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MEMORANDUM

TO: Jeanne Korn, Glen Canyon Environmental Studies

FROM: Rich Valdez, BIO/WEST Principal Investigator

SUBJECT: Publication Request

DATE: August 26, 1991

Enclosed is a copy of the only publication developed by BIO/WEST on the Glen Canyon Environmental Studies entitled Methodologies for Investigating the Life History and Ecology of the Endangered Humpback Chub (Gila cypha) in the Colorado River of Grand Canyon National Park. The paper was presented at the First Biennial Conference on Research in Colorado Plateau National Parks held in Flagstaff July 22-25, 1991.

Please call me at (801) 752-4202 if you have any questions.

AQU 709

METHODOLOGIES FOR INVESTIGATING THE LIFE HISTORY AND ECOLOGY OF THE ENDANGERED HUMPBACK CHUB (*Gila cypha*) IN THE COLORADO RIVER OF GRAND CANYON NATIONAL PARK

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ABSTRACT

Investigations were initiated in September 1990 to characterize the life history and ecology of the endangered humpback chub (Gila cypha) in the Colorado River of Grand Canyon. These studies are part of the Glen Canyon Environmental Studies to evaluate the operation of Glen Canyon Dam. Several new and innovative techniques for sampling and monitoring fish in whitewater riverine habitat are described and evaluated. Small research boats from established base camps have allowed increased access to many previously unsampled habitats both up and downstream, but they have increased inherent risks to personnel and equipment and demand skilled handlers. Gill and trammel nets set for less than 2 hours have reduced stress to fish and practically eliminated injury of chubs at the cost of increased labor for net maintenance and cleaning. Small maneuverable electrofishing boats have increased access to shallow shorelines but reduced the number of netters to capture fish. Radiotelemetry has become a valuable tool for monitoring fish movement and habitat use, but signal strength is restricted by water depth, specific conductance, and canyon geologic features. Greater access to sample areas and increased efficiency in capturing and monitoring humpback chub in the Grand Canyon will lead to a better understanding of the life history and ecology of this endangered species as impacted by Glen Canyon Dam.

INTRODUCTION

This paper evaluates fish sample methods employed in the first phase of the investigation of the life history and ecology of the humpback chub (Gila cypha) in the Grand Canyon. The investigation is being conducted by BIO/WEST, Inc. as part of the Glen Canyon Environmental Studies of the U.S. Bureau of Reclamation to evaluate the operation of Glen Canyon Dam. The first phase of the study extends from September 1990 through December 1991, and includes fifteen monthly field trips. Small research boats, new fish sample methods, and radiotelemetry are evaluated for their continued use in describing the life history and ecology of the endangered humpback chub.

The whitewater canyon regions of the Colorado River Basin are some of the last areas in the U.S. to receive intensive fisheries investigations. The logistics of accessing these areas as well as the difficulty in using conventional sample gears have delayed thorough surveys. Cursory surveys of whitewater regions under the jurisdiction of the National Park Service have shown that these areas often harbor some of the last remaining populations of the endangered Colorado River fishes; Colorado squawfish (Ptychocheilus lucius), humpback chub, bonytail (Gila elegans), and razorback sucker (Xyrauchen texanus). Populations of humpback chub have been found in Yampa Canyon of Dinosaur National Monument (Karp and Tyus 1990), in Cataract Canyon of Canyonlands National Park (Valdez 1990), and in the Colorado River of Grand Canyon National Park (Carothers and Minckley 1981) (Kaeding and Zimmerman 1982). Humpback chub are also found in other canyon regions including Black Rocks, Westwater Canyon, and Desolation/Gray Canyons (Valdez and Clemmer 1982), all under Bureau of Land Management jurisdiction. Colorado squawfish and razorback suckers are also found in these regions and bonytail have been recently captured in Black Rocks, Gray Canyon, and Cataract Canyon (Valdez and Moretti 1991).

The Colorado River Basin is a particularly difficult ecosystem for conducting ichthyofaunal investigations. Much of the basin is accessible from only limited access points, some hundreds of kilometers apart. River flow varies dramatically by season and high spring flows from snowmelt may increase the volume by ten to twenty-fold (e.g. 7,000 to 70,000 cfs in 1986). Daily flow fluctuations also occur below hydropower dams such as in the Green River below Flaming Gorge Dam and in the Colorado River below Glen Canyon Dam. Turbidity and conductivity also vary dramatically and may impede sample efforts, especially electrofishing. The whitewater canyon regions are particularly difficult to sample because, compounded with the variable conditions identified above, there are swift and turbulent rapids which impede travel and restrict sampling. New techniques are being employed in the Colorado River Basin and have been introduced into the Grand Canyon to enable biologists to better deal with these difficult sample conditions. These techniques are designed to facilitate ichthyofaunal surveys and to more closely examine the life history and ecology of the fishes of these whitewater regions, particularly the endangered species.

STUDY AREA

This evaluation was conducted in 275 km of the Colorado River in the Grand Canyon from Kwagunt Rapid (RK 91) to Diamond Creek (RK 366) (Figure 1). The study area was divided longitudinally into three reaches including (1) The Upper Reach from Kwagunt Rapid (RK 91) to Red Canyon (RK 124) also known as the LCR (Little Colorado River) Reach, (2) The Middle Reach from Red Canyon to Havasu Creek (RK 254) also known as the Granite Gorge Reach, and (3) The Lower Reach from Havasu Creek to Diamond Creek (RK 366) also known as the Havasu Creek Reach. Each reach was further divided into geomorphic strata based on the initial categorization of geomorphology of the Grand Canyon by Howard and Dolan (1981) which was further differentiated by Schmidt and Graf (1988). Sampling was conducted by subreach within each of these geomorphic strata to insure an approximately even distribution of sample effort, and to allow equal opportunity for sampling the various fish habitats determined by geologic features.

EVALUATION OF SAMPLE METHODS

Three aspects of the sample methods are evaluated including small manuverable research boats, new fish sample methods, and radiotelemetry. Some aspects of these methods are new in the Grand Canyon and need evaluation for their use with the endangered humpback chub.

Research Boats

The research boats were sport utility SU-16 (16 feet long) and sport heavy-duty SH-170 (17 feet long) hypalon inflatable boats manufactured by Achilles Corporation. The model SU-16 was used for electrofishing and the model SH-170 for netting and radiotracking. Each boat was powered by a 40 horsepower Yamaha outboard motor. A model SH-170 was first introduced into whitewater fishery research in Cataract Canyon in 1987 (Valdez 1990). These boats have been used as recreational river boats in the Colorado River since the early 1980's. The hard sectional floor (aluminum or marine plywood) provides the rigidity of a hard bottom boat while the hypalon construction dampens impacts with waves or rocks. The inflatable keel and tapered construction facilitate handling in swift water and are ideal for fishery research in whitewater because of their ability to travel quickly over flatwater, maneuver around dangerous rapids, uprun rapids to reaccess sample sites and relocate radiotagged fish, and maneuver during netting and electrofishing. Prior to their introduction, the conventional boat for whitewater sampling was a hypalon raft with a 5 to 25 horsepower outboard motor. These rafts were limited in speed and upstream travel by their oval configuration and the absence of a rigid floor. Many whitewater areas could not be thoroughly sampled with these conventional rafts.

The model SU-16 was selected for electrofishing because of the square bow which provides more room in the front compartment for netters. A two-piece frame was constructed (Figure 2); the front a small deck and railing for netters and the back a cargo deck for a generator, fish processing kit, spare tools, first aid kit, raft repair kit, and waterproof boxes for cameras, fathometers, and electrofishing components. The fathometers were used to assess depth contours associated with radiotagged fish and to presurvey bottom contours for net sets and electrofishing. Lights for nighttime electrofishing were attached to the front railing and powered by the generator. The boats were steered and shifted manually to reduce weight and space needed for remote controls. The model SH-170 was selected for setting nets and radiotracking. This boat has a tapered bow and was thought to be more maneuverable than the SU-16, but no differences in boat performance were noted. A one-piece frame was constructed (Figure 2) to serve as a live well and to hold fish processing equipment.

Handling these boats requires a thorough knowledge of whitewater rafting techniques. Since the boats are small and the risk of overturning is great, large rapids are often navigated by "backing down" the boat under power to avoid the larger and more powerful hydraulics. Other rapids are negotiated in a downstream orientation. The maneuverability and power of these boats often allowed the operator to avoid hazards altogether.

Fish Sample Gears

Twelve fish sample gears were used during this investigation including three active and nine passive methods (Table 1). The active methods were electrofishing, seining, and floated trammel nets. The passive methods were two sizes of trammel nets, three sizes of gill nets, three dimensions of hoop nets, and minnow traps. Each gear was evaluated for the following criteria: (1) effectiveness at catching fish, (2) degree of injury or damage to the fish, and (3) ease of operation or use.

Electrofishing. Two electrofishing boats were assembled for this investigation with virtually identical design. Each had two subdecks as previously described. The electrofishing system was powered by a 5,000-watt Yamaha industrial grade generator Model YG-5000-D. Voltage output was controlled by a Mark XX Complex Pulse System (CPS) developed by Coffelt Manufacturing in response to fish spinal injury observed with other conventional systems (Sharber and Carothers 1988). Pulsed direct current was supplied to the water through two spherical stainless steel electrodes measuring about 40 cm in diameter. The anode was suspended from the bow and the cathode from the stern. The combination of the CPS and spherical electrodes is believed to reduce voltage differentials that minimize injury to fish (Novotny and Priegel 1974, Norm Scharber, personal communication).

The CPS was normally operated at a voltage output of 200 to 250 volts and a range of 8 to 15 amperes. Conductivity ranged from 832 to 1,103 umhos/cm. The anode and cathode were interchanged every hour of electrofishing to clean the cathode surface by reversing the electroplating process.

Although it was possible for two people to net fish from the bow, generally only one netter was used because of the space restriction. This was seen as a disadvantage when compared to previous electrofishing efforts in the Grand Canyon using a 22-foot "snout boat" or "J rig" and two netters. The increased maneuverability of the SU-16 and the ability to access upstream locations and shallow shorelines far outweighed the loss of a netter. No loss in netting efficiency was seen with the reduction of a netter primarily because the anode was located close to the boat where stunned fish were readily accessible to one netter. The netter also controlled the safety footswitch which activated the system and simplified communications with the boat operator.

All fish captured with electrofishing were placed in an internal live well and examined for evidence of injury (e.g. burn marks, spinal deformity, failure to recover). Humpback chub were transported to a central processing station on shore where they were measured, weighed, photographed, and tagged, then released near their original capture site to avoid biasing movement data. Nontarget species were measured, weighed and released immediately. Passive Integrated Transponders (PIT) tags were injected intraperitoneally in all humpback chub 175 mm total length and over. This marking technique enabled biologists to permanently identify individual fish ranging from juveniles to adults. The method was introduced to humpback chub in 1988 by the Arizona Game and Fish Department.

Other electrofishing efforts in the Grand Canyon have used a suspended live well with a Faraday shield to protect the fish from further electroshock (Sharber and Carothers 1987).

The SU-16 incorporated the live well into the internal frame design since it was felt that a suspended live well would cause drag and interfere with the performance and maneuverability of the boat.

Of the twelve fish sample methods used, electrofishing produced the highest catch rate of humpback chub of 18.53 fish per 10 hours in Reach 1 (Figure 3) and 5.69 for the three reaches combined. This high catch rate is attributed to large numbers of juvenile humpback chub along shallow shorelines below the LCR in May and June 1991. When the catch in Reach 1 is presented by age group, catch rate of age-0, juveniles, and adults was 0.36, 14.96, and 3.21 fish per 10 hours, respectively (Figure 4). No known injury or mortality was caused to humpback chub from electrofishing.

Trammel Nets. Two mesh sizes of trammel nets were used, 1 and 1.5-inch. All trammel nets were 75 feet long and 6 feet deep with 12-inch mesh outer panel. All mesh was constructed of double-knotted #139 multifilament twine. Each net was tied to shore and extended into the channel with weights at each end of the lead line and a visual float to mark the outer end of the net and facilitate retrieval. Small polypropylene mesh gear bags were filled with rocks and used as net weights to avoid the need to carry extra weight in the boats.

Each net was set for a maximum of 2 hours to minimize stress to entangled fish and to rotate nets clogged by drifting Cladophora glomerata. Clumps of this dislodged algae quickly accumulated and rendered the nets visable to fish and ineffective for sampling. Depending on river flows (increasing flows carried greater volumes of algae), each net was rotated for cleaning following one to three 2-hour sets. Nets were cleaned by spreading them on a beach for drying and brushing the mesh across a table to dislodge the dry algae. The disadvantage of having to frequently clean the trammel nets was far outweighed by the catch efficiency of this gear and minimal injury to the fish. Catch rates with trammel nets were adjusted to 100 feet to make them comparable with catch rates for gill nets.

Trammel nets were the second most efficient gear overall for catching humpback chub with catch rates of 1.01 and 0.45 fish per 100 feet per 10 hours (FPH) for the 1.5 and 1.0-inch mesh, respectively (Figure 3). When presented by age group for Reach 1, the 1.5-inch mesh nets yielded the highest catch rate of any gear for adults with 3.38 FPH. The 1.0-inch mesh nets yielded a catch of 1.12 FPH. The only known mortality of a humpback chub from fish sample gears in the first 9 months of this investigation was a fish captured in a 1-inch trammel net.

<u>**Gill Nets**</u>. Three types of gill nets were used including 1.5 and 2-inch mesh, as well as experimental gill nets with four mesh sizes of 2, 1.5, 1, and 0.5-inch mesh. All gill nets were 100 feet long and 6 feet deep, and constructed of double knotted #139 nylon multifilament twine. The float and lead lines consisted of 0.5-inch diameter braided poly foamcore float line and 5/16-inch leadcore leadline, respectively. Gill nets were set, handled and cleaned in the same manner as described for trammel nets. Although the accumulation of algae was not as great on gill nets as on trammel nets, requiring less cleaning, fewer gill nets were used because of the greater risk of injury to the fish. Gill nets generally held the fish by the head and gill area while trammel nets frequently entangled the body of with less stress.

The three types of gill nets (2.0, 1.5, and experimental) yielded similar catch rates for humpback chub of 0.27, 0.53, and 0.59 FPH, respectively. The catch rates by age group in Reach 1 were also similar with 0.97, 1.25, and 0.95 FPH (Figure 4). No known injury or mortality was caused to humpback chub by this gear.

__Traps.__ Hoop nets of three diameters were used including 2, 3, and 4-feet. The 2-foot diameter hoop nets were 10 feet long with 0.5-inch mesh, the 3-foot nets were 12 feet long with 0.75-inch mesh, and the 4-foot nets were 16 feet long with 1-inch mesh. Each net had two 25-foot wings of 1-inch mesh. Hoop nets were set by anchoring the rear of the net to the substrate with a length of rebar or fence post and the mouth oriented downstream to capture upstream moving fish. Hoop nets were checked every 4 to 8 hours.

The opportunities for setting hoop nets in the main channel were limited (i.e. side channels, stable backwaters, shallow shoreline runs). Of the three hoop sizes (2, 3, and 4 feet), only the 4-foot hoop net produced humpback chub at a rate of 0.16 FPH in Reach 1 (Figure 3). One chub was caught in a small hoop, near the mouth of Shinumo Creek in May 1991.

Unbaited minnow traps were also used in small pocket waters, rocky shorelines, backwaters, and small pools. The traps were standard commercial Gee Minnow Traps, 17.5 inches long and 9 inches in diameter, and made of galvanized wire and steel with openings at both ends. Minnow traps were tethered to a secure anchor point, flagged for easy location, and checked for fish every 4 to 8 hours.

Minnow traps were also limited in use because the fluctuating river flows quickly inundated and desiccated shallow shorelines. Nevertheless, minnow traps and electrofishing may prove valuable in monitoring the relative abundance, distribution, and habitat use of juvenile chubs. No known injury or mortality was caused to humpback chub by either hoop nets or minnow traps.

Seining. Shallow shoreline areas were seined to locate larvae and age-0 fish. The seines were 10 feet long and 3 feet deep with 1/8-inch mesh. All shallow shorelines were sampled but few backwaters were seined to avoid overlap with other investigators.

Another active method of sampling fish in the midchannel was the floating trammel net. A 1.5-inch mesh trammel net as described above was either tied to shore and swung in a downstream quadrant or tied to two boats and wrapped following a short float. This method attempted to sample the main channel, which is an area rarely affected by sample gear. Seining and floating trammel nets failed to produce humpback chub.

Radiotelemetry

Radiotelemetry was first used on humpback chub in Black Rocks, Colorado in 1980-81 (Valdez and Clemmer 1982) and 1983-85 (Kaeding et al. 1990). The method was introduced to humpback chub in the Grand Canyon in October 1990 as part of this investigation. The purpose of radiotelemetry was to monitor the hourly, daily, monthly, and seasonal fish activity as impacted by the operation of Glen Canyon Dam. A total of 38 adult humpback chub were radiotagged in the first 9 months of the project, from October 1990 through June 1991. This aspect of the project led to one known mortality.

The radiotransmitters were manufactured by Advanced Telemetry Systems, Inc. and weighed 9 and 11 gm. The transmitters were two stage model BEI 10-18, No. 1 transmitters with an external whip antenna of teflon-coated stainless steel 11.5 cm long. The 9 gm transmitters were 3.8 cm long and 1.3 cm diameter. The 11-gm transmitters were 7.5 cm long and 1.3 cm diameter. Frequencies of 40.600 to 40.740 MHz. were used, separated by 10 hertz intervals (i.e. 40.600, 40.610, 40.620, etc.). The combination of fifteen different frequencies and three pulse rates (40, 60 or 80) allowed for a total of 45 unique signatures to identify individual fish. The same combination of frequency and pulse was reused following expiration of the original transmitter, which was about 50 days for 9-gm transmitters and 90 days for 11-gm transmitters.

The criterion was established that air weight of the transmitter not exceed 2% of the body weight of the fish. Thus, 9-gm transmitters were implanted in fish weighing 450 gm or more, and 11 gm transmitters were implanted in fish weighing 550 gm or more. Larger transmitters such as 13 and 15-gm packages may last longer but the availability of fish for implanting is greatly reduced (Figure 5). The radiotransmitters were surgically implanted in the peritoneum of the fish according to the procedures described by Valdez and Nilson (1982) for humpback chub. The transmitters rested on the pelvic girdle of the fish with the antennae protruding just past the pelvic fin. The trailing antenna was clipped at the hypural plate of the fish to prevent fraying of the tail fin.

The radiotagged fish were relocated and monitored with the aid of two models of receivers, a model 2000 ATS programmable receiver and a Smith-Root SR-40 simultaneous scanning search receiver. The two receivers were used simultaneously with Larsen-Kulrod omni-directional antennae during the search mode, and the ATS receiver was used with a directional loop antenna for locating the fish. The majority of tracking was done from boats and from the shoreline. Aerial tracking was used on three occasions but was found unnecesary since there was little movement by the fish.

Prior to the investigation, a pilot study (Yard et al. 1990) was conducted to determine signal extinction of internal (13-g) and external (9-g) antenna transmitters in the mainstem Colorado River and in the LCR. It was determined that signal reception for both types of transmitters in the mainstem was effective at a maximum depth of 8 feet (2.4 m) and at distances not in excess of 57 m at 860 umhos/cm conductance. Signal reception in the LCR was a depth of 2.8 to 3.4 feet at a distance of 3 m at 4,630 umhos/cm conductance. Thus, it was anticipated at the beginning of this investigation that maximum signal reception in the mainstem would probably be less than 3 m (depending on conductance and distance), and reception in the LCR would be about 1 m at a distance of 3 m. This depth extinction was seen as an opportunity to monitor vertical movement and use of shallow shorelines by the radiotagged fish.

From three to ten radiotransmitters were implanted on approximately a bimonthly schedule to maintain five to ten active transmitters per month. Ten transmitters were implanted in October, seven in November, 1990; seven in January, seven in March, three in May, and four in June, 1991. Fewer numbers of adults were available in the mainstem for implanting in April, May, and June because of the spawning movement into the LCR. Of the 38 radiotransmitters implanted, six weighed 9 gm and thirty-two weighed 11 gm. The manufacturer's estimated life of the 9-gm transmitters was 50 days; the 11-gm transmitters with a pulse rate of 80 pulses per minute were expected to last 75 days, those with 60 pulses per minute were expected to last 100 days, and those with 40 pulses per minute were expected to last 120 days. Two of the fish with 9-gm transmitters entered the LCR where high conductivity prevented continued monitoring. The remaining four fish with 9-gm transmitters were monitored for 30 to 59 days for an average of 50.75 days, which was not significantly different from the manufacturer's estimated transmitter duration of 50 days (Table 2). Of the twenty-eight fish implanted with 11-gm transmitters, four were not contacted after they moved into the high conductivity water of the LCR, three were still active after 30 to 33 days of monitoring, and one was lost after 5 days from suspected transmitter failure. The remaining twenty fish with 11-gm transmitters were monitored for 56 to 147 days for an average of 99.15 days, which was not significantly different from the manufacturer's estimated duration of 75 to 120 days (weighted average of 93.00 days). A precise evaluation of transmitter duration is not possible with the current sample schedule since the fish are monitored monthly for 10-day periods with intervening 20-day periods without monitoring.

Although transmitter duration and frequency were consistent with manufacturer standards, considerable variation was seen in pulse rates (Figure 6). Of 29 transmitters with assigned pulse rates of 40, 60, or 80 pulses per second, fifteen varied by more than 10%, and two varied by more than 20%. This pulse variation did not cause problems with identifying fish because transmitters with similar frequencies were implanted in fish some distance apart. In only one case did two fish carrying transmitters with the same frequency and similar pulse rates occupy the same area (during a spawning aggregation at the mouth of the LCR), but the pulse rates did not vary sufficiently to overlap and fish identity was maintained. A possible cause for pulse variation was the cold water temperatures in the study area (7-12° C).

DISCUSSION

The 16 and 17-foot sport utility and sport heavy duty inflatable boats are considered a major asset to the investigation. These boats have greatly expanded sample areas and opportunities, enabling investigators to better define the distribution and abundance of the humpback chub population in the Grand Canyon. The electrofishing systems on these small research boats have also been effective in capturing particularly juvenile chubs along shallow rocky shorelines that would be inaccessible to larger conventional rafts. These boats have also enabled investigators to radiotrack fish moving up or downstream and to return repeatedly to monitor the same fish.

Six sample gears (electrofishing, 1 and 1.5-inch mesh trammel nets, 1.5 and 2.0-inch mesh gill nets, and experimental gill nets) proved equally effective at catching adult humpback chub with catch rates of 0.95 to 3.38 FPH. The most effective nets were the 1.5-inch mesh trammel nets (3.38 FPH) and the 1.5-inch gill nets (1.25 FPH). Electrofishing yielded 3.21 adults and 14.96 juveniles per 10 hours, which was the highest catch rate of any gear for juveniles.

Radiotelemetry has shown great utility in defining movement and habitat use of adult humpback chub. Radiotransmitters have met manufacturer's standards, and the majority of the fish appeared to be behaving normally, including spawning ascents into the LCR. Movement by radiotagged adults to the mouth of the LCR was confirmed as a movement by most adults from the mainstem with dramatic decreases in catches at standard gill and trammel net sets. Fish movement was determined by radiotelemetry and recapture of PIT-tagged fish. Signal depth extinction was used as an indicator of vertical movement and occupation time of shallow (signal reception) and deep (no signal reception) regions of the river. Activity of radiotagged humpback chub will be related to flow and turbidity as one aspect of assessing the impact of Glen Canyon Dam on this endangered species.

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Table 1. Fish sample gears and effort in the Grand Canyon, October 1990 - June 1991.

Gear Type	Gear Code	No. of Efforts	Total Hours
Electrofishing			
220-V DC	EL	304	93.08
Netting			
Trammel net 75'x6'x1½"x12"	TL	850	1,922.69
Trammel net 75'x6'x1"x12"	TK	720	1,939.14
Gill net 100'x6'x2	GM	244	518.45
Gill net 100'x6'x1½"	GP	437	1,201.20
Gill net experimental	GX	113	236.03
Trapping			
Hoop net 4' diameter	HL	30	462.06
Hoop net 3' diameter	HM	14	192.39
Hoop net 2' diameter	HS	37	488.55
Minnow trap	MT	66	824.00
Seining			
Trammel net - floated	TF	4	-
Seine 10'x3'x1/8"	SA	21	3,518.4

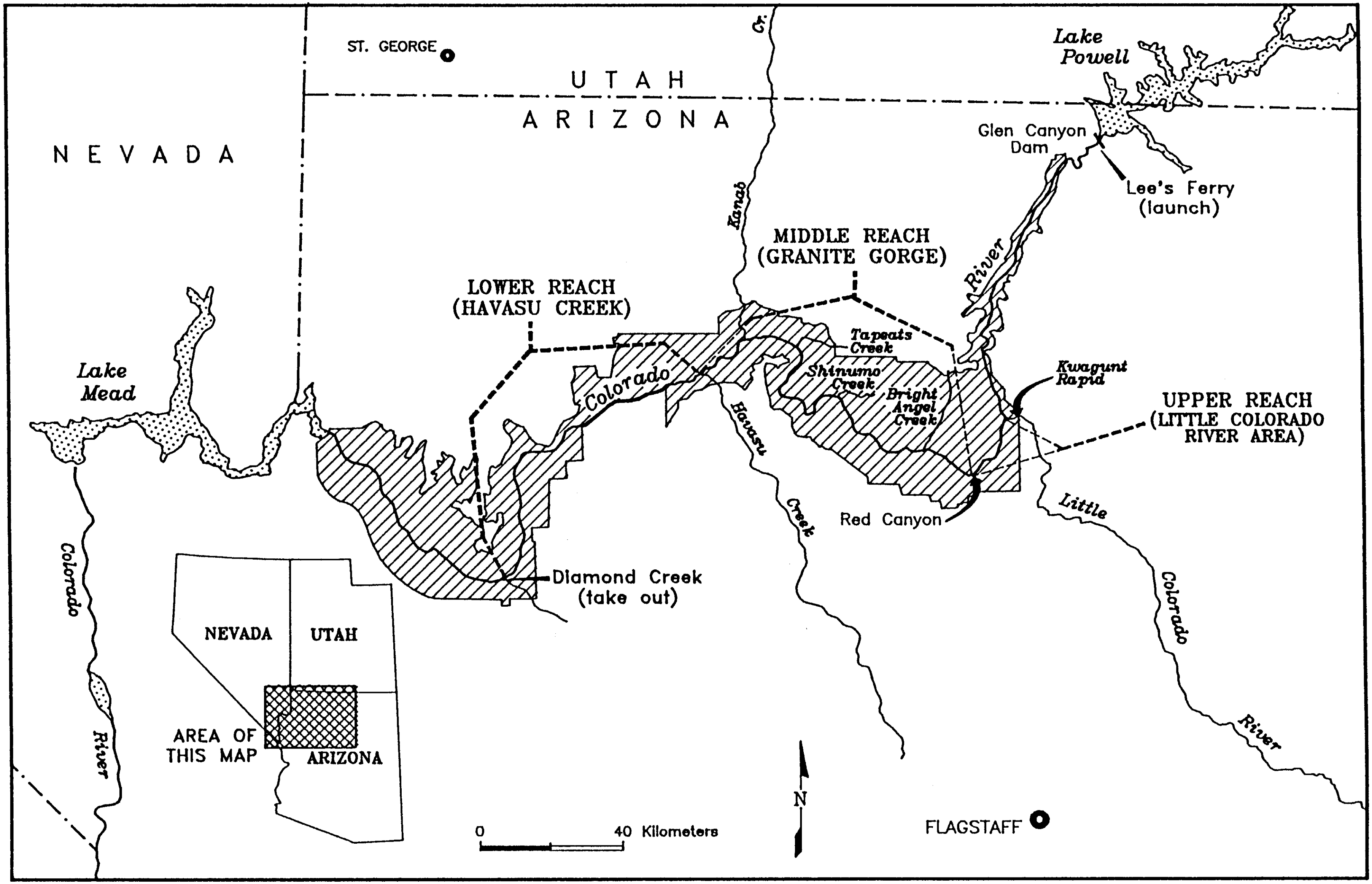
[1] Area in feet

ÁTablê. Summary of contact time for radiotransmitters implanted in humpback chub.

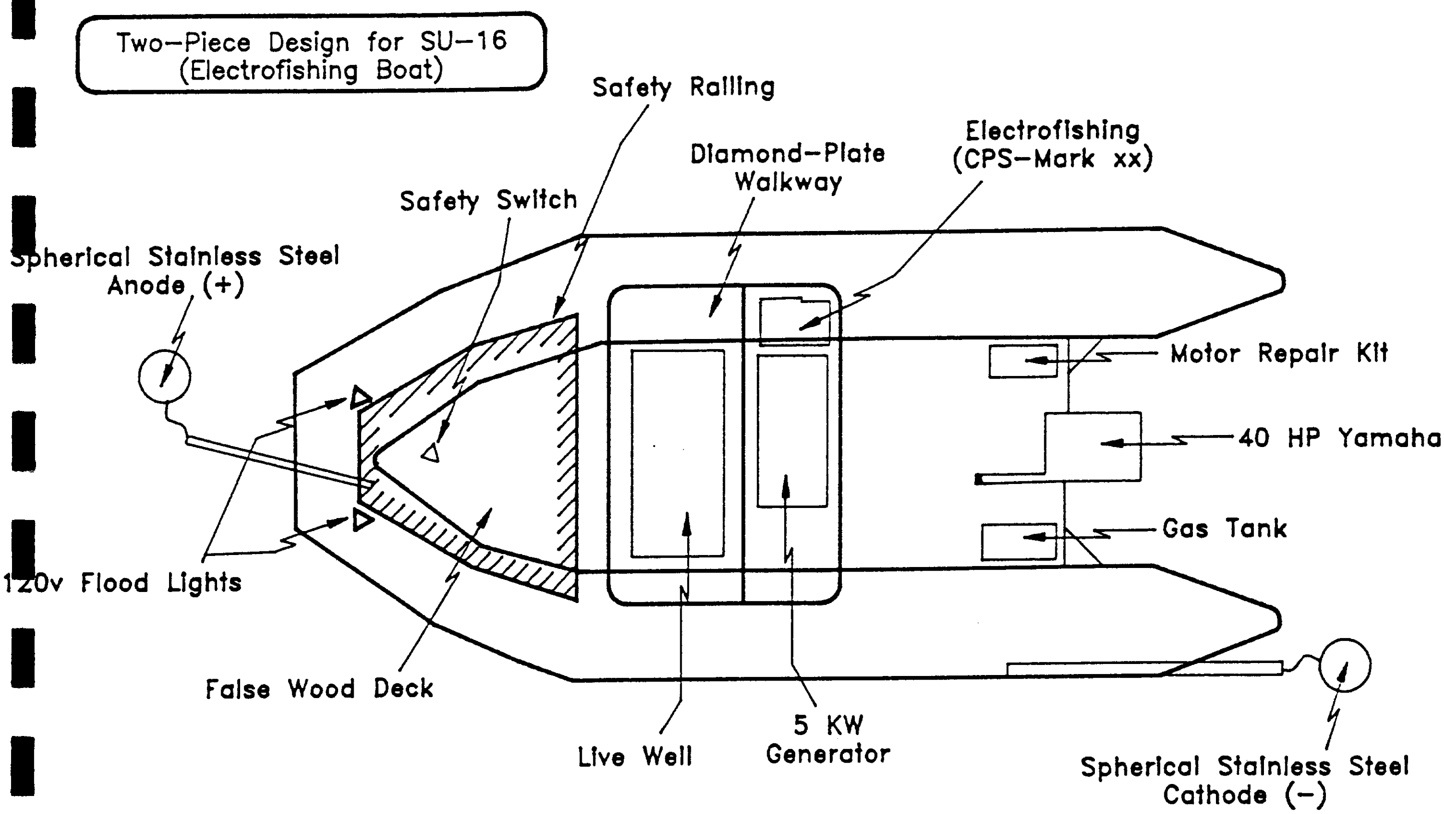
			Manufacturer Transmitter Duration (days)		**Actual Field Contact Time (days)**	
Transmitter weight (gm)	**Number implanted**	**Number Monitored**	**mean (range)**	**st. dev.**	**mean (range)**	**st. dev.**
9	6[1]	4	50.00 (50)	0	50.75 (30-59)	12.00
11	28[2]	20	93.00 (75-120)	16.16	99.15 (56-147)	28.04

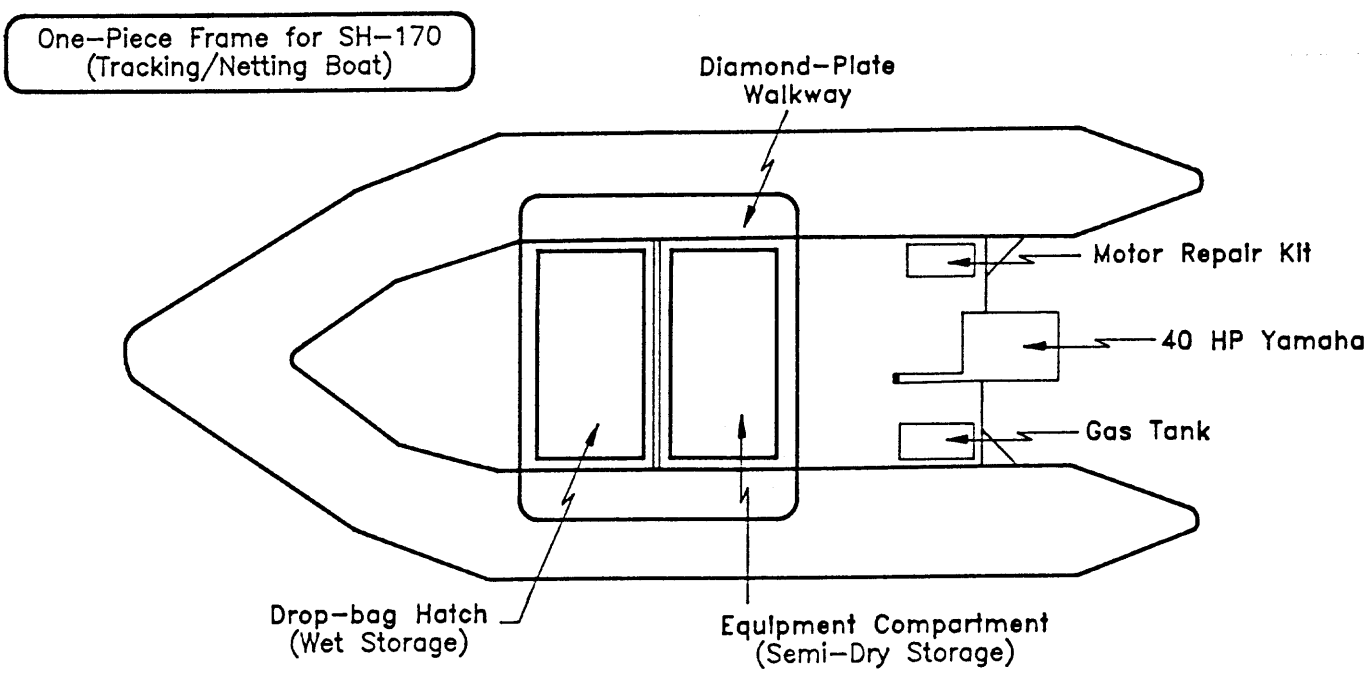
[1]two moved into Little Colorado River, lost contact.
[2]four moved into Little Colorado River, lost contact;
three still active after 30-33 days;
one suspected transmitter failure after 5 days.

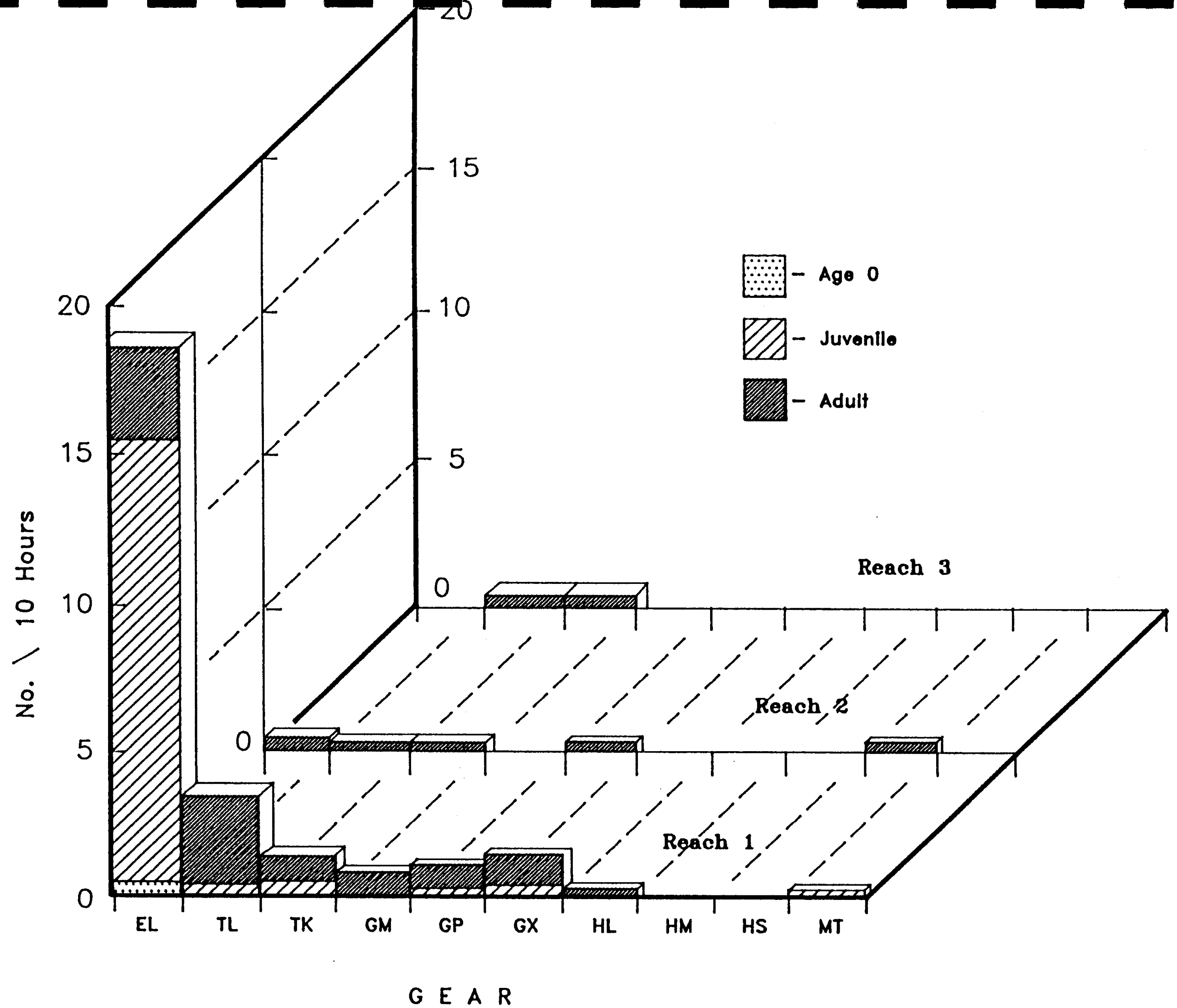
LIST OF FIGURES



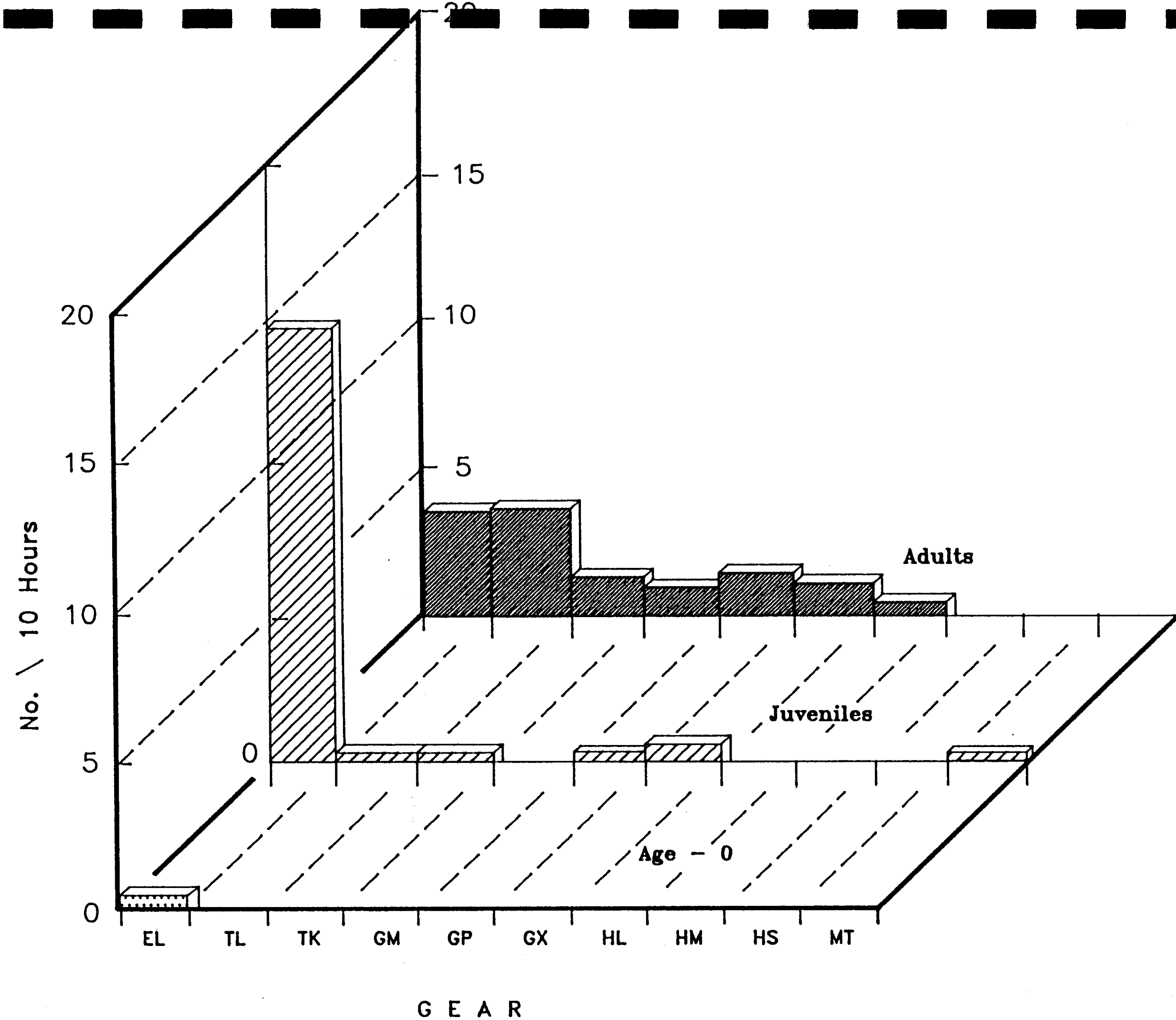
ST. GEORGE
UTAH
ARIZONA
NEVADA
Lake Powell
Glen Canyon Dam
Lee's Ferry (launch)
Kanab Cr.
MIDDLE REACH (GRANITE GORGE)
LOWER REACH (HAVASU CREEK)
River
Tapeats Creek
Shinumo Creek
Bright Angel Creek
Kwagunt Rapid
UPPER REACH (LITTLE COLORADO RIVER AREA)
Lake Mead
Colorado
Havasu Creek
Red Canyon
Little Colorado River
Diamond Creek (take out)
NEVADA
UTAH
AREA OF THIS MAP
ARIZONA
Colorado River
0
40 Kilometers
N
FLAGSTAFF

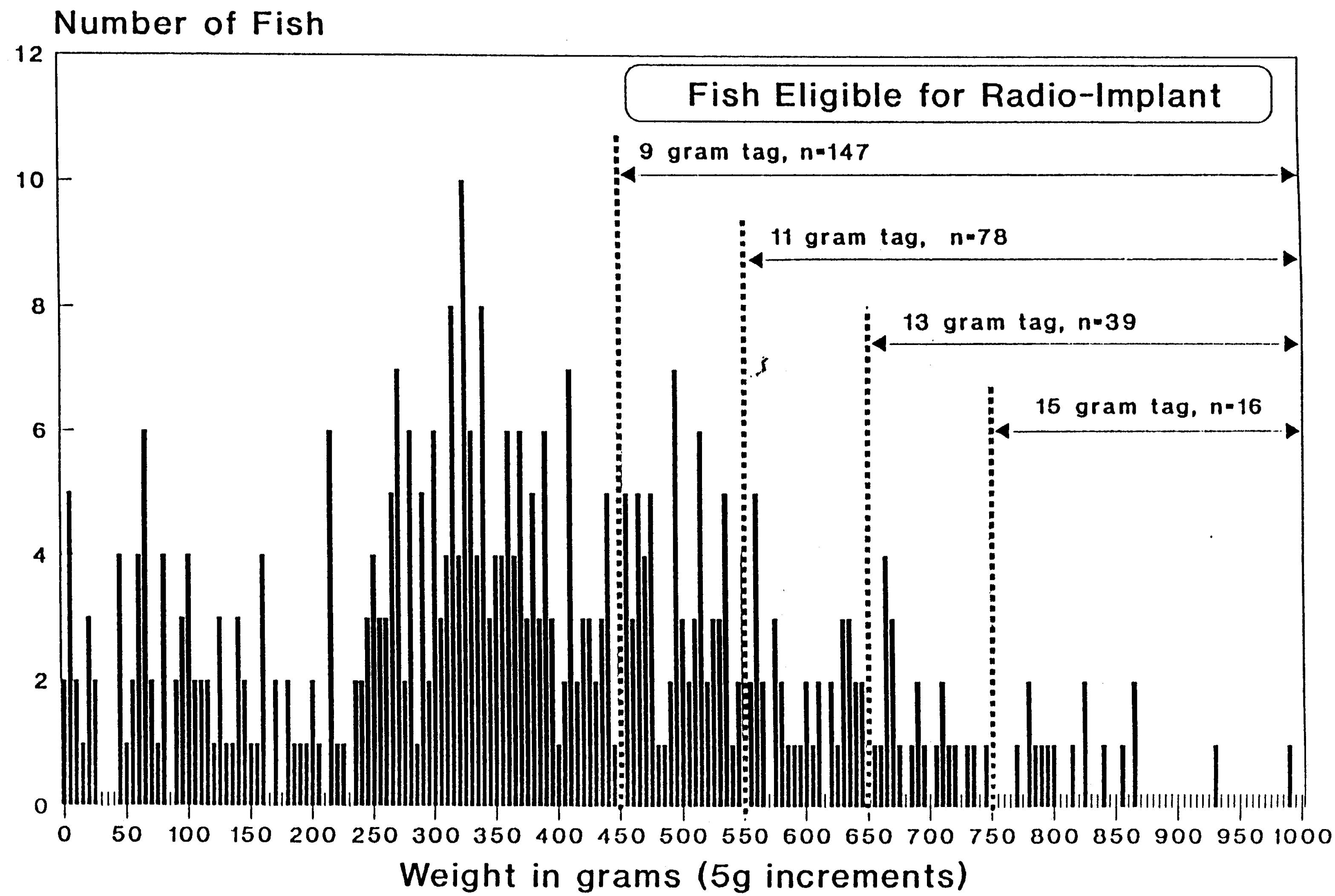

Two-Piece Design for SU-16
(Electrofishing Boat)
Safety Railing
Diamond-Plate Walkway
Electrofishing (CPS-Mark xx)
Safety Switch
Spherical Stainless Steel Anode (+)
Motor Repair Kit
40 HP Yamaha
Gas Tank
120v Flood Lights
False Wood Deck
Live Well
5 KW Generator
Spherical Stainless Steel Cathode (-)

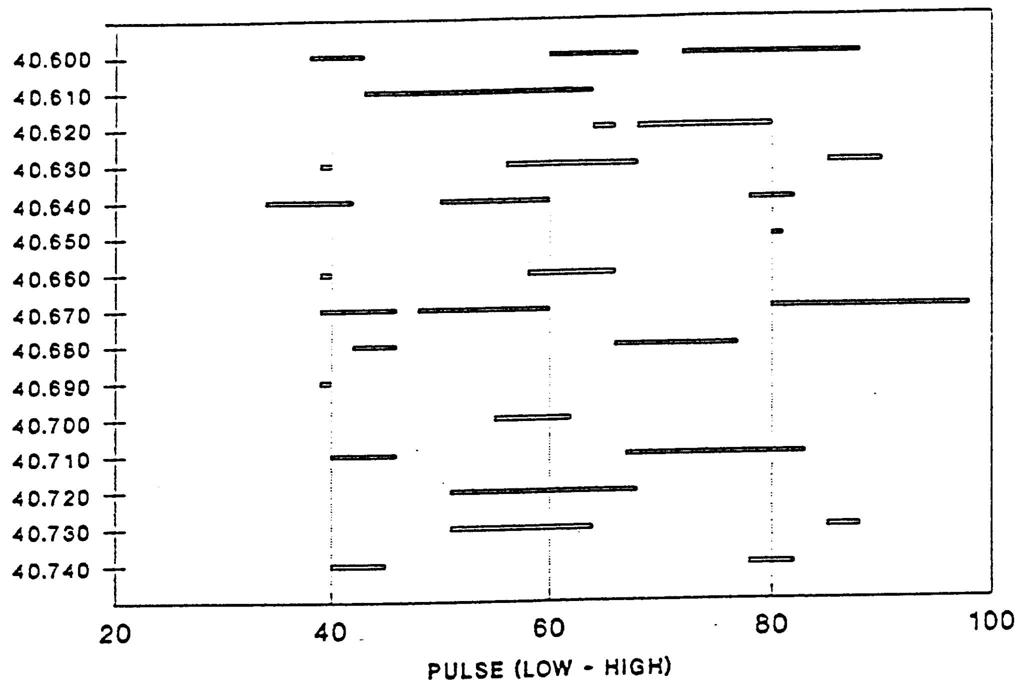

One-Piece Frame for SH-170
(Tracking/Netting Boat)
Diamond-Plate Walkway
Motor Repair Kit
40 HP Yamaha
Gas Tank
Drop-bag Hatch (Wet Storage)
Equipment Compartment (Semi-Dry Storage)



No. \ 10 Hours
20
15
10
5
0
Age 0
Juvenile
Adult
Reach 3
Reach 2
Reach 1
EL
TL
TK
GM
GP
GX
HL
HM
HS
MT
GEAR


No. \ 10 Hours
20
15
10
5
0
Adults
Juveniles
Age - 0
EL
TL
TK
GM
GP
GX
HL
HM
HS
MT
GEAR


Number of Fish
Fish Eligible for Radio-Implant
9 gram tag, n=147
11 gram tag, n=78
13 gram tag, n=39
15 gram tag, n=16
0
2
4
6
8
10
12
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000
Weight in grams (5g increments)



RANGE IN PULSES PER MINUTE