trips.

TEN DAY TRIPS

Personnel: 6 B/W + 2 BOR
Boats: 1 Electrofishing + 2 Netting/Tracking Sportboats; 1 37-foot S-rig

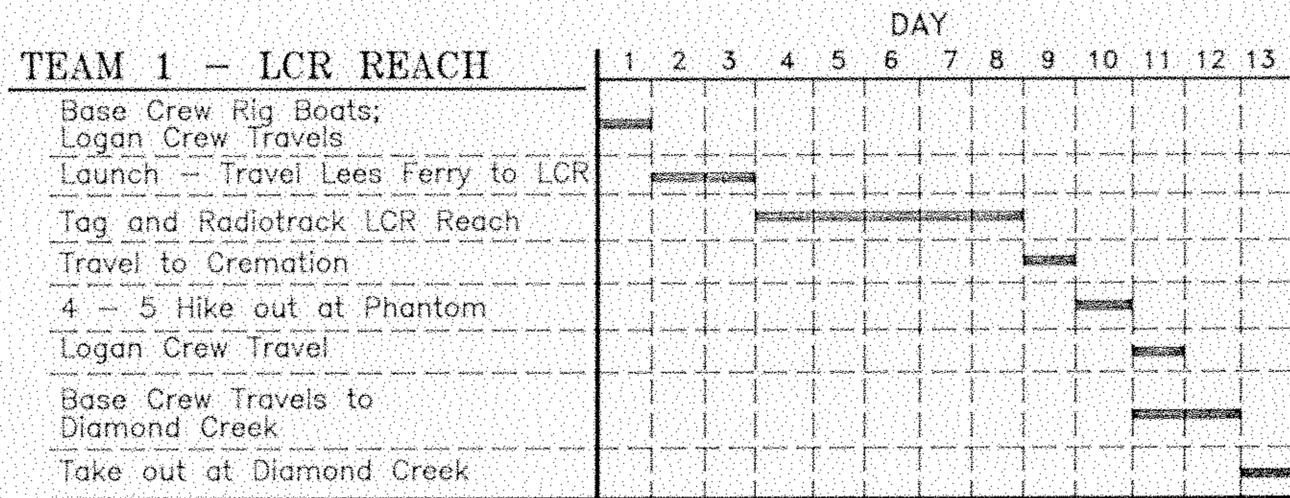

Figure 3. BIO/WEST's sample schedule for 10 day trips.

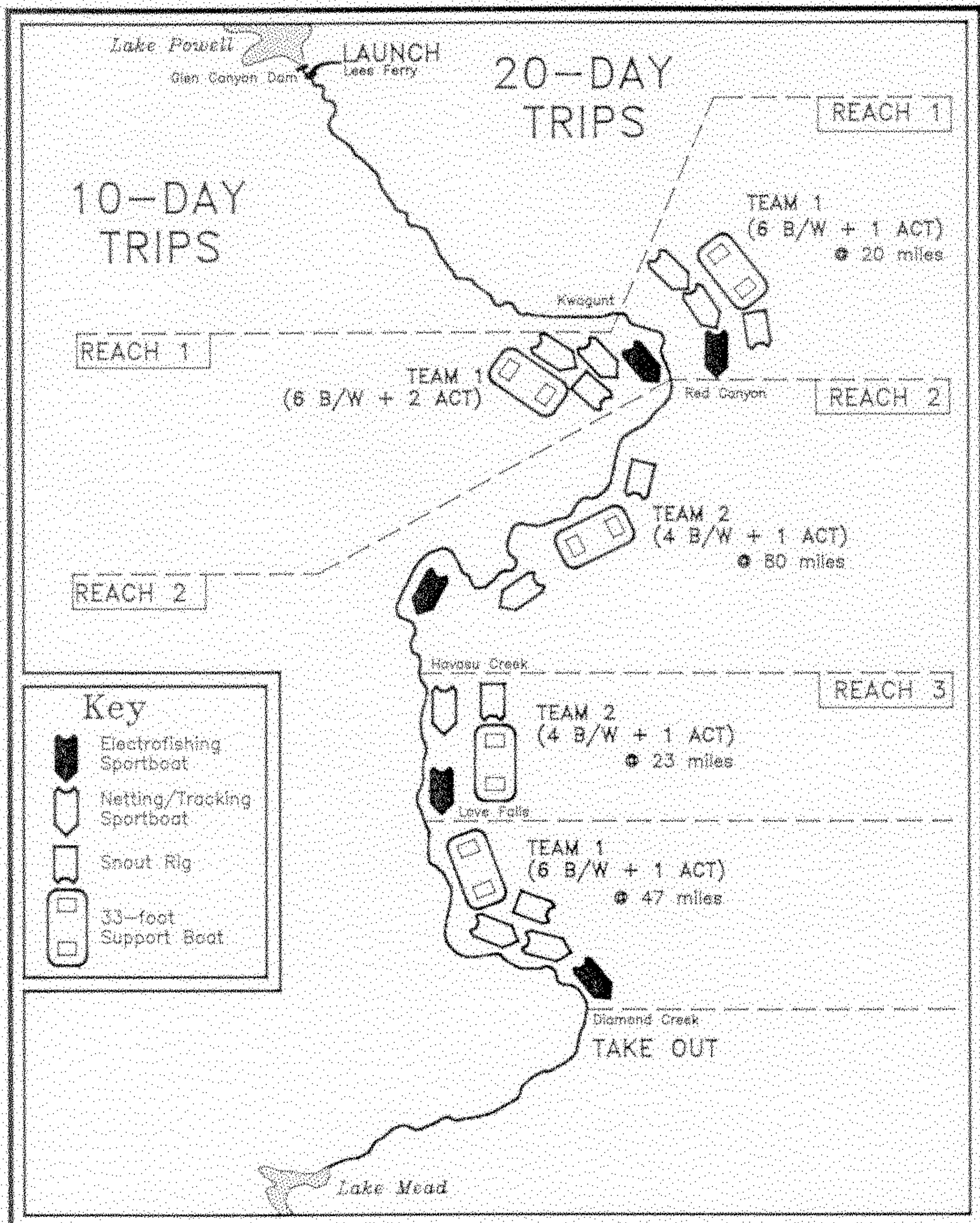

Figure 4. Diagramatic representation of the number of research and support boats and personnel on each team during the 10-day and 20-day field trips.

The following is an outline of the 20-day trips (Figure 2):

Day 1: 2 or 3 people from Flagstaff drive to Lees Ferry with gear; help Oars rig boats and load B/W gear on Oars boats; rest of crew travels to Flagstaff. 1 B/W biologist conducts helicopter aerial radiotracking.

Day 2: Rigging and loaded completed; rest of crew travels to Lees Ferry on GCES bus; launch boats 10 am to 12 noon.

Day 3: Arrive at LCR late; Team 1 start rigging reserach boats.

Days 4-13: Team 1 samples LCR confluence area.

Day 5: Team 2 arrives at Granite Gorge.

Days 5-14: Team 2 samples Granite Gorge.

Days 14-16: Team 1 moves to Havasu Creek.

Days 15-16: Team 2 moves to Havasu Creek.

Day 16: Teams 1 and 2 meet at Havasu Creek.

Days 17-20: Teams 1 and 2 sample Havasu Creek to Diamond Creek.

Day 21: Take out at Diamond Creek, return to Flagstaff.

Day 22: Logan crew travels to Logan.

Ten Day Trips

The purpose of the 10-day trips is similar to that of the 20-day trips, but will concentrate in the area of the LCR (The Upper Reach). The 10-day trips will involve one field team with 6 B/W and 1 ACT biologists (Figure 3). This team will sample exclusively near the confluence of the LCR for about 5 days. Following sampling, 3 or 4

B/W people will hike out at Phantom Ranch while the remaining 2 or 3 proceed to the Diamond Creek takeout with the Oars crew to disassemble gear and return to Flagstaff. The Team will have three 16-foot sportboats (1 electrofishing and 2 netting/tracking) provided by B/W. All 3 boats will be rolled and loaded on one 37-foot S-rig and one J-rig which will remain with the Team during the entire trip. The following is an outline of the 10-day trips (Figure 3):

Day 1:	2 or 3 people from Flagstaff drive to Lees Ferry with gear; help Oars rig boats and load B/W gear on Oars boats; rest of crew travels to Flagstaff. 1 B/W biologist conducts helicopter aerial radiotracking.
Day 2:	Rigging and loaded completed; rest of crew travels to Lees Ferry on GCES bus; launch boats 10 am to 12 noon.
Day 3:	Arrive at LCR late; Team start rigging boats.
Days 4-8:	Team samples LCR confluence area.
Day 9:	Team travels to Cremation.
Day 10:	4 or 5 B/W people hike out at Phantom Ranch; rest of crew to Diamond Creek.
Day 11:	Logan crew travels to Logan.
Days 11-12:	Base crew travels to Diamond Creek.
Day 13:	Take out at Diamond Creek; return to Flagstaff.

METHODOLOGY

This investigation will be conducted in the mainstem Colorado River in cooperation with the Service, AGF, and ASU who will be investigating aspects of the ecology of the humpback chub in the LCR and other tributaries in the Grand Canyon. The objectives of the combined humpback chub investigations and a description of BIO/WEST's role are as follows:

Objective 1: To determine the ecological and limiting factors of all life stages of humpback chub in the mainstem Colorado River, Grand Canyon, and the effects of the Glen Canyon Dam operations on the humpback chub.

A thorough literature review will be conducted to determine the known ecological requirements of the humpback chub. Much of this information is currently being assembled by Dr. C.O. Minckley as part of a separate project, through which BIO/WEST will request access. This literature review will reflect known habitat, water conditions, and biological needs of the species in the lower and upper Colorado River basins. A list of known ecological requirements will be developed to compare with existing conditions of the Colorado River in the Grand Canyon. This background information will enable us to focus on specific ecological conditions in order to determine if these are currently lacking or limiting in the Grand Canyon, or affected by Glen Canyon Dam operations.

Field investigations will focus on describing the critical life history requirements of the humpback chub in the mainstem Colorado River and on identifying the relationships and importance of the tributaries and the mainstem to the species. Changes in habitat conditions will be monitored during scheduled research flows to determine if the operation of Glen Canyon Dam further limits or enhances these conditions. This information will be used to assess the effects of dam operation on the life history of the species. Data collection will be tailored to take full advantage of the GCES research flows. We propose to describe and quantify, where possible, the various aspects of the life history of the humpback chub. Each of the following sub-objectives or tasks will be addressed by testing one or more hypotheses (Ho):

Task 1A: **Determine resource availability and resource use (habitat, water quality, food, etc.) of humpback chub in the mainstem Colorado River.**

Ho 1A-1: **Habitat is limiting under certain flow conditions to the humpback chub in the mainstem Colorado River, Grand Canyon.**

Macrohabitat availability will be determined for each of the three study reaches with the aid of selected aerial photographs available from Reclamation, and through still and video photography from permanent riverside stations. Surface changes in macrohabitat (backwaters, eddies, pools, runs, riffles, rapids, slackwaters, etc.) will be mapped at different water levels using existing aerial photographs and direct observations similar to the technique employed by Valdez and Masslich (1990) in the Green River, Utah. Observed changes will be sketched on mylar overlays during scheduled flow releases. The surface area of macrohabitats on these mylar overlays will be interpreted with an AutoCad System to provide surface area of habitat types. Relationships between macrohabitat area and flow levels will be determined for as many water levels as possible. This method will provide a quantification of macrohabitats in each of the three regions by river flow.

Ho 1A-2: Water quality is limiting under certain flow conditions to the humpback chub in the mainstem Colorado River, Grand Canyon.

Changes in water quality, such as temperature, turbidity, salinity, and various chemical parameters, will be recorded during the scheduled release flows to determine if impacts of dam operations on humpback chub are caused by changes in water chemistry. Permanent water quality stations will be established and diel measurements taken with a Hydrolab. This will provide changes in basic water chemistry over 24-hour periods, and seasonal changes as well. These limnological stations will be coordinated with Arizona Game and Fish Department.

Ho 1A-3: Food is limiting under certain flow conditions to the humpback chub in the mainstem Colorado River, Grand Canyon.

We plan to use the nonlethal method of stomach pumping to examine food habits of humpback chub in the mainstem Colorado River of the Grand Canyon. Stomach pumps will be built from the design developed by Seaburg (1957), using several size nozzles to accommodate various fish sizes (Figure 5). The fish will be mildly anesthetized with MS-222 before inserting the pump nozzle into the buchal cavity. Material pumped from each fish will be stored separately and examined in the laboratory to determine composition and volume. Food habits will be assessed primarily to determine if dam operations are affecting the availability of food sources as well as the timing of availability. We intend to sample humpback chub during changes in flow to determine if changes in behavior (i.e. additional movement) are induced by greater availability of food or habitat changes. We have successfully used stomach pumps with roundtail chub in the upper Colorado River basin (Personal communications, R.A. Valdez, BIO/WEST).

Task 1B: Determine the reproductive capacity and success of humpback chub in the mainstem Colorado River.

Ho 1B-1: Humpback chub do not actively spawn in the mainstem Colorado River, Grand Canyon.

Main channel reproduction by humpback chub is at best extremely limited, or more likely nonexistent as a result of cold water temperatures (Maddux et al. 1987). We will attempt to determine if spawning occurs in the mainstem by observing the nuptial condition of captured fish and by following closely the movements of radiotagged fish that we suspect are in spawning condition. Sudden movements and aggregations of radiotagged fish may lead us to specific spawning locations that can be confirmed by intensively sampling the area with various gears for gravid females and ripe males. Discovery of such an area will invoke intensive sampling for eggs and larvae. It is also possible that radiotagged fish will ascend to spawn in one of several tributaries in the Grand Canyon (Little Colorado River, Shinumo Creek, Havasu Creek, Kanab Creek, Bright Angel Creek, Tapeats Creek). We intend to follow radiotagged fish that ascend these tributaries and coordinate data collections with the Service and AGF. The lower reach (1-2 km) of these tributaries will also be rountinely ground searched for radiotagged fish when crews are in the vicinity. Spawning locations, concentration areas, and staging areas identified in the mainstem will be carefully mapped in detail at various flow stages.

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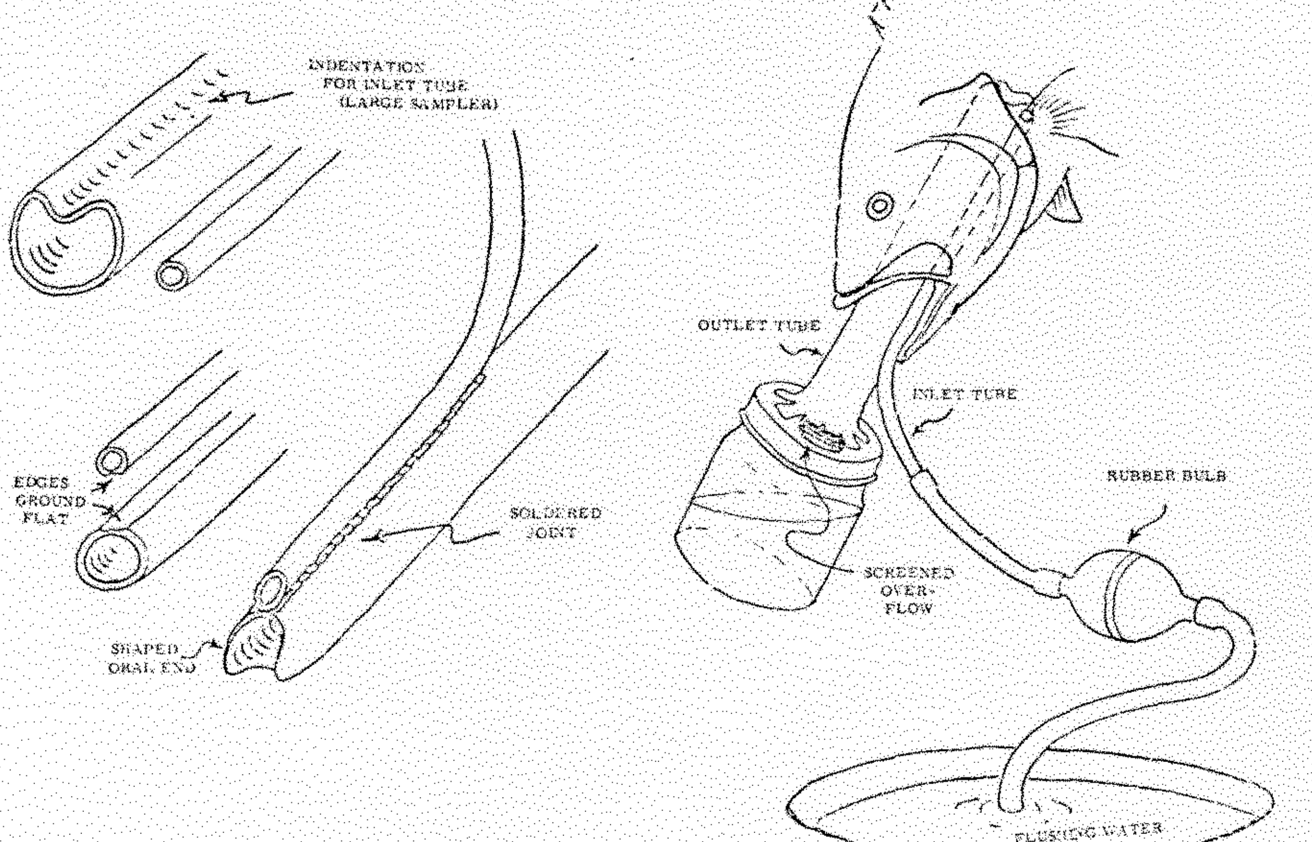


(Drawings courtesy of the author)

Figure 5 Joining the inlet and outlet tubes for the oral or upper end of the sampler.

Cross sectional profiles will be taken with stadia rods and sonar units, and velocities will be measured across the channel. Substrate will be assessed where possible. Shoreline habitats near and below suspected spawning areas will be sampled intensively to confirm the presence of YOY chubs and to assess relative densities as well as habitat use.

Task 1C: **Determine the survivorship of early stages of the humpback chub in the mainstem Colorado River.**

Ho 1C-1: **Survival of early life stages of humpback chub is low in the mainstem Colorado River, Grand Canyon.**

The survival of early life stages of humpback chub will be assessed with the aid of population modeling and data gathered from spawner numbers, fecundity, and escapement from tributaries into the mainstem. Much of these data will be gathered in cooperation with AGF and the Navajo Nation.

Task 1D: **Determine the distribution, abundance and movement of the humpback chub in the mainstem Colorado River, and effects of dam operations on the movement and distribution of humpback chub.**

Ho 1D-1: **Humpback chub in the mainstem Colorado River, Grand Canyon, remain in areas less than 1 km except during spawning season in spring.**

Ho 1D-2: **The presence and operation of Glen Canyon Dam has altered the distribution and abundance humpback chub in the mainstem Colorado River, Grand Canyon.**

Distribution, abundance and movement of humpback chub in the mainstem

Colorado River will be assessed seasonally. Distribution by age group will be determined from monthly sampling with a variety of gear types throughout the 170-mile region from Kwagunt Rapid (RM 56) to Diamond Creek (RM 226). Relative abundances of age groups will be determine from catch-per-effort indices. Movement information will be collected by capturing and radiotagging adults and PIT tagging adults and juveniles. Movements of the radiotagged fish will be monitored during each of the monthly field trips, and movements between captures will be determined for those fish tagged with PIT tags. A concerted effort will be made to sample near designated tributaries and coordinate our efforts with the ongoing AGF and Service programs in these tributaries since the greatest area of impact to humpback chub may be in staging areas at tributary mouths. We plan to conduct a telemetry surveillance of the lower 3 km of the LCR during each of our tracking trips to determine if radiotagged humpback chub have ascended this tributary. Tracking will be conducted by helicopter and by at least two people on foot following each of the banks of the stream with radio-receivers.

Ho 1D-3: Movements of humpback chub in the mainstem Colorado River, Grand Canyon are affected by Glen Canyon Dam operation.

The effects of Glen Canyon Dam operations on movement and distribution will be assessed by continuously monitoring radiotagged fish during flow changes and by observing changes in location of recaptured PIT-tagged fish. Specific movements and habitat use of individual radiotagged fish will be monitored during scheduled flow releases in order to ascertain the reaction of the fish and their habitat to flow changes (See Section entitled

GCES RESEARCH FLOWS). Fish movement will be mapped on mylar overlays using aerial photographs of the study areas to indicate changes in habitat during the GCES research flows.

Task 1E: Determine important biotic interactions with other species for all life stages of humpback chub.

Ho 1E-1: Introduced non-native fish species have a negative effect on humpback chub in the mainstem Colorado River, Grand Canyon.

There may be important biotic interactions with other species of fish (i.e. channel catfish, rainbow trout) that may be effecting various aspects of the life history of the humpback chub. Their influence will need to be identified in order to separate these from effects of dam operations. Stomachs will be examined from channel catfish to determine the degree of predation on humpback chub. Where possible, these fish will be captured with hook and line to avoid possible biases imposed by conventional sample gears (regurgitation, consuming other species while holding in hoop nets). Other interspecific interactions such as overlap in habitat use and food resources will be assessed by keeping records of all fish captured during sampling.

Objective 2: Determine the life history schedule for the Grand Canyon humpback chub population.

The life history schedule of the humpback chub population in the Grand Canyon will be described with the aid of seasonal sampling in the 170-mile region. Statistics will be recorded on individuals as well as populations, including but not limited to spawning time and conditions, appearance of larvae, habitat use by age class, and movement of fish between the mainstem and tributaries. Also, length-weight, length-frequency, catch-per-effort, sex ratios, and age class structure statistics will enable us to gain information on the life history of the humpback chub in the mainstem Colorado River in the Grand Canyon. We intend to assist the ACT in assimilating this information with tributary data to gain a better understanding of the species in this region.

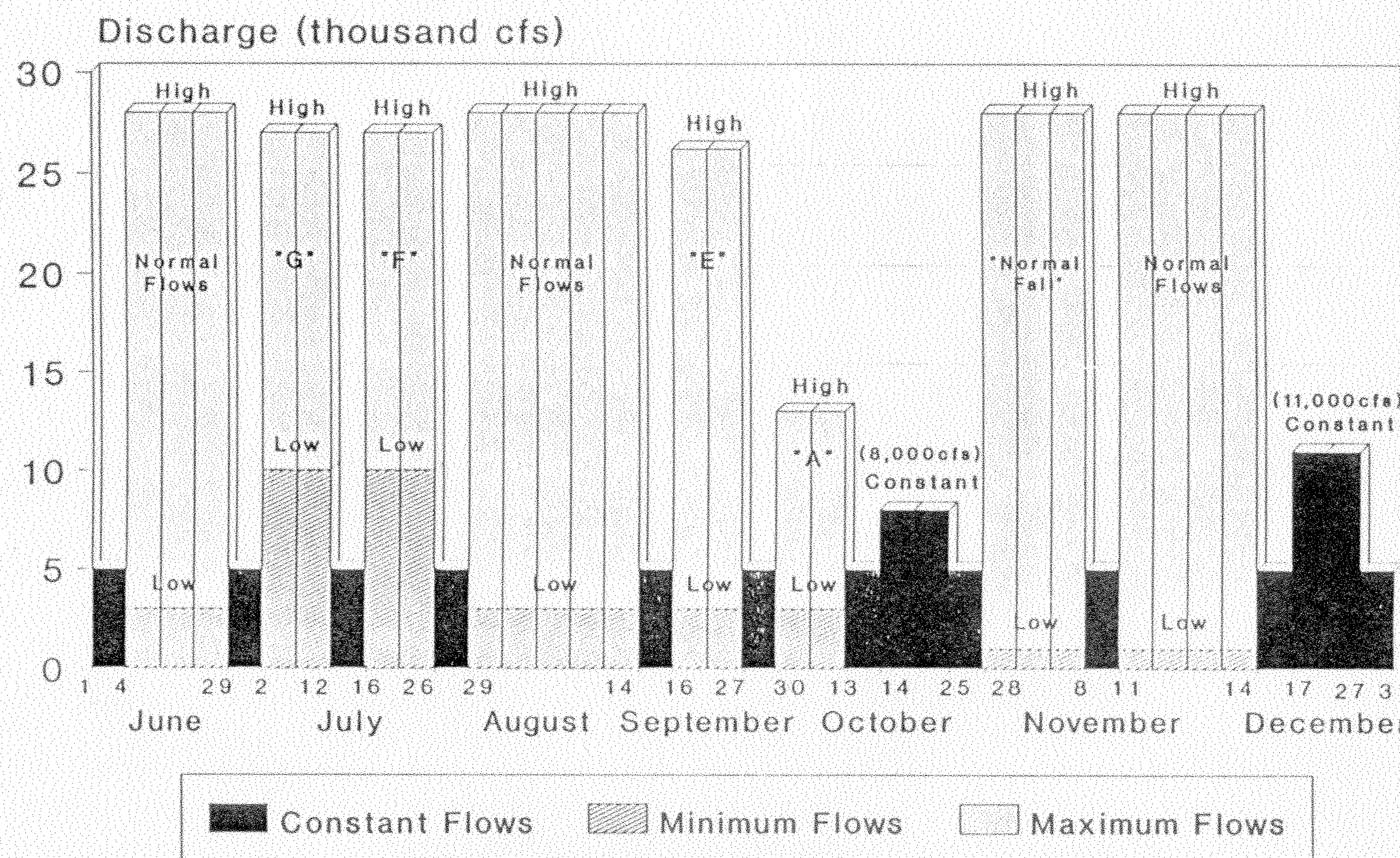
Task 2A. Develop or modify an existing population model from empirical data collected during the study for use in analyses of reproductive success, recruitment and survivorship.

Year-around sampling scheduled for this investigation will provide seasonal information on the life history of the humpback chub in the Grand Canyon. We intend to gather empirical data on the various life history aspects of the species in order to integrate the data of other past and present investigations into an existing population model. This model is to be used as a tool to identify relationships and functions of components.

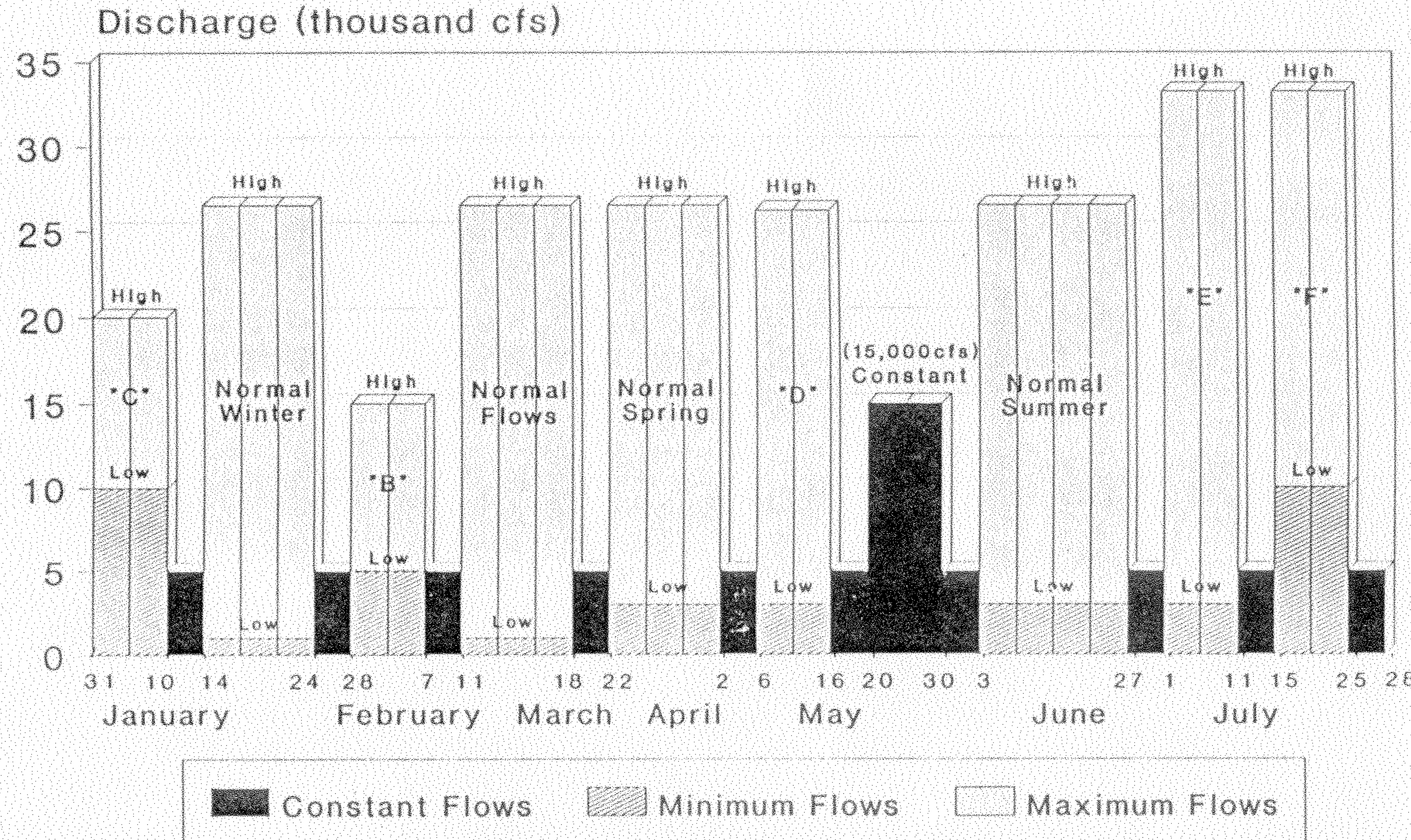
GCES RESEARCH FLOWS

Data collection schedules will be tailored to take full advantage of the GCES research flows (Figures 6 and 7) scheduled for the first 10 months of this investigation (October 1, 1990 to July 28, 1991). These controlled releases from Glen Canyon Dam will provide short-term stable flows at high, normal and low levels with intervening rapid flow changes. We recognize that data gathered from these research flows will be incorporated into the Glen Canyon Dam Environmental Impact Statement, but we caution discretion

GLEN CANYON ENVIRONMENTAL STUDIES
Research Flow Schedule
Calendar Year 1990



GLEN CANYON ENVIRONMENTAL STUDIES
Research Flow Schedule
Calendar Year 1991



with one year's worth of data.

Physical, chemical, and biological aspects of the riverine ecosystem in the Grand Canyon will be monitored routinely during these research flows. These parameters will be measured on a regular basis during sampling and related to flow stage through temporary staff gages which will eventually be tied to discharge through USGS gaging stations.

Physical parameters will include macrohabitat and shoreline exposure. Examples of macrohabitat are backwaters, pools, eddies, runs, riffles, rapids, and slackwaters. Changes in macrohabitat and shoreline exposure will be documented with the aid of existing aerial photographs (1:2400). Also, permanent still photo and video stations will be established for each of the three study regions.

Aerial photographs of selected areas within each of the three study reaches will be used to monitor changes in macrohabitat and shoreline exposure. A single aerial photograph taken at a point in time will provide a reference for shoreline configuration and recognizable landmarks. Mylar overlays will be used to trace existing shorelines and macrohabitats at various flow levels. These macrohabitat observations will be made from high vantage points overlooking the river. Date, time of day, and flow stage will be recorded on each mylar overlay. Aerial surface of macrohabitats will be quantified with the aid of an Autocad Computer System, and a relationship established between flow and macrohabitat types. Relationships will be established for each of the three study reaches under the various research flows. This will enable us to quantify changes in macrohabitat longitudinally from Glen Canyon Dam to assess amelioration effects on fish habitat.

Permanent still-photo and video stations will be established within each of the three study reaches and at the mouths of important tributaries (e.g. Little Colorado River, Bright Angel Creek, Kanab Creek, Shinumo Creek, Havasu Creek). Photographs from these stations will enable us to qualitatively assess changes to the shoreline and macrohabitat for different flows and seasons. These stations are not intended to incorporate constant time-lapse photography.

Permanent stations will be established to monitor diel, seasonal, and flow-related changes in water chemistry. Stations will be located above and below tributaries to monitor the impact of their inflow.

In addition to routine sampling during the GCES research flows, special studies will be designed to monitor radiotagged adult humpback chub. Selected radiotagged fish will be monitored during steady flows and during dramatic flow changes to assess movement and habitat use. Radiotagged fish observed during steady flows will be considered 'control animals' and those observed during fluctuating flows will be considered 'test animals'. The same fish will be monitored during both flow scenarios to reduce variability of individual fish behavior.

Relationships will be established between the rate of change in river stage and rate of movement for each group of animals. Also, movement rate will be compared between the control and test groups using Chi^2 to test the hypothesis that fluctuating releases cause changes in microhabitats that cause the fish to move to more suitable locations. Microhabitats occupied by the fish will be measured for depth and velocity changes under control and test conditions.

An alternative hypothesis to be tested with the GCES research flows is that fluctuating flows (particularly increases) induce feeding by fish because of increased availability of suspended foods such as cladophora and gammarus as reported for trout in tailwaters (Gosse 1982). In order to distinguish behavior-induced movement caused by increased feeding, stomach contents of humpback chub captured during both flow scenarios will be examined with the aid of a nonlethal stomach pumping technique.

The start of field trips will be timed as much as possible to take full advantage of the GCES research flows. For example, teams will arrive at given study sites during a period of steady flow to enable researchers to contact previously radiotagged fish and observe their habitat use and movement for at least 3-5 days before a shift in flow occurs. It will be important to observe radiotagged fish during this change in flow or fluctuating phase and it will be ideal to observe the same fish under both stable and fluctuating flow scenarios. Such observations may require constant hourly monitoring. It will be important for both BIO/WEST teams to know ahead of time the arrival of a flow change at a particular study site, and so we plan to request flow predictions from Reclamation such as results of SARR modeling. The magnitude of change at a given location is not as critical as the time of change to enable the teams to begin monitoring the fish well in advance of, during, and after the change.

PROPOSED BIO/WEST TEAM – GRAND CANYON HUMPBACK CHUB STUDY

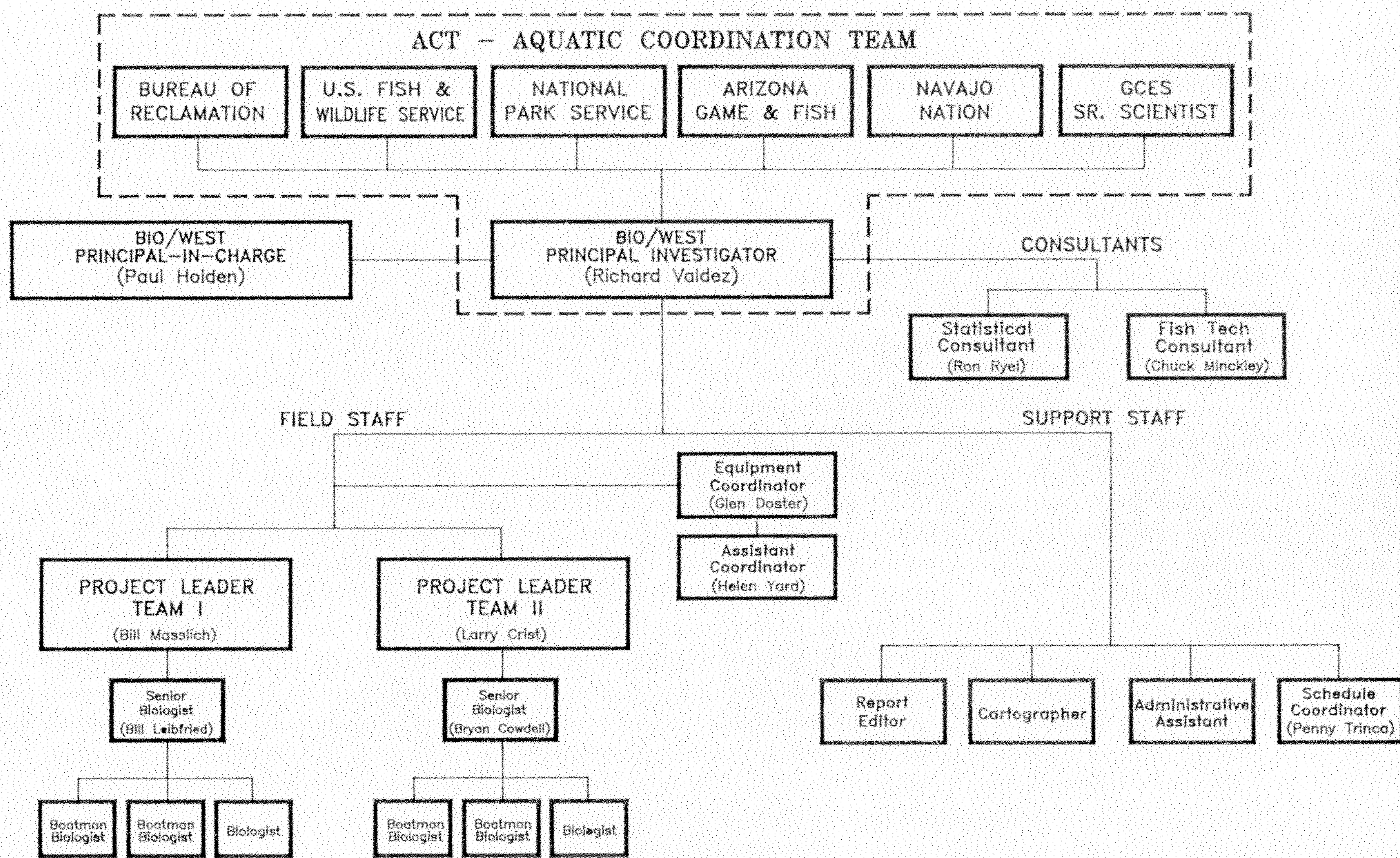


Figure 8. The BIO/WEST Team.

PERSONNEL

The professional experience and commitment of project personnel is critical to the success of this project. BIO/WEST has assembled a staff of professional biologists and boatmen that enable us to maintain small but efficient crews (Figure 8). This reduces visibility of researchers afield to park visitors and enhances the quality of data collection. Most important, the involvement of experienced professionals in this project increases in-field problem-solving capabilities, and promotes innovative adjustments in sample design to take advantage of unexpected opportunities afield. The following are the BIO/WEST personnel that will participate in the study:

Richard A. Valdez, Ph.D. - Principal Investigator: Dr. Valdez has over 20 years of experience as a professional fishery biologist. He has worked with the endangered fish of the Colorado River since assisting Dr. Paul Holden with some of the original studies of Colorado squawfish, humpback chub, bonytail, and razorback sucker in the Green River in the early 1970's. Dr. Valdez served as Project Leader for the Grand Junction Field Station of the Colorado River Fishery Project for the U.S. Fish and Wildlife Service from 1979 to 1982. From 1985 to 1989, he was Principal Investigator for the Cataract Canyon Studies, a contract for the Bureau of Reclamation. He also served as Co-Principal Investigator for Developing HSI curves for Colorado squawfish, humpback chub, and razorback sucker for the U.S. Fish and Wildlife Service. In 1987 and 1988, Dr. Valdez assessed winter movement and habitat use of Colorado squawfish and razorback suckers in the Green River as part of the Flaming Gorge Biological Studies. Dr. Valdez is also

Principal Investigator for the Dolores River Fisheries Studies, and assists the Utah Division of Wildlife Resources in their annual monitoring of humpback chub in Desolation, Cataract, and Westwater Canyons. Dr. Valdez was the first to report reproducing populations of humpback chub from Westwater Canyon and Cataract Canyon. He was also the first to radiotag humpback chub, and has extensive radiotelemetry experience with humpback chub, Colorado squawfish, razorback sucker, bonytail, northern pike and cui-ui lake suckers. Dr. Valdez has numerous articles and publications on the endangered fishes of the Colorado River System, and is currently authoring the book Utah's Native Fishes. Dr. Valdez is a licensed Utah River Guide I.

Mr. William J. Masslich - Project Leader: Mr. Masslich has 10 years of experience as a professional biologist. He has extensive experience with aquatic, terrestrial, and riparian ecosystems throughout the western United States. Mr. Masslich helped develop a backwater classification system for the lower Colorado River. He has worked extensively with Dr. Valdez on the Cataract Canyon Studies; Winter Habitat Studies; Dolores River Studies; Westwater, Desolation, and Cataract monitoring studies. Mr. Masslich is coauthor with Dr. Valdez of Winter Habitat Study of Endangered Fish in the Green River. Mr. Masslich has extensive radiotelemetry experience including surgical implants of Colorado squawfish, razorback sucker, and northern pike; as well as aerial and ground tracking.

Mr. Lawrence W. Crist - Project Leader: Mr. Crist has 15 years experience as a professional fishery biologist. He has extensive experience with IFIM and instream flow studies. Mr. Crist has many years of experience with a variety of fish sample gears including boat, raft, and canoe electrofishing systems, passive nets, active nets, drift nets, hoop nets, and seines. He also has an excellent working knowledge of water chemistry and limnology, and an excellent background in invertebrate stream ecology. Mr. Crist also has experience radiotagging Colorado squawfish, razorback suckers, and northern pike. He is also very familiar with radiotracking procedures. Mr. Crist is a licensed Utah River Guide I.

William C. Leibfried - Senior Biologist: Mr. Leibfried is currently President of William Leibfried Environmental Service in Flagstaff, Arizona. He has over 10 years of experience as a professional biologist with expertise in many fields. He has assessed survival of stocked Colorado squawfish and razorback suckers in the Verde and Salt Rivers in Arizona. Mr. Leibfried has conducted numerous scientific investigations in the Grand Canyon including feeding studies of rainbow trout, bald eagle surveys, aquatic macroinvertebrate studies, impact assessments on tributary streams and extensive studies of Cladophora glomerata. Mr. Leibfried has extensive familiarity with the Grand Canyon ecosystem as well as specific knowledge of macroinvertebrate, plant, riparian, and fish communities. His experience and extensive knowledge of the Grand Canyon is a valuable asset to this project. Mr. Leibfried is also a licensed Utah River Guide I and a Certified Grand Canyon River Guide.

Mr. Bryan R. Cowdell - Senior Biologist: Mr. Cowdell has 6 years of experience as a professional fishery biologist. He has worked on various project in the upper

Colorado River Basin including the Union Oil intake structure EIS, White River Oil Shale EIS, Cataract Canyon Studies, Winter Habitat and Movement Studies of Colorado squawfish and razorback suckers. Mr. Cowdell has extensive experience with IFIM and has worked on instream flow studies in Colorado, Idaho, and Utah. He has served as Database Manager for several projects including the Cataract Canyon Studies, Jordan River Studies, and Snake, Blackfoot, and Portneuf River Studies. Mr. Cowdell has an excellent working knowledge of dBASE III+ and a field-oriented background that enables him to provide quality assurance and quality control to data before analyses.

Randy Van Haverbeke - Biologist: Mr Van Haverbeke has extensive field work experience with humpback chub in the Grand Canyon. He has assisted Dr. C.O. Minckley in the annual AGF monitoring program of the species in the Little Colorado River. He is very familiar with humpback chubs in the system and has hands-on experience with PIT tagging of the species. Mr. Van Haverbeke has also worked on other rivers of the southwest on a variety of fish species.

Erika Prats - Biologist: Ms. Pratt has worked for several years with the fishes of the southwest, including the native species of the Colorado River. She spent much of the summer of 1990 working at the Dexter National Fish Hatchery in southeastern New Mexico, assisting hatchery and field biologists with culture and recovery efforts of the Colorado River endangered fish. She has worked in numerous river systems of the southwest and Mexico.

Lydia "Penny" Trinca - Schedule Coordinator/Database Manager: Ms. Trinca has

6 years of experience as a fishery biologist, including 2 years with the Vernal Field Station of the Colorado River Fishery Project of the U.S. Fish and Wildlife Service. She has an excellent knowledge of and personal work experience with the endangered fish of the Colorado River Basin. Ms. Trinca has participated in instream flow and fisheries studies in New Hampshire, the lower Colorado River, Jordan River, Montezuma Creek, and Provo River. Ms. Trinca has an excellent working knowledge of various database management systems and is well qualified to manage data collection, storage and analyses for this project.

<u>Mr. Glenn Doster - Equipment Coordinator</u>: Mr. Doster has over 15 years of experience as a biologist. He has participated in instream flow studies of Gore Creek, Colorado; fishery studies of the Jordan River, Utah and several streams in the Shoshone-Bannock Indian Reservation, Idaho. Mr. Doster is currently a biologist in the Dolores River Fishery Study and Cataract Canyon Study of the endangered Colorado River fishes. Mr. Doster also worked as a foreign fisheries observer for the National Marine Fisheries Service in the North Pacific. His extensive experience as a boatman with rafts and kayaks, and his familiarity with the Grand Canyon are an asset to this project. Mr. Doster has recently moved from Logan, Utah to Flagstaff, Arizona to manage the BIO/WEST equipment warehouse.

<u>Ms. Helen Kalevas Yard - Biologist</u>: Ms. Yard has participated in several biological field studies in the Grand Canyon including the Glen Canyon Environmental Studies, Arizona Game and Fish Department aquatic studies, effects studies on breeding birds, and a radiotelemetry test pilot investigation in the Grand Canyon. Her background as Primary Surgeon for medical research with W.L. Gore and Associates brings valuable surgical skills to this project for implanting radiotags. Ms. Yard will be responsible for developing the surgical protocol to be used for surgically implanting radiotags in humpback chubs in the Grand Canyon. Ms. Yard currently resides in Flagstaff, Arizona, and is very familiar with the Colorado River in the Grand Canyon.

Mr. Ron J. Ryel - Statistical Consultant: Mr. Ryel has 10 years of experience as a biologist and population ecologist. He brings a unique pragmatic approach to ecosystems and population modeling that is considered a great asset to this investigation. Mr. Ryel has worked extensively with Dr. Valdez on the endangered Colorado River fishes in the upper basin and is familiar with practical field problems of data collection for endangered species such as the humpback chub. He is currently self-employed as a systems ecologist and is involved in projects in Kauai, Hawaii; Bear River, Utah; riparian ecosystems in Utah; and several hydroelectric environmental studies. Mr. Ryel served as Database Manager with Dr. Valdez to compile a complete database of endangered species for the upper Colorado River basin. Mr. Ryel also served as Operations Research Analyst for the Northern Fur Seal Project in the Pribilof Islands, Alaska. He has extensive experience with model development plus the fishery background for practical application. Mr. Ryel is a licensed Utah River Guide I.

Mr. Chuck O. Minckley - Fishery Consultant: Mr. Minckley has worked on the humpback chub population in the Little Colorado River of the Grand Canyon for over 10 years. He has served as field coordinator for the Arizona Game and Fish Humpback Chub Monitoring Program in the LCR for several years. His knowledge of the species in the LCR and the Colorado River in the Grand Canyon is a great asset to this investigation. Mr. Minckley also has extensive fishery experience throughout the southwestern United States.

Mr. Greg Williams - Certified Boatman: Mr. Williams has 20 years of whitewater river experience with a number of commercial concessionaires including Harris, Slight, Martin Litton, Hatch, and Tag-A-Long. Mr. Williams has a B.S. Degree in Physics from the University of Utah and has extensive experience as an electrician. Mr. Williams has extensive experience with a variety of whitewater craft including S-rigs, J-rigs, and snouts. He owns his own sportboat similar to the ones that will be used for this investigation. Mr. Williams is a certified outboard motor mechanic with extensive experience in repairing the types of outboard motors to be used in this study. Mr. Williams is a Certified Guide and Trip Leader in the Grand Canyon.

Mr. Brian Dierker - Certified Boatman: Mr. Dierker has 19 years of whitewater river experience, much of which has been in the Grand Canyon. He has worked for several commercial companies and has extensive experience with a variety of whitewater craft including S-rigs, J-rigs, snouts, and sportboats of the type to be used in this study. He has worked with the Glen Canyon Environmental Studies and is familiar with research activities and schedules in the Grand Canyon. Mr. Dierker is a Certified Guide and Trip Leader in the Grand Canyon.

<u>Mr. Peter S. Resnik - Certified Boatman</u>: Mr. Resnik has 23 years of whitewater river experience primarily in the Grand Canyon. He has worked with several commercial concessionaires including Hatch and Oars. He has extensive experience in operating a variety of whitewater craft including S-rigs, J-rigs, snouts, and sportboats of the type to be used in this study. Mr. Resnik owns a sportboat. He has worked with the Glen Canyon Environmental Studies and is familiar with research activities and schedules in the Grand Canyon. Mr. Resnik is a Certified Guide and Trip Leader in the Grand Canyon.

APPENDIX A

Fish Handling Protocol

APPENDIX A - TABLE OF CONTENTS

FISH HANDLING PROTOCOL

1.0 RAFTING/BOATING

BIO/WEST will use one SU-16 and three SH-170 Achilles sportboats powered by 40 hp Yamaha motors for conducting research activities. The SU-16 will be used as an electrofishing boat and the three SH-170 as radio-tracking and netting boats. An SD-170 with 40 hp Yamaha motor was used by BIO/WEST for conducting fisheries studies in Cataract Canyon. The boat/motor combination proved adequate in terms of hull design, power and weight carrying capabilities to perform all research tasks in the Cataract Canyon, including upstream movement in rapids. Similar performance is expected in the Grand Canyon.

All boats and frames will be designed for safety and functionality in addition to quick breakdown for transport on support rafts. Standard safety equipment will be provided with each boat including:

1. Standard First Aid Kit
2. 65' Throw Line
3. Throwable 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 'Overboard' Lanyard Motor Switch

11. Boat Patch Kit

12. Motor Repair Kit

13. Spare Motor

14. Q-beam and battery

The electrofishing boat will be designed to accommodate three biologists -- an operator and one or possibly two netters. The boat will be equipped with one 5-kw generator, electrofishing apparatus, front electrofishing rail, internal live well, dry equipment storage compartments and spare gasoline in addition to the safety equipment listed above. Total maximum weight expected at one time in the electrofishing boat is an estimated 1200 pounds. The load capacity for this boat is 3210 pounds.

The tracking/netting boats will be designed to accommodate two to three biologists -- an operator and two biologists to perform various research tasks such as setting nets or radio tracking. Each boat will be equipped with a live well, dry equipment storage compartments, radio-telemetry apparatus and a breakdown antenna extension boom in addition to the safety equipment listed above. Total maximum weight expected at one time in tracking netting boats is an estimated 800 pounds.

Principal BIO/WEST biologists with experience in operating research vessels will handle boats during most sampling activities. Maneuvering research vessels through rapids will done only by boatmen who possess qualifications outlined in the Colorado River

Management Plan (CRMP) and/or a Commercial Operating Certification. All of BIO/WEST's biologists and personnel will be familiar with and adhere to the National Park Service's CRMP regulations regarding river safety, experience, and boating restrictions.

2.0 FISH CAPTURE

2.1 Electrofishing

Electrofishing will be used to sample most habitat types in the Grand Canyon. The technique is most effective for sampling the larger life stages, but smaller fish can also be captured depending on water conditions and habitats sampled. All electrofishing efforts will separated by major shoreline habitat type, i.e. sheer wall, tallus and sand beach. This will be accomplished by conducting discrete electrofishing runs within each habitat type.

The basic layout and schematic of the electrofishing boat that will be used for the Grand Canyon studies is presented in Figure A-1. The system will be powered by a 5000 watt Yamaha industrial grade generator, Model YG-500-D. Power from the generator will be routed through a Mark XXII Complex Pulse System (CPS) developed by Coffelt Manufacturing where the current is transformed from a 220 volt AC to pulsed DC current. The pulsed DC current is then supplied to the water through to one anode (+) mounted on a boom projecting from the front of the boat. A stainless steel sphere manufactured by Coffelt Electronics mounted on a boom that will be projecting from the rear of the boat will serve as a cathodes (-) to complete the circuit and create the electric field in the water around the boat.

Output settings that will be used with the new Mark XXII electrofisher will range from 15 to 20 amperes and 300 to 350 volts as recommended by Coffelt Electronics for shocking in the Colorado River below Glen Canyon Dam (Pers. Comm. with Norm Scharber, October 9, 1990). Some trial and error will be required to determine the optimum output settings within these ranges that will be used during electrofishing in the Grand Canyon.

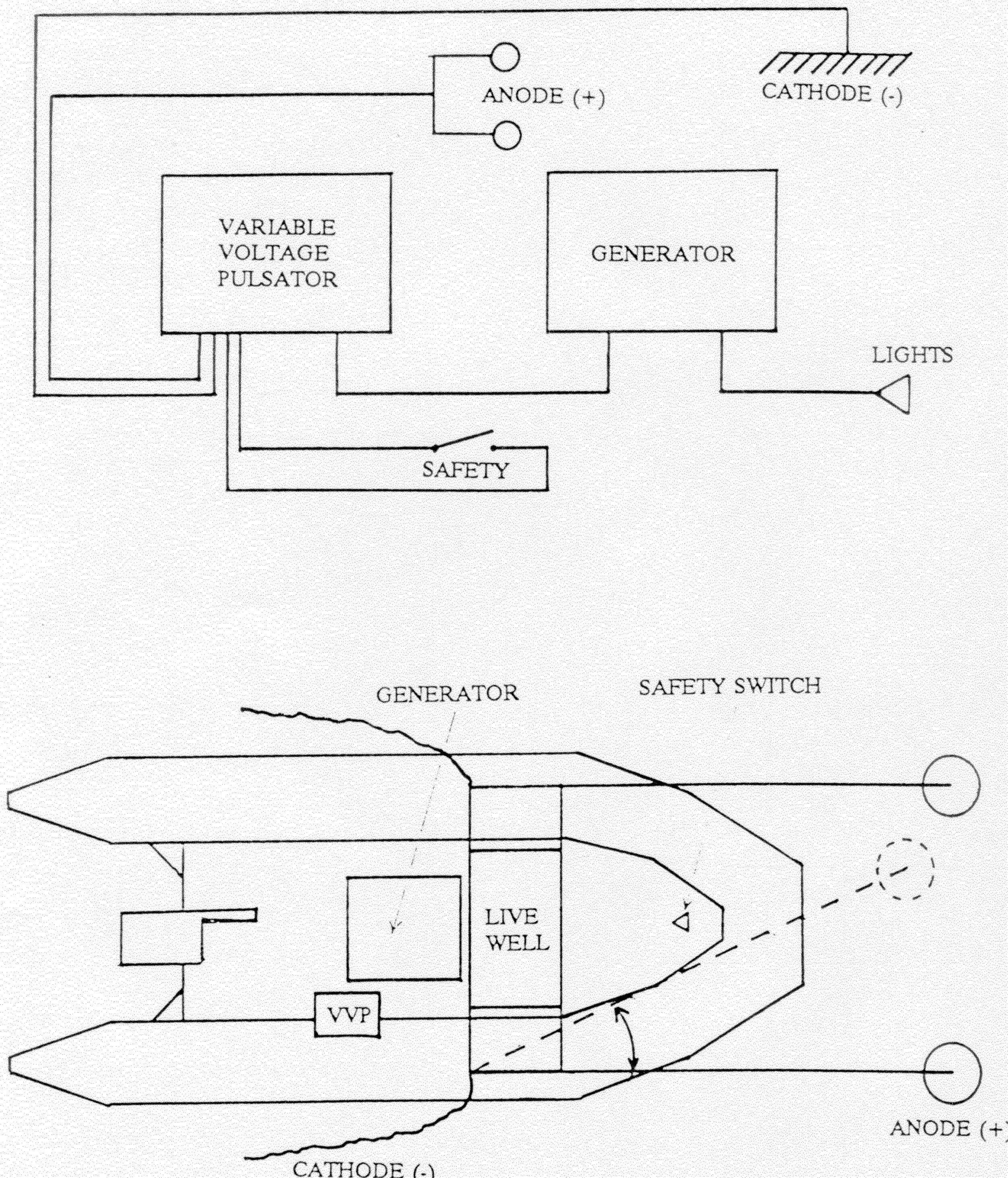


Figure A-1. Layout and schematic of electrofishing raft to be used in the Grand Canyon humpback chub studies.

The anode (+) and cathode (-) will each consist of a stainless steel sphere at the end of a fiberglass boom. It is anticipated that electroplating of various metals ions will occur on the cathode surface during all electrofishing. This will increase electrical resistance at the electrode surface and decrease electrofishing efficiency. Consequently, the anode and cathode will be made so that they are easily interchangable, allowing for cleaning of the electrode surfaces by reversing the electroplating process. The anodes and cathodes will be switched each time 45 to 60 minutes of electrofishing has been conducted.

During electrofishing runs, one or two netters will be positioned in the bow of the boat to capture stunned fish. Dip nets used to capture fish will have an opening of 324 square inches (18"x18"), a bag depth of 24 inches and be constructed of 1/4-inch knotless mesh. One netter will be designated to operate a "deadman" foot switch which must be depressed for the system to be under power. The boat operator will also be able to quickly shut off power at the control unit. As fish are netted, they will immediately be placed into a live well which will be positioned just to the rear of the netters. Rubber gloves, rubber boots and insulated nets will be provided for all persons in the boat to minimize the chance of being shocked.

Individual electrofishing runs will be conducted for each designated shoreline habitat type, e.g. sheer wall shore line, talus shoreline, backwater, or mixed. In the main channel, electrofishing runs will generally be made running with the current, adjacent to shoreline, maneuvering the boat in and out among shoreline cover to adequately shock all possible areas used by fish as well as avoiding obstacles. Electronic clocks, built into the Mark XX electrofishing units will serve to keep track of time associated with each run.

During night time operation, power will be supplied by the generator to two 150 watt floodlights mounted on the electrofishing safety railing at the front of the boat. The operator will also have access to a battery operated 500,000 candlepower Q-beam spotlight to aid in navigating the boat.

All fish captured during electrofishing will be processed immediately upon completion of a run within a habitat type. All fish will be visually examined for evidence of injury associated with shocking. Any fish showing obvious signs of injury will be noted. Injured specimens may be collected if deemed necessary (See Section 3.3 for protocol on preserving specimens). Fish will be released immediately after being processed. It is anticipated that fish will be generally released within 0.1 to 0.2 mile of the point of capture. Details on data collection associated with electrofishing are presented in Appendix B, Sec. 1.11.

2.2 Netting

2.21 Gill Netting Techniques

Gill netting is a passive netting technique that will be conducted in all habitat types of the Colorado River in the Grand Canyon. Three types of gill nets will be used during the study including 1) standard 1 1/2" gill net; 2) standard 1" gill net and; 3) experimental gill nets consisting of four mesh sizes, 2",1 1/2",1",1/2", graduated from large to small mesh at 25 foot intervals. All nets will be constructed of double knotted #139 nylon multifiliment twine and be 100 feet in length by 6 feet in height. Float and lead line will consist of 1/2" diameter braided poly foamcore float line and 5/16" braided leadcore leadline, respectively. Mooring boat bumpers will be used as gill net marker/floats. Markers will be white for high visibility and labeled to alert other boaters of their purpose. Polypropylene mesh bags filled with rocks will be used as net weights.

Setting gill nets will be accomplished by anchoring one end of the float line to the shoreline or other secure object using a length of line long enough to allow the shore end of the net to reach into the water, but remain within a meter of the shore line. A net weight will be attached to the shoreline end of net to secure the leadline. When setting experimental gill nets, the small mesh end of the net is always attached to the shoreline. Nets will then be strung out to maximize their fishing efficiency according to conditions at the point of the net set. In areas with current, nets are generally strung out downstream, parallel with the current either along eddy lines, runs or pools. In areas with little or no current nets will be placed strategically according to anticipated fish movements. A net weight is attached to the distal end of the net using a length of line varying from 6" to 5' depending on conditions. A marker line is then attached to the float line and the net is lowered into the water until the weight has reached the bottom, at which point the marker/float is attached. Figure A-2 illustrates a typical gill net set.

Nets will be 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 working into the shoreline or attachment point. If the distal net weight becomes lodged on the bottom it may be necessary to work from the shoreline out in order to free the weight.

All fish are removed as they are encountered with priority to endangered species, native species, trout and other exotics in that order. The netting may have to be cut to remove endangered fish that are severely entangled, but only when necessary. Fish will be identified and enumerated to the data recorder as they are removed from the net and either placed in the live well or measured, weighed and released.

Net sets will be run for one to two hours, depending on debris and Cladophora accumulation. If nets are found with significant Cladophora accumulation, the net will be pulled and a clean one put in its place. In order to reduce netting stress and mortality, the maximum duration of a gill net set will be approximately 2 hours. Details on data collection associated with gill netting are presented in Appendix B, Sec. 1.11.

2.22 Trammel Netting Techniques

Trammel netting is generally considered a passive netting techniques and will be used in all habitats in the Colorado River through the Grand Canyon. Trammel nets can also be used actively by floating nets through areas where concentrations of fish are expected. This active technique may be used occasionally if conditions dictate, but generally trammel nets will be used passively.

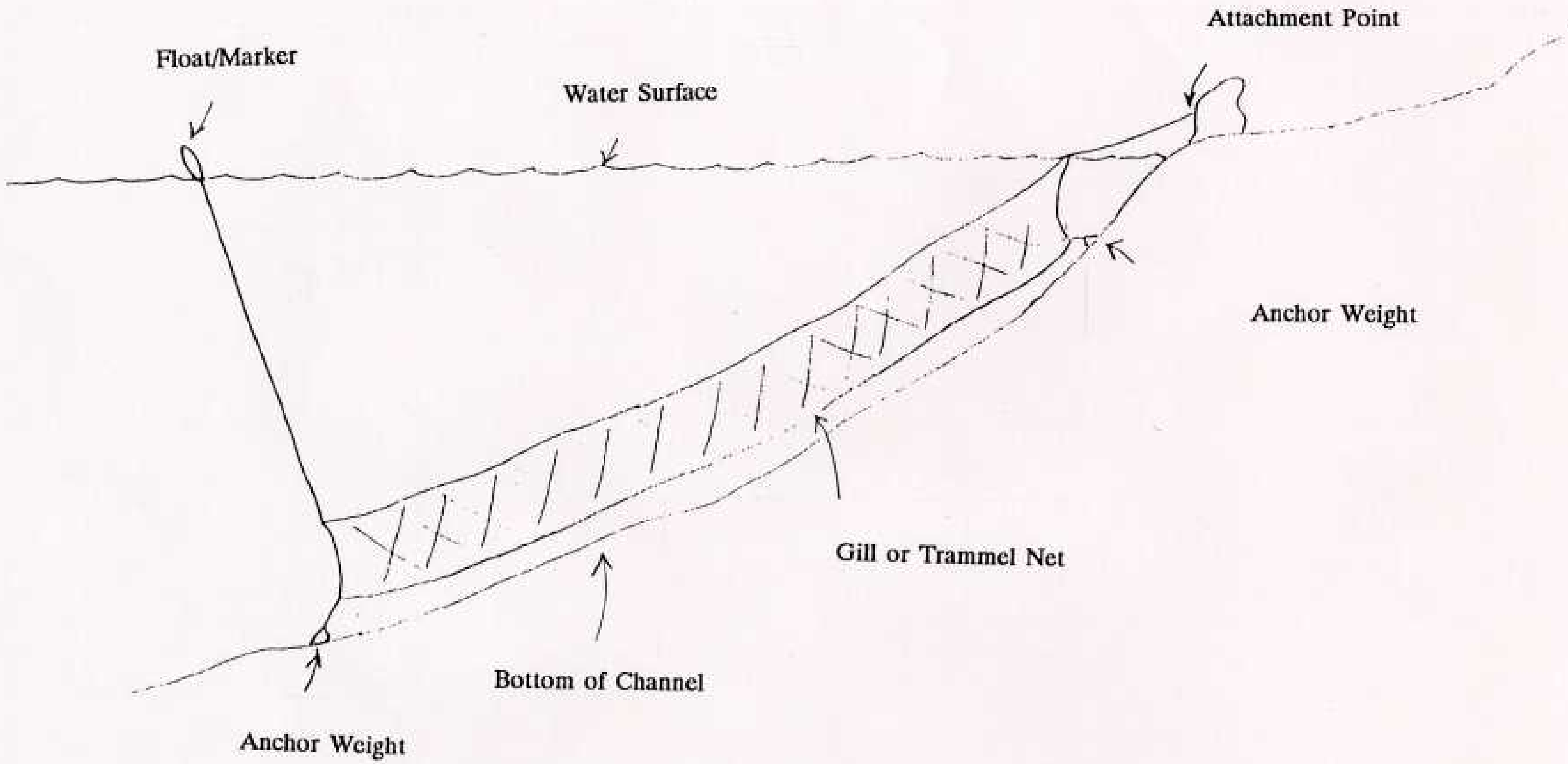


Figure A-2. Typical gill or trammel net set.

Trammel nets consist of three panels of netting, two outer walls of large mesh and one inner panel of a small mesh netting. The outer walls on all trammel nets will consist of no. 139 multifiliment twine netting with a 12" mesh. The inner panel will consist of one of two different mesh sizes, either 1" or 1 1/2". All inner panels will be constructed of double knotted no. 139 nylon multifiliment twine.

Methods for setting and pulling trammel nets and handling fish are the same as those for gill nets (see Section 2.21). Details on data collection associated with trammel netting are presented in Appendix B, Sec. 1.11.

2.3 Seining

Seining is an active netting technique that will be used to sample various shoreline habitats in the Grand Canyon including runs, riffles, pools and backwaters. This techniques is especially effective for sampling younger age classes of fish, although larger fish are sometimes captured. Three sizes of seines will be used for this study including 30'x6'x1/4", 15'x6'x1/4" and 10'x4'x1/8" (length x height x mesh size). The top or float line will be constructed of 5/16-inch braided polypropylene with hard foam floats placed at 18" intervals. The bottom line will consist of braided polypropylene line with lead sinkers placed at 6" intervals.

Seining techniques vary with condition. In areas with current, the seine haul is generally taken in the same direction as the flow. A typical shoreline seine haul taken in a run is initiated by one man stretching the seine out from the shoreline perpendicular to the shoreline. The shore end of the seine is usually positioned either at the waters edge or within 1 meter from shore depending on conditions. Once the seine is in position, it is pulled with the current as quickly as possible with care taken that the bottom line is on the substrate. To end the seine haul, the shoreline man comes to a stop as the outside man quickly arcs the seine into shore while maintaining tension on the seine. Once the fish are trapped, the seine is gently pulled under the fish and they are lifted from the water.

Seining in backwaters is accomplished in essentially the same manner. However, without current the seine can be pulled in any direction in the water and is generally pulled in the most strategic manner in terms of corralling fish. Seining is only effective as long as both persons pulling the seine are able to walk firmly and relatively unimpeded on the bottom. Water deeper than 4 to 5 feet generally cannot be seined effectively and will be sampled using other techniques. Substrate consisting of deep silt or boulders also limit the effectiveness of the technique by either impeding the people pulling the seine or by snagging the seine. These areas will generally not be sample with seines.

The backwater will be checked for longitudinal thermal stratification prior to seining. If extreme temperature differences exist at different locations in the backwater, extreme care will be taken not to subject fish to thermal shock by pulling them across a wide temperature gradient.

Once fish are secured in the seine, it will remain suspended in the water while all endangered and native fishes are sorted out and placed into live wells (bail buckets). Again, it will be important to insure that water temperature in the live well is within a 1 or 2 degrees of the water where the fish were captured to avoid thermal shock or stress. Once endangered and native fish have been sorted from the haul, the seine will be beached. On the beach a second intensive search for endangered and native fish will be made very quickly. After all endangered and native fish have been removed the remainder of the fish will be placed in a live well. Fish being held will then be immediately processed with priority on endangered species, native species, trout and other exotic species in that order. Fish will be immediately returned to the location of capture after being processed. Details on data collection associated with seining are presented in Appendix B, Sec. 1.11.

2.4 Fish Traps

2.41 Minnow Traps

Minnow traps are a passive sampling apparatus that will be used to sample young age classes of fish in various slackwater habitats in the Grand Canyon such as backwaters and pools. Minnow traps used for the study will be standard Gee Minnow Traps, 17 1/2" long, 9 inches in diameter, constructed of galvanized wire and steel. Openings are located on both ends of the trap.

Traps will either be placed on the bottom or suspended in the water column depending on conditions. No bait will be used in the traps. Each trap will be tethered to a secure anchor point and flagged for easy location. Traps will be checked at a maximum of every 8 hours to minimize trap related stress and mortality.

Fish captured in the traps will be transferred to a live well for processing. Fish will be processed immediately and released. Details on data collection associated with minnow traps are presented in Appendix B, Sec. 3.21.

2.42 Hoop Net Traps and Frame Nets

Hoop nets are a passive sampling technique that will be used in various low velocity habitats in the Grand Canyon such as slow runs, pools, backwaters shoreline indentations and side channels. Two sizes of hoop net traps will be used for the study including 2'X10'x1/2" and 4'x16'x1" (diameter x length x mesh size). Two wings made of 1" #15 nylon will be attached to the opening of the hoop nets. These wings will be 25' in length.

Hoop nets will be set in shallow slow velocity habitats. The net will be set by anchoring the rear of the net to the substrate with a length of rebar or fence post and then playing the net out so that the mouth is oriented in the desired direction. The wings are then extended out at an approximate 45° angle and attached to fence posts or rebar to hold tension on the net set. Generally hoop nets are set in anticipation of specific fish movements, e.g. into or out of a backwater or along a shoreline. Nets will be checked at least every 8 hours to minimize trap stress or mortality.

Frame nets are similar to hoop nets except for differences in the shape of the net frame and configuration of the lead (wing). Frame nets are set in the same manner as hoop nets.

Fish captured in the hoop net traps will be placed in a live well for processing. Fish will be processed immediately and released near the point of capture. Details on data collection associated with minnow traps are presented in Appendix B, Sec. 1.11.

2.5 Angling

Angling is an active sampling technique that may be used under limited circumstances in the Grand Canyon. Angling has proven to be an effective method for capturing humpback chubs in the upper basin. Fish captured by angling will be processed immediately after being caught. Angling effort will be recorded as time spent with line in the water.

3.0 FISH HANDLING

3.1 Holding Live Fish

Live wells will be used extensively to hold fish captured by the various sampling techniques in this study. Several types of live wells or containers will be used, each associated with a specific type of sampling method. These will range from 5 gallon buckets, for use during seining, to 40 gallon live wells mounted in the electrofishing boats.

Five gallon buckets will be used to hold fish captured in seines and net traps. Separate buckets will be used to hold endangered and native species. Water will be replaced in these containers for each seine haul, with care taken to insure that the temperature in the live well is within 1 or 2 °C of the temperature of the water where the fish are captured. All fish will be monitored continuously while being held in live wells to insure that no evidence of stress is being exhibited. Signs of stress include fish swimming near the surface, loss of equilibrium while swimming, change in coloration of individual fish.

Under conditions where fish will be held for prolonged periods, water will be exchanged in the live well every 15 minutes.

Larger live wells used in the boats to hold fish captured electrofishing or in nets will have a minimum capacity of 25 gallons. Water quality in the live wells will be maintained by exchanging water following each sample effort. Monitoring of fish and maintanence of water quality in the live well will be conducted as described above. Care will be taken not to overcrowd live wells, by making sure that fish are able to move freely while being held.

Live wells used in electrofishing boats will not be subjected to any electrical current since they will be mounted inside of the electrofishing raft.

3.2 Tagging and Marking

3.21 PIT Tagging

PIT tagging will be performed only by personnel designated by the Principle Investigator or Project Leaders. Key personnel will be trained in the use of PIT tagging apparatus during the first field trip. PIT tagging is relatively easy to learn, and can be quickly taught to biologists experienced with handling fish and with other tagging procedures such as radiotagging, Carlin tagging, and Floy tagging. PIT tagging procedures will follow those described by Burdick et. al. and Minckley et. al (19__). Only fish greater than 150 mm total length will be PIT tagged.

3.22 Fin Clipping

Fin clipping is an easy, effective and relatively harmless method for the short term marking of fish. Much of the sampling for this study will take place in relatively specific river reaches and a certain amount of redundancy in sample effort expected within a given trip, particularly with gill and trammel netting. Light fin clipping (e.g. 2 to 3 mm taken from the lower caudal fin lobe) will allow a degree of insight into fish movement, abundance and redundant data collection on individual fish, for a given trip.

All juvenile and adult fish, except those PIT tagged or radiotagged, that are captured in an area that will be sampled intensively (more than one time or by multiple techniques) during a given trip, may be marked by a light fin clip of the lower lobe of the caudal fin. This mark is expected to be effective through the duration of the trip in which the fish was marked.

3.3 Preserving Fish

Collection and preserving of fish in fixatives will only be done when absolutely necessary, unless collection for taxonomic reasons is prescribed by the ACT. Fish not able to be identified afield and incidental mortalities associated with sampling will be preserved in a 10% solution of formalin. A prescribed number of preserved specimens may be in taxonomic studies (Starnes 1990). These fish will be placed in uncrowded containers of 10% formalin solution for 2 to 3 days, then transfered to containers of 70% enthanol.

All fish collected with be placed in containers of adequate size and strength to prevent distortion or damage to specimens during collection and transportation. Care will be taken not to overcrowd specimens in containers. A small incision into the parietal cavity will be made on the right side of any specimen greater than 150 mm in length, to insure against decomposition. All collections will be labeled with sample #, date, RMI corresponding to that recorded on the data sheet for the sampling effort. Labeling will be done with permanent markers on the outside of the containers and/or in pencil on collection labels that will be placed in the preservative with the fish.

3.4 Stomach analysis

Stomach analysis will be conducted on live humpback chub using a stomach pump described by Seaburg (1957). Stomachs will also be collected from all incidental mortalities including humpback chub.

3.5 Capture of a Razorback Sucker

In the event of capture of a razorback sucker the following proceedures will be followed unless otherwise modified by the ACT. Any razorback sucker will be handled with utmost care to reduce handling stress. Total length and weight of the fish will be recorded. Photographs of the fish will be taken with a 35 mm camera. The fish will be PIT tagged and and comments on condition or other pertinent observations will be recored. All other information, including location, date, habitat, etc. will be recorded on the associated sampling data form. The fish will then be released as near to the point of capture as possible.

4.0 RADIO-TELEMETRY

4.1 Fish Transport and Holding

Fish captured for radiotagging will be handled with the particular care and attention to minimize handling stress. This includes holding the fish in a separate live well for transportation to the base camp or other locations where surgery will be performed. Fish will be constantly monitored while being held to insure that no signs of stress are evident.

Surgical equipment and working area in the base camp will be kept readily available to minimize set up and handling time when attempting to capture fish for radiotagging. A live car will also be set up and maintained to hold fish during preparation for surgery.

When fish are captured at locations that are distant from a permanent base camp, a field surgical station will be set up in the most convenient location close to the point of capture. Each research vessel used to capture fish for radiotagging will carry surgical apparatus including surgical tools, sterilizing agents and reservoirs, portable work area, necessary telemetry equipment and a live car. All attempts will be made to implant fish as soon as possible following capture to minimize handling time and stress.

4.2 Radiotag Implanting

4.21 Telemetry Check

All radiotags will be checked at BIO/WEST facilities upon receipt from the factory. Actual frequency and pulse rate will be recorded for each transmitter. Frequency and pulse rate will again be checked and recorded just prior to implantation and immediately following release into the river. All telemetry check information will be recorded on Form

4 (Appendix B), as part of the telemetry log for each transmitter.

4.22 Surgical Procedures

Surgical techniques for implanting radio transmitters outlined in Yard et al. 1990 (Pilot Study to Determine the Feasibility of Employing Radiotelemetry in the Grand Canyon on the Endangered Species Humpback Chub) will be followed for this study. The principle investigator will be responsible for selecting individuals to be trained in techniques for implanting radio transmitters in humpback chubs. These individuals will undergo training during Trip 1 of 1990.

4.3 Tracking

4.31 Aerial Radio-Tracking

Aerial tracking will generally be conducted prior to each field trip to provide field crews with preliminary data on locations of radiotagged fish. Aerial tracking will be conducted from a helicopter, flying at an altitude fo 500 to 1000 feet (depending on NPS regulations) and a speed of approximately 30 to 80 mph. A trial and error process will be required to determine the optimum elevation and speed for radio tracking.

Aerial radiotracking will employ the use of two radio receivers, one Model 2000 ATS programmable receiver and one Smith-Root SR-40 simultaneous scanning receiver. Two Larsen-Kulrod omni-directional whip antennae will be mounted to the skids of the helicopter. The antenna on the pilot's side will be connected to the Model 2000 ATS receiver. The antenna on the passenger's side will be connected to the SR-40 receiver. Output signals from both receivers will be routed through a switch box to two sets of headphones, one for the tracker and one for the pilot. This enables the tracker to switch back and forth between the two receiver outputs.

All current transmitter frequencies will be programed into the Model 2000 ATS programmable receiver prior to each aerial tracking effort. A list of all frequencies and pulse rates for active transmitters and the last known location of the transmitter will be readily available to the tracker. Surveilance flights will proceed in a downstream directionfor the entire length of the study area. Since the SR-40 has the capability of simultaneously scanning all frequencies, the chance of missing signals is minimized and tracking speeds will not be as restricted as if a cycling search receiver was being employed.

When a signal or signals are received by the SR-40, the pilot will be asked to remain stationary or circle the area slowly in a counter clockwise rotation so that the pilot side or programmable receivers antenna is located on the inside of the rotation. The tracker then tunes the programmable receiver to the most likely frequency in the area. The transmitter signal is then identified by switching back and forth between the programable reciever (ATS Model 2000 or Smith-Root RF-40) and the search receiver (SR-40), while tuning the programmable receiver to the most likely frequencies. When the signals match the transmitter can be identified by reading the frequency from the programable reciever. Since only three pulse rates will be used for transmitters the operator should also be able to quickly determine the general pulse rate (40, 60 or 80 pulses per minute. The location of fish can be estimated by listening to variation in signal strength as the pilot circles and the orientation of the entenna changes. Generally the 'on ground' resolution of the fish location is within 0.1 to 0.2 miles. Once a frequency has been confirmed, the fish location will be plotted on a map of the river that will be provided for each tracking trip.

The aerial tracking will continue until all of the transmitters have been located or a reasonable search has been conducted.

Engine noise from the helicopter may cause interference with the ATS Model 2000 receiver's signal reception. Any problems associated with engine noise will be identified during the first aerial tracking effort and measures will be taken to rectify the problem.

4.32 Ground Radio-Tracking

Radio tracking from boats will be conducted during all downstream travel, beginning from Lee's Ferry and continuing to the take out point for each trip. Radio receivers will be stowed in water-proof boxes during white water sections, but remain accessible so that tracking efforts may continue once rapids have been negotiated.

While tracking from the S-rig support boats, an omni-directional whip antenna will be mounted on a rocket box situated as high as possible on the rigging. The SR-40 receivers will be used to monitor for transmissions. Where possible, operators of the support boats will be asked to traverse opposite sides of the channel. However,for travel efficency most tracking from the support boats will be conducted from the center of the channel.

Depending on circumstances, radio contacts made while traveling on the S-rig will be handled as deemed appropriate. If it is possible for the researchers to return to the point of radio contact within a short period of time using SH-170 tracking boats, the location of the fish will be recorded and the support boats will continue on to base camp. Researchers will then immeadiately return to the point of radio contact and proceed with telemetry efforts. If a radio contact is made from the support boats at a location where a return trip would be considered impractical, the operator of the support boat will be asked to make an effort to land the boat, so that the location of the fish can be pinpointed. If possible, habitat measurements will be attempted from the support boats.

Radio tracking from the research tracking boats will involve two boats. Each boat will move along the opposite shoreline while tracking. Tracking efforts to locate radio-tagged fish will be made using the SR-40 receiver attached to an omni-directional whip antenna. The whip antenna will be mounted on a metal base plate, suspended above the boat by a frame apparatus.

Once contact is made with a fish, an attempt will be made to determine the general location of the fish from the boat using an ATS Model 2000 receiver and a directional loop antenna. After the general location of the fish is determined, the tracking boat will be landed on the appropriate shoreline, with care taken not to disturb the fish. An ATS Model 2000 programmable receiver and directional loop antenna will be used from shore to locate the position of the fish in the channel. Once the fish has been located in an area, it will be monitored for at least thirty minutes to determine if its position is static or dynamic. If the fish is stationary, its location will be triangulated and marked. The fish will then be monitored for an additional 1.5 hours to determine habitat use. Triangulation sightings will be marked for all locations where the fish remains stationary for 30 minutes or more during the 1.5 hour monitoring period.

If the fish is moving, its movements will be monitored for an undetermined amount of time, to ascertain its behavior and or movement patterns in relation to various factors including: 1) stage changes; 2) local macrohabitats and/or; 3) other radiotagged fish in the area. If the fish becomes stationary, it will be monitored as described above for a stationary fish.

A detailed hand drawn map or a detailed map using mylar overlay of an aerial photo (depending on photo availability) will be prepared for each fish that is monitored (See Section 5.3). Distance and direction of all movements of the fish will be recorded on the map and in the telemetry log (Form 2) relative to time and stage of the river.

At the conclusion of monitoring, habitat measurements will be taken at all locations where the fish was stationary for at least 30 minutes. Habitat measurements taken at each point include depth, velocity, substrate, temperature, cover, and water quality. Procedures for measuring each of these microhabitat parameters are presented in Section 5.2. All radiotelemetry tracking information will be recorded on either Form 4 or Form 5.

5.0 HABITAT SAMPLING

Aquatic habitats will be quantified in conjunction with fish collections and radio telemetry studies. The purpose of habitat sampling will be to quantify micro and macrohabitats utilized by humpback chub, and to determine how variations in river stage affect habitat availability and its use by humpback chub. Types of data which will be collected include, river stage data, depth, velocity and substrate in microhabitats utilized by fish, macrohabitat features, and water quality.

5.1 FLOW/STAGE MONITORING

Variation in river stage at a location will be monitored primarily with temporary staff gages. Temporary bench marks (TBM) will be established at strategic locations in the study area and will be surveyed into the permanent USGS bench marks at a latter date. During specific sampling efforts, such as radiotelemetry monitoring or habitat mapping, temporary staff gages will be emplaced as near as possible to the sample site and monitored a minimum of every 30 minutes or as deemed necessary. These measurements will be able to be correlated to the nearest USGS gaging information by use of the TBMs.

5.2 MICROHABITAT MEASUREMENTS

Microhabitat measurements will be taken in conjunction with radio telemetry observations to evaluate habitat use. In areas where the total depth exceeds the length of the metered rod, depth will be taken using a fathometer. Depth, velocity, substrate and cover measurements will be taken at locations utilized by humpback chub during resting periods. Procedures for determining the number and location of microhabitat measurements for resting fish are described in section 4.32.

Measurements of physical habitat will be taken either from a boat or by wading to the predetermined location. Depth will be measured to the nearest tenth of a meter. Measurements will be made with either a telescoping meter rod or a wading rod. Water velocity will be measured to the nearest tenth of a meter per second at the same location as the depth measurement. Velocity of the water column will be measured at 3 cm off the river bottom, and at two-tenths, six-tenths and 8-tenths of the water depth. In extremely deep water, an effort will be made to collect as many of the column velocities as possible. Selection of the depths of water velocity measurements will be made using a top setting wading rod to facilitate correct depth selections. In deep waters a manual operated system will be used to select proper depths for water velocity measurements. Velocity measurements will be made using a Swoffer current meter. When measurements are taken in an eddy or reverse river current, greater than 90 degrees from the main directional flow of the river velocities will be recorded as negative.

Substrate will be categorized as silt, sand, gravel, cobble, boulder or bedrock by visual observation, probing with depth rod, or physical examination of the substrate. Substrate categories are defined in Table A-1 . Primary substrates will also be categorized as either dominant or subdominant. The substrate which accounts for the greatest surface area will be considered dominant. The second most commonly occurring substrate will be considered subdominant.

Table A-1. Proposed Substrate Code.

Substrate	Description
Silt	fine material <.062 mm in diameter
Sand	coarse fines .062 - 2 mm in diameter
Gravel	particles 2 to 75 mm in diameter
Cobble	particles 75 to 300 mm in diameter
Boulder	particles >300 mm in diameter
Bedrock	substrate a solid rock shelf

Cover at the fish location will be characterized in terms of lateral, overhead and instream cover based on observations at the microhabitat sampling location. Overhead cover will be characterized as overhanging bank cover such as rock ledges, or cover provided by streamside vegetation. Lateral cover types include vertical rock walls and boulders. Instream covers types include boulder, log or debris jam, sand shoal, or rock jetty. For each type of cover there is also a designation for no cover.

5.3 MAPPING

Some habitats containing humpback chub will be intensively mapped to document changes in riverine habitat and use of those habitats by the fish under different river discharges and fluctuating discharges. Areas selected for mapping will be determined at a later date but will depend on availability of aerial photos, presence of tagged humpback chub, and the perceived importance of the area based on biological sampling.

Once a location is selected for mapping, base maps will be constructed from aerial photographs. Overlays of acetate sheets will then be used to draw in changing habitat features visible to the investigator at different river stages. Locations of fish for which telemetry data is available will also be plotted.

As part of the mapping effort cross-sectional profiles of the river section being mapped will be constructed using boat mounted fathometers. Rough bathymetric contours of the river section will be determined at a known flow so that relative depths at different flow levels can be approximated based on empirical observations. The number of cross-sectional profiles used to characterize the a river section will depend on the variability of the channel morphology. A minimum of three cross-sectional profiles will be used in each mapping section. Additional profiles will be used as necessary to describe channel conditions. More refined bathymetric profiles of depth and velocity are being developed by L. Stevens which will be used in combination with our habitat mapping efforts to characterize the fish habitat in three-dimension.

Supplemental photography will also be incorporated into the mapping effort. A photographic record will be made of conditions during each mapping effort. Photographs will be taken from an established photo point using the same film size and lenses with similar focal lengths to facilitate comparisons over time.

5.4 WATER QUALITY

Basic water quality data will be collected to supplement physical habitat measurements. Parameters which will be recorded include dissolved oxygen, temperature, pH, conductivity, salinity, redox potential, and turbidity. All parameters except turbidity will be collected with a Hydrolab water quality monitor. Turbidity will be determined using a colorimeter and a Hach test kit. Water quality data will be collected at various locations within the study are at various times of the day and night. A water quality log will be maintained for each trip.

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