U.S. Fish and Wildlife Service, Colorado River Fishery Project. 1982.
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REPORT 1

GREEN RIVER FISHERY INVESTIGATIONS: 1979-1981

by

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INTRODUCTION

General

The Vernal field station was staffed May 1979. Field sampling of approximately 300 miles (480 kilometers) of the Green River began in July. Field work was divided into a standardized sampling program and a special investigations program. The standardized program characterized fishery habitat and species distribution; the special investigations program provided in-depth studies of life history requirements of rare and endangered fishes. It is important to note that collections utilized different methods between seasons and locations. Different collections are cited when data are reported.

Two other studies (White and Yampa Rivers investigations) conducted by the Vernal station are not included in this report. These two studies included work in the upper Green River Basin and provided other information directly related to this study. For a holistic understanding of the Green River ecosystem, these other studies should be considered with this study. The White River study (funded largely by the Bureau of Land Management) and the Yampa River study (funded by Congress, the National Park Service, and the Fish and Wildlife Service) will be available February 1982.

Setting

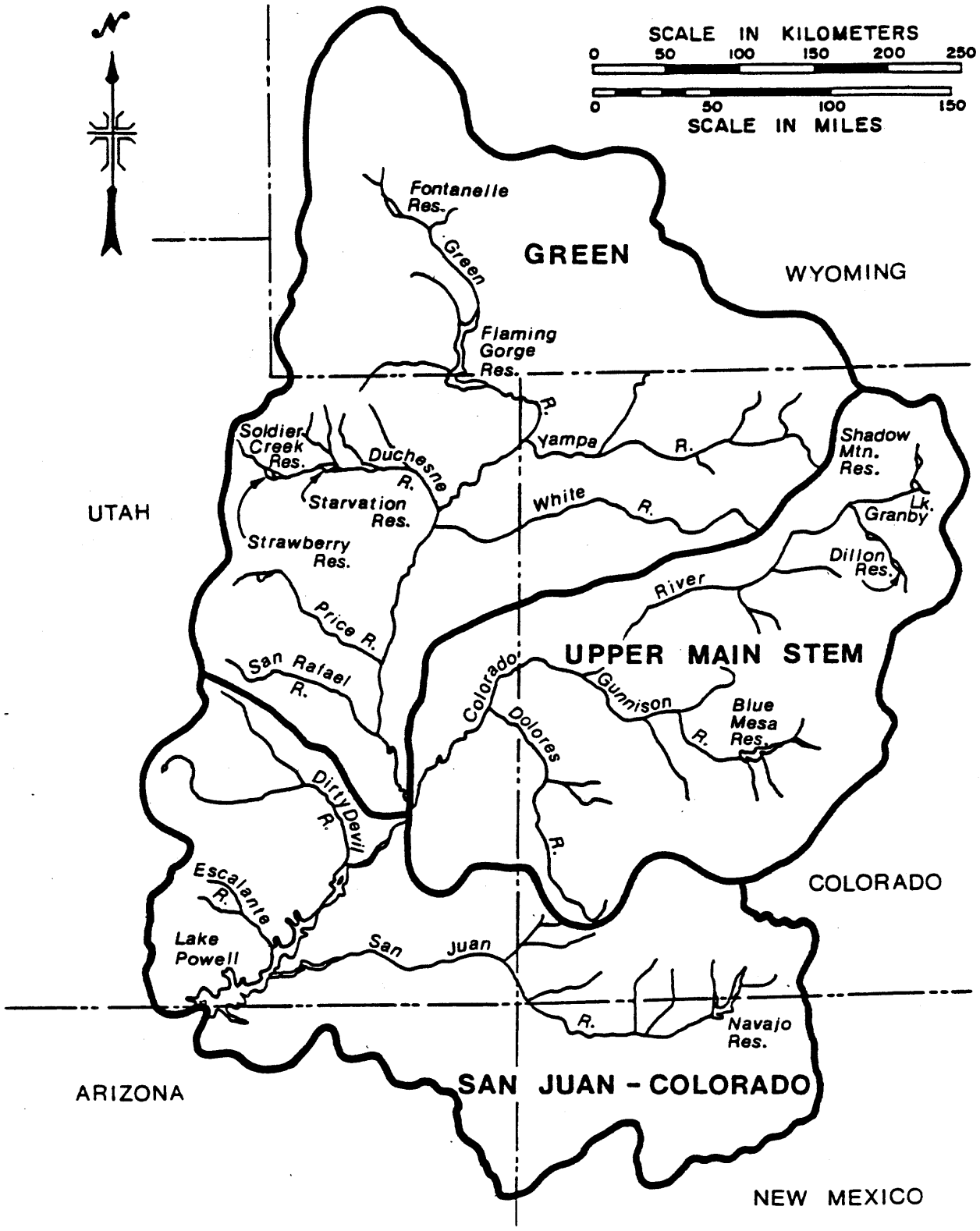
The Colorado River Basin is separated into upper and lower basins near Lee's Ferry, Arizona. The upper basin is further subdivided into its three major river systems, or hydrologic subbasins; Green, upper main stem, and San Juan-Colorado (Figure 1).

The Green River subbasin comprises about 45,000 square miles (116,000 square kilometers) of the 109,500 square miles (284,000 square kilometers) occupied by the Upper Colorado River Basin. The Green River is the largest tributary to the Colorado River and extends about 500 linear miles (800 kilometers) to its source, the Wind River Range in western Wyoming.

The study area extends from Split Mountain, the lower boundary of Dinosaur National Monument, to the confluence of the Green and Colorado Rivers in Canyonlands National Park. The Yampa River, the major tributary to the Green, enters the Green in the monument. The Green River above the mouth of the Yampa River is strongly influenced by releases from Flaming Gorge Dam, constructed in 1963.

The Green River flows through different geologic formations and has several tributaries as it proceeds to its mouth. Leaving Dinosaur National Monument, the Green River flows into the Uinta Basin, an open

Figure 1



The hydrologic subregions of the Upper Colorado River Basin
(After Joseph et al. 1977)

valley. The Duchesne River enters near Ouray, Utah, draining the southern slope of the Uinta Mountains. The White River enters below the mouth of the Duchesne, having its headwaters on the western slope of the Rocky Mountains. Below these principle tributaries, the Green proceeds 120 miles (193 kilometers) through Desolation and Gray Canyons. The Price River enters the Green in lower Gray Canyon. The Green River then enters the Green River Valley near the town of Green River, Utah. The San Rafael River enters the Green about 25 miles (40 kilometers) below the town of Green River. The Green River then proceeds south through Labyrinth and Stillwater Canyons in Canyonlands National Park to join the Colorado River. During its course, the Green River drops from about 14,000 feet (4,300 meter) near its source to about 4,000 feet (1,200 meters) at its mouth, a 10,000-foot (3,000-meter) drop in elevation.

Historically, the Colorado River has been characterized by great seasonal fluctuations, high turbidities, highly fluctuating temperatures, and high dissolved solids. The fish fauna of the Colorado River evolved in such conditions and are adapted to them. However, changes occurring in the basin have severely altered the aquatic system. These include the construction of reservoirs, flow diversions, consumptive use, and the introduction of exotic (i.e. introduced, non-native) species.

The geological history of the upper Colorado River Basin is recounted from exposed deposits ranging from Precambrian to recent. John Wesley Powell (1961) explored the Green River in 1896, described the geologic origin of the river. The existing system has persisted since the Pliocene epoch and has been isolated with surrounding basins for millions of years (Behnke and Benson, 1980). This period of isolation has been reflected in the fish fauna and Carlson and Carlson (1982) stated that although Homo sapiens dates back to about 35,000 years, fossils of Gila and Ptychocheilus similar to our existing native fishes (Miller 1958) have been traced to the middle Pliocene, or about 8 million years ago.

Climatic conditions in the upper Colorado River Basin are highly variable. This is reflected in a precipitation range from about 50 inches (1.3 meters) in the mountains to less than 6 inches (0.2 meters) in the arid valleys. Iorns et al. (1965) indicated a contrasting climate between wet, cool, high mountains; drier plateaus and low mountains with widely fluctuating temperatures; and dry interior valleys which are hot in summer and very cold in winter. These conditions result in a mixture of plant communities in the Green subbasin ranging from alpine meadows and subalpine and montane forest; mountain brush, pinyon-juniper forests; sagebrush, greasewood; and grassland communities.

Objectives

The objectives of this study were provided in the joint Bureau of Reclamation (BR) - Fish and Wildlife Service (FWS) Memorandum of Understanding (MOU), dated April 16, 1979 (Contract No. 9-07-40-L1016). Primary emphasis was directed toward habitat requirements and life history information for endangered fishes; Colorado squawfish (Ptychocheilus lucius) and humpback chub (Gila cypha). Since then the

bonytail chub (Gila elegans) was listed as endangered (USFWS, 1980) and the razorback sucker (Xyrauchen texanus) was proposed for listing as threatened; they have been included as target species.

In order to evaluate the status, life history, and habitat requirements for the four target species it was necessary to characterize fishery habitat (including physicochemical and biological parameters) so that the function and interactions of the endangered fish could be investigated from an ecosystem approach. Also, certain life history information about these endangered species was needed. The Vernal field station, therefore, organized its study with two main objectives:

1. To characterize fishery habitat. This included collections of physicochemical data for all fish species in identified habitats. Habitat preferences and species interactions for all species was the desired end product. A standardized sampling program was designed to meet this general objective.

2. To obtain life history information for rare and endangered fish species. As stated in the MOU, specific information about young and adult habitat requirements, migration and movement, interspecific competition, etc., was desired. A special investigations program was developed to meet this objective, and a series of separate studies was included in the program. These individual studies included:

   a. Abundance and distribution of young Colorado squawfish.

   b. Movements and habitat preferences of young Colorado squawfish.

   c. Radiotelemetry of adult Colorado squawfish.

   d. Habitat preference and taxonomy of Gila spp.

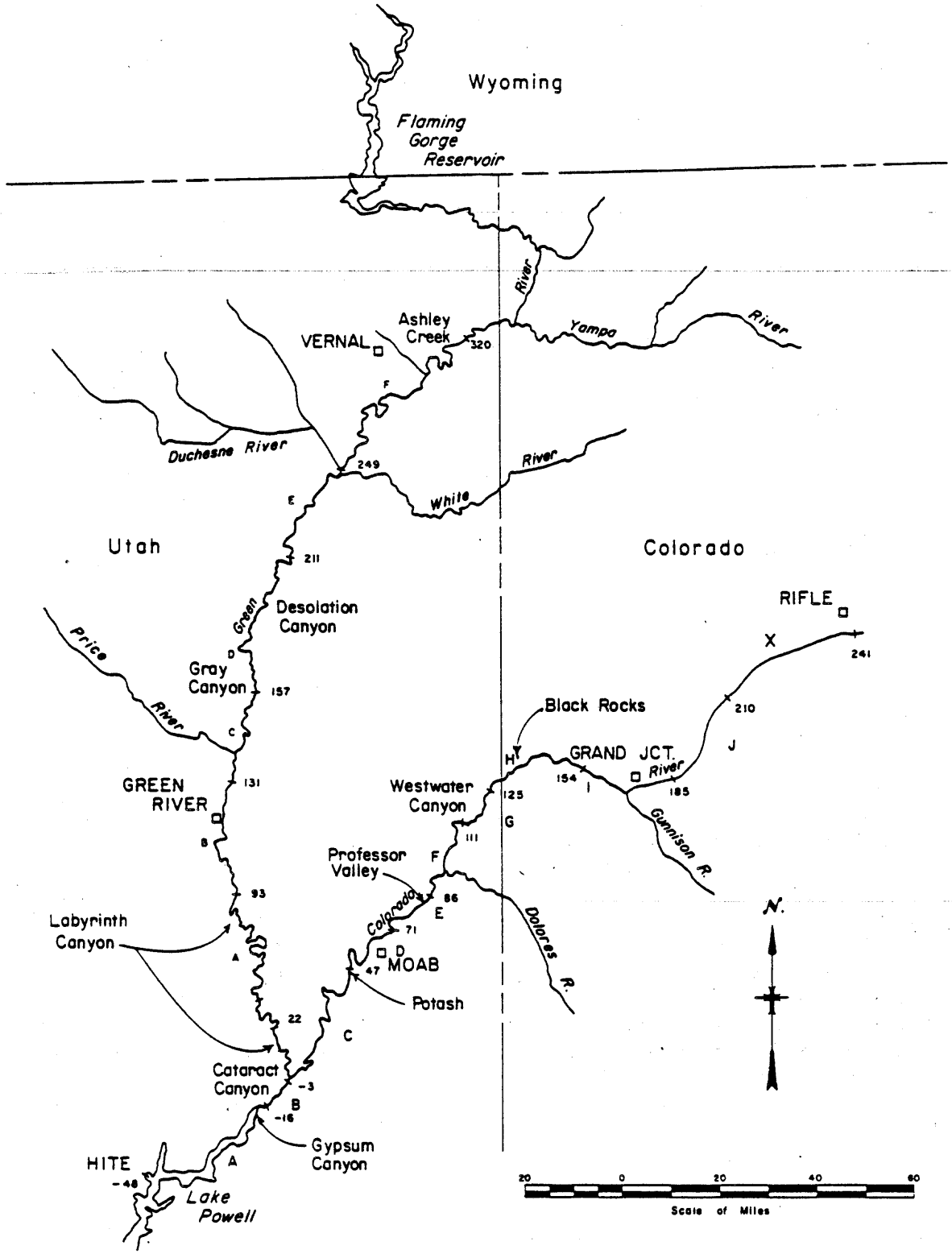
METHODS

Standardized Sampling Program

The standardized program was designed for sampling about 300 miles (480 kilometers) of the Green River in 1979 to 1981: from Turks Head at river mile RM 22 (kilometer 35) to Split Mountan, RM 320 (kilometer 515). Since it was impossible to adequately sample this entire riverine area with allocated manpower, a sampling program was developed.

The river system consists of several 30- to 70-mile (48- to 113-kilometer) sections of relatively homogeneous fishery habitat, including high-gradient canyons, low-gradient braided sections, and transition zones between these two main types. The development of the sampling design incorporated treatment of these homogeneous sections as discrete strata (Figure 2) in order to provide a good distribution of

Figure 2



Delineation of Strata, Standardized Sampling Program, Green River

samples and reduce within-strata sampling variability. Criteria incorporated into the delineation of strata included both geophysical (river channel configuration, substrate types, gradient, and depth) and biological parameters (productive bottomlands, sterile sand flats, productive backwaters, swift canyons, and point sources of allochthonous organic materials).

The six homogeneous strata were as follows:

Stratum	Length miles	Length kilometers	River miles[1/]	Landmark description
A	71	114	22-93	Turks Head to Labyrinth Canyon
B	37	59	94-131	Labyrinth Canyon to Gunnison Butte
C	24	38	132-156	Gunnison Butte to Three Ford's Rapid
D	54	86	157-211	Three Ford's Rapid to Duche's Hole
E	37	59	212-249	Duche's Hole to Duchesne River
F	70	112	250-320	Duchesne River to Split Mountain

1/ River mile from confluence of the Green and Colorado Rivers.

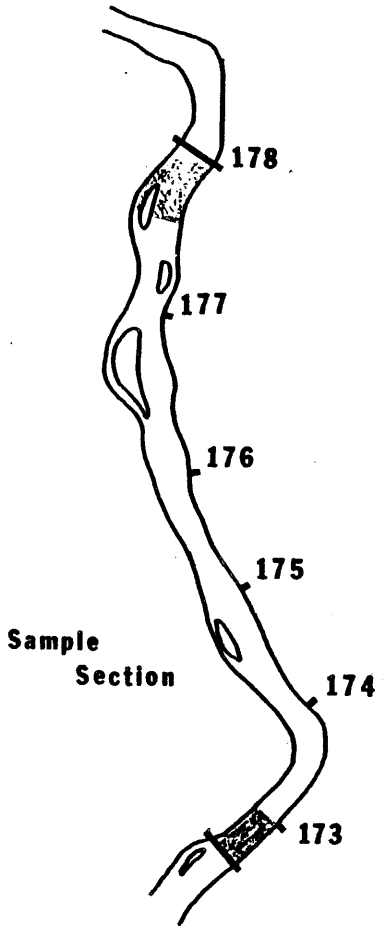
Sampling design and procedure

Sampling procedures were presented in Archer et al. (1979). During the first year a random sampling design was utilized to establish the sampling sequence. One stratum (B) was selected as the starting point with the sampling series progressing sequentially downstream to the last stratum, shifting back to the uppermost stratum to complete the series. Within each stratum sample stations were selected according to a random sampling design. In order to avoid sampling bias in the selection of stations a table of random digits was consulted and the first number encountered in the table that appeared in the section was chosen for the first sample station. To permit replication and to insure that representative stations were chosen, each station consisted of two 0.5-mile (0.8-kilometer) reaches; one extending downstream from the selected river mile starting point, the other 5 miles (8 kilometers) downstream (Figure 3). Standardized sampling began in the uppermost 0.5-mile (0.8-kilometer) reach continuing for 24 hours. The second day the intervening 4.5-mile (7.2-kilometer) reach was surveyed by electro fishing starting at the lower boundary of the previous sample station and continuing downstream to the upstream point of the second 0.5-mile (0.8-kilometer) station. From this point the second 0.5-mile (0.8-kilometer) station was intensively sampled for 24 hours.

Within each 0.5-mile (0.8-kilometer) station discrete habitat types were delineated (Figure 4) and fish collections conducted within them rather than across several habitats. This permitted a delineation of habitat preferences for fish species with depths, velocities, and substrates recorded for each subsample.

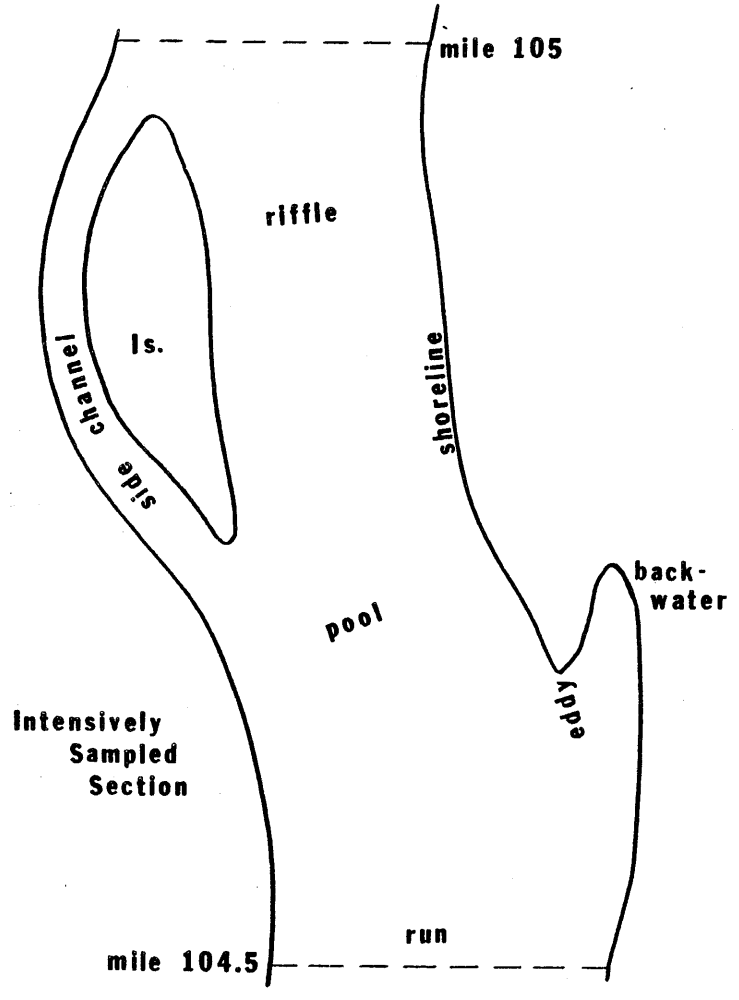
Sampling was not only stratified spatially, but also temporarily by day and season. Days were subdivided into three sampling periods

Figure 3



Sampling site divisions

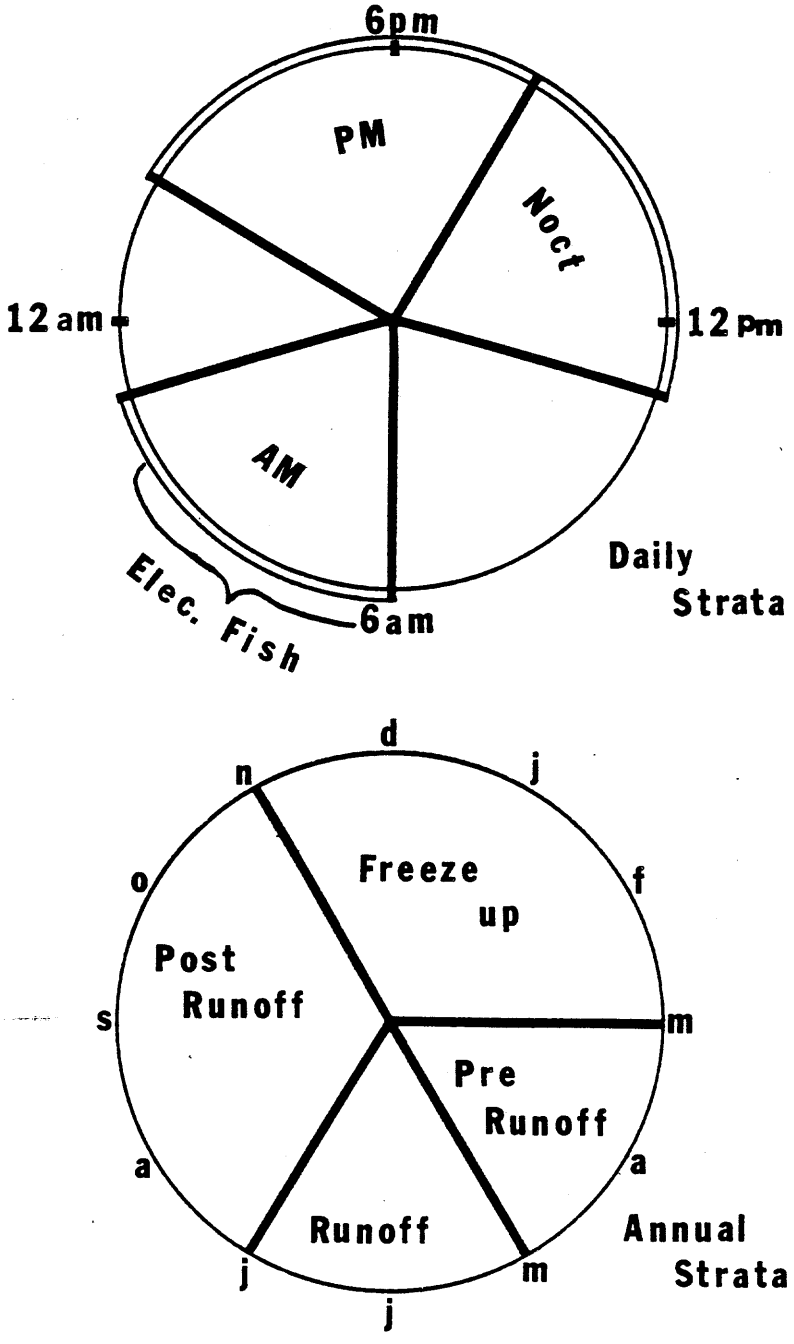
Figure 4



Habitat types

and a midday period of sampling inactivity was reserved for equipment maintenance, travel, and personal activities of the crew (Figure 5). Daylight activities were devoted to netting, trapping, electrofishing and physical/chemical measurements. Activities during darkness were devoted to tending nets, traps, electrofishing, and some seining. Seasonal sampling conformed to river stage. Each year (when work was in progress) prerunoff, runoff, and postrunoff river stages were sampled in each of the six strata.

Figure 5



Temporal sampling design

The standardized sampling schedules and procedures were strictly adhered to; however, weather conditions, manpower shortages, and equipment failures dictated minor changes in schedules and sampling procedures at times. Schedules of the 1979, 1980, and 1981 standardized sampling are included in Tables 1, 2, and 3.

Table 1
Standardized sampling schedule, Green River, Utah, 1979

Station	River mile[1]	Date	Type[2]	Station	River mile	Date	Type
B-1	121-120.5	7/16-17	I	B-3	128-127.5	9/17-18	I
B-1-2	121-116	7/17	E	B 3-4	128-123	9/18	E
B-2	116-115.5	7/17-18	I	B-4	123-122.5	9/18-19	I
A-1	086-085.5	8/2-3	I	A-3	44-43.5	9/24-25	I
A 1-2	086-081	8/3	E[3]	A 3-4	44-39	9/25	E
A-2	081-080.5	8/3-4	I	A-4	39-38.5	9/25-26	I
F-1	299-298.5	8/6-7	I	F-3	307-306.5	10/3-4	I
F 1-2	299-294	8/7	E	F 3-4	307-302	10/4	E
F-2	294-293-5	8/7-8	I	F-4	302-301.5	10/4-5	I
E-1	237-236.5	8/8-9	I	E-3	228-227.5	10/10-11	I
E 1-2	237-232	8/9	E[3]	E 3-4	228-223	10/11	E
E-2	232-231.5	8/9-10	I	E-4	223-222.5	10/11-12	I
D-1	174-173.5	8/17-19	I	D-3	163-162.5	10/16-17	I
D 1-2	174-169	8/18	E	D 3-4	163-158	10/17	E
D-2	169-168.5	8/18-19	I	D-4	158-157.5	10/17-18	I
C-1	156-155.5	8/21-22	I	C-3	141-140.5	10/23-24	I
C 1-2	156-151	8/22	E	C 3-4	141-136	10/24	E
C-2	151-150.5	8/22-23	I	C-4	136-135.5	10/24-25	I

1/ Miles from the confluence with the Colorado River.
2/ I = Intensive, E = Electrofishing.
3/ Electrofishing gear inoperable.

Sample sites were precisely located on river maps and aerrial photographs. Sketches were made of each 0.5-mile (0.8-kilometer) intensively samples reach illustrating the prevalence and juxtaposition of habitat categories (Table 4).

Three cross-sectional depth profiles were recorded at each 0.5-mile (0.8-kilomter) intensive section using an electronic depth recorder. Depth profiles were recorded at each end of the 0.5-mile sample sections and at the midpoint of the section.

Water quality measurements were taken at each intensive sample site. These included dissolved oxygen (DO), turbidity, air and water temperatures, salinity, and conductivity. Such variable parameters as temperature and DO were taken between 1,000 and 1,400 hours.

Table 2
Standardized sampling schedule, Green River, Utah, 1980

Station	River mile[1/]	Date	Type[2/]	Station	River mile	Date	Type
B-1	122-121.5	4/1-2	I	B-3	100-99.5	5/19-20	I
B 1-2	121.5-117	4/2	E	B 3-4	99.5-95	5/20	E
B-2	117-116.5	4/2-3	I	B-4	95-94.5	5/20-21	I
A-1	35-34.5	4/8-9	I	A-3	29-28.5	5/28-29	E
A 1-2	34.5-39.5	4/9	E	A 3-4	28.5-24	5/29	E
A2	40-39.5	4/9-10	I	A-4	24-23.5	5/29-30	I
F-1	260-259.5	4/14-15	I	F-3	293-292.5	6/3-4	I
F 1-2	259.5-255	4/15	E	F 3-4	292.5-288	6/4	E
F-2	255-254.5	4/15-16	I	F-4	288-287.5	6/4-5	I
E-1	244-243.5	4/21-22	I	E-3	219-218.5	6/10-11	I
E 1-2	243.5-239	4/22	E	E 3-4	218.5-214	6/11	E
E-2	239-238.5	4/23-24	I	E-4	214-213.5	6/11-12	I
D-1	171-170.5	5/3-4	I	D-3	172-171.5	6/20-21	I
D 1-2	170.5-166	5/4	E[3/]	D 3-4	171.5-167	6/21	E
D-2	166-165.5	5/4-5	I	D-4	167-166.5	6/21-22	I
C-1	138-137.5	5/5-6	I	C-3	139-138.5	6/23-24	I
C 1-2	137.5-133	5/6	E[3/]	C 3-4	138.5-134	6/24	E
C-4	133-132.5	5/6-7	I	C-4	134-133.5	6/24-25	I
B-5	129-128.5	7/8-9	I	B-7	102-101.5	8/26-27	I
B 5-6	128.5-124	7/9	E	B 7-8	101.5-97	8/27	E
B-6	124-123.5	7/9-10	I	B-8	97-96.5	8/27-28	I
A-5	56-55.5	7/15-16	I	A-7	67-66.5	9/3-4	I
A 5-6	55.5-51	7/16	E	A 7-8	66.5-62	9/4	E
A-6	51-50.5	7/16-17	I	A-8	62-61.5	9/4-5	I
F-5	297-296.5	7/22-23	I	F-7	262-261.5	9/9-10	I
F 5-6	296.5-292	7/23	E	F 7-8	261.5-257	9/10	E
F-6	292-291.5	7/23-24	I	F-8	257-256.5	9/10-11	I
E-5	221-220.5	7/29-30	I	E-7	231-230.5	9/16-17	I
E 5-6	220.5-216	7/30	E	E 7-8	231.5-226	9/17	E
E-6	216-215.5	7/30-31	I	E-8	226-225.5	9/17-18	I
D-5	165-164.5	8/9-10	I	D-7	196-195.5	9/25-26	I
D 5-6	164.5-160	8/10	E	D 7-8	195.5-191	9/26	E
D-6	160-159.5	8/10-11	I	D-8	191-190.5	9/26-27	I
C-5	146-145.5	8/12-13	I	C-7	154-153.5	9/28-29	I
C 5-6	145.5-141	8/13	E	C 7-8	153.5-149	9/29	E
C-6	141-140.5	8/13-14	I	C-8	149-148.5	9/29-30	I

1/ Miles from the confluence with the Colorado River.
2/ I = Intensive: E = Electrofishing.
3/ Electrofishing gear inoperable.

Table 3
Standardized sampling schedule
Green River, Utah, 1981

Station	River mile	Sampling dates
B1	126.0	3/30-4/3
B2	121.0	3/30-4/3
A1	50.0	4/6-4/10
A2	45.0	4/6-4/10
F1	275.0	4/13-4/17
F2	270.0	4/13-4/17
E1	218.0	4/20-4/24
E2	213.0	4/20-4/24
D1	167.0	4/27-5/1
D2	162.0	4/27-5/1
C1	153.0	5/4-5/8
C2	148.0	5/4-5/8
B3	113.0	5/18-5/22
B4	108.0	5/18-5/22
A3	74.0	5/26-5/29
A4	69.0	5/26-5/29
F3	310.0	6/1-6/5
F4	305.0	6/1-6/5
E3	230.0	6/8-6/12
E4	225.0	6/8-6/12
D3	197.0	6/15-6/19
D4	192.0	6/15-6/19
C3	145.0	6/22-6/26
C4	140.0	6/22-6/26

Table 4
Descriptions of eight major habitat types

Habitat	Description
Main channel	Primary river course that carries the major water flow throughout most of the year.
Backwater	A body of water off the main channel with no measurable velocity; often created by an eddy or drop in water level which partially isolates a former side channel or low-lying area.
Side channel	A side channel which carries appreciable flow during high water and provides a low velocity habitat during low flow.
Eddy	A portion of the stream deeper than the adjacent channel with a distinct whirlpool effect.
Pool	A portion of the stream that is deep and quiet relative to the main current.
Riffle	A shallow, fast-flowing area where the water surface is broken into waves by obstructions wholly or partly submerged.
Run	A stretch of relatively deep, fast, laminar flow with the surface essentially nonturbulent.
Shoreline	The shallow, low-to-negligible velocity waters next to shore.

An effort was made to collect fish from every habitat present in a sample station. The habitat where each fish was collected was described from a series of depth, velocity, and substrate measurements. Bottom substrates were classified according to the following scheme:

Silt	Fine gritty material
Sand	Less than 3 millimeters (mm) diameter
Gravel	3 mm to 76 mm
Rubble	76 mm to 305 mm
Boulder	305 mm and larger
Bedrock	Rock outcropping

The 4.5-mile (7.2-kilometer) reach between stations was sampled in a more general manner, primarily by electrofishing, in order to provide a survey of adult fishes. Physical data were collected only at sites of rare fish captures.

Each habitat present in the standardized sampling station was sampled with every effective gear type. Rare fish captures were located on river maps to the nearest 0.1-mile (1.6-kilometer) and water depth, velocity measurements, and the predominant substrate type recorded. All fish collections were accompanied with detailed information regarding location, date, time of day, measure of effort, habitat type, substrate type, and a series of depth and velocity measurements.

Fish larger than 100 millimeters total length (TL) were weighed and measured individually. Large samples of smaller fish were sorted into 10 millimeter groups and counted. Stomachs were removed from the rare fish that succumbed and the rest of the carcass preserved for later examinations. All rare fishes greater than 200 millimeters TL were

tagged with a Carlin dangler tag attached through the dorsal musculature immediately below the posterior one-third of the dorsal fin.

Sampling equipment

The effectiveness of electroshocking equipment is diminished substantially by high conductivities, great depths, and high turbidities encountered in the Green River. However, a Coffelt RF-10 unit was used since a rotating field with pulsed DC current is reasonably effective under these conditions. The unit employed a 4.0-kilowatt, 220-volt generator as a power source. A smaller unit of 1.8 kilowatt was also used on a raft in canyon areas. Conductivities fluctuated during the year, requiring frequent adjustments of the electrical equipment. Electroshocking gear was especially useful in collecting Colorado squawfish, a species which appeared to be more vulnerable to electroshock than others. Another unit (Coffelt VVP-15) was employed as a replacement of the RF-10 unit in 1981 and proved more effective. Fishing effort was measured in hours.

Trammel nets were set in slow-flowing runs and eddies. Nets were tended regularly, from 1- to 3-hour intervals depending upon temperature and conditions. Gill nets were occasionally used as supplemental gear but were generally discontinued. The trammel nets were 1-inch and 1.5-inch (2.5-centimeter to 3.8-centimeter) bar mesh, 150 feet long x 6 feet deep (45.0 meters x 1.8 meters) with a wall of 10-inch to 12-inch mesh (25.4-centimeter to 30.5-centimeter), respectively. Fishing effort was measured in net hours.

Funnel-type wire traps of 1-inch (2.5-centimeter) chicken wire, approximately 1.5 feet (0.5 meters) in diameter x 2-1/2 feet (0.8 meters) long were set among large boulders or accumulations of debris.

Compact, durable, time-efficient equipment was procured to collect physical and chemical data. This included the Marsh-McBirney Model 201 portable water velocity meter, a direct-readout device. Water velocity measurements were taken at 0.6 distance from the substrate. Water depths were recorded with a collapsible stadia rod and a Lowrance depth finder (Model LRG 1510A).

Total dissolved solids, salinities, and conductivities were measured with a Yellow Springs Meter (Model 33) which had a combined conductivity and temperature probe. Conductivity was expressed as micromhos per centimeter. Salinity was temperature compensated and recorded in grams per kilogram. A Hach Colorimeter (Model DR/1) was used to measure dissolved oxygen and turbidity. Turbidities were measured in formazin turbidity units (FTU) which are equivalent to Jackson turbidity units.

No single technique efficiently sampled all habitats for all sizes and species of fish. Every attempt was made to use gear or combinations of gear that would adequately sample a cross section of the fish population in each habitat. The gear most utilized were seines. While a variety of seine sizes and meshes were used, 1/4-inch mesh nets were used predominantly.

Seines were hung with double weighted lead lines so they would stay on the bottom in all anticipated water velocities. Catch per effort was determined by dividing the number of fish captured in a given area by the area (square meters) sampled.

Several boat sizes were used but the unit that was the best adapted to general river use was a 16-foot (4.9-meter) flat-bottom boat powered with a 25-horsepower outboard. White water river reaches were traversed with 18-foot (5.5-meter) rubber rafts.

Special Investigations

Abundance and distribution of young Colorado squawfish

The Vernal field office initiated a special investigation in the late summer-early fall of 1979 to obtain information about early life history of Colorado squawfish. Directed toward "filling in" needed information not obtained by the standardized sampling program, this special effort was designed to evaluate the distribution and abundance of (young-of-the-year) Colorado squawfish. Collections were made from RM 363 (kilometer 581) at the upstream end of Dinosaur National Monument and extended to RM 22 (kilometer 35.2) near the confluence of the Green and Colorado Rivers.

Due to limited manpower, a knowledge of young squawfish behavior (based on field work and information from others) was applied in developing a sampling program. In 1979, all backwaters encountered were sampled.

In 1980, a limited sampling of shoreline habitat near the sampled backwaters was added and the number of backwater/shoreline habitats sampled was restricted to approximately one location per 2 miles (3.2 kilometers) of river. After sampling the first backwater no more samples were taken for 2 river miles (3.2 kilometers), then the next backwater encountered was sampled and so forth. In addition, seine hauls were made in shoreline habitats near the mouth of each sampled backwater. Collections in 1979 were made with 1/4- (0.6-centimeter) and 1/8-inch (0.3-centimeter) mesh seines. However, little was gained at the expense of extra effort; therefore, in 1980, only 1/4-inch (0.6-centimeter) mesh seines were used as a standardized collection tool. Data obtained from these collections were recorded in the same manner as in the standardized program.

In 1981, additional changes were made in the sampling design in order to make this investigation more compatible with work in progress by the Colorado Division of Wildlife. Larval fish collections were made in addition to collections for the larger (30 to 70 millimeters) young Colorado squawfish. The larval collections were made as follows:

1. At the top of each stratum, each team proceeded downstream 5 miles (8 kilometers) and initiated sampling at that location. All required habitats were sampled with a larval seine (about 0.2-centimeter mesh) in the first initial 0.5-mile (0.8-kilometer) reach. If all habitats were not available in the initial 0.5-mile

(0.8-kilometer) reach, such lacking habitat was searched for and sampled in the remaining 4.5 miles (7.2 kilometers) of the section. Records were kept of effort and the depth velocity and substrate of each sample was recorded.

2. In addition to the quantitative collections outlined above, qualitative samples were also taken, using a larval dip net. The investigators actively searched out larvae (any habitat) at the site of the seine collections. A sample of these larvae was taken with a dip net. In addition, other samples were taken and accurate records were kept for each collection.

3. The investigators then proceeded to the beginning of the next 5-mile (8-kilometer) section and repeated the process.

Samples were collected over three habitats: backwaters, eddies, and shorelines. The number of samples collected per habitat are given below:

1.	Backwater (four collections)	
	Deep	2
	Shallow	2
2.	Eddy (four collections)	
	Deep	2
	Shallow	2
3.	Shoreline (six collections)	
	Vegetation	2
	Gravel/cobble	2
	Sand/silt	2

Larval collections were made in late July 1981 and sent to the Larval Fish Laboratory, Colorado State University, for sorting and identification. Beginning in September, YOY collections for larger Colorado squawfish were made using the same sampling design, with the exception that fishes were identified in the field instead of shipped to a contractor and a 1/4-inch (0.6 centimeter) mesh seine was used for all collections.

Movements and habitat preferences of young Colorado squawfish

Preliminary sampling conducted by the Vernal station in October 1979 indicated that YOY Colorado squawfish exhibited a diel (24-hour) movement pattern. In 1980, studies were initiated to further examine potential habitat preferences for backwater areas and to explore movement patterns. Sample sites were selected in strata A, C, and F, since young Colorado squawfish were more abundant in those strata in 1979. Each stratum was scheduled for sampling during prerunoff, runoff, and post-runoff river stages to coincide with the standardized sampling program. Each site was sampled for 4 days. Each day was divided into three 8-hour periods; in turn, these 8-hour periods were divided into two 4-hour periods (Table 5). The selected backwater was sampled during each 8-hour period by systematic sampling using a random start. Sampling alternated between the two halves of an 8-hour period. For example, if sampling on

the first day included time periods A-1, B-1, and C-2, then sampling on the second day would be done during periods A-2, B-2, and C-1. Sampling on the third day included the same periods as sampled on the first day. Data were recorded in the same manner as were other collections except all Colorado squawfish were fin-clipped before release.

Table 5
Sampling periods used during diel sampling
for young Califonia squawfish

A-1	A-2	B-1	B-2	C-1	C-2
2400	0400	0800	1200	1600	2000	2400

Military time

All habitat types found in proximity to a selected backwater were sampled with a 1/4-inch (0.6 centimeter) mesh seine at the same time with comparable effort. This allowed comparisons of the abundance of Colorado squawfish in backwaters with other habitat types.

On October 9, 1980, the Vernal field office initiated a small study in cooperation with the Bureau of Reclamation and Fish and Wildlife Service (Division of Ecological Services). The objectives of this study were two: (1) to determine if peaking power type releases from Flaming Gorge Dam would have a measurable effect on backwater habitat (important for young Colorado squawfish) as far downriver as Ouray, Utah; and (2) to evaluate any potential effects on movement or habitat preferences of young Colorado squawfish.

In order to monitor any effects a large backwater was selected at RM 255.4 (409 kilometers) in stratum F. Samples of fish populations were made as stated for the diel investigations. Depths and relative size of the backwater and depth of the river was recorded each time fish samples were taken. Noted effects were compared with the U.S. Geological Survey (USGS) stream discharge monitoring station at Jensen, Utah.

Radiotelemetry of Colorado squawfish

A radiotelemetry program was initiated at the Vernal station in March 1980. The objective of this work included an investigation of major movements, habitat preference, and spawning of Colorado squawfish. In addition to work done on the Colorado squawfish, observations were also made on one razorback sucker.

During the spring of 1980, extensive sampling was conducted in strata E and F to collect Colorado squawfish for use in radiotelemetry studies. It is emphasized that these collections were biased in favor of obtaining Colorado squawfish from habitats where they were most abundant. Although cold weather made it difficult to collect fish, the collections began in March so that the fish might recover from the surgery before spawning season. Collections were initiated using trammel nets and electrofishing gear; however, trammel nets were discontinued because of manpower shortages and a lack of success. Early efforts also included the use of larger seines. These efforts were also terminated because of manpower shortages.

Colorado squawfish (TL 508-707 millimeters) and razorback suckers were captured by electrofishing in the Green River. Fish were anesthetized with MS222 and surgically implanted with radiotransmitters immediately after capture. Surgical procedure was similar to Bidgood (1980) except for several departures. Sutures were individual (usually five) rather than the continuous suture used by Bidgood and the incision was made laterally, immediately anterior and slightly dorsal to the insertion of the right pelvic fin. Suture knots were coated with "Krazy Glue" (Bill Loudemilk, letter to the U.S. Fish and Wildlife Service, March 27, 1980).

Surgical implantation was completed with AVM fish modules (AVM 1979) dipped in melted beeswax. These transmitters (Sm-1) weighed approximately 11 grams and are of "padlock" shape. The units are powered by a mercury (HG-630) battery and have a theoretical life of about 215 days. The units transmitted in the 40.660-40.700 MHz frequency range. Radio receiver sets used were Smith-Root RF-40 and SR-40 models. The RF type enables the investigator to identify any particular frequency transmitted in the 40 MHz range. The SR receiver is a "search" type and will pick up all emitted frequencies in the range.

Omnidirectional and pinpointing type antennas were employed. A Larson-Kulrod whip antenna was used to search for implanted fish. This antenna was mounted on a 7.9-inch (20-centimeter) square steel plate elevated about 13 feet (4 meters) above the water when mounted on a boat, or mounted directly to an airplane wing strut. The loop antenna (directional) was used only to triangulate fish location. This was done by boat or from shore.

It was necessary to use aircraft to keep contact with several fish at one time. The most successful aircraft used were helicopters and a Piper Supercub (the Piper airplane was designed for low altitude and slow flight). The aircraft were operated as slow as practicable at low elevation.

The radiotelemetry program utilized two different methods for recording information about habitat preferences and movement. Long distance movement was determined by attempting to locate all radio tagged fish on a 1 to 2 day interval. The location of a fish was recorded on a one time basis when encountered. In order to obtain more specific information on movement and habitat preferences, a diel sampling procedure was employed. This sampling procedure consisted of observations made continuously over a 24 hour basis as follows:

1. The day was divided into three 8-hour periods and one selected at random. A fish was then observed during this period with depth, velocity, and substrate determinations made every 15 minutes. Habitat measurements were not recorded unless fish were stationary for 30 minutes.

2. After a fish had been monitored for three 8-hour periods, the fish with the next tag number was then selected for study.

Habitat preference and taxonomy of *Gila* spp.

Gila spp. (including the humpback chub, *Gila cypha*, and bonytail chub, *Gila elegans*) were extremely rare in collections made the first year of study. Therefore, a special sampling effort for collection of *Gila* spp. was undertaken in Gray Canyon of the Green River September 27, 1980, and April 23, June 6, July 10, and September 27, 1981, with major emphasis on collection of bonytail chub. This site was selected after several *Gila* spp. previously collected here were tentatively identified as humpback and bonytail chub. Based on all other areas sampled, it was judged to be the best location for humpback and bonytail chubs in the Green River system. Objectives of these collections were to obtain habitat information and also to provide bonytail chub for possible hatchery propagation.

Fish were collected with 150-foot (45-meter) multifilament trammel nets, multifilament gill nets, and seines. Sampling was conducted within a 0.1 mile (0.2 kilometer) river reach over a 4-day duration. However, because of manpower limitations, continuous 24-hour sampling over the 4 days was impossible and a sampling design was initiated.

A 24-hour period was divided into three subperiods, 2400-0800, 0800-1600, and 1600-2400. Sampling alternated between subperiods. For example, sampling was conducted for a 8-hour subperiod with a subsequent 8-hour nonsampling subperiod followed by another 8-hour sampling subperiod and so on. This allowed every subperiod to be sampled at least twice over the 4 days. The first subperiod to be sampled was determined when the sampling team arrived at the sampling site.

Seven sites encompassing three habitat types (eddy, run, and backwater) were selected for seining. Five sites, all eddy habitats, were selected for trammel and gill netting. All sampling sites were replicated during the period sampled. Trammel and gill nets were checked once every 2 to 3 hours. Seining was conducted twice during a subperiod but was terminated after the first day because of a manpower shortage.

Prior collections indicated that field indentification of *Gila* spp. was difficult. Therefore, specimens collected at Coal Creek were transported to Vernal for use in evaluating all known methods of species identification.

Different morphological counts and measurements presented by various authors (Smith et al., 1979; Minckley, 1973) were made on live and preserved specimens. Taxonomists and knowledgeable field workers were also contacted during the interpretation of the results of this work. In addition, selected specimens were sent to noted authorities for identification. Although all specimens were not sacrificed, a square centimeter grid board was utilized for photographing all *Gila* spp. for future study. During one field trip, fin tissue was taken from all collected *Gila* spp. and shipped to Arizona State University for electrophoretic analysis.

Sacrificed specimens were subjected to a taxonomic study. Specimens were X-rayed and vertebral counts were made. Eight meristic characters and gross morphological shape were used to segregate species. Characters

were weighted since considerable overlap occurs between species for particular meristic characters (e.g., precaudal vertebrae counts for Gila cypha and Gila robusta). Meristic characters exhibiting the least overlap were weighted more than those with considerable overlap as follows:

Character	Weighting factor
1. Mouth, whether terminal or inferior	2
2. Eye diameter	1
3. Gill raker counts on second arch	4
4. Precaudal vertebrae	2
5. Dorsal and anal fin ray number	1
Total	10
6. Head length divided by caudal peduncle depth	3
7. Caudal peduncle length divided by head length	2
8. Total vertebrae count	5
Total	10

Characters 1 through 5 gave the best separation into the three species. Characters 6 through 8 were utilized to separate Gila cypha from Gila elegans if meristic characters 1 through 5 did not segregate the two.

Four Vernal FWS fishery biologists then participated in the identification of specimens and a score sheet was compiled for each specimen. A total of 7.5 out of 10 points (75 percent) was required to classify a specimen as to species; less than 7.5 was considered an unknown.

Data Storage and Retrieval

The MANAGE data-based management system developed by the Western Energy and Land Use Team (WELUT) in Fort Collins, Colorado, was used for the project. This system provides storage, retrieval, and manipulation of large volumes of data. In addition, data analysis capability was integrated into the MANAGE system by integrating certain features of the IMSL (International Mathematical and Statistical Library) Package (Shumate et al., 1981).

Field data were organized into four data sets in the Vernal data base. Data sheets and the following data sets were developed:

1. Physical: Physical and chemical data, including water and air temperature, dissolved oxygen, conductivity, salinity, turbidity, and stream width and depth.

2. Catch-Green: Catch data for fishes; includes sample time, duration, gear type, habitat, area sampled, depth, velocity, and substrate for each fish species (endangered and nonendangered) by age groups.

3. Rare: Includes sample time, duration, gear type, habitat area sampled, depth, velocity, substrate type, sex, length, weight, tag size and number, and macroscopic external parasite load for each endangered or threatened fish captured.

4. Radio: Movement data for radiotagged fish, including observation time, distances for movements, type of movement, depth, velocity and substrate of preferred habitat, water flow and temperature.

MANAGE accepts alphanumeric codes. Fish species and other observations were coded on the data sheets as letters rather than numerals. As an example, the substrate 'sand' was coded as 'SA.' This facilitated field recording. Numeric information was also entered directly.

RESULTS AND DISCUSSION

General

Although field collections were completed in November, all data analyses were not completed by the required report deadline. Problems with entering data into the MANAGE system, development of a statistical program for integration into MANAGE, and preparation of software have delayed analysis of completed work. Transfer of the Vernal data-base from the Fort Collins computer to the NOAA computer also caused delays.

Information presented is accurate; however, where needed analyses have not been performed or where all data have not been received, it may be necessary to supplement this report. In this text, every attempt has been made to:

1. Define the nature of any deficiency; whether the data-base is incomplete or analyses have yet to be performed.

2. Suggest possible changes in conclusions after pending studies are completed.

Another problem concerned with interpretation of the results pertains to other field studies. Studies in progress on the Yampa River, the Green River in Dinosaur National Monument, and the White River have a bearing on the results of this study. These other studies will not be reported until February 1982. Where suspected areas of support or conflicts occur, these are stated.

Survey of the Habitat and Relationships of Fishes

General

Joseph et al. (1977) divided streams of the Upper Colorado River Basin into three zones:

1. Upper or headwaters - "trout water" having cold temperatures, clear water, and high gradients. Substrate is rocky, primary productivity is significant, benthic invertebrates are substantial.

2. Intermediate - warmer water, less gradient, having greater flows with increased levels of suspended and dissolved solids. Waters clear except during runoff and rainy periods. Rocky to sandy substrate; abundant benthic invertebrates in rocky areas to scarce in sandy areas. Cyprinid and catostomid fishes predominate. Primary production is high.

3. Lower - large river channels divided into two subunits; canyon areas of steep gradient, rocky bottoms, and meandering river sections with sand-silt bottoms. Water in this zone is warm,

turbid, high in nutrients. Primary production is low, benthic invertebrates dependent on substrate. Fish species composition was variable but dominated by cyprinids, catostomids, and influenced by introduced fish species.

Following Joseph et al. (1977), the Green River should be included in the third subdivision. As indicated by Smith (1981), the habitat for periphyton and benthos is limited by high discharge relative to channel capacity. Fishes are, therefore, exposed historically to an "unsteady" supply of food, swift current, and great seasonal fluctuation in stream discharge.

High stress associated with life in the lower riverine zones results in a lower productivity than occurs in upstream headwaters of the Green. This is evidenced by a sharp species segregation which represents a demarcation between the short growing season, but good food conditions of headwaters versus the stressful discharge and poor food conditions of life in the main channel. According to Smith (1981), these factors may explain the development of longevity and large size of endemic large river forms (such as the Colorado squawfish) in the main channels of the Green River.

Because seasonal differences in discharge dominate the Green River ecosystem, sampling schedules were designed to measure the different conditions existing in the different river runoff stages. Discharge records were obtained from the U.S. Geological Survey (USGS) and utilized to construct discharge hydrographs for 1979-1981 (Figures 6 to 8). Pre-, post-, and runoff periods for each year were delineated from inspection of these hydrographs as follows:

	Prerunoff	Runoff	Postrunoff
1979	1/1 - 4/19 (not sampled)	4/20 - 6/30 (not sampled)	7/1 - 12/31
1980	1/1 - 4/19	4/20 - 6/30	7/1 - 12/31
1981	1/1 - 4/29	4/30 - 6/14	6/15 - 12/31 (not sampled)

Runoff in 1979 and 1980 was similar both in duration and magnitude. In 1981, however, runoff was less sharply defined and of much smaller magnitude.

Physicochemical description of strata

As stated previously, various physicochemical parameters were measured in order to characterize strata. Mean water temperatures generally reflected the order in which strata were sampled (i.e., B-A-F-E-D-C). Mean water temperatures for each stratum during runoff were higher than during prerunoff but were much less variable, reflecting both higher stream discharge and less variability in air temperatures.

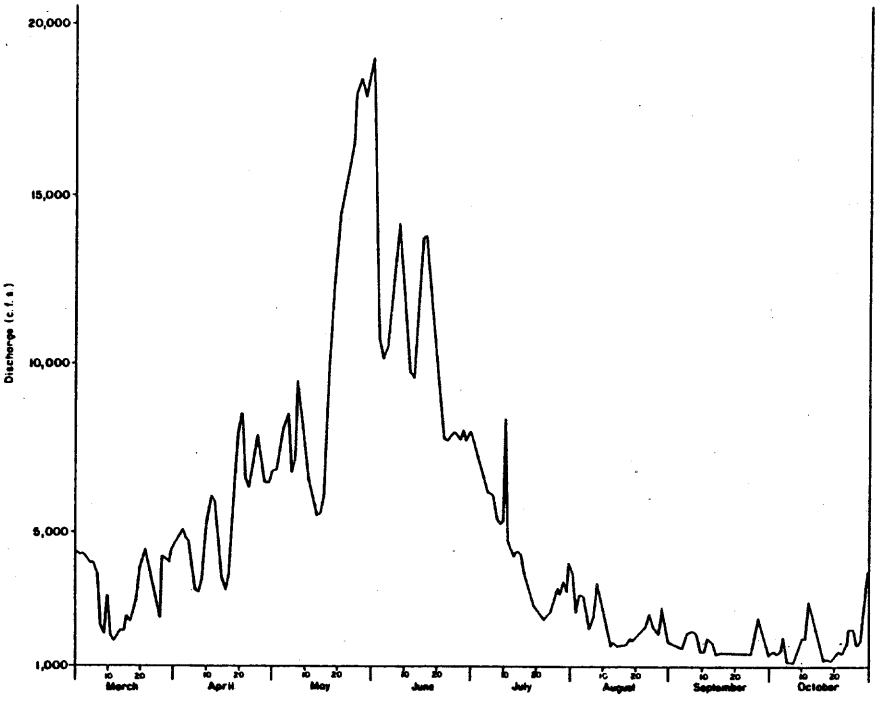
Lower discharges and increased summer air temperatures in the postrunoff period resulted in more variable water temperatures. Mean water temperatures for all strata except C and D increased regularly from prerunoff through postrunoff. Strata C and D include Gray Canyon and Desolation Canyon, respectively, and are deeper (Table 6, Figure 9)

Table 6
Selected physical and water quality data, Green River, Utah
June 1979 - June 1981

	Prerunoff					Runoff					Postrunoff				
Stratum	Maximum depth (feet)	Average depth (feet)	Average H_2O ^oC	Average[1] condition (umhos)	Average turbulance	Maximum depth (feet)	Average depth (feet)	Average H_2O ^oC	Average condition (umhos)	Average turbulance	Maximum depth (feet)	Average depth (feet)	Average H_2O ^oC	Average condition (umhos)	Average turbulance
A	19	4.3	12	800	208	28	7.0	18	323	621	18	4.0	22	816	465
B	9	3.3	7	663	690	28	6.1	15	440	457	27	4.2	23	801	900
C	33	8.1	16	625	165	62	13.3	19	321	608	38	7.3	18	753	189
D	20	4.7	17	765	90	24	8.6	18	302	660	29	6.4	19	764	217
E	6	1.2	12	535	45	24	7.0	17	345	1,050	16	4.4	24	818	80
F	14	4.0	11	608	495	17	4.7	17	213	334	12	3.2	20	606	132
Grand mean	16.8	4.3	12.5	666	282	30.5	7.8	17.3	324	622	23.3	4.9	21.1	760	331

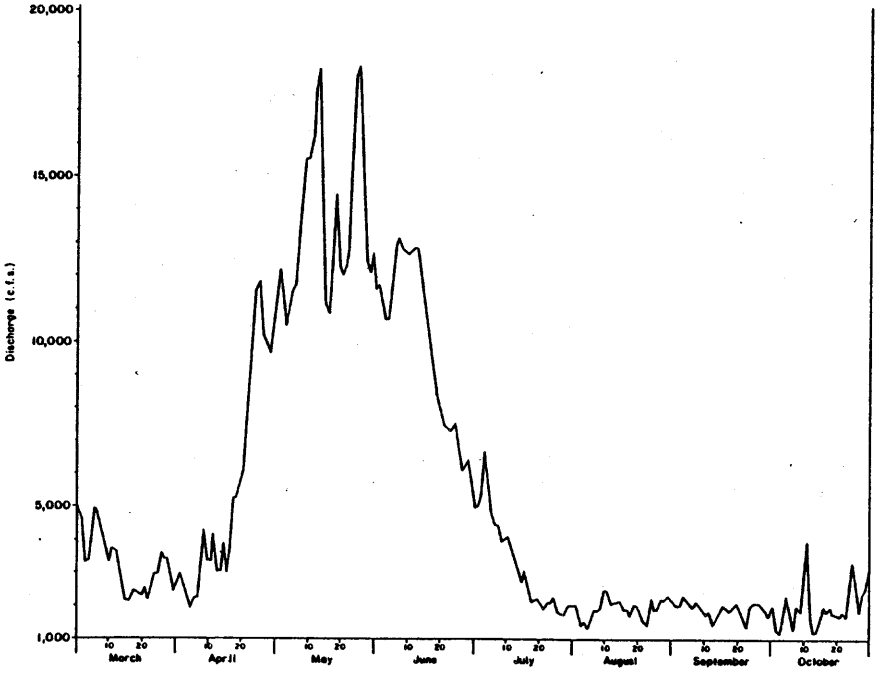
[1] Not temperature compensated.

Figure 6



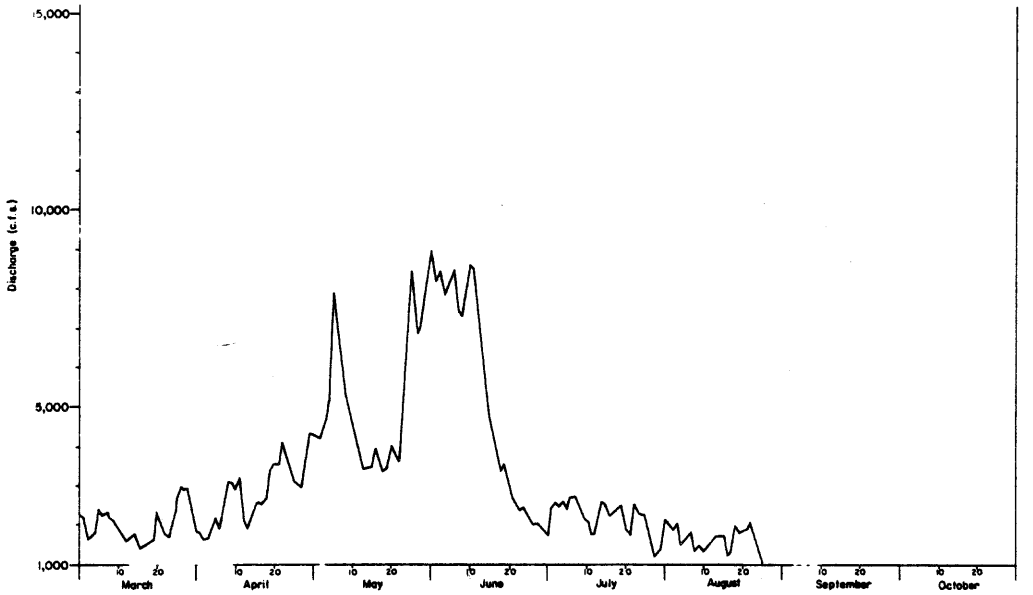
Green River discharge at Jensen, Utah 1979

Figure 7



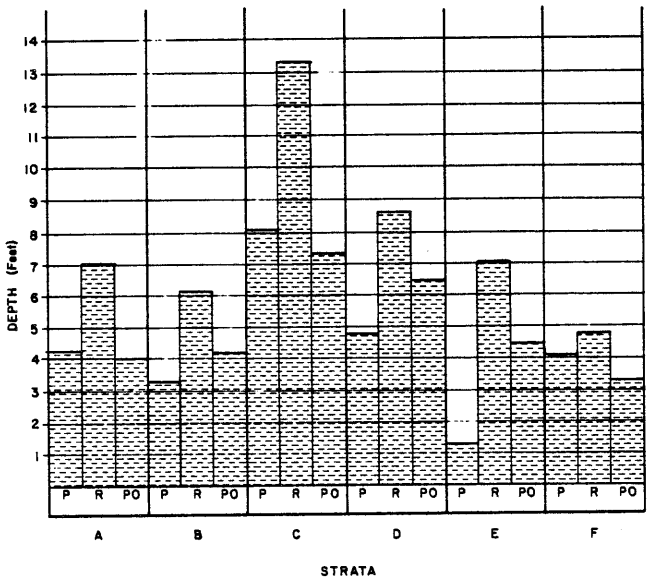
Green River discharge at Jensen, Utah 1980

Figure 8



Green River disharge at Jensen, Utah 1981

Figure 9



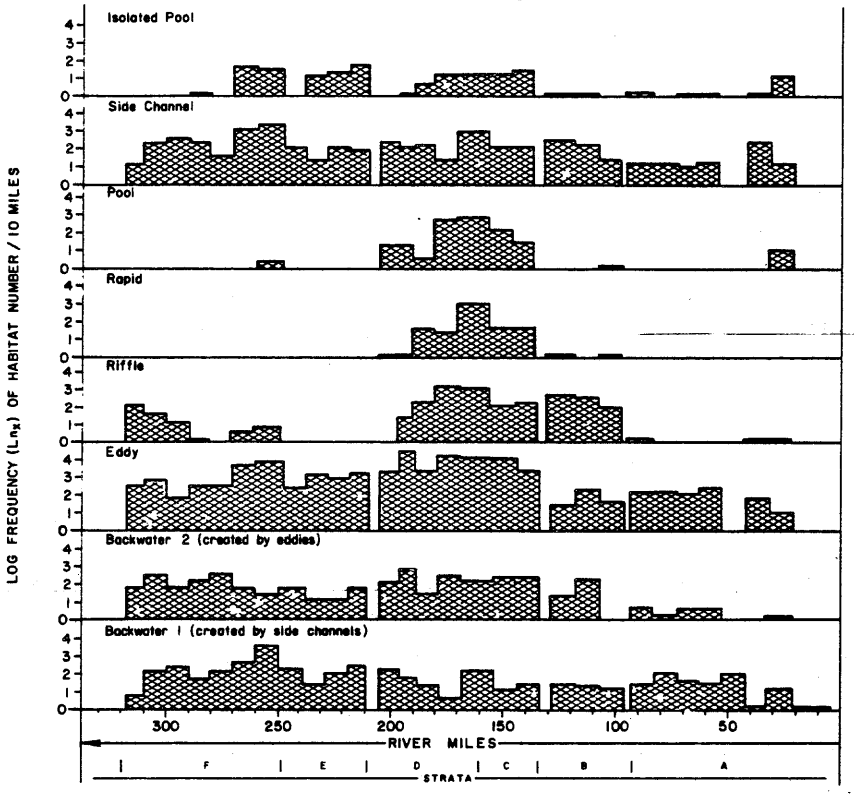
Mean depth by strata and runoff period (P=prerunoff, R=runoff, PO=postrunoff). Green River, Utah, June 1979 - June 1981.

and colder than other strata due to shading from canyon walls. No discernible pattern was identified among mean conductivity and turbidity for each stratum during a given sampling period (Table 6). However, differences occurred between sampling periods for most strata. Conductivities were much lower ($\bar{x}$ = 324) during runoff than during prerunoff ($\bar{x}$ = 666) or postrunoff ($\bar{x}$ = 760). Conversely, except for strata B and F, turbidities were higher during runoff than during pre- or postrunoff. Increased

of suspended particles and is a general characteristic of streams and rivers (Dorris and Copeland 1963).

Stratum A began at Turk's Head, RM 22 (35 kilometers) above the confluence with the Colorado River and extended to the vicinity of Ruby Ranch (RM 93, 150 kilometers). This stratum extended through Stillwater and Labyrinth Canyons. Depths averaged 4 feet during postrunoff stage and 7 feet during runoff (Table 6). Conductivity ranged from 340 micromhos during runoff stage (1980) to 1,050 micromhos during postrunoff (1980). This area had a sand/silt substrate with a sandy to rocky shoreline. The stratum was characterized by eddies and side channels. There are few or no riffles or pools, depending upon river stage, and no rapids (Figure 10). Canyon walls were typically sloping and of a dark red color.

Figure 10



Log frequency of eight habitats per 10-mile river reach for strata A through F (river mile 0-315) Green River, Utah, August 1981.

Stratum B began near Ruby Ranch (RM 94, 150 kilometers) and extended to Gray Canyon at Gunnison Butte (RM 132, 211 kilometers) near the vicinity of the Green River diversion dam. This stratum had a gravel/rubble to sand/silt substrate and was dominated by man-influenced drainage and runoff from agriculture and the city of Green River, Utah. This stratum was strongly influenced by boulders deposited from Gray Canyon. The average midstation depth was 4.2 feet (1.3 meters) during postrunoff periods and 6.1 feet (1.8 meters) during runoff. Conductivities ranged from 470 micromhos (Table 6) during runoff (1980) to 1,600 micromhos

during postrunoff (1980). This high conductivity can be partially attributed to a substantial input of highly mineralized and saline water at one location (RM 115.3, 186 kilometers), Crystal Geyser. This stratum was dominated by riffles, side channels, and eddy habitats. There were few backwater habitats in stratum B (Figure 10).

Stratum C included Gray Canyon and extended from Gunnison Butte (RM 132, 211 kilometers) to Desolation Canyon at Three Ford's Rapid (RM 157, 253 kilometers). Of the six strata it was the shortest, 38 RM (62 kilometers). During runoff stage, the average depth was 13.3 feet (4 meters), during postrunoff 7.3 feet (2.2 meters). Mean depth was 9.6 feet (2.9 meters), which was significantly ($P = 0.0002$) deeper than all other strata. Conductivity ranged from 260 (runoff 1980) to 851 (postrunoff 1979). The substrate here was predominately a mix of boulder/rubble with gravel. A diversity of habitat types were available to fishes in stratum C, including rapids, riffles, and eddies which were the most common. Other habitats included deep pools at the base of rapids, side channels, pools, and eddy-created backwaters (Figure 10). Gray Canyon was composed of low cliffs of gray to yellow tint with sparse plant life. Inaccessible for most of its extent except by river raft or kayak, the river was dominated by 16 named rapids.

Desolation Canyon makes up the largest portion of stratum D, which extended from Gray Canyon (RM 157, 253 kilometers) to Duche's Hole (RM 211, 340 kilometers). Depths during postrunoff averaged 6.4 feet (1.9 meters); during runoff depths averaged 8.6 feet (2.6 meters). Conductivity ranged from 270 micromhos during runnoff (1980) to 1,000 micromhos (Table 6) during postrunoff (1979). The three most prevalent habitats in this stratum were eddies, rapids, and riffles. Large pools at the tailrace of rapids were common in this section (Figure 10). The primary substrate was boulder. This canyon is more constricted than Gray and composed of high red walls with pinyon-juniper and Douglas fur growing on the talus slopes.

Stratum E extended from Duche's Hole (RM 212, 341 kilometers) to a point upstream of the mouth of the Duchesne River (RM 249, 401 kilometers). Depths during postrunoff averaged 4.4 feet (1.3 meters) but during runoff depths averaged 7 feet (2.1 meters). Conductivity ranged from 260 micromhos during runoff (1980) to 1,300 micromhos during postrunoff (1979). Unlike its downstream stratum (D), this stratum had no rapids or riffles. Habitats dominating this stratum in descending order were eddies, backwaters (created by side channels), side channels, and isolated pools (Figure 10). Substrate type was predominately sand/silt. Dominated by drainage from open, rolling country (which is largely undeveloped) and allochthonous input from the Duchesne and White Rivers, this broad, sandy reach is still deeper than its upstream stratum (F).

Stratum F was the most shallow river reach in the study area. This stratum extended to Split Mountain (RM 320, 515 kilometers). It is highly braided with islands and was characterized by broad sandy areas which can be traversed in a floating boat only with difficulty during low water. Depths averaged 3.2 feet (1.0 meters) during postrunoff periods and only 4.7 feet (1.4 meters) during runoff. Substrate in this stratum was predominately sand/silt; however, some rubble/gravel substrate was found near the upper end of the reach (near the lower end of Dinosaur

National Monument), a result of outwash and scouring from Split Mountain Canyon. Side channels and backwaters were the most common habitats in this reach, but riffle habitat, if found, was at the upper end. The drainage area was dominated by agriculture in the Uintah Basin and by the city of Vernal, Utah.

Distribution and relative abundance of all fish species

Fish representing nine families and 26 species were collected from the Green River 1979 to 1981. Relative to the Colorado River basin, these included nine native (six endemic) and 17 exotic (introduced) fish species. In addition, five hybrids were collected during this investigation.

Red shiner, channel catfish, and carp were the most common and most widely distributed of the introduced species. They were found in all strata and usually were the most common species in collections (Table 7). Carp were slightly less abundant in stratum C than in the other strata, probably a reflection of habitat availability. Channel catfish were collected in fewer numbers from stratum F than the other strata. Red shiner was undoubtedly the most common species in the Green River and abundant in all strata.

The fathead minnow and black bullhead are also distributed throughout the study area, but generally occur in fewer numbers than the above mentioned species. However, fathead minnows were considered abundant in strata B and E.

Green sunfish and smallmouth bass were found in limited numbers in most strata, but were most common in strata E and F near the mouth of the Duchesne River. Smallmouth bass were stocked in the Duchesne River in the 1960's and have apparently moved downstream into the Green River. The smallmouth bass appear to be reproducing in the Green River since several size classes of fish were collected.

Introduced species that were occasionally collected include white sucker, creek chub, redside shiner, sand shiner, Utah chub, northern pike, walleye, brown trout, cutthroat trout, and rainbow trout. Redside shiner and sand shiner were consistently collected only in a few widely scattered locations. Walleye were collected mainly near the mouth of the Duchesne River (they were originally introduced in the Duchesne River system). The remaining species were collected in very low numbers. Several of these species are represented by only one or two individuals.

Flannelmouth sucker was the most abundant native fish species collected, followed in abundance by bluehead sucker. Both species were collected in all strata. However, the bluehead sucker was considered rare in strata A and B. The bluehead sucker prefers rubble or gravel substrate and was most common where that substrate was available (C and D). The speckled dace was collected in small numbers in all strata. Mottled sculpin were only collected in the upper portion of stratum F, which appears to be lower limits of its distribution in the main stem Green River.

Table 7
Relative abundance of fishes collected, standardized sampling stations Green River, 1979 - 1981

Family name Common name Scientific name	A	B	C	D	E	F
Catostomidae						
Bluehead sucker[1/] *Catostomus discobolus*	R	R	A	A	C	A
Flannelmouth sucker[2/] *Catostomus latipinnis*	C	A	A	A	A	A
Razorback sucker[2/] *Xyrauchen texanus*	O	R	O	O	R	R
White sucker[3/] *Catostomus commersoni*	O	O	O	O	O	R
Flannelmouth sucker X Razorback sucker[2/]	O	O	O	O	O	I
Flannelmouth sucker X Bluehead sucker hybrid	O	I	O	O	O	I
Centrarchidae						
Green Sunfish[3/] *Lepomis cyanellus*	I	I	I	R	R	I
Smallmouth bass[3/] *Micropterous dolomieu*	I	I	I	O	R	R
Codidae						
Mottled sculpin[1/] *Cottus bairdi*	O	O	O	O	O	I
Cyprinidae						
Carp[3/] *Cyprinus carpio*	A	A	C	A	A	A
Colorado squawfish[2/] *Ptychocheilus lucius*	R	R	R	R	R	R
Creek chub[3/] *Semotilus atromaculatus*	O	I	O	O	O	O
Fathead minnow[3/] *Pimephales promelas*	C	A	R	C	A	C
Gila spp.[2/4/]	R	R	C	C	R	R
Red shiner[3/] *Notropis lutrensis*	A	A	A	A	A	A
Red shiner[3/] *Rechardsonus baltiatus*	O	I	O	O	I	C
Sand shiner[3/] *Notropis stramineus*	C	C	I	O	O	R
Speckled dace[1/] *Rhinichthys osculus*	R	C	C	C	R	A
Utah chub[3/] *Gila atraria*	O	I	O	I	I	O
Esocidae						
Northern pike[3/] *Esox lucius*	O	O	O	O	O	I
Ictaluridae						
Black bullhead[3/] *Ictalurus melas*	R	R	C	I	I	I
Channel catfish[3/] *Ictalurus punctatus*	A	A	A	A	A	C
Percidae						
Walleye[3/] *Stizostedian vitreum*	O	O	O	O	O	R
Salmonidae						
Brown trout[3/] *Salmo trutta*	O	O	O	O	O	I
Cutthroat trout[3/] *Salmo clarki*	O	I	I	O	I	O
Rainbow trout[3/] *Salmo gairderneri*	I	O	O	I	O	O

1/ Denotes a species native to the Colorado River Basin but not endemic.

2/ Denotes a native species endemic to the Colorado River Basin.

3/ Denotes a species introduced to the Colorado River Basin.

4/ Although specimens representing *G. robusta*, *G cypha* and *G. elegans* were collected during this study, the three species including their hybrids are included in one category in this table.

A = Consistently collected in large numbers.

C = Frequently collected in moderate numbers.

R = Collected in low numbers in a restricted area or having a sporadic distribution over a larger area.

I = Collected in very low numbers and from only a few point collections.

O = Not collected.

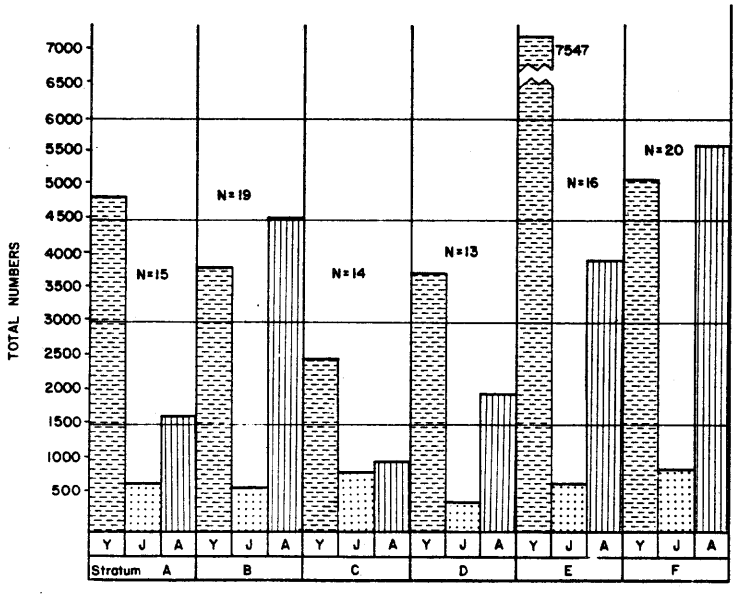
The Colorado squawfish was the most uniformly distributed of the rare species and was collected in low numbers in all strata. YOY, juveniles, and adults were collected in all strata. Standardized sampling collections indicated strata B, E, and D were more important for young; however, more rigorous fall collections indicated strata E, F, and A contained more YOY and juveniles than the other strata. A total of 47 adult Colorado squawfish were caught within standardized stations, 1979 to 1981. Stratum F contained the largest number of adults (15), followed by E (12), B (8), A (6), D (4), and C (2).

Only four razorback suckers were collected during 3 years of standardized sampling, two in stratum F and one each in strata B and E. However, relatively large numbers of razorback suckers were collected in stratum F during special collections (see section on razorback sucker). Nonetheless, this species seems to be quite rare in the Green River.

Members of the genus Gila were collected in all strata during standardized sampling. Strata C contained the largest number of Gila spp. Five specimens of humpback chub and one of bonytail chub were collected from this stratum as well as numerous roundtail chub. Gila spp. collected from the other strata were considered to be roundtail chubs. A more thorough discussion of the distribution of Gila spp. and their taxonomy is contained in the section on Habitat Preferences and Taxonomy of Gila spp.

A measure of fish diversity can be obtained from Figure 11 by dividing the total number of fishes collected in a stratum with the number of

Figure 11



Total number of fishes collected during standardized sampling program

species collected in that stratum. Strata F and B contained the largest number fish species with 20 and 19, respectively (Figure 11), (genus Gila included as one species). Strata C and D contained the lowest number of species with 14 and 13, respectively. Strata E and A were intermediate in numbers of fish and species collected, with 16 and 15 species. The numbers of fish species generally reflects the suitability of environmental conditions in those strata. Strata C and D, with the fewest species, were dominated by riffles and rapids, stressful conditions for the existence of fish. Strata F and B, with the largest numbers of fish species, did not contain rapids, but all other habitats were present in them. Strata E and A, which were intermediate in fish species, did not contain rapids, but differed conspicuously from F and B since riffle habitat were virtually nonexistent (Figure 10).

Strata C and D (Figure 10) contained a very diverse assemblage of habitats. However, the stress imposed on fishes by the rapids in these areas and the short, heterogeneous ordering of the available habitats apparently dominated the response of different fish species and made these areas unsuitable habitat for many. Strata E contained the largest numbers of fish collected, followed by F, B, D, and C. Stratum E also contained a very high number of young fish, probably because of good nursery habitat afforded by backwaters and quiet eddies. Juvenile fish were collected in about the same numbers in all strata. Adult fish were most numerous in strata F, B, and E and less numerous in the canyon areas, C, A, and B. The number of young fish was dominated by red shiners and channel catfish. Adult fish were predominately red shiner, flannelmouth sucker, fathead minnow, channel catfish, and speckled dace.

Various gear types differed in their ability to effectively sample different habitat types and tended to select for different species and sizes. Seines were effective in sampling shallow water areas for small fishes while trammel nets, gill nets, and electrofishing were more effective for larger fish in deeper water. Although not as effective in a variety of habitats as the other gear types, wire traps were used in shallow, boulder substrate areas and where high water velocity dictated that other gear types could not be used.

Seines were most effective for red shiner, fathead minnow, green sunfish, speckled dace, redside shiner, and sand shiner as well as small individuals of all the other species. Occasionally these small fishes were collected by electrofishing but not consistently. None of the above species were collected with trammel or gill nets. Although no statistical analysis has been done, there does not appear to be any difference between catch rates for 1/4-inch mesh seines and 1/8-inch mesh seines.

Trammel nets were the most effective gear for large fishes in deep water areas. Electrofishing was more successful in shallow areas, particularly with rubble or gravel substrate.

No gear type was very effective for juveniles of the large species These individuals were generally large enough to avoid capture with seines, but were not large enough to be captured with trammel nets. These fish were collected most effectively with electrofishing gear.

River stage was an important factor in determining sampling efficiency. Field teams had little success in collecting fish during early prerunoff with all gear types, especially with passive gear. Because passive entangling nets (gill and trammel) rely upon fish to be active and moving, it was reasonable to attribute the low catch rates to cold water temperatures, which cause fishes to be inactive. Electrofishing and seining (active gear) were most successful during prerunoff. Effectiveness in catching fish during runoff was complicated by high, turbulent water conditions. Seining during runoff was difficult and sometimes impossible. Trammel and gill nets during runoff were exclusively used in eddies with only limited success.

Habitat preferences of all fish species

This section presents data obtained from the enumeration of fishes collected in five habitat types. Habitat preference is inferred from conditions measured at point of capture. Extreme caution should be used when interpreting the information presented on number of fishes collected for the various habitats since these data represent the total number of fishes collected in a given habitat type using all gear types. These habitat types are not uniformly represented in all strata. However, all habitat types within an intensive reach were sampled using at least one gear type. More complete analysis of these data will be made later, using a number of variables including stratum, habitat type, water depth, water velocity, and substrate type.

Backwaters generally contained more fish than any other habitat, primarily the small species of minnows (e.g., red shiner and fathead minnow) and young and juveniles of the larger species (e.g., Colorado squawfish and flannelmouth sucker). Adults of species other than the small cyprinids were uncommon. YOY Colorado squawfish and fathead minnows showed a high preference for this type of habitat. Red shiners coexisted with young Colorado squawfish but were ubiquitious in all other five habitats sampled.

Eddies frequently contained the greatest number of adults of the larger species, and occasionally contained large numbers of young red shiners, carp, roundtail chubs, and channel catfish. Black bullheads were also found in eddies.

Collections made in shoreline habitat also contained high numbers of the larger species as well as red shiners. Adult bluehead suckers, flannelmouth suckers, Colorado squawfish, and Gila spp. were collected from this habitat type in most strata.

Flannelmouth suckers and red shiners were more numerous than other species in runs. However, this reflects general abundance through several habitats rather than a preference for runs, since run is a relative descriptor. Channel catfish were also common in runs.

Riffles are limited in the Green River, occurring most frequently in strata C and D. No riffle habitat was sampled in strata E and F. The only species collected from riffles were red shiners, Gila spp., speckled dace, flannelmouth suckers, and bluehead suckers. The latter three were the most common species collected.

species collected in that stratum. Strata F and B contained the largest number fish species with 20 and 19, respectively (Figure 11), (genus Gila included as one species). Strata C and D contained the lowest number of species with 14 and 13, respectively. Strata E and A were intermediate in numbers of fish and species collected, with 16 and 15 species. The numbers of fish species generally reflects the suitability of environmental conditions in those strata. Strata C and D, with the fewest species, were dominated by riffles and rapids, stressful conditions for the existence of fish. Strata F and B, with the largest numbers of fish species, did not contain rapids, but all other habitats were present in them. Strata E and A, which were intermediate in fish species, did not contain rapids, but differed conspicuously from F and B since riffle habitat were virtually nonexistent (Figure 10).

Strata C and D (Figure 10) contained a very diverse assemblage of habitats. However, the stress imposed on fishes by the rapids in these areas and the short, heterogeneous ordering of the available habitats apparently dominated the response of different fish species and made these areas unsuitable habitat for many. Strata E contained the largest numbers of fish collected, followed by F, B, D, and C. Stratum E also contained a very high number of young fish, probably because of good nursery habitat afforded by backwaters and quiet eddies. Juvenile fish were collected in about the same numbers in all strata. Adult fish were most numerous in strata F, B, and E and less numerous in the canyon areas, C, A, and B. The number of young fish was dominated by red shiners and channel catfish. Adult fish were predominately red shiner, flannelmouth sucker, fathead minnow, channel catfish, and speckled dace.

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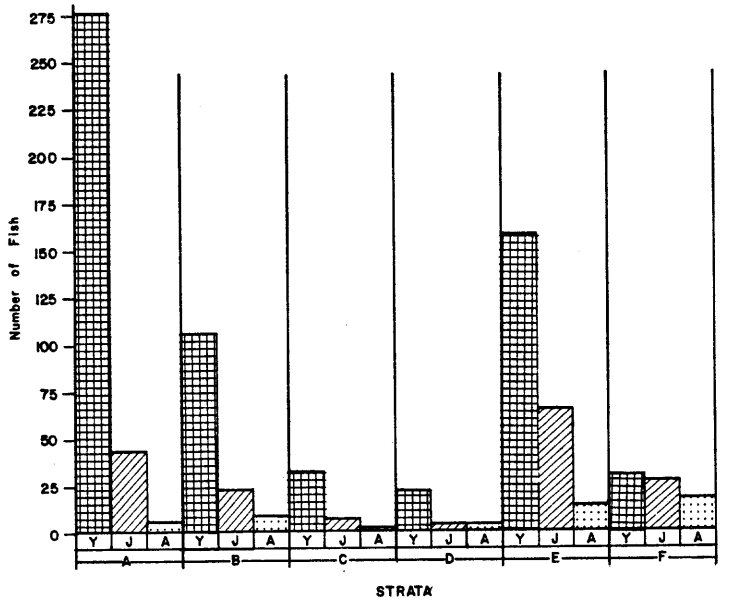
No gear type was very effective for juveniles of the large species These individuals were generally large enough to avoid capture with seines, but were not large enough to be captured with trammel nets. These fish were collected most effectively with electrofishing gear.

Table 8
Colorado squawfish by size classes, standardized sampling stations, Green River, 1979 - 1981

Size class Total length (millimeters) (average)	$\bar{x}$ depth $\bar{x}$ velocity	Strata A	B	C	D	E	F	Total number of fish	Percent
0-60	1.0 0.4	276	106	32	23	160	30	627	74
60-100 (76)	0.9 0.3	28	13	4	2	53	20	120	14
100-200 (122.2)	1.2 0.3	11	7	0	0	11	6	35	4
200-300 (270.3)	3.0 1.0	4	2	0	1	0	0	7	1
300-400 (349.0)	4.0 1.0	3	1	3	1	1	1	10	1
400-500 (448.5)	4.9 0.6	5	3	1	0	7	10	26	3
500-600 (534.4)	5.1 0.6	1	3	1	3	4	4	16	2
600-700 (627.5)	4.0 0.4	0	2	0	1	1	0	4	-
700-800 -	- -	0	0	0	0	0	0	0	0
800-900 (867)	3.9 0.5	0	0	0	0	0	1	1	-
Totals		328	137	41	31	237	72	846	99

Figure 12



Colorado squawfish collected, standardized sampling stations, Strata A through F, 1979, 1980, and 1981. (Y=young of the year, J=juveniles, A=adult.)

Specific analysis relating species associations between all fish species by habitat will be provided later. Analysis of variance will be used for significance testing for different flow conditions.

Rare Fishes

Specific information about the life history of four target species, Colorado squawfish, humpback chub, bonytail chub, and razorback sucker is presented in this section. General information was also presented in the preceding section on the habitat and relationships of all fishes.

Colorado squawfish

Distribution and relative abundance

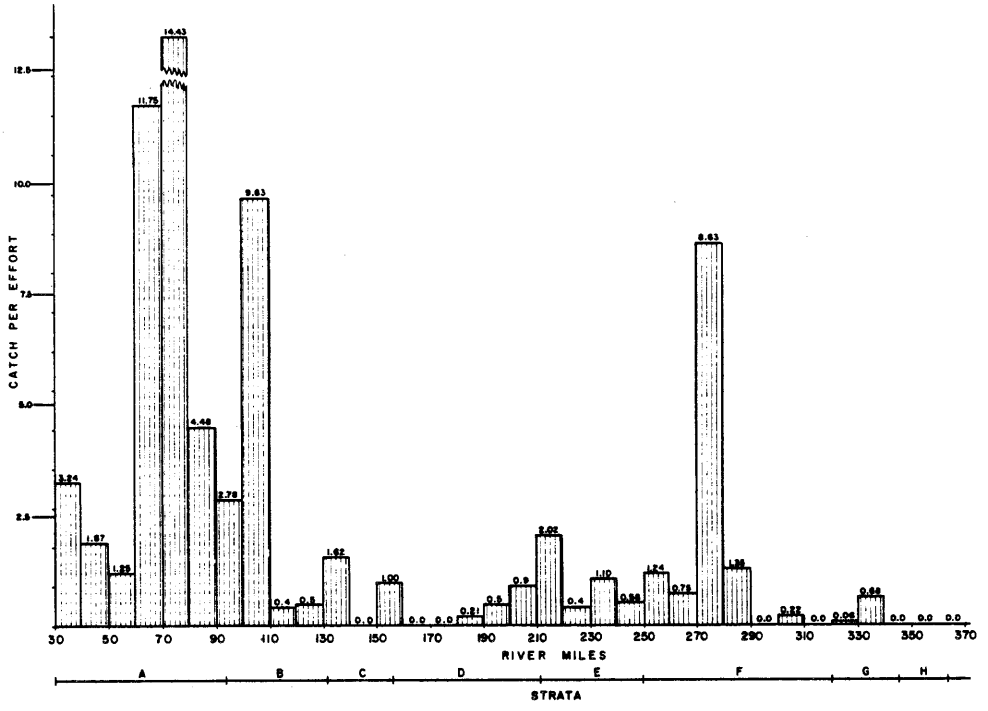
Distribution and abundance information was presented for all fish species in the preceding section. When all collections were combined a total of 5,422 YOY, 403 juvenile, and 185 adult Colorado squawfish were collected from 1979 to 1981. These data are heavily biased since different programs resulted in different procedures. Also, many more collections were made in some strata than others. For these reasons, only results from the standardized sampling program were used to obtain relative abundance data.

The abundance of Colorado squawfish collected at standardized sampling stations for different size classes is given in Table 8. Total numbers of Colorado squawfish for YOY, juveniles, and adults (Figure 12) were used to produce a catch curve for each stratum. Strata A, B, C, and E produced the expected histographs with the numbers of young exceeding juveniles and juveniles exceeding adults in turn. However, the histograph was distorted in strata D and F, with smaller than expected young relative to the numbers of adults.

The distribution and relative abundance of YOY Colorado squawfish was studied by a special investigations program in 1979 and 1981. In 1981, both larval and larger young were collected.

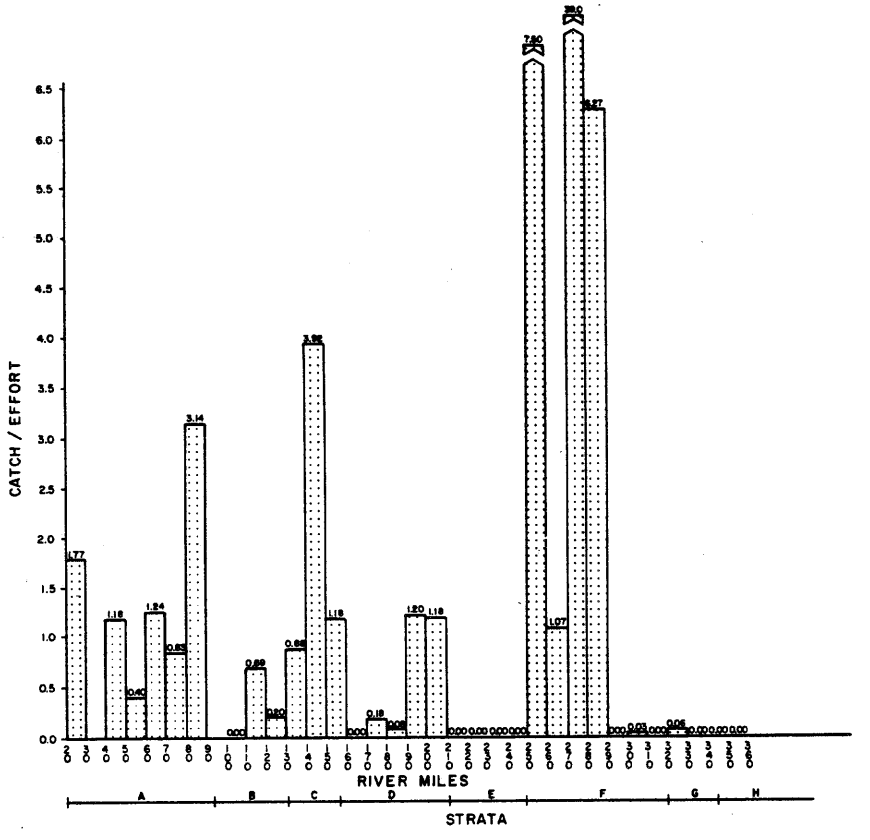
Adult Colorado squawfish (TL 400 millimeters) were most abundant in strata F and E and least abundant in strata C and D (Table 8). Although data from the standardized sampling stations were used for these comparisons (since effort expended in each stratum was equivalent), other collections also tended to support these observations. Colorado squawfish of over 700 millimeters TL were extremely rare and only one specimen was collected in the standardized collections. Adult Colorado squawfish were rare in overall sampling, amounting to only 14 percent of Colorado squawfish collected.

Figure 14



Catch per unit effort of young-of-the-year Colorado squawfish during YOY investigations from backwaters, Green River, 1980. One unit effort equals $10m^2$ sampled with seines.

Figure 15

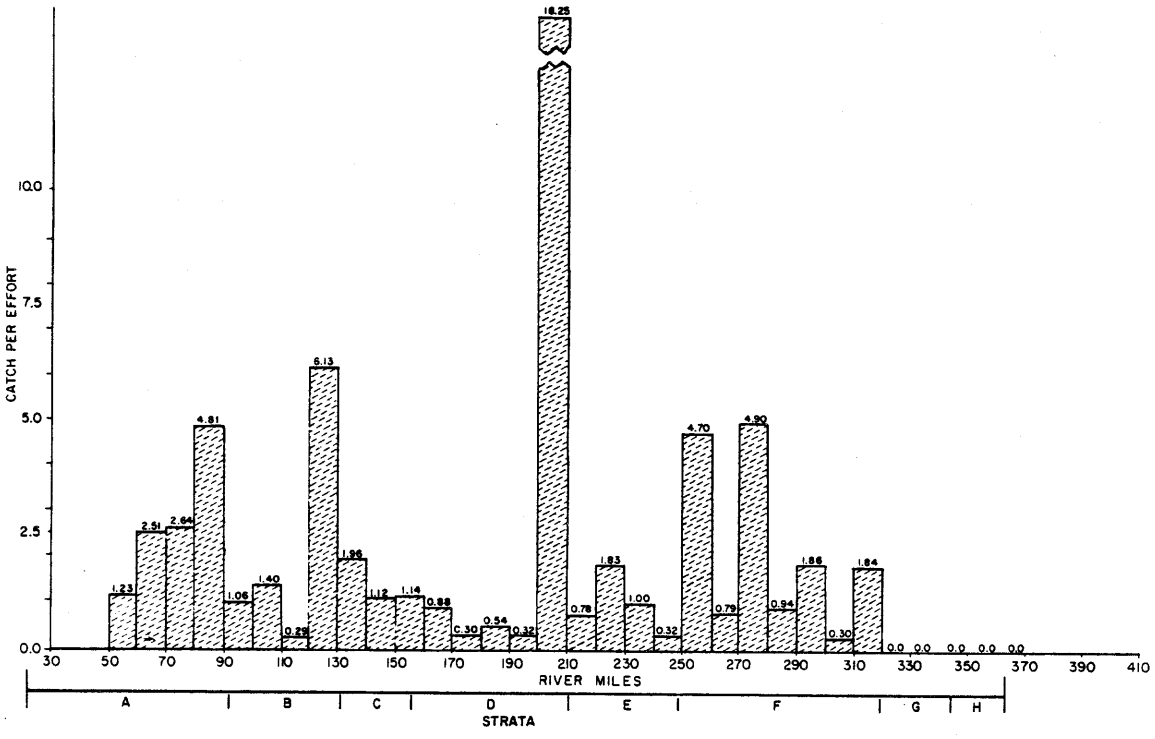


Catch per effort of young-of-the-year Colorado squawfish, special investigation, backwater habitat, Green River, 1981. One unit of effort equals $10m^2$ sampled with seines.

Radiotelemetry studies (see Migration and Movement section) in the Green River in 1980 and 1981 and the Yampa River in 1981 (Tyus et al. 1981, 1982) clarified some confusion about distribution and abundance patterns of adult Colorado squawfish. Colorado squawfish are migratory and apparently seek limited spawning areas. These spawning areas are not utilized to any great extent other than during the July spawning season when adults appear relatively common on these sites. We believe this is an important finding and should be used to interpret collections of Holden and Stalnaker (1975), Seethaler (1978) and others who noted unusual distribution patterns of adult Colorado squawfish during the spawning season.

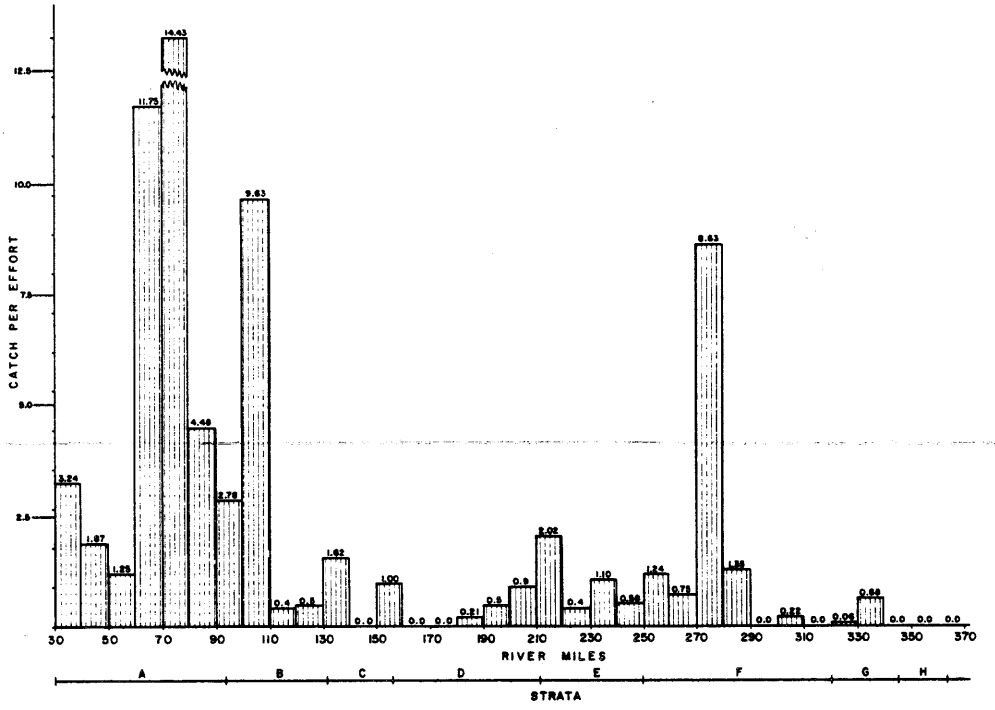
The distribution and relative abundance of YOY Colorado squawfish was determined in part by special collections made each fall, 1979 to 1981 (Figures 13 to 15). YOY fish were distributed from the mouth of Split Mountain Canyon (RM 320, 515 kilometers) to Mineral Bottom (RM 50, 81 kilometers) all 3 years. Newly-spawned fish (n = 32) were also found in Island Park (RM 325-340, 523-547 kilometers) in 1980 and 1981.

Figure 13



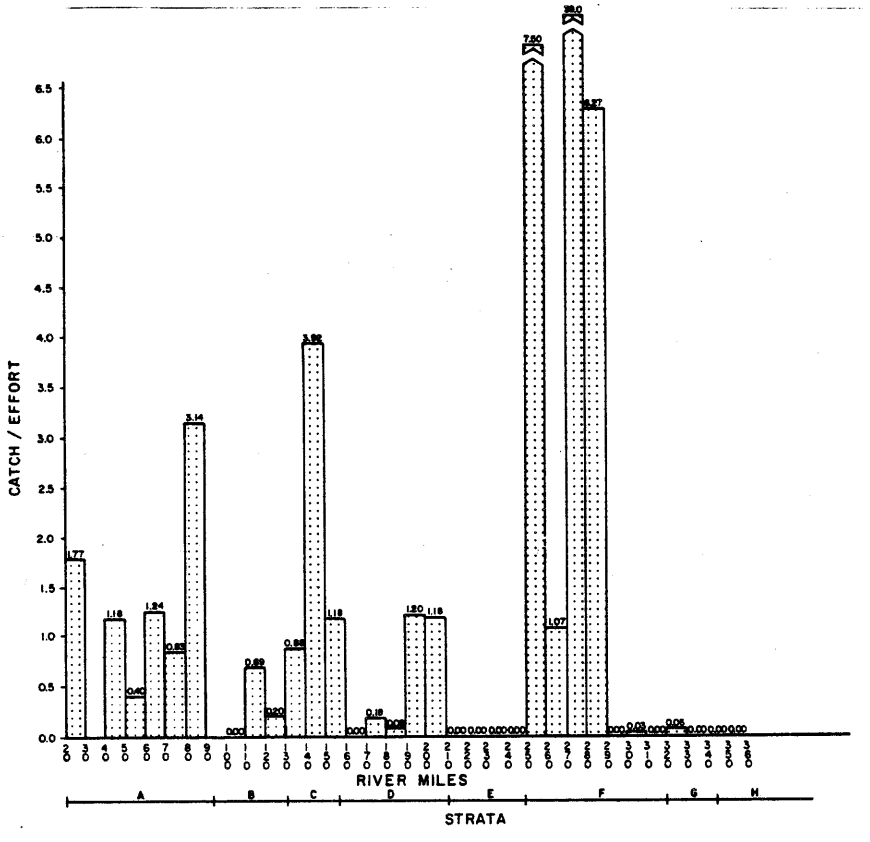
Catch per unit effort of young-of-the year Colorado squawfish special investigations from backwaters, Green River, 1979. One unit of effort equals $10m^2$ sampled with seines.

Figure 14



Catch per unit effort of young-of-the-year Colorado squawfish during YOY investigations from backwaters, Green River, 1980. One unit effort equals $10m^2$ sampled with seines.

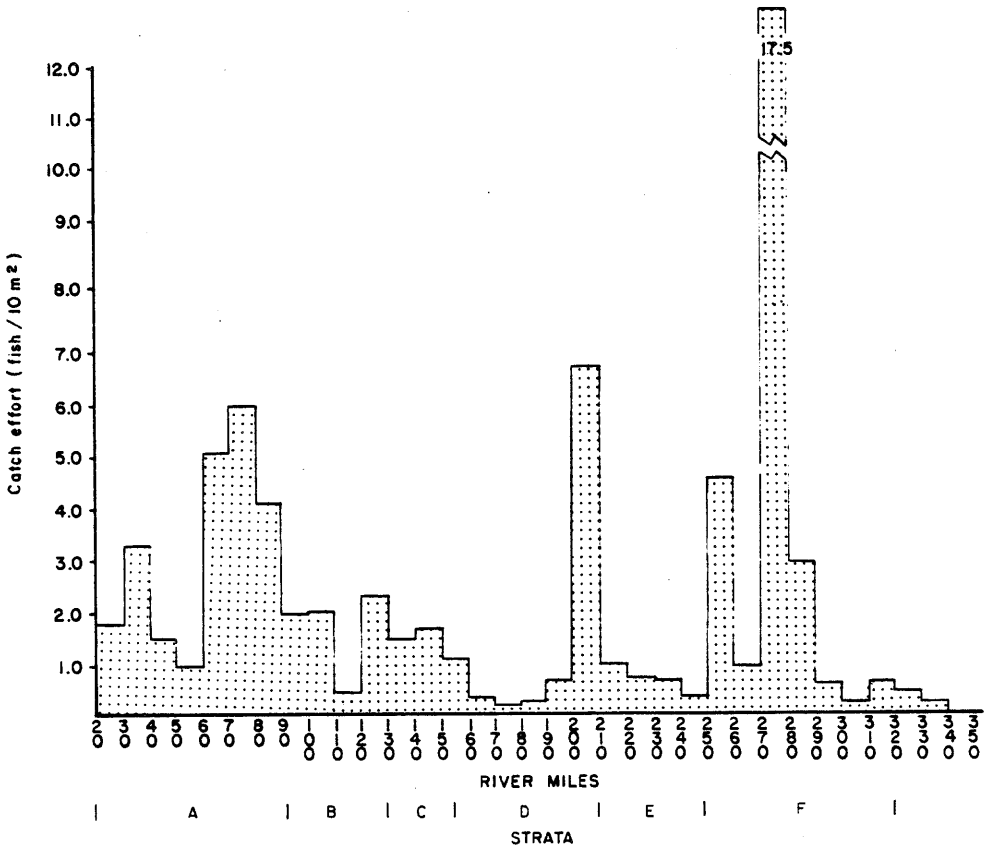
Figure 15



Catch per effort of young-of-the-year Colorado squawfish, special investigation, backwater habitat, Green River, 1981. One unit of effort equals $10m^2$ sampled with seines.

Peaks in abundance were generally the same for young Colorado squawfish during all 3 years (Figure 16). Strata A, E, and F generally had the largest number of YOY Colorado squawfish; however, stratum C had relatively large numbers of young fish in 1981. No young fish were collected in stratum E in 1981 and this could be an artifact of sampling time and efficiency since stratum E was sampled 1 month later than other collections. The distribution of larval (<20 millimeters TL) Colorado

Figure 16



Mean catch per effort of young Colorado squawfish, Green River, 1979-1981.

squawfish indicated that strata A and F were the two centers of distribution in 1981, with B, E, and G containing lesser but sizeable numbers (Table 9).

Young Colorado squawfish are usually found in backwaters where many introduced species were abundant. Red shiner, channel catfish, and fathead minnow were commonly collected with small Colorado squawfish. Sand shiner, speckled dace, small bluehead and flannelmouth suckers, green sunfish, and black bullhead also occurred with small Colorado squawfish. Inspection of field data does not indicate a relationship (either positive or negative) between the abundance of YOY Colorado squawfish and abundance of introduced species; however, all analyses have not been completed using catch per effort data.

Table 9
Abundance of larval Colorado squawfish, Green River 1979 - 1981 (from Snyder 1982)

River Strata	River miles (km)	Sample dates (July 1981)	Total number of samples	Number of fish	Number of Colorado squawfish	Size range (mm TL) of Colorado squawfish
Aa	0-50 (0-81)	19-21	32	490	4	16-21
Ab	52-97 (84-154)	21-23	35	2,366	27	10-22
B	96-126 (154-203)	22-23	28	1,169	33	9-21
C	126-151 (203-243)	24-25	30	224	2	20-20
D	151-206 (243-332)	21-24	67	639	3	10-18
E	207-248 (333-399)	21-23	34	1,792	5	9-22
F	248-315 (399-507)	28-31	68	4,730	21	11-23
G	328-345 (528-555)	22-24	28	1,380	0	-
H	347-362 (559-583)	21-22	14	312	0	-
Combined	0-362 (0-583)	19-31	336	13,102	95	9-23

Migration and Movement

Information on movement of Colorado squawfish was obtained from conventional tag recaptures and radiotelemetry which provided data on daily and seasonal movement patterns. In addition, diel studies of young provided short-term movement information. Little information was obtained for juvenile Colorado squawfish.

Adults.--A total of 118 Colorado squawfish were tagged with Carlin dangler tags in the Green River study. Of these, 14 have been recaptured (Table 10), including four fish implanted with radiotags. Most (12) recaptures occurred in the Green River, but two fish (Nos. 058 and 110) were recaptured in the Yampa River, one (No. 259) was recaptured in the White River and one fish (No. 230) was recaptured in Pariette, Wash. The most spectacular movement exhibited by these Colorado squawfish (Table 10) occurred in fishes Nos 058, 110, and 1604. Fish number 058 traveled 206 miles (330 kilometers) in the year between its capture in

Table 10
Recaptures of adult Colorado squawfish, Green River, 1979-1981

Carlin tag number	Total length	Weight (grams)	Capture			Recapture			Distance[1]	
			Date	River mile (km)	River	Date	River mile (km)	River	miles	(km)
001	595	1,160	04-03-80	251 (402)	GN	04-17-80	235 (376)	GN	[2]16	(25)
019	414	565	05-07-80	243 (389)	GN	05-29-80	243 (389)	GN	4	(6)
058	418	596	05-29-80	247 (395)	GN	06-04-80	108 (173)	YA	205	(330)
064	510	880	05-06-80	244 (390)	GN	08-08-80	246 (394)	GN	[2]2	(3)
078	361	375	05-28-80	247 (395)	GN	05-28-80	246 (394)	GN	1	(2)
110	136	12	08-06-79	299 (478)	GN	10-10-80	55 (88)	YA	101	(162)
165	545	1,130	04-18-80	248 (397)	GN	09-02-80	246 (394)	GN	[2]2	(3)
170	436	620	06-11-80	217 (347)	GN	04-08-81	218 (349)	GN	1.4	(2)
230	536	840	04-15-81	247 (395)	GN	05-14-81	0.3 (0.5)	PA	8.0	(11)
259	473	800	05-08-81	243 (389)	GN	06-26-81	1.0 (1.6)	WH	4	(6.4)
262	446	720	05-08-81	243 (389)	GN	05-08-81	243 (389)	GN	0.1	(0.2)
264	525	1,220	05-27-81	305 (488)	GN	05-27-81	305 (488)	GN	0	(0)
290	507	1,060	05-08-80	241 (386)	GN	05-14-81	240 (384)	GN	1	(2)
357	425	600	05-27-81	305 (488)	GN	05-27-81	305 (488)	GN	0.2	(0.3)

[1] From point of capture to point of recapture, rounded.
[2] Radiotagged fish.

the Green River (May 29, 1980) and recapture in the Yampa River (June 4,1981). Fish No. 110 also moved into the Yampa River, traveling 101 miles (162 kilometers) from August 6, 1979, until its recapture on October 10, 1980, by the Colorado Division of Wildlife. In contrast to the movement exhibited by some of these fish, fish No. 170 was recaptured about 1 mile from its release point almost 1 year later (Table 10). Four of these tagged fish (Nos. 078, 262, 264, and 357) were recaptured on the same day, and five were recaptured after only 1 month or less from the time of release and recapture (Nos. 001, 019, 058, 230, and 290).

Radiotelemetry of Colorado squawfish was initiated March 1980 and continued in 1981 with efforts to capture fish and test equipment. Success in following the first fish implanted in 1980 was greater than anticipated. Radio transmitters were, therefore, implanted in five more Colorado squawfish and one razorback sucker in 1980. Table 11 presents information on the capture, release, and major movements of all radiotelemetered Colorado squawfish studied in 1980.

Table 11
Capture, release and major movement of radiotelemetered Colorado squawfish, Green River, 1980

Fish number	Total length of fish (mm)	Date captured	Date released	Date of last contact	River	Major movement miles(km)
1/001	595	4/3/80	4/15/80	4/17/80 RC2/	Green	24 (38)
028	508	4/10/80	4/21/80	8/20/80	Green	284 (455)
165	541	4/18/80	4/21/80	9/02/80 RC2/	Green White Duchesne	223 (356)
064	510	5/06/80	5/13/80	8/08/80	Green	Stationary
060	525	5/07/80	5/13/80	8/20/80	Green	Stationary
006	707	5/29/80	6/03/80	6/17/80	Green White	Stationary

1/ This fish is considered only as a test animal because it was not in good conidition when captured.
2/ RC = recaptured.

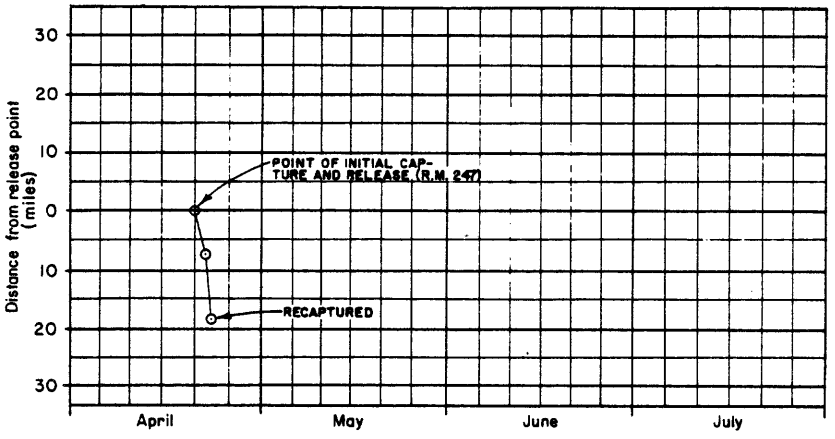
Four Colorado squawfish were followed over 4 months in 1980. These fish displayed two different types of behavior. Two fish (Nos. 028 and 165) moved upstream in the Green River from the initial release site reaching the upstream limit of movement in late June-early July after traveling about 50 miles (80 kilometers). These two fish then moved back downstream past the point of release. Fish No. 028 was last located by airplane in Labyrinth Canyon, over 185 miles (300 kilometers) downstream from its release point. Fish No. 165 ascended the White River to a point 34 miles (56 kilometers) above its mouth, returning to the Green River-White River junction. The remaining two Colorado squawfish (Nos. 060 and 006) were relatively stationary, with one fish remaining within 3 miles (5 kilometers) of its release point and the other traveling only about 9.6 miles (16 kilometers).

One Colorado squawfish was recaptured from each group exhibiting the two different movement patterns in 1980. This was done to determine if

there was any relationship between these patterns and sex, sexual maturity, condition of the fish, or effects of carrying the implanted radio transmitter. Fish No. 064 (stationary group) was recaptured and dissected August 8, 1980. This fish was an immature male. Fish No. 165 (movement group) was recaptured and dissected September 2, 1980. This fish was a female in advance stage of sexual maturity. While monitoring the movement of Fish No. 165, it was observed orienting to a riffle area in the White River on July 16, 1980 (after a movement of about 100 miles (161 kilometers) in 5 days). Although the significance of this behavior was unknown in 1980, work done in 1981 suggests that considerable movement during the expected spawning season by mature fish in contrast to little movement by immature fish is to be expected for Colorado squawfish.

The long distance movement patterns of the six Colorado squawfish radiotagged in 1980 exhibit considerable differences (Tyus et al., 1981). Fish No. 001 was in poor condition and was removed. Its movement (Figure 17) was significantly different than the other Colorado

Figure 17

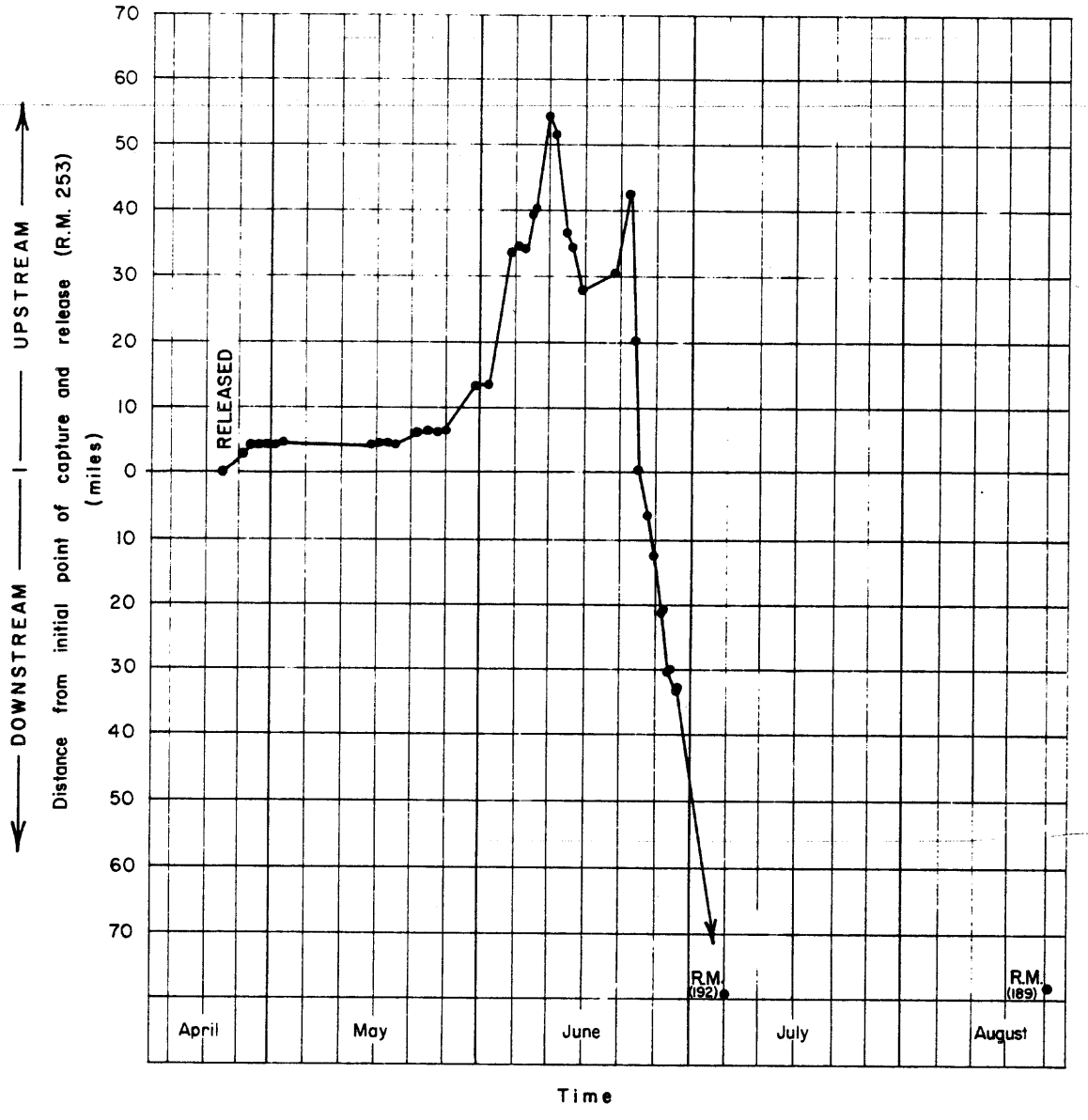


Long distance movement of Colorado squawfish No. 001. Point of release taken as zero. Lines drawn by hand. Green River, 1980.

squawfish because it moved steadily downstream from the point of release. Colorado squawfish Nos. 028 and 165 exhibited similar upstream movement in June (Figure 18 and 19); however, this behavior changed in July with fish No. 028 moving downstream. Colorado squawfish Nos. 064, 060, and 006 remained relatively stationary at their respective points of initial capture (Figures 20, 21, and 22).

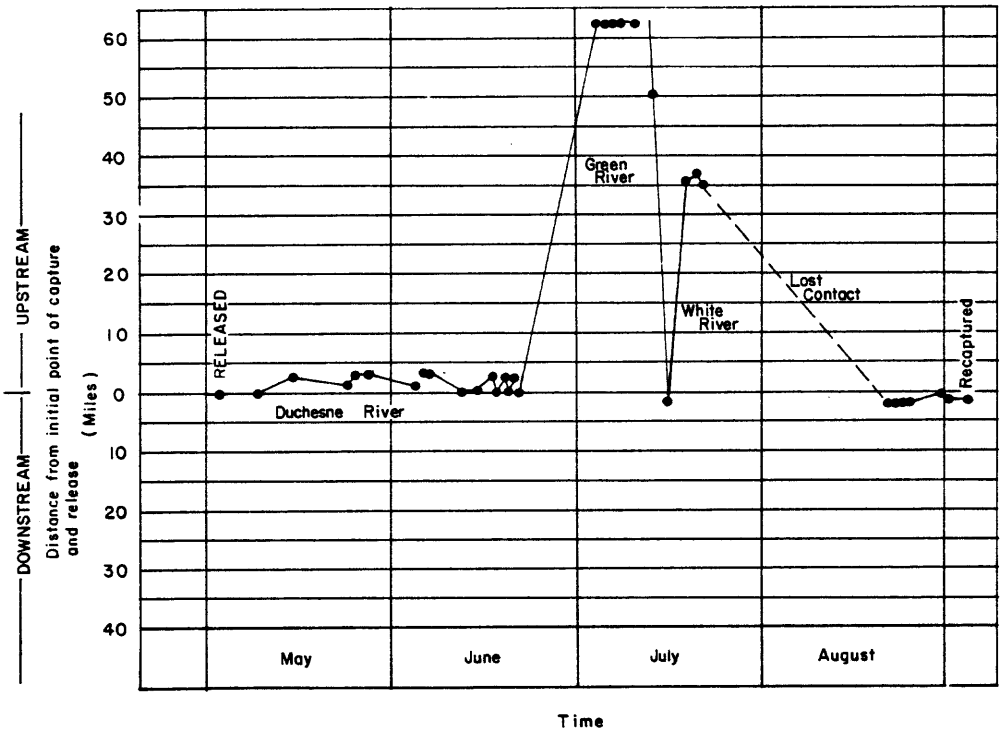
Temporal movement patterns were investigated by diel studies rather than point observations. Colorado squawfish Nos. 028, 165, 064, and 060 were included in these samples and the period of most activity included the interval 0600-2200 hours, with the least movement occurring from 2300-0600 hours (Figures 23 to 26).

Figure 18



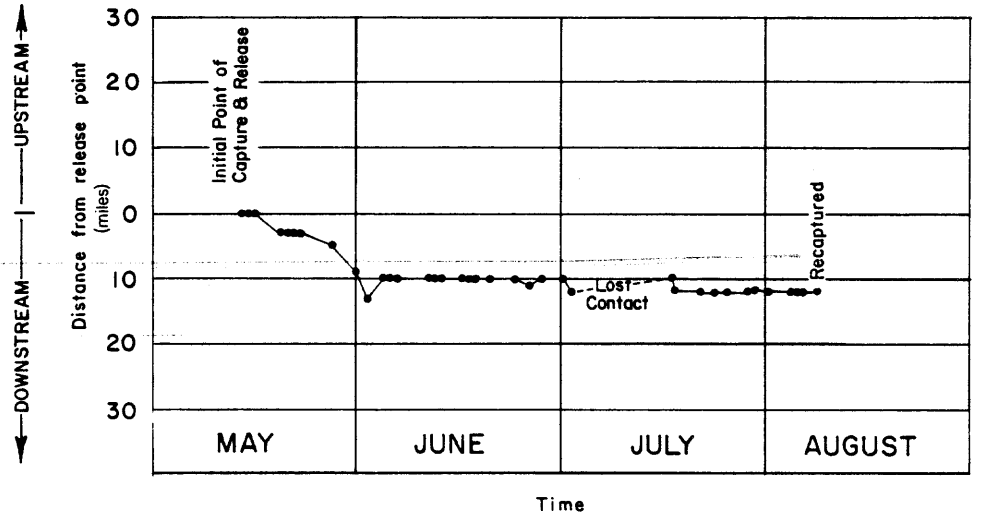
Long distance movement of Colorado squawfish No. 028, release point (RM 133) taken as zero. Lines drawn by hand. Green River, 1980.

Figure 19



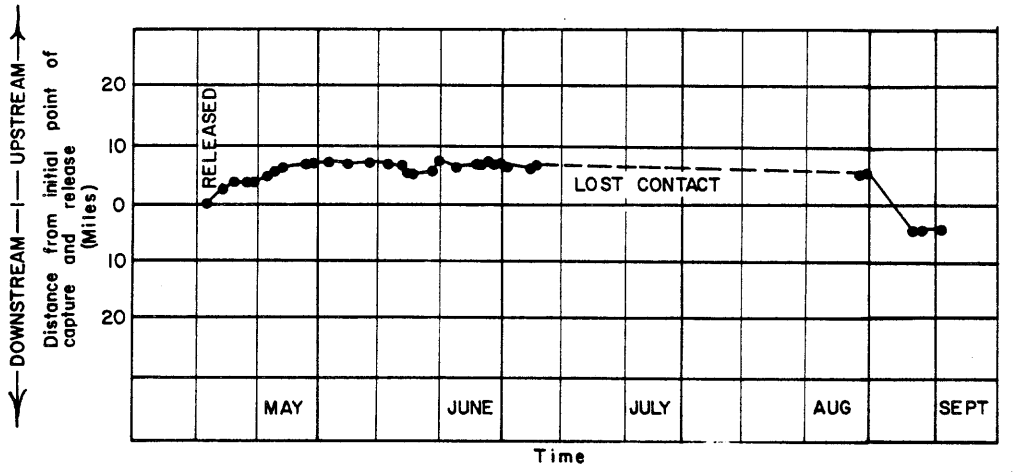
Long distance movement of Colorado squawfish No. 165, mouth of Duchesne River taken as zero. Lines drawn by hand. Green, Duchesne, and White Rivers, 1980.

Figure 20



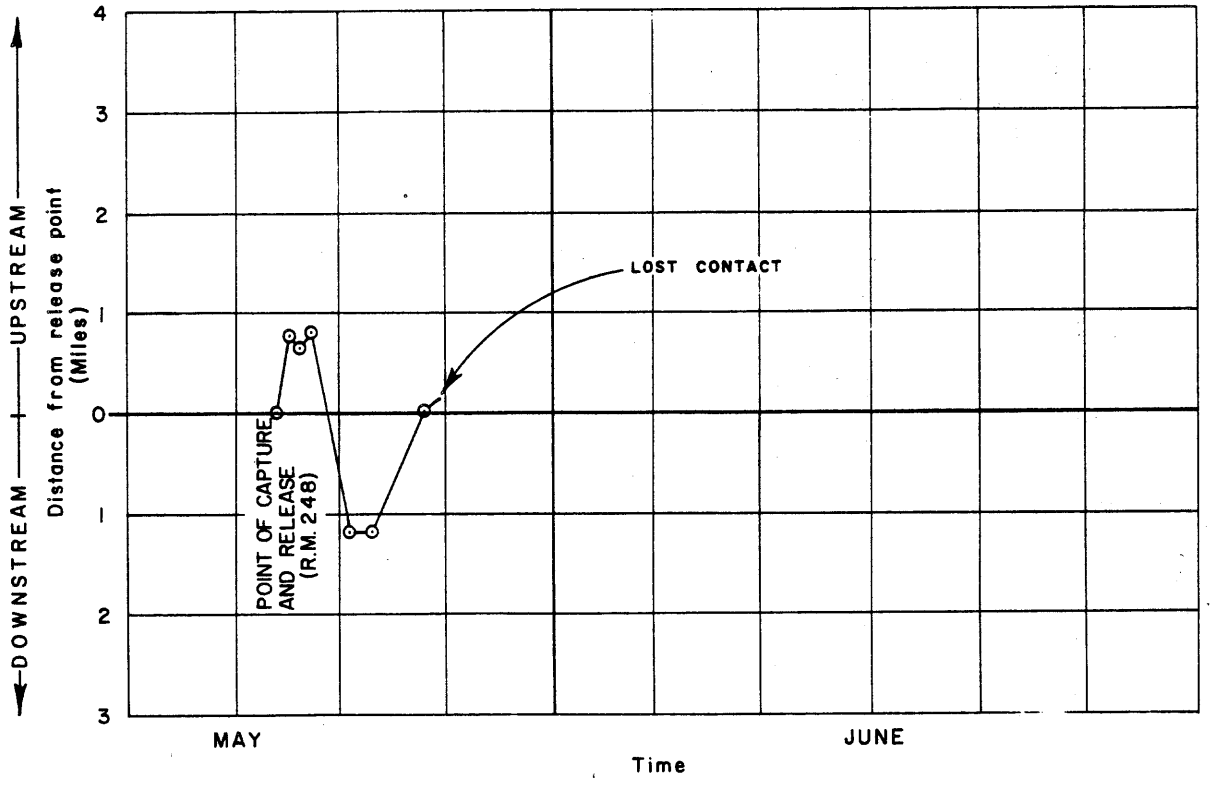
Long distance movement of Colorado squawfish No. 064. Release point (RM 253) taken as zero. Lines drawn by hand. Green River, 1980.

Figure 21



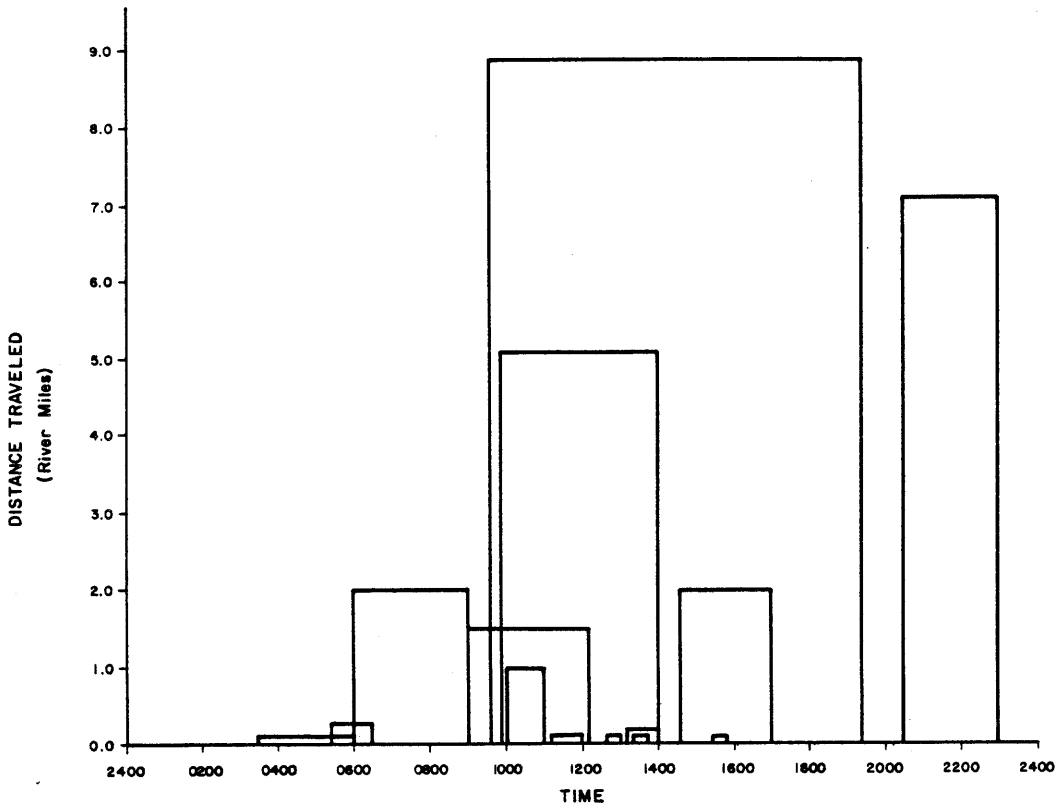
Long distance movement of Colorado squawfish No. 060. Release point (RM 253) taken as zero. Lines drawn by hand. Green River, 1980.

Figure 22



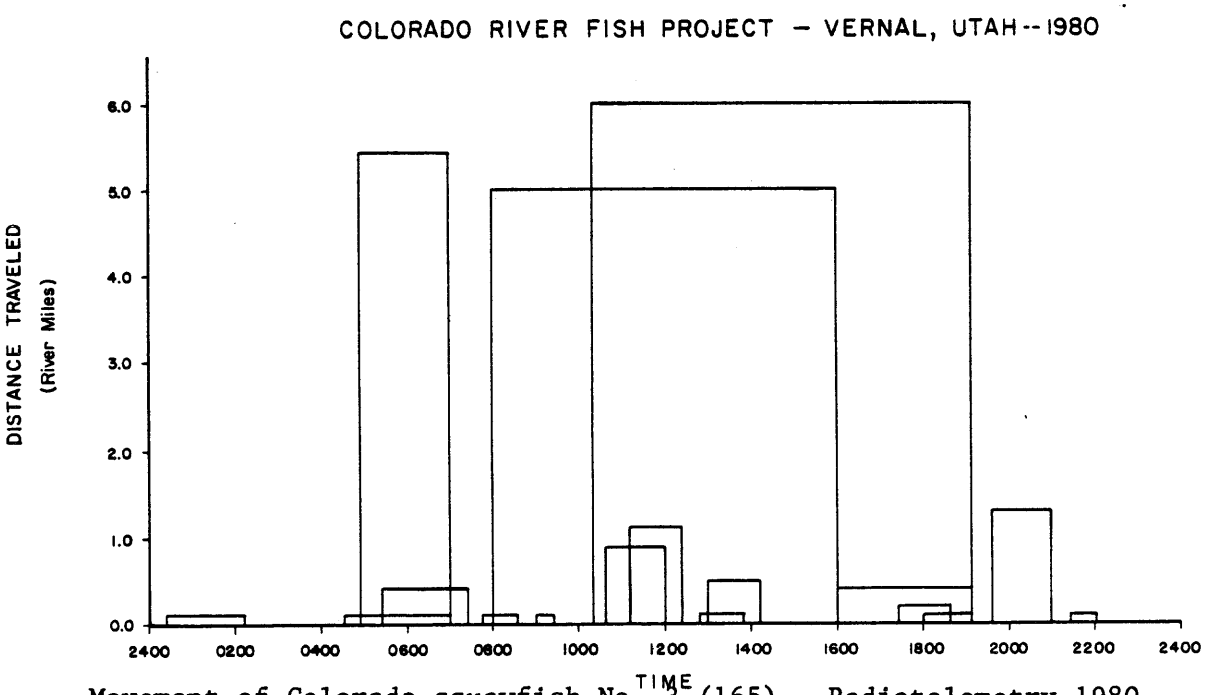
Long distance movement of Colorado squawfish No. 6 (006). RM 248 taken as zero. Lines drawn by hand. Green River, 1980.

Figure 23



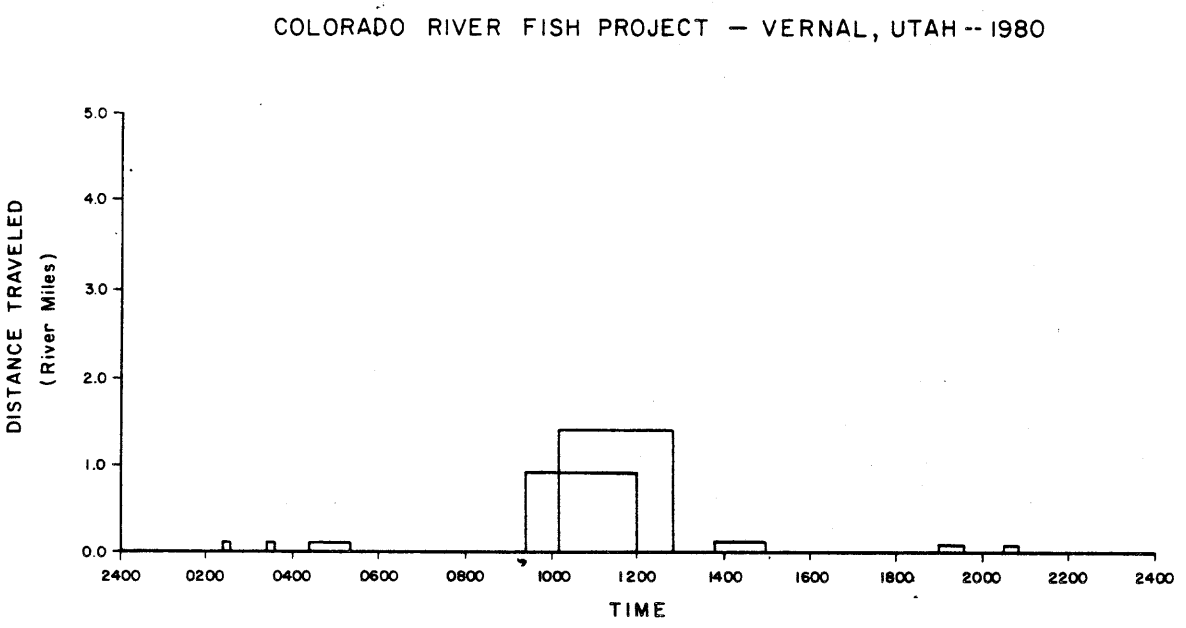
Movement of Colorado squawfish No. 2 (028). Radiotelemetry, 1980. Observations during diurnal study periods. Reported if interval 0.1 mile or greater. Each histogram is one observation.

Figure 24



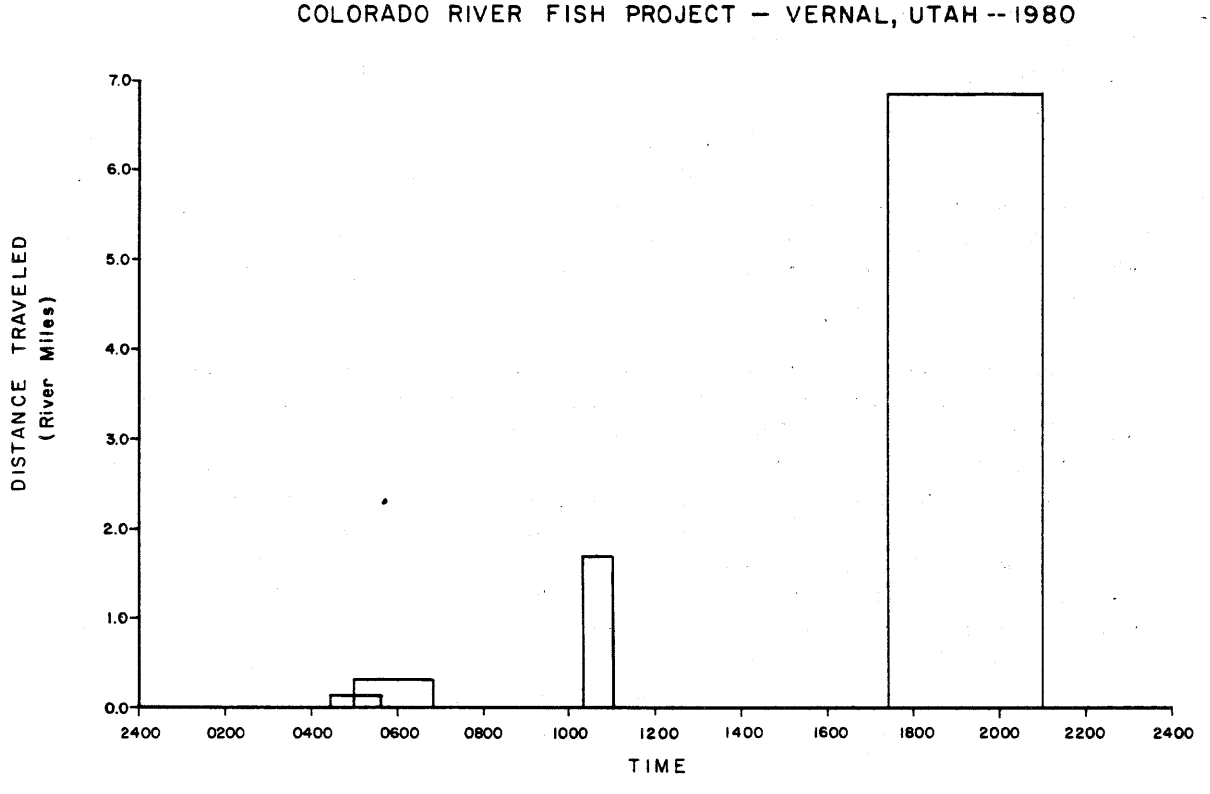
Movement of Colorado squawfish No. 3 (165). Radiotelemetry 1980. Observations during diurnal study periods. Reported if interval 0.1 mile or greater. Each histogram is one observation.

Figure 25



Movement of Colorado squawfish No. 4 (064). Radiotelemetry 1980. Observations during diurnal study periods. Reported if interval 0.1 mile or greater. Each histogram is one observation.

Figure 26



Movement of Colorado squawfish No. 5 (060). Radiotelemetry, 1980. Observations during diurnal study periods. Reported if interval 0.1 mile or greater. Each histogram is one observation.

An additional eight Colorado squawfish were implanted with radio-transmitters in 1981. Table 12 presents information on the capture, release, and major movement of all Colorado squawfish radiotelemetered in the Green River in 1981 (this table does not present information about Colorado squawfish radiotelemetered in the White and Yampa river studies that also utilized the Green River).

Table 12
Capture, release and major movement of radio telemetered Colorado squawfish, Green River, 1981

Fish number	Total length of fish (mm)	Date captured	Date released	Date of last contact	River	Major movement miles(km)
1(079)	421	4/07/81	4/13/81	7/15/81	Green	0.6 (1)
2(170)	471	4/08/81	4/13/81	9/10/81	Green	3 (5)
3(243)	447	4/08/81	4/13/81	6/25/81	Green	34 (54)
4(230)	539	4/15/81	4/20/81	5/26/81	Green	9 (15)
5(204)	564	4/17/81	4/20/81	5/21/81	Green	3 (5)
6)525)	614	4/28/81	5/01/81	9/01/81	Green Yampa	217 (347)
7(014)	385	5/07/81	5/11/81	8/06/81	Green	1/
8(286)	601	5/08/81	5/11/81	8/25/81	Green	10 2/(16)

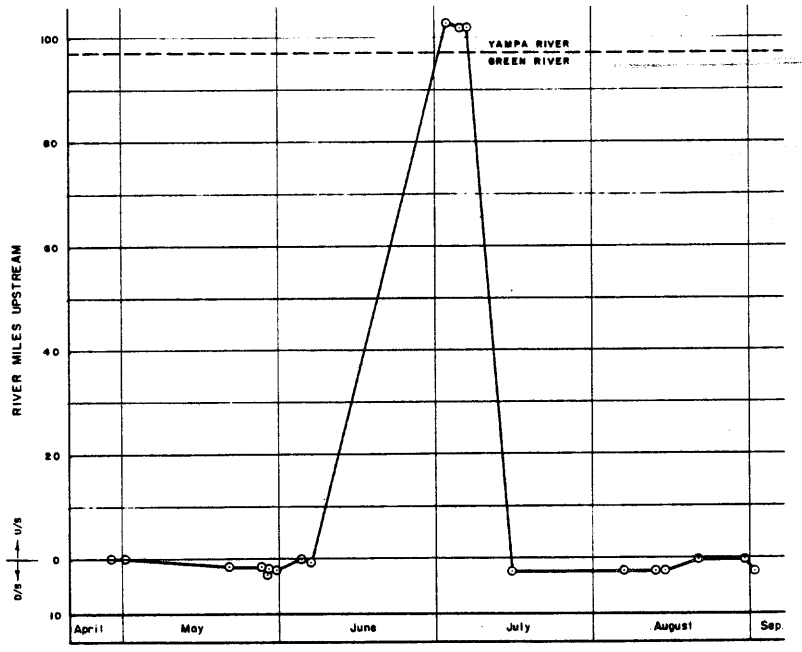
1/ Fish 014 believed dead after moving 5 miles (8 km) downstream.
2/ Contact lost during most of year.

Only two Colorado squawfish (Nos. 079 and 525) were monitored on a continuous basis throughout the 1981 season. Fish No. 079 was probably an immature fish (TL 421 millimeters) and remained stationary from April through July when contact was lost. Fish No. 525 was an adult (TL 614 millimeters) fish that moved 100 miles (161 kilometers) upstream and ascended the lower Yampa River in late June (Figure 27). Fish No. 525 was located in the lower Yampa Canyon on July 2-4 in the approximate location where several (13) ripe Colorado squawfish were collected. Fish No. 525 moved back downstream and was relocated at its point of capture at Ouray, Utah, on July 14, 1981. One other Colorado squawfish (No. 243) exhibited the same upstream movement in June, but contact was lost June 24, 1981 (Figure 28).

Contact with fishes Nos. 170, 204, 230, and 286 was lost. Fish No. 170 (Figure 29) did not exhibit an upstream movement pattern until July when contact was lost. However, it is probable that its stationary existence reflected a lack of reproductive maturity. The fish was only 471 millimeters and it is possible that it was an immature female. Ripe males this size have been observed and females generally are larger when they become mature. Fishes Nos. 204, 230, and 286 (Figures 30, 31, and 32) were not followed long enough to draw conclusions about probable movement patterns. When long distance movement occurred in adult Colorado squawfish, it was in mid- to late June. This coincides with results obtained in the Yampa River study, in which adults migrated to spawning grounds in the lower Yampa River at this time. When the results of that study are prepared we plan to analyze the Green River radiotelemetry studies with them. Unfortunately, radiotelemetry data are still preliminary and the 4,007 records on movement have not been thoroughly analyzed.

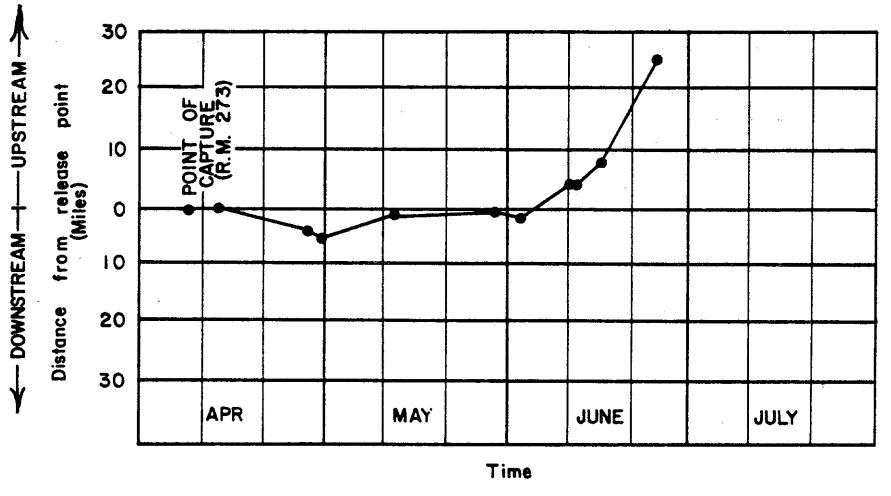
Further evidence of spawning migration was obtained from a radio-telemetered adult which left the White River and moved 129 miles (208 kilometers) downstream from mid-June to early July. It was located below Three Ford's Rapid (Gray Canyon) on July 10, 1981. This fish subsequently reentered the White River in mid-October. More information about this fish will be provided in the White River Study (in preparation).

Figure 27



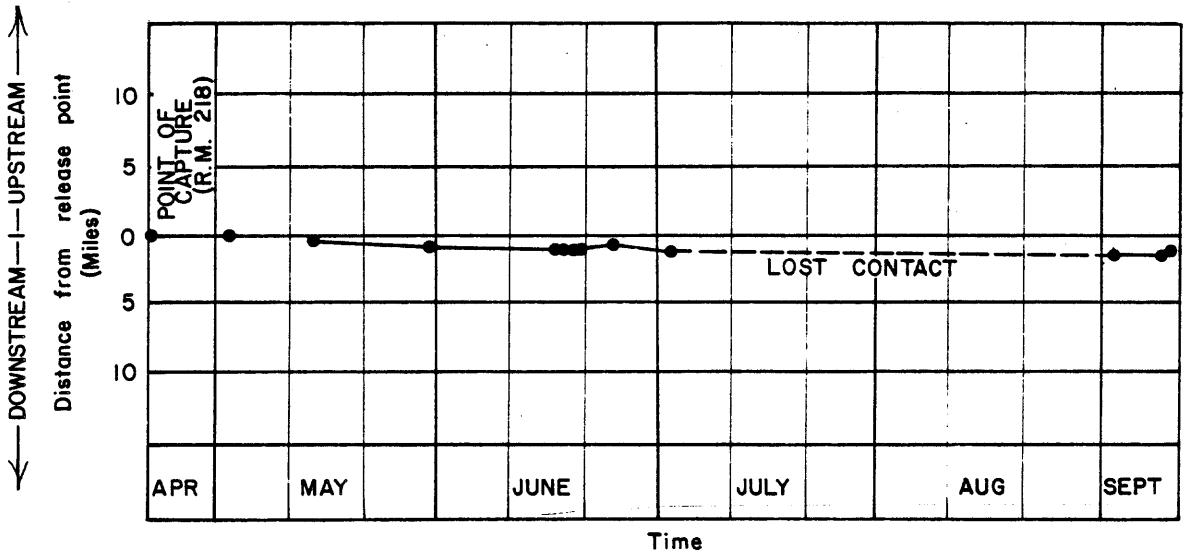
Long distance movement of Colorado squawfish No. 525, Green River, 1981. Release point (RM 248) taken as zero.

Figure 28



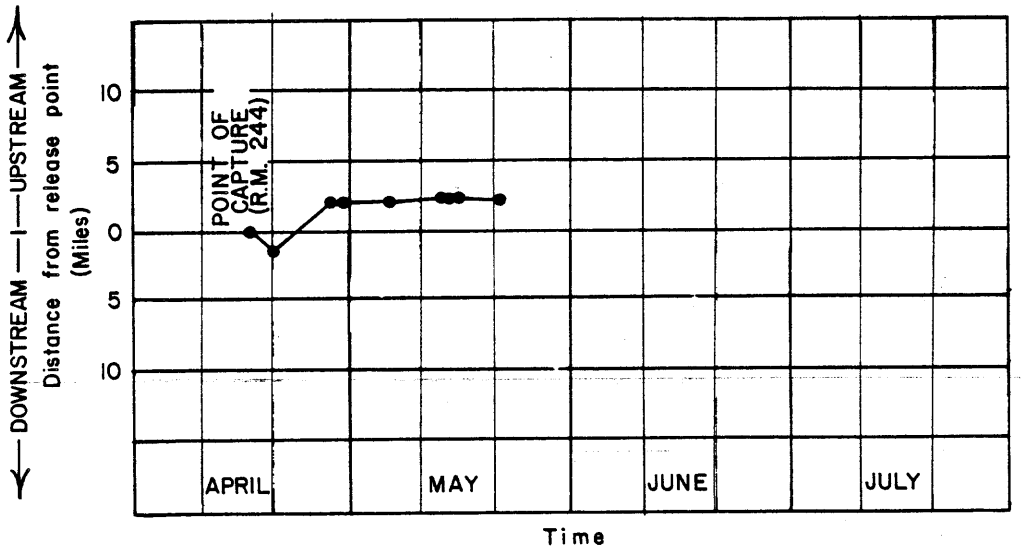
Long distance movement of Colorado squawfish No. 243. Release point (river mile 273) taken as zero. Green River, 1981.

Figure 29



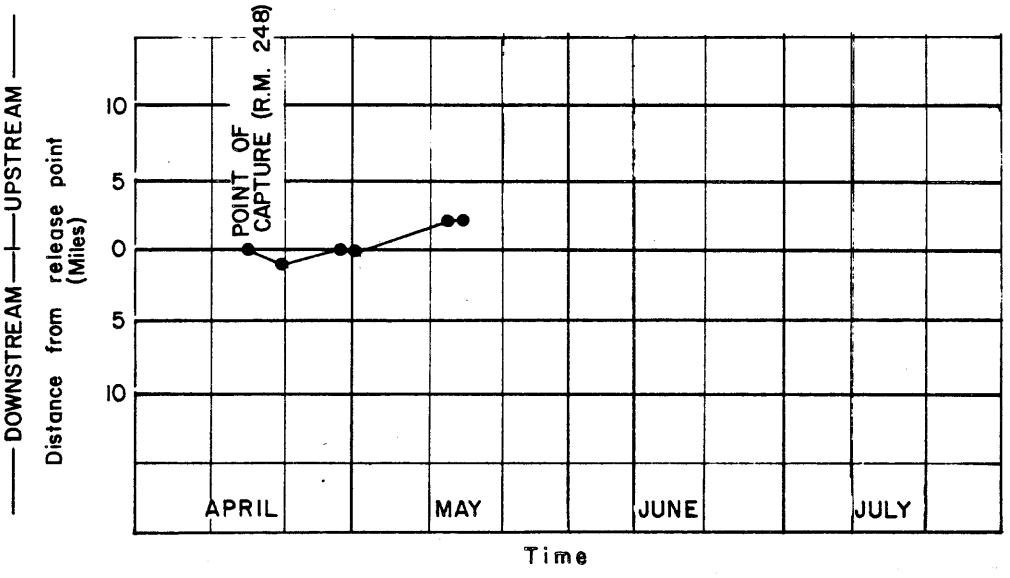
Major movement of Colorado squawfish No. 170. Release point (RM 218) taken as zero. Green River, 1981.

Figure 30



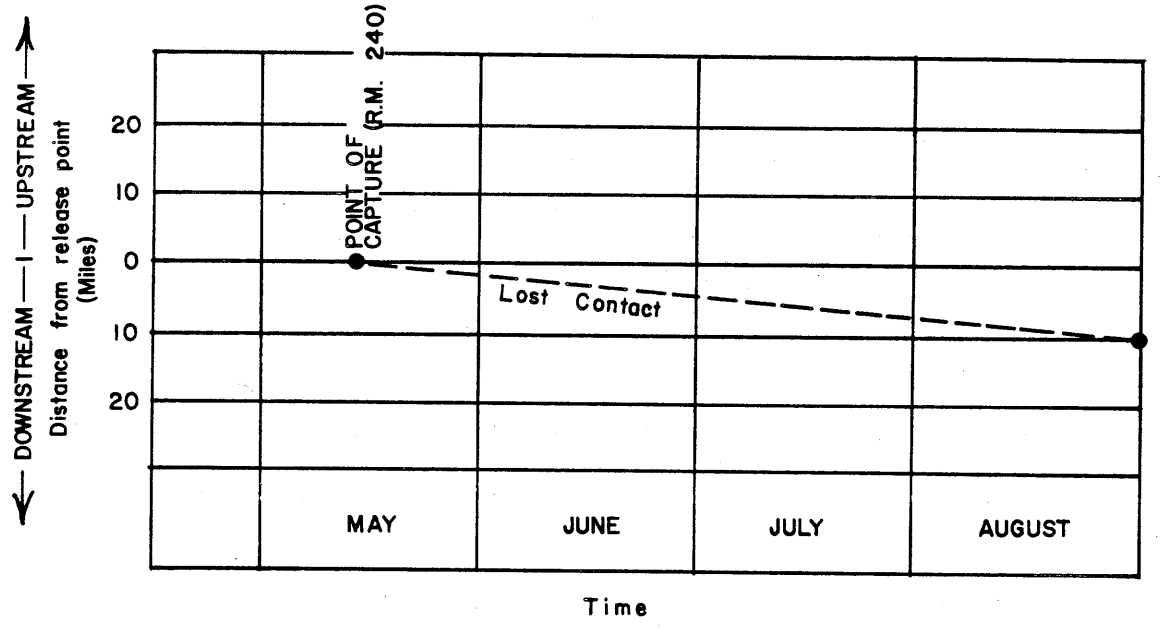
Long distance movement of Colorado squawfish No. 204. Release point (RM 244) taken as zero. Green River, 1981.

Figure 31



Major movement of Colorado squawfish No. 230. Release point RM 248 taken as zero, Green River, 1981.

Figure 32



Major movement of Colorado squawfish No. 286. Release point (RM 240) taken as zero, Green River, 1981.

An attempt was made to implant a radiotransmitter in a juvenile Colorado squawfish (No. 014) in order to learn more about movement and habitat preferences. Unfortunately, this fish was believed dead when attempts to recapture it indicated it was not moving and evidently was covered by sediment.

An inspection of the viscera of the two recaptured Colorado squawfish implanted with radiotransmitters was made in order to evaluate possible obvious adverse effects from the implanted fish module. If such effected, they could affect fish behavior (and hence movement). The fish module was effectively walled off from the intestines by adhesions and had to be teased free from this mass for inspection. No evidence of irritation to internal organs was seen in either fish. The small size of the fish module and the absence of any sharp projections was no doubt responsible for this favorable condition.

Long distance (over 100 kilometers) spawning migrations in freshwater fish species is generally uncommon in North America although Nikolsky (1961) cites examples in Asia of Cyprinid fishes that migrate over 1,000 kilometers. Other fishes of the genus Ptychocheilus include the northern squawfish, (Ptychocheilus oregonensis) and the Sacramento squawfish (Ptychocheilus grandis). These two squawfishes, the only living congeners of the Colorado squawfish, also make freshwater spawning migrations (Reid, 1971; Moyle, 1976).

Regarding the family cyprinidae, little is known about behavior in endemic cyprinids of the United States since they are not generally important for commercial and sports fisheries. Indeed, it is only recently that mechanisms for migration and homing of more important species have been worked out, and most emphasis is placed upon anadromous (shad, salmon, and striped bass) and catadromous (eel) forms. Virtually nothing has been learned about potomadromous (Gauthreaux 1980) migrations. Certainly, such migrations occur in the cyprinidae and some are well known in Europe and Asia (Stoot et al., 1962; Nikolsky, 1961). Because the family cyprinidae is the largest family of fishes in the world, with 275 genera and over 1,600 species (Nelson, 1976), it is evident that a high degree of diversity and adaptation occurs in this family, possibly more than in any other.

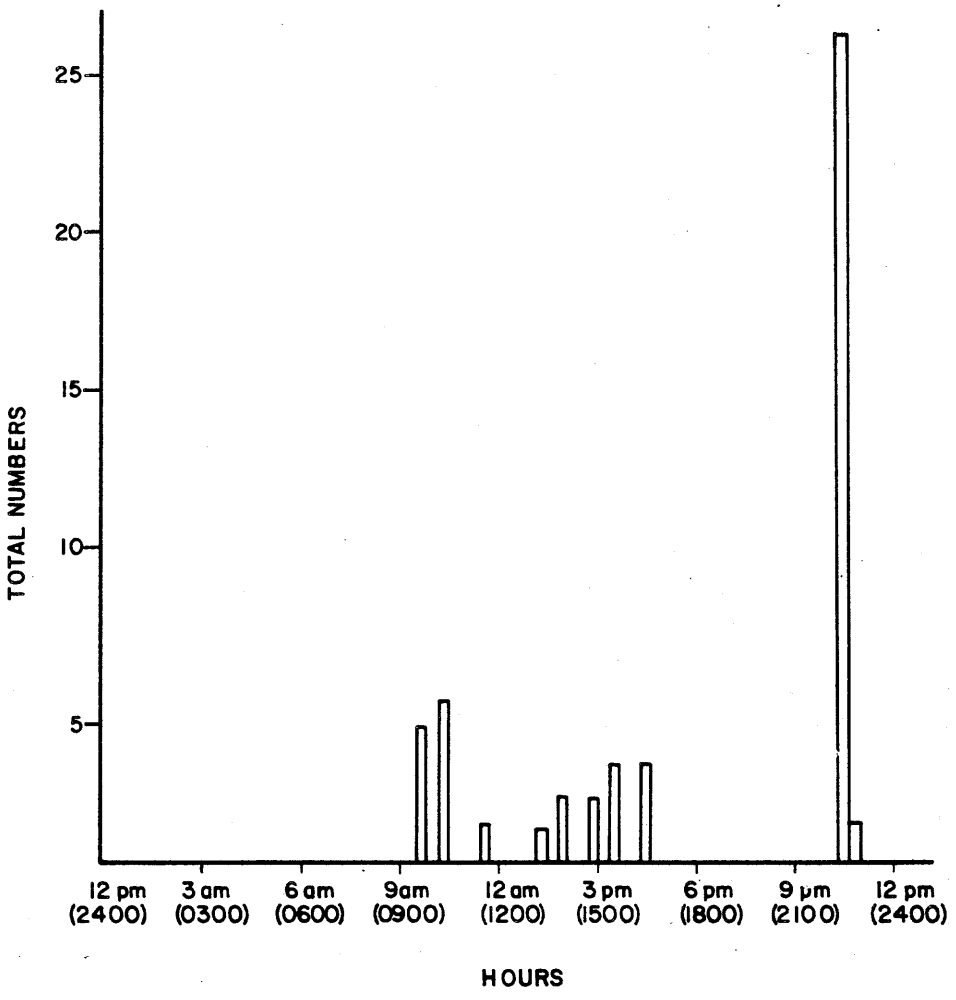
Other workers have postulated spawning migrations in Colorado squawfish and there are many reports of spring spawning migrations by early settlers who called the Colorado squawfish "salmon" (Sigler and Miller, 1963). Joseph et al. (1977) provided a review of known information concerning movement and spawning and concluded that large individuals possibly migrate long distances and smaller ones may move shorter distances.

Identification and protection of long distance spawning migrations of Colorado squawfish may be the most significant factor for the preservation of this endangered fish. The loss of fish passage may offer an explanation for its disappearance from the lower Colorado River basin. Blockage of such migrations by the construction of dams may result in its loss from the upper basin as well; however, it is possible that passageways might be utilized by Colorado squawfish since northern squawfish have been reported to use them (Park and Farr, 1972).

Diel movements were studied for radiotagged fish in 1981. These data will be subjected to statistical analysis and results will be submitted in subsequent papers.

Young.--Preliminary sampling conducted by the Vernal station in October 1979 indicated that YOY Colorado squawfish exhibited a diel (24-hour) movement pattern with the young fish occupying backwaters from 0900-2400 hours. The largest concentration of fish was captured from 2100-2400 hours (Figure 33). No fish were captured from 2400-0900 hours. Of the 54 young squawfish captured, marked, and released, a total of nine were subsequently recaptured. Since the backwater was so thoroughly seined, we concluded these nine fish had left it and returned later. Because of these preliminary results, the investigation was expanded in 1980 and 1981 to further examine potential movement patterns of young Colorado squawfish.

Figure 33



Catch of YOY Colorado squawfish from backwaters during special investigations, Green River, 1979.

Studies in 1980 emphasized yearling squawfish. Backwaters were studied in strata A (April, June, and July), C (April), and F (May and July). Stratum C was not sampled after the initial attempt because of low numbers of young Colorado squawfish and the difficulties involved in reaching the study site. Samples made in 1981 emphasized YOY Colorado squawfish in stratum F (September and October).

Prerunoff A (April) and runoff F (May) 1980 were the only samples where adequate numbers of fish for analysis were collected. Movement patterns of the young squawfish were established only in these strata and river stages, but the other samples are discussed in the habitat preference section.

During prerunoff in stratum A (1980), 620 yearling Colorado squawfish were collected from the primary collection site. A total of 579 of these fish were collected from backwater habitats. Eighty-six fish were subsequently recaptured in the backwater. Collections were only made from 0800-2400 hours. Young Colorado squawfish were collected in the backwater during all time periods, but were most abundant between 1200-2000 hours on 3 out of 4 days.

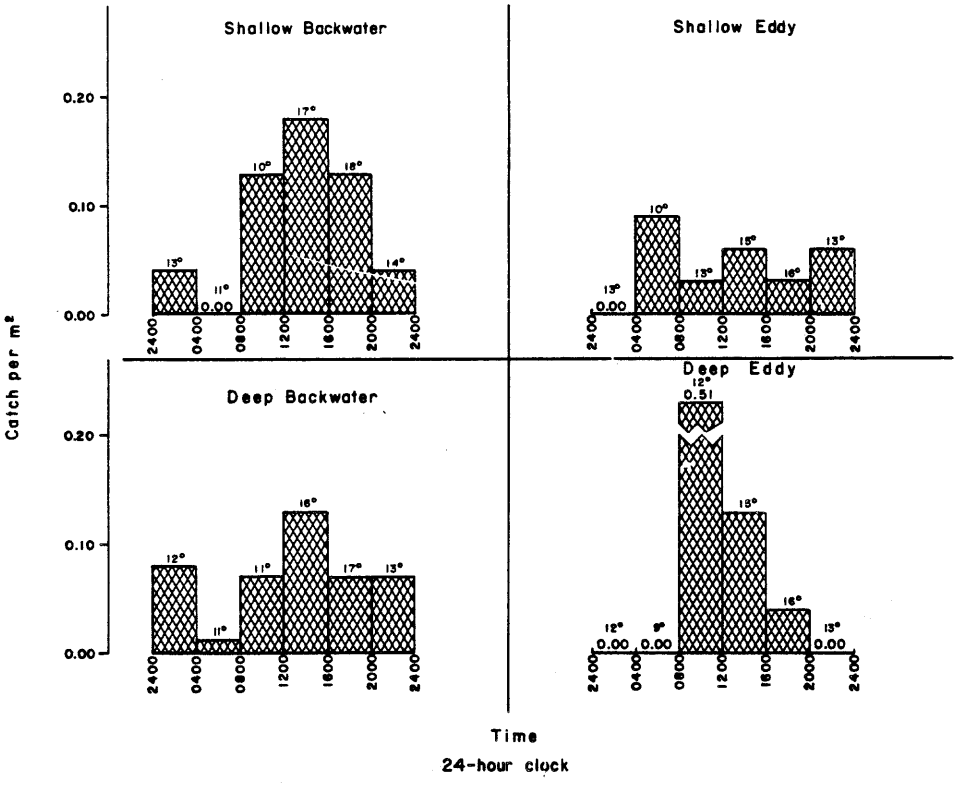
A total of 292 yearling Colorado squawfish were collected during runoff at stratum F (1980) of which 267 fish came from backwaters. There was no evident trend in Colorado squawfish abundance over time in stratum F, but sampling was biased by rapidly rising and falling water levels. Young Colorado squawfish were slightly more abundant in the backwater between 1200-2400 hours than during other time periods.

Water temperature was probably an important factor in the movement of young Colorado squawfish in and out of the backwater in 1980. However, there was no significant relationship between catch per effort of Colorado squawfish and water temperature in the backwater in 1980. This may be a result of fluctuating water levels affecting sampling efficiency and habitat availability.

Diel sampling of backwaters was continued in 1981. Samples were collected at RM 64.8 (104 kilometers) (April 1 - April 3), RM 263.5 (424 kilometers) (October 6 - October 7 and October 28 - October 29) and RM 263.6 (424 kilometers) and 263.8 (425 kilometers) (November 4 - November 6). Young Colorado squawfish were collected during all samples, but squawfish numbers were insufficient for analysis on October 28 - October 29 and November 4 - November 6.

Movement patterns of young Colorado squawfish in 1981 were similar to those observed in 1979 and 1980. More squawfish were collected per effort in backwater habitat between 1200 and 0200 hours than other time periods (Figure 34). Other habitats sampled contained larger numbers of squawfish between 0400 and 1200 hours (Figure 34).

Figure 34



Catch per effort, of YOY Colorado squawfish, diel sampling, Green River, Utah, RM 264, km 424, October 6-7, 1981.

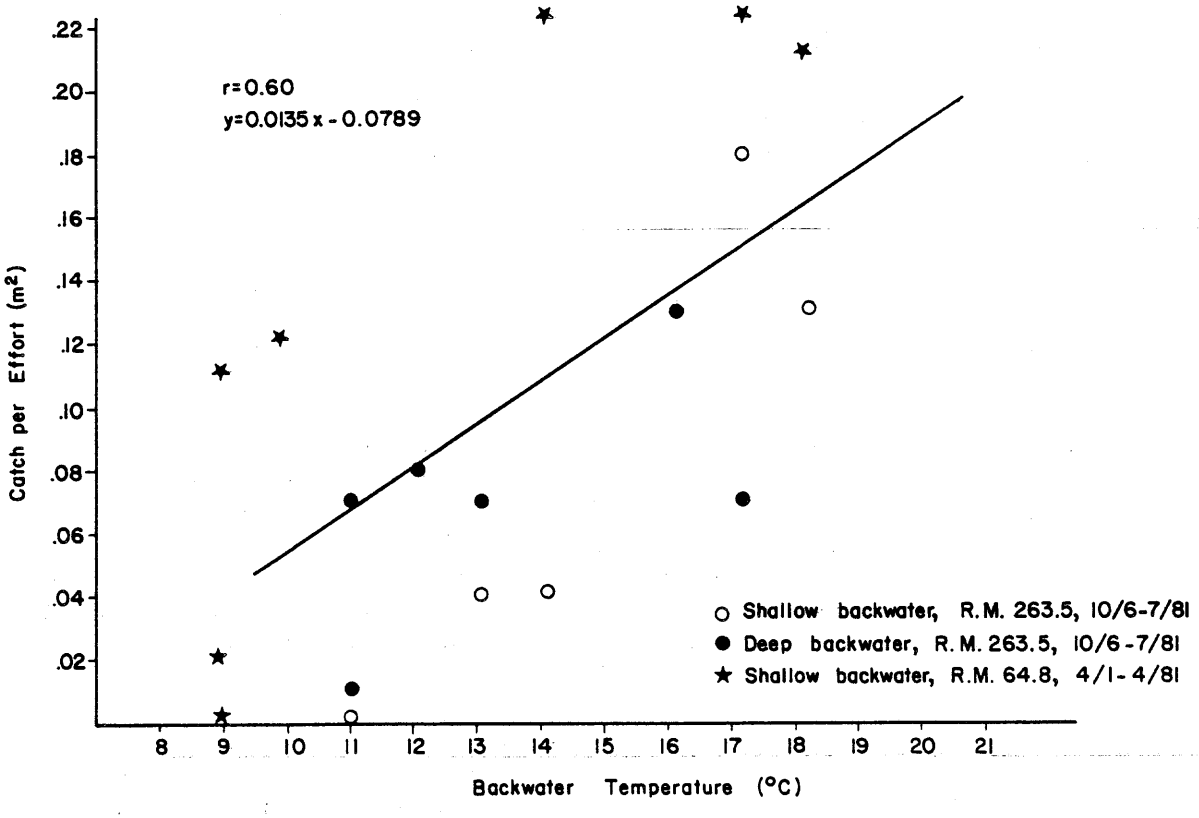
A total of 212 Colorado squawfish were marked during 1981 fall collections in stratum F. Eighty-six of these fish were subquently recaptured (Table 13). Recaptures of individual marked fish showed that the same fish moved between backwater and eddy or shoreline habitat. Recaptures also showed that fish remain in the same vicinity for extended periods. Fish movement with changing water levels indicated these small Colorado squawfish (40-60 millimeters) could successfully swim upstream against the current to locate preferred habitat.

Water temperatures taken at point of collection suggest a possible correlation ($r = 0.60$) was found between increasing water temperatures and catch per effort of young Colorado squawfish in specific backwaters (Figure 35). Catch per effort was greatest in other habitats when those areas were slightly warmer than the backwaters.

Table 13
Movement of marked YOY Colorado squawfish between habitats, Green River, 1981 RM 263.5 (424 km, 10/6-10/7 and 10/28-10/29; RM 263.6 (424 km) and 263.8 (425 km) 11/4-11/6)

Capture site		Recapture site				
Habitat	Number of fish marked	Deep backwater	Shallow backwater	Deep eddy	Shallow eddy	Run
Deep backwater	118	35	1	2	2	3
Shallow backwater	20	4				
Deep eddy	51	8	20	10	1	
Shallow eddy	6					
Run	17					
Totals	212	47	21	12	3	3

Figure 35



Catch per effort of young Colorado squawfish versus water temperature, Green River, 1981.

Habitat Preferences

Colorado squawfish selected different habitat types according to life history stages. Habitat preference was recorded by two different methods: (1) measurement of habitat parameters at the point of collection, and (2) measurement of habitat parameters of relocated radiotagged fish.

To obtain the best information about habitat preferences, data on depth, velocity and substrate (at point of capture) was obtained from the standardized sampling program. All collected fish were divided into 100-millimeter size groups and the recorded depths and velocities (Table 8) were subjected to analysis of variance (ANOVA) between groups. There was a significant difference ($p=0.01$) in selected depths and velocities between Colorado squawfish less than 200 millimeters TL and greater than 200 millimeters TL. Further significance testing with ANOVA indicated no significant differences ($p=0.01$) between standardized collections and other collections with respect to depth and velocity. Therefore, all collections were combined for the two size groups for further analysis since this resulted in more statistical power.

The difference noted in habitat selection at the 200 millimeter size may result from a change in food habits. Vanicek and Kramer (1969) found Colorado squawfish became obligate piscivores at this size. Fish smaller than 200 millimeters fed on microcrustaceans, aquatic insects, and fish.

Regression analyses were performed for the TL of all collected Colorado squawfish from standardized stations versus depth and velocity at point of capture. These analyses indicate larger fish seek deeper water ($r=0.75$) and higher velocity ($r=0.3$).

Adults.--Adult Colorado squawfish (>400 millimeters TL) were primarily collected from shoreline habitat (53 percent), but 26 percent were collected from eddies and 14 percent from runs (Table 14). The distribution of adult Colorado squawfish by strata and habitat is given in Figure 36. To date, no analysis has been made to determine any probable relationships between strata and habitat; however, some expected response can be noted by inspection of Figure 36 (e.g., prevalence of eddy habitat selected in C, Gray Canyon, relative to shore habitat in E, a flatwater section). Depths and velocities recorded at point of capture in different habitats are presented in Figure 37.

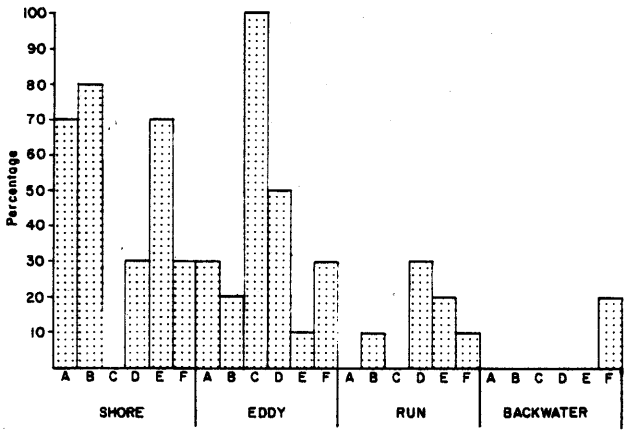
Table 14
Habitat preferences, adult Colorado squawfish (400 mm TL +) collected from all sampling programs, Green River 1979-1981

	Strata							Per-
Habitat	A	B	C	D	E	F	N	cent
Backwater	0	0	0	0	0	8	8	6
Eddy	3	2	7	2	6	12	32	26
Run	0	1	0	1	12	3	17	14
Riffle	0	0	0	0	0	1	1	1
Shoreline	6	9	0	1	38	12	66	53
Totals	9	12	7	4	56	36	124	100
$\bar{X}$ depth	4.4	3.5	7.3	4.7	4.1	4.9	-	-
$\bar{X}$ velocity	0.9	0.9	-	-	0.8	0.6	-	-

Recorded depths and velocities, tested by ANOVA, indicated no significant difference in velocities recorded between strata (Table 14). A highly significant difference ($p = 0.01$) was found with respect to depths between strata. An inspection of average depths recorded for collections (Table 14) indicated that depths recorded in stratum C were responsible for the difference between strata. Unfortunately, no velocity measurements were taken at point of capture in strata C or D.

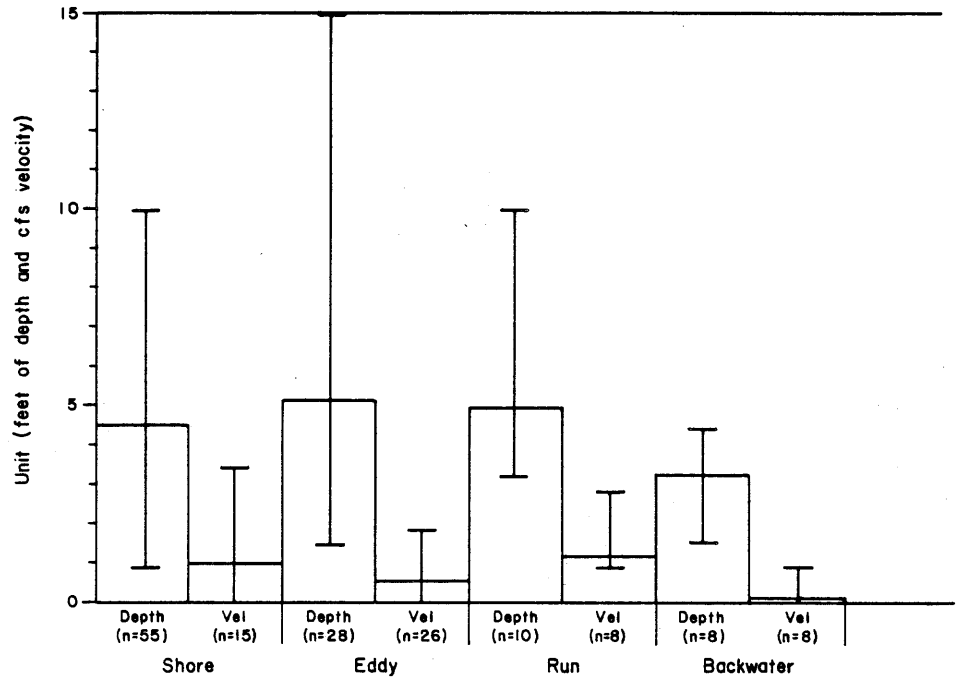
The distribution of adult Colorado squawfish by strata and habitat is given in Figure 36. To date, no analysis has been made to determine any probable relationships between strata and habitat; however, some expected response can be noted by inspection of Figure 36 (e g., prevalence of eddy habitat selected in C, Gray Canyon, relative to shore habitat in E, a flatwater section). Depths and velocities recorded at point of capture in different habitats are presented in Figure 37.

Figure 36



Occurrence of adult Colorado squawfish (TL = 400 mm+) by strata for four habitats, Green River, 1979, 1981.

Figure 37



Depth and velocity at point of capture with 95 percent confidence limits for Colorado squawfish (TL 400mm+) from four habitats.

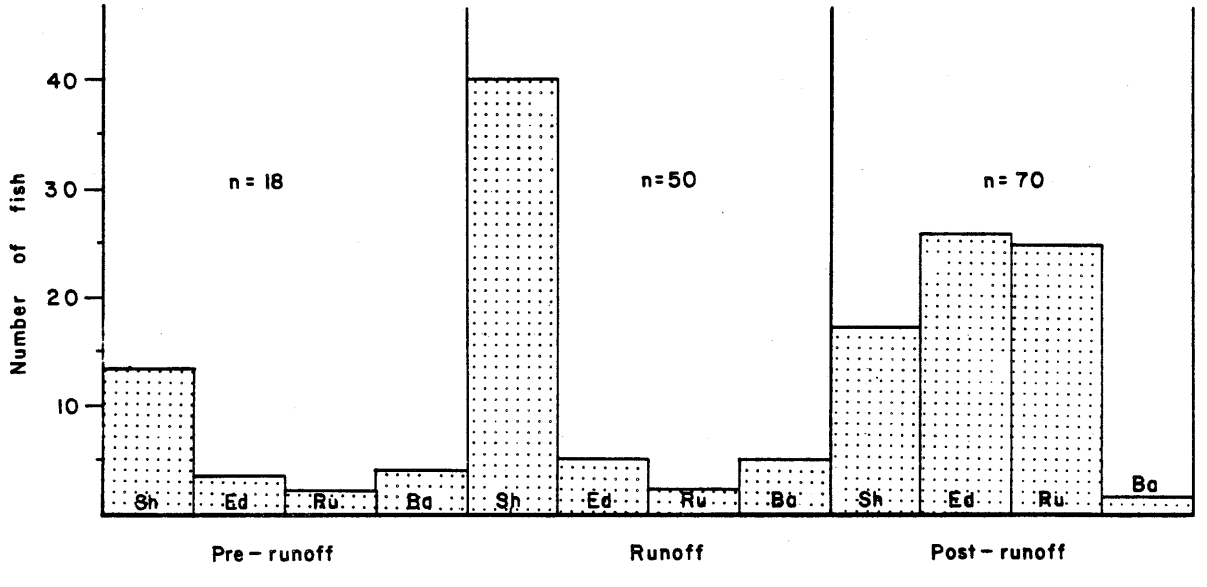
Habitat preference of adult Colorado squawfish were also investigated by river runoff period for 1979-1981. As indicated in Table 15, selected depths were not significantly different (a 0.01) for the different runoff periods; however, a difference existed between the recorded velocities. ANOVA indicated a significant difference existed between velocities measured for the prerunoff vs. runoff and for prerunoff vs. postrunoff. There were no significant differences for velocity measurements between runoff and postrunoff periods. Because water temperature was colder during prerunoff (12.5° C) than either runoff (17° C) or postrunoff (21° C) samples (Table 6), the higher velocities could indicate a preference for warmer conditions (that might occur more in the faster runs).

Table 15
Depth and velocity at point of collection of adult Colorado squawfish (TL>400 mm), Green River, 1979-1981

	Prerunoff 1/01/80 - 4/19/80 1/01/81 - 4/29/81	Runoff 4/20/80 - 7/01/80 4/30/81 - 6/15/81	Postrunoff 6/30/79 - 11-01/79 6/30/80 - 11/01/80 6/14/81 - 11/01/81
Depth	4.1 ft (n=19)	3.9 (n=46)	5.2 (n=48)
Velocity	1.16 cfs (n=19)	0.7 (n=45)	0.6 (n=41)
Total length (average)	493 millimeters	501 millimeters	508 millimeters

Habitat preference for adult Colorado squawfish from point of capture collections are presented in Figure 38 by runoff period. Adult Colorado squawfish were collected primarily in shoreline habitat in prerunoff and runoff periods, but selected a wide variety of habitats in postrunoff when a much greater proportion were collected in eddies and runs.

Figure 38



Distribution of adult Colorado squawfish by riverstage in four habitats, Green River, 1979-1981

Habitat preferences of radiotagged adult Colorado squawfish were also recorded. These data include seasonal and diel (24-hour) information for 1980 and 1981. However, 1981 data are not yet available and diel observations during 1980 have not been analyzed. Although information was obtained for the Duchesne, Green, and White Rivers in 1980, only the data from the Green was summarized since these fish had the Green River habitat in common. During May, July, and August four radiotagged Colorado squawfish (Table 16) preferred depths averaging 4.0 to 4.5 feet (1.2 to 1.4 meters). In June, an average depth of 6.4 feet (1.9 meters) was selected. Velocities selected in May, July, and August averaged from 1.1 to 1.3 ft/sec (0.3 to 0.4 m/sec), but in June velocities selected were 0.7 ft/sec (0.2 m/sec), (Tables 17 to 20).

Table 16

Habitat preferences of four radiotelemetered Colorado squawfish during diel sampling, May to September 1980, Green River, Utah

Month	Fish number	Number of observations	Average depth (feet)	Average velocity (feet per second)	Substrate[1/]	Habitat[2/]
May	(060)	13	3.7	1.7	Sa/Si	Sh
	(165)	19	5.5	1.1	Sa	Sh
	(028)	4	5.2	1.1	Sa/Si	Sh/Mc
	(064)	5	2.0	0.0	Si	Sh
		41	4.5	1.3	Sa/Si	Sh/Mc
June	(060)	46	6.8	0.8	Sa/Si	Sh/Ed
	(165)	18	12.2	0.9	Sa	Ed
	(028)	50	5.1	0.6	Sa/Bo/Co	Sh/Ed
	(064)	28	4.2	0.6	Sa/Bo/Si	Sh
		142	6.4	0.7	Sa/Bo/Co	Sh/Ed
July	(060)	25	3.5	1.1	Sa	Sh/Ed
	(165)	164	4.1	1.1	Sa/Co	Sh/Ed
	(064)	4	2.5	0.6	Sa/Si	Sh/Ed
		193	4.0	1.1	Sa/Co/Si	Sh/Ed
August	(060)	2	6.0	0.7	Gr/Si	Sh/Mc
	(165)	10	4.4	1.4	Si	Sh/Mc
	(064)	1	1.0	0.6	Sa	Sh
		13	4.4	1.2	Sa/Gr/Sa	Sh/Mc
September	(060)	1	3.0	0.4	Sa	Sh

1/ Sa=sand, Si=silt, Bo=boulder, Co=cobble, Gr=gravel.
2/ Sh=shore, Ed=eddy, Mc=main channel.

Although the 1980 data have not been subjected to statistical analysis, it appears the radiotelemetered Colorado squawfish selected deeper water of lower velocity in June. This could be due to runoff conditions or a behavioral response to the spawning season.

Monthly habitat preference data obtained from radiotelemetry in 1980 (Table 16) provides more information than depths and velocities recorded at point of collection (Table 15). Unfortunately, 1981 radiotelemetry data are not available for comparison. Also, no statistical analyses can be performed until the radiotelemetry data are computerized. There are 4,007 records of habitat preferences recorded for radiotelemetered Colorado squawfish that have not been reported to date. Since this is about 40 times the amount of data generated by the point collections, this is viewed as a serious deficiency.

Table 17
Habitat preferences of Colorado squawfish No. 2 (028) from radiotelemetry, Green River, 1980

River	Month	Number of observations	Average depth (feet)	Average velocity (ft/sec)	Primary substrate	Habitat
Green	May	2	4.6	0.3	Silt	Shoreline
	May	1	2.5	0.7	Sand	Shoreline
	May	1	9.0	3.2	Sand	Main channel
	June	29	3.4	0.9	Sand	Shoreline
	June	14	8.5	1.5	Boulder	Shoreline
	June	7	5.1	0.5	Cobble	Eddy
		54				

Table 18
Habitat preferences of Colorado squawfish No. 3 (165)[1/] from radiotelemetry, Duchesne, Green and White Rivers, 1980
Diel study observations unless noted (*)

River	Month	Number of observations	Average depth (feet)	Average velocity (ft/sec)	Primary substrate	Habitat
Duchesne	May*	5	2.18	0.4	Silt	Shoreline
	June	19	4.4	1.23	Sand	Shoreline
		24				
Green	May	10	5.5	1.1	Sand	Shoreline
	June	18	12.2	0.9	Sand	Eddy
	July	107	4.2	1.1	Sand	Shoreline
	July	33	4.5	1.8	Rubble	Shoreline
	July	24	2.8	0.3	Sand	Eddy
	August*	5	5.7	0.4	Silt	Shoreline
	August	5	3.0	2.3	Silt	Main channel
		211				
White	July	1	4.0	0.0	Sand	Eddy
	July	3	1.0	2.8	Cobble	Riffle
	July	38	2.3	0.5	Sand	Shoreline
	July	13	3.0	0.0	Silt	Shoreline
		55				

1/ Implanted with radiotransmitter frequency 40.688 MHz.

Table 19
Habitat preferences of Colorado squawfish No. 4 (064)
from radiotelemetry, Green River, 1980
Diel study observations unless noted(*)

River	Month	Number of observations	Average depth (feet)	Average velocity (ft/sec)	Primary substrate	Habitat
Green	May	5	2.0	0.0	Silt	Shoreline
	June	15	6.3	0.6	Sand	Shoreline
	June	1	4.0	1.7	Silt	Shoreline
	June	12	1.6	0.6	Boulder	Shoreline
	July	2	2.5	0.6	Sand	Shoreline
	July	1	3.0	0.8	Sand	Eddy
	July	1	1.9	0.5	Silt	Shoreline
	August	1	1.0	0.6	Sand	Shoreline
		38				

Table 20
Habitat preferences of Colorado squawfish No. 5 (060)
from radiotelemetry, Green River, Utah 1980
Diel study observations unless noted (*)

River	Month	Number of observations	Average depth (feet)	Average velocity (ft/sec)	Primary substrate	Habitat
Green	May	10	2.1	1.8	Silt	Shoreline
	May	3	9.0	1.4	Sand	Shoreline
	June	19	6.5	1.5	Sand	Shoreline
	June	5	8.0	1.0	Sand	Eddy
	June	22	6.8	0.1	Silt	Shoreline
	July	12	2.4	0.8	Sand	Eddy
	July	13	4.5	1.3	Sand	Shoreline
	August*	1	6.0	0.4	Gravel	Shoreline
	August*	1	6.0	0.9	Silt	Main channel
	September	1	3.0	0.4	Sand	Shoreline
		87				

Data from radiotelemetry studies are in general agreement with data from the standardized sampling program; however, they are more refined. Statistical tests will be made between radiotelemetered fish for habitat preferences for season, month, and time of day. Goodness of fit tests will be made between standardized collections and raiotracking collections. These data and analyses will be submitted in subsequent papers. In addition, there are 4,439 records of USGS flow and temperature information and temperature records from FWS thermographs that have not been analyzed. These data will be used to see if predictive movement patterns can be established.

Radiotracking and general collections of adult Colorado squawfish provide one final observation. A large number (over 25 percent) of Colorado squawfish were collected at the mouth of the White and Duchesne Rivers and radiotagged fish spent much time at these locations. It is possible they find these locations desirable for feeding; however, this is an assumption.

Juveniles.--For coding purposes, juvenile Colorado squawfish were considered to be between 60 and 400 millimeters TL. However, depth and velocity at point of capture for fish between 200 and 400 millimeters TL were not significantly different from those measured for adults. Therefore, fish in that size group are considered with adults.

Colorado squawfish between 60 and 200 millimeters TL were predominately collected from backwater habitat with silt or sand substrate (Table 21). Shoreline habitat contained the next largest collection of this size group. A total of 250 Colorado squawfish in this size group collected between 1979-1981 had velocity measurements and 79 percent of these fish were collected from areas with a velocity of less than 0.3 ft/sec (0.09 m/sec) (Table 22). Of 255 fish, about 81 percent were collected from a water depth less than 1.4 feet (0.4 meters) (Table 23).

Table 21
Habitat and substrate at point of capture, juvenile Colorado squawfish, all sampling programs, 1979, 1980, and 1981

Habitat	Number of fish	Subtrate	Number of fish
Backwater	170	Silt	146
Shoreline	66	Sand	103
Eddy	20	Rubble (cobble)	4
Run	6	Boulder	2
Pool			

Table 22
Water velocity at point of capture, juvenile Colorado squawfish (60 to 200 mm TL), all sampling, 1979-1981 ($n=250$, $\bar{x}=0.20$, min=0.0, max=1.5, variance=0.1

Water velocity (ft/sec)	Number of fish	Frequency (percent)
0.000 to .150	165	66.00
.150 to .300	33	13.20
.300 to .450	7	2.80
.450 to .600	19	7.60
.600 to .750	2	0.80
.750 to .900	12	4.80
.900 to 1.050	1	0.40
1.050 to 1.200	9	3.60
1.200 to 1.350	0	0.00
1.350 to 1.500	2	0.80

Table 23
Water depth at point of capture, juvenile Colorado squawfish (60 to 200 mm TL) collected during all sampling, Green River, 1979-1981. ($n=255$, $\bar{x}=1.06$, min=0.2, max=4.3, variance=0.47

Water depth (feet)	Number of fish	Frequency (percent)
.200 to .610	69	27.06
.610 to 1.020	101	39.61
1.020 to 1.430	36	14.12
1.430 to 1.840	20	7.84
1.840 to 2.250	10	3.92
2.250 to 2.660	13	5.10
2.660 to 3.070	2	0.78
3.070 to 3.480	0	0.78
3.480 to 3.890	0	0.00
3.890 to 4.300	4	1.57

Young.--YOY Colorado squawfish captured during standardized sampling were collected largely from backwater habitats (Table 24) although collections also included shoreline and other habitats. Substrate at point of capture was predominately silt or sand.

Table 24
Habitat and substrate at point of capture, YOY Colorado squawfish, standardized sampling program

Habitat	Number of fish	Substrate	Number of fish
Backwater	477	Silt	442
Shoreline	111	Sand	167
Side channel	12	Gravel	6
Eddy	9	Rubble (cobble)	12
Isolated pool	3		
Pool	2		
Riffle	6		
Run	7		

Data collected in the standardized sampling program 1979-1981 (Tables 25 and 26) for YOY Colorado squawfish indicated water depth and velocity at capture sites averaged 0.98 feet (0.3 meters) and 0.43 ft/sec (0.1 m/sec), respectively.

Table 25
Water depth at point of capture, YOY Colorado squawfish, standardized sampling program, 1979-1981 (n=92, $\bar{x}$=0.98, min=0.1, max=3.5, st. dev=0.59)

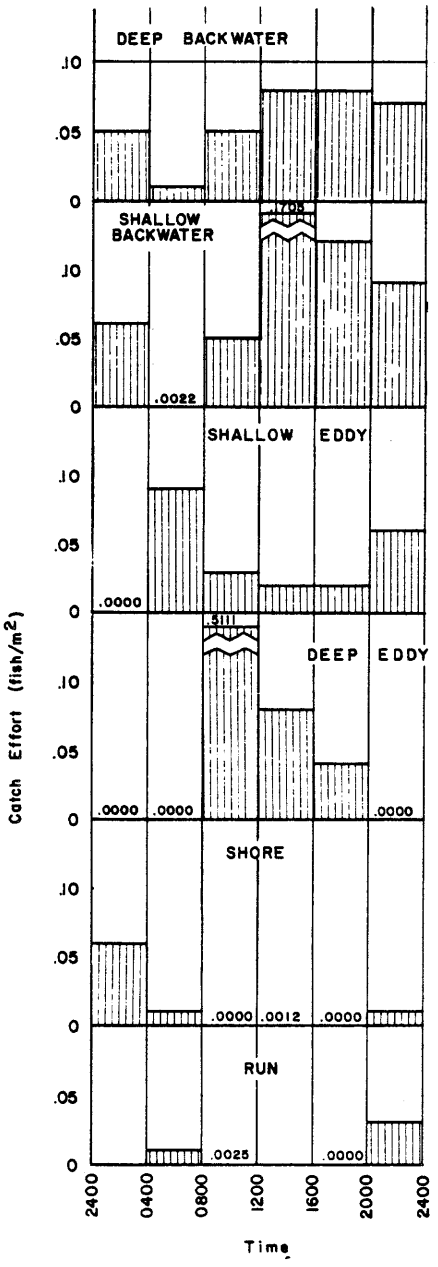
Water depth (feet)	Number of fish
0.0 to 0.4	158
0.5 to 0.9	284
1.0 to 1.4	147
1.5 to 1.9	25
2.0 to 2.4	1
2.5 to 2.9	11
3.0 to 3.4	0
3.5 to 3.9	1
4.0 to 4.4	0

Table 26
Water velocity at point of capture, YOY Colorado squawfish, standardized sampling program, 1979-1981 (n=92, $\bar{x}$=.4315, min=0.0000, max=2.4000, st. dev=0.51)

Water velocity (ft/sec)	Number of fish
0.0	467
0.1	18
0.2	16
0.3	11
0.4	18
0.5	19
0.6	3
0.7	3
0.8	5
0.9	18
1.0	2
1.1	6
1.2	17
1.3	0
1.4	3
1.5	8
1.6	0
1.7	1
1.8	3
1.9	0
2.0	0

As stated in the Movement section (young), young Colorado squawfish appeared to select certain habitats on a diel basis. Standardized collections made in 1981 provided further information. Six different habitats were sampled repetitively for 7 days in 1981 (October 6 - October 7, October 28 - October 29, and November 4 - November 6) at RM 264 (425 kilometers) near Ouray, Utah. The results of that investigation are provided in Figure 39. Young Colorado squawfish selected backwaters between 1200-2000 hours but were found in eddies between 0400-1200 hours. Mark and recapture information (Table 13) substantiates a movement between backwaters and eddies. As stated in the Movement section (Figure 35) this movement was correlated (r = 0.60) with warmer water temperatures.

Figure 39

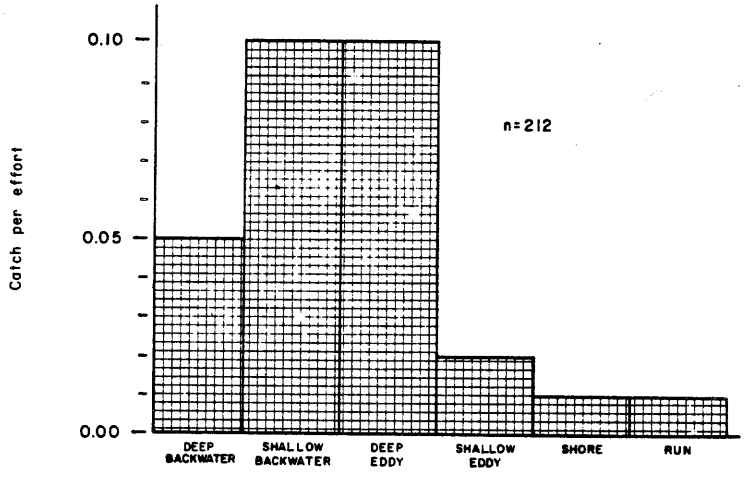


Catch per effort of young Colorado squawfish from six habitats, Green River, October and November, 1981 (n=212).

The preference for certain habitats was evidently a major factor in the movement patterns of young Colorado squawfish. Rising water levels, upon occasion, changed backwaters and eddies to runs. Marked young Colorado squawfish were captured in preferred backwater or eddy habitat at upstream locations from their capture and marking site. Upstream habitats were also selected according to the information presented in Figure 39.

Young Colorado squawfish captured in October - November 1981 were collected from six habitats. Catch per effort indicated general habitat preference from most to least preferred as: (1) shallow backwater and deep eddy; (2) deep backwater; (3) shallow eddy; (4) shoreline and run (Figure 40).

Figure 40



Catch per effort of young Colorado squawfish from six habitats, diel sampling, Green River, October and November 1981.

Habitat preferences of young Colorado squawfish were also studied in connection with peaking power releases from Flaming Gorge Dam. In October 1980, BR released flows from the dam ranging from 884 to 3,737 ft^3/sec (25 to 105 m^3/sec). These flows were monitored immediately below the dam at a hydrologic station set up jointly by the FWS, BR, and Utah Division of Wildlife Resources (UDWR). The Vernal office of CRFP also set up a study area 153 miles (246 kilometers) downriver at Ouray, Utah, in order to assess possible changes in backwater nursery habitat for young Colorado squawfish.

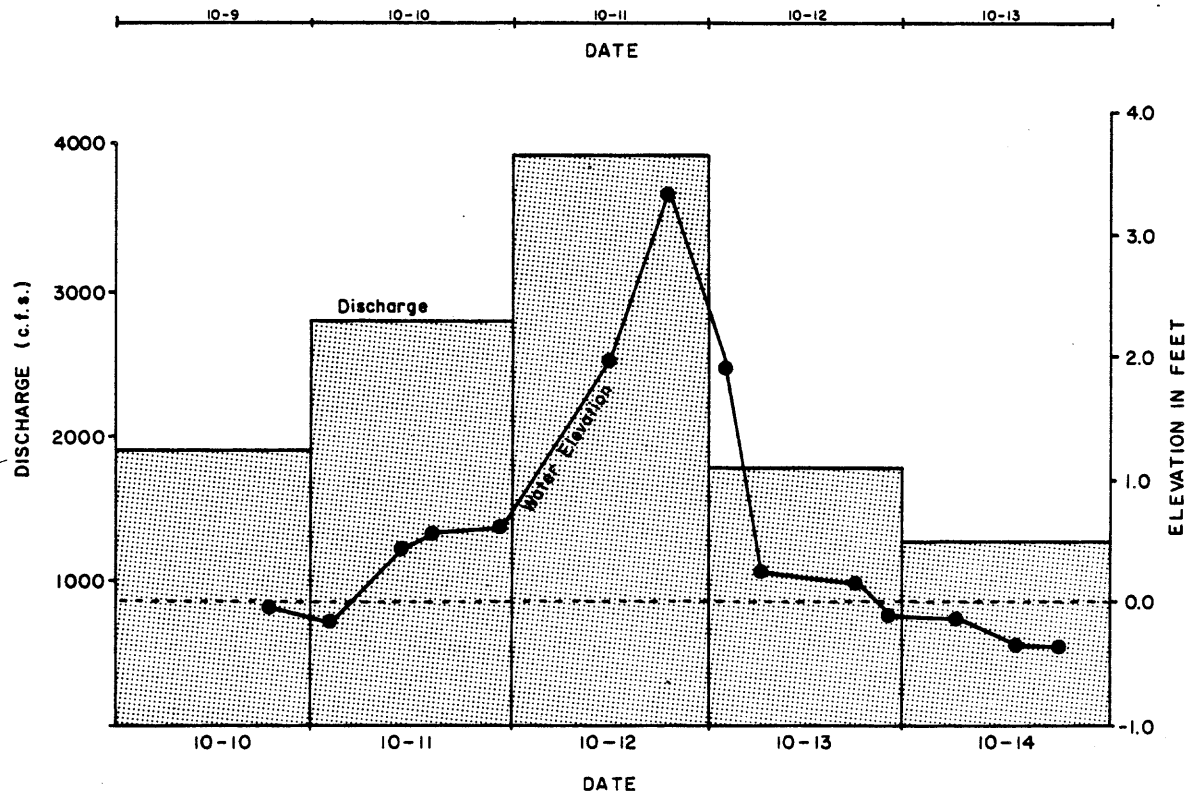
Hydrologists with BR were contacted regarding the time the increased flows would arrive at Ouray and the expected magnitude of such flows. BR personnel stated that the fluctuations were not expected to be measurable that far downstream. Expected travel time was estimated at about 4 days.

Flows released from the dam averaged 2,322 ft^3/sec (65 m^3/sec) during the October 7-8 period, 3,737 ft^3/sec (105 m^3/sec) during the October 9-10 period, and 884 ft^3/sec (25 m^3/sec) during the October 11-12 period. These releases resulted in significant effects on the studied backwater at Ouray on October 12, with water depth increasing

3.3 feet (1.0 meters) above and then decreasing 0.6 feet (0.2 meters) below the October 11 reference point.

In order to compare this unexpected change in backwater habitat with discharge data, 1980 USGS records for Jensen, Utah, were obtained and inspected. On October 11, the Jensen station recorded an abnormally high flow of 3,910 ft^3/sec (109 m^3/sec). This high flow represents the flooding which occurred at Ouray on October 12 (Figure 41). The average flow for October at Jensen was recorded at 2,045 ft^3/sec (57 m^3/sec), which is normal for that time of year (the September average was 1,931 ft^3/sec or 54 m^3/sec). Apparently, the very high flow recorded at Jensen on October 11 was offset by lower releases from Flaming Gorge Dam which resulted in the average value (that would be expected) for the month.

Figure 41



Histogram of discharge (cfs) at USGS station at Jensen (legend left and above) and fluctuation (feet) of backwater at Ouray (legend right and below) October 1980.

YOY Colorado squawfish were most common in collections made when flows of 2,500 ft^3/sec (70 m^3/sec) reached the sample area. Squawfish became less available as water level rose and the size of the backwater increased. The maximum flow released (4,000 ft^3/sec, 112 m^3/sec) reached the study area October 12. Although the relative abundance of YOY Colorado squawfish increased when flows dropped to 800 ft^3/sec (22 m^3/sec) on October 13-14, it did not reach the level attained at the beginning of the study. The reason for this is unknown.

Red shiners and fathead minnows were the dominant species in the collections. Red shiners were more common in the shallow portions of the backwater while fathead minnows became more common in the deeper areas. Green sunfish were first collected when the backwater reached maximum size and were collected in association with freshly flooded vegetation.

It is unknown if the observed effects are totally due to the releases from Flaming Gorge Dam. The flows of the Yampa River have not been compared with noted effects and there might have been other unknown factors which influence results. It is recommended that BR study our results and provide guidance. In any event, the magnitude of the effects at Ouray are undeniably related to the changes in discharge at Jensen, presumably caused by the peaking power discharges.

Although samples were taken according to a sampling design which provided collections "around the clock," results did not indicate a movement pattern. Previous work indicated YOY Colorado squawfish exhibited different behavior than was observed; however, low numbers of fish collected during this study make these observations inconclusive. Young squawfish may have responded more to increased flows and changing conditions than to a normal diel pattern. An example was the larger numbers of Colorado squawfish remaining in the backwater between 2400-0800 hours during increasing flows (October 11 and 13). Low numbers of fish captured on October 12 may be due to the greatly increased size of the backwater during that day.

YOY surveys in the fall of 1979-1981 (Figure 16) provided 3 years of catch per effort data for the abundance of young Colorado squawfish throughout the study area. These data provided remarkably similar histographs (Figures 13 to 15) and indicate the possibility of a drift mechanism occurring in larval Colorado squawfish. This observation is made because, for all 3 years, peaks of abundance in September occur approximately the same distance downstream from suspected spawning areas. Two drift mechanisms are theorized:

1. A long drift period of approximately 110 miles (177 kilometers). One interpretation of Figure 16 indicates two major peaks of abundance, one at RM 240 (386 kilometers) (includes two peaks: RM 275 (443 kilometers) and RM 205 (330 kilometers)) and the other at RM 80 (129 kilometers) (includes three peaks: RM 130 (209 kilometers), RM 75 (129 kilometers), and RM 35 (56 kilometers)). The first peak occurs about 110 miles (177 kilometers) downstream of the known spawning area in the Yampa River. If the second peak also occurs 100 miles (161 kilometers) downstream, this would place the other spawning location at RM 190 (306 kilometers), Desolation Canyon.

2. A shorter drift period of approximately 75 miles (121 kilometers). Major peaks of abundance obtained from Figure 16 occurred at RM 275 (443 kilometers), RM 205 (330 kilometers), and RM 75 (121 kilometers). Lesser peaks occurred at RM 130 and RM 35. The first peak (RM 275) was about 75 miles downstream of the spawning area in the Yampa River. The second

peak occurred about 75 miles downstream of the proposed spawning area in the White River. The third major peak, RM 75, occurred 75 miles downstream from RM 30 (48 kilometers), a point between Range Creek and Coal Creek rapids in Gray Canyon, definitely a suspected spawning area. Lesser peaks at RM 130 (209 kilometers) and RM 35 (56 kilometers) would place potential spawning areas (75 miles upstream) at RM 205 in upper Desolation Canyon (previously suggested in Theory 1) and at RM 100 (161 kilometers), slightly above the beginning of Labyrinth Canyon. The location at RM 100 is the only site that could be ruled out for a potential spawning area based on the habitat selected in the Yampa River.

The two preceding theories provide possible sites for future study. If such a mechanism exists, it would cause these larvae to drift downstream from the rocky spawning areas to more favorable, nursery habitat. This hypothesis should be more fully investigated since management implications are great.

Results obtained from 1981 larval collections (Table 9) indicated Colorado squawfish larvae of 9-23 millimeter size were obtained primarily in strata A and F, from RM 220-300 (354-483 kilometers) (mean RM 260, 419 kilometers) and from RM 50-100 (81-161 kilometers) (mean RM 75, 121 kilometers). These results tend to substantiate the 100-mile drift theory (Theory No. 1 above). Also, the presence of a radiotagged fish moving into Gray Canyon and the capture of two tuberculated adults (RM 146, July 12, 1981) lends credence to the existance of a spawning area near RM 80 (129 kilometers).

Associated Species

Numbers of fishes and catch per unit effort for fishes collected with Colorado squawfish for 1979-1981 will be analyzed by stratum, habitat type, and time of year. General information was presented in the section "Distribution and Abundance of all Fish Species."

Information from YOY collections included catch per effort of all fishes found associated with young Colorado squawfish; however, these data have not been subjected to analysis. The introduced red shiner was the most common fish found associated with young Colorado squawfish, followed by channel catfish and fathead minnows. Flannelmouth sucker and bluehead sucker were the most abundant native fishes collected with adult Colorado squawfish. Young Colorado squawfish apparently do not coexist with redside shiners and this lack of association will be further analyzed.

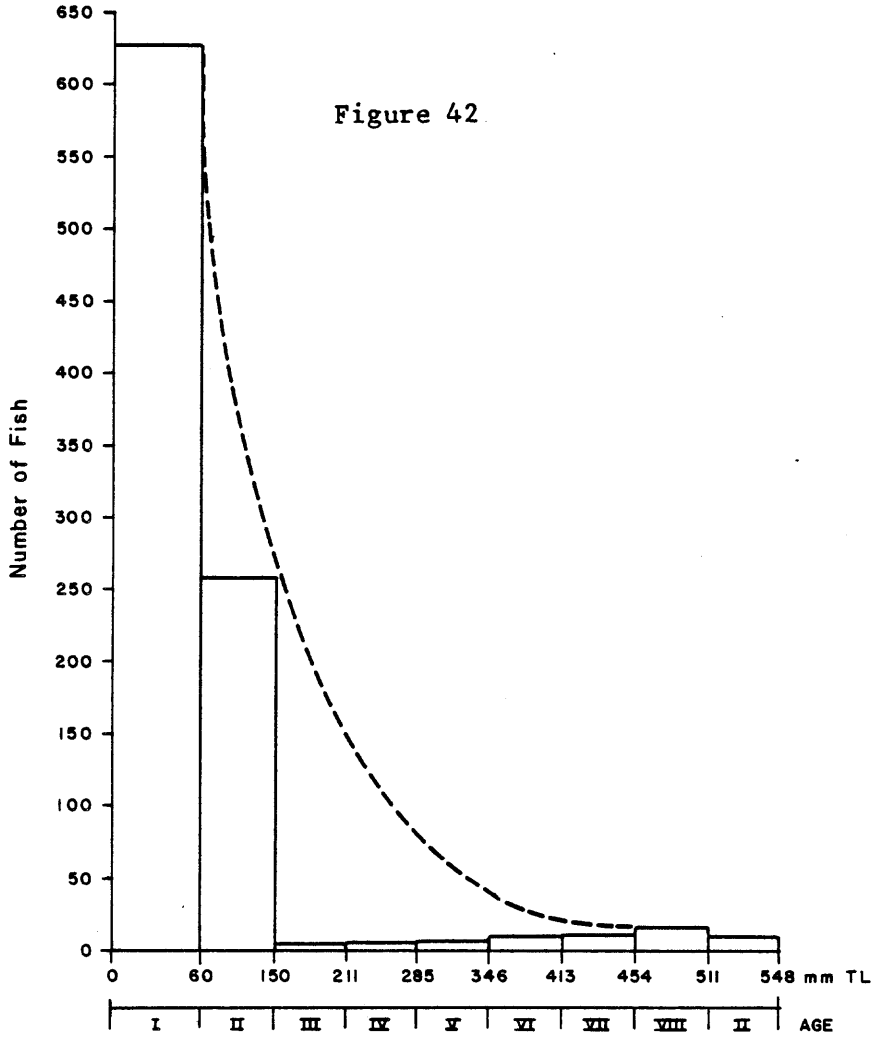
Age, Growth, and Mortality

Scale samples taken from Colorado squawfish captured in the Green River were analyzed by Musker (1981). Mean fish length reported from annulus length indicated an average annual growth of 56.8 millimeters. Growth was found to vary between 36 to 74.5 millimeters between annulus formation and growth appeared to slow after the fifth (V) annulus. The period of slowest growth (36 millimeters) was found between VII and VIII.

The first annulus Musker (1981) reported is apparently the second annulus, since the predicted TL at I was 150.3. Our collections indicate Colorado squawfish do not obtain this length until the second year of life. Work done by Seethaler (1978) indicated the third annulus is formed at 173 millimeters. If II is taken at 150.3 millimeters, Musker's (1981) findings are in general agreement with Seethaler (1978), except our 1979-1981 collections exhibited faster growth during younger stages than the 1974-1976 collections of Seethaler (1978). It is expected that TL at II would be greater than the 71 millimeter average obtained by Seethaler (1978). Vanicek and Kramer (1969) indicated their fish were all collected above Jensen, Utah, and would be expectd to grow slower. Vanicek and Kramer indicated the average TL at I to be 44 millimeters and average TL at II to be 95 millimeters. It is probable that TL at I from the 1979-1981 collections are between the sizes predicted by these workers (44-71 millimeters).

Collections of YOY fish were made throughout the study and their TL in October (end of growth for the year) ranged from 30-70 millimeters, with an average value of 50 millimeters. In order to provide the best estimate of the number of YOY fish in October, it appears better to use 60 millimeters to include a better approximation of the actual numbers present. This appears to be consistent with the preceding information. In order to approximate survivorship of Colorado squawfish by TL (Ricker, 1958), catches obtained by standardized sampling 1979-1981 were divided into the seven size classes (150-548 millimeters) determined by annuli. In addition, numbers of age 0 and I (age 0 to 1 year and age 1 to 2 years old) were obtained by using 60 millimeters as a dividing point since no first annulus was obtained. Figure 42 presents the resulting survivorship curve, which reflects the poor efficiency of collecting intermediate size fish (age II-III). The survival rate between 0 and I was 0.24 with the instantaneous rate of mortality (Z) = 1.43.

There does not appear to be a difference in gear selectivity for Colorado squawfish age 0 and I (less than 150 millimeters TL). This finding was used to calculate survivorship by another method. Since Colorado squawfish were found to spawn about July 1 (Tyus et al., 1982), catches were obtained for the 1979-1980 year of life by obtaining the number of YOY collected in the standardized program between July 1979 and July 1980. This number of young was then divided into the number of age I (TL 60-150 millimeters) Colorado squawfish collected between July 1980 and July 1981. The resulting survival rate was 0.28 (Z = 1.27). This rate (0.28) compares favorably with that obtained from using total catch, 1979-1981 (0.24). Unfortunately, data were obtained for only 2 years and further comparisons need to be made to substantiate these findings. Estimation of survival rate for young Colorado squawfish (age 0-I) is offered as a tool for monitoring long term survivorship since the method can be easily implemented in the field without sophisticated equipment.



Survivorship curve for Colorado squawfish, standardized sampling program, Green River, 1979-1981.

Spawning

Studies on the Yampa River documented spawning by Colorado squawfish in the lower 20 miles (32 kilometers) of Yampa Canyon in 1981, but these have not been compiled or analyzed. As described in the Movement and Migration section, a spawning migration of Colorado squawfish occurred by fish radiotagged in the Green and upper Yampa Rivers. There is no doubt that a "homing" instinct existed in these fish and data acquired will be computerized and analyzed with respect to relationships between behavior and environmental conditions.

Colorado squawfish appear to be very selective in their choice of spawning locations. Radiotelemetry studies in 1980 and 1981 and general habitat conditions observed on the spawning grounds identified in the lower 20 miles (32 kilometers) of the Yampa River suggest that suitable spawning habitat for Colorado squawfish is very limited in the Green River. Potential spawning sites include Split Mountain Canyon and Gray Canyon, with no suitable spawning areas existing between these two locations.

Tributary streams may be important as spawning grounds or summer habitat for Colorado squawfish. Radiotelemetry and recaptures of tagged

fish indicate there is spawning migration of Green River fish into the lower Yampa River and there is evidence of spawning movement between the White and Green Rivers also. More information will be provided in the Yampa and White River reports.

Distribution and abundance data for larval squawfish have aided in the identification of spawning areas in the Green River and these data are reported in the Habitat Preference and Movement and Migration sections. Two potential spawning areas for the Green River identified above have been substantiated by these collections.

Condition factors (K = wt. $10^5/TL^3$) were calculated for all adult (400 millimeters +) Colorado squawfish collected in 1979-1981. Since K is an index of spawning condition, collections were analyzed by K factor during prespawning (January - May), spawning migration (June), and postspawning (July - December) periods. K values for these periods were 0.76, 0.79, and 0.72, respectively. Although higher during the spawning migration period, no significant difference was obtained by ANOVA ($P = .0.10$).

It was suspected that the lack of significance was due to the presence of immature fish in the spawning migration subsample since Seethaler (1978) found 76 percent of Colorado squawfish males were mature at 503 millimeters TL but only 50 percent of the females matured by 503 millimeters TL (n=147). Based on 1981 radiotelemetry data, Colorado squawfish began migrating about May 20 and spawned July 1, 1981. Data for all adult Colorado squawfish collected during this period were retrieved (n=30) and K values calculated (K average = 0.779). If it is assumed that the sex ratio is about 1:1, it is probable that many of the smaller fish are immature females and a few would be immature males. Therefore, only Colorado squawfish with an above average K value were investigated as potential spawners.

Table 27 presents adult Colorado squawfish collected between May 20 and July 1, 1980 and 1981, with K values above average. The 14 fish obtained had an average K value of 0.848. These fish were further divided into two groups: (1) those collected within 2 weeks of the known 1981 spawning date (June 15 - July 1) and (2) those collected before this period (May 20 - June 15). The first group contained fish that should have been collected near the actual spawning site. The second group would not have been collected near the spawning site (Tyus et al., 1982) but rather would have been in migration.

The first four Colorado squawfish in Table 27 represent the first group and were probably near a spawning ground. All of these were collected between the mouth of the Yampa River and Split Mountain. Spawning is known to occur near the mouth of the Yampa and is suspected at Split Mountain.

The remaining Colorado squawfish (Table 27) represent the second group and were probably collected in migration and not on the spawning grounds. Of these, fishes Nos. 5-9 captured in an area of river with sand/silt habitat (not a suitable spawning substrate) and, if in migration, could have been moving upstream into the Split Mountain - lower Yampa area. Fishes Nos. 9 and 10 were collected near the

mouth of the White River and could have been migrating in or out of it. Fishes Nos. 11-13 were collected immediately below Gray Canyon, a suspected spawning location. Finally, fish No. 14 was collected slightly above Labyrinth Canyon and could also have been in migration to Gray Canyon.

Table 27
Adult Colorado squawfish collected during prespawning period (5/20 through 7/1), Green River, 1980 and 1981, with above average condition factors (K)[1/]

Fish number	River location[2/] RM	KM	Date	Tag	Total length	K	Sub[3/]	Habitat
1	344	550	06/19/81	0201	477	.8845	BO	ED
2	323	517	06/22/81	0411	603	.8392	BO	ED
3	323	517	06/23/81	0283	446	.8059	BO	SH
4	321	514	06/23/81	0468	641	.8353	RU	SH
5	308	493	05/27/81	0264	522	.8507	SI	BA
6	308	493	05/27/81	0357	422	.7957	SI	BA
7	308	493	05/27/81	0326	562	.8789	SI	PO
8	299	478	05/28/81	0364	532	.9298	SA	SH
9	247	395	05/28/81	0006	707	.9366	SI	SH
10	247	395	05/29/80	0058	418	.8161	SI	SH
11	118	189	05/20/81	0337	606	.8538	SI	ED
12	113	181	05/20/81	0311	508	.8086	RU	SH
13	97	155	05/21/80	0145	602	.8251	SA	SH
14	73	117	05/28/81	0454	518	.8058	BO	SH
Average					540	.8476		

1/ $K = Wt10^5TL^3$.
2/ From confluence with Colorado River.
3/ Primary substrate at point of capture.

Radiotelemetry studies initiated on the Yampa project have been most helpful in evaluating spawning of Colorado squawfish. One final observation made from the preliminary results of that study deals with one very large Colorado squawfish radiotagged in Echo Park. This fish moved upstream in the Green River and was found occupying potential spawning habitat near the Gates of Lodore. Although extensive sampling was conducted at that location, no other Colorado squawfish were found. It is possible that fish historically migrated into Lodore Canyon during the spawning season in response to a homing instinct. Changed conditions due to Flaming Gorge Dam could preclude or reduce successful spawning at that location today.

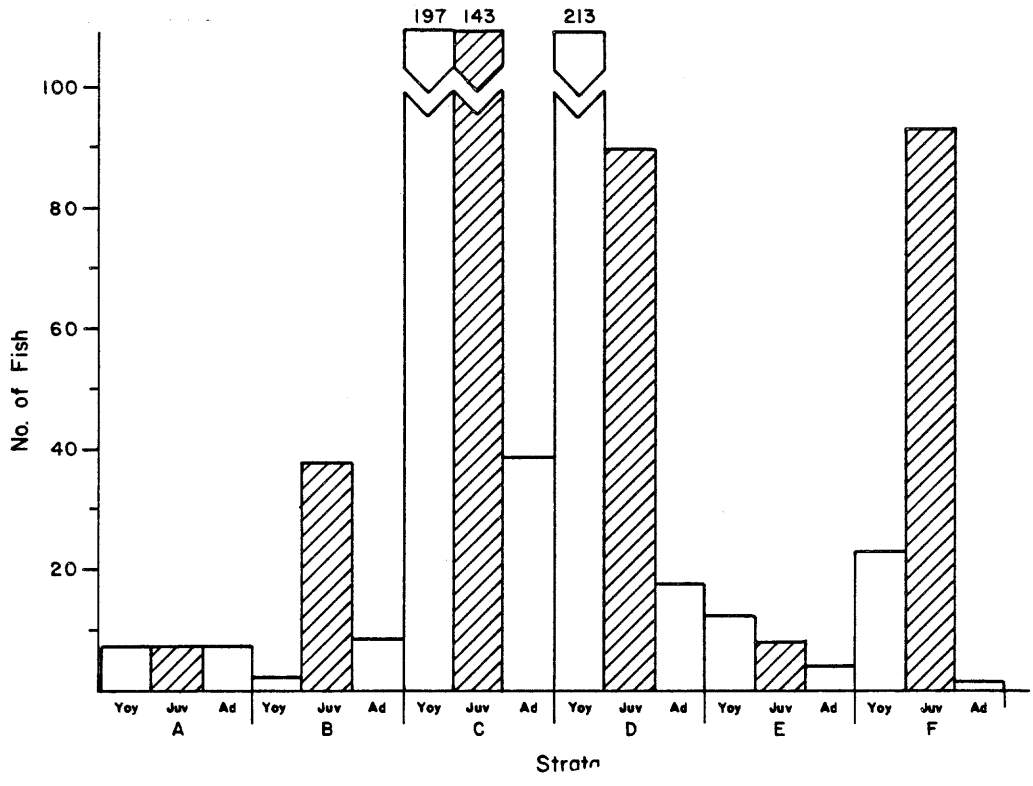
Humpback and Bonytail Chub

The endangered humpback chub (*Gila cypha*) and bonytail chub (*Gila elegans*) are difficult to identify at all life stages. This problem is also compounded by the presence of the roundtail chub (*Gila robusta*). For the purpose of this report, chubs of the genus *Gila* are referred as *Gila* species (spp.) except where more definitive information exists. Taxonomy of *Gila* species is discussed in the Taxonomy section of this report.

Distribution and Relative Abundance

A total of 910 Gila spp. were captured from the standardized sampling program, 1979-1981. Of these, 456 were YOY, 378 juveniles, and 76 adults. Gila spp. were distributed over all six strata. Most Gila spp. were collected from strata C (379) and D (319) (Figure 43). These strata are enclosed by canyon walls of rock substrate and contain deep swift water and large eddies and rapids. These habitat features are unlike those of the other four Green River strata. Most adult Gila spp. were collected in stratum C (39). Stratum A contained the fewest Gila spp. (21). Although efficiency of collection between gear varies with sampled habitat and the size of fish, these data appear to offer an approximate abundance for the different age groups.

Figure 43



Number of young-of-the-year (YOY), juvenile (Juv), and adult (Ad) Gila spp. per strata caught during standardized stations, 1979-1981, Green River, Utah.

In 1980 and 1981, humpback and bonytail chubs were collected in Gray Canyon (tailrace of Coal Creek Rapid) of the Green River. During the 4-day sampling period in 1980, 27 Gila spp. were collected with trammel or gill nets. Of these, nine were less than 260 millimeters TL and, therefore, classified as juveniles. A total of three YOY and 17 juveniles were collected with 1/4-inch mesh seines. During four different collections in 1981 (April, June, July, and September) a total of 37 Gila spp. were captured in the 0.2 mile (0.3 kilometer) tailrace below

Coal Creek Rapid (RM 145.5-146.7, 234-236 kilometers) using trammel nets; 38 were collected by seine. A total of 68 juvenile and adult Gila spp. were captured in 1980 and 1981 at the base of Coal Creek Rapid. A representative subsample of these fish indicates that humpback and roundtail chub predominated, but bonytail chub also were found there (see Taxonomy section).

Migration and Movement

Migration and movement data for Gila spp. were based primarily on conventional tag returns. Diel studies of juvenile and adult Gila spp. provided short term movement information.

During the 2-year study period a total of 128 Gila spp. were tagged with Carlin dangler tags. This included fish tagged during the standardized sampling and special investigation programs. During that period, only 13 fish were recaptured (Table 28). Five Gila spp. were recaptured in 1979, two in 1980, and six in 1981. Twelve Gila spp. were recaptured during the special investigations and only one during the standardized sampling. In 1979, three recaptures of Gila spp. were made either the same or 1 day after the initial capture in the same location as released. The two remaining fish moved short distances downstream (3.3 and 5.2 miles (5.3 and 8.4 kilometers), respectively). These Gila spp. were all recaptured in stratum C. In 1980, the two recaptured Gila spp. were caught within 0.2 mile (0.3 kilometer) of their original capture site.

The special surveys at Coal Creek Rapid revealed some interesting and important findings. During six individual surveys, a total of 71 Gila spp. were captured. Of these, 52 were Carlin dangler-tagged and released. Over a 12-month period, 10 Gila spp. were recaptured within 0.1 mile (0.2 kilometer) of the initial release point. Even more interesting were the multiple recaptures of Gila: Tag No. 2046 was recaptured three times and Tag No. 074 recaptured twice. These two fish were last recaptured July 12, 1981, 10 months after their initial capture. One Gila spp., Tag No. 2055, was recaptured September 1981, 362 days after its release.

The recapture of these fish after several months appeared to be an important finding since only 71 adult and juvenile fish were captured at this site. When calculated as a percentage, recaptures amounted to 15 percent of the total catch of adults and juveniles. This would suggest that these fish were relatively stationary at that location. Also, since 15 percent of the total adult and juvenile catch were recaptures, Gila stocks in this locale are not large.

Gila spp. tagged with Carlin tags appeared to remain in the same general area. This is consistent with findings by other researchers (Valdez, 1980; Kaeding and Zimmerman, 1980) who reported recaptures of Gila spp. in the same area up to 1 year after release. A Schumacher-Eschmeyer estimator was used to provide a population estimate. The mean point estimate was 185 with a 95 percent confidence interval of 158 to 223 fish.

Table 28

Recaptures of Gila spp., all collections Green River, 1979-1981

Carlin tag number	Capture					Recapture					Distance[1/]	
	Total length	Weight (grams)	Date	River mile	(km) River	Total length	Weight (grams)	Date	River mile	(km) River	mile	(km)
034	283	140	8-12-80	145.5	(234) GN	283	140	9-29-80	145.5	(234) GN	0	
040	350	340	9-17-80	229.7	(370) GN	355	340	6-03-81	224.8	(360) GN	4.9	(7.9)
048	320	200	8-12-80	145.6	(234) GN	325	240	4-23-81	145.6	(234) GN	0	
069	335	250	8-13-80	145.4	(234) GN	339	244	9-29-80	145.6	(234) GN	0.1	(1.6)
074	237	104	9-30-80	145.6	(234) GN	251	120	7-10-81	145.6	(234) GN	0	
074	-	-	-	-	-	251	120	7-12-81	145.6	(234) GN	0	
109	360	345	8-21-79	155.5	(250) GN	360	345	8-21-79	155.5	(250) GN	0	
117	304	300	8-21-79	155.5	(250) GN	304	300	8-21-79	155.5	(250) GN	0	
120	327	280	8-21-79	155.5	(250) GN	327	280	8-21-79	152.2	(245) GN	3.3	(4.9)
121	296	245	8-21-79	155.5	(250) GN	296	245	8-22-79	150.3	(242) GN	5.2	(8.4)
143	270	130	10-23-79	140.6	(226) GN	270	130	10-23-79	140.5	(226) GN	0	
2004	292	176	9-30-80	145.6	(234) GN	298	170	7-11-81	145.6	(234) GN	0	
2046	339	244	9-30-80	145.6	(234) GN	341	275	4-23-81	145.6	(234) GN	0	
2046	-	-	-	-	-	343	220	7-11-81	145.6	(234) GN	0	
2046	-	-	-	-	-	343	220	7-12-81	145.6	(234) GN	0	
2055	242	124	9-30-80	145.6	(234) GN	248	105	9-27-81	145.6	(234) GN	0	

1/ From point of release to point of recapture.

During September 1980 and July 1981, the diel movement patterns of juvenile and adult Gila spp. were evaluated at Coal Creek Rapid. In order to compare daily activity patterns, catch per unit effort (fish/net hour) was employed. Although low catch rates may reflect net avoidance, the relationship between time of day and the numbers of Gila spp. collected provided information regarding diel activity patterns.

In September 1980, Gila spp. catch rates were highest at 0900, 1200, and 1600 hours (Figure 44). In July 1981, manpower shortages precluded around the clock sampling. The time period 2400 to 0900 hours was not fished during this sampling. The time of the highest catch rate in July 1981 for Gila spp. (1100 hours) closely resembled that of the September 1980 sampling (1200 hours). Identical areas and eddy habitats sampled during 1981 suggested that use of these areas occurs during midday (Figure 45).

Habitat Preferences

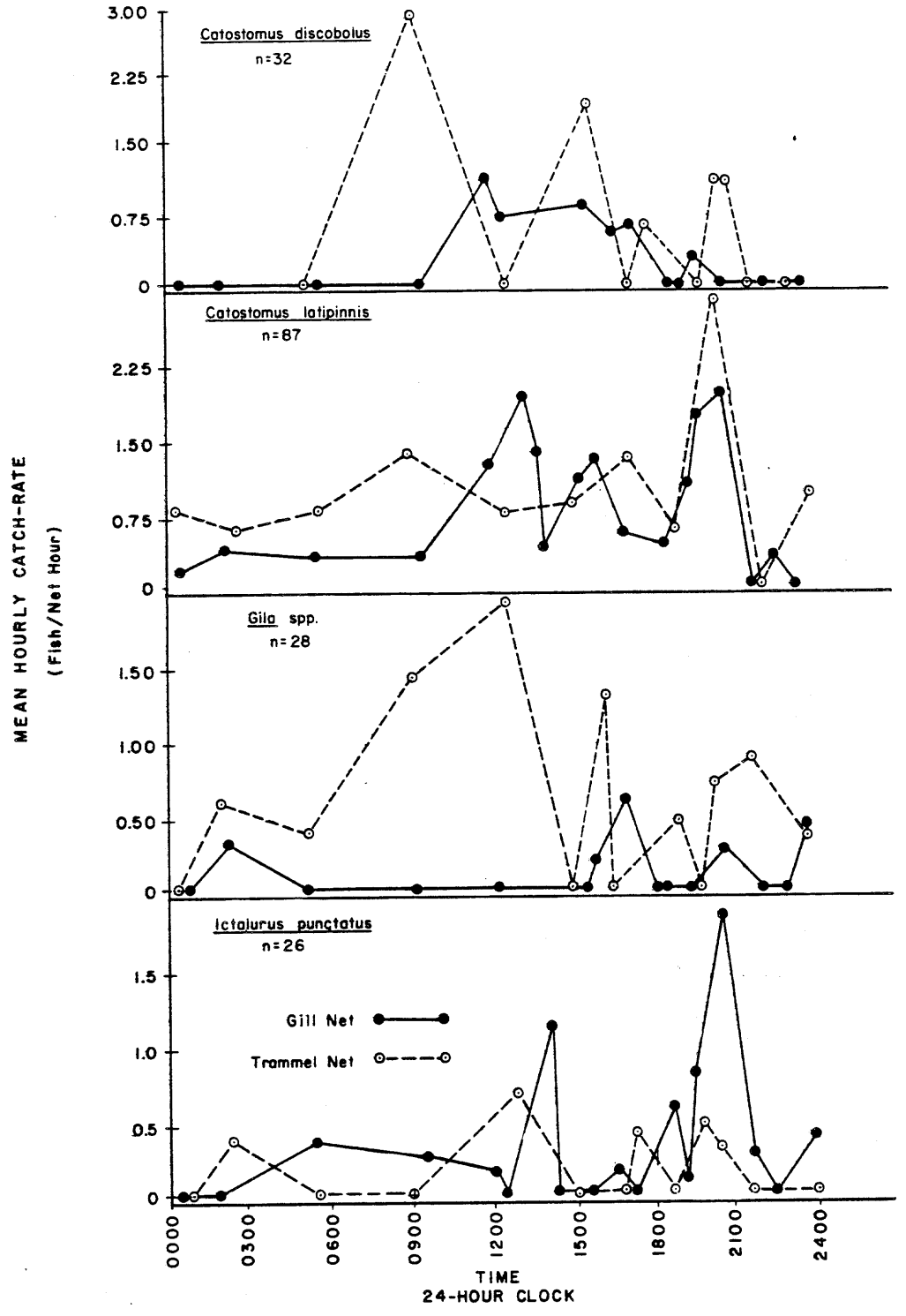
Adult.--Adult Gila spp. appear to select a variety of habitats, depending upon the life history. Adult Gila spp. were defined as those fish greater than 260 millimeters TL, juveniles 61-259 millimeters TL, and YOY 1-60 millimeters TL.

Habitat preference data for adult Gila spp. were collected during the 1979-1981 standardized sampling program. Adult Gila spp. selected eddy and shoreline habitats over sand/silt substrate almost exclusively (Table 29). A few adult Gila spp. were collected in runs. Adult Gila spp. collected during the standardized sampling, all collections in 1979-1981, preferred water velocities with a mean of 0.8 ft/sec (0.3 m/sec) (Table 30). Water depths averaged 4.2 feet (1.3 meters) during the standardized sampling and 5.0 feet (1.5 meters) for all collections (Table 31).

Table 29
Habitat and substrate at point of capture for adult Gila spp., standardized sampling (SS) and all collections (AC), 1979-1981, Green River, Utah

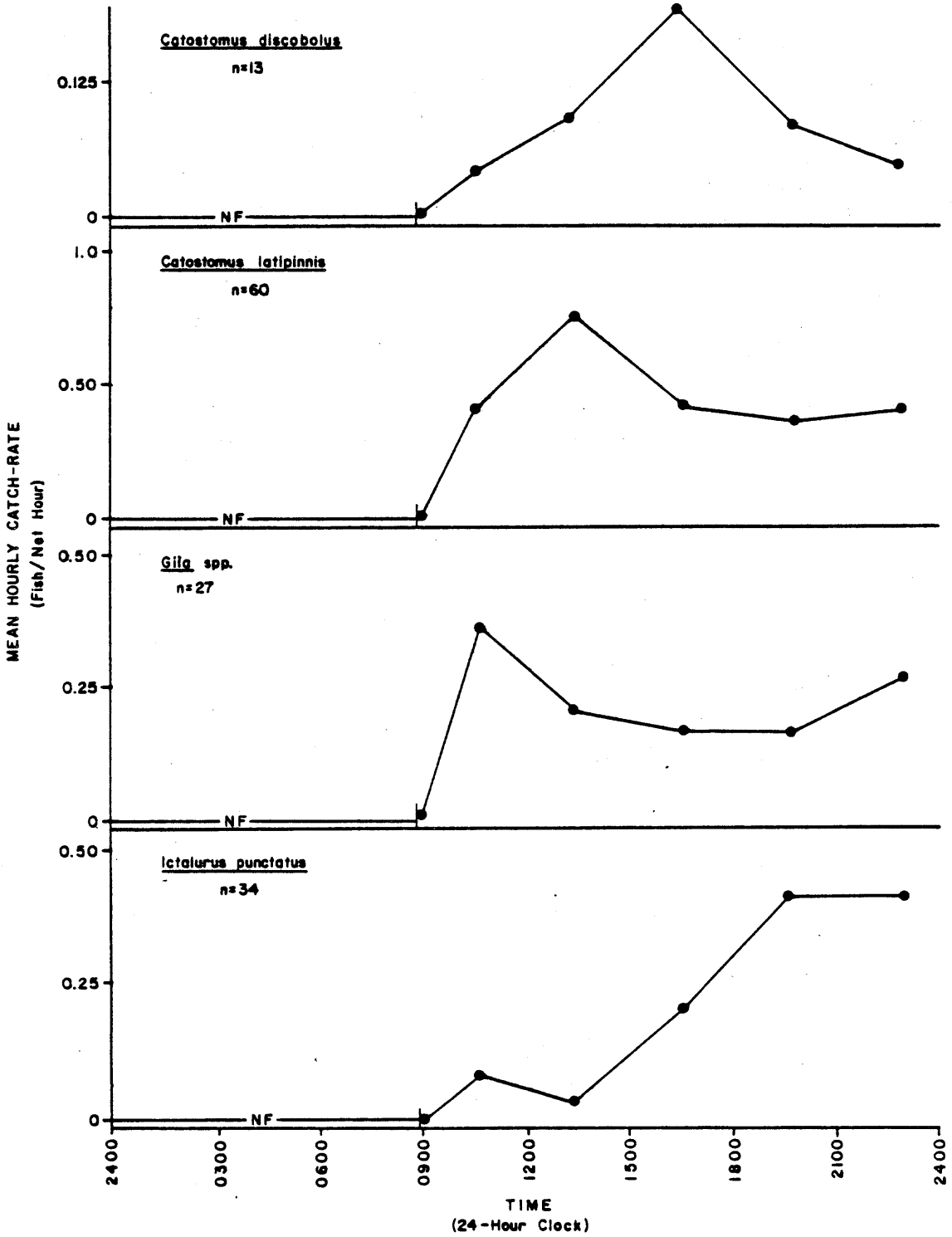
	Number of fish			Number of fish	
Habitat	SS	AC	Substrate	SS	AC
Backwater	1	3	Silt	10	13
Eddy	26	76	Sand	20	21
Isolated pool	0	0	Gravel	1	1
Main channel	0	0	Rubble	2	2
Pool	1	0	Boulder	4	2
Riffle	1	1	Bedrock	0	0
Run	9	11			
Shoreline	16	22			
Side channel	0	0			

Figure 44



Catch per unit of effort (fish/net hour) vs. time of four fish species collected by trammel and gill nets in Gray Canyon (stratum C) of the Green River, September 27-30, 1980. Note: One net hour equals one trammel net 150' x 6' x 1" (inner bar) x 10" (outer bar); one gill net 150' x 6' x 1½" bar. Total effort for the trammel and gill net was 35.6 and 80.1 hours, respectively.)

Figure 45



Catch per unit of effort (fish/net hour) vs. time of four fish species collected with trammel nets in Gray Canyon (stratum C) of the Green River, July 10-13, 1981.

Table 30
Water velocity at point of capture for adult Gila spp. collected during standardized sampling program and all collections, 1979, 1980, and 1981

Standardized sampling program[1]			All collections[2]		
Water velocity (ft/sec)	Number of fish	Frequency (percent)	Water velocity (ft/sec)	Number of fish	Frequency (percent)
0.000 to .109	3	10.00	0.000 to .380	10	28.57
.109 to .217	3	10.00	.380 to .760	12	34.29
.217 to .326	4	13.33	.760 to 1.140	6	17.14
.326 to .434	5	16.67	1.140 to 1.520	2	5.71
.434 to .543	3	10.00	1.520 to 1.900	2	5.71
.543 to .651	1	3.33	1.900 to 2.280	0	0.00
.651 to .760	1	3.33	2.280 to 2.660	1	2.86
.760 to .869	2	6.67	2.660 to 3.040	0	0.00
.869 to .977	1	3.33	3.040 to 3.420	1	2.86
1.086 to 1.194	1	3.33	3.420 to 3.800	1	2.86
1.194 to 1.303	1	3.33			
1.303 to 1.411	0	0.00			
1.411 to 1.520	0	0.00			
1.520 to 1.629	0	0.00			
1.629 to 1.737	1	3.33			
1.737 to 1.846	0	0.00			
1.846 to 1.954	1	3.33			
1.954 to 2.063	0	0.00			
2.063 to 2.171	0	0.00			
2.171 to 2.280	0	0.00			
2.280 to 2.389	0	0.00			
2.389 to 2.497	0	0.00			
2.497 to 2.606	1	3.33			
2.606 to 2.714	0	0.00			
2.714 to 2.823	0	0.00			
2.823 to 2.931	0	0.00			
2.931 to 3.040	0	0.00			
3.040 to 3.149	1	3.33			
2.149 to 3.257	0	0.00			
3.257 to 3.366	0	0.00			
3.366 to 3.474	0	0.00			
3.474 to 3.583	0	0.00			
3.583 to 3.691	0	0.00			
3.691 to 3.800	1	3.33			

1/ n=35, $\bar{x}$=0.83, min=0.0, max=3.8, st. dev=0.85, variance = 0.74
2/ n=35, $\bar{x}$=0.82, min=0.0, max=3.8, st. dev=0.93, variance=0.86

Table 31
Water depths at point of capture for adult Gila spp. collected during standardized sampling and all collections, 1979, 1980, and 1981, Green River, Utah

Standardized sampling program 1/			All collections 2/		
Depth (feet)	Number of fish	Frequency (percent)	Depth (feet)	Number of fish	Frequency (percent)
1.100 to 2.140	15	36.59	1.100 to 2.660	23	44.23
2.140 to 3.180	8	19.51	2.660 to 4.220	13	25.00
3.180 to 4.220	8	19.51	4.220 to 5.780	2	3.85
4.220 to 5.260	2	4.88	5.780 to 7.340	2	3.85
5.260 to 6.300	1	2.44	7.340 to 8.900	3	5.77
6.300 to 7.340	1	2.44	8.900 to 10.460	1	1.92
7.340 to 8.380	2	4.88	10.460 to 12.020	1	1.92
8.380 to 9.420	0	0.00	12.020 to 13.580	0	0.00
9.420 to 10.460	1	2.44	13.580 to 15.140	5	9.62
10.460 to 11.500	0	0.00	15.140 to 16.700	2	3.85
11.500 to 12.540	0	0.00			
12.540 to 13.580	0	0.00			
13.580 to 14.620	1	2.44			
14.620 to 15.660	0	0.00			
15.660 to 16.700	2	4.88			

1/ n=15, $\bar{x}$=4.2, min=1.1, max=16.7, variance=15.2
2/ n=52, $\bar{x}$=5.0, min=1.1, max=16.7, variance=21.9

Juveniles.--Juvenile Gila spp. were captured most frequently in shoreline and backwater habitats. They were also collected in runs and eddies (Table 32). Juveniles were collected consistently over sand and silt substrates located near boulders.

Table 32
Habitat and substrate at the point of capture for juvenile Gila spp. collected during standardized sampling (SS) and all collections (AC), 1979-1981, Green River, Utah

	Number of fish			Number of fish	
Habitat	SS	AC	Substrate	SS	AC
Backwater	39	65	Silt	60	115
Eddy	19	49	Sand	72	96
Isolated pool	0	0	Gravel	0	0
Main channel	0	1	Rubble	10	10
Pool	0	6	Boulder	15	15
Riffle	4	4	Bedrock	0	0
Run	23	64			
Shoreline	84	140			
Side channel	3	3			

Juvenile Gila spp. collected during the standardized sampling were collected in habitats having a mean water velocity of 0.8 ft/sec (0.2 m/sec), slightly less than that of the mean velocity preferred by fish in all collections - (0.90 ft/sec, 0.3 m/sec (Table 33).

The recorded water depth was nearly identical for both the standardized sampling (1.5 feet, 0.5 millimeters) and all collections (1.4 feet, 0.4 meters) (Table 34).

Table 33

Water velocity at point of capture for juvenile Gila spp. collected during standardized sampling program and all collections, 1979, 1980 and 1981, Green River, Utah

Standardized sampling program[1]			All collections[2]		
Water velocity (ft/sec)	Number of fish	Frequency (percent)	Water velocity (ft/sec)	Number of fish	Frequency (percent)
0.000 to .100	32	22.70	0.000 to .100	58	26.61
.100 to .200	11	7.80	.100 to .200	12	5.50
.200 to .300	10	7.09	.200 to .300	14	6.42
.300 to .400	6	4.26	.300 to .400	23	10.55
.400 to .500	0	0.00	.400 to .500	0	0.00
.500 to .600	24	17.02	.500 to .600	39	17.89
.600 to .700	0	0.00	.600 to .700	4	1.83
.700 to .800	12	8.51	.700 to .800	13	5.96
.800 to .900	6	4.26	.800 to .900	12	5.50
.900 to 1.000	0	0.00	.900 to 1.000	0	0.00
1.000 to 1.100	5	3.55	1.000 to 1.100	7	3.21
1.100 to 1.200	0	0.00	1.100 to 1.200	0	0.00
1.200 to 1.300	4	2.84	1.200 to 1.300	4	1.83
1.300 to 1.400	4	2.84	1.300 to 1.400	4	1.83
1.400 to 1.500	0	0.00	1.400 to 1.500	0	0.00
1.500 to 1.600	8	5.67	1.500 to 1.600	9	4.13
1.600 to 1.700	0	0.00	1.600 to 1.700	0	0.00
1.700 to 1.800	0	0.00	1.700 to 1.800	0	0.00
1.800 to 1.900	3	2.13	1.800 to 1.900	3	1.38
1.900 to 2.000	0	0.00	1.900 to 2.000	0	0.00
2.000 to 2.100	2	1.42	2.000 to 2.100	2	.92
2.100 to 2.200	0	0.00	2.100 to 2.200	0	0.00
2.200 to 2.300	6	4.26	2.200 to 2.300	6	2.75
2.300 to 2.400	0	0.00	2.300 to 2.400	0	0.00
2.400 to 2.500	0	0.00	2.400 to 2.500	0	0.00
2.500 to 2.600	7	4.96	2.500 to 2.600	7	3.21
2.600 to 2.700	0	0.00	2.600 to 2.700	0	0.00
2.800 to 2.800	1	.71	2.700 to 2.800	1	.46

1/ n=141, $\bar{x}$=0.79, min=0.0, max=2.8, st. dev=0.76
2/ n=218, $\bar{x}$=0.90, min=0.0, max=2.8

Table 34

Water depths at point of capture for juvenile Gila spp. collected during standardized sampling and all collections, 1979, 1980 and 1981, Green River, Utah

Standardized sampling program[1]			All collections[2]		
Water depth (feet)	Number of fish	Frequency (percent)	Water depth (feet)	Number of fish	Frequency (percent)
.400 to .657	22	13.58	.300 to 1.280	104	43.33
.657 to .914	30	18.52	1.280 to 2.260	112	46.67
.914 to 1.171	12	7.41	2.260 to 3.240	21	8.75
1.171 to 1.429	13	8.02	3.240 to 4.220	2	.83
1.429 to 1.686	29	17.90	4.220 to 5.200	0	0.00
1.686 to 1.943	29	17.90	5.200 to 6.180	0	0.00
1.943 to 2.200	6	3.70	6.180 to 7.160	0	0.00
2.200 to 2.457	4	2.47	7.160 to 8.140	0	0.00
2.457 to 2.714	10	6.17	8.140 to 9.120	0	0.00
2.714 to 2.971	2	1.23	9.120 to 10.100	0	0.00
2.971 to 3.229	2	1.23	10.100 to 11.080	0	0.00
3.229 to 3.486	0	0.00	11.080 to 12.060	0	0.00
3.486 to 3.743	2	1.23	12.060 to 13.040	0	0.00
3.743 to 4.000	1	.62	13.040 to 14.020	0	0.00
			14.020 to 15.000	1	.42

1/ n=162, $\bar{x}$=1.5, min=0.4, max=4.0, st. dev=0.71
2/ n=240, $\bar{x}$=1.4, min=0.3, max=15.0

Young.--YOY Gila spp. were found in a diversity of habitat types; however, they were captured mainly in backwaters, shorelines, and runs. Collections were made primarily over sand and silt substrates, but occasionally over rubble (Table 35).

Table 35
Habitat and substrate at point of capture for YOY Gila spp. collected during standardized sampling (SS) and all collections (AC), 1979-1981, Green River, Utah

Habitat	Number of fish SS	Number of fish AC	Substrate	Number of fish SS	Number of fish AC
Backwater	128	1,074	Silt	171	890
Eddy	85	15	Sand	223	301
Isolated pool	0	0	Gravel	0	0
Main channel	0	0	Rubble	37	39
Pool	2	6	Boulder	9	5
Riffle	4	2	Bedrock	0	0
Run	77	13			
Shoreline	124	58			
Side channel	33	33			

Most YOY Gila spp. appeared to select water velocities ranging from 0.0-1.0 ft/sec (0.0-0.3 m/sec). Fish collected during the standardized sampling preferred velocities of 0.5 ft/sec (0.2 m/sec) while young Gila collected during all collections preferred a lower mean velocity (0.3 ft/sec, 0.1 m/sec) (Table 36). YOY Gila were found over a variety of water depths ranging from 0.5 to 4.0 feet (0.2 to 1.2 meters) with a mean of 1.4 feet (0.4 meters) and 0.7 feet (0.2 meters) for fish collected during standardized sampling and all collections, respectively (Table 37).

Table 36
Water velocities at point of capture for YOY Gila spp. collected during standardized sampling and all collections, 1979, 1980, and 1981, Green River, Utah

Standardized sampling program[1] Water velocity (ft/sec)	Number of fish	All collections[2] Water velocity (ft/sec)	Number of fish
0.0 to 0.2	242	0.0 to 0.2	335
0.2 to 0.4	148	0.2 to 0.4	59
0.4 to 0.6	27	0.4 to 0.6	24
0.6 to 0.8	12	0.6 to 0.8	0
0.8 to 1.0	13	0.8 to 1.0	12
1.0 to 1.2	6	1.0 to 1.2	7
1.2 to 1.4	1	1.2 to 1.4	0
1.4 to 1.6	2	1.4 to 1.6	1
1.6 to 1.8	0	1.6 to 1.8	0
1.8 to 2.0	0	1.8 to 2.0	0

1/ n=451 x=0.5, min=0.0, max=1.5, st. dev=0.7
2/ n=428, x=0.3, min=0.0, max=1.5, st. dev=0.6

Table 37
Water depths at the point of capture for YOY Gila spp. collected during standartdized sampling and all collections 1979-1981, Green River, Utah

Standardized sampling program[1/]		All collections[2/]	
Water depth (feet)	Number of fish	Water depth (feet)	Number of fish
0.0 to 0.4	33	0.0 to 0.4	664
0.4 to 0.9	102	0.4 to 0.9	1,069
0.9 to 1.4	169	0.9 to 1.4	224
1.4 to 1.9	34	1.4 to 1.9	90
1.9 to 2.4	52	1.9 to 2.4	153
2.4 to 2.9	50	2.4 to 2.9	51
2.9 to 3.4	0	2.9 to 3.4	7
3.4 to 3.9	16	3.4 to 3.9	16
3.9 to 4.4	0	3.9 to 4.4	3
		4.4 to 4.9	1

1/ n=456, $\bar{x}$=1.4, min=0.0, max=3.6, st. dev=0.6
2/ n=2,278, $\bar{x}$=0.73, min=0.1, max=4.8, st. dev=0.7

Associated Species

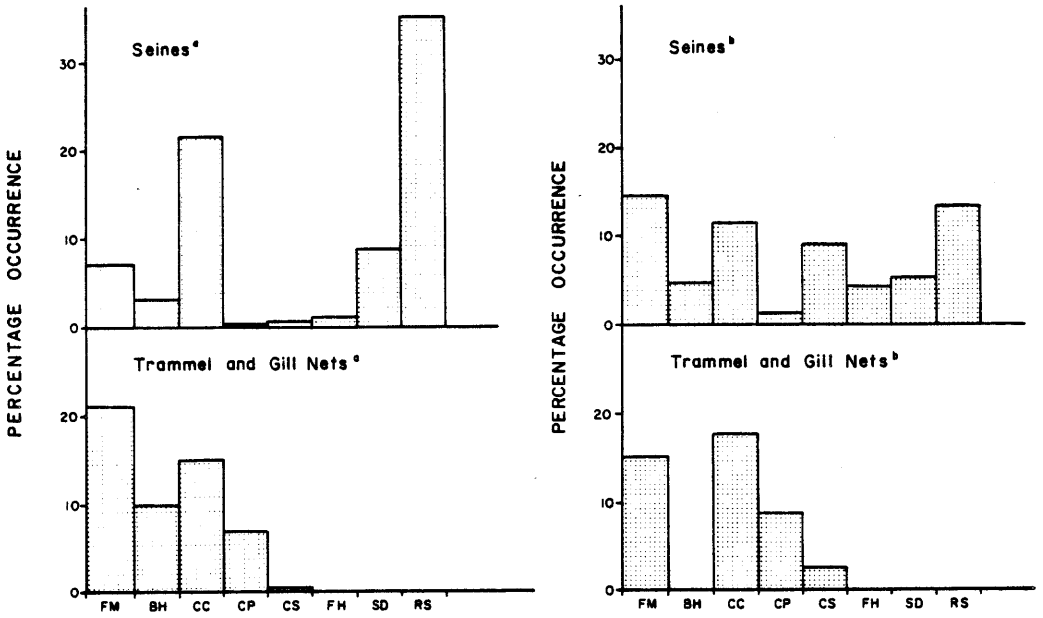
In order to evaluate the numbers and fish species associated with Gila spp., collections made at Coal Creek Rapid in 1980 and 1981 were analyzed and compared with other collections in stratum C. Catch rates of juvenile and adult fishes (trammel and gill nets) were compared during different times of day. In addition, a percentage occurrence index for two gear types (trammel and gill nets and seines) was utilized in support of catch per effort data to determine species coexistance with Gila spp.

Juvenile and adult Gila spp. were collected in association primarily with four fish species at Coal Creek. These were: flannelmouth suckers, 22 percent of the time; channel catfish, 15 percent of the time; bluehead suckers, 10 percent of the time; and carp 7 percent. Adult and juvenile Colorado squawfish were found associated only 1 percent of the time with Gila spp. Red shiners were found associated 35 percent of the time with YOY and juvenile Gila spp.; channel catfish, 22 percent of the time; and speckled dace and flannelmouth each about 13 percent of the time (Figure 46).

Because of the abundance of Gila spp. at Coal Creek Rapids, these collections were compared to collections in stratum C. Species found in association most with Gila spp. in trammel and gill net catches were channel catfish (17 percent), flannelmouth suckers (15 percent), carp (8 percent), and Colorado squawfish (3 percent) (Figure 46).

Eight species were found in association with YOY and juvenile Gila spp. collected with seines at Coal Creek Rapids. Juvenile and YOY flannelmouth suckers were found with Gila spp. 14 percent of the time, red shiners 13 percent, and channel catfish 12 percent (Figure 46).

Figure 46



Occurrence of fish species collected with Gila spp. at Coal Creek Rapid (a) and in stratum C (excluding Coal Creek Rapid (b)), Green River, Utah, 1979-1981. (FM = flannelmouth sucker, BH = bluehead sucker, CC = channel catfish, CP = carp, CS = Colorado squawfish, FH = fathead minnow, SD = speckled dace, RS = red shiner).

In September 1980, movement patterns of five fish species captured with Gila spp. were recorded. These included a total of 20 adult and 67 juvenile flannelmouth suckers, 26 adult and 6 juvenile bluehead suckers, 13 adult and 13 juvenile channel catfish, 1 adult carp, and 1 adult Colorado squawfish. However, because of small sample size, only the daily activity patterns of four species are discussed: bluehead and flannelmouth suckers, channel catfish, and Gila spp.

Marked changes in the catch rates vs. time for flannelmouth suckers and channel catfish were noted (Figure 44). Both species were more abundant in catches during 1200-1400 hours and 1900-2200 hours. Trammel net catch per effort for bluehead suckers exhibited three peaks; one at 0900, 1500, and 2100 hours, although a consistant gill net catch rate was evident from 1200-1700 hours (Figure 44). Gila spp. catch rates were highest at 0900, 1200, and 1600 hours (trammel nets). This information is hard to interpret since the catches represent one trammel net catch for each time. Gill net catch rates during the same time periods were nonexistent or low.

Considering both gear types, all four species generally exhibited lower catch rates from 2200-0600 than from 0600-2200 hours. It is possible that these four species are less active during the periods of low catchability and more active during periods when they are more effectively captured by these gear types.

In July 1981, a total of 51 juvenile and 9 adult flannelmouth suckers, 8 juvenile and 5 adult bluehead suckers, 3 adult carp, 5 juvenile and 22 adult Gila spp., and 26 juvenile and 9 adult channel catfish were collected. Gila spp. catch rates were highest during midday (1100-1200 hours), bluehead catch rates were highest at 1500-1800 hours, and flannelmouth catch rates were highest at 1300-1500 hours (Figure 45).

Because around the clock sampling was not feasible in July 1981, it is difficult to make comparisons with the catch rates obtained in September 1980. However, some gross deductions regarding movement can be made from the two individual samplings: (1) Gila spp. appear to be more active at midday in the habitat (eddies) sampled; (2) channel catfish are more active in the habitat sampled between 1800-2300 hours; (3) bluehead suckers appeared to be more active around midmorning (0900 hours) and at midafternoon (1500 hours); and (4) flannelmouths tended to be active at 1200 and 2100 hours. These data suggest endemic species may tend to be more active during the same time periods.

Taxonomy

The genus Gila is represented by G. cypha, G. elegans, and G. robusta. Adult specimens exhibiting the characteristic features of G. cypha and G. robusta are readily identified afield by gross morphology. However, the features are often not well developed and difficult to observe in young and juveniles. Intermediates or variants of both species also occur and field identification of these is difficult.

Several criteria have been utilized to assist in the identification of the three species of Gila afield; fin ray counts, scale counts, fin lengths, nuchal hump depth, eye diameter, squamation, etc. No single criterion or set of criteria appear to readily segregrate the species.

The nuchal hump ratio was developed by Smith, et al. (1979) to assist identification of Gila spp. and hopefully eliminate the need for many other morphologic measurements that were cumbersome or required sacrifice of the fish. The ratio $\frac{P_1P_2}{d}$ is derived by dividing the distance between the origin of the pelvic and pectoral fins (P_1P_2) by the depth of the nuchal hump (d) the depth of plane measured from the highest part of the nuchal hump and dorsal tip of the snout to the bottom of the frontal depression.

A frequency distribution of nuchal hump ratios from 100 Gila spp. captured from the Green River in 1980 and 1981 was plotted for preliminary use. This figure indicated considerable overlap between species. Problems detected during our use of the nuchal hump ratio (Smith et al., 1979) are as follows:

1 (a) The method was developed from preserved specimens not live Gila. Measurements taken during this study are from live Gila (personal communication, G. R. Smith).

1 (b) Since it was possible that measurements may differ between live vs. preserved fish, measurements from the same fish,

both live and preserved, were taken. The measurements (P_1P_2 and d) differ after preservation. No consistent pattern developed between these two measurements among the six fish tested. This precluded the use of a common conversion factor. A Chi square analysis of the calculated ratio from live fish vs. preserved fish was performed. This analysis indicated a statistically significant difference ($p=0.001$ $n=16$, 15 df) between the ratio of the live fish vs. the ratio of the preserved fish.

2. Measurements taken by CRFP personnel have differed up to five units from person to person and from those measurements taken by G. R. Smith. Because four different people have taken measurements, interpretation of these ratios is difficult.

3. Gila spp. measured by FWS personnel having ratios in the midrange of being G. elegans (15-29) were later identified as being G. cypha by G. R. Smith and R. R. Miller.

Further refinement of this method is needed for field use. An attempt to resolve some of these problems was made in 1981. Gila spp. (adult and juvenile) collected in 1981 were photographed on a large square-centimeter grid board. This should aid in identifying those fish since morphologic counts and measurements can be made from the photographs. Photographs will be measured independently by several workers and results of these analyses will be compared.

No single criterion is available that can appropriately identify the fish in the laboratory or afield. The need to take morphomeristic measurements (possibly as many as 20) is impractical afield because it is time consuming and cumbersome and could lead to death of the fish. Additionally, it is difficult to transport the necessary equipment to remote areas where Gila spp. commonly occur. Most morphomeristic measurements (gillraker and vertebrae counts) taken from Gila spp. require the fish to be sacrificed. Also, standard systematic techniques require a large number of specimens. However, legal constraints for sacrificing a large number of endangered fishes preclude extensive collection and preservation to verify their identification.

All preserved specimens of Gila spp. collected from the Green River were recalled to the Vernal station. An effort was made to identify these specimens using taxonomic keys, professional judgment, and by corroborating with known authorities.

A number of meristic characters identified earlier (see Methods) were utilized to segregate Gila spp. Nineteen specimens subjected to this taxonomic analysis were identified as follows:

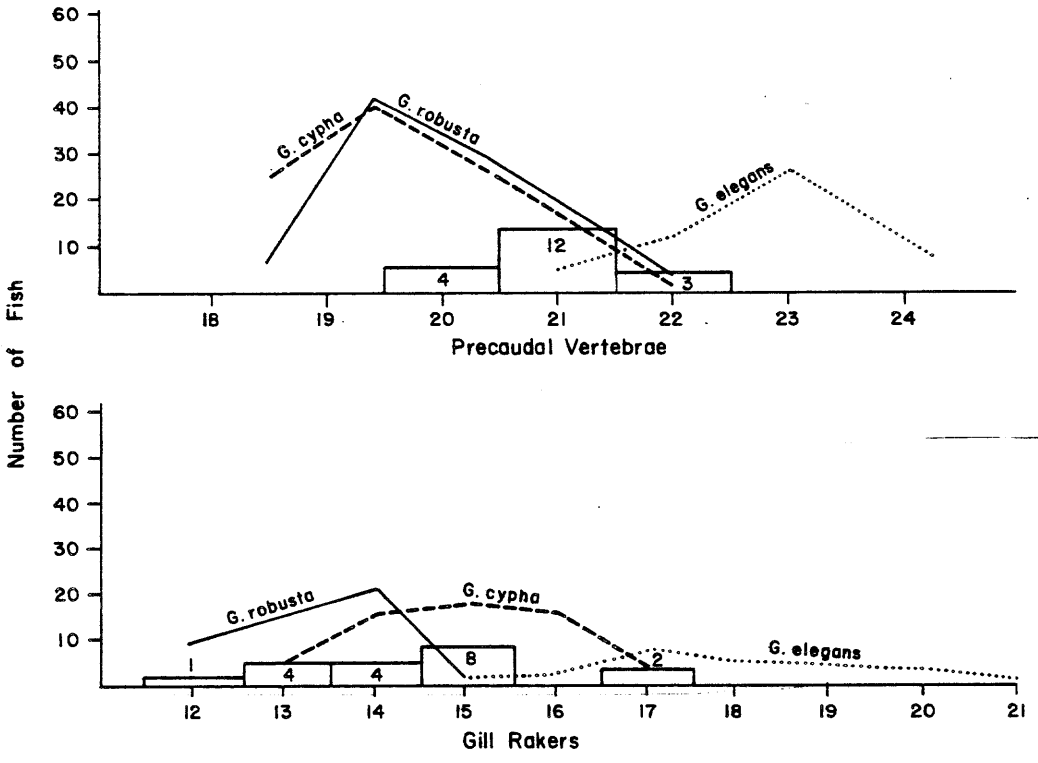
1. G. robusta (4)
2. G. cypha (5)
3. G. elegans (1)

In addition, three specimens appeared to be G. cypha influenced with G. robusta characteristics, two specimens appeared to be G. robusta

influenced with G. cypha characteristics, one specimen appeared to be G. cypha influenced with G. elegans characteristics, and three were classified unknown.

Meristic characters considered important were counts of precaudal vertebrae and gillrakers of the second arch (Smith, et al., 1979; Figure 47). Sixteen of the 19 Green River Gila specimens had precaudal vertebrae counts in the G. cypha, G. robusta range; three had precaudal vertebrae counts in the G. elegans range. Nine specimens had gillraker counts in the G. robusta range, eight were in the G. cypha range, and two in the G. elegans range (Figure 47).

Figure 47



Precaudal vertebrae and gill rakers (2nd arch), Gila spp. (after Smith et al. 1979). Histograms indicate number of specimens that occurred in that range.

Taxonomic analysis is continuing for Gila spp. More information will be provided in subsequent reports and publications.

Spawning

Little information has been collected at this station regarding the spawning of Gila spp. The only information noted by the Vernal field station were Gila spp. collected July 10-13, 1981 (water temperature 23° C) at Coal Creek Rapid. Several fish were tuberculated and six males exuded milt. Only one female Gila spp. was found ripe. It is assumed that humpback and bonytail chub utilize this location for spawning.

Razorback Sucker

Distribution and Relative Abundance

A total of 92 razorback suckers were collected in the Green River, 1979-1981. Of these 92, nine were subsequently recaptured. Only five individuals were collected during standardized sampling in the Green River, 1979-1981: one in stratum F, 1979; one each in strata B and F, 1980; and two in stratum E, 1980. No razorback sucker were collected during standardized sampling in 1981. However, large numbers (87) of razorbacks were caught during special investigations and 42 of these were collected near the mouth of Ashley Creek (RM 299, stratum F) in spring 1981.

Special collections involved considerable extra effort (in addition to standardized collections) and were concentrated in readily accessible parts of strata E and F, therefore, direct comparison of numbers collected between strata is not possible. However, strata E and F seasonally contained more razorback sucker than was anticipated from the standardized sampling program, which is consistent with the known habitat preferences of them. Strata E and F contain more of the quiet water areas apparently preferred by razorback sucker than do the other strata.

Migration and Movement

Eight razorback suckers tagged with conventional tags were recaptured once during this study (Table 38). One was recaptured twice in the same months these fish were initially collected by other investigators. One razorback sucker tagged May 20, 1975, at RM 345 (555 kilometers) on the Green River by investigators from Utah State University was recaptured on July 30, 1980, at RM 216 (348 kilometers) on the Green River. The fish had moved 129 miles (208 kilometers) downstream from the original capture site. However, the 5-year span between captures discourages speculation on movement patterns. A second razorback sucker originally collected May 16, 1979, at the mouth of Ashley Creek (RM 299.0, 481 kilometers) by Bio/West Inc., was recaptured May 7, 1981, at the same location.

From May 7-28, 1981, 42 razorback suckers were collected in and near the mouth of Ashley Creek. Three of these fish were subsequsently recaptured at the same location (one to two different occasions). The recaptures indicated a tendency to remain in the area for several weeks. However, collections in that area after May 28 produced no razorback suckers.

Three of the fish collected in Ashley Creek were ripe (one male and two females) and several others were tuberculate. This congregation of razorback sucker during spawning season may indicate spawning in the vicinity. However, spawning was not observed.

In addition, two other razorback suckers were collected during this study. One fish (Tag No. 422) was recaptured on the same day it was initially collected. The second fish (Tag No. 179) was recaptured in the same location 2.5 years after it was tagged.

Table 38

Recaptures of adult razorback suckers, Green River, 1979-1981

Carlin tag number	Capture						Recapture						Distance[1]	
	TL	WT	Date	River mile	(km)	River	TL	WT	Date	River mile	(km)	River	miles	(km)
000	539	2,420	5-20-75	345	(555)	GN	527	1,220	7-30-80	215.8	(347)	GN	129.2	(208)
179	505	820	4-03-80	252	(406)	GN	505	820	4-04-80	250.8	(404)	GN	2.8	(4.5)
179	535	-	10-23-79	247	(398)	GN	528	-	4-17-81	247.1	(398)	GN	0.1	(0.2)
234	542	1,490	5-13-81	299	(481)	GN	540	1,550	5-28-81	299.0	(481)	GN	0	
239	519	-	5-16-81	299	(481)	GN	527	1,500	5-07-81	299.0	(481)	GN	0	
249	512	1,470	5-07-81	299	(481)	GN	-	-	5-13-81	299.0	(481)	GN	0	
249	-	-	5-07-81	299	(481)	GN	515	1,400	5-28-81	299.0	(481)	GN	0	
250	490	1,280	5-07-81	299	(481)	GN	495	1,370	5-28-81	299.0	(481)	GN	0	
422	502	1,240	8-31-81	245.9	(396)	GN	502	1,240	8-31-81	245.9	(396)	GN	0	

1/ From point of capture to point of recapture.

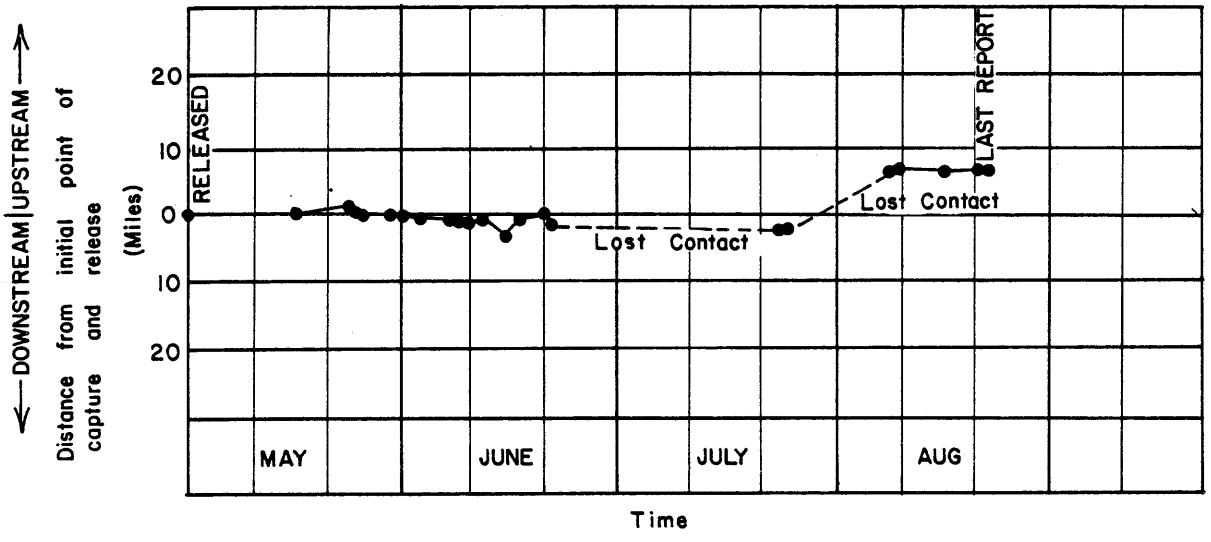
The movement of razorback sucker was also investigated by radiotelemetry. One razorback was implanted with a radio transmitter in 1980 and two were implanted in 1981 (Table 39). No data were obtained in 1981 because the fish were never relocated.

Table 39
Capture, release and major movement of radiotelemetered razorback suckers Green River, 1980 and 1981

Fish number	Total length of fish (mm)	Date captured	Date released	Date of last contact	River	Major movement mile(km)
1(025)	510	4/03/80	4/21/80	8/13/80	Green Duchesne	14 (23)
2(330)	-	5/28/81	6/01/81	6/01/81	Green	-
3(366)	-	9/01/81	9/94/81	9/04/81	Green	-

The razorback sucker implanted in 1980 moved about 3.8 miles (6 kilometers) downstream of its capture location and into the Duchesne River (Figure 48). It remained less than 0.6 miles (1 kilometer) inside the Duchesne River until flooding occurred in early June when it moved into the Green at the mixing zone of the two rivers. The sucker then slowly moved upstream in the Green River about 7 miles (11 kilometers). Contact was lost at that location August 13. Attempts to recapture this fish were unsuccessful.

Figure 48



Long distance movement of razorback sucker No. 025, mouth of Duchesne River taken as zero. Lines drawn by hand. Duchesne and Green Rivers, 1980.

Habitat Preference

Habitat information was recorded at the collection sites of razorback sucker from 1979-1981 (Tables 40 and 41).

Table 40
Primary substrate type at the capture sites or adult razorback suckers during all collections, Green River, 1979-1981

Substrate type	Number of fish
Silt	32
Sand	49
Gravel	1
Rubble	0
Boulder	0

Table 41
Habitat at the capture sites of adult razorback suckers during all collections Green River, 1979-1981

Habitat type	Number of fish
Backwater	22
Eddy	3
Run	2
Main channel (Ashley Creek only	21
Shoreline	27
Pool	0
Side channel	12
Riffle	1

Razorback sucker were always collected over sand or silt substrate. The fish were usually collected in quiet water; 50 percent were collected in a variety of habitats in which water velocity was always low (Table 42).

Table 42
Water velocity[1/] at the capture site of adult razorback suckers during all collections, Green River, 1979-1981

Water velocity (ft/sec)	Number of fish	Frequency (percent)
0.000 to .240	44	53.66
.240 to .480	1	1.22
.480 to .720	21	25.61
.720 to .960	1	1.22
.960 to 1.200	7	8.54
1.200 to 1.440	2	2.44
1.440 to 1.680	1	1.22
1.680 to 1.920	1	1.22
1.920 to 2.160	1	1.22
2.160 to 2.400	3	3.66

1/ n=82, $\bar{x}$=0.5, min=0.0, max=2.4, st. dev=0.61, variance=0.37.

Water depth was between 1.8 feet (0.5 meters) and 4.3 feet (1.3 meters) for 64 percent of the collections (Table 43).

Table 43
Water depth 1/ at the capture site of adult razorback suckers during all collections, Green River, 1979-1981

Water depth (feet)	Number of fish	Frequency (percent)
.600 to 1.220	3	3.66
1.220 to 1.840	5	6.10
1.840 to 2.460	14	17.07
2.460 to 3.080	9	10.98
3.080 to 3.700	22	26.83
3.700 to 4.320	10	12.20
4.320 to 4.940	3	3.66
4.940 to 5.560	4	4.88
5.560 to 6.180	7	8.54
6.180 to 6.800	5	6.10

1/ n=82, $\bar{x}$=3.5, min=0.6, max=6.8, st. dev=1.42, variance=2.4

Water depth and velocity recorded at point of capture of razorback sucker were compared for the spawning period (May 1 to June 15, 1981) versus the nonspawning period (January 1 to April 30 and June 16 to December 31). The mean water depth (4.0 feet, 1.2 meters) selected by razorback during spawning was significantly different than that selected during the nonspawning period (2.3 feet, 0.1 meters) (Table 44 and 45).

Table 44
Water velocity and water depth at point of capture for adult razorback suckers during nonspawning periods, Green River, Utah 1979-1981

Water velocity (ft/sec) 1/	Number of fish	Frequency (percent)	Water depth (ft/sec) 2/	Number of fish	Frequency (percent)
0.000 to .240	17	73.91	.800 to 1.400	2	8.70
.240 to .480	1	4.35	1.400 to 2.000	4	17.39
.480 to .720	1	4.35	2.000 to 2.600	13	56.52
.720 to .960	1	4.35	2.600 to 3.200	2	8.70
.960 to 1.200	0	0.00	3.200 to 3.800	1	4.35
1.200 to 1.440	1	4.35	3.800 to 4.400	0	0.00
1.440 to 1.680	1	4.35	4.400 to 5.000	0	0.00
1.680 to 1.920	0	0.00	5.000 to 5.600	0	0.00
1.920 to 2.160	0	0.00	5.600 to 6.200	0	0.00
2.160 to 2.400	1	4.35	6.200 to 6.800	1	4.35

1/ n=23, $\bar{x}$=0.3, min=0.0, max=2.4, st. dev.=0.62, variance=0.40
2/ n=23, $\bar{x}$=2.3, min=0.80, max=6.8, st. dev.=1.11, variance=1.30

This may be due, in part, to the runoff period occurring during the spawning period. The mean water velocity selected during spawning (0.6 ft/sec, 0.2 m/sec) was greater, but not statistically significant, than nonspawning (0.3 ft/sec, 0.1 m/sec). Further information is needed before meaningful conclusions can be drawn.

Table 45
Water velocity and water depth at point of capture for adult razorback suckers during spawning periods, Green River, Utah, 1979-1981

Water velocity (ft/sec)1/	Number of fish	Frequency (percent)	Water depth (ft/sec)2/	Number of fish	Frequency (percent)
0.000 to .230	23	43.40	.600 to 1.220	1	1.89
.230 to .460	0	0.00	1.200 to 1.840	0	0.00
.460 to .690	2	3.77	1.840 to 2.460	1	1.89
.690 to .920	17	32.08	2.460 to 3.080	7	13.21
.920 to 1.150	0	0.00	3.080 to 3.700	17	32.08
1.150 to 1.380	7	13.21	3.700 to 4.320	9	16.98
1.380 to 1.610	1	1.89	4.320 to 4.940	3	5.66
1.610 to 1.840	0	0.00	4.940 to 5.560	4	7.55
1.840 to 2.070	0	0.00	5.560 to 6.180	7	13.21
2.070 to 2.300	3	5.66	6.180 to 6.800	4	7.51

1/ n=53, x=0.6, min=0.0, max=2.3, st. dev.=0.50, variance=0.34
2/ n=53, x=4.0, min=0.6, max=6.8, st. dev.=1.23, variance=1.55

From April to June 1980, radiotelemetry of one razorback sucker in the Duchesne and Green Rivers provided some habitat preference information (Table 46). It selected depths ranging from 2.0 to 8.0 feet (0.6 to 2.4 meters) and velocities ranging from 0.2 to 1.6 feet per second (0.1 to 0.5 meters per second). Preferred substrate types were sand/silt in shoreline and main channel habitats. The fish selected midchannel and deep shoreline habitats in the Duchesne River. During flood stage it moved into the mixing zone of the Duchesne and Green Rivers (eddy) and was last observed on a submerged sand bar (run) in the Green River in August.

Table 46
Habitat preferences of razorback sucker implanted with radiotransmitter, Duchesne and Green Rivers, 1980
Diel study observations unless noted (*)

River	Month	Number of observations	Average depth (feet)	Average velocity (ft/sec)	Substrate	Habitat
Duchesne	April	1*	4.4	0.6	Sand	Shore
	May	1*	4.5	0.2	Silt	Shore
	May	1*	5.7	0.6	Sand	Main chan.
	May	34	2.0	0.2	Silt	Shore
		37				
Green	June	6	3.3	1.6	Sand	Shore
	June	1	8.0	0.7	Sand	Main chan.
		7				
Total		44	2.5	0.42	Sand/silt	Shore/Mc

Spawning

Little information was obtained about spawning of razorback sucker. The only information obtained included the recapture of a razorback in the Green River, 1980, and the collection of 42 razorback suckers at the mouth of Ashley Creek in 1981.

One ripe razorback sucker tagged at the mouth of the Yampa River on May 20, 1975 (McAda 1977) was recaptured in July 1980 at RM 216 (348 kilometers) in the Green River 129 miles (208 kilometers) downstream. It is possible that spawning migrations are made by razorback sucker moving upstream into the Yampa area from downstream areas. Unfortunately, the 5-year interval between capture and recapture makes such a hypothesis largely speculation.

During collections in 1981, a total of 42 razorback suckers were collected at the mouth of Ashley Creek (RM 299, 481 kilometers) on the Green River. Three of the fish were ripe. Only 61 razorback suckers were captured all year in 1981, making this collection a phenomenal event. These fish were collected from May 7 to 28; however, no razorback sucker were collected after May 28 from that location.

CONCLUSIONS AND RECOMMENDATIONS

General

1. The Green River ecosystem is dominated by exotic (man-introduced) species. Endemic suckers and chubs were more common in canyon areas where exotics are less abundant. Although more stressful environmental conditions occur in the canyons, these endemics appear to be more adapted to them. Canyon areas should be maintained to closely approximate historic conditions.

2. As in most rivers, the mainstem Green River is dominated by seasonal variations in discharge and the input of sediment and allochthonous organic material from tributary streams. Fishery habitat is dependent on these factors. Peak releases from Flaming Gorge Dam in 1980 had a pronounced effect on backwater nursery habitat as far downstream as Ouray, Utah. The effects of peak discharges on shallow habitats should be studied in greater detail in the future for more definitive cause-effect relationships.

Colorado squawfish

1. This study has proven that Colorado squawfish have a complicated life history. Not only do adults exhibit seasonal movements into preferred habitats, but radiotelemetry and tag returns have identified long spawning migrations (upstream and downstream) to restricted areas of suitable spawning habitat. This study indicates two main spawning locations occur in the entire Green River Basin; the lower Yampa Canyon and in Gray Canyon. It is critical that migration routes and spawning grounds be protected.

2. Adult Colorado squawfish are capable of rapid long distance migration of over 100 miles (161 kilometers) in 1 week. Also, adults have been found to congregate at certain times of the year. For these reasons, distribution and abundance data obtained from conventional fish collections should be interpreted with caution.

3. Adult Colorado squawfish are not common in canyon areas and were found on the spawning grounds in the Yampa River for a very short time period (only 3 weeks). This habitat is apparently unfavorable to them except for spawning.

4. Seasonal and daily movement patterns may be an important management tool for Colorado squawfish. Data obtained from radiotelemetry have not been analyzed with respect to time of day, discharge, and temperature. However, preliminary findings indicate the possibility of some premigration triggering mechanism connected with flow, temperature, and physiological conditions.

5. Larval Colorado squawfish were not recovered from the only known spawning location in the Yampa River in 1981. Distributional

data show that peaks of abundance occur approximately 110 miles (177 kilometers) downstream from suspected spawning sites. Since larval Colorado squawfish prefer shallow backwaters and eddies with silty bottoms it is apparent that the known spawning location would be hostile to them. It is suggested that Colorado squawfish have developed a drift mechanism which promotes their survival by allowing the larvae to drift into favorable habitat. This drift mechanism probably developed as an adaptation to natural flow conditions. Flow manipulations away from the normally descending hydrograph could pose a threat to these larvae by: (1) flushing out or flooding favorable nursery habitat created by receding floodwaters or (2) stranding or flushing larvae into undesirable habitats.

6. Young Colorado squawfish (40 to 60 millimeters TL) exhibit strong habitat preferences. These young fish moved upstream against current to more favorable habitat when rising water levels changed their occupied habitat to a less desirable one. Also, young Colorado squawfish established a rhythm of moving between certain habitats during the day, apparently related to temperature preferences. These findings have a significant management implication, since once the young fish reach this size they may be able to withstand environmental stresses in discharge regimens.

7. It is not known if competition with exotic fishes has resulted in the decline of the Colorado squawfish. A food habits study of young Colorado squawfish from the Green River indicate they eat red shiner, and they certainly coexist in the same habitat. The only logical conclusion is the larger young Colorado squawfish benefit from red shiner. Young Colorado squawfish are absent or few in collections that contain redside shiner, presumably due to a less desirable set of physical habitat conditions (where redside shiners are found) rather than due to competition. Certainly, there must be competition between Colorado squawfish and other pisciverous fish species such as larger centrarchid species, walleye and northern pike. It is not known if a high degree of competition exists between Colorado squawfish and either channel catfish or carp. It is possible that multivariate analysis could provide answers to these questions.

Humpback and Bonytail Chub

1. Humpback chub and bonytail chub exist in the Green River but were found only in low numbers. Gray Canyon appears to be the only location in the study area that has the potential for supporting these species.

2. Taxonomy of Gila spp. is difficult for small specimens taken from the Green River and this difficulty is compounded by: (1) the occurrence of all three species in the same location; (2) the high degree of morphological variation inherent within the genus Gila; (3) the presence of certain specimens that appear to share the characteristics of two or more of these species; and (4) the need to sacrifice fish in order to make a defensible species indentification. Taxonomic studies at Vernal have aided in clearing up

much of this confusion. In the future, an attempt will be made to identify all collected (but alive) Gila spp. Unfortunately, these studies are incomplete.

3. Hybridization has been implicated as a main factor in the decline of the humpback and bonytail chub. Studies in the Green River do not necessarily support this view since the bonytail, once abundant in the upper Green, has been abruptly lost. Although not entirely dismissed, it is doubtful that hybridization alone would have resulted in a loss of population isolating mechanisms. Although some hybridization is normal with most fish species under altered conditions and is, therefore, likely to occur in the Green River, taxonomic work indicates a high degree of variability and a great degree of overlap between the different Gila species. It is unknown how much of the variability observed can be attributed to hybridization.

Razorback sucker

1. Razorback suckers were very rare in the Green River and only collected in any numbers in strata E and F.

2. Only adult razorback sucker were collected, indicating reproductive success was low or nonexistent in recent years.

3. Large numbers (42) of adult razorback sucker were captured in or near the mouth of Ashley Creek in May and June of 1981. Ripe razorback suckers were collected at this time, suggesting this area as a potential spawning site. However, no young were subsequently captured.

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REPORT 2

UPPER COLORADO RIVER INVESTIGATION (RIFLE, COLORADO TO LAKE POWELL, UTAH)

by

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INTRODUCTION

General Setting

The Colorado River Fishery Project (CRFP) was initiated in April 1979 to assess the habitat requirements of the endangered Colorado squawfish (Ptychocheilus lucius) and humpback chub (Gila cypha). The bonytail chub (Gila elegans) was added to the list of target species after it was listed as endangered by the Fish and Wildlife Service (FWS) in May 1980. The razorback sucker (Xyrauchen texanus) is also considered in this investigation because of its apparently precarious status.

CRFP was established through a Memorandum of Understanding (MOU) with the Bureau of Reclamation (BR) on 14 April 1979, effective through 31 March 1981, (Contract No. 9-07-40-L-1016). This MOU was subsequently extended to 31 October 1981. Additional funding was granted for work in the State of Colorado through a MOU (No. CO-910-IA9-933) with the Bureau of Land Management (BLM).

The biological data needs of the four target species, established in the MOU, include: spawning requirements; young and adult habitat requirements; migration and movement patterns; interspecific competition; effects of temperature, salinity and selected chemicals (bioassays); feasibility of propagation and rearing; and assessments of fish pathogens and parasites. Field investigations, controlled laboratory bioassays, hatchery-culture studies and habitat-use evaluations were established to satisfy these data needs.

Objectives

The field investigations were conducted on the Green River by a field station in Vernal, Utah, and on the Colorado River by a field station in Grand Junction, Colorado. The Grand Junction Field Station (GJFS) was established in May 1979, and field work began in mid-July. This station supported one to four permanent biologists and one to six biologists' aides at any one time. The primary function of the GJFS was to conduct intensive investigations of endangered fish habitat as stated in the MOU. The specific objectives were to assess:

1) spawning requirements,
2) young and adult living requirements,
3) migration and movement patterns, and
4) interspecific competition.

Fishery investigations conducted in the upper Colorado River from July 1979 to July 1981 are included in this final report. Additional investigations on the Gunnison and Dolores Rivers are reported under separate cover.

METHODOLOGY

Study Area

The study area for the GJFS encompassed 289 miles of the Colorado River from Rifle, Colorado, to Hite Marina at Lake Powell, Utah (Figure 1). This section of river was divided into 11 longitudinal strata, each 13-50 miles long. Each stratum was a relatively homogeneous section of river based on gradient, channel morphology, substrate and perceptible fish habitat, e.g. high gradient-canyons and low-gradient braided sections represented the extremes in geomorphology. A description of each of these strata is presented in Results and Discussion. Sites referred to in this report are in river miles upstream or downstream (-) from the confluence of the Colorado and Green Rivers. The English system of measure is used in lieu of metric to avoid confusion with conventional uses such as river miles and sample gear types. The deviation from this practice is that temperatures are given in degrees centigrade and fish lengths in millimeters.

Sample Design

Sample design, methodology and gear used in this investigation were previously described (Archer et al. 1979). These procedures were standardized with those used by the Vernal Field Station.

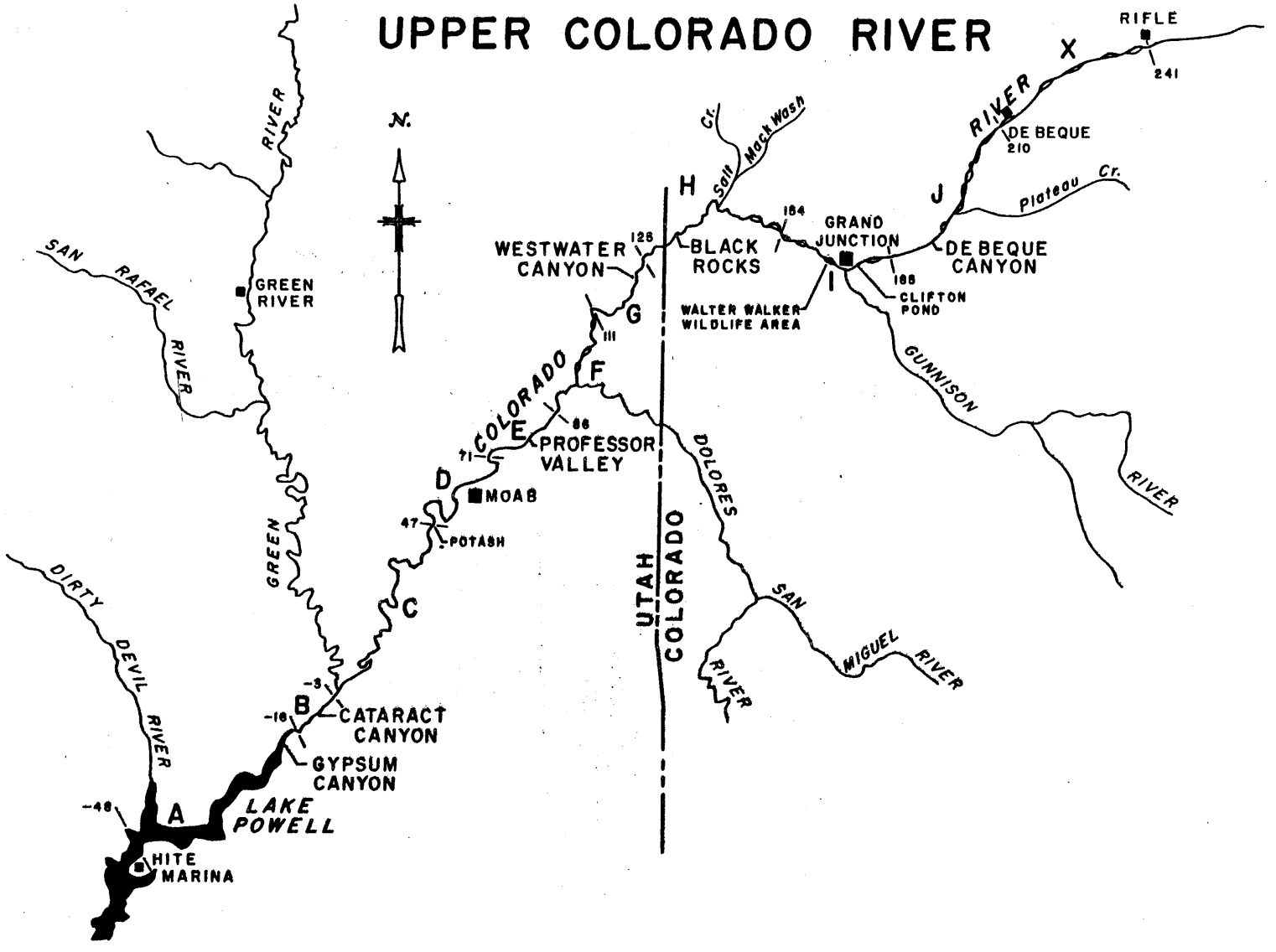
Sampling was conducted by one field team of two to four investigators in one stratum at a time. All strata were sampled three times a year, from 15 March to 1 November, i.e. before runoff, during runoff and after runoff. These flow periods varied by year according to snow level and melt time (Figures 2-4). Field work was not conducted between November and March because of severe winter weather.

The first sample stratum for each flow period was selected randomly and subsequent strata were selected downstream. Selection continued with the upstream strata after the last stratum downstream. Intensive sampling was conducted each flow period within two 0.5-mile sections of river selected for each stratum. The upper section was selected randomly from the river miles in the stratum, and the lower intensive automatically began 5.0 miles downstream from the starting point of the upper intensive.

All distinct habitat types in the upper intensive were sampled with a variety of gears for 24 hours. Sampling was continued primarily with electrofishing gear, in the intervening 4.5 miles for the next 24 hours. The lower intensive was sampled in the same manner as the upper during the third 24-hour period.

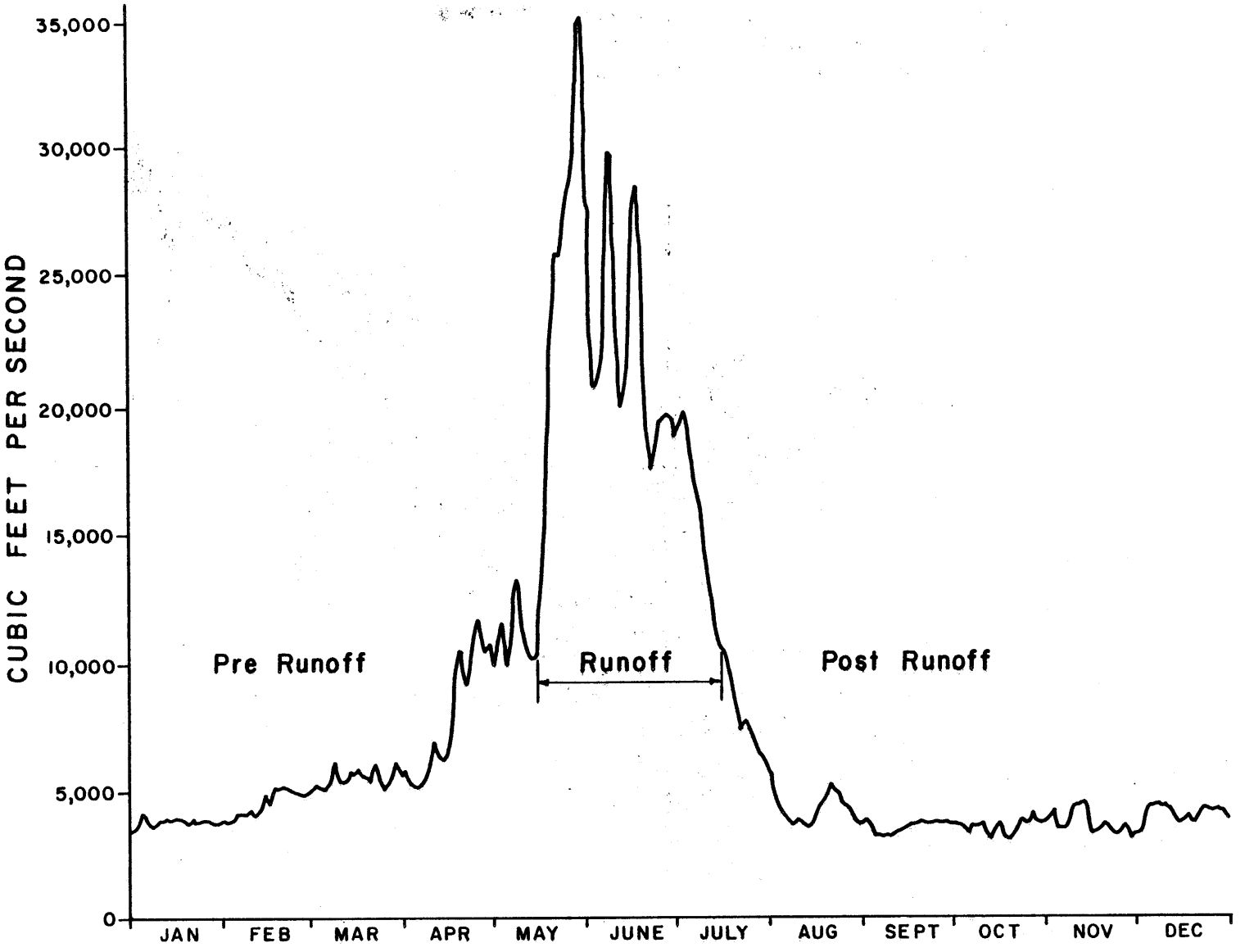
Sampling in each intensive section over the 24-hour period was stratified temporally into three subperiods; morning, daylight and

Figure 1



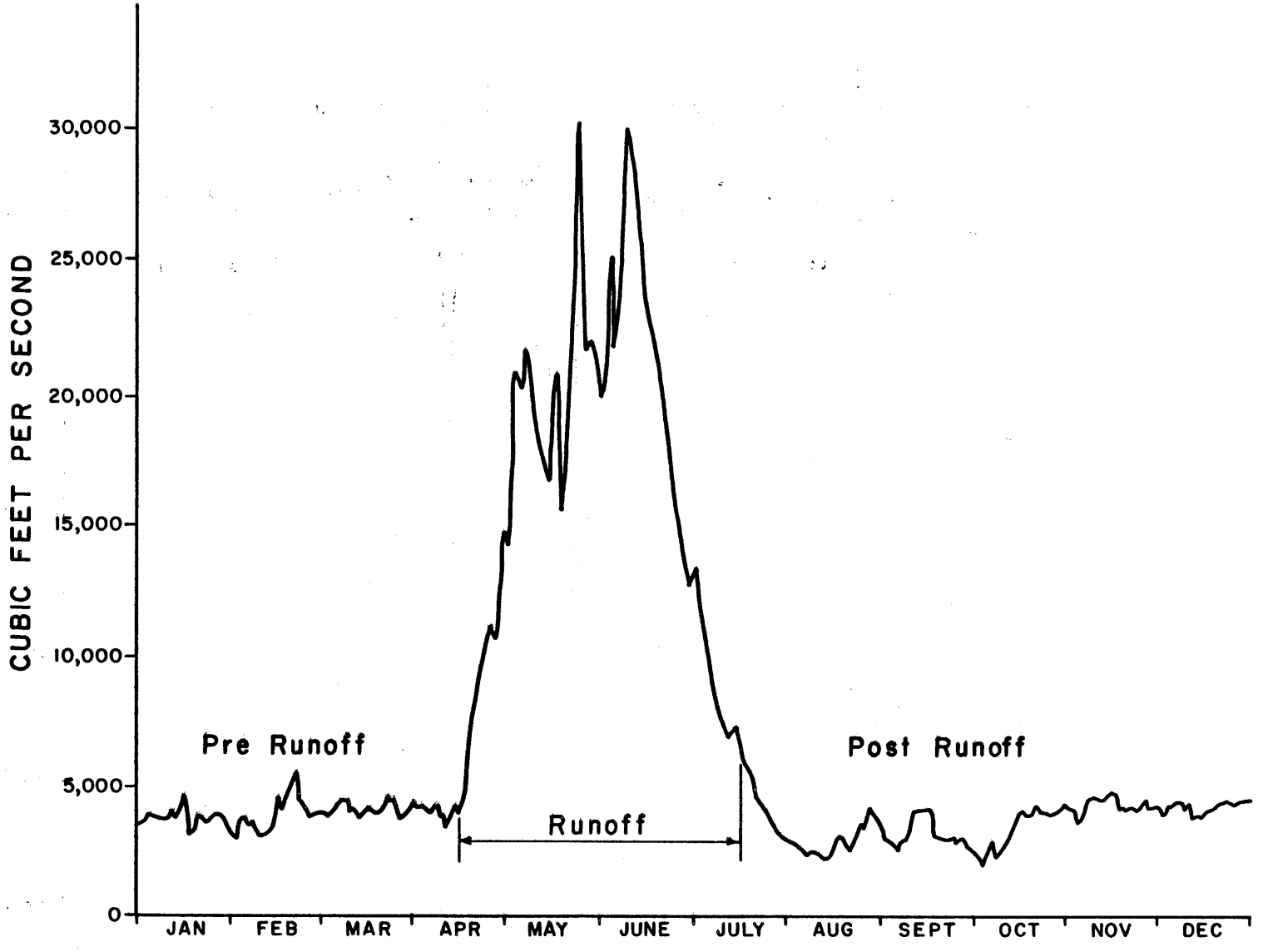
The area of the upper Colorado River investigated by CRFP, including study strata (A-J, X), prominent sample sites, and river miles from the Green River confluence.

Figure 2



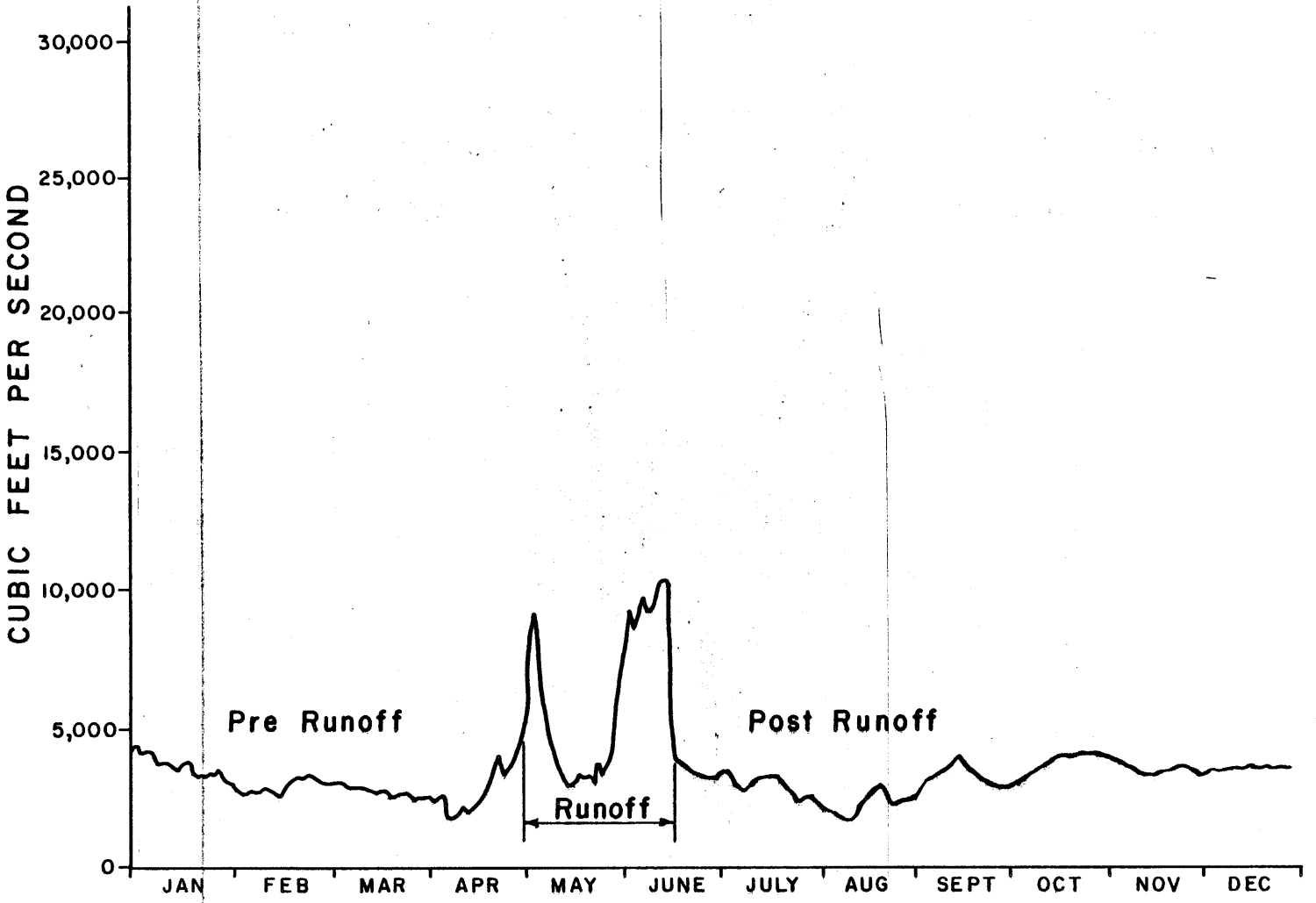
Flow of the upper Colorado River at the Utah/Colorado State line, 1979 (USGS records).

Figure 3



Flow of the upper Colorado River at the Utah/Colorado State line, 1980 (USGS records).

Figure 4



Flow of the upper Colorado River at the Utah/Colorado State line, 1981 (USGS records).

nighttime. A midday subperiod of relative inactivity was reserved for travel, equipment maintenance and personal activities of the field team members.

Physical and Chemical Parameters

Physical and chemical parameters of the river were measured and recorded at every intensive section sampled. The physical information consisted of channel width; and average and maximum water depth in cross section at the upstream, middle and downstream points of the section. These measurements were taken with a Lowrance Model LRG 1510-A sonar depth finder. A permanent record of the stream cross section was kept in the form of a paper printout from the depth finder.

Chemical data were recorded once for each intensive section between 1100 and 1500 hours. This time-window represents the normal diurnal water chemical conditions. Parameters measured included (1) water temperature, °C, (2) air temperature, °C, (3) conductivity, umhos/cm, (4) salinity, ppth, (5) turbidity, JU's and (6) dissolved oxygen, mg/L. Water and air temperature, conductivity and salinity were measured with a Yellow Springs Instruments Model 33 conductivity/salinity meter. Turbidity was measured with a Baush and Lomb mini-spec 20, model DR/1. Dissolved oxygen concentration was determined with a Hach model OX-10 analysis kit.

Gear

A variety of active and passive gear was used to sample the many habitats and conditions of the upper Colorado River. The principal gears employed were electrofishing, trammel nets, gill nets and beach seines. Angling, fyke nets, wire traps, trawls and trot lines were used less often. The relative efficiency of each varied with different habitats (Table 1).

Table 1.
Principal gears used by CRFP to sample fish habitat in the upper Colorado River.

Gear	Habitats
Electrofishing	run, rifle, shoreline, side channel large backwater, mid-channel
Trammel and gill nets	pool, eddy, large backwater, slow run, mid-channel
Seines	small backwater, shoreline, run, riffle, pool

Electrofishing

A standard electrofishing system was developed early in the project and used throughout. The electrofishing gear was mounted on a 16-ft flat-bottom painted aluminum boat (Loweline) for flatwater strata, or a 16 to 18-ft hypalon raft (Campways Havasu or Miwok) for whitewater strata. The system was powered by a portable Briggs and Stratton engine and a "Power Guard" unit generating 220 volts with a potential of 5 Kw. The variable voltage pulsator was a Coffelt RF-10 unit which accomodates up to ten anodes (positive electrodes) rotating in sequence. Sections of 3/8-inch stainless steel cable were used as anodes and cathodes; numbers and lengths of these electrodes were varied with electrofishing conditions. Generally, the system was most effective with two anodes and two to three cathodes, depending on water temperature, conductivity, turbidity and depth.

Fish were collected most effectively with 250-300 volts and 10-15 Amps. Runs, riffles, shorelines, side channels, and medium to large backwaters were sampled most effectively with electrofishing.

Trammel Nets

Two sizes of trammel nets were used: (1) 150-feet long, 8 feet deep, 1.5-inch mesh inner panel and 12-inch mesh outer panel and (2) 150-feet long, 6 feet deep, 1-inch mesh inner panel and 10-inch mesh outer panel. These nets were usually set for 1-3 hours in the morning, evening and at night. Nets were checked most frequently in areas suspected of harboring the target fishes. A profile of the river bottom was recorded with a Lowrance depth finder as the net was being set to help determine depth, velocity and substrate of all target fish capture sites.

Gill Nets

Gill nets used were 150 feet long and 6 feet deep with uniform square mesh size of 1.5, 2 or 3 inches. Experimental gill nets with panels of 1/2-inch and 3/4-inch mesh were also used. The different mesh sizes were used in an attempt to capture various sizes of target fishes, particularly juvenile Colorado squawfish (100-300 mm total length). A depth contour was also recorded to help determine depth, velocity and substrate for target fish capture sites.

Seines

Three types of beach seines were used: (1) 8 feet long and 3 feet deep, 1/8-inch square mesh, (2) 15 feet long and 4 feet deep with 1/4-inch square mesh and (3) 30 feet long and 6 feet deep with 1/2-inch square mesh.

The 1/8-inch mesh seines were used to collect larvae and small YOY fishes. The 1/4-inch mesh seines were used most often to catch young endangered fishes and associated species in small, restricted habitats (Table 1). The 1/2-inch mesh seines were used less frequently, and were most effective in large backwaters or small pools or eddies.

Habitat Parameters

The water depth, velocity (at six-tenths the distance from the water surface) and substrate were recorded at every capture site of a target fish and for most nontarget fishes. Depth was measured with either an extendible surveyor's Philadelphia rod or the Lowrance depth finder. Velocity was measured with a Marsh-McBirney model 201 current meter with the sensor attached to either the depth rod for shallow water or to a lead weight ("bomb") for deep, swift water. Substrate was assessed visually and classified according to Table A-1 (Appendix A).

Data Analyses

Fish sampling was conducted in a stratified random manner to enable temporal and spatial comparisons of fish species and numbers caught. Total catches, species composition, and catch/effort were compared between years, year classes, flow periods, strata, and habitats for both area and hour-related gear.

Each target fish caught was measured as total length (TL) in millimeters, weighed in grams, and examined for ectoparasites or diseases. Each was then marked with a color-coded and serially-numbered Carlin tag, 16 mm by 6 mm in size. The tag was attached to the base of the dorsal fin with polyethylene thread (Valdez et al 1981).

A sample of scales was taken from below the origin of the dorsal fin and above the lateral line of those fish that did not appear weakened or stressed. Scale samples were placed in waxed paper and in a coin envelope and forwarded to a subcontractor for age determinations.

Samples of nontarget species from each catch effort were also weighted, measured and tagged with Floy FD-67 anchor tags. Ectoparasites and diseases were also noted.

All data collected by CRFP were recorded on computer format field data sheets and entered on a database storage and retrieval system called MANAGE (Valdez and Wilcott 1979). The data were stored in three datasets, PHYSICAL, CATCH AND RARE with 21, 20 and 29 searchable fields respectively (Appendix B). The PHYSSCAL dataset contains all data on water chemistry and cross sections of the intensive sample sites. The CATCH dataset contains the catch records for each sample, and the RARE dataset contains all information associated with each target fish captured. The statistical package IMSL was incorporated into MANAGE to allow descriptive, univariate and bivariate testing within as well as between datasets.

The habitat parameters--velocity, depth and substrate--associated with each capture of a target fish were evaluated with the aid of the instream flow methodology (IFM) developed by the Insteam Flow Group of the Western Energy and Land Use Team, U.S. Fish and Wildlife Service (Prewitt 1981). Preference curves were developed for these three parameters to help interpret habitat requirements of the target species.

RESULTS AND DISCUSSION

Geophysical and Chemical Description

The 11 longitudinal strata of the upper Colorado River ranged from 13 to 50 miles in length (Table 2). Each differed from the adjacent stratum in terrain, channel depth, river gradient and predominant substrate type. Five additional strata were established to include areas of the river that warranted special consideration. These special strata were sometimes unique segments of regular strata, e.g. Black Rocks (stratum K) occurred within the Westwater to Loma stratum (stratum H). Selected river miles within each of the 11 strata were sampled during postrunoff in 1979, the three flow periods in 1980 and prerunoff and runoff in 1981 (Table 3). Intensive sampling during each flow period of each year encompassed 11 miles or 4% of the study area. Less intensive sampling during each sample round covered 99 miles or 34% of the area. Thus, each sample round encompassed 110 miles or 38% of the 289 miles of river. A total of 297 miles of river were sampled in the 2.5-year study; some areas were sampled twice.

The widths and depths of the river at selected cross sections within each stratum varied considerably (Appendix C), as expected with the variable river morphology of the Colorado River, particularly during different flow periods. Depth measurements were especially valuable for characterizing certain river reaches, and relating such characterized reaches to associated fish composition. Except for stratum A, which is inundated by Lake Powell, maximum water depth ranged from 18 feet in stratum I to 92 feet in stratum B. The latter was recorded in Cataract Canyon below the Green - Colorado confluence. Average water depth ranged from 2 feet in several strata to 65 feet in stratum B.

Water chemistry was more variable than river depth and width (Appendix D). Date of sampling probably attributed more to these variations than unique chemical qualities of the strata. Water temperatures during the sample period ranged from 7.8° C in March to 27.0° C in August. from 280 umhos/cm in April and May to 1720 in August. Turbidity was also highly variable, and ranged from 10 J.U's in July to 575 in May.

Available fish habitat in the Colorado River was difficult to assess because of the complexity and dynamics of the system. The numbers of backwaters and eddies tabulated within each stratum (Table 4) provides an index to the occurrence of these two habitats. The greatest frequency of backwaters occurred in the strata near the Green-Colorado confluence (C, D, F). Eddies were most common in strata B, C, D, F, and G.

A total of 27 fish species and 4 hybrids representing 12 families were encountered in the upper Colorado River (Table 5). These represent 5 endemic, 4 native, and 18 nonnative species. Only flannelmouth sucker, common carp, and fathead minnow were present in all regular strata (Table 6), and only common carp were abundant in all strata. Humpback chub were found in 4 of the regular strata, Colorado squawfish were in all but 1 and razorback sucker were in 7. Bonytail chub were not encountered during this investigation. The endemics are often combined with natives and referred to as natives in certain analyses of this report.

Table 2
Strata sampled by the Grand Junction Field Station in the upper Colorado River

Stratum	Description	Boundaries (river miles)*	Length of stratum (miles)	(kilometers)
A	Hite Marina - Rapid 27	-48 -(-16)	32	51
B	Rapid 27 - Spanish Bottom	-16 -(-3)	13	21
C	Spanish Bottom - Potash	-3 -47	50	0
D	Potash - Big Bend	47 -71	24	39
E	Big Bend - Onion Creek	71 -86	15	24
F	Onion Creek - Agate Wash	86 -111	25	40
G	Agate Wash - Westwater	111 -125	14	23
H	Westwater - Loma	125 -154	29	47
I	Loma - Palisade	154 -185	31	50
J	Palisade - Debeque	185 -210	25	40
X	Debeque - Rifle	210 -241	31	50
	Special strata			
K	Black Rocks	135.6-136.6	1	2
M	Walter Walker	163.6	-	1
N	Westwater Canyon	116 -124	8	13
O	Clifton Pond	177.8	-	1
P	Gypsum Canyon	-21 -(-20)	1	2

* distance from the Green-Colorado Rivers confluence (Belknap and Belknap 1974)

Table 3
River miles sampled by the Grand Junction Field Station in the upper Colorado River

Stratum (river miles)*	River miles sampled# 1979 Post	1979 Pre	1980 Run	1980 Post	1980 Pre	1981 Run
Regular strata						
A (-48 - -16)	---+	191, 186	---	178, 173	---	---
B (-16 - -3)	213, 208	206, 201	---	212, 207	208, 203	---
C (-3 - 47)	27, 22	10, 5	34, 29	9, 4	37, 32	41, 36
D (47 - 71)	65, 60	67, 62	60, 55	54, 49	58, 53	53, 48
E (71 - 86)	80, 75	76, 71	78, 73	84, 79	80, 75	82, 77
F (86 - 111)	93, 88	93, 88	91, 86	95, 90	110, 105	107, 102
G (111 - 125)	121, 116	124, 119	---	122, 117	118, 113	12S, 120
H (125 - 154)	153, 148	143, 138	140, 135	131, 126	147, 142	149, 144
I (154 - 185)	170, 165	176, 171	159, 154	177, 172	178, 173	151, 176
J (185 - 210)	190, 185	197, 192	200, 195	201, 196	209, 204	203, 198
X (210 - 241)	---	---	---	---	---	241, 232
Special strata						
K (135.6 - 136.6)	136	136	---	136	136	136
M (163.6)	163.6	163.6	163.6	163.6	---	163.6
N (116 - 124)	117	120	---	122	118	120
O (177.8)	---	---	177.8	---	---	177.8
P (-21 -(-20)	---	---	197	---	---	---

* distance from the Green-Colorado Rivers confluence (Belknap and Belknap 1974).

0.5 miles of each sampled intensively, see methodology in text.

\+ Stratum not sampled.

Table 4
Occurrence of backwaters and eddies in the 11 sample strata during the postrunoff period, 1981

Stratum	Backwaters (No./10 Km)	Eddies (No./10 Km)
A	---	---
B	3.6	22.4
C	11.5	17.1
D	7.4	9.4
E	0.5	1.0
F	9.0	18.2
G	3.0	18.2
H	0.8	1.0
I	2.7	7.4
J	1.1	1.1
X	0.8	6.1

Table 5
Fish species and hybrids encountered in the upper Colorado River from Hite Marina, Lake Powell, Utah to Rifle, Colorado, 1979-1981

Family Species	CRFP Codes	Common Name	Status*
Catostomidae			
Catostomus discobolus	BH	Bluehead sucker	N
Catostomus latipinnis	FM	Flannelmouth sucker	E
Catostomus commersoni	WS	White sucker	X
Xyrauchen texanus	RZ	Razorback sucker	E
C. discobolus X *C. commersoni*	WB	White X bluehead sucker	
C. latipinnis X *C. commersoni*	WF	White X flannelmouth sucker	
C. latipinnis X *X. texanus*	FR	Flannelmouth X razorback sucker	
C. latipinnis X *C. discobolus*	FB	Flannelmouth X bluehead sucker	
Centrarchidae			
Lepomis cyanellus	GS	Green sunfish	X
Lepomis machrochirus	BG	Bluegill	X
Micropterus salmoides	LG	Largemouth bass	X
Pomoxis nigromaculatus	BC	Black crappie	X
Clupeidae			
Dorosoma petenense	TS	Threadfin shad	X
Coregonidae			
Prosopium williamsoni	MF	Mountain whitefish	N
Cottidae			
Cottus bairdi	MS	Mottled sculpin	N
Cyprinidae			
Cyprinus carpio	CP	Common carp	X
Gila cypha	HB	Humpback chub	E
Gila robusta	RT	Roundtail chub	E
Notropis lutrensis	RS	Red shiner	X
Notropis stramineus	SS	Sand shiner	X
Pimephales promelas	FH	Fathead minnow	X
Ptychocheilus lcius	CS	Colorado squawfish	E
Rhinichthys osculus	SD	Speckled dace	N
G. robusta X *G. cypha*	RH	Roundtail X humpback chub	
Gila sp.	CH	Unidentified chub	
Cyprinodontidae			
Fundulus kansae	PK	Plains killifish	X
Esocidae			
Esox lucius	NP	Northern pike	X
Ictaluridae			
Ictalurus melas	BB	black bullhead	X
Ictalurus punctatus	CC	channel catfish	X
Percidae			
Stizostedion vitreum	WE	walleye	X
Salmonidae			
Salmo trutta	BN	brown trout	X
Salmo gairdneri	RB	rainbow trout	X
Serranidae			
Morone saxatilis	SB	striped bass	X

N = native
E = endemic
X = non-native

Table 6

Occurrence of fishes in the 16 strata studied by the GJFS/CRFP, 1979-1981 (A = abundant throughout, N = numerous throughout, C = locally common, R = rare)

	Regular strata												Special strata			
Species	A	B	C	D	E	F	G	H	I	J	X	K	M	N	O	P
Bluehead sucker		R	R	N	N	A	N	A	A	A	A	N	R	N		
Flannelmouth sucker	N	N	C	A	A	A	N	A	A	A	A	N	N	N	N	N
White sucker		R	R	R	R	R		N	N	N	N		N			
Razorback sucker	R		R	R				R	R	R	R		R		N	R
white x bluehead								R			R					
white x flannelmouth		R						R	R	R	R					
Flannel x razorback						R			R	R	R		R			
Green sunfish	C	R		C	R	C	R	C	C	N	N	R	A			C
Bluegill	C		C	R					R				R			C
Largemouth bass	C		R	N	N	N	R	N	N	R		R	C			C
Black crappie	C		R	R	R		R	R	R			R	R	R		C
Threadfin shad	A															A
Mountain whitefish										R						
Mottled sculpin										N	N					
Common carp	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Humpback chub		R			R		N	R				N		N		
Roundtail chub		R	R	N	A	A	A	A	A	A	A	A	C	A		
Roundtail x humpback						R	N			C		N		N		
Unidentified chub		R	R		R	R	R									
Red shiner	A	C	A	A	A	A	N	A	A	N		C	C	C		A
Sand shiner	C	C	A	A	A	A	N	A	A	N		N	C	C		C
Fathead minnow	N	C	C	C	N	N	N	A	A	N	N	N	R	N		N
Colorado squawfish	R	R	R	R	R	R	R	R	R	R		R	R	R	R	R
Speckled dace		R	R	R	R	R	R	N	N	A	A	R		R		
Plains killfish			R	R	R	R	R							R		
Northern pike													R			
Black bullhead	R		C	C	C	R	R	C	C	N	R		A			R
Channel catfish	N	A	A	A	A	A	A	A	N			N	N	N		N
Walleye	N	R														N
Brown trout			R		R	R	R			R	N					
Rainbow trout										N	N					
Striped bass	C															C
Total No. species	16	14	18	18	18	16	17	17	17	18	13	13	17	13	4	16
No. non-natives	13	8	12	12	13	11	11	10	11	11	11	8	12	7	1	13
No. natives	3	6	6	6	5	5	6	7	6	7	6	6	5	6	3	3

Stratum A: Hite Marina to Rapid 27

Stratum A encompassed the upper-most 32 miles of Lake Powell. Rapid 27 was the last major rapid (near Imperial Canyon) not usually inundated by the lake at a level of about 3675-feet elevation. The banks were high sandstone walls with few beaches or shallow embankments. Much of this stratum resembled a large, deep, slow-flowing river rather than a lake, especially during runoff, when logs and debris from the Colorado River were prevalent.

Maximum depths recorded were greater than 100 feet (Table C-10). Much of the substrate was boulders and bedrock covered by several feet of silt deposited by the river as it entered the lake. Water clarity and chemistry varied with flow stage (Table D-1), but water in the lower half of the stratum was usually very clear.

The complement of fishes in stratum A strongly reflected the composition of fishes in Lake Powell (Table 6). Threadfin shad, common carp and red shiner were abundant, and sunfishes and catfishes were numerous. Razorback sucker and Colorado squawfish were both captured in the stratum during this investigation. Although both species were rare throughout, 5 razorbacks and 43 squawfish were taken from the Gypsum Canyon area as the result of intensive gill netting for striped bass in April, May, and June of 1980. (Persons and Bulkley 1980). Humpback chub were not taken from stratum A, although these were in Lake Powell in the 1960's (Holden and Stalnaker 1975).

The presence of razorback sucker and Colorado squawfish in upper Lake Powell suggests that the deep riverine environment is desireable to these fish. Threadfin shad, bluegill and crappie are an abundant source of prey for squawfish, and there is an abundance of insect and plant debris for razorbacks. The concentration of large squawfish found in Gypsum Canyon in spring 1980 suggests that either the fish drifted downstream from the Colorado or Green Rivers (the confluence of the Green River is 20 miles upstream), or were staging for an upstream ascent to spawning areas. In either case, upper Lake Powell may be important to Colorado squawfish as a feeding or staging area. Small numbers of juvenile squawfish in this stratum suggest the possibility of reproduction nearby. The absence of silt-free areas for spawning and backwaters as nurseries probably preclude reproduction in Lake Powell. Young Colorado squawfish may travel great distances from spawning sites on the Colorado or Green Rivers upstream.

Intensive gill netting in 1981 yielded only two squawfish and no razorback sucker from Gypsum Canyon. The decrease in numbers of squawfish from 1980 remains a mystery, although the large difference in lake level--3700 ft in 1980 and 3650 ft in 1981--may explain this change in fish numbers. The squawfish may have changed their behavior and relocated themselves either in the river further upstream or in the lake further downstream.

Stratum B: Rapid 27 to Spanish Bottom

The major whitewater area of the upper Colorado River was designated stratum B. It covered 13 miles of river in the heart of Canyonlands

National Park, and included the 27 major rapids of Cataract Canyon. The river is swift, deep and voluminous after receiving flow from both the Colorado and Green Rivers at their confluence about 3 miles upstream. The river cuts deeply through steep canyons and talus slopes.

Maximum water depth encountered was 92 ft (Table C-2). The river in this stratum had many deep swift runs, large eddies, some deep pools and a few shallow runs, riffles and backwaters (Table 4). The abundance of large angular rocks and the steepest gradient of the upper Colorado River created large dangerous rapids difficult to sample. The rapids were treacherous during runoff, and the stratum was not sampled at that time.

Only 14 species of fishes were caught in Cataract Canyon, whereas most other strata of the river supported 16-17 (Table 6). Only common carp and channel catfish were abundant throughout the stratum. Red shiner, sand shiner and fathead minnow were common in quiet shallow waters, but were rare in turbulent areas. Native species which were numerous in ocher strata (bluehead sucker, flannelmouth sucker and roundtail chub) were less abundant in Cataract Canyon. Colorado squawfish and humpback chub were caught in stratum B, but in very low numbers. Only YOY squawfish were caught in this stratum; less than 25 were taken all together. Although several variants of humpback chub or possibly hybrids of G. cypha X G. robusta were caught in this stratum, only one fish was caught with typical morphologic features of G. cypha.

The physical similarities between Cataract Canyon (stratum B) and Westwater Canyon (stratum G) suggest that Colorado squawfish, and particularly humpback chub should be numerous in Cataract. Perhaps the physical rigors of runoff excludes the species from the canyon, although humpback chub were present in Glen Canyon as indicated by catches in Lake Powell soon after impoundment. The emaciated condition of channel catfish in Cataract Canyon and the absence of other insectivores such as roundtail chub suggests a low food supply for humpback chub. Nevertheless, Cataract Canyon warrants consideration as a site for introducing hatchery-reared humpback chub and bonytail chub.

Stratum C: Spanish Bottom to Potash

Stratum C extended for 50 miles from Spanish Bottom (3 miles downstream from the Green River confluence) to Potash, near Moab, Utah. The river in this stratum flows into Canyonlands National Park in a meandering channel with a wide flood plain and high sandstone walls. The substrate was nearly all sand and sand-silt and the banks were overgrown by tamarisk.

Maximum depth recorded in this stratum was 27 feet but the average depth was 1 foot (Table C-3). This relatively shallow, flat section of river consisted mostly of shallow runs and shoreline habitat, but had a greater number of backwaters than any other stratum (Table 4). Water chemistry varied dramatically by years and flow periods; this stratum exhibited the highest conductivity (1720 umhos/cm at 23.5° C) of the upper Colorado River (Table D-3).

A total of 18 fish species were found in stratum C. Common carp, red shiner, sand shiner and channel catfish were abundant throughout. Adults, juveniles and YOY squawfish were more numerous in this stratum than in any other in the study region. As many as 106 YOY squawfish were seined from one backwater, although most catches were much smaller. This stratum appears to be important as a nursery to the squawfish reared in the upper Colorado River because of a relatively large number of backwaters. It also appears suitable for juveniles, as indicated by the good condition of the squawfish recaptured from a lot of 1500 hatchery-reared fish released at Potash in April 1980 (see section on Colorado squawfish). Only two adult razorback sucker were taken within this stratum at The Slide, 1.5 miles above the Green River confluence.

Stratum D: Potash to Big Bend

Stratum D was a 24-mile section of river that flows through a small open valley near Moab, Utah. It had a predominantly sand-silt substrate and sandy banks overgrown with tamarisk. The habitat was predominantly runs, but backwaters and eddies were common (Table 4). The upper end of this stratum was the transition between the predominantly sand and sand-silt substrate of the lower river and the rocky substrate of the upper strata. Moab is one of the two major communities along the upper Colorado River and it influences the river with water withdrawals; industrial, domestic and agricultural pollution; and some stream-side gravel pit operations.

Maximum depth of the river in stratum D was 19 feet and average depth was 5.0 feet (Table C-4). Water chemistry varied considerably with flow period, and conductivity was often high in early fall during low flow (Table D-4).

Eighteen species of fish inhabit stratum D. Flannelmouth sucker, common carp, red shiner, sand shiner and channel catfish were abundant, while bluehead sucker, largemouth bass and roundtail chub were common. Strata C, D and E (near Moab, Utah), supported the greatest numbers of non-native fishes of any strata of the upper Colorado River, presumably because of attempts by state agencies to provide a stream fishery for residents and the large number of independently-owned and operated farm ponds near the river that overflow and release these fish.

Several adults, juveniles and YOY Colorado squawfish were caught in stratum D during this investigation. The few backwaters appear to provide habitat for YOY and juveniles, including some of the previously mentioned hatchery-reared fish. One large backwater near Potash was often occupied by hatchery-reared and wild juveniles. The only razorback sucker taken in this stratum was in this backwater at RM 48.2. Unfortunately, this large backwater was partially filled in October 1980 by a bulldozer apparently preparing a pipeline corridor through the area.

Stratum D is important to Colorado squawfish because of numerous backwaters for rearing and feeding by YOY and juveniles, and feeding by adults. However, several industries in the area are modifying the river channel with flow diversions, pipeline corridors and gravel pit operations. Unless properly managed, these activities may have a detrimental effect on use of the area by the few remaining squawfish of the upper Colorado River.

Stratum E: Big Bend to Onion Creek

Stratum E was a scenic stretch of river that extended 15 miles through Moab Canyon to the foothills of the LaSal Mountains near Fisher Towers. The river is paralleled by a two-lane highway and is a popular recreational area for rafting, canoeing, camping and fishing. The river meanders through steep canyon walls with intermittent open valleys. This stratum was characterized by deep, slow-flowing runs and pools over sand-rock substrate. There were few backwaters or eddies in this stratum (Table 4). The river had intermittent swift runs or small rapids created by rocky deltas from washes or gulches.

Maximum water depth in stratum E was 46 feet and average depth was 6.8 feet (Table C-5). Water chemistry of this stratum revealed no aberrancies. Conductivity reached levels of 1250 umhos/cm at 18° C in early October (Table D-5).

Eighteen fish species were found in stratum E. Flannelmouth sucker, common carp, roundtail chub, red shiner, sand shiner and channel catfish were abundant; and bluehead sucker, largemouth bass and fathead minnow were numerous. The abundance of roundtail chub in this stratum and all others upstream suggests a direct correlation with the predominately rock substrates in the cooler upstream reaches.

Two juvenile humpback chub and several adult and juvenile Colorado squawfish were found in stratum E. The lack of large numbers of eddies, along with existing deep runs, may exclude large numbers of humpback chub from the area.

The juvenile squawfish caught in stratum E include three of the hatchery-reared fish released at Potash. This stratum is important to the squawfish of the upper Colorado River because of the numerous catches of adults and juveniles.

Stratum F: Onion Creek to Agate Wash

Stratum F encompassed 25 miles of meandering slow-flowing river among shallow canyons and rolling foothills. The substrate was primarily rock and sand or rock and sand-silt. This stratum contains some backwaters but the predominant habitats were runs and eddies (Table 4).

Maximum depth was 35 feet and average depth was less than 5 feet (Table C-6). Conductivity (Table D-6) varied from 280 umhos/cm (at 11.2° C) to 1200 umhos/cm (at 17.0° C). Water chemical features were probably influenced by the Dolores River, which flows into the Colorado River midway through stratum F.

The fish composition of stratum F was characterized by fewer species (16) than stratum E, but a greater abundance of some species. Bluehead sucker, flannelmouth sucker, common carp, roundtail chub, red shiner, sand shiner and channel catfish were abundant; while largemouth bass and fathead minnow were numerous.

Adults and YOY Colorado squawfish were caught in low numbers in stratum F. The latter were taken primarily from one backwater near the upper end of the stratum. Although a flannelmouth X razorback sucker

hybrid was caught in this stratum, no razorback sucker were taken. No target fish species were caught from the mouth of the Dolores River or from its vicinity. A report on the fishes of the Dolores River was prepared by the GJFS and is under separate cover.

Stratum G: Agate Wash to Westwater

This stratum included Westwater Canyon, a series of rapids like those of Cataract Canyon, but of less volume and severity. The 14 miles of Westwater Canyon represents a geologic anomoly of upthrust black metamorphic gneiss rock. This material is much harder than the overlying sandstone, and the river channel is confined, narrow and deep. The streambank was mostly steep, vertical walls with pockets and angular depressions carved by the swift water. The habitat was predominately deep runs, eddies and pools (Table 4). There were few backwaters in stratum G, especially during runoff. Westwater Canyon was difficult to sample because of treacherous rapids that independently varied in severity with flow period.

Westwater Canyon was one of the three deepest reaches of the upper Colorado River (Cataract Canyon was deeper and Black Rocks was as deep) with a maximum depth of 60 feet and a mean depth of 7.9 feet (Table C-7). Water chemistry varied (Table D-7), with conductivity of up to 1490 umhos/cm.

A total of 17 fish species inhabited Westwater Canyon and adjacent areas (Table 6), although the river in the canyon itself supported only 13 species (stratum N, Table 5). Common carp, roundtail chub and channel catfish were abundant in stratum G; while bluehead sucker, flannelmouth sucker, humpback chub, red shiner, sand shiner and fathead minnow were common.

Humpback chub in Westwater Canyon, discovered in September 1979 during this investigation, probably constitute the largest population of the species in the upper Colorado River System; and the second largest in the entire basin (the population in the Little Colorado River is probably larger). Young, tentatively identified as G. cypha, and juveniles and adults evidence a self-sustaining, reproducing population. Only two adult Colorado squawfish were found in stratum G. Westwater Canyon is an important enclave for humpback chub. Maintaining the physical, biological and chemical integrity of this canyon is critical to the survival and recovery of the species.

Stratum H: Loma to Westwater

The Colorado River in this 29-mile stretch meanders gently through Horsethief and Ruby Canyons, an area of alternating high sandstone walls and open, sagebrush and pinyon-juniper parks. The river substrate was generally gravel and rubble with substantial deposits of sand and silt. The habitat was generally runs, with some pools and eddies, but few backwaters (Table 4). An upthrust of metamorphic gneiss, near the lower end of the stratum, was considered a geologic anomoly and designated as a

separate and special stratum, K. This Black Rocks stratum is discussed later in this section.

The maximum depth of stratum H was 18 feet and average depth was 4.0 feet (Table C-8). Water temperature ranged from 14.0° C in April to 26.0° C in August (Table D-9). Conductivity ranged from 250 umhos/cm (at 17.5° C) to 1100 (at 22.0°.C).

Seventeen fish species were caught in stratum H (Table 6). Bluehead sucker, flannelmouth sucker, common carp, roundtail chub, red shiner, sand shiner, fathead minnow and channel catfish were abundant, while green sunfish and black bullhead were locally common in the few backwaters of the stratum.

Colorado squawfish, humpback chub and razorback sucker were all captured within this stratum. Juvenile and adult squawfish were caught in several locales, and this stratum yielded the upstream-most capture of YOY. Additional YOY were captured by the Colorado Division of Wildlife (Wick, et al. 1981). Two adult razorback sucker were taken from backwaters of this stratum. Humpback chub in this stratum all occurred near the Black Rocks area, where one of the four known concentrations of the species exists. This stratum is critical to humpback chub. Its physical, biological and chemical integrity must be maintained to insure survival of the species. The stratum also appears to be important to Colorado squawfish. The YOY found in the stratum may have been spawned locally.

Stratum I: Palisade to Loma

The Colorado River in stratum I flows for 31 miles through Grand Junction, Colorado and several surrounding communities. The Gunnison River enters the Colorado River midway in the stratum. The river in stratum I leaves Debeque Canyon and meanders through a large agricultural-residential valley. The channel is extensively braided around many vegetated gravel islands. These islands and adjacent alluvium attract many gravel-extraction operations for domestic and industrial use near Grand Junction. The result is a series of inundated gravel pits that pockmark the river channel throughout the stratum. Some of these gravel pits (Walter Walker Wildlife Area and Clifton Pond) were used during runoff by a variety of riverine fishes including the target species. (see this section, strata M and N for descriptions of these gravel pits).

The predominate substrate type of stratum I was gravel and rubble, and the habitat was mostly runs and riffles with some eddies, backwaters and side channels (Table 4). Irrigation laterals withdraw and return substantial volumes of water in this area of the river. Maximum depth of the stratum was 18 feet and average was 3.9 feet (Table C-9). Water temperatures ranged from 14.0° C in April and June to 26.0° C in August (Table D-9), and conductivity ranged from 250 umhos/cm (at 17.5° C) to 1100 (at 22.0° C).

Seventeen fish species were found in stratum I (Table 6). Bluehead suckers, flannelmouth suckers, common carp, roundtail chub, red shiner, sand shiner and fathead minnow were abundant. Green sunfish and black

bullheads were locally common, especially in the gravel pits; and white sucker, black crappie, speckled dace and channel catfish were numerous.

This stratum was the upstream-most section of the river with numerous catches of Colorado squawfish and razorback sucker. This stratum yielded the greatest number of razorback sucker of any in the study area. Most of these fish were captured in gravel pits or irrigation return flows, areas where the species were probably most susceptible to our sample gear. The area is significant to endangered species, as indicated by their presence year-round. However, disturbances from gravel pit excavations, and domestic, agricultural and industrial pollution apparently impede extensive natural reproduction and proliferation of the species in the area (see section on Razorback Sucker).

Stratum J: Debeque to Palisade

The Colorado River in stratum J meanders for 25 miles through Debeque Canyon. The channel is paralleled by Interstate Highway 70 and the Union Pacific Railroad, and has been altered considerably by these two right-of-ways. The river has in many places been confined by banks riprapped with boulders. Flow in this stratum was swift over mostly gravel, rubble and boulder substrate. Few sand or silt areas occurred except in the small reservoir created by the Government Highline Dam midway through the stratum. This dam appeared to be an effective fish barrier to upstream movement. Plateau Creek enters the Colorado River just below this dam site. The habitat in stratum J consisted mostly of runs, small pools, eddies and few backwaters (Table 4).

Maximum depth in stratum J was 17 feet and average depth was 5.9 feet (Table C-10). Water temperature ranged from 11.4° C in April to 22.5° C in September (Table D-10). Conductivity ranged from 450 (at 20° C) to 900 umhos/cm (at 22.5° C).

The fish composition of stratum J suggests a transition between warm and cool water fisheries (Table 6). Bluehead sucker, flannelmouth sucker, common carp and roundtail chub were abundant; and white sucker, green sunfish, mottled sculpin, red shiner, sand shiner, fathead minnow, black bullhead and rainbow trout were numerous. Flannelmouth sucker, bluehead sucker and roundtail chub concentrated in the spillway of the Government Highline Dam during spring runoff.

Only one razorback sucker and two Colorado squawfish were taken in this stratum. The squawfish were caught at the downstream end of the stratum in the proximity of the Grand Valley Irrigation Company Diversion. This structure is not considered a fish barrier as is the Government Highline Dam. The razorback sucker was caught at RM 205 near the town of Debeque, Colorado.

Only one humpback chub was recently reported from this stratum (Kidd 1977); an adult taken near the Grand Valley Diversion. But, a form of chub with morphological features of both G. cypha and G. robusta is locally common at Beavertail Mountain in Debeque Canyon (Valdez 1981). This form was tentatively identified as a G. cypha X G. robusta cross (see section on Humpback Chub).

Stratum X: Rifle to Debeque

Fishery investigations were initiated in this stratum after an amendment to BLM/MOU CO-910-IA9-933. This section of the Colorado River was added to the study to provide information to the Glenwood Springs Resource Office of the BLM. An interim report was submitted subsequent to initial sample efforts (Mangan and Valdez 1981).

The stratum was 31 miles long, and the river meanders through open valleys and rolling sagebrush foothills. Fields of alfalfa and grain and a few fruit orchards line the river banks. Recent improvements to Interstate Highway 70 have resulted in increased gravel excavations along the river in this stratum.

The substrate of stratum X was predominately rock (gravel, rubble, boulder) with some areas of silt and sand. Most of the stratum was shallow to moderate-depth runs and riffles. Pools and eddies were numerous, but backwaters were uncommon. Maximum depth in the stratum was about 18 ft with an average depth of about 2 feet. Water clarity was usually high, and summer water temperatures were cool.

This stratum encompassed the transition zone between warm and cool water fisheries. Bluehead sucker, flannelmouth sucker, common carp, roundtail chub and speckled dace were abundant (Table 6); while white sucker, green sunfish, mottled sculpin, fathead minnow, brown trout and rainbow trout were numerous. The two species of trout were introduced locally by the Division of Wildlife Resources. Two razorback sucker were captured by this investigation in this stratum (see section on Razorback Sucker). These constitute the upstream-most records for the razorback in the last 5 years. Colorado squawfish, humpback chub and bonytail chub were not found in this stratum. Water temperatures, especially in fall, winter and spring are probably prohibitively cold for these species.

Special Stratum K: Black Rocks

The Colorado River before reaching the Colorado-Utah stateline flows through an upthrust of metamorphic gneiss. This Black Rocks area is only 1 mile long but constitutes one of the most unique fish habitats of the upper Colorado River. The area is composed of large pillars of hard black rock cut deeply by the river channel. The habitat was predominantly deep eddies, pools and runs, with few backwaters and shorelines. The river was narrow and deep, and the banks are either vertical walls of gneiss or sand beaches that occurred intermittently between rock pillars.

Maximum depth of Black Rocks was 60 feet about the same maximum depth as Westwater Canyon. Mean depth in Black Rocks was 17.2 feet (Table C-11). The water chemistry of Black Rocks was like that of the adjacent stratum H. Water temperature was recorded as 11.5° C in June and 24.0° C in August (Table D-11). Conductivity ranged from 290 umhos/cm (at 11.5° C) to 1200 umhos/cm (at 24.0° C).

Only 14 fish species were found in Black Rocks, compared to 17-18 for most other strata (Table 6). Only common carp and roundtail chub were abundant throughout the stratum, and red shiner were common in quiet areas. Bluehead sucker, flannelmouth sucker, humpback chub, sand shiner,

fathead minnow and channel catfish, as well as possible roundtail chub X humpback chub hybrids were numerous (see section on Humpback chub).

Black Rocks contains one of the largest populations of humpback chub in the upper Colorado River Basin. Young-of-the-year, juveniles and adults were all present (see section on Humpback Chub). Only adult and large juvenile Colorado squawfish were taken from Black Rocks. An apparent concentration of squawfish was noted in this deep river region in the fall. This area of the Colorado River is vital to the survival of humpback chub in the upper basin, and present flow and temperature regimes must be maintained.

Special Stratum M: Walter Walker Wildlife Area

Part of the Walter Walker Wildlife Area near Grand Junction, Colorado, was an abandoned gravel-extraction pit (excavated in 1965) adjacent to the Colorado River. It was selected as a special study site because of past fishery data available and the unique opportunity to assess use of artificial backwaters by endangered fishes. The 27-hectare pit was isolated from the Colorado River except during runoff, at flows exceeding 7500 cfs. The river at runoff flowed into the gravel pit through a single inlet, but there was little circulation and much of the silt load of the river was deposited on the gravel substrate. Silt on the pit bed was 1-2 feet deep.

Maximum depth of this gravel pit was 6 feet and average depth was 2 feet (Table C-12). The maximum conductivity of this small body of water was 1650 umhos/cm at 24.5° C (Table D-12).

The fish composition of Walter Walker Wildlife Area varied dramatically with flow period. Riverine species occupied the pit when the river flooded but returned to the river with receding waters. Flannelmouth sucker and roundtail chub often abounded near the outlet during runoff (Table 6). Some bluehead sucker, white sucker, razorback sucker and Colorado squawfish also moved into the pit at this time. Some of these riverine fish remained or were trapped in the pit after the water receded. Fish collections when the pit was isolated from the river yielded large numbers of common carp, black bullhead and green sunfish. Largemouth bass, red shiner and fathead minnow were common in these samples, and channel catfish were numerous. Walter Walker Wildlife Area had a high percentage of non-native fishes except when native riverine species temporarily invaded the pit during runoff. Black crappie, bluegill and northern pike were also taken from the gravel pit.

Colorado squawfish and razorback sucker were often caught during runoff, and sometimes when the pit was isolated from the river. Walter Walker may be a resting or feeding area for these endemics, as well as a staging area for reproduction (see section on Colorado Squawfish and Razorback Sucker). Walter Walker Wildlife Area does not appear to benefit the endemic species, and may be detrimental via parasite infestations, competition and predation (Valdez and Wick 1981). We tentatively propose permanent closure of this area from the river and eradication of all fishes (with efforts to save endangered species) for establishing a closed system largemouth bass - bluegill - channel catfish recreational

fishery. In lieu of these gravel pits, modifications could be made to new or existing pits that could improve conditions for razorback sucker (Valdez and Wick 1981) (see Razorback Sucker).

Special Stratum N: Westwater Canyon

Stratum N included a portion of stratum G that was the center of Westwater Canyon. It was an area of 8 miles of steep walls of black gneiss through which the Colorado River flows in a series of rapids, deep pools, eddies and runs. The physical and chemical description of stratum G also applies to strata N (Tables C-13 and D-13).

The stratum contained only 13 fish species (Table 6), including what appears to be the largest population of humpback chub in the upper Colorado River System. Common carp and roundtail chub abounded, and the intermediate form of G. cypha and G. robusta was numerous, as in Black Rocks and Debeque Canyon. Westwater Canyon is vital to humpback chub of the upper Colorado River. Flow and temperature regimes must be maintained to insure the survival of the species in the upper basin.

Special Stratum O: Clifton Pond

Clifton Pond was a series of small, shallow, vegetated gravel pits covering about 2 hectares. It was located about 1 mile east of the Highway 146 bridge crossing the Colorado River near Clifton, Colorado. The pond was usually dry or with little standing water except in runoff when waters from the river entered a 20-inch culvert pipe beneath an earthern berm isolating the pond from the river.

Maximum depth of the pond when flooded was 10 feet and average depth was 2 feet (Table C-14). The substrate was primarily gravel beneath a thin layer of silt, and the bottom was very uneven. Water temperature in early June was 13.5-14.0° C, dissolved oxygen was 8 mg/l and conductivity was 1100 umhos/cm (Table D-14).

Only 4 fish species were found in Clifton Pond (Table 6). Common carp were abundant; flannelmouth sucker were numerous; and Colorado squawfish and razorback sucker were rare. Razorback sucker entered Clifton Pond and Walter Walker Wildlife Area at flood stage (see Razorback Sucker); this was the only time of year and locales in which these target fishes were caught in concentrations.

Clifton Pond, like Walter Walker Wildlife Area, is probably more detrimental than beneficial to the endemic fishes. More information is needed on this and other gravel pits in the area to make management recommendations.

Special Stratum P: Gypsum Canyon

Gypsum Canyon was in upper Lake Powell, 4 miles downstream from the inlet of the Colorado River. It was a deep, slow-flowing riverine environment, although part of the lake. An ephemeral stream flowed through Gypsum Canyon into Lake Powell. The lake was mostly steep sandstone walls, talus slopes and some low rolling hills.

This site was selected as a special study area because of the large number of juvenile and adult Colorado squawfish (41) caught April-June 1980, incidental to striped bass investigations (Persons and Bulkley 1980). This catch occurred at or near maximum lake level of 3700-ft elevation. A concerted effort to capture the fish in 1981 yielded very few squawfish (Persons and Bulkley 1981), perhaps because the much lower lake level of about 3650-ft elevation altered the behavior of these fish. This lowered lake level exposed many sand and silt bars that later characterized the substrate of upper Lake Powell. Maximum depth at the 3700-ft lake level was 30 feet and average depth was 15.8 feet (Table C-15).

Fish Species Composition by Habitat

Fishes in the upper Colorado River were recorded from 11 major habitat types; backwaters, eddies, gravel pits, irrigation ditches, lakes, main channels, pools, riffles, shorelines, side channels and runs. The occurrence of species in each habitat is presented as percentage composition of total catch for 1979-1981 with all gears used (Figure 5). This analysis provides an overview of species use by young-of-the-year, juveniles and adults (Table 7). Species composition by habitat is presented in tables 8-18 with the number of samples (n) indicated.

Backwaters

Fish diversity of backwaters (21 species) was surpassed only by that of runs (23 species). Over 46 percent of the fishes caught in backwaters were red shiner, nearly 22 percent were sand shiner, and over 16 percent were fathead minnow (Table 8). These three species composed 85 percent of the catch in backwaters. The most common native species in backwaters was roundtail chub with about 7 percent of the catch.

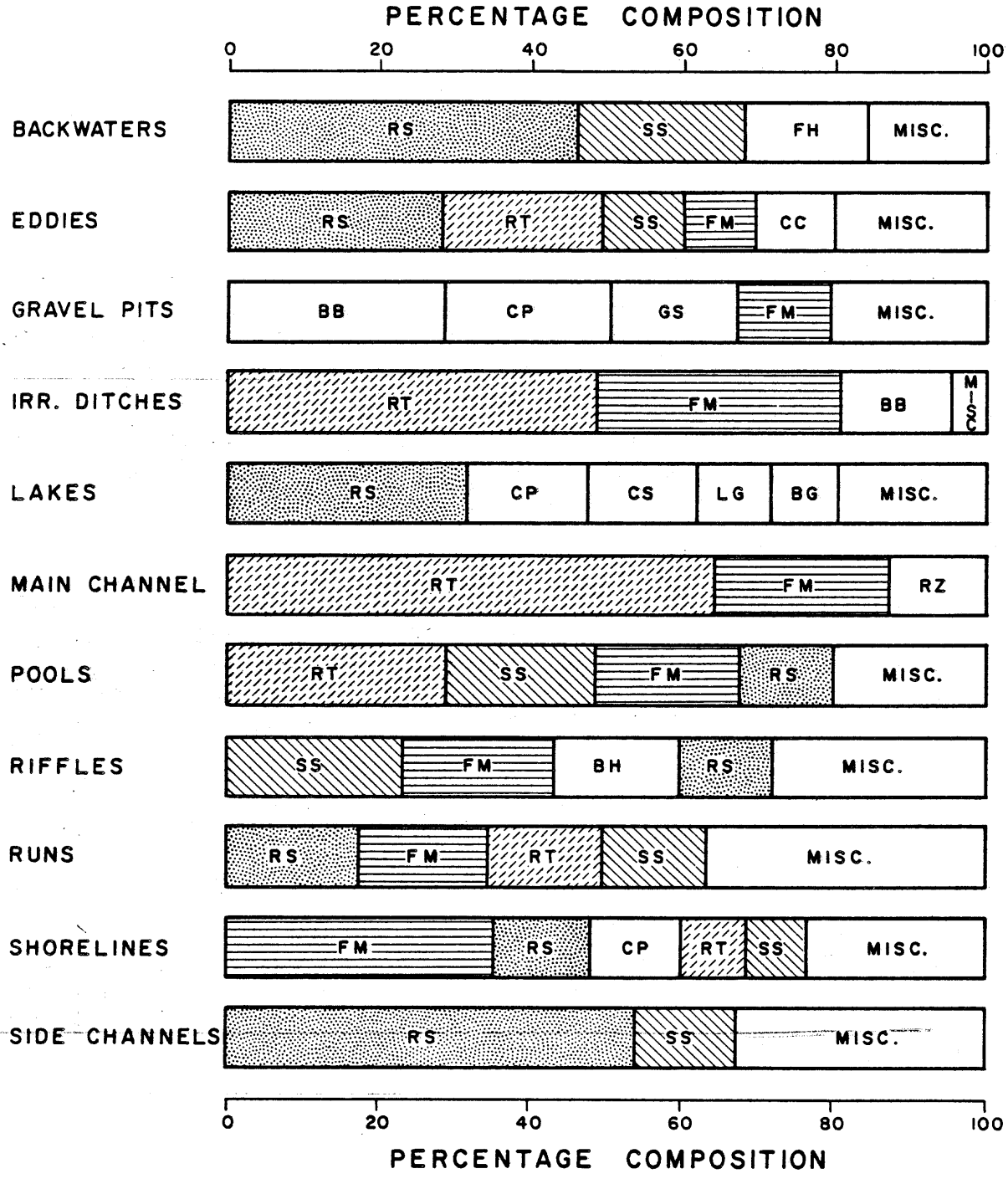
Colorado squawfish made up only 1.07 percent of the catch, and the majority of these were YOY (315 of 373 fish). Only two YOY tentatively identified as humpback chub were found in backwaters. A total of six adult razorback sucker were caught in backwaters.

Backwaters appear to be important to YOY and age group I Colorado squawfish, as well as to adult razorback sucker. However, backwaters are usually occupied by large numbers of nonnative cyprinids, especially red shiner, sand shiner and fathead minnow. Nonnative fishes in backwaters made up 89.1 percent of the total catch.

Eddies

A total of 18 fish species were found in eddies (Table 9). The predominant species were red shiner (27.86 percent) and roundtail chub (21.44 percent) Sand shiner composed about 11 percent of the catch, and channel catfish and flannelmouth sucker each contributed about 10 percent. Non-native species made up 60.7 percent of the catch in eddies.

Figure 5



Percentage composition of fishes in 11 habitats of the upper Colorado River, 1979-81.

Table 7
Numbers and percentage of total catch of young-of-the-year (Y), juveniles (J), and adults (A) for the three target species in major habitats of the upper Colorado River

	Colorado squawfish				Humpback chub				Razorback sucker	
	Y	J	A	percent	Y	J	A	percent	A	percent
Backwaters	315	50	8	1.08	2	0	0	0.01	6	0.02
Eddies	0	2	12	0.43	0	16	44	1.84	1	0.03
Gravel pits	0	0	9	0.60	0	0	0	—	37	2.45
Irrigation ditches	0	0	0	—	0	0	0	—	0	—
Lakes	0	0	43	14.48	0	0	0	—	5	1.68
Main channel	0	0	0	—	0	0	0	—	1	12.50
Pools	0	1	2	0.22	0	2	66	4.92	0	—
Riffles	0	0	0	—	0	0	0	—	0	—
Runs	20	11	36	0.42	0	16	91	0.77	2	0.01
Shorelines	0	0	10	0.70	0	0	1	0.07	0	—
Side channels	1	1	1	0.31	0	0	1	0.10	0	—

Table 8
Fish species composition in backwaters of the upper Colorado River, 1979-1981 (n = 842)

Species	Number[1/]				Percentage composition
	YOY	JUV	ADU	Sum	
Black bullhead	11	122	15	148	0.42
Black crappie	1	3	4	8	0.02
Bluegill	0	1	0	1	0.01
Bluehead sucker	140	99	76	315	0.90
Brown trout	0	0	1	1	0.01
Channel catfish	192	94	12	298	0.85
Gila sp.	6	2	0		0.02
Carp	35	116	280	431	1.23
Colorado squawfish	315	50	8	373	1.07
Fathead minnow	2,234	805	2,807	5,846	16.75
Flannelmouth sucker	311	218	110	639	1.83
Green sunfish	65	68	45	178	0.51
Humpback chub	2	0	0	2	0.01
Largemouth bass	17	106	8	131	0.38
Plains killfish	2	12	19	33	0.09
Rainbow trout	0	6	0	6	0.02
Red shiner	6,444	1,108	8,682	16,234	46.51
Roundtail chub	499	1,630	198	2,377	6.67
Razorback sucker	0	0	9	6	0.02
Speckled dace	46	18	69	133	0.38
Sand shiner	1,025	779	5,867	7,671	21.98
White sucker	2	40	69	111	0.32
Total	11,346	5,277	18,277	34,900	100.0

1/ YOY = young-of-year; JUV = juvenile; ADU = adult

Table 9
Fish species composition in eddies of the upper Colorado River, 1979-1981 (n = 486)

Species	Number[1/]				Percentage composition
	YOY	JUV	ADU	Sum	
Black bullhead	0	1	1	11	0.34
Bluehead sucker	4	30	49	83	2.54
Channel catfish	75	199	48	322	9.89
Gila sp.	0	0	2	2	0.06
Carp	0	32	63	95	2.92
Colorado squawfish	0	2	12	14	0.43
Fathead minnow	16	118	104	238	7.31
Flannelmouth sucker	21	135	167	323	9.92
Flannelmouth x razorback sucker	0	0	2	2	0.06
Green sunfish	2	4	7	13	0.40
Humpback chub	0	16	44	60	1.84
Largemouth bass	0	3	3	6	0.15
Plains killfish	0	1	0	1	0.03
Rainbow trout	0	5	0	5	0.15
Roundtail x humpback chub	0	12	5	17	0.52
Red shiner	373	298	231	907	27.86
Roundtail chub	32	466	200	698	21.44
Razorback sucker	0	0		1	0.33
Speckled dace	2	5	71	77	2.36
Sand shiner	96	75	195	366	11.24
White x flannelmouth sucker	0	1	0	1	0.03
White sucker	0	3	10	13	.04
Total	625	1,415	1,215	3,255	100.00

1/ YOY = young-of-year; JUV = juvenile; ADU = adult.

Adult Colorado squawfish and humpback chub were frequently caught in eddies, but composed only 0.43 and 1.84 percent of the total catch. Eddies and boundaries between eddies and runs were favored by roundtail chub and humpback chub, and are considered important habitat to survival of the species. Presumably, eddies provide quiet resting areas while accumulating drifting insects for food. Eddies during runoff often create small backwaters around sand bars that harbor many young fishes during low flow.

Gravel Pits

Three major gravel pits were sampled in the Grand Junction area; Walter Walker Wildlife Area, Clifton Pond and Connected Lakes. A total of 17 fish species were found in these gravel pits (Table 10). Black bullhead (29.11 percent), common carp (22.08 percent) and green sunfish (15.64 percent) dominated the catch. Only 5 of these 17 species were natives. Nine adult Colorado squawfish were taken for less than 1 percent of the catch, and 37 adult razorback sucker were caught for 2.45 percent of the catch. This habitat yielded the greatest number of razorbacks, especially at flood stage. These two target species were taken from Walter Walker Wildlife Area and Clifton Pond.

The 12 nonnative species of fishes in gravel pits composed 81.16 percent of the catch. Gravel pits, like backwaters, appear to be highly competitive environments for endemic species, because of the large numbers of nonnative fish and the presence of many parasites and pathogens. Further study is needed to accurately assess the role of gravel pits for these endemics, but it is probably best to close the inlets and prevent endemics from entering them. Since they are probably subjected to intense competition and predation that can thwart any spawning attempts.

Irrigation Ditches

Irrigation ditches were the least frequently sampled habitat. These were usually sampled at the point where the lateral returned flow to the river after agricultural uses. Salt Wash, Reed Wash and Big Salt Wash as well as several unnamed laterals near Grand Junction were sampled about 100 yards upstream from the main river. Depth was usually less than 3 feet, and the substrate was silt or sand. Conductivity in these irrigation return flows usually exceeded river levels, with a maximum of 2,000 umhos/cm.

Only seven fish species were found in irrigation ditches (Table 11). Roundtail chub (49.33 percent) and flannelmouth sucker (31.41 percent) dominated the catch. These two riverine species as well as bluehead sucker occurred in these laterals almost exclusively during runoff. During receding flows, black bullhead, carp and channel catfish dominated the catch. Many other riverine species often congregated at the mouths of these return flows, including Colorado squawfish.

Irrigation ditches do not appear important to the target species, although the habitat could provide shelter and food. The high salinity and turbidity in these laterals may prevent access by many fish.

Table 10
Fish species composition in gravel pits of the upper Colorado River, 1979-1981 (n = 257)

Species	Number[1/]				Percentage Composition
	YYY	JUV	ADU	Sum	
Black bullhead	0	292	147	439	29.11
Black crappie	0	3	1	4	0.27
Bluegill	0	0	4	4	0.27
Bluehead sucker	0	0	1	1	0.07
Channel catfish	0	97	7	86	5.70
Carp	0	24	309	333	22.08
Colorado squawfish	0	0	9	9	0.60
Fathead minnow	0	0	1	1	0.07
Flannelmouth sucker	0	56	130	186	12.32
Flannelmouth x razorback sucker	0	0	1	1	0.07
Green sunfish	0	98	138	236	15.64
Largemouth bass	0	22	5	27	1.79
Northern pike	0	0	1	1	0.07
Red shiner	0	0	27	27	1.79
Roundtail chub	0	22	43	65	4.31
Razorback sucker	0	0	37	37	2.45
Sand shiner	0	0	2	2	1.33
White x flannelmouth sucker	0	0	3	3	0.20
White sucker	0	2	23	46	3.05
Total	0	549	959	1,S08	100.00

1/ YOY = young-of-year; JUV = juvenile; ADU = adult.

Table 11.
Fish species composition in irrigation ditches of the upper Colorado River, 1979-1981 (n = 9)

Species	Number[1/]				Percentage Composition
	YOY	JUV	ADU	Sum	
Black bullhead	0	0	100	100	14.81
Black crappie	0	1	0	1	0.15
Bluehead sucker	0	1	16	17	2.52
Channel catfish	0	2	3	5	0.74
Carp	0	0	7	7	1.04
Flannelmouth sucker	0	8	204	212	31.41
Roundtail chub	0	3	330	333	49.33
Total	0	15	660	675	100.0

1/ YOY = young-of-the year; JUV = juvenile; ADU = adult.

Lakes

The only lake habitat sampled in the study was the upper 32 miles of Lake Powell. This area of the lake yielded 16 fish species, including 13 non-native and 3 natives that accounted for 82.83 percent and 17.17 percent, respectively (Table 12). Red shiner dominated the catch with 31.65 percent. Common carp and Colorado squawfish accounted for 15.82 percent and 14.48 percent of the catch, respectively. This high percentage composition of squawfish (43 adults) occurred primarily in Gypsum Canyon, a riverine-like environment near the inlet of the Colorado River, as a result of intensive sampling for striped bass in 1980. Investigation in 1981 did not reveal any large number of squawfish or razorback sucker, perhaps the result of a much lower lake level (3700 ft vs 3650 ft). Five razorback sucker were also caught in Lake Powell by investigators from Utah State University and from the Utah Division of Wildlife Resources (see sections on Colorado Squawfish and Razorback Sucker).

The importance of lake habitat to Colorado squawfish and razorback sucker warrants further study. Upper Lake Powell is probably not suited for reproduction by these species because of deep silt deposits that prevent successful egg incubation, and the lack of backwaters as nurseries for the young.

Main Channels

The low number of fishes captured from the main channel (Table 13) probably reflects the inefficiency of existing gear to sample that central, swift habitat, and not necessarily a paucity of fishes. Also, much of the midchannel sampling was usually associated with more specific habitat types, e.g. runs, riffles. Only three fish species were reported from main channels. Roundtail chub were very common, and flannelmouth sucker were often found congregated over gravel and rubble bars. A single razorback sucker was captured in main channel habitat.

Pools

Sixteen fish species were caught in pools, including 6 natives and 10 non-native for 51.40 percent and 48.60 percent of the catch, respectively (Table 14). Roundtail chub (25.16 percent) and sand shiner (23.36 percent) each accounted for about one-fourth of this catch. Flannelmouth sucker (18.08 percent) and red shiner (13.38 percent) were also commonly associated with this habitat. Few Colorado squawfish (3 fish for 0.22 percent) were taken in pools, but many of the humpback chub (68 fish for 4.92 percent) were associated with this habitat.

Pools appear to be important to humpback chub and roundtail chub in much the same way as eddies (Table 9). Fish appear to rest in pools and eddies and feed on material drifting from adjacent runs.

Riffles

Fifteen fish species were caught in riffles, (Table 15) including 5 natives (52.00 percent) and 10 non-natives (48.00 percent). Sand shiner and flannelmouth sucker dominated the catch with 23.3 percent and 20.6 percent, respectively. Sand shiner often occurred in small, shallow,

Table 12
Fish species composition in lakes of the upper Colorado River, 1979-1981 (n = 92)

Species	Number YOY	JUV	ADU	Sum	Percentage Composition
Black bullhead	0	1	0	1	0.34
Black crappie	0	1	1	2	0.67
Bluegill	0	7	21	28	9.43
Channel catfish	0	9	2	1	3.70
Carp	0	20	27	47	15.82
Colorado squawfish	0	0	43	43	14.48
Fathead minnow	0	0	1	1	0.34
Flannelmouth sucker	0	0	3	3	1.01
Green sunfish	2	2	20	24	8.08
Largemouth bass	2	17	9	28	9.43
Red shiner	0	0	94	94	31.65
Razorback sucker	0	0	5	5	1.68
Striped bass	0	0	1	1	0.34
Sand shiner	0	0	4	4	1.35
Threadfin shad	0	0	2	2	0.67
Walleye		0	4	4	1.35
Total	4	57	236	297	100.0

1/ YOY = young-of-the-year; JUV = juvenile; ADU = adult.

Table 13
Fish species composition in the main channel of the upper Colorado River, 1979-1981 (n = 16)

Percentage(s)	Number YOY	JUV	ADU	Sum	Percentage Composition
Flannelmouth sucker	1	0	1	2	25.0
Roundtail chub	4	1	0	5	62.5
Razorback sucker	0	0	1	1	12.5
Total	5	1	2	8	100.0

1/ YOY = young-of-year; JUV = juvenile; ADU = adult.

Table 14
Fish species composition in pools of the upper Colorado River, 1979-1981 (n = 143)

Species	Number[1/] YOY	JUV	ADU	Sum	Percentage composition
Bluehead sucker	3	16	21	46	3.32
Brown trout	0	0	1	1	0.07
Channel catfish	2	5	9	16	1.15
Carp	12	2	14	28	2.02
Colorado squawfish	0	1	2	3	2.22
Fathead minnow	32	11	30	73	5.28
Flannelmouth sucker	19	122	109	250	18.00
Flannelmouth x razorback sucker	0	0	1	1	0.07
Green sunfish	5	0	1	6	0.43
Humpback chub	0	2	66	68	4.92
Largemouth bass	2	0	0	2	0.14
Rainbow trout	0	3	3	6	0.43
Roundtail x humpback chub	0	0	2	2	0.14
Red shiner	39	19	127	185	13.38
Roundtail chub	31	171	146	348	25.16
Speckled dace	1	0	2	3	0.22
Sand shiner	266		63	323	22.36
White sucker	0	5	14	19	1.37
Total	406	357	620	1,383	100.0

1/ YOY = young-of-year; JUV = juvenile; ADU = adult.

Table 15
Fish species composition in riffles of the upper Colorado River, 1979-1981 (n = 58)

Species	Number[1/] YOY	JUV	ADU	Sum	Percentage composition
Bluehead sucker	0	159	4	163	16.51
Channel catfish	10	7	0	17	1.92
Carp	0	4	1	5	0.51
Fathead minnow	7	59	9	75	7.60
Flannelmouth sucker	0	194	9	203	20.60
Green sunfish	0	11	0	11	1.11
Largemouth bass	0	2	0	2	0.20
Mottled sculpin	0	3	0	3	0.30
Plains killfish	0	1	0	1	0.10
Rainbow trout	0	1	0	1	0.10
Red shiner	4	60	65	129	13.07
Roundtail chub	0	83	2	85	8.61
Speckled dace	4	24	31	59	5.98
Sand shiner	9	80	141	230	23.30
White sucker	0	0	3	3	0.30
Total	34	688	265	987	100.0

1/ YOY = young-of-year; JUV = juvenile; ADU = adult.

sandy riffles along shorelines, while juvenile flannelmouth sucker often occurred in moderate-depth rocky riffles. No target species were caught in riffles suggesting that this habitat is favored by nontarget suckers, shiners, and dace.

Runs

Runs supported the greatest number of species (23) of any habitat sampled. Nine natives and 14 nonnative made up 42.86 percent and 57.07 percent of the catch, respectively (Table 16). This habitat supported the greatest number and percentage composition of native species of any sampled. It is the most common habitat classified in the upper Colorado River.

Red shiner (18.06 percent), flannelmouth (16.26 percent), roundtail chub (15.28 percent), sand shiner (14.28 percent), and carp (12.58 percent) were the dominant species in runs. Although 67 Colorado squawfish, 107 humpback chub, and 2 razorback sucker were caught in runs, the large numbers of sympatric species resulted in a low percentage of the target species. Runs appear to be used extensively by the target species. The shallow slow runs are preferred by juveniles and the deep, slow runs by adults.

Shorelines

Sixteen fish species were caught in shorelines. This habitat, like midchannels, was often more specifically classified as a run or riffle along the shore. Six native species accounted for 55.41 percent of the catch, and 10 nonnatives accounted for 44.51 percent (Table 17). Over one-third (35.54 percent) of the catch in shorelines was flannelmouth sucker. Red shiner (12.75 percent), carp (11.63 percent), roundtail chub (10.60 percent), sand shiner (10.03 percent), channel catfish (8.15 percent), and bluehead sucker (7.94 percent) each accounted for about 10 percent of the catch. Ten adult Colorado squawfish (0.70 percent) and one humpback chub (0.07 percent) were represented in this habitat. Shorelines were reported important for YOY tentatively identified as Colorado squawfish by Colorado Division of Wildlife (Wick, et al. 1981).

Side Channels

Side channels were inhabited by 15 fish species, including 6 natives and 9 nonnative representing 11.78 percent and 88.22 percent of the catch, respectively (Table 18). Red shiner were prevalent in this habitat with 54.04 percent of the catch. Sand shiner accounted for 12.90 percent.

Only 3 Colorado squawfish (0.31 percent) and 1 humpback chub (0.10 percent) were caught in side channels. This habitat is common in the upper Colorado River during runoff. Backwaters are sometimes formed in these secondary channels at low flow. Side channels do not appear critical to the target species, unless they form these backwaters.

Table 16
Fish species composition in runs of the upper Colorado River, 1979-1981 (n = 1,436)

Species	Number[1/]				Percentage composition
	YOY	JUV	ADU	Sum	
Black bullhead	0	13	5	18	0.13
Black crappie	0	4	1	5	0.04
Bluehead sucker	125	621	434	1,183	8.49
Brown trout	0	6	3	9	0.06
Channel catfish	330	342	186	858	6.15
Gila sp.	2	0	1	3	0.22
Carp	41	779	933	1,753	12.58
Colorado squawfish	20	11	36	6*	0.48
Fathead minnow	246	69	345	66*	4.73
Flannelmouth sucker	37	1,293	936	2,266	16.26
Green sunfish	4	21	19	44	0.32
Humpback chub	0	16	91	107	0.77
Largemouth bass	0	29	9	38	0.27
Mottled sculpin	0	2	10	12	0.09
Plains killifish	0	0	1	1	0.01
Rainbow trout	0	15	0	18	0.11
Roundtail x humpback chub	0	7	24	31	0.22
Red shiner	554	125	1,838	2,517	18.06
Roundtail chub	1,040	793	297	2,130	15.28
Rocky mountain whitefish	0	1	0	1	0.01
Razorback sucker	0	0	2	2	0.01
Speckled dace	15	7	152	174	1.25
Sand shiner	309	143	1,538	1,990	14.28
White x bluehead sucker		0	3	3	.22
Walleye	0	0	1	1	0.01
White x flannelmouth sucker	0	0	5	5	0.04
White sucker	2	11	33	46	0.33
Total	2,728	4,308	6,904	13,940	100.0

1/ YOY = young-of-year; JUV = juvenile; ADU = adult.

Table 17
Fish species composition in shorelines of the upper Colorado River, 1979-1981 (n = 178)

Species	Number[1/]				Percentage composition
	YOY	JUV	ADU	Sum	
Black bullhead	0	3	0	3	0.21
Bluehead sucker	2	59	53	114	7.94
Channel catfish	6	88	23	117	8.15
Carp	0	63	104	16	11.63
Colorado squawfish	0	0	10	10	.70
Fathead minnow	0	0	15	15	1.14
Flannelmouth sucker	1	242	267	510	35.54
Flannelmouth x razorback sucker	0	0	1	1	.07
Green sunfish	0	0	3	3	.21
Humpback chub	0	0	1	1	.07
Largemouth bass	0	1	0	1	.07
Rainbow trout	0	1	0	1	.07
Red shiner	86	0	97	183	12.75
Roundtail chub	55	71	26	152	10.60
Speckled dace	0	0	8	8	.56
Sand shiner		0	143	144	10.03
White sucker	0	0	5	5	.35
Total	151	528	756	1,435	100.0

1/ YOY = young-of-year; JUV = juvenile; ADU = adult.

Table 18
Fish species composition in side channels of the upper Colorado River, 1979-1981 (n = 70)

Species	Number[1/]				Percentage composition
	YOY	JUV	ADU	Sum	
Black bullhead	0	25	0	25	2.56
Bluehead sucker	14	5	0	19	1.94
Channel catfish	31	28	1	60	6.14
Carp	1	31	19	51	5.22
Colorado squawfish	1	1	1	3	0.31
Fathead minnow	8	0	43	51	5.22
Flannelmouth sucker	14	19	0	33	3.38
Green sunfish	0	0	6	6	0.61
Humpback chub	0	0	1	1	0.10
Largemouth bass	0	6	0	6	0.61
Red shiner	0	1	253	528	54.04
Roundtail chub	274	36	4	51	5.22
Speckled dace	11				0.82
Sand shiner	9	2	115	126	12.90
White sucker	9	1	8	9	0.92
Total	364	155	458	977	100.0

1/ YOY = young-of-year; JUV = juvenile; ADU = adult.

Colorado Squawfish

The Colorado squawfish is the largest minnow native to North America, reaching lengths of 1.5-1.8 m (Behnke and Benson 1980). In the early 1800's, the Colorado squawfish was the top piscivore of the Colorado River system. Its range included the Colorado River and all of the larger tributaries from Wyoming to the Gulf of California. Archaeological findings and records of early white settlers documented the species as an abundant and important food source.

The Colorado squawfish is now rare and limited to the upper Colorado River basin. The species was included in the original list of endangered species issued by the Office of Endangered Species in 1964, and was offered protection by the Endangered Species Act of 1973. This act recognized the Colorado squawfish as "...a species of esthetic, ecological, educational, historical, recreational, and scientific value to the nation and it's people." Section 7 of the Act provides protection for the Colorado squawfish by mandating that "...any action authorized, funded or carried out by a federal agency does not jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat." Design, construction and operation of federally-funded water projects in the upper Colorado River basin are required by the Act to be compatible with the habitat requirements of the Colorado squawfish.

The Colorado squawfish is an indicator of the well being of the Colorado River ecosystem, since the species is affected by hazardous or imprudent water use potentially harmful to man. The decline of the Colorado squawfish as a result of man-made alterations may be a forewarning of water-related problems facing man in the west.

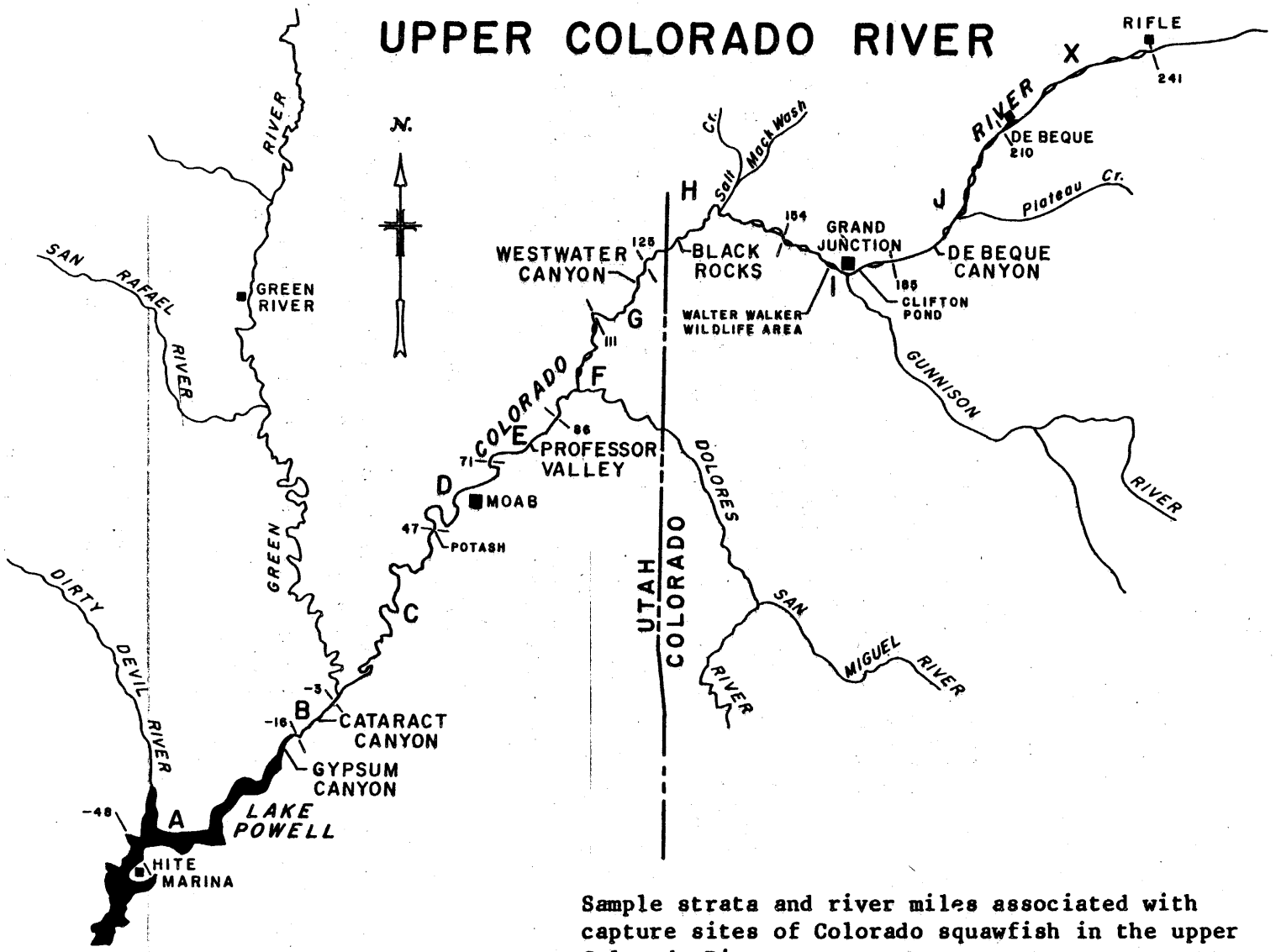
Distribution and Abundance

Colorado squawfish were collected in all strata between Gypsum Canyon (RM -19.6) in upper Lake Powell, Utah and Palisade, Colorado (RM 177.8) (Figure 6). Northwest Fisheries Research and the Utah Division of Wildlife Resources investigators extended the range to the Grand Valley Diversion, near Palisade, Colorado (RM 185.1) (Kidd 1979) and the upper end of Bullfrog Bay (RM -96.5) in Lake Powell (Ottenbacker 1980).

The distribution of YOY, juvenile and adult squawfish was significantly different ($\alpha = .01$). Young-of-the-year were most common in lower river reaches, adults in upstream reaches, and juveniles in middle reaches (Figure 7). The smaller squawfish were found primarily in downsteam reaches and larger fish were found progressively upstream (Figure 8).

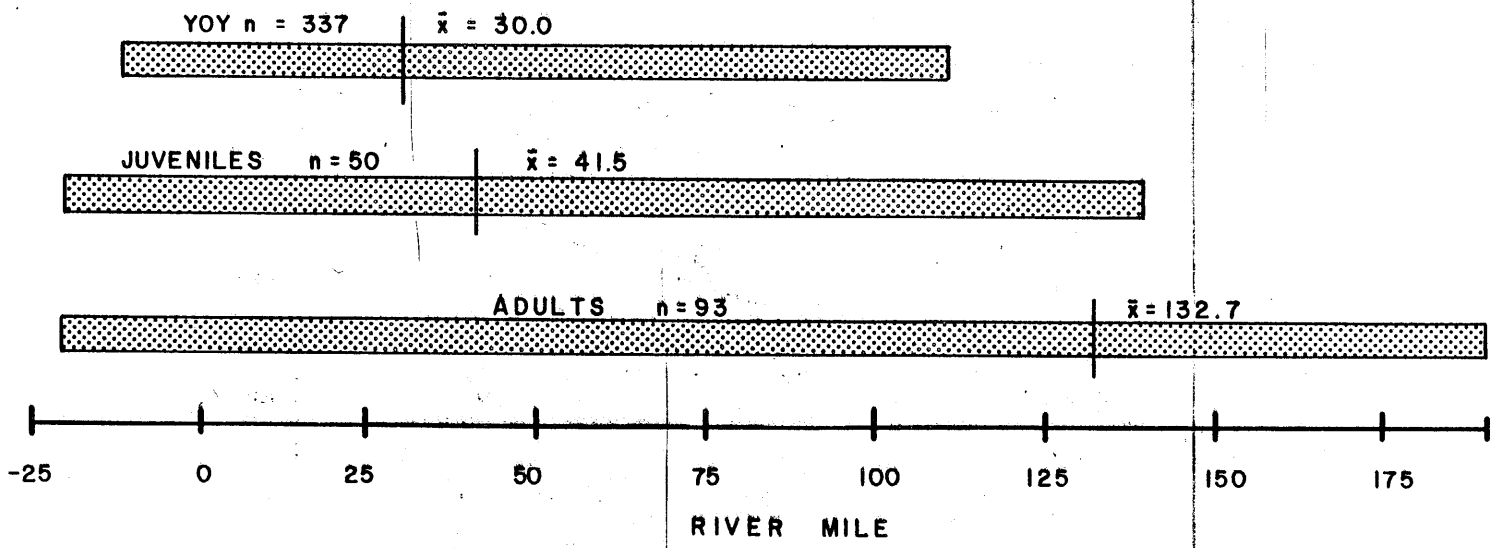
Young-of-the-year were distributed over a distance of 121.4 miles, from Range Canyon (RM -11.0) in Cataract Canyon to the downstream end of Westwater Canyon (RM 110.4), corresponding to strata B-F. A 65-mile section between Cataract Canyon and Moab, Utah contained 79.4 percent of the YOY captured. Distribution of YOY did not change significantly between years (1979, 1980, 1981) or flow periods (prerunoff, runoff, postrunoff).

Figure 6



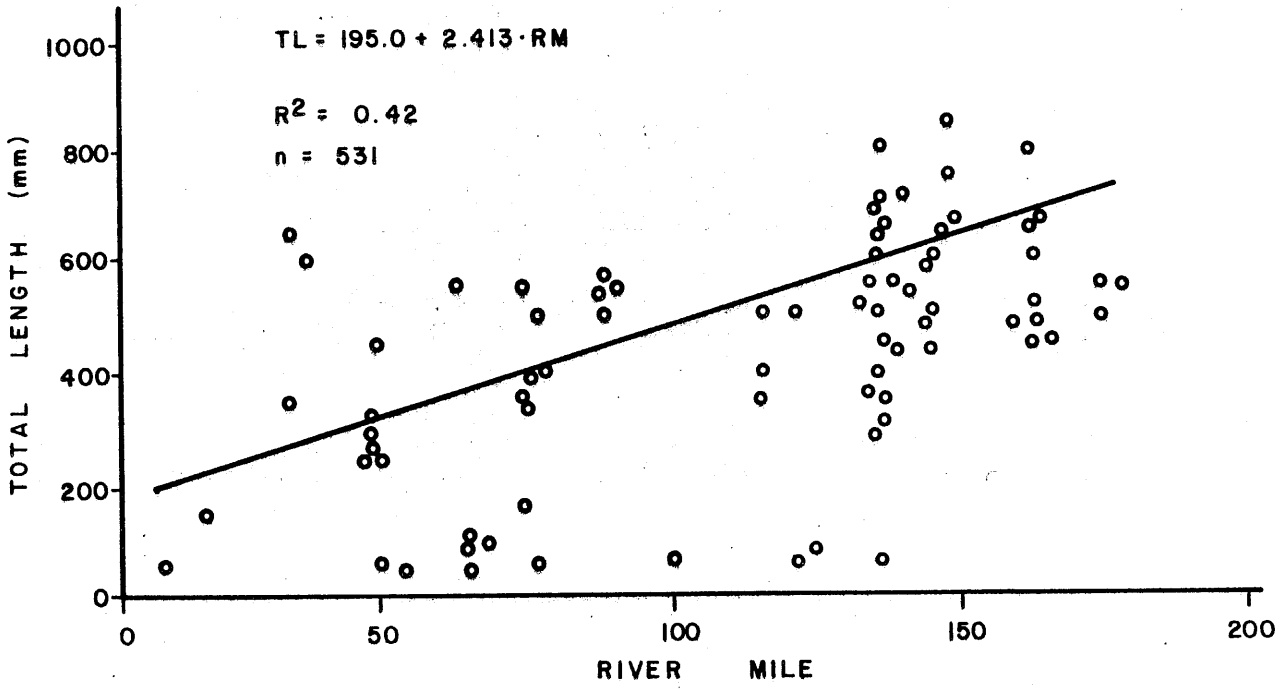
Sample strata and river miles associated with capture sites of Colorado squawfish in the upper Colorado River.

Figure 7



Distribution of young-of-the-year (YOY), juvenile, and adult Colorado squawfish in the upper Colorado River, 1979-81. (n = sample size, x = weighted mean distribution, river miles from Green River confluence.)

Figure 8



Distribution of Colorado squawfish by size in the upper Colorado River, 1979-81. (RM = river miles upstream from Green River confluence.)

Juvenile squawfish were collected between Gypsum Canyon (RM -19.6) and the Black Rocks area (RM 136.6) (Figure 6). Two-thirds (66 percent) of the juveniles were collected between river miles 26.8 and 77.5. The distribution of juveniles between years and flow periods was not significantly different (α = .01).

Adult squawfish had the widest distribution of any age group, their range extended 197 miles, from Gypsum Canyon, Utah (RM -20.0) to Palisade, Colorado (RM 177.2) in all strata except B; Cataract Canyon. Adult distribution did not change between years but differed significantly (α = .05) between flow periods.

Catch Per Effort

A total of 513 squawfish were caught by the CRFP between 1979 and 1981. This included 105 adults, 71 juveniles, and 337 YOY. Absolute abundance was not estimated due to the small number of captures and recaptures. However, catch per effort (CPE) and percentage species composition (PSC) were used as indices of relative abundance. PSC is the percentage of the total catch in a given area or time. CPE is the number of a given species caught from the total effort expended in a given area or time.

CPE was calculated for area and hour-based gear. Area gears were all seines, and CPE was represented as number of fish per $100m^2$. Hour gears included trammel nets, gill nets, and electrofishing; CPE was represented as number of fish per 10 hours effort. No adult Colorado squawfish were caught with area-related gears, nor were YOY caught with hour gears. Sixteen juveniles were caught with hour-related gears and 34 with area-related gears.

Squawfish were caught by area gears in strata B through G during regular sampling and in strata K and N during special sampling (Table 19). CPE did not differ significantly (.01) in the regular strata. The relative abundance of squawfish per $100m^2$ ranged from 2.77 in stratum C to 0.04 in stratum G. Young-of-the-year and juvenile squawfish caught with area gears were most abundant in the six contiguous strata (B-G) above Lake Powell (stratum A).

Squawfish were caught by hour gears in strata C through I during regular sampling and strata M, P, and K in special sampling (Table 20). CPE did not differ significantly (α = .01) for strata C through I but differed for the special strata. The relative abundance for regular strata ranged from 0.56 in stratum H to 0.09 in stratum G. The relative abundance for special strata was lowest in Walter Walker, stratum M (0.29) and highest in stratum K (8.93). Adult and juvenile squawfish caught in hour gears were widely distributed but were caught most frequently between Loma, Colorado, and Westwater, Utah, particularly in the area of Black Rocks.

The CPE of Colorado squawfish during prerunoff, runoff, and postrunoff flows in 1980 were compared (Table 21). Squawfish were caught during runoff and postrunoff at rates of 0.45 and 0.10 fish/10 hours, respectively. Sampling effort for hour gears between flow did not differ significantly (α = .05). Adult and juvenile squawfish may appear to be more abundant during runoff because they congregate in backwaters

Table 19
Ranked catch per 100 m^2 of area for fishes of the Upper Colorado River
by 12 sample strata (gear = 1/8, 1/4, 1/2-in. seines)

	Regular strata[1/]										Special strata[1/]	
Rank	A	B	C	D	E	F	G	H	I	J	K	N
1	RS(151.67)	RS(96.79)	RS(58.07)	SS(64.8)	RS(85.73)	RS(160.90)	SS(17.38)	RS(29.00)	RT(38.92)	SS(30.78)	RS(127.69)	RS(31.79)
2	SS(6.67)	SS(31.54)	FH(15.26	RS(54.23)	SS(39.64)	SS(113.12)	RS(15.88)	RT(21.18)	FH(17.60)	RT(15.33	FH(57.53)	RT(12.33)
3	GS(1.67)	FH(26.67)	SS(13.64)	FH(31.40)	FH(27.21)	FH(29.51)	FH(13.66)	SS(13.81)	SS(11.44)	FH(10.22)	RT(25.81)	BH(4.04)
4		CC(21.70)	CC(2.91)	CP(1.48)	RT(2.44)	RT(15.25	RT(12.15)	FH(10.43)	RS(11.37)	FM(10.11)	SS(20.83)	FH(2.89)
5		CS(0.55)	CS(2.77)	BH(1.50)	FM(0.97)	BH(8.75)	FM(9.67)	FM(2.46)	SD(7.06)	SD(6.89)	FM(3.63)	CS(1.16)
6		CH(2.15)	CP(0.33)	GS(1.50)	SD(0.94)	FM(2.13)	SD(2.08)	BH(1.65)	BH(3.93)	RS(0.89)	SD(3.63)	SS(1.16)
7		FM(0.15)	FM(0.22)	RT(0.78)	CS(0.54)	SD(1.29)	BH(0.80)	LG(0.93)	FM(0.97)	BH(0.67)	BH(1.61)	FM(0.58)
8		SD(0.10)	BH(0.18)	CC(0.74)	BH(0.51)	CP(0.55)	CP(0.71)	SD(0.68)	CP(0.94)	GS(0.22)	GS(0.94)	HB(0.39)
9		BH(0.05)	LG(0.18)	CS(0.58)	CP(0.42)	PK(0.40)	GS(0.62)	CP(0.64)	GS(0.90)		CC(0.67)	SD(0.39)
10		GS(0.05)	FM(0.18)	FM(0.37)	CC(0.27)	LG(0.29)	CC(0.35)	BB(0.56)	LG(0.52)		LG(0.40)	PK(0.19)
11		RT(0.05)	BB(0.11)	BB(0.30)	GS(0.27)	CS(0.22)	BB(0.13)	GS(0.32)			CS(0.13)	
12		WE(0.05)	PK(0.09)	PK(0.28)	LG(0.24)	GS(0.18)	CH(0.13)	WS(0.20)			HB(0.13)	
13		WS(0.05)	BB(0.06)	SD(0.16)	CH(0.09)	CC(0.15)	LG(0.13)	CC(0.16)				
14			SD(0.04)	LG(0.12)	BC(0.06)	WS(0.04)	BC(0.09)					
15			WS(0.02)	BG(0.02)	BB(0.03)		CS(0.04)					
16			CH(0.01)		PK(0.03)		PK(0.04)					
17					WS(0.03)							

1/ See Table 2

Table 20
Ranked catch per 10 hours of effort for fishes of the Upper Colorado River
by 13 sample strata (gear = trammel nets, gill nets, electrofishing)

Rank	Regular strata[1/]										Special strata[1/]		
	A	B	C	D	E	F	G	H	I	J	K	M	N
1	CP(2.80)	CC(4.71)	CP(2.43)	CP(23.16)	CP(25.06)	FM(28.73)	RT(13.34)	FM(15.43)	FM(47.74)	FM(70.34)	RT(95.54)	BB(12.34)	RT(72.44)
2	BG(1.67)	CP(2.33)	FM(1.20)	FM(6.37)	FM(17.89)	CP(12.54)	CC(5.47)	RT(8.48)	BH(39.82)	RT(66.67)	HB(39.58)	CP(10.84)	CP(33.07)
3	LG(1.67)	FM(0.84)	CC(0.93)	CC(3.71)	CC(7.43)	CC(7.19)	BH(4.62)	CP(7.54)	CP(19.87)	BH(16.75)	CP(34.23)	GS(7.24)	CC(22.83)
4	GS(1.37)	BH(0.05)	RS(0.57)	GS(0.56)	BH(4.24)	BH(3.21)	CP(3.51)	BH(6.50)	RT(15.27)	WS(8.50)	FM(25.89)	FM(6.27)	HB(18.11)
5	CC(0.66)	HB(0.05)	BH(0.42)	BB(0.53)	LG(1.26)	RT(1.56)	HB(3.25)	CC(4.83)	BB(9.05)	CP(6.94)	BH(9.82)	CC(2.82)	BH(15.75)
6	WE(0.24)	RT(0.05)	CS(0.42)	LG(0.53)	RT(0.91)	LG(0.29)	FM(1.11)	LG(1.22)	CC(2.75)	RH(2.86)	CS(8.93)	RT(2.21)	RH(3.15)
7	FM(0.18)	WF(0.05)	GS(0.24)	BH(0.49)	CS(0.35)	CS(0.21)	GS(0.51)	CS(0.56)	WS(2.02)	BB(1.06)	GS(4.46)	RZ(0.86)	BC(2.36)
8	RS(0.18)		BB(0.15)	RT(0.45)	BB(0.30)	BB(0.16)	RH(0.51)	GS(0.45)	LG(1.62)	MS(0.90)	CC(3.27)	WS(0.86)	CS(2.36)
9	BC(0.12)		RT(0.12)	RS(0.38)	GS(0.30)	CH(0.12)	LG(0.43)	BB(0.24)	GS(1.13)	SD(0.90)	RH(1.49)	CS(0.29)	FM(0.79)
10	TS(0.12)		FH(0.06)	CS(0.34)	BN(0.05)	RB(0.08)	RS(0.26)	HB(0.21)	WF(0.24)	GS(0.57)	LG(0.60)	LG(0.29)	
11	BB(0.06)		RZ(0.06)	WS(0.15)	RS(0.05)	BN(0.04)	SD(0.26	FH(0.10)	CS(0.16)	RB(0.25)	BD(0.30)	BC(0.11)	
12	RZ(0.06)		BC(0.03)	BC(0.04)	WS(0.05)	FR(0.04)	BN(0.09)	RZ(0.07)	RZ(0.16)	BN(0.08)		BG(0.11)	
13	SB(0.06)		BN(0.03)	FH(0.04)		GS(0.04)	CS(0.09)	WF(0.07)	BH(0.08)	FH(0.08)		RS(0.07)	
14			LG(0.03)	RZ(0.04)		RS(0.04)	FH(0.09)	BC(0.03)	FR(0.08)	FR(0.08)		BH(0.04)	
15				SS(0.04)		SS(0.04)		SD(0.03)		LG(0.08)		FR(0.04)	
16								WB(0.03)		RZ(0.08)		NP(0.04)	
17										RW(0.08)			
18										WF(0.08)			

1/ See Table 2

Table 21
Ranked catch per 10 hours of effort for fishes of the upper Colorado River during prerunoff, runoff, and postrunoff

	Flow period		
Rank	Prerunoff (n = 85)	Runoff (n = 285)	Postrunoff (n = 392)
1	RT(4.70)	FM(26.79)	FM(33.79)
2	CP(1.83)	CP(12.68)	BH(16.27)
3	CC(1.47)	RT(10.53)	RT(14.11)
4	HB(1.16)	CC (6.18)	CP(11.86)
5	BH(0.79)	BH (4.26)	CC (4.87)
6	FM(0.62)	RH (0.48)	LG (1.75)
7	GS(0.06)	GS (0.45)	GS (0.98)
8	RZ(0.06)	CS (0.45)	BG (0.67)
9	SD(0.06)	LG (0.32)	RH (0.50)
10		BB (0.29)	WS (0.48)
11		RB (0.16)	HB (0.28)
12		WS (0.13)	SD (0.26)
13		MS (0.10)	RS (0.22)
14		RZ (0.06)	MS (0.19)
15		BN (0.03)	BB (0.14)
16		FR (0.03)	CS (0.10)
17		RW (0.03)	FH (0.10)
18		SD (0.03)	WE (0.10)
19		WF (0.03)	BC (0.10)
20			TS (0.05)
21			SB (0.02)
22			WB (0.02)

and side channels which were probably sampled with greater efficiency than main channel habitats. Movement related to spawning may also make squawfish more available to passive gears during runoff.

Squawfish were taken in area gears during all flow periods with no significant difference (α = .01) in CPE (Table 22). CPE was greatest during prerunoff (1.13) and least in runoff (0.36).

The CPE of YOY squawfish in 1979 and 1980 differed significantly (α = .10). The numbers of YOY Colorado squawfish per $100m^2$ were 1.38 and 13.40 for the 1979 and 1980 year classes, respectively. Temperature and flow regimes for 1980 appear to have favored spawning success and survival of larval squawfish.

Percentage Species Composition

Colorado squawfish comprised 2.1, 0.6 and 0.3 percent of the total catch and ranked 7th, 13th and 13th in 1979, 1980 and 1981, respectively (Table 23). Table 23 suggests a decrease in relative abundance between 1979 and 1981. This trend may be due to a decline in the squawfish population or an increase in other species. CPE based on effort which captured squawfish showed a decline of 2.4 adults/hour in 1979 to 0.1 adults/hour in 1981. Several factors may explain this phenomenon, including environmental variables as well as sampling variation.

Migration and Movement

About 1,500 Colorado squawfish (age group VI) were tagged with Carlin tags in February 1980 at the Willow Beach National Fish Hatchery in Arizona. These hatchery-reared fish were released near Moab, Utah (RM 47.3) in April 1980. Thirteen of these fish were recaptured 1-14 months after release at distances of 0.9-45.8 miles from the release site (Table 24). Ten of the 13 recaptures were caught at two locations, the White Rapid area (RM 76.6) of Professor Valley and a large backwater 0.9 mile upstream from the release site.

Seven of the 144 wild adult Colorado squawfish caught and tagged from July 1979 to July 1981 were recaptured 1-230 days after release and 0-19.8 miles from the release site (Table 24). The wild squawfish were recaptured closer to their release sites than were the Willow Beach squawfish. The Willow Beach fish may have moved farther because of their unfamiliarity with the riverine environment.

Two of the three wild squawfish which overwintered between initial capture and recapture moved less than 0.5 miles. The third squawfish recaptured the spring after its initial capture moved 19.8 miles. The sedentary squawfish were recaptured during prerunoff while the active squawfish was recaptured during runoff. These observations and those by Wick (1980) suggest that squawfish congregate in deep pools in response to cooler water and remain relatively inactive until warmer water and higher flows of runoff stimulate their dispersion. Inactivity coincides with lower catch per effort of adult squawfish in late autumn and early spring. Similar overwintering congregations were reported by Minkley (1980) for native cyprinids in Mexican desert rivers.

Table 22
Ranked catch per $10m^2$ of area for fishes of the upper Colorado River during prerunoff, runoff, and postrunoff

Rank	Flow period		
	Prerunoff (n = 73)	Runoff (n = 131)	Postrunoff (n = 354)
1	SS(65.39)	SS(170.55)	RS(67.54)
2	RS(43.62)	CP(238.74)	RT(31.22)
3	FH(10.64)	RT (23.29)	FH(28.05)
4	RT(3.83)	BH (12.31)	SS(25.11)
5	CS (1.13)	FH (11.34)	CC(16.18)
6	CC (1.13)	FM (4.28)	SD (4.07)
7	FM (0.42)	SD (3.26)	BH (2.37)
8	BH (0.28)	CP (1.20)	FM (2.13)
9	SD (0.21)	GS (0.36)	CP (1.99)
10	GS (0.07)	CS (0.36)	GS (1.47)
11	WE (0.07)	CC (0.24)	CS (0.92)
12		LG (0.12)	LG (0.71)
13		WS (0.06)	BB (0.31)
14			CH (0.12)
15			WS (0.12)
16			PK (0.09)

Table 23
Ranked percentage species composition for all fishes caught in 1979, 1980, and 1981 in the upper Colorado River

Rank	Species	1979 n=16,677	1980 n=23,611	1981 n=19,214
1	Red shiner	59.5	24.5	26.5
2	Fathead minnow	15.8	6.5	14.9
3	Roundtail chub	6.3	16.5	6.5
4	Sand shiner	6.1	20.4	26.4
5	Flannelmouth sucker	3.3	12.1	6.4
6	Common carp	2.1	5.0	7.3
7	Colorado squawfish	2.1	0.6	0.3
8	Channel catfish	1.4	5.1	2.0
9	Bluehead sucker	0.9	4.8	3.5
10	Speckled dace	0.7	1.0	0.5
11	Humpback chub	0.6	0.4	0.1
12	Black bullhead	0.4	1.1	2.3
13	Largemouth bass	0.3	0.6	0.3
14	Green sunfish	0.1	0.8	1.7
15	Razorback sucker	0.1	0.1	0.0
16	White sucker	0.1	0.2	1.1
17	Black crappie	0.1	0.1	0.1
18	Bluegill	0.1	0.1	0.1
19	*Gila* sp.	0.1	0.1	0.1
20	Flannelmouth x razorback	0.1	0.1	0.1
21	Plains killifish	0.1	0.1	0.1
22	Roundtail x humpback	0.1	0.2	0.1
23	White x flannelmouth	0.1	0.1	0.1
24	Threadfin shad	0	0.1	0
25	Rocky Mt. whitefish	0	0.1	0
26	Mottled sculpin	0.1	0.1	0.1
27	Northern pike	0	0.1	0
28	Walleye	0.1	0.1	0.1
29	Brown trout	0.1	0.1	0.1
30	Rainbow trout	0.1	0.1	0.1
31	Striped bass	0	0.1	0

Table 24

Movement and growth of 20 hatchery-reared and wild Colorado squawfish marked with Carlin Tags in the upper Colorado River, 1979-81.

	Original capture and release										
Tag No.	TL (mm)	WT (g)	RM	Date	TL (mm)	WT(g)	RM	Date	Growth (mm)	Distance (miles)	
2145 WB*	315	232	47.3	80/04/10	---	--	77.0	80/10/12		+29.7	186
2332 WB	291	0181	47.3	80/04/10	297	0200	48.2	80/05/06	6	+0.9	27
2417 WB	326	0240	47.3	80/04/10	409	0500	76.7	80/06/04	83	+29.4	56
2418 WB	320	0242	47.3	80/04/10	330	0340	48.2	80/06/11	10	+0.9	63
2498 WB	315	0216	47.3	80/04/10	---	--	77.0	80/10/12		+29.7	186
2584 WB	295	0180	47.3	80/04/10	301	0200	48.2	80/05/06	6	+0.9	27
2825 W*	301	0194	47.3	80/04/10	369	0380	31.6	81/04/02	68	-15.7	358
3222 WB	270	0140	47.3	80/04/10	381	0580	75.0	81/04/29	111	+27.7	385
3409 WB	320	0240	47.3	80/04/10	412	0680	76.6	81/06/07	92	+29.3	1210
3507 WB	330	0284	47.3	80/04/10	340	0340	48.2	80/06/11	10	+0.9	56
3811 WB	329	0278	47.3	80/04/10	---	--	44.3	80/10/04		-3.0	178
3824 WB	303	0212	47.3	80/04/10	381	0420	1.5	81/04/03	78	-45.8	359
3966 WB	292	0185	47.3	80/04/10	305	0270	48.2	80/06/11	13	+0.9	56
0503	495	0925	135.5	79/10/13	493	0890	138.8	79/11/03	-2	+0.3	22
0506	578	1210	135.6	79/08/25	560	1300	135.7	79/10/13	-18	+0.1	50
0516	559	1550	143.8	79/10/13	595	1542	143.4	80/03/25	36	-0.4	165
0521	530	1100	143.8	79/10/13	524	1400	163.6	80/05/28	-6	+19.8	230
0528	543	1100	135.5	79/10/13	543	1100	135.8	79/10/14	0	+0.3	1
0679	577	2183	196.4	80/06/12	577	2013	196.4	80/06/17	0	0.0	5
0746	718	2948	135.7	80/11/01	726	3060	135.5	81/05/01	8	-0.2	182

*WB indicates tagged fish reared at Willow Beach National Fish Hatchery.

+ = upstream displacement, - = downstream displacement.

Movement by Colorado squawfish appears to be related to flow, temperature, feeding and spawning. Adults were found significantly further upstream during postrunoff than in prerunoff periods ($\alpha = .01$). This suggests adults move upstream during runoff, and downstream between postrunoff of one year and prerunoff of the following calendar year. Upstream movement during runoff may be related to spawning as described in early observations (Seethaler 1978). Adults and juveniles exhibited flow-related habitat preferences by leaving main channel habitats during runoff in favor of backwaters, tributary streams, side channels and irrigation-return streams. These slack-water habitats appear to be important during runoff as shelter from high water velocities and as feeding areas.

The greater numbers of adult squawfish in the upper reaches of the river, especially during spawning period, and the large numbers of YOY in the lower reaches suggest spawning occurs in the upper reaches (Moab to Grand Junction) and rearing occurs in the lower reaches (Moab to Lake Powell). Appararently, YOY move downstream with age, and juveniles and adults subsequently move upstream with increasing age. Backwaters were the preferred habitat for YOY squawfish, but none were captured in the isolated pools left after descending flow. This indicates that young squawfish are sensitive to flow fluctuations and leave receding backwaters before they become isolated from the river.

Observations of YOY and juvenile squawfish in a backwater of the upper Colorado River suggests different movement by the two ages of fish. Young-of-the-year moved between shoreline runs and backwaters apparently preferring the warmer daytime water temperatures; they moved into backwaters in late morning and returned to the main channel at night (Figure 9). Juveniles moved out of backwaters in the morning and into backwaters in the evening. This movement may be related to feeding on the abundant small fishes in backwaters. CPE of adult and juvenile squawfish was greatest during crepuscular periods suggesting that adults and juveniles were most active in shallow water at dawn and dusk. Juveniles appear to leave backwaters in favor of main channel habitats at about age III (175 mm TL).

Habitat Preference

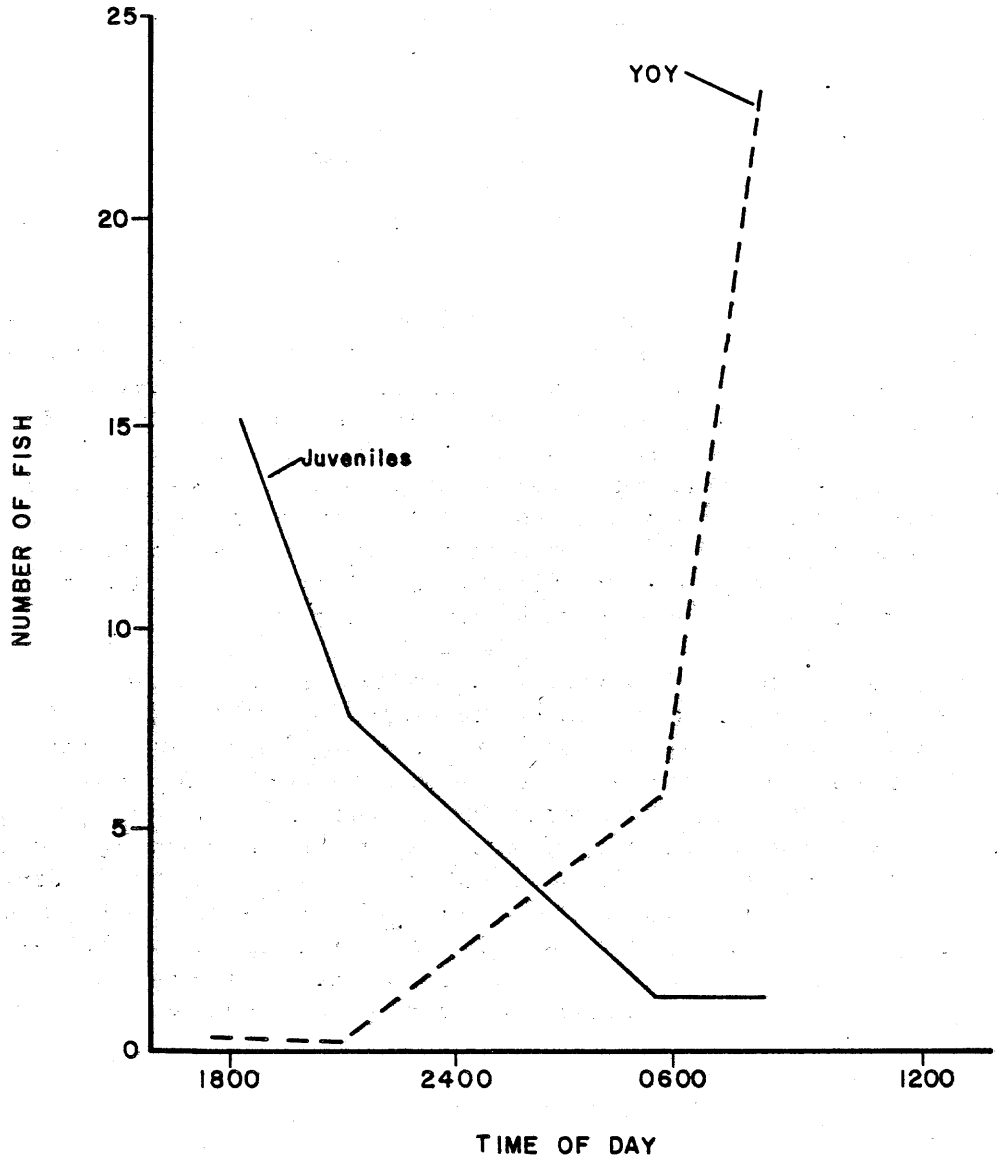
Squawfish caught above Lake Powell were partitioned into three groups representing YOY, juvenile and adult life stages. Depth, velocity and predominant substrate associated with these fishes are illustrated by histograms using raw data and curves smoothed to represent actual uses without observed aberancies.

Suitability-of-Use-Criteria

Young-of-the-year.--All squawfish less than 60 mm TL were classified as YOY. These 337 fish were found in depths of 0.3-3.0 feet, velocities of 0-0.5 feet per second (fps) and over silt, sand and gravel substrates. The YOY histograms and curves indicate a preference for depths of approximately 0.61 feet, zero velocity, and silt substrate (Figure 10).

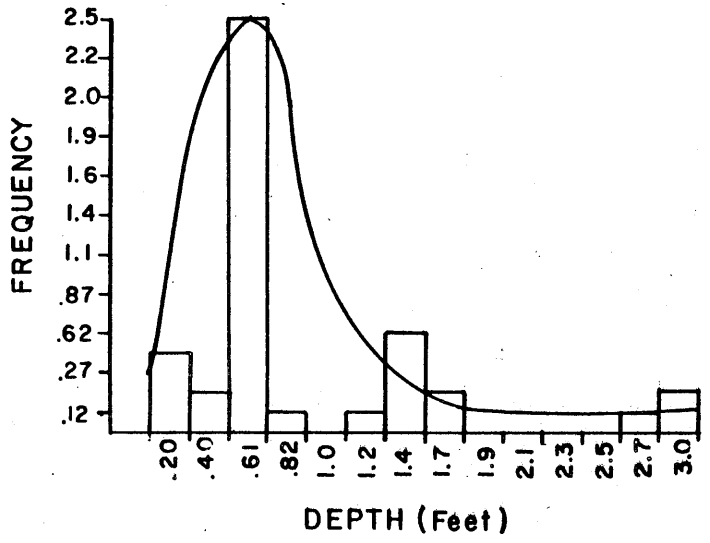
Juveniles.--Thirty-four squawfish 60-229 mm TL were categorized as juveniles. These fish were caught in water 0.5-4.9 feet deep,

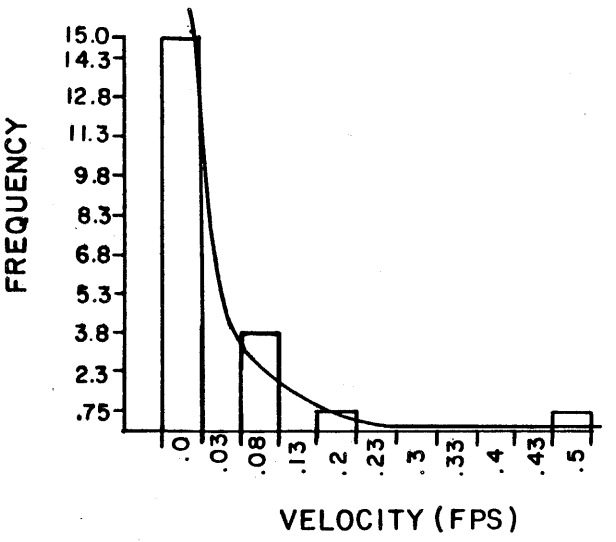
Figure 9

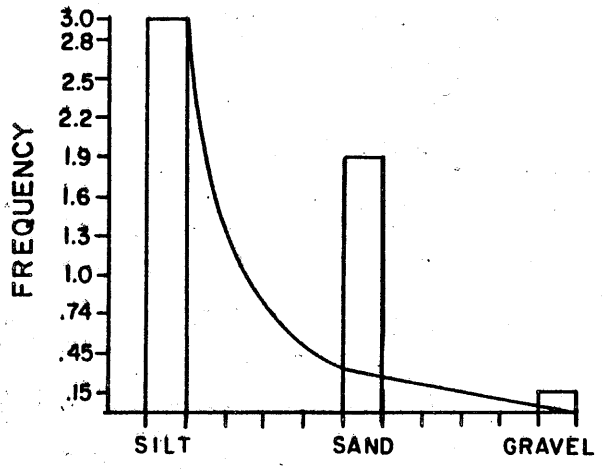


Occurrence of young-of-the-year (YOY) and juvenile squawfish in a backwater at river mile 26.8 on the upper Colorado River.

Figure 10







Depth, velocity and substrate used by 377 young-of-the-year Colorado squawfish from the upper Colorado River, 1979-1981.

0-15 fps velocity and over silt, sand and gravel substrates. Histograms and curves indicate a preference for depths of 1.6-2.0 feet, zero velocity, and silt substrate (Figure 11). The majority of juveniles were caught over silt (88.2 percent) and zero velocity (82.3 percent).

Adult.--Adult and subadult squawfish (>229 mm TL) were represented by 105 fish. These were taken in water 1.0-23.8 feet deep, velocities of 0-1.7 fps, and over six substrate sizes ranging from silt to bedrock. Depth histograms and curves indicate that adults frequented depths of 2.9-7.1 feet (Figure 12). Most adults were taken from velocities of 0.0-0.2 fps; although there appears to be a slight preference for velcities of about 1.1 fps. The histogram in Figure 12 illustrates preference for silt and boulder substrates. The preference for boulders reflects catches from the geologically unique area of Black Rocks (RM 136.6). Curve smoothing best represents the depth-use relationship for adult squawfish in the upper basin of the Colorado River.

Synthesis.--Juvenile and YOY squawfish appear to have similiar preferences for silt substrate and near zero velocity but exhibit significantly different (.01) preference for mean depths used; YOY (1.0 feet) and juveniles (3.3 feet). Older fish exhibit a preference for deeper water and are caught in a wider variety of velocities and substrates. All age groups displayed a preference for lower velocities and shallower depths within their respective length ranges.

CPE and Habitat Use

CPE for squawfish was compared between habitats as an additional analysis of habitat use. Squawfish were taken in eight habitats by hour gears (Table 25). The CPE for hour gears differed significantly (.01) between habitats. Relative abundance was highest in shorelines (1.05) and lowest in pools (0.10) and eddies (0.10). High CPE in shallow, low-velocity habitats may reflect better gear efficiency rather than habitat preferences. Squawfish were caught by area gears in backwaters, eddies, runs and side channels (Table 26). Relative abundance, based on CPE, was highest in backwaters (1.89) and lowest in eddies (0.05).

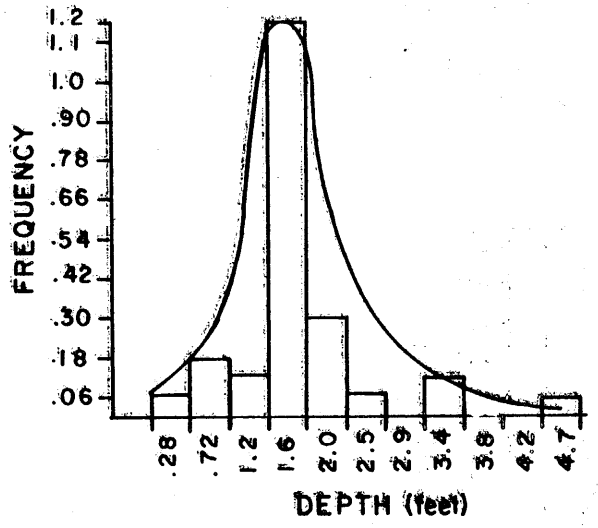
Backwaters and side channels ranked high as habitats most often associated with squawfish captures. Since squawfish appear to prefer these habitats at all life stages, the species may be benefitted by their construction (Valdez and Wick 1981).

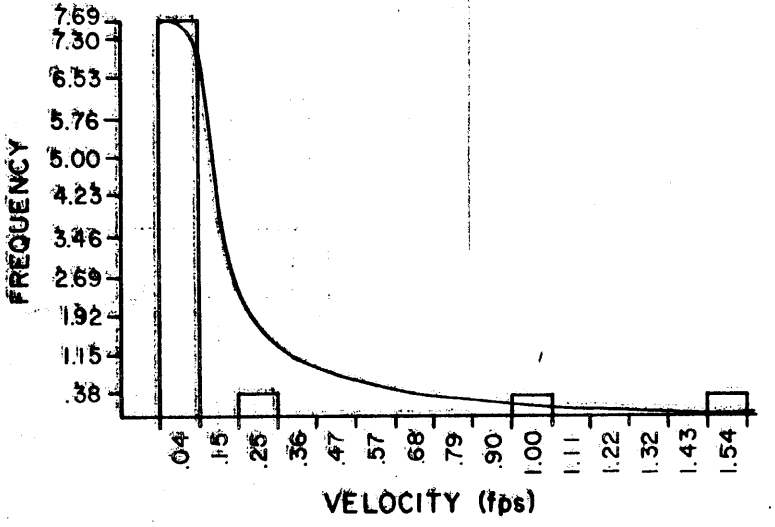
Spawning

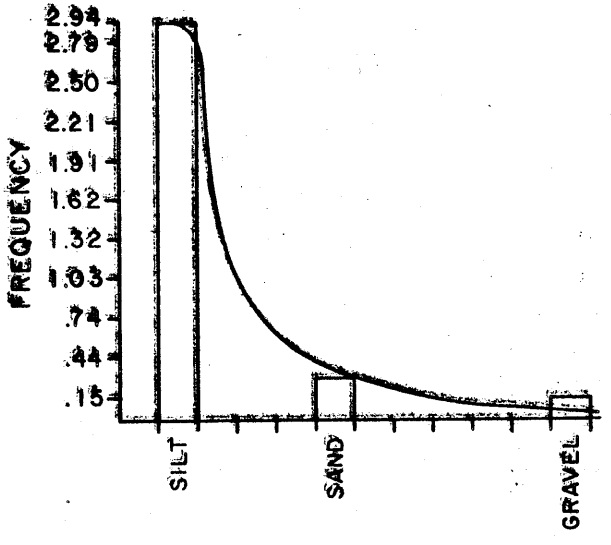
No Colorado squawfish were caught spawning in the upper Colorado River. To evaluate spawning habitat, a theoretical "spawning partition" was established based on water temperatures at which squawfish have exhibited spawning behavior (Vanicek and Kramer 1969, Seethaler 1978). It was based on capture dates when adult squawfish were caught between 18.1° C and peak water temperature for each of the study years (1979-1981) and yielded 24 fish (Table 27).

Nuptual coloration, tuberculation and swollen papillae were used to determine the sex of adult squawfish. Development of these features

Figure 11

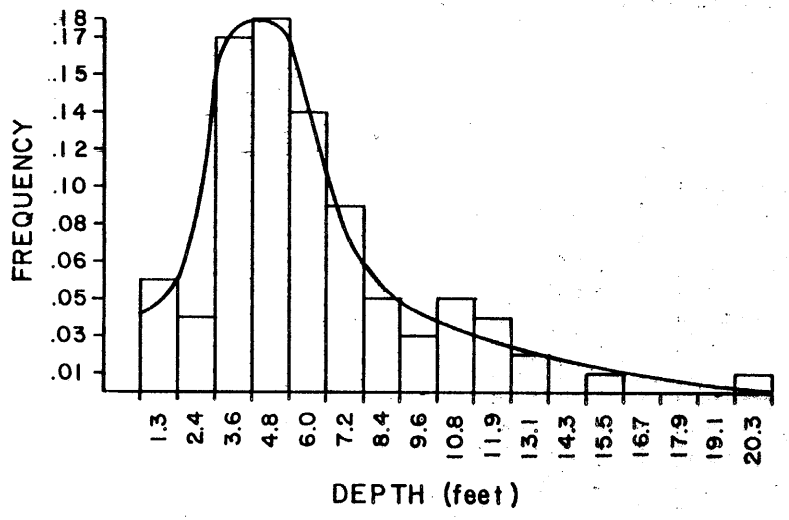


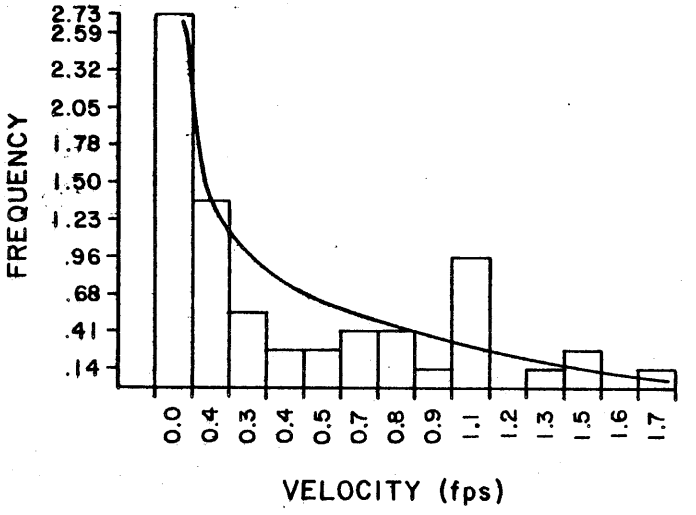


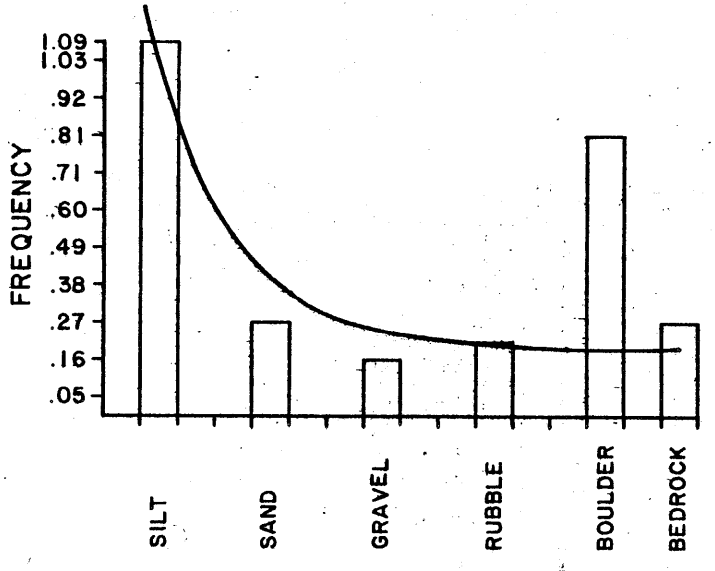


Depth, velocity and substrate used by 34 juvenile Colorado Squawfish 60-229mm TL frm the upper Colorado River, 1979-1980.

Figure 12







Depth, velocity and substrate used by 105 subadult and adult Colorado squawfish > 230mm TL from the upper Colorado River, 1979-1981.

Table 25
Ranked catch per 10 hours of effort for fishes of the upper Colorado River by 11 habitat types (trammel nets, gill nets, electrofishing)

Rank	Habitats[1]										
	BA	ED	GP	PO	RI	RU	SH	SC	MC	ID	LR
1	CP(11.68)	RT(6.15)	BB(11.45)	RT(25.50)	FM(1000)	FM(23.01)	FM(87.04)	CP(11.17)	FM(14.29)	BH(170.00)	CP(2.75)
2	FM(7.69)	FM(4.93)	CP(10.06)	FM(21.39)	BH(861.11)	CP(17.13)	CP(28.72)	RT(5.05)	RZ(14.29)	FM(120.00)	BG(1.64)
3	RT(7.22)	CC(3.53)	GS(6.72)	BH(3.25)	RT(188.89)	BH(9.70)	CC(18.39)	FM(3.72)		RT(80.00)	LG(1.64)
4	WS(4.17)	CP(1.34)	FM(5.82)	WS(1.81)	CP(16.67)	RT(9.29)	BH(18.04)	WS(2.39)		CP(70.00)	GS(1.35)
5	BB(2.91)	BH(1.16)	CC(2.61)	CC(1.15)	MS(16.67)	CC(4.89)	RT(8.58)	BB(2.13)		CC(50.00)	CC(0.64)
6	BH(2.77)	HB(0.51)	RT(2.05)	CP(1.05)	WS(16.67)	WS(0.44)	CS(1.05)	GS(1.60)			CS(0.18)
7	LG(2.02)	RH(0.24)	RZ(1.22)	RB(0.57)	CC(5.56)	LG(0.38)	WS(0.88)	LG(1.65)			RM(0.18)
8	CC(0.84)	WS(0.22)	WS(0.79)	HB(0.38)	RB(5.56)	RS(0.36)	BB(0.53)	BH(0.53)			RS(0.18)
9	CS(0.84)	CS(0.10)	CS(0.43)	FB(0.29)		GS(0.33)	GS(0.53)	CS(0.53)			WE(0.23)
10	GS(0.84)	BB(0.08)	LG(0.26)	BN(0.10)		RH(0.31)	FR(0.18)				BC(0.12)
11	RZ(0.28)	LG(0.08)	BC(0.10)	CS(0.10)		SD(0.23)	RB(0.18)				TS(0.12)
12	FH(0.19)	CH(0.04)	BG(0.10)	FR(0.10)		CS(0.19)	SD(0.18)				BR(0.06)
13	RB(0.19)	FR(0.04)	RS(0.07)			BB(0.17)					RZ(0.06)
14	BC(0.09)	GS(0.04)	BH(0.13)			HB(0.16)					SB(0.06)
15	BN(0.09)	RB(0.02)	FR(0.03)			RB(0.16)					
16		RZ(0.02)	NP(0.03)			MS(0.14)					
17		SD(0.02)				BN(0.10)					
18		WF(0.02)				FH(0.05)					
19						WF(0.05)					
20						WB(0.03)					
21						RZ(0.02)					
22						SS(0.02)					

1/ See Appendix A

Table 26

Ranked catch per 100 m^2 of area for fishes of the upper Colorado River by eight habitat types (gear = 1/8, 1/4, 1/2" seines).

	Habitats[1/]							
Rank	BA	ED	PO	RI	RU	SH	SC	LK
1	RS(85.18)	RS(24.23)	SS(87.95)	SS(20.80)	RS(28.42)	RT(10.02)	RS(52.23)	RS(151.67)
2	SS(41.31)	SS(16.70)	RS(37.26)	RS(11.66)	SS(23.30)	SS(8.86)	SS(13.45)	SS(6.67)
3	FH(30.92)	RT(5.50)	FH(13.15)	FH(6.78)	RT(13.54)	RT(1.91)	CC(5.64)	GS(1.67)
4	RT(6.80)	FH(5.12)	RT(10.68)	SD(5.33)	FH(7.04)	SD(0.43)	FH(5.04)	
5	FM(2.35)	CC(4.43)	CP(4.38)	RT(4.61)	CC(4.53)	CC(0.31)	RT(2.97)	
6	CS(1.89)	SD(3.63)	FM(4.11)	CC(1.45)	BH(3.08)	BH(0.18)	FM(1.68)	
7	CC(1.50)	FM(0.85)	SD(0.82)	GS(0.99)	SD(1.70)	FH(0.06)	BH(1.48)	
8	BH(1.25)	BH(0.43)	CC(0.55)	BH(0.75)	FM(0.70)	FM(0.06)	SD(0.79)	
9	GS(0.72)	CP(0.27)	GS(0.27)	FM(0.54)	CP(0.63)		CS(0.99)	
10	SD(0.65)	GS(0.21)		CP(0.18)	CS(0.31)			
11	CP(0.61)	RB(0.21)		LG(0.11)	GS(0.07)			
12	LG(0.43)	CS(0.05)		K(0.09)	WS(0.06)			
13	BB(0.21)	PK(0.05)			CH(0.02)			
14	PK(0.17)				LG(0.01)			
15	WS(0.10)				PK(0.01)			
16	CH(0.04)				WE(0.01)			
17	BC(0.02)							
18	RB(0.01)							
19	BG(0.01)							

1/ See Appendix A

Table 27
Adult Colorado squawfish caught during the 1980 and 1981 spawning period in the upper Colorado River

Total Length (mm)	Sex+	Condition factor (K^{TL})	Habitat*	River mile	Capture date
524	I	0.97	GP	163.6	80/05/28
543	I	0.91	GP	163.6	80/05/28
502	F	1.04	GP	163.6	80/05/28
596	I	0.81	GP	163.6	80/05/28
590	I	0.80	GP	177.8	80/06/05
586	I	0.87	GP	177.8	80/06/08
586	I	0.73	GP	177.8	80/06/08
468	I	0.98	BA	048.2	80/06/11
688	F	1.05	SC	153.0	80/06/18
690	F	0.73	RU	136.6	80/07/22
668	I	0.76	SH	147.0	80/08/13
510	I	1.03	ED	135.7	80/08/15
726	M	0.80	BA	135.5	81/05/01
659	F	0.94	BA	146.9	81/05/12
760	F	1.19	RU	146.6	81/05/12
585	I	0.93	RU	142.5	81/05/14
625	F	0.89	RU	036.0	81/05/27
503	F	0.90	GP	163.6	81/06/01
541	M	1.03	ED	107.0	81/06/02
539	I	0.88	RU	076.8	81/06/04
409	I	0.73	RU	076.7	81/06/04
412	I	0.97	RU	076.6	81/06/04
528	F	1.01	BA	175.2	81/06/10
572	F	0.87	BA	175.2	81/06/10

\+ I = undetermined, M = male, F = Female
* see Appendix A

enabled sex determination of the species only during this temperature-based partition in 1980 and 1981. In 1979, sampling did not start until after spawning, partially explaining the absence of fish for which sex could be determined. During 1980 and 1981 the spawning window encompassed an 11 to 13- week period from mid-May to mid-August.

Eight of 47 squawfish caught in this spawning window were at Gypsum Canyon in Lake Powell, Utah (Persons and Bulkley, 1980) (Figure 6). The sex of these fish was undetermined, but their condition factor (K_{TL}) did not differ significantly ($\alpha = .05$) from that of adult fish captured at Gypsum Canyon outside the spawning window. Lack of tuberculation and nuptual coloration, and similarity in condition factor between these fish suggests that the squawfish at Gypsum Canyon were not in spawning condition.

The occurrence of eight ripe adult squawfish in gravel pits within the spawning window suggests that this habitat may be used for spawning or some part of reproductive behavior. Based on the location of catches, K factor, tuberculation, and nuptual coloration of adult squawfish, Kidd (1981) believes that river seepage through gravel in the east end of Walter Walker Wildlife Area (WWWA) near Grand Junction, Colorado, provides a suitable spawning site for adult squawfish. No physical evidence for spawning has been found in WWWA, other than the presence of individuals in spawning condition. The absence of young squawfish may be due to high densities of predaceous black bullhead and green sunfish. Fishery biologists with the Colorado Division of Wildlife (DOW) on the Yampa River observed radiotagged adult squawfish congregating in large backwaters before moving to suspected spawning area (Wick, 1981). Abandoned gravel pits may also be sites for "staging" prior to spawning.

Condition factor of adult Colorado squawfish within the spawning window was significantly higher ($\alpha = .05$) than that of adults caught outside the spawning window (Table 27). Squawfish caught during runoff had a significantly higher condition ($\alpha = .05$) than during either prerunoff or postrunoff. This suggests that water temperature and flow may be a reliable basis for determining the spawning period of Colorado squawfish.

Habitat preference of fish within the spawning window did not differ significantly ($\alpha = .01$) from that of squawfish caught outside the window. None of the adult squawfish within the spawning window were caught in habitats like those described by Seethaler (1978) and Burdick (1981) as spawning sites.

Adult and young squawfish were distributed differently ($\alpha = .05$) during and after the spawning window; adults were furthest upstream and fish of the previous year class were furthest downstream. This suggests that spawning takes place in the upper reaches of the river and that YOY may drift or move downstream as much as 100 miles.

Associated Species

Species in association with Colorado squawfish were recorded to recognize potential competition by nonnative species. Fourteen species were associated with YOY Colorado squawfish (Tables 28 and 29). Red

Table 28

Ranked percentage frequency of occurrence of fish associated with young-of-the-year (YOY), juvenile (JUV) and adult Colorado squawfish in 1979-1981 in the Upper Colorado River[1/]

	1979 (percent)			1980 (percent)			1981 (percent)		
Rank	YOY n=11	JUV n=13	ADULT n=25	YOY n=19	JUV n=9	ADULT n=11	YOY n=6	JUV n=11	ADULT n=15
1	RS(90.9)	RS(61.5)	RT(28.0)	RS(94.7)	CP(66.7)	CP(45.5)	SS(100.0)	RT(72.7)	FM(66.7)
2	FH(63.6)	RT(61.5)	CP(20.0)	FH(84.2)	RT(66.7)	FM(36.4)	RS(100.0)	FM(63.6)	CC(46.7)
3	CP(45.4)	FH(53.8)	HB(16.0)	SS(84.2)	FH(55.5)	RZ(27.3)	FH(100.0)	RS(54.5)	CP(46.7)
4	CC(45.4)	CC(46.1)	RZ(16.0)	FM(31.6)	SS(44.4)	RT(18.2)	RT(66.7)	FH(54.5)	RT(46.7)
5	RT(45.4)	CP(38.5)	CC(12.0)	CC(26.3)	FM(33.3)	BH(18.2)	GS(66.7)	SS(54.5)	BH(40.0)
6	BH(18.2)	SS(30.8)	FM(4.0)	BH(26.3)	RS(33.3)	CC(18.2)	PK(50.0)	GS(45.4)	BB(33.3)
7	PK(18.2)	CH(30.8)	RH(4.0)	CP(21.0)	LG(33.3)	HB(9.1)	BB(33.3)	BH(45.4)	BC(13.3)
8	FM(18.2)	FM(23.1)		GS(15.8)	GS(33.3)	SD(9.1)	CP(33.3)	BB(36.4)	GS(13.3)
9	SS(9.1)	LG(23.1)		LG(10.5)	BH(33.3)	NP(9.1)	BH(16.6)	CP(36.4)	RZ(13.3)
10	WS(9.1)	BH(15.4)		RT(10.5)	CC(22.2)	LG(9.1)	SD(16.6)	PK(36.4)	WS(13.3)
11	BB(9.1)	PK(7.7)		PK(10.5)	SD(22.2)	FR(9.1)	FM(16.6)	LG(36.4)	LG(6.7)
12	SD(9.1)	GS(7.7)		SD(5.3)	BC(11.1)		CC(16.6)	RZ(9.1)	SS(6.7)
13	HB(9.1)			WS(5.3)	BB(11.1)			BC(9.1)	
14					RZ(11.1)			SD(9.1)	
15								BG(9.1)	
16								CC(9.1)	

Table 29

Ranked percentage composition of fish associated with young-of-the-year (YOY), juvenile (JUV) and adult Colorado squawfish in 1979-1981 in the Upper Colorado River[1/]

	1979 (percent)			1980 (percent)			1981 (percent)		
	YOY	JUV	ADULT	YOY	JUV	ADULT	YOY	JUV	ADULT
1	RS(74.5)	RS(55.8)	RT(43.9)	SS(40.2)	SS(46.8)	CP(32.0)	SS(42.0)	SS(49.9)	RT(31.1)
2	FH(19.6)	FH(27.1)	CS(24.0)	RS(36.7)	RS(34.7)	FM(18.0)	RS(38.0)	FH(24.5)	CP(21.0)
3	CS(2.6)	SS(7.4)	CC(8.6)	FH(14.5)	RT(8.6)	BH(18.0)	FH(12.8)	RS(17.6)	FM(16.8)
4	RT(1.5)	CS(5.4)	FM(7.7)	CC(3.8)	BH(3.7)	CS(11.7)	BH(2.6)	CP(4.0)	BB(10.6)
5	CC(0.8)	CC(1.6)	CP(6.6)	CP91.6)	FH(1.7)	RT(10.9)	CS(1.5)	BH(0.8)	CC(6.7)
6	BH(0.4)	RT(1.4)	RZ(5.6)	CS(1.4)	CP(1.3)	RZ(3.1)	RT(1.2)	FM(0.7)	BH(6.7)
7	CP(0.2)	CP(0.4)	HB(3.1)	GS(0.6)	LG(1.1)	CC(2.3)	GS(0.9)	CS(0.6)	CS(2.7)
8	SS(0.1)	GS(0.3)	RH(0.5)	FM(0.6)	FM(0.8)	HB(0.8)	SD(0.2)	GS(0.6)	GS(2.5)
9	FM(0.1)	BH(0.2)		SD(0.3)	GS(0.5)	SD(0.8)	PK(0.2)	RT(0.6)	WS(0.9)
10	PK(<0.1)	LG(0.2)		BH(0.1)	CS(0.4)	NP(0.8)	BB(0.2)	PK(0.4)	RZ(0.3)
11	SD(<0.1)	PK(0.2)		LG(0.1)	SD(0.1)	LG(0.8)	CP(0.2)	LG(0.2)	BD(0.3)
12	HB(<0.1)	FM(<0.1)		RT(<0.1)	CC(0.1)	FR(0.8)	FM(0.1)	BB(0.2)	LG(0.2)
13	BB(<0.1)	CH(<0.1)		PK(<0.1)	WS(0.1)		CC(0.1)	BD(<0.1)	SS(0.2)
14	BB(<0.1)			WS(<0.1)	RZ(<0.1)			SD(<0.1)	
15					BB(<0.1)			BG(<0.1)	
16					BD(<0.1)			CC(<0.1)	

1/ Based on catches in which Colorado squawfish occurred.

shiner, sand shiner, and fathead minnow were the most abundant (92.7 percent) and frequently (80.7 percent) associated species with YOY from 1979 to 1981. Red shiner, sand shiner, and fathead minnow were the most abundant of the 13 species associated with juvenile squawfish comprising 88.5 percent of the catch. Roundtail chub and flannelmouth sucker were not as abundant but were frequently associated with juveniles. Common carp, roundtail chub, and flannelmouth sucker were the most abundant and frequently-occurring species with adult squawfish. Adult squawfish declined in catch from 24.0 percent in 1979 to 2.7 percent in 1981. Juveniles exhibited a similar decline of 5.40 percent to 0.56 percent for the same period. The decline in relative abundance of juvenile and adult squawfish may be due to an increase in the number or frequency of nontarget species or to a decrease in the number of Colorado squawfish. Relative abundance of species associated with squawfish was similar to the relative abundance of all catches, suggesting that Colorado squawfish do not select for unique species associations.

The majority of the species associated with young and juvenile squawfish were nonnatives whereas most of the species associated with adults were native (Table 30). Juvenile and YOY squawfish comprised less than 7 percent of the catch in samples from which they were caught. The potential for competition between Colorado squawfish and nonnative species appears greatest with pre-adult and adult squawfish.

Table 30
Percentage composition of native and nonnative species associated with Colorado squawfish in the upper Colorado River, 1979-1981

Species	Young-of-the-year	Juvenile	Adult
Native	6.8	14.0	73.8
Nonnative	93.2	86.0	26.2

YOY squawfish and juveniles less than 230 mm TL (total length) preferred shallow, zero-velocity habitats. These backwaters were dominated (89.1 percent) by nonnative species; the most common, red shiner and fathead minnow, are capable of exerting competitive pressure on YOY squawfish by spawning several times a year, at least once before the Colorado squawfish. They may also prey on squawfish larvae. Black bullhead, green sunfish, channel catfish, and largemouth bass, common nonnatives in large backwaters and gravel pits, are also capable of imposing predation on YOY and juvenile squawfish. Ulmer (1981) and Loudermilk (1981) documented such predation on the razorback sucker in the lower Colorado River basin.

Fish association may be an important consideration to the survival of Colorado squawfish. There is much speculation regarding competition and predation on the squawfish by other riverine species, especially the introduced nonnatives. This study did not specifically address this phenomenon, but the inferences from the data suggest the presence of competition and predation.

Larval and postlarval squawfish occupying shallow shoreline are often accompanied by large number of young of other species, indicating that space and prime microhabitat may be a premium. Large numbers

of fishes are also found in backwaters, the preferred habitat of YOY squawfish. The presence of these fishes also suggest competition for space and food as well as possible predation pressures.

Juveniles, subadult, and adult Colorado squawfish are chiefly piscivorous and apparently capable competitors and predators. These life stages are probably not subjected to these pressures experienced by the larval and postlarval stages.

One of the factors limiting the survival of young Colorado squawfish in the upper Colorado River may be competition and predation by introduced fishes. This is certainly one hypothesis that warrants further investigation.

Age and Growth

An attempt was made to determine growth rates for Colorado squawfish using scale radius (SR) measurements at each annulus as related to body length (TL). The relationship between SR and TL for squawfish captured in this study was described by the equation TL = 9.37 + 3.60 SR (Musker, 1981) (Figure 13). Using this equation, TL was calculated for each year at the time of annulus formation (Table 31). Growth ranged from 21.0-154.4 mm/year with a mean annual growth rate of 71.5 mm for all age groups. Growth rates were compared with those for squawfish in the Green River (Vanicek, 1967) and rates from an earlier Colorado River study (Seethaler, 1978) (Figure 14). From these comparisons it appears that Colorado squawfish in this study had slightly greater growth rates than reported in previous field studies.

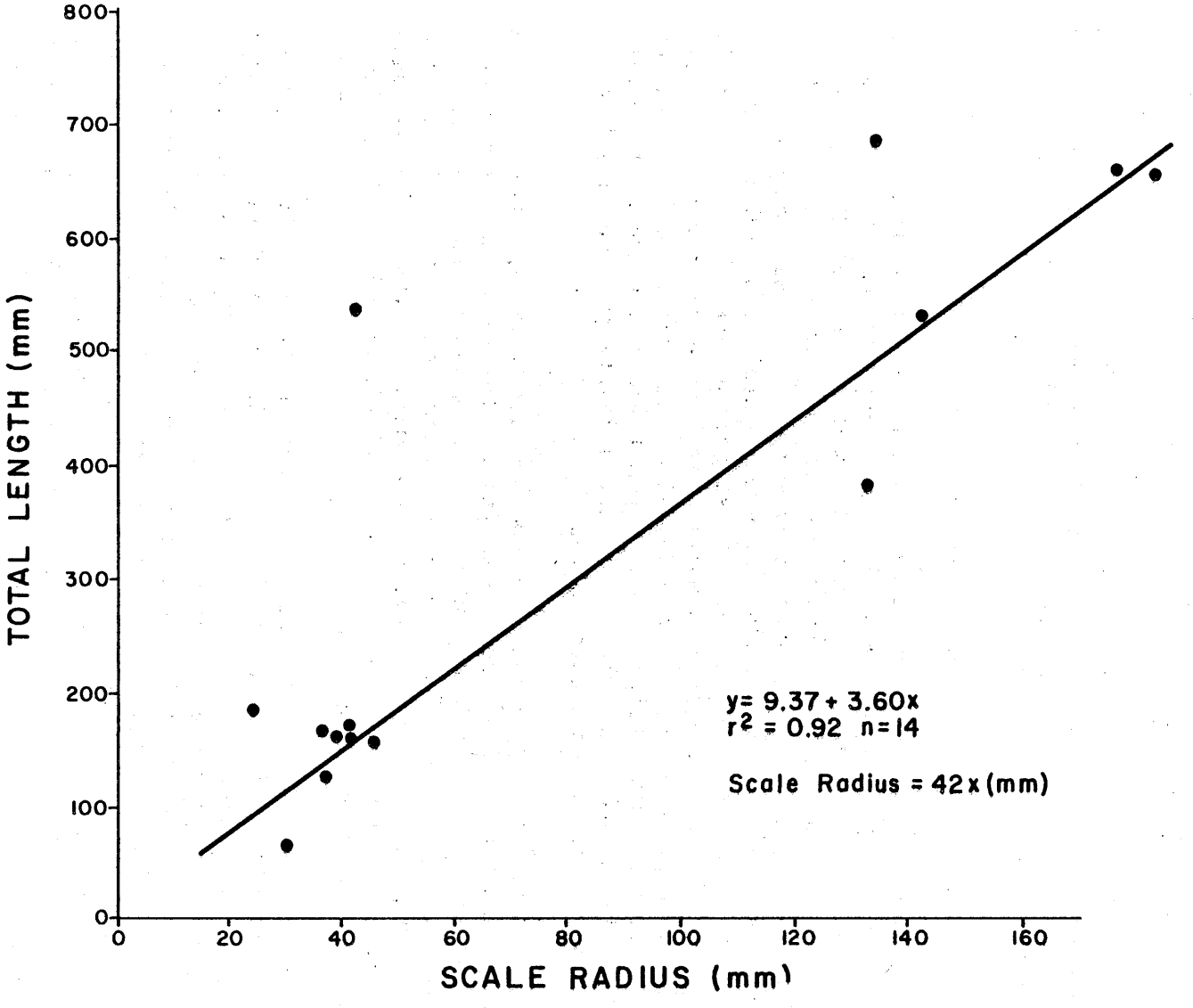
Growth of three hatchery-reared squawfish of known age was compared with back-calculated rates for wild fish. Colorado squawfish reared at Willow Beach National Fish Hatchery were released into the Colorado River in the spring of their sixth year, and three individuals were recaptured approximately 1 year later. The growth of these fish averaged 83.9 mm/year, as compared to 63.3 mm/year calculated from scale readings of wild fish in the same age group.

A length-frequency histogram for 145 Colorado squawfish caught in the upper Colorado River between 1979 and 1981 was used in an attempt to determine the age composition and year class strength of the population (Figure 15). The small number of fish captured at any one time and the difficulty of aging older squawfish severely limited the analysis. The absence of fish corresponding to age group III suggests an artifact of sampling or an unexplainable loss of fish 211-316 mm TL. Age group II (107-204 mm) fish were present in all months sampled, but at low densities. The low numbers of this age group in all months except August-September may reflect a behavioral anomaly which makes them less susceptible to the sample gear. The length-weight relationship for 137 squawfish in the upper Colorado River was described by the equation:

$$\log Wt = -6.154 + 3.387 \times \log TL \quad (r^2 = 0.98, n = 137)$$

where: Wt = weight in grams
TL = total length in millimeters
r^2 = coefficient of determination

Figure 13

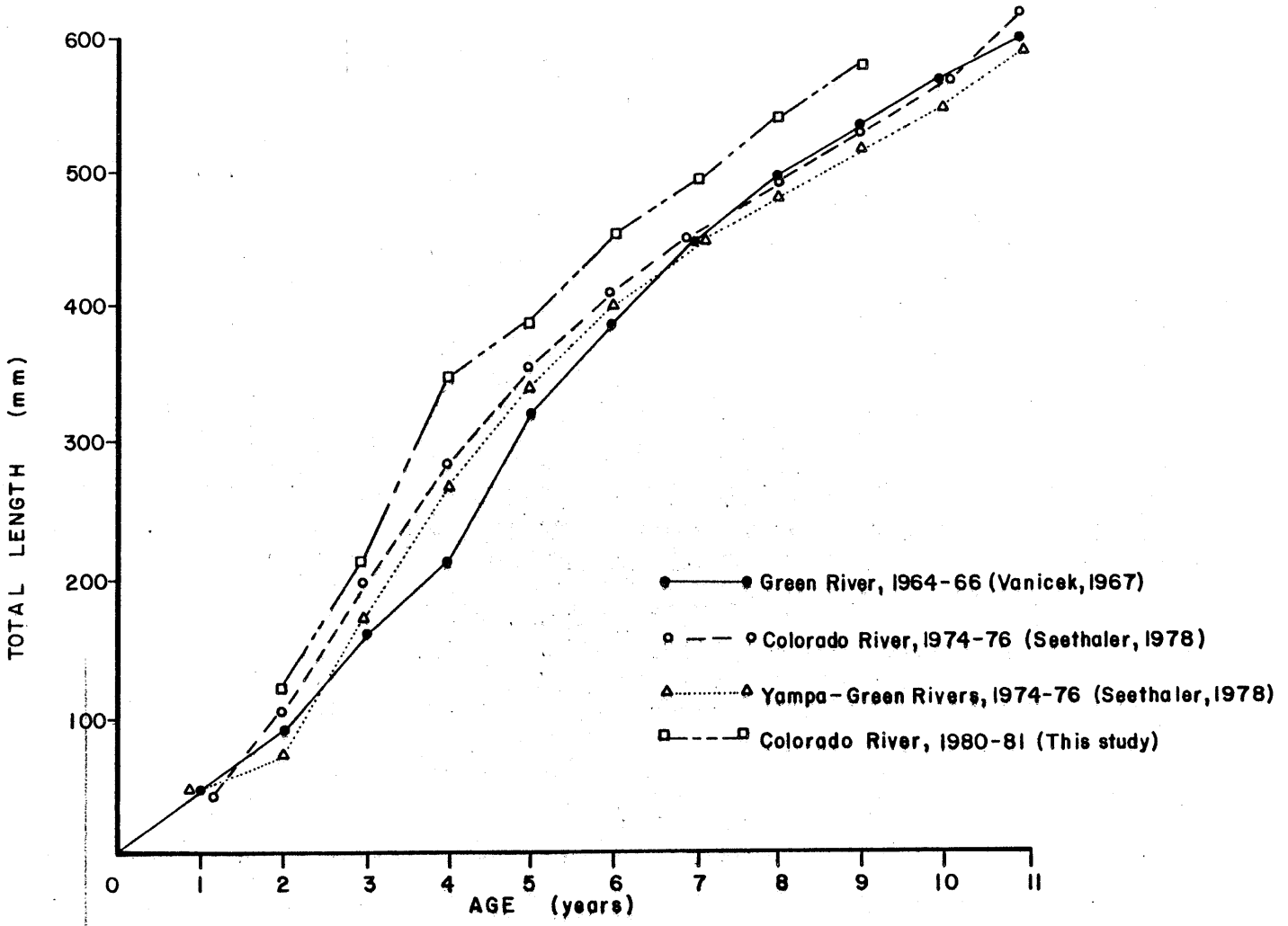


Relationships between total length and scale radius for 14 Colorado squawfish from the upper Colorado River, 1980-81 (from Musker, 1981).

Table 31
Estimated total length at time of annulus formation for 10 Colorado squawfish from the upper Colorado River, 1980-1981

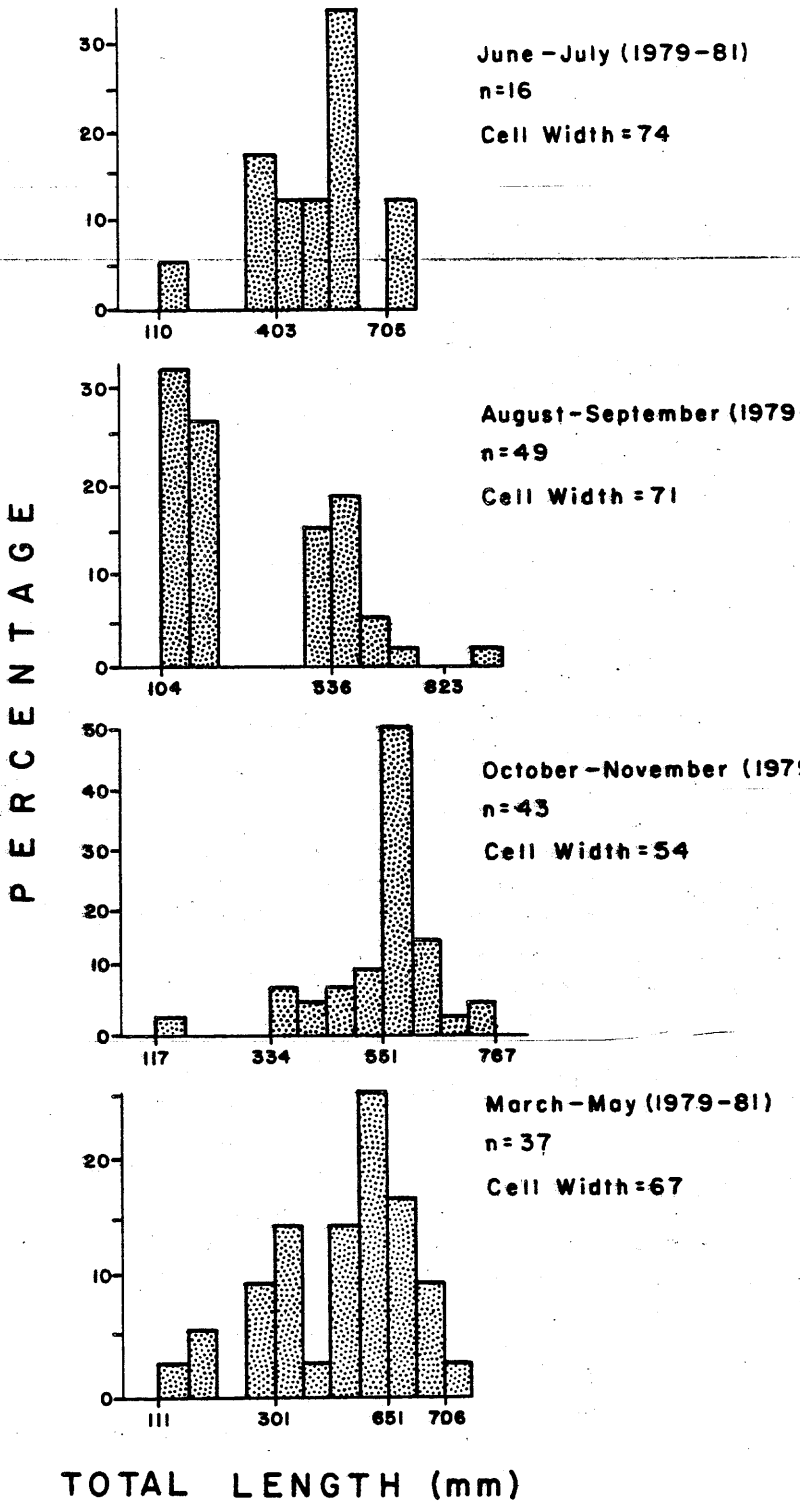
		Mean calculated total length at each annulus (mm)							
Age group	Number of fish	2	3	4	5	6	7	8	9
II	4	118.8							
III	0								
IV	1	103.7	210.2	331.1					
V	0								
VI	1	121.8	254.8	313.8	406.1	457.8			
VII	2	110.7	234.6	312.4	391.1	457.0	537.5		
VIII	1	77.2	133.4	200.1	340.6	435.4	512.6	586.4	
IX	1	106.9	186.3	275.9	379.4	472.5	507.0	548.4	607.0
Average (mm)		106.5	203.9	358.3	379.3	455.7	519.0	567.4	607.0
Increment (mm)			97.4	154.4	21.0	76.4	63.3	48.4	39.6
Number		10	6	6	5	5	4	2	1

Figure 14



Growth rates for the Colorado squawfish in the Green River, 1967-66; the Colorado River near Grand Junction, 1974-76; the Yampa-Green Rivers, 1974-76; upper Colorado River, 1980-81 (from Seethaler 1978).

Figure 15



Length-frequency histograms for four groups of Colorado squawfish from the upper Colorado River (n = number of fish).

This equation is similar to that developed for the same relationship by Seethaler (1978) for 68 squawfish from the Grand Junction, Colorado area.

Humpback Chub

The humpback chub (Gila cypha) was described from the lower basin of the Colorado River in 1946 (Miller). Adults have a characteristic nuchal hump that rises abruptly behind the head and distinguishes the species from the closely-related roundtail chub (G. robusta) and bonytail chub (G. elegans).

The historic distribution of the humpback chub is not well known, but records suggest the species was found in several locales of the upper and lower basins. The species is now concentrated in only five restricted areas of the Colorado River System; Black Rocks, Colorado; Westwater Canyon, Utah; Gray Canyon, Utah; and The Little Colorado River, Arizona (Valdez and Clemmer 1981). Recent collections (Wick et al. 1981) suggest a fifth concentration from Yampa Canyon in the Yampa River.

Reductions in numbers of the species became apparent with construction of the large mainstem dams after 1950. Humpback chub were included in the initial list of endangered species issued by the Office of Endangered Species in 1964. The species and its habitat was afforded protection by the Endangered Species Act of 1973.

Distribution and Abundance

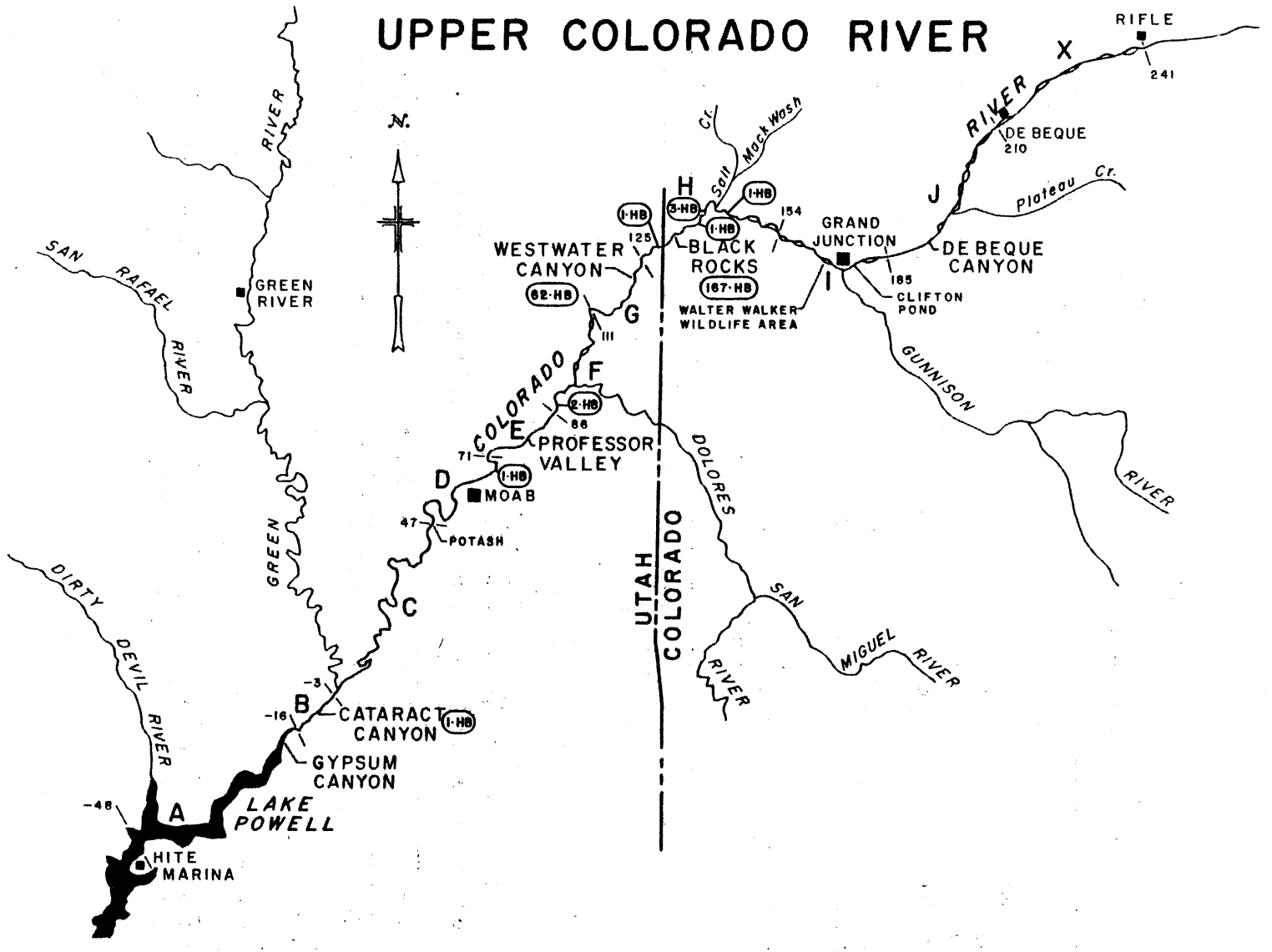
A total of 239 humpback chub were captured from nine locations in the upper Colorado River from Lake Powell, Utah to Rifle, Colorado in 1979-81 (Figure 16). Included in this catch were 203 adults (Table F-1) and 34 juveniles (Table F-2). Two young-of-the-year (Table F-3) were tentatively identified and more are being examined because of their similarity to other young members of the genus Gila. The larval fish sampling program yielded two more young humpback chub (see Larval Sampling).

The nine capture locations include: Cataract Canyon, Moab Canyon, Agate Wash, Westwater Canyon, Utah line, Black Rocks, RM 138.8, RM 139.8 and Salt Creek confluence (Figure 16). Only Westwater Canyon and Black Rocks yielded more than three specimens (Table 32). These two areas appear to support the only concentrations of humpback chub in the upper Colorado River. Both populations appear to have reproducing adults as indicated by a variety of age groups.

The occurrence of these two concentrations of fish correlates with the relatively deep, swift reaches of the upper Colorado River (Valdez 1980). Maximum depth of Black Rocks and Westwater Canyon is about 60 feet (Table 33) compared to an average maximum river depth of 26.7 feet. The sporadic occurrence of these habitats may account for the present, and perhaps historic, clumped distribution of the species.

The absolute abundance of humpback chub in the relatively open system of the Colorado River is an elusive statistic because of the rarity of the species and difficult sample conditions. Percentage

Figure 16



Locations and numbers of humpback chub captured in the upper Colorado River, 1979-81.

Table 32
Numbers of humpback chub from the nine capture sites of the upper Colorado River, 1979-1981

Locale	River mile	Number of fish caught			
		YOY	Juvenile	Adult	Total
Cataract Canyon	-10.8	0	0	1	1
Moab Canyon	72.5	0	1	0	1
Agate Wash	110.4	2	0	0	2
Westwater Canyon	116.0-124.4	0	19	43	62
Utah Line	132.0	0	0	1	1
Black Rocks	135.6-136.6	0	12	155	167
RM 138.8	138.8	0	0	1	1
RM 139.8	139.7-139.8	0	2	1	3
Salt Creek	143.9	0	0	1	1
Totals:		2	34	203	239

Table 33
Average and maximum river depths[1/] of three areas of the upper Colorado River that support humpback chub

Locale (river mile)	Average depth (feet)	Maximum depth (feet)
Black Rocks (136)	18.5	62.0
Westwater Canyon (122)	18.5	60.0
Cataract Canyon (-5)	50.2	92.0

1/ Measurements taken in August-September during moderate post-runoff flows; depths may vary with flow stage.

Table 34
Ranked percentage species composition for all fishes caught in 1979, 1980, and 1981 in the upper Colorado River

Rank	Species	1979 n=16,677	1980 n=23,611	1981 n=19,214
1	Red shiner	59.5	24.5	26.5
2	Fathead minnow	15.8	6.5	14.9
3	Roundtail chub	6.3	16.5	6.5
4	Sand shiner	6.1	20.4	26.4
5	Flannelmouth sucker	3.3	12.1	6.4
6	Common carp	2.1	5.0	7.3
7	Colorado squawfish	2.1	0.6	0.3
8	Channel catfish	1.4	5.1	2.0
9	Bluehead sucker	0.9	4.8	3.5
10	Speckled dace	0.7	1.0	0.5
11	Humpback chub	0.6	0.4	0.1
12	Black bullhead	0.4	1.1	2.3
13	Largemouth bass	0.3	0.6	0.3
14	Green sunfish	0.1	0.8	1.7
15	Razorback sucker	0.1	0.1	0.0
16	White sucker	0.1	0.2	1.1
17	Black crappie	0.1	0.1	0.1
18	Bluegill	0.1	0.1	0.1
19	Gila sp.	0.1	0.1	0.1
20	Flannelmouth x razorback	0.1	0.1	0.1
21	Plains killifish	0.1	0.1	0.1
22	Roundtail x humpback	0.1	0.2	0.1
23	White x flannelmouth	0.1	0.1	0.1
24	Threadfin shad	0	0.1	0
25	Rocky Mt. whitefish	0	0.1	0
26	Mottled sculpin	0.1	0.1	0.1
27	Northern pike	0	0.1	0
28	Walleye	0.1	0.1	0.1
29	Brown trout	0.1	0.1	0.1
30	Rainbow trout	0.1	0.1	0.1
31	Striped bass	0	0.1	0

Table 35
Percentage species composition for six strata in which humpback chub occurred in the upper Colorado River

Species	Strata					
	B	E	G	H	K	N
	(3705)	(6506)	(2119)	(3449)	(2383)	(496)
Black bullhead		0.4	0.1	1.6		
Black crappie		0.1	0.1	0.1	0.1	0.6
Bluehead sucker	0.1	1.6	6.1	6.6	1.9	8.3
Brown trout		0.1	0.1			
Channel catfish	14.4	2.8	3.4	4.2	0.7	5.8
Gila sp.	0.1	0.1				
Common carp	1.3	8.1	2.7	6.9	4.8	8.5
Colorado squawfish	0.3	0.4	0.1	0.5	1.7	1.8
Fathead minnow	14.1	13.9	14.6	7.6	18.0	1.0
Flannelmouth sucker	0.6	5.8	10.9	14.8		0.8
Green sunfish	0.1	0.2	0.9	0.9	0.5	
Humpback chub	0.1	0.1	1.8	0.2	6.9	5.0
Largemouth bass		0.5	0.4	1.9	0.2	
Plains killifish		0.1	0.1			0.2
Roundtail x humpback			0.3		0.2	0.8
Red shiner	52.0		17.0			33.3
Roundtail chub	0.1	4.9		20.9	21.5	32.3
Razorback sucker				0.1		
Speckled dace	0.1	0.5	2.4	0.6	1.4	0.4
Sand shiner	17.0	20.2	18.5	9.9	2.3	1.2
White sucker	0.1	0.1		0.4		

Table 36
Ranked catch per 10 hours of effort for fishes of the Upper Colorado River during prerunoff, runoff, and postrunoff.

RANK	Runoff period		
	PRE (n=85)	RUN (n=285)	POST (n=392)
1	RT(4.70)	FM(26.79)	FM(33.79)
2	CP(1.83)	CP(12.68)	BH(16.27)
3	CC(1.47)	RT(10.53)	RT(14.11)
4	HB(1.16)	CC(6.18)	CP(11.86)
5	BH(0.79)	BH(4.26)	CC(4.87)
6	FM(0.62)	RH(0.48)	LG(1.75)
7	GS(0.06)	GS(0.45)	BG(0.67)
8	RZ(0.06)	CS(0.45)	BG(0.67)
9	SD(0.06)	LG(0.32)	RH(0.50)
10		BB(0.29)	WS(0.48)
11		RB(0.16)	HB(0.28)
12		WS(0.13)	SD(0.26)
13		MS(0.10)	RS(0.22)
14		RZ(0.06)	MS(0.19)
15		BN(0.03)	BB(0.14)
16		FR(0.03)	CS(0.10)
17		RW(0.03)	CS(0.10)
18		SD(0.03)	WE(0.10)
19		WF(0.03)	BC(0.07)
20			TS(0.05)
21			SB(0.02)
22			WB(0.02)

Table 37
Ranked catch per 10 hours of effort for fishes of the upper Colorado River by 12 sample strata (gear = trammel nets, gill nets, electrofishing)

	Regular Strata 1/												
Rank	A	B	C	D	E	F	G	H	I	J	K	M	N
1	CP(2.80)	CC(4.71)	CP(2.43)	CP(23.16)	CP(25.06)	FM(28.73)	RT(13.34)	FM(15.43)	FM(47.74)	FM(70.34)	RT(95.54)	BB(12.34)	RT(72.44)
2	BG(1.67)	CP(2.33)	FM(1.20)	FM(6.37)	FM(17.89)	CP(12.54)	CC(5.47)	RT(8.48)	BH(39.82)	RT(66.67)	HB(39.58)	CP(10.84)	CP(33.07)
3	LG(1.67)	FM(0.84)	CC(0.93)	CC(3.71)	CC(7.43)	CC(7.19)	BH(4.62)	CP(7.54)	CP(19.87)	BH(16.75)	CP(34.23)	GS(7.24)	CC(22.83)
4	GS(1.37)	BH(0.05)	RS(0.57)	GS(0.56)	BH(4.24)	BH(3.21)	CP(3.51)	BH(6.50)	RT(15.27)	WS(8.50)	FM(25.89)	FM(6.27)	HB(18.11)
5	CC(0.66)	HB(0.05)	BH(0.42)	BB(0.53)	LG(1.26)	RT(1.56)	HB(3.25)	CC(4.83)	BB(9.05)	CP(6.94)	BH(9.82)	CC(2.82)	BH(15.75)
6	WE(0.24)	RT(0.05)	CS(0.42)	LG(0.53)	RT(0.91)	LG(0.29)	FM(1.11)	LG(1.22)	CC(2.75)	RH(2.86)	CS(8.93)	RT(2.21)	RH(3.15)
7	FM(0.18)	WF(0.05)	GS(0.24)	BH(0.49)	CS(0.35)	CS(0.21)	GS(0.51)	CS(0.56)	WS(2.02)	BB(1.06)	GS(4.46)	RZ(0.86)	BC(2.36)
8	RS(0.18)		BB(0.15)	RT(0.45)	BB(0.30)	BB(0.16)	RH(0.51)	GS(0.45)	LG(1.62)	MS(0.90)	CC(3.27)	WS(0.86)	CS(2.36)
9	BC(0.12)		RT(0.12)	RS(0.38)	GS(0.30)	CH(0.12)	LG(0.43)	BB(0.24)	GS(1.13)	SD(0.90)	RH(1.49)	CS(0.29)	FM(0.79)
10	TC(0.12)		FH(0.06)	CS(0.34)	BN(0.05)	RB(0.08)	RS(0.26)	HB(0.21)	WF(0.24)	GS(0.57)	LG(0.60)	LG(0.29)	
11	BB(0.06)		RZ(0.06)	WS(0.15)	RS(0.05)	BN(0.04)	SD(0.26)	FH(0.10)	GS(0.16)	RB(0.25)	BC(0.30)	BC(0.11)	
12	RZ(0.06)		BC(0.03)	BC(0.04)	WS(0.05)	FR(0.04)	BN(0.09)	RZ(0.07)	RZ(0.16)	BN(0.08)		BG(0.11)	
13	SB(0.06)		BN(0.03)	FH(0.04)		GS(0.04)	CS(0.09)	WF(0.07)	BG(0.08)	FH(0.08)		RS(0.07)	
14			LG(0.03)	RZ(0.04)		RS(0.04)	FH(0.09)	BC(0.03)	FR(0.08)	FR(0.08)		BH(0.04)	
15				SS(0.04)		SS(0.04)		SD(0.03)		LG(0.08)		FR(0.04)	
16								WB(0.03)		RZ(0.08)		NP(0.04)	
17										RW(0.08)			
18										WF(0.08)			

1/ See Table 2

species composition (PSC) and catch per unit effort (CPE) are two statistics used as indices of abundance. These provide the relative numerical importance of the species over time and space. PSC was computed for each species as a percentage of the total catch for a given area or time. CPE was the number of a given species caught for the total effort (hour or area) expended for all samples that did or did not yield the target species.

The absolute abundance of humpback chub in the relatively open system of the Colorado River is an elusive statistic because of the rarity of the species and difficult sample conditions. Percentage species composition (PSC) and catch per unit effort (CPE) are two statistics used as indices of abundance. These provide the relative numerical importance of the species over time and space. PSC was computed for each species as a percentage of the total catch for a given area or time. CPE was the number of a given species caught for the total effort (hour or area) expended for all samples that did or did not yield the target species.

Percentage Species Composition

Humpback chub constituted 0.6, 0.4 and 0.1 percent of the total fish catch in 1979, 1980 and 1981, respectively (Table 34). These figures are too low to indicate any trends in abundance. The species ranked 11th, 13th and 14th most common of the 23 species caught in 1979, 1980 and 1981, respectively.

Humpback chub were caught in only 4 of the 11 regular study strata, (B, E, G, H) and in no stratum did the species exceed 1.8 percent of the catch (Table 35). Chubs in the special strata K (Black Rocks) and N (Westwater Canyon) constituted 6.9 and 5.0 percent of the fish composition. The PSC shows that humpback chub are rare throughout the Upper Colorado River but may be common locally and in restricted habitats.

Catch Per Effort

Humpback chub were caught at the rate of 1.16 and 0.28 fish/10 hours of effort in prerunoff and postrunoff flows in 1980 (Table 36). No humpback chub were caught during runoff by regular sampling, but several were caught in special sample efforts. CPE did not differ significantly ($\alpha = .01$) for the two flow periods presented nor in the areas captured, suggesting a lack of movement by the species with flow period.

CPE of adult and juvenile humpback chub in the 11 study strata shows that the species was caught in strata B, G and H at rates of 0.05, 3.25 and 0.21 fish/10 hours, respectively (Table 37). These catch rates differed significantly ($\alpha = .01$), indicating a greater density of fish in stratum G (Westwater Canyon). Special sampling designed to catch humpback chub in strata K (Black Rocks) and N (Westwater Canyon) yielded 39.58 and 18.11 fish/10 hours, respectively, revealing the two areas of highest abundance for the species. These CPE statistics illustrate two points:

(1) Densities of humpback chub in strata K and N are higher than in any other strata sampled, and

(2) a comparison of CPE between random sampling (stratum G) and special sampling (stratum N) for the same reach of river, Westwater Canyon, suggests that randomized sampling does not adequately assess distribution and relative abundance of this tightly clumped species.

This statistic also infers that the species is rare throughout the river (never ranked higher than 5th most commonly caught), except in very localized areas.

CPE for area-dependent gear (1/8, 1/4, 1/2" seines) yielded humpback chub only from special strata K and N (Table 38). These were small numbers of young-of-the-year (YOY) and juvenile fish that totaled 0.13 and 0.39 fish/100 m^2.

Several fish tentatively identified as young humpback chub (CH) were caught in strata B (0.15), C (0.01), E (0.09) and G (0.13). The difficulty in distinguishing young humpback chub from young roundtail chub was a major problem in documenting successful humpback chub reproduction in the upper Colorado River (see Morphology).

Migration and Movement

Migration and movement of humpback chub in the upper Colorado River was monitored with the aid of Carlin tags and AVM radio tags (see Radio Telemetry). Extensive longitudinal movement was considered 'migration' and short, local longitudinal and vertical displacements were considered 'movement'.

Sixteen of 218 fish tagged with Carlin tags were recaptured 1-434 days after release (Table 39). Recapture sites ranged from 0 to 14.4 miles from release sites for an average distance of 1.0 miles. All but one fish were recaptured less than 0.4 miles from their release site. One fish initially tagged in Westwater Canyon 10 September 1980, was recaptured 232 days later, 14.4 miles upstream in Black Rocks. This was the greatest movement observed for humpback chub and was the only recorded exchange of a fish between Westwater Canyon and Black Rocks. This is the only evidence of migration exhibited by the species. This fish grew 4 mm and lost 206 grams between captures.

Migration, or extensive upstream or downstream movement, is not strongly indicated for humpback chub by these tagging studies. The absence of large numbers of humpback chub outside of Black Rocks and Westwater Canyon from March to November also suggests a minimum of migration by the species.

Several humpback chub recaptured short periods after initial tagging reveal interesting aspects of their behavior and adaptability to handling and tagging. Fish No. 515, captured by electrofishing at 1130 hours was recaptured 5 hours later on hook and line near the original point of release. The bait used was a live grasshopper fished in about 18 feet of water. Fish No. 903, captured by electrofishing April 29, 1981, was recaptured 3 days later by a recreational fisherman using commercial-bottled salmon eggs. These short-term recaptures by angling indicate the

Table 38
Ranked catch per 100 m^2 of area for fishes of the Upper Colorado River by 12 sample strata (gear = 1/8, 1/4, 1/2-in. seines)

	Regular strata[1/]										Special strata[1/]	
Rank	A	B	C	D	E	F	G	H	I	J	K	N
1	RS(151.67)	RS(96.79)	RS(58.07)	SS(64.8)	RS(85.73)	RS(160.90)	SS(17.38)	RS(29.00)	RT(38.92)	SS(30.78)	RS(127.69)	RS(31.79)
2	SS(6.67)	SS(31.54)	FH(15.26)	RS(54.23)	SS(39.64)	SS(113.12)	RS(15.88)	RT(21.18)	FH(17.60)	RT(15.33)	FH(57.53)	RT(12.33)
3	GS(1.67)	FH(26.67)	SS(13.64)	FH(31.40)	FH(27.21)	FH(29.51)	FH(13.66)	SS(13.81)	SS(11.44)	FH(10.22)	RT(25.81)	BH(4.04)
4		CC(21.70)	CC(2.91)	CP(1.48)	RT(2.44)	RT(15.25)	RT(12.15)	FH(10.43)	RS(11.37)	FM(10.11)	SS(20.83)	FH(2.89)
5		CS(0.55)	CS(2.77)	BH(1.50)	FM(0.97)	BH(8.75)	FM(9.67)	FM(2.46)	SD(7.06)	SD(6.89)	FM(3.63)	CS(1.16)
6		CH(2.15)	CP(0.33)	GS(1.50)	SD(0.94)	FM(2.13)	SD(2.08)	BH(1.65)	BH(3.93)	RS(0.89)	SD(3.63)	SS(1.16)
7		FM(0.15)	FM(0.22)	RT(0.78)	CS(0.54)	SD(1.29)	BH(0.80)	LG(0.93)	FM(0.97)	BH(0.67)	BH(1.61)	FM(0.58)
8		SD(0.10)	BH(0.18)	CC(0.74)	BH(0.51)	CP(0.55)	CP(0.71)	SD(0.68)	CP(0.94)	GS(0.22)	GS(0.94)	HB(0.39)
9		BH(0.05)	LG(0.18)	CS(0.58)	CP(0.42)	PK(0.40)	GS(0.62)	CP(0.64)	GS(0.90)		CC(0.67)	SD(0.39)
10		GS(0.05)	FM(0.18)	FM(0.37)	CC(0.27)	LG(0.29)	GC(0.35)	BB(0.56)	LG(0.52)		LG(0.40)	PK(0.19)
11		RT(0.05)	BB(0.11)	BB(0.30)	GS(0.27)	CS(0.22)	BB(0.13)	GS(0.32)			CS(0.13)	
12		WE(0.05)	PK(0.09)	PK(0.28)	LG(0.24)	GS(0.18)	CH(0.13)	WS(0.20)			HB(0.13)	
13		WS(0.05)	BB(0.06)	SD(0.16)	CH(0.09)	CC(0.15)	LG(0.13)	CC(0.16)				
14			SD(0.04)	LG(0.12)	BC(0.06)	WS(0.04)	BC(0.09)					
15			WS(0.02)	BG(0.02)	BB(0.03)		CS(0.04)					
16			CH(0.01)		PK(0.03)		PK(0.04)					
17					WS(0.03)							

1/ See Table 2

Table 39

Movement by 16 Carlin-tagged humpback chub in the Upper Colorado River

Tag No.	Original capture/release				Recapture				Between captures			
	TL (mm)	WT(g)	RMI	Date	TL (mm)	WT(g)	RMI	Date	Growth (mm)	Growth (g)	Distance miles	Days
0504	350	320	136.3	79/08/24	354	420	136.4	80/05/15	+4	+100	+0.1	264
0511	347	305	136.3	79/08/24	352	376	136.1	80/05/14	+5	+72	-0.2	263
0514	290	210	135.9	79/08/25			135.8	80/08/20	--	--	-0.1	360
0515	310	240	135.9	79/08/25	310	240	135.9	79/08/25	0	0	0	0
0550	342	300	135.9	79/08/25	345	300	135.8	79/10/13	+3	0	-0.1	49
0553	327	260	136.0	79/10/13	321	275	136.1	79/11/04	-6	-15	+0.1	22
0567	373	410	135.9	79/08/25	373	410	135.9	79/08/26	0	0	0	1
0569	402	408	136.4	79/10/13	395	605	136.4	80/05/15	-7	+197	0	214
0586	321	240	135.9	79/08/25	326	113	135.6	80/11/01	+5	-127	-0.3	434
0588	331	300	135.9	79/08/25	335	310	135.8	79/10/14	+4	+10	-0.1	50
0595	325	240	135.6	79/10/13			136.0	80/08/01	--	--	+0.4	292
0682	312	350	136.4	80/05/15	312	350	136.4	80/05/15	0	0	0	0
0719	299	181	135.8	80/03/26	299	181	135.8	80/03/26	0	0	0	0
0857	210	78	123.7	80/04/08	210	78	123.8	80/04/08	0	0	+0.1	0
0903	352	576	136.2	81/04/29			135.8	81/05/02	--	--	-0.4	5
2974	315	290	121.5	80/09/10	319	496	135.9	81/04/29	+4	-206	+14.4	232
								Means:	+0.9	+2.4	1.0	136.6

fish were feeding and presumably unstressed shortly after being handled by CRFP biologists. This rapid return to feeding strongly suggests good recovery and adaptability by the fish to electrofishing, handling and tagging.

The manner of attaching the Carlin tags to the fish was critical to prevent losses and minimize injury (Valdez et al. 1981). Some periphyton growth was noted on orange-colored tags, but the volume or weight never appeared to injure the fish or impede movement. There was considerable periphyton growth, however, on the white Carlin tags used on Colorado squawfish from Willow Beach NFH and released in the Colorado River near Moab. White apparently attracts more sunlight and is more conducive to periphyton growth than the darker-colored tags. Caution is advised in using these light-colored plastic tags in warm waters.

Habitat Preference

Habitat preference of humpback chub was evaluated as percentage species composition (PSC), catch per unit effort (CPE), and suitability-of-use criteria.

Percentage Species Composition

Humpback chub were found in only four habitats; backwaters, eddies, pools and runs. An analysis of the habitats from which the species was caught reveals that 45.16 percent of all chubs taken were in pools, 29.77 percent were in runs, 21.74 percent were in eddies, and 0.76 percent in backwaters (Table 40).

Catch Per Effort

Humpback chub (adults and juveniles) were caught in eddies, pools and runs at rates of 0.51, 0.38 and 0.16 fish/10 hours of effort, respectively (Table 41). The closely-related roundtail chub had the highest CPE in both eddies and pools, and the fourth highest in runs, showing that the habitats occupied by humpback chub often support large numbers of roundtail chub. This analysis and the PSC showed that humpback chub were caught from only three, presumably preferred, habitats.

Suitability-of-Use Criteria

Habitat information on humpback chub of the upper Colorado River was partitioned for developing suitability-of-use criteria as follows with the indicated sample sizes:

(1) all adults (184),

(2) all juveniles (36),

(3) adults from Black Rocks (136),

(4) juveniles from Black Rocks (12),

(5) adults from Westwater Canyon (43),

Table 40
Native and nonnative fishes associated with humpback chub in four habitat types of the upper Colorado River, 1979-1981

	Percentage composition			
	Backwaters n=264	Eddies n=300	Pools n=156	Runs n=348
Native species				
Roundtail chub	24.33	40.47	38.06	20.52
Humpback chub	0.76	21.74	45.16	29.77
Bluehead sucker	7.98	12.71	7.10	8.67
Flannelmouth sucker	1.14	1.00	1.94	18.21
Colorado squawfish	2.28	1.34	0.65	0.58
Roundtail x humpback		0.67	0.65	0.29
Speckled dace	0.76	0.33		0.29
Totals:	37.25	78.26	93.56	78.33
Non-native Species				
Red shiner	58.17			
Common carp		6.02		19.65
Channel catfish		12.71	6.45	2.02
Black bullhead		2.01		
Sand shiner	2.28			
Fathead minnow	1.90			
Largemouth bass		0.67		
Green sunfish		0.33		
Plains killifish	0.38			
Totals	62.73	21.74	6.45	21.67

Table 41
Ranked catch per 10 hours of effort for fishes of the upper Colorado River by 11 habitat types (trammel nets, gill nets, electrofishing)

Rank	Habitats[1/]										
	BA	ED	GP	PO	RI	RU	SH	SC	MC	ID	LK
1	CP(11.68)	RT(6.15)	BB(11.45)	RT(25.50)	FM(1000)	FM(23.01)	FM(87.04)	CP(11.17)	FM(14.29)	BH(170.00)	CP(2.75)
2	FM(7.69)	FM(4.93)	CP(10.06)	FM(21.39)	BH(861.11)	CP(17.13)	CP(28.72)	RT(5.05)	RZ(14.29)	FM(120.00)	BG(1.64)
3	RT(7.22)	CC(3.53)	GS(6.72)	BH(3.25)	RT(188.89)	BH(9.70)	CC(18.39)	FM(3.72)		RT(80.00)	LG(1.64)
4	WS(4.17)	CP(1.34)	FM(5.82)	WS(1.81)	CP(16.67)	RT(9.29)	BH(18.04)	WS(2.39)		CP(70.00)	GS(1.35)
5	BB(2.91)	BH(1.16)	CC(2.61)	CC(1.15)	MS(16.67)	CC(4.89)	RT(8.58)	BB(2.13)		CC(50.00)	CC(0.64)
6	BH(2.77)	HB(0.51)	RT(2.05)	CP(1.05)	WS(16.67)	WS(0.44)	CS(1.05)	GS(1.60)			CS(0.18)
7	LG(2.02)	RH(0.24)	RZ(1.22)	RB(0.57)	CC(5.56)	LG(0.38)	WS(0.88)	LG(1.65)			RM(0.18)
8	CC(0.84)	WS(0.22)	WS(0.79)	HB(0.38)	RB(5.56)	RS(0.36)	BB(0.53)	BH(0.53)			RS(0.18)
9	CS(0.84)	CS(0.10)	CS(0.43)	FB(0.29)		GS(0.33)	GS(0.53)	CS(0.53)			WE(0.23)
10	GS(0.84)	BB(0.08)	LG(0.26)	BN(0.10)		RH(0.31)	FR(0.18)				BC(0.12)
11	RZ(0.28)	LG(0.08)	BC(0.10)	CS(0.10)		SD(0.23)	RB(0.18)				TS(0.12)
12	FH(0.19)	CH(0.04)	BG(0.10)	FR(0.10)		CS(0.19)	SD(0.18)				BR(0.06)
13	RB(0.19)	FR(0.04)	RS(0.07)			BB(0.17)					RZ(0.06)
14	BC(0.09)	GS(0.04)	BH(0.13)			HB(0.16)					SB(0.06)
15	BN(0.09)	RB(0.02)	FR(0.03)			RB(0.16)					
16		RZ(0.02)	MP(0.03)			MS(0.14)					
17		SD(0.02)				BN(0.10)					
18		WF(0.02)				FH(0.05)					
19						WF(0.05)					
20						WB(0.03)					
21						RZ(0.02)					
22						SS(0.02)					

1/ See Appendix A

(6) juveniles from Westwater Canyon (19), and

(7) adults from Black Rocks and Westwater Canyon (179).

These partitions were selected according to logical groupings, i.e. life stage and locale. Other partitions were attempted, but the records were too few to permit this type of analysis. This analysis generated histograms of the raw data and smooth curves were developed to describe the data.

Young-of-the-year--Too few young chubs were even tentatively identified as humpback chub to enable generation of habitat preference information for this life stage. Fish believed to be YOY humpback chub and roundtail chub appear to prefer small pockets of quiet waters among the boulders and swift waters of Black Rocks and Westwater Canyon. Many young chub were observed in shoreline eddies and backwaters but the latter habitat was too sparse in the two sites mentioned to be considered an important habitat.

Juveniles--Juveniles were found in depths of 0.90-35.0 feet with a mean of 11.16 feet. Depths commonly occupied ranged from 2.32-19.37 feet with high use of 5.16-8.00 feet (Figure 17). Juveniles from Black Rocks demonstrated a bimodal choice of depth, which probably reflects the geomorphology of Black Rocks; an abundance of shallow and very deep water but few intermediate depths because of the steep rock walls. Preferred depths were 2.94-14.54 feet and 17.44-29.04 feet (Figure 18). Depths used by juveniles in Westwater canyon were not represented bimodally like those of fish from Black Rocks. Depths preferred by juveniles from the former area were 6.23-11.86 feet (Figure 19).

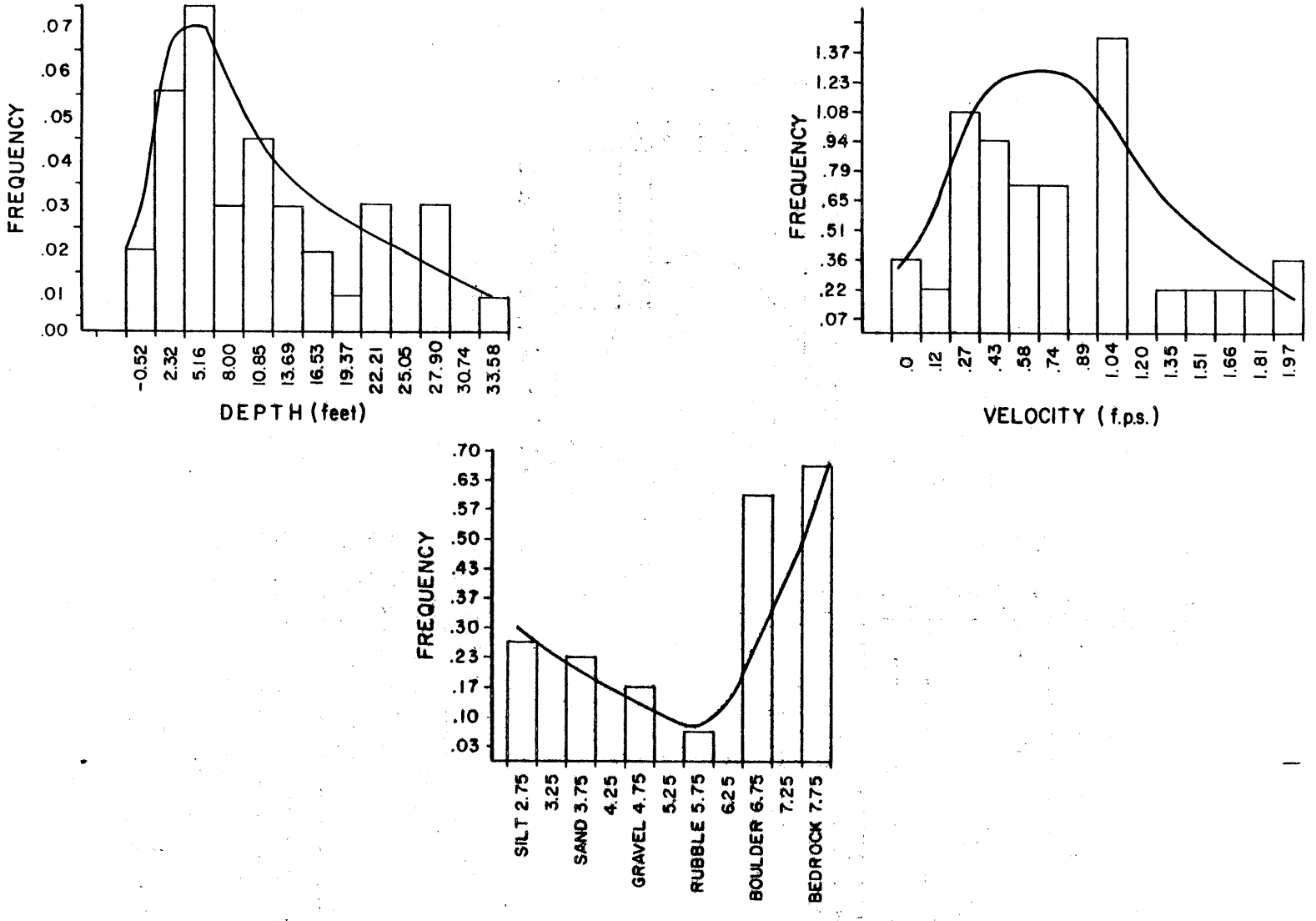
Juvenile humpback chub were caught in velocities of 0-2.0 fps, with a mean of 0.76 fps. Velocities of 0.16-1.09 fps were preferred (Figure 17). A partition for juveniles from Black Rocks shows a high use range of 0.19-0.35 fps, but no observations in the range 0.35-0.83 fps (Figure 18). Juvenile humpback chub from Westwater Canyon also used a variety of velocities, with high use of 0.66-0.83 fps (Figure 19).

Juveniles were found over six substrate types; silt, sand, gravel, rubble, boulder and bedrock (Figure 17). Juveniles from Black Rocks were found only over silt, sand, boulder and bedrock (Figure 18). These probably describe the predominant substrates of Black Rocks. It was the juvenile chubs from Westwater Canyon that were caught over the great variety of substrates including sand, gravel, rubble, boulder and bedrock (Figure 19). Boulder and bedrock were clearly used most often by all juveniles.

Juvenile humpback chub of the upper Colorado River were found in low velocity water, in medium to deep water, and over a variety of substrates, but primarily boulder and bedrock. These fish usually occupied runs, eddies and pools but a few were found along shorelines or in backwaters. This accounts for the variety of substrates encountered.

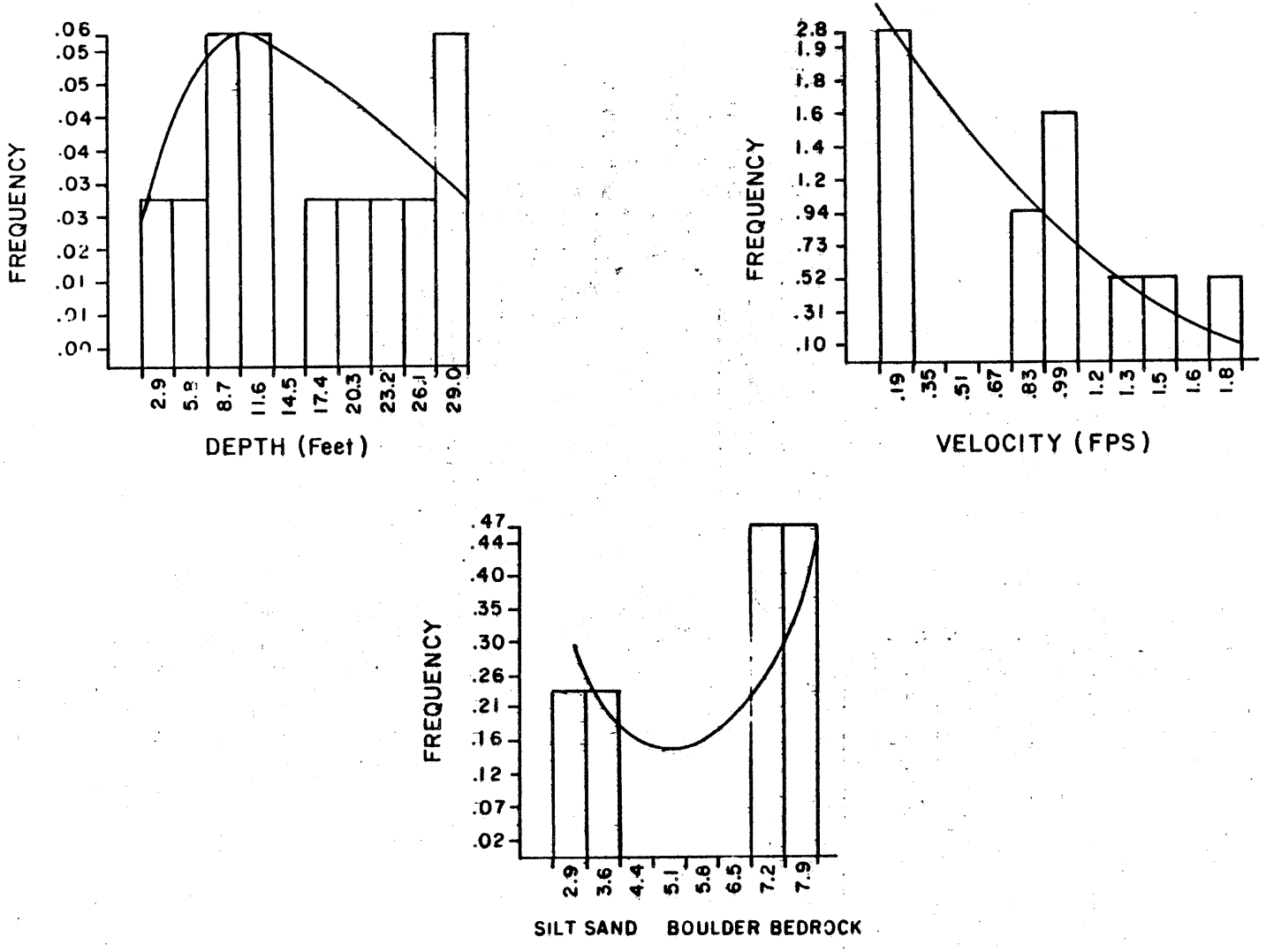
Adults.--Adult humpback chub were found in depths ranging from 2.4-40.0 feet, and a mean of 13.16 feet. High use was demonstrated for

Figure 17



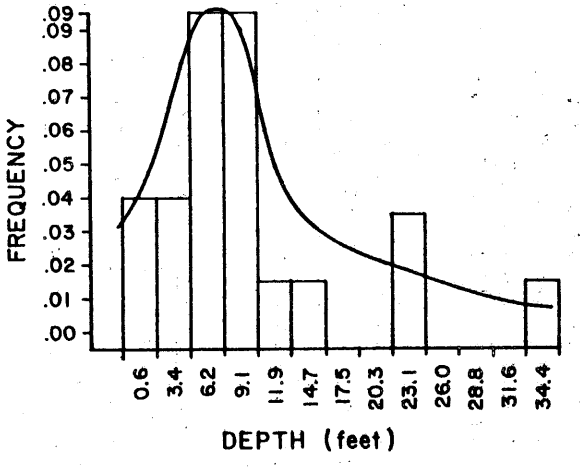
Depth, velocity and substrate use by 36 juvenile humpback chub from the upper Colorado River, 1979-1981.

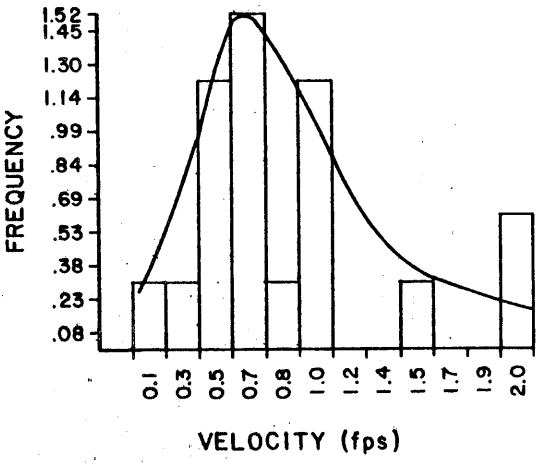
Figure 18

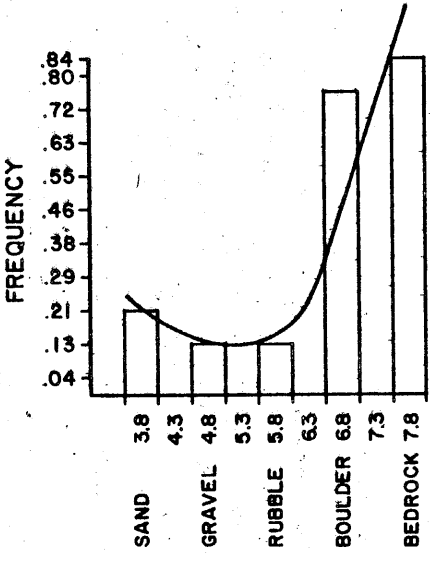


Depth, velocity and substrate used by 12 juvenile humpback chub from Black Rocks, Colorado, 1979-1981.

Figure 19







Depth, velocity and substrate used by 19 juvenile humpback chub from Westwater Canyon, Utah, 1979-1981.

water 5.4-9.8 feet deep (Figure 20). Use of deeper water appeared to diminish except for the cell 20.8-23.1 feet.

The depth information from Black Rocks is similar to that just discussed. Preferred depths in Black Rocks were 6.83-8.47 and 19.94-21.58 feet (Figure 21). Depths occupied in Westwater Canyon--like velocities--are different from those in Black Rocks. Adults in Westwater Canyon preferred water 5.91-8.81 feet deep, but also used a variety of depths (Figure 22).

The histogram of combined data for adult chubs of Black Rocks and Westwater Canyon shows a broad range of depths commonly used by the species (Figure 23). Preferred depths were 18.96-21.05 feet, and the bulk of observed depths were 2.25-21.05 feet.

Adult humpback chub were taken in velocity ranges of 0-3.8 fps and an average of 0.60 fps (Figure 20). A histogram of the data show few fish from the near zero velocities, but a dominant mode in the 0.17-0.38 fps range. The two principle locale partitions of humpback chub, Black Rocks and Westwater Canyon, revealed apparent differences by the fish for preferred velocity. This histogram of Black Rocks data shows a unimodal distribution of observations, strongest in the 0.20-0.41 fps cell (Figure 21).

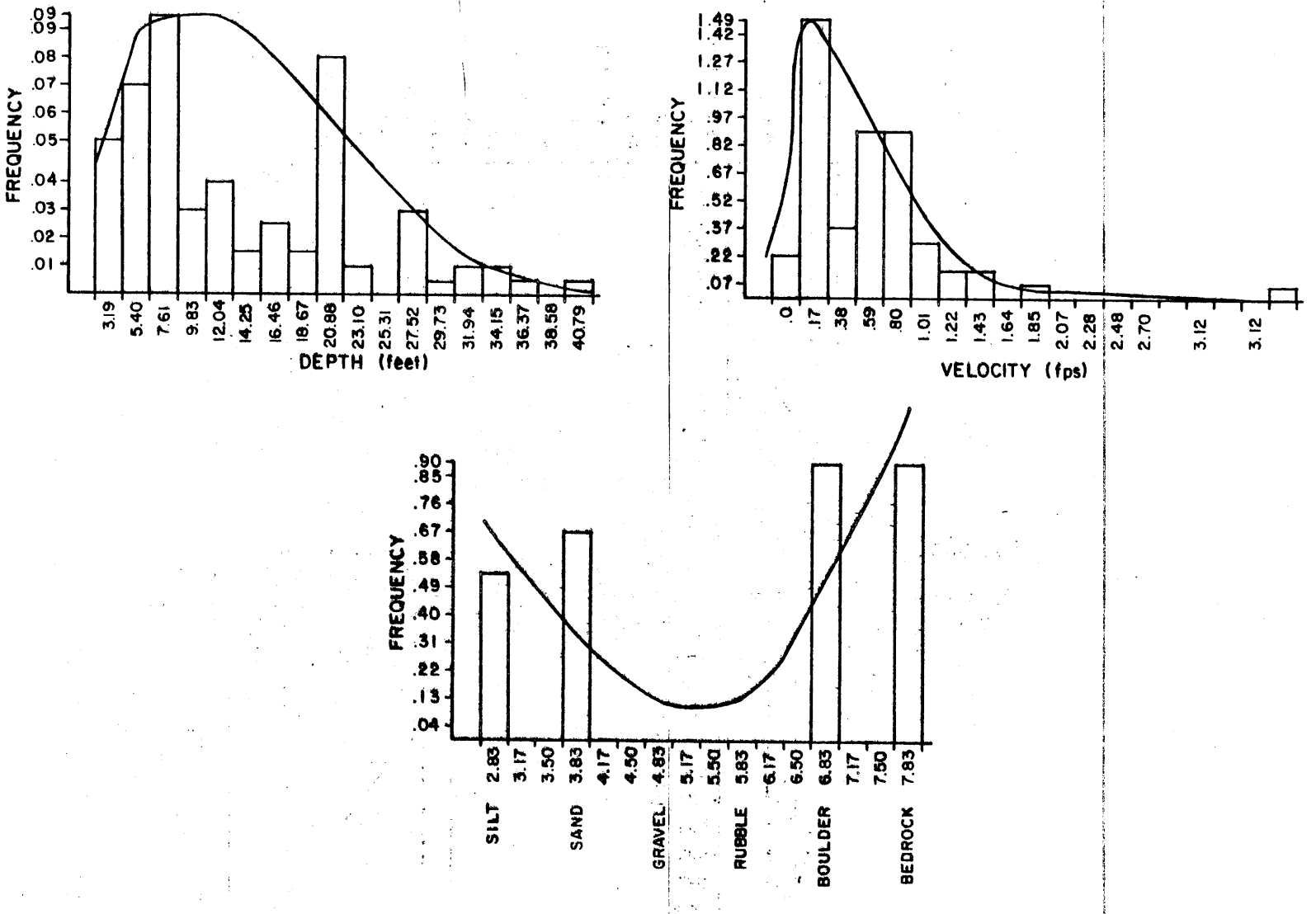
The distribution of velocities associated with adult humpback chub in Westwater Canyon showed high use of velocities of 0.25-0.38 fps but were also commonly found in velocities of 0.52-1.34 fps (Figure 22). Adults from Westwater Canyon appear to occupy a wide range of velocities, but prefered 0.55-0.85 fps. These results may relate closely to the hydraulic uniqueness of Westwater Canyon; Westwater and Cataract Canyons appear to have the highest velocity waters of the upper Colorado River.

Combining velocity data of these two partitions (Black Rocks and Westwater Canyon) may be tenuous. Nevertheless, combined data represented by a histogram (Figure 23) show a similar distribution to that for Black Rocks alone, except for a secondary peak in the 0.70-0.93 fps cell.

Four substrates were associated with adult humpback chub of the upper Colorado River; silt, sand, boulder and bedrock (Figure 20). Boulder and bedrock appeared to be the preferred substrate. This was true of adults in Black Rocks (Figure 21) and Westwater Canyon (Figure 22), as well as the combined data (Figure 23).

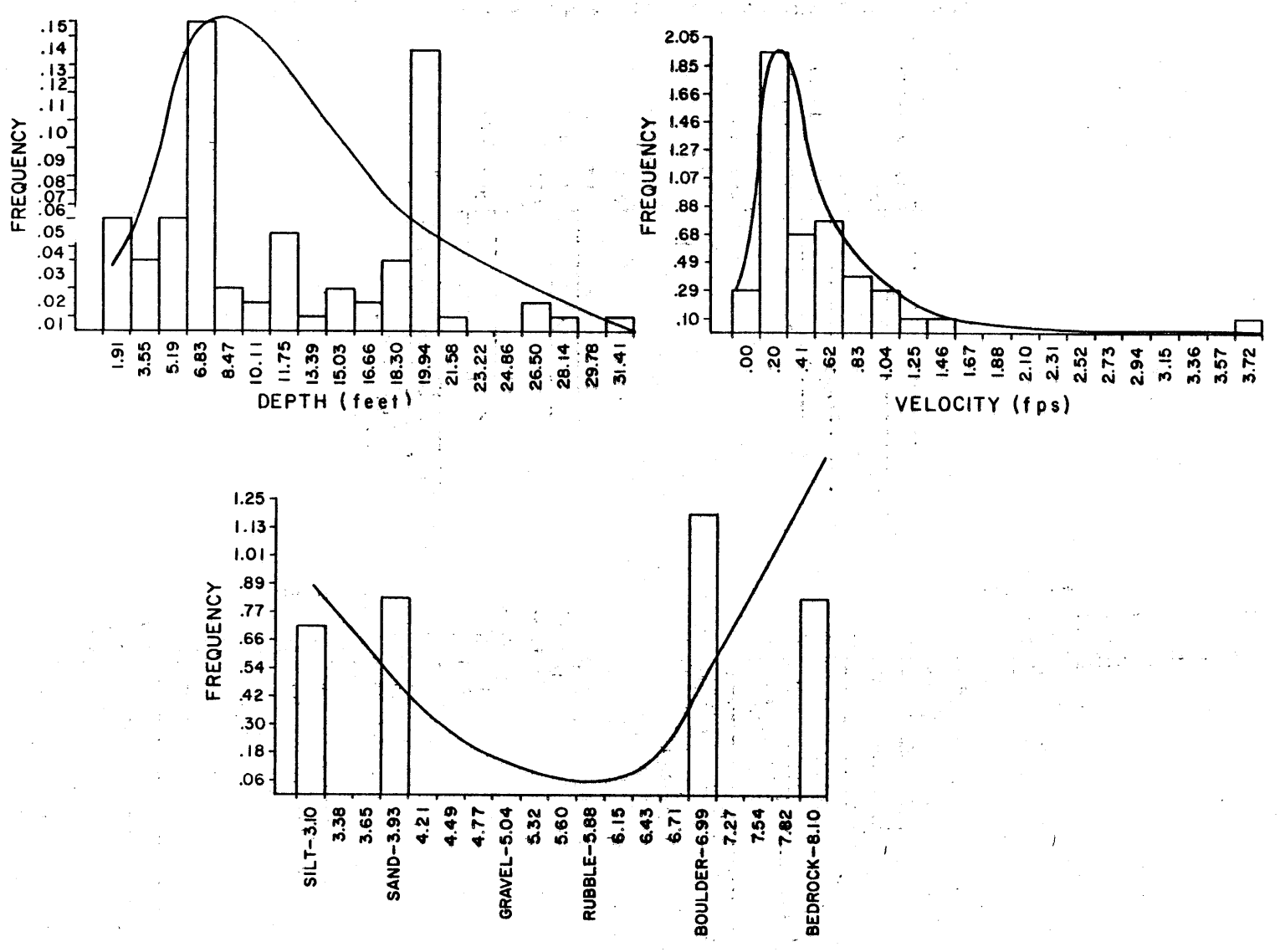
Histograms of raw data and resulting curves for adult humpback chub show high use of low velocities, and the apparent need for at least some current. Preferred depths were mid-range to deep, and preferred substrate was boulder and bedrock with intermittent pockets of silt and sand. Adults preferred runs, eddies and pools, but few were found in shallow, quiet backwaters, as are the other native fishes. Adult humpback chub appear to be well adjusted to deep, moderately swift water, and may be specifically adapted to restricted habitats at the exclusion of much of the river.

Figure 20



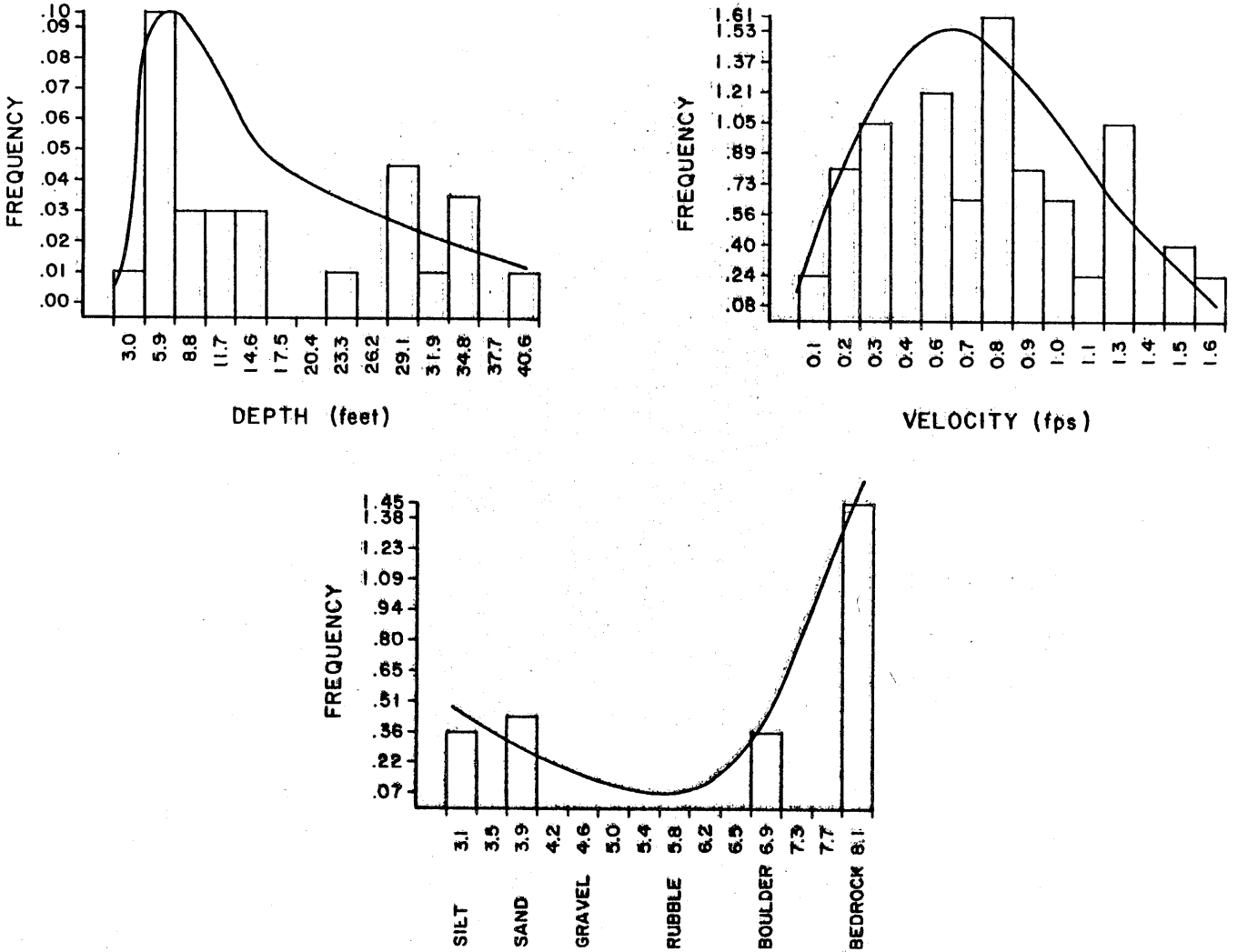
Depth, velocity and substrate used by 184 adult humpback chub rom the upper Colorado River, 1979-1981.

Figure 21



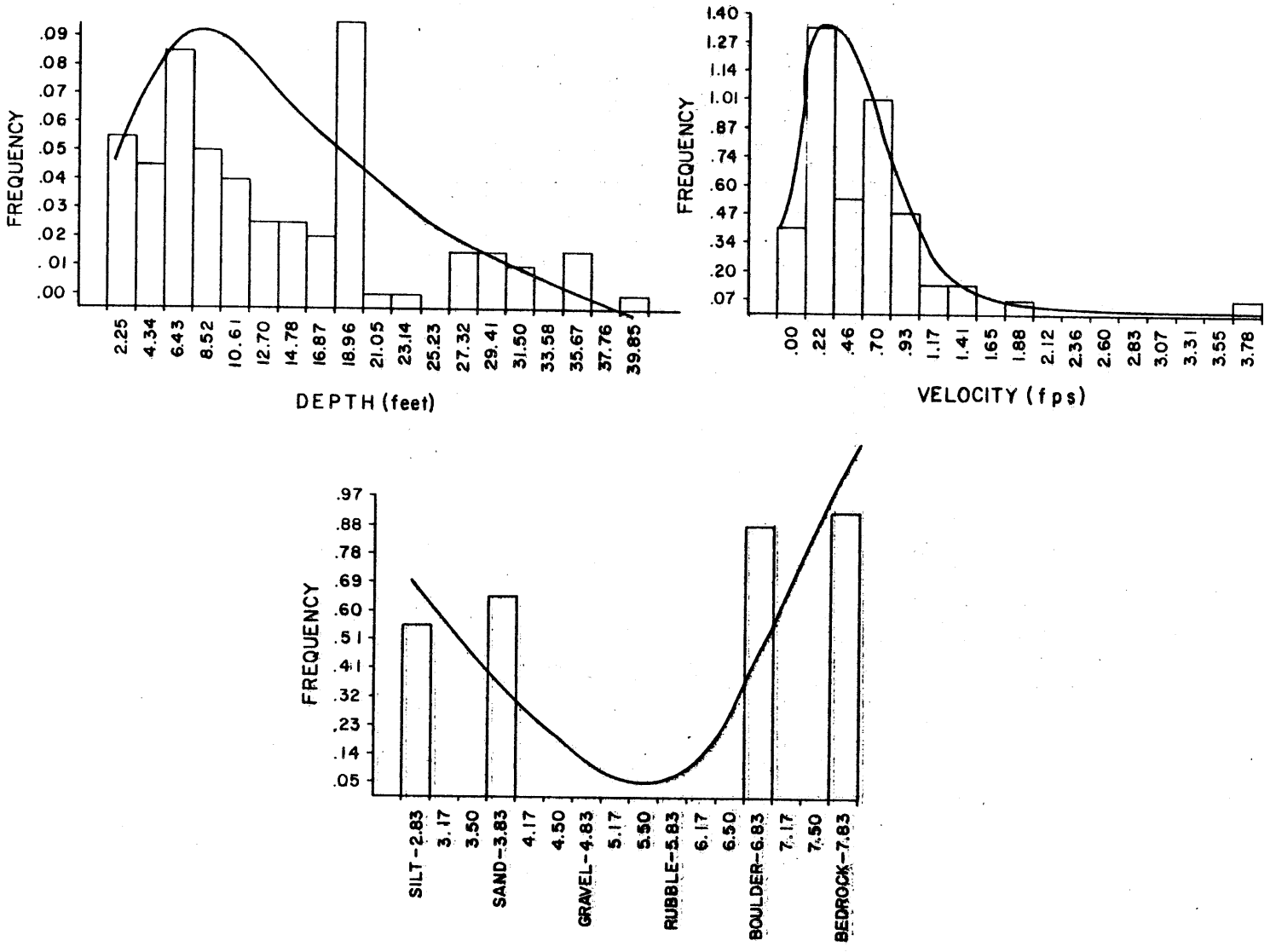
Depth, velocity and substrate used by 136 adult humpback chub from Black Rocks, Colorado, 1979-1981.

Figure 22



Depth, velocity and substrate used by 43 adult humpback chub from Westwater Canyon, Utah, 1979-1981.

Figure 23



Depth, velocity and substrate used by 179 adult humpback chub from Black Rocks and Westwater Canyon, 1979-1981.

Synthesis--Adult and juvenile humpback chub showed very similar habitat uses. Velocities occupied by adults and juveniles were 0-3.8 fps and 0-2.0 fps with means of 0.60 and 0.76 fps, respectively. Adults and juveniles occupied depths of 2.4-40.0 and 0.90-35.0 feet and means of 13.16 and 11.16 feet, respectively. The preferred substrates were boulder and bedrock with some silt and sand. Juveniles were also found over gravel and rubble associated with shorelines and backwaters--habitats rarely occupied by the species.

Spawning

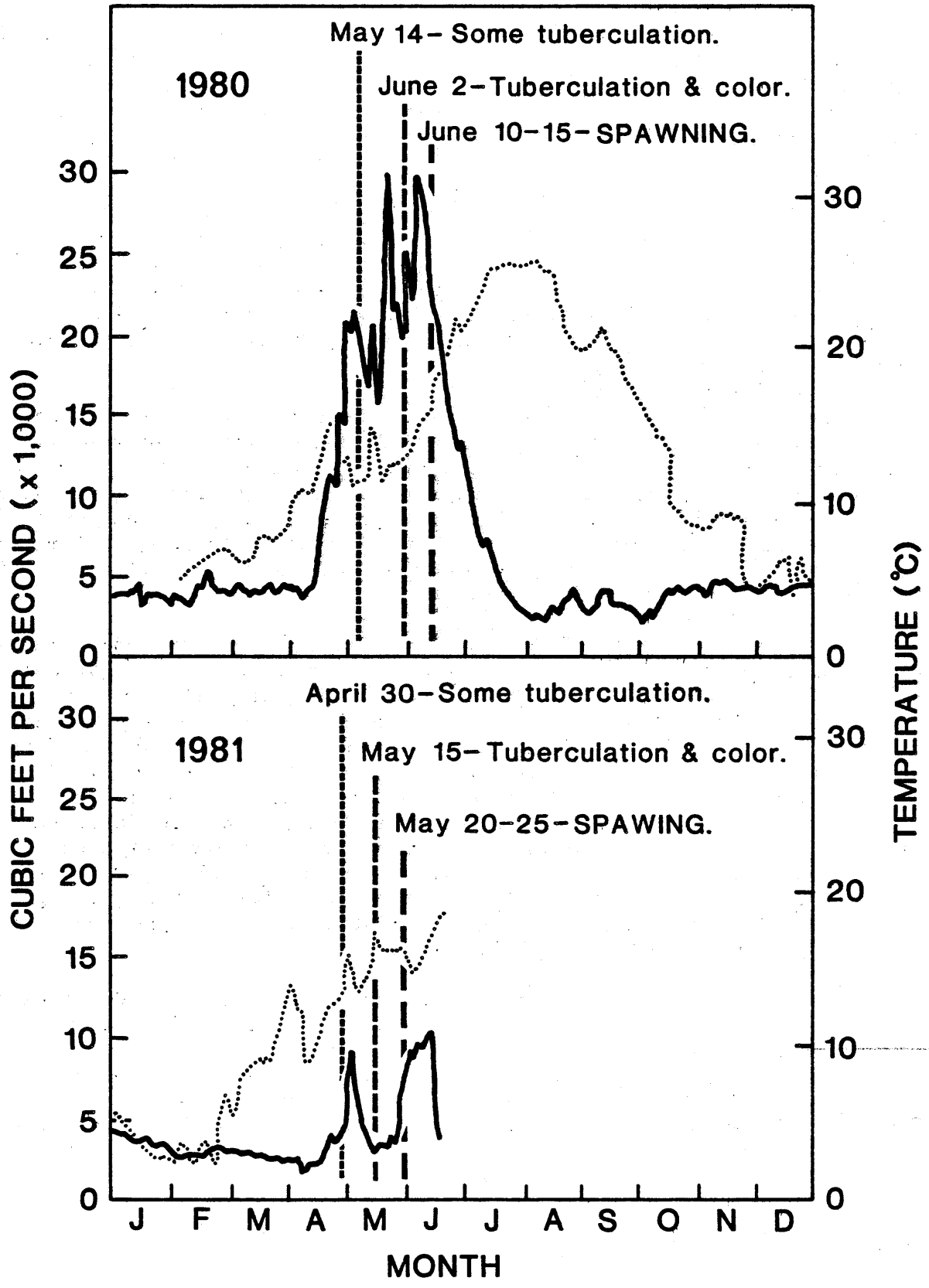
Natural reproduction of humpback chub occurs in Black Rocks and Westwater Canyon, as indicated by recent collection of young, juveniles and subadults in the presence of adults. Little is known about the natural reproduction of humpback chub primarily because spawning occurs at or near spring runoff, a difficult time to sample the deep turbulent waters inhabited by the species.

Spawning time and water conditions for humpback chub were documented in Black Rocks in 1980 and 1981. In 1980, tuberculate fish were first seen May 14 at a mean daily water temperature of 11.3° C and flow of 18,000 cfs (Figure 24). Seven of eight males captured had light orange abdomens, with tubercles on the head and paired fins. But, only two of the six females captured exhibited these prenuptual features. Similar tuberculation and coloration were described for the species in the Grand Canyon area (Suttkus and Clemmer 1977).

Eighteen fish collected on June 2 were all tuberculate and colored at a water temperature of 11.5° C and flow of 21,500 cfs. All males produced milt, but eggs could not be naturally stripped from females. Three females, injected with a preparation of carp pituitary (Valdez-Gonzalez 1980), released 18,000 eggs (4,000; 4,000; 10,000 per fish) which were transported to the Willow Beach NFH. Eggs incubated at 12-13° C failed to develop and died after 110 hours, while those incubated at 20-21° C hatched in 120-160 hours (Hamman 1980). Maximum daily water temperatures at Black Rocks in 1980 did not reach the expected optimum incubation level of 20° C until 26 June and a mean of 20° C was not seen until June 29. Spent fish were found June 15 indicating that spawning in Black Rocks probably occurred June 2-15, 1980, at water temperatures of 11.5-16.0° C and flows of 21,500-26,000 cfs.

Flow in the Colorado River in 1981 was unusually low and humpback chub spawned earlier than in 1980 (Figure 24). Tuberculate fish were found in Black Rocks on 10 April at a mean daily water temperature of 14.0° C and a flow of 4300 cfs. Tuberculation and coloration were extensive on May 15 at 16.5° C and a flow of 3000 cfs. Spent fish were captured 27 May indicating that spawning occurred 15-27 May at water temperatures of 16.0-16.5° C and flows of 3000-5000 cfs. Spawning in 1981 occurred about 2 weeks earlier than in 1980, probably because of the early warm water temperatures and the absence of a high volume runoff to cool the water and delay spawning as in normal water years. Relative survival of these two year classes is yet unknown.

Figure 24



Water temperatures and flows associated with spawning of Gila cypha in Black Rocks, Colorado.

Associated Species

Humpback chub in the upper Colorado River were associated with a high percentage (70.65 percent) of native fishes, although this involved only 6 species and 1 hybrid (Table 42). Roundtail chub accounted for 30.26 percent while humpback chub constituted 22.25 percent of the total fish composition, where the target species occurred. Bluehead sucker and flannelmouth sucker were associated at lower levels of 9.49 and 6.70 percent, respectively. Intermediates (rountail x humpback chub) were usually associated with humpback chub, but at relatively low densities.

Nine non-native species were associated with humpback chub for 29.31 percent of the fish composition. Red shiner (14.24 percent), common carp (8.00 percent) and channel catfish (5.12 percent) were the most common non-native associates. A few medium-sized predators, such as black bullhead, largemouth bass and green sunfish also occurred, but these primarily lentic species are probably excluded from humpback chub association by the rigorous habitat conditions.

This exclusion of some non-native species is demonstrated by examining the numbers of species associated with humpback chub in Black Rocks, Westwater Canyon and Cataract Canyon and comparing that with numbers of species in adjacent river sections of equal length (Table 43). Black Rocks and Westwater Canyon support 14 species of fish including 8 and 9 non-natives, while adjacent areas support 19 and 18 species with 13 and 14 non-natives, respectively. This difference of fish diversity suggests that habitats occupied by humpback chub are unfavorable to some non-natives but apparently not to native species.

Over 78 percent of the fishes associated with humpback chub in eddies, pools and runs were native species (Table 40). Backwaters harbored only 37.25 percent native fauna in association with humpback chub. A strong association is evident between roundtail chub and humpback chub in eddies, pools and runs, where the two species jointly made up 62.21, 83.22 and 50.29 percent of the fish composition. This association is not as strong in backwaters since few humpback chub (0.76 percent) were found in this habitat in spite of an abundance of roundtail chub (24.33 percent). This dominance is attributed principally to large numbers of red shiner (58.17 percent).

Humpback chub appear to live in greater sympatry with native fishes than with nonnatives in eddies, pools, and runs--their principal habitat in the upper Colorado River. These associations strongly suggest that humpback chub occupy habitats still unfavorable to some nonnatives.

Species associated with humpback chub may also be sources of diseases and parasites. The parasitic copepod, Lernaea cyprinacea, introduced into the Colorado River via an unknown host was found near fin bases of 26 percent of the 234 humpback chub examined from the upper Colorado River. The parasite was not found in young fish, but 17 percent of juveniles and 31 percent of adults were infested with 1-13 copepods. None of the infested fish exhibited signs of stress or illness, although some had small open lesions at the parasite anchor points.

Table 42
Native and nonnative fishes associated with humpback chub in the upper Colorado River, 1979-1981

	Percentage Composition (n=1068)
Native species	
Roundtail chub	30.26
Humpback chub	22.25
Bluehead sucker	9.49
Flannelmouth sucker	6.70
Colorado squawfish	1.21
Roundtail x humpback	0.37
Speckled dace	0.37
Total:	70.65
Non-native species	
Red shiner	14.24
Common carp	8.00
Channel catfish	5.12
Black bullhead	0.56
Sand shiner	0.56
Fathead minnow	0.46
Largemouth bass	0.19
Green sunfish	0.09
Plains killifish	0.09
Total:	29.31

Table 43
Numbers of fish species associated with humpback chub within and adjacent to three areas of the upper Colorado River (numbers of nonnative species are shown in parentheses)

Locale	Within area	Adjacent area
Black Rocks	14 (8)	19 (13)
Westwater Canyon	14 (9)	18 (14)
Cataract Canyon	13 (7)	19 (13)

Morphology

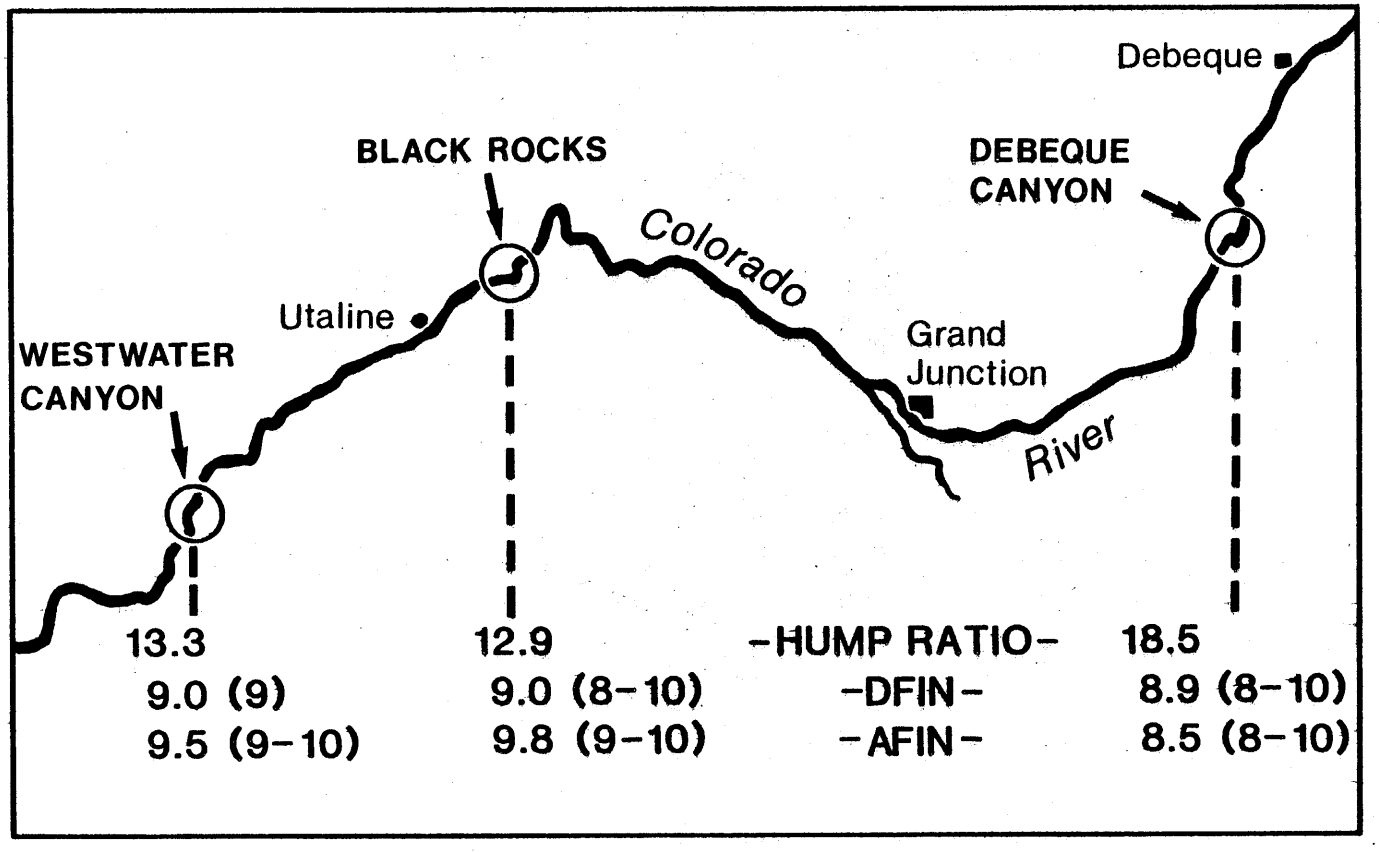
The humpback chub has a laterally compressed body with sides slightly convex, and long, slender paired and caudal fins (Miller 1946). The head is small with a flat, often concave, occiput and small eyes. A broad fleshy, scaleless nuchal hump rises abruptly behind the head. The mouth is usually inferior and the nare flaps often protrude prominently. Humpback chub generally have 9 dorsal and 10 anal-fin rays. The body is sparsely scaled with 80 scales in the lateral line. The hump, caudal peduncle, chest, breast and belly often lack scales or are sparsely scaled. Scales on the body are often isolated and deeply imbedded. The prominent hump of G. cypha may aid the fish in holding its position in swift water, especially near the bottom where the flow is not as torrential as in midchannel. The small eyes may represent a degeneration correlated with reduced light due to excessive silt or it may be a response to the scouring action of the silted river, or both (Miller 1946).

Coloration varied with age and sexual maturity. Young-of-the-year were silvery throughout with a white belly and a prominent black triangular spot at the base of the caudal fin. Juveniles usually had silver sides, white belly and a greenish back. The adults had a creamy-white belly tinted with yellow; silver green sides; and a slate green back. Spawning adults developed strong orange tint on the abdomen, sides and opercles, as well as tubercles on the head, nape, opercles and pectoral fins.

The genus Gila was represented in the upper Colorado River by G. cypha and G. robusta. Variations or possibly hybrids of these species also occurred. The two species were distinct as adults and readily identified afield by gross morphology. But, the features of young and juveniles were not easily distinguished and were hard to examine. Variants or hybrids are also difficult to identify in the field. Several meristic features, including fin-ray counts, scale counts, fin lengths, nuchal hump depth, eye diameter and squamation, were used to help identify the two species of Gila afield. No single meristic or set of meristics appeared to readily identify young, juveniles and intermediates.

The nuchal hump ratio developed by Smith et al. (1979) has limited application for identifying adults. The ratio is derived by dividing the distance between the origin of the pelvic and pectoral fins by the depth of the nuchal hump, which is the distance from a straight line between the highest part of the nuchal hump and dorsal tip of the snout and the frontal depression. Nuchal hump ratios for preserved specimens of G. cypha (6-13), G. elegans (15-29), and G. robusta (28-207) (Smith et al. 1979) were compared with those derived from live fish. Mean ratios for samples of G. cypha from Westwater Canyon (13.3) and Black Rocks (12.9) were near the upper range of ratios generally associated with the species (Figure 25). A few small adults and large juveniles in the samples probably raised the means disproportionately and reinforces applying the ratio only to mature adults. The methodology was further tested using a group of 35 humpback-like fish from Debeque Canyon, Colorado. Of the 10 fish sent to R. R. Miller for examination, 6 were tentatively identified as hybrids of G. cypha x G. robusta and the

Figure 25



Mean nuchal hump ratios and fan ray counts for adult Gila cypha from Black Rocks and Westwater Canyon and G. cypha x G. robusta from DeBeque Canyon.

remainder were considered as G. robusta. The mean ratio of 18.5 for these 35 fish fell within the expected range of G. elegans; however, these fish failed to exhibit other features of the species including anal and dorsal fin-ray counts. Complete analyses of meristics including a discriminate function analysis is being conducted.

The humpback chub-like fish from Debeque Canyon were caught on three occasions from the same area near Beavertail Mountain, upriver from Grand Junction about 20 miles. The fish are prevented from moving downstream and back by the Government Highline Dam, about 1 mile downstream. The fish were usually caught in about 16 feet of water along the boulder riprap of Interstate Highway 70.

It is hypothesized that a population of humpback chub once occupied the area. Upstream water diversions, channelization for I-70, and the construction of the Government Highline Dam probably affected the habitat of the population and allowed encroachment by roundtail chub. Reproductive-isolating mechanisms such as unique habitat, high river flows during spawning and earlier warm temperatures were apparently affected and hybridization between G. cypha and G. robusta occurred. If this scenario is accurate, it may foretell the fate of the other populations of humpback chub in an ever-developing river.

Identifying young, juveniles and intermediates of the genus Gila was a paramount problem. Specimens were sometimes captured for which no confident field identification would be made, and the paucity of these endangered species precluded extensive collection and preservation for verification. Questionable specimens were photographed for future examination.

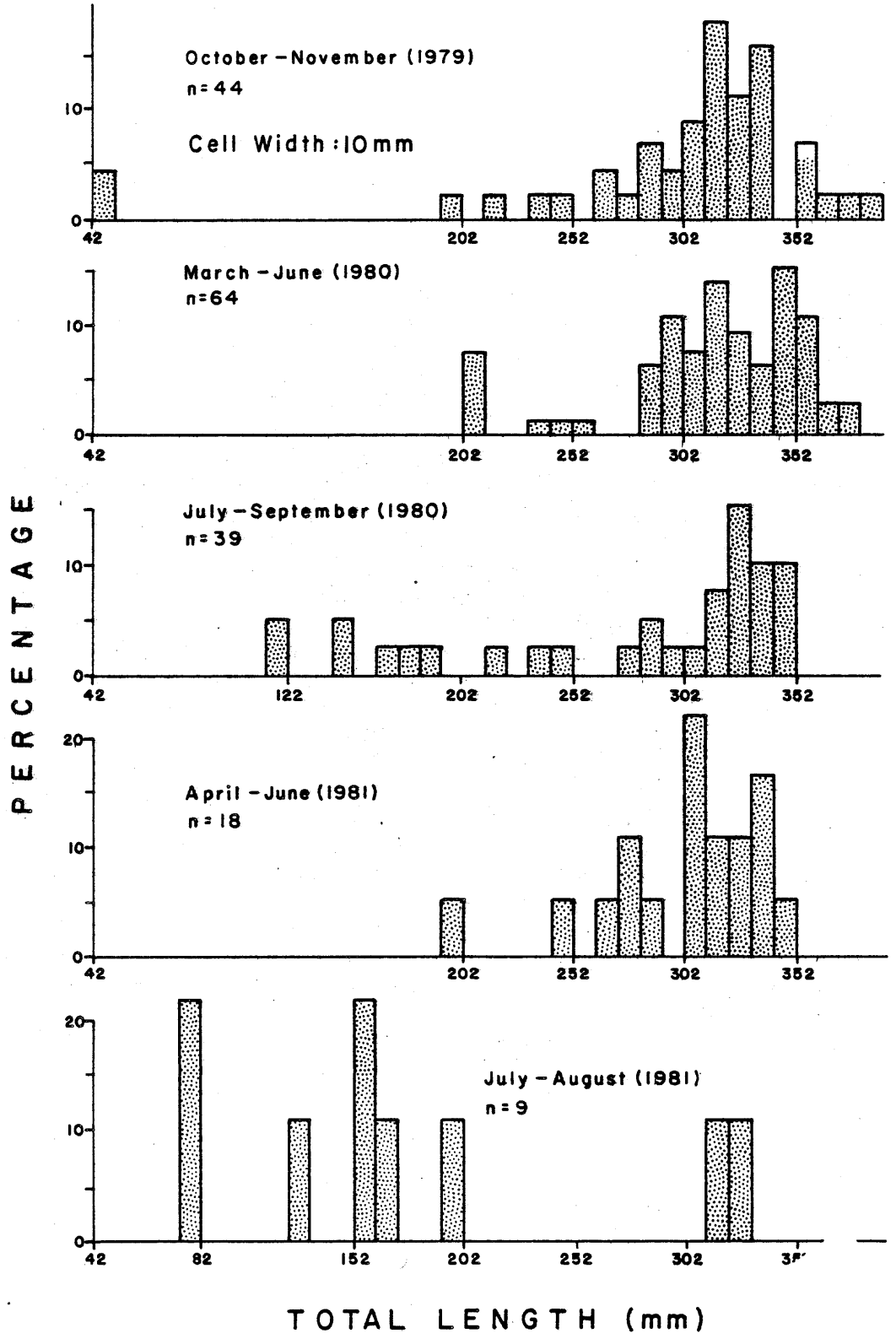
Age and Growth

Length-frequency histograms for five groups of humpback chub captured in 1981 in the upper Colorado River fail to reveal any distinct age groups (Figure 26). Too few fish were caught at any one sample time to generate reliable histograms, so the fish were grouped into five arbitrary partitions. This analysis shows a strong representation of adults and subadults. Young-of-the-year and juveniles were not well represented because of the difficulty in identifying these afield and distinguishing than from the more common roundtail chub (see Morphology). The two fish identified as YOY humpback chub (one tentative) were 28 and 40 mm long (see Larval Sampling).

Radiotelemetry

Radiotelemetry was used to supplement information on spawning and habitat requirements of humpback chub. This was the first known attempt at using radio transmitters with this species. Objectives of the radiotelemetry study were to locate spawning sites, monitor movements, and assess habitat requirements of the humpback chub. Work was conducted in the Black Rocks area of Ruby Canyon near the Colorado-Utah state line (Figure 16), which supports a concentration of the species.

Figure 26



Length-frequency histograms for five groupings of humpback chub from the upper Colorado River (n = number of fish).

Methods

Eight humpback chub (280-366 mm TL) were equipped with radio tags. Four fish (2 males, 2 females) were tagged on April 30, 1981, and an additional four (2 males, 2 females) were tagged on May 27, 1981 and each released 3 days later. The fish were tagged in two lots to test varying periods of physiological adjustment to implant procedures and to the transmitter. The fish were captured with the aid of a 220-V, DC electrofishing boat and held in the river in cotton mesh pens.

Surgical Procedures

AVM radio transmitters (SM-1 Fish Modules)[1/] were surgically implanted according to the procedures described by Bidgood (1980) and refined by Tyus et al. (1980) for use on Colorado squawfish:

(1) Fish were anesthetized in a mixture of Tricaine Methane Sulfonate (MS222) and river water in a laundry tub.

(2) Each fish was placed in the anesthesia for 4-5 minutes until only opercular movement was perceptible. The immobilized fish was then placed into position on a measuring board for implantation.

(3) A lateral incision 3-4 cm was made on the side of the fish into the posterior region of the abdominal cavity through the peritoneal lining.

(4) The AVM module (previously activated and coated with melted beeswax) was inserted into the abdominal cavity.

(5) The incision was closed with three separate sutures about 1 cm apart.

(6) Each suture was tied with a surgical knot with Ethilon, black mondle. Each surgical knot was secured with waterproof contact cement.

(7) The body and gills of the fish were periodically bathed during implantation with the anesthetic solution to prevent dessication and enhance anesthesia (implantation averaged 2-3 minutes per fish).

(8) After the incision was closed, the fish was gently placed in a recovery tub filled with fresh river water.

(9) Each fish recovered within 2-3 minutes and was transported from the recovery tub to a holding pen located in the river for a 2-3 day observation period preceding release.

1/ Manufactured by AVM Instruments Company, 3101 W. Clark Road, Champagne, Illinois 61820.

Transmitters and Receivers

The AVM modules were 3.0 cm long x 1.2 cm wide x 6 mm thick and weighed approximately 4.5 grams (0.6-1.6 percent of the body weight of the fish). Each module has a theoretical life of approximately 90 days and an effective radiated power range of 0.8-2.4 km. Range depends on water conditions such as turbidity, conductivity, and instream obstructions which have a tendency to block signals. Radiated power range of the modules is relatively unaffected between 0 and 40° C.

Each of the eight radio-equipped fish was identified by an assigned frequency between 40.370 and 40.430 MHz emitted by the transmitter. A Smith-Root SR-40 Search Receiver was used to monitor all eight frequencies simultaneously with the scanning feature of the unit. Audio and visual cues were emitted by the SR-40 when a frequency was detected. The SR-40 was used in conjunction with a Smith-Root RF-40 which enables an identification of the frequency and thus, the fish. The RF-40 tracking receiver enabled the investigator to pin-point a fish by using a 2 KHz bandwidth for general coverage and 0.5 KHz bandwidth for close range reception and triangulation. The antenna used with the RF-40 was a 50 ohm directional loop.

A transmitter was implanted in a surrogate species, roundtail chub (Gila robusta), to test the implant procedures and determine the limitations of the search and tracking receivers. The roundtail was selected for the experiment because of its similar body size and shape to the humpback chub. The experiment simulated implantation techniques and was used to assess range and depth of reception, as well as develop triangulation and search techniques. The roundtail chub was placed in a nylon mesh bag, freely suspended with floats and held at various depths and distances from the receivers. The maximum depth received was 18 feet and the maximum longitudinal range was 640 feet at 3-foot depth (Table 44). The transmitter was retrieved and the roundtail chub released when triangulation and search techniques were refined.

Table 44
Depth-range relationship of radio-equipped roundtail chub (G. robusta)

Equipment and location	Depth (feet)	Maximum longitudinal distance for signal (feet)1/
RF-40 tracking receiver on boat	3	150
	6	50
	9	0-35
RF-40 tracking receiver and SR-40 search receiver on 30-foot cliff (with both direction and whip antenna)	3	640
	6	195
	9	30
	18	33

1/ Distances measured with a Zeiss Range Finder and depth with a graduated nylon line tied to the fish bag.

Search Techniques

The search technique involved continual travel by boat through Black Rocks and the surrounding areas. A typical search involved scanning the area with the SR-40 search receiver. When a signal was received, the channel corresponding to the frequency was used to identify the fish, and the RF-40 tracking receiver was fixed on the correct frequency and monitored for pin-point location. This involved a 10-15 minutes search in the area where the signal audibility was strongest. Triangulation to pin-point a fish was calculated from boat and shore by taking bearings on the audible signal from several fixed points and locating the intersection of those bearings. The pin-point accuracy was within 90 ft^2 as determined by audibility of the signal on the 2 KHz bandwidth and finally on the 0.5 KHz filtered bandwidth.

The following data were recorded for each fish located: date and hour; river mile location (to the nearest tenth of a river mile); pulse rate of module (measured by the minute); bottom profile and depth of pinpoint location (measured with a Lowrance sonar depth finder and graduated depth pole); velocity (measured with an electronic Marsh-McBirney current meter); substrate (assessed visually); salinity, conductivity and temperature (measured with a battery-powered Yellow Springs Instrument); signal strength was noted to help monitor movements in depth and range; general observations and discoveries were also noted for improving techniques and for future reference.

Aerial reconnaissance was done in the latter part of the study and included the entire stretch of river from Loma, Colorado, to Lake Powell, Utah. The aerial search helped scan areas other than Black Rocks where radio-equipped fish may have migrated; however, 7 of the 8 fish were continually relocated at Black Rocks and the study continued at that location. The one fish may have moved from the area or been equipped with a defective transmitter; the fish was never relocated.

The field schedule for the study involved a 2-day trip each week into the Black Rocks area. A typical daily search involved scanning with the equipment between 0500 and 2300 hours. Search efforts later included scanning between 2300 and 0500 hours to allow complete documentation of diurnal patterns of the radio-equipped fish. Travel into Black Rocks to monitor fish began on April 30, 1981 and ended August 6, 1981.

The effect of radio transmitters on the behavior of humpback chub is unknown. It is assumed that the observed movement and behavior of these fish is normal, but it is also acknowledged that their behavior could have been altered by the capture, surgical implantation, and presence of the radio transmitter.

Results

The first four humpback chub equipped with radio transmitters were released in Black Rocks at 1500 hours on May 3, 1981 (Table 45). The four fish were penned and observed for 60 hours after implantation and appeared fully recovered at the time of their release. A tuberculate, colored male and a large, colored, robust female were among the four selected to help locate spawning sites. These two fish retained their

Table 45
Associated data for eight Gila cypha equipped with radiotransmitters

Identifier	Transmitter frequency	Sex	Total length (mm)	Weight(g)	Date of implant	Carlin tag number	Module pulse rate/min. Before implant	Module pulse rate/min. After implant
A	40.376	M	330	397	04/30/81	0905	90	74
B	40.391	F	339	701	04/30/81	0975	74	62
C	40.406	F	366	525	04/30/81	0967	108	92
D	40.421	M	336	500	04/30/81	0912	66	64
E	40.382	M	286	280	05/27/81	2911	76	90
F	40.401	F	326	310	05/27/81	2980	89	78
G	40.416	F	320	300	05/27/81	0884	66	64
H	40.427	M	280	280	05/27/81	2960	120	106

secondary sex characters and coloration throughout their captivity, implantation and recovery. All four fish were monitored for approximately 2 hours after release. Failure of the directional antennae precluded precise tracking and location at release time.

A second trip to Black Rocks to equip four more fish with radio transmitters May 27, 1981, revealed that spawning had occurred earlier than expected; approximately May 15-27, 1980 (Valdez and Clemmer 1981). There was no significant movement of the two gravid fish identified as fish A and C (Table 45), during the suspected spawning period or the total period from their release to May 27, 1981. These results indicate spawning probably occurred in the Black Rocks area, a 1-mile reach of river.

The second group of four radio-equipped fish were released in Black Rocks at 1,500 hours on May 30, 1981. These four fish dispersed immediately upon release with the exception of fish G (Table 43) which moved 500 feet upstream. Fish G was monitored for 30 minutes and pin-pointed at mid-channel, 40 feet deep and 0.9 fps velocity.

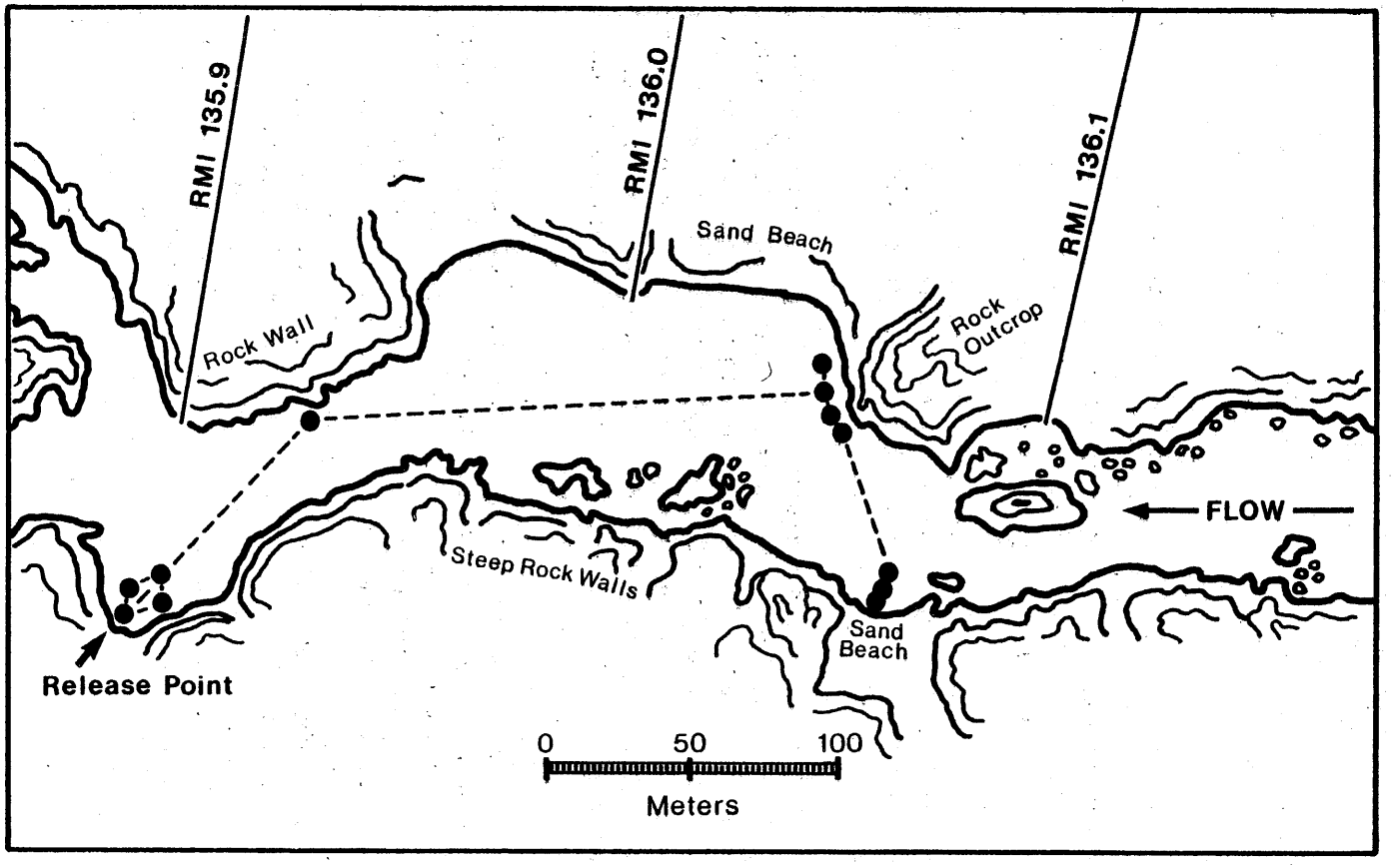
The first four fish equipped with radio transmitters were tracked over a period of 93 days. Contact with these fish occurred on 21 separate search days. The majority of contacts with these fish occurred within the first 30 days of release.

The second four fish equipped with radio transmitters were tracked over a period of 68 days. Contact with these fish occurred on 8 occasions during 16 search days. The majority of contacts with these fish occurred within the first 30 days of their release. These results indicate the batteries in all 8 modules were probably weakening under the field conditions. Total movement for radio-equipped fish was 0.1-2.3 mil for an average of 0.4 miles. Average net movement was less than 0.1 miles upstream from the release point.

Movement of radio-equipped fish is illustrated by one individual that moved 0.2 miles upstream within a period of 26 days (Figure 27). Fish A was located 24 days after release, 160 feet upstream from the release site. The following day fish A was located 650 feet upstream. The fish moved the following day 160 ft upstream to its original capture site, where he was found throughout the remaining 37 days of contact. These results indicate the fish remained at the release site for the first 23 days then moved upstream for the next 2 days before reaching his original capture site. These movements and movement of other radio-equipped fish indicated a possible homing behavior of humpback chub. No contact was made with fish A during the 33 days after July 4, 1981 to the end of the telemetry work on August 6, 1981, suggesting a loss of battery strength in the transmitter. Movement of the radio-equipped fish was restricted to the 1-mile Black Rocks area, except for fish D, which moved upstream nearly 0.3 miles from Black Rocks but returned within 14 days.

The adaptability to the radio transmitters by the eight radio-equipped fish was demonstrated by their movement through turbulent water, in and out of deep holes and fluctuating velocities as well as distances traveled, turbidities, temperature influx and varying chemical conditions (Table 46).

Figure 27



Movement of a male Gila cypha in Black Rocks, Colorado, monitored by radiotelemetry.

Three fish with transmitters exhibited patterned diurnal and nocturnal vertical movements (Figure 28). These fish were monitored for most of a 24-hour period on several occasions in May, June and July 1981. Generally the fish spent dawn (0600-0800 hours) and evening (2000-2300 hours) along relatively shallow shore or downstream of rocks in water less than 16 feet deep. Their longitudinal position on shore often varied by 100-150 feet daily, and the fish often remained in eddies behind submerged rocks for extended periods of time. The fish were most often found in midmorning (0800-1100 hours) and midafternoon (1700-1800 hours) in water 16-22 feet deep, and further toward mid-channel at midnight (2400-0600 hours) and midday (1100-1700 hours) especially during warm sunny weather. Signal strength from the transmitters waned with depth and precluded constant monitoring at times for precise locations, especially in water deeper than about 18 feet. This patterned and localized behavior further supports the hypothesis of homing behavior by humpback chub.

Table 46
Average water temperature and conductivity of the Colorado River near Black Rocks (stateline gauge, 5 km downstream) during the radiotelemetry study, 1981

Date of Locates	Temperature (C°)			Conductivity (umhos/cm)		
	Max.	Min.	Mean	Max.	Min.	Mean
5/12	15.8	13.9	14.7	835.0	795.0	814.2
5/26	19.0	17.4	18.1	970.0	940.0	955.4
5/27	19.5	17.0	18.3	972.0	952.5	963.3
5/28	20.0	18.4	19.3	965.0	935.0	952.9
5/29	19.8	7.7	18.7	937.5	877.5	912.5
6/4	18.7	16.8	17.8	689.0	679.0	681.1
6/5	19.6	16.9	18.2	658.0	548.0	606.7
6/11	20.3	18.3	19.4	649.1	629.1	633.7
6/18	20.0	17.8	18.7	1225.0	835.0	1086.0
6/25	25.3	22.7	23.9	989.5	939.5	968.7
7/3	24.3	22.0	23.1	1182.0	1162.0	1170.0
7/4	24.5	22.4	23.4	1164.0	1144.0	1157.0
7/17	23.7	21.5	22.5	1274.0	1134.0	1167.0
7/30	23.7	21.6	22.7	1441.0	1381.0	1409.0

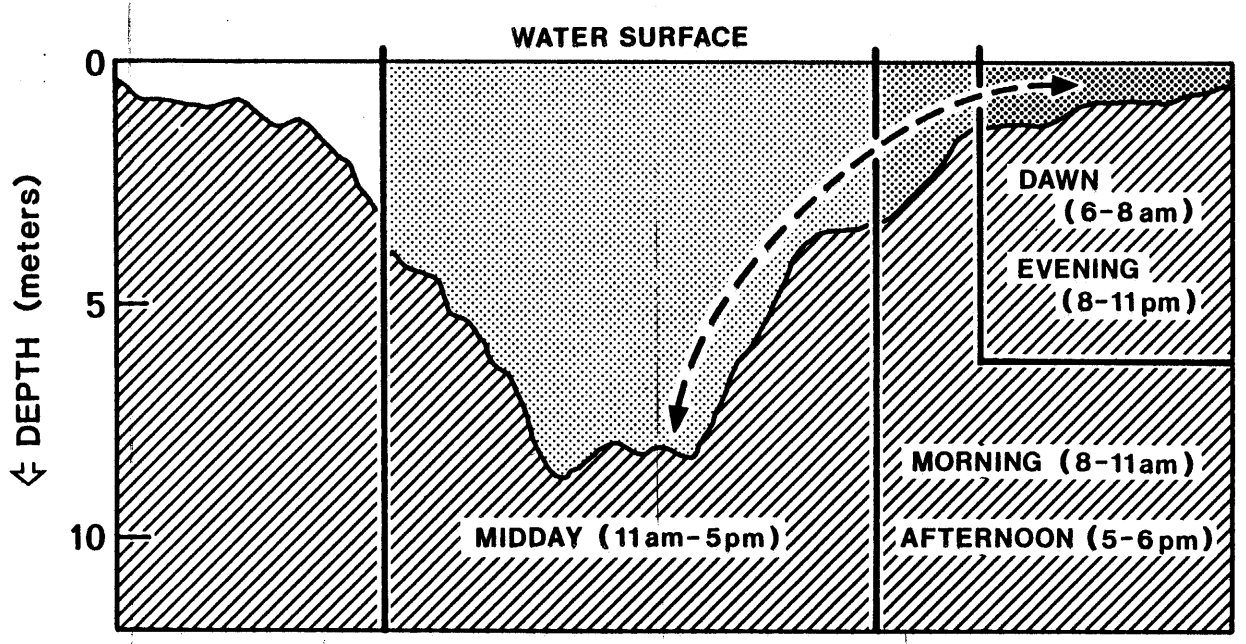
Habitat Preference

Habitat preferred by humpback chub equipped with radio transmitters was evaluated by using histograms of actual data, and smooth curves developed from these data. These data and functions will be compared later with curves generated from data of fish catches. Eighty-five observations were made on five radio-equipped fish.

Depth--Humpback chub with radio transmitters were located in water depths of 0.85-48.45 feet and a mean of 15.51 feet. A histogram of the raw data indicates high use of water [redacted] that diminishes with depth (Figure 29).

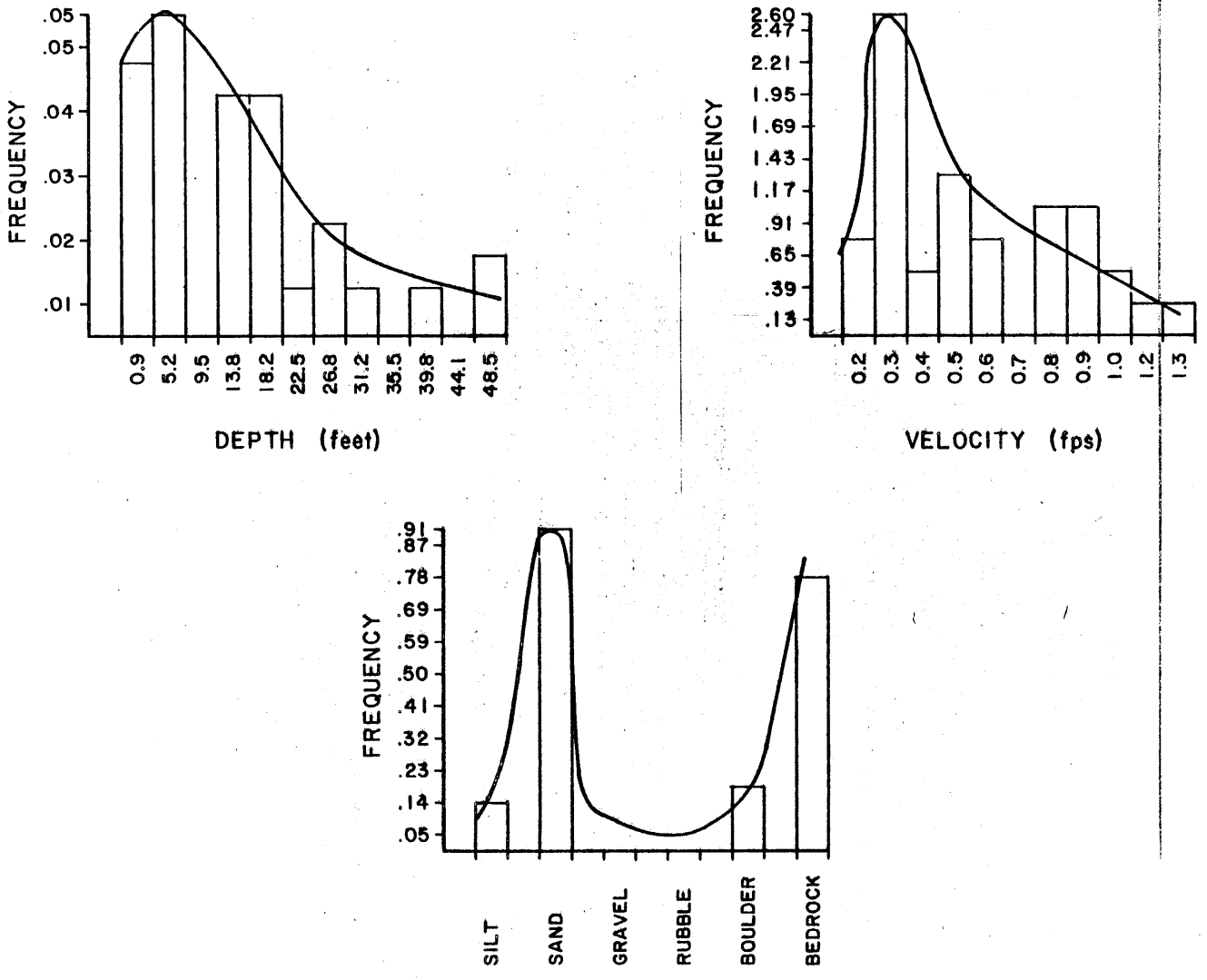
Velocity--Humpback chub were observed in ranges of 0.2-1.3 feet per second (fps) and a mean of 0.6 fps. The histogram of data representing velocity indicates a high use of 0.2-0.3 fps and less use of higher velocities (Figure 29).

Figure 28



River depths and regions occupied by Gila cypha monitored with radiotelemetry in Black Rocks, Colorado, May-July 1981.

Figure 29



Depth, velocity and substrate used by eight adult humpback chub equipped with radio transmitters in Black Rocks, Colorado, 1981.

Substrate--Radio-equipped humpback chub were monitored over silt, sand, boulder and bedrock with a distinct high use for sand and bedrock as the primary substrate (Figure 29). These substrates often occurred together.

Synthesis--Radio-equipped humpback chub preferred velocities of 0.2-0.3 fps, depths of 3-6 feet, and sand-bedrock substrates. These data suggest the species inhabits medium depth river regions with low velocities and sand-bedrock substrates. However, these data reflect microhabitat parameters and not general habitat. Humpback chub are concentrated in distinct river reaches such as Black Rocks and Westwater Canyon, the deepest and swiftest regions of the river. Although humpback chub range in all depths and velocities present, they seem to prefer the shallow calmer regions. These deep swift areas, however, are still key to their survival because they provide a habitat inaccessible to most other competitive species, and they apparently provide the insectivorous chub with a continuous influx of food.

Depth, velocity and substrate used by radio-equipped humpback chub were similar to those parameters measured for non-telemetered fish. the range of velocities used by both groups was similar (Figure 29), as were the depths and substrates. This suggests that standard sample techniques capture humpback chub in representative habitats. It also suggests that radio-telemetry is a feasible tool for assessing habitat needs of the species.

Razorback Sucker

The adult razorback sucker is readily identified by an abrupt, sharp-edged hump immediately posterior to the head and a fleshy, subterminal mouth (Behnke and Benson 1980). Young razorback suckers 200 mm TL) have smaller humps and may be confused with small flannelmouth suckers, except for the greater number of dorsal rays (14-15 vs 10-11). Hybrids (razorback x flannelmouth suckers) are intermediate in size of hump and other characteristics.

The razorback sucker was proposed for federal listing as "threatened" on April 23, 1978. This proposal became subject to the provisions of the Endangered Species Act of 1973, as amended in 1978. The amended act required (in most cases) critical habitat designation as a part of listing the species. Data gaps associated with identifying critical habitat within a 2-year deadline for the listing process forced the removal of the razorback sucker from proposed status in April 1980.

On November 14, 1978, the Colorado Wildlife Commission listed the razorback sucker as "endangered" in the State. This protection measure carries with it a fine for anyone knowingly taking or harming a razorback sucker, but provides no recovery plan for the species.

Captures of razorback suckers during this study were limited to 14 sites on the upper Colorado River. A total of 47 individuals were taken during the 2-yr investigation. All of these specimens were adults and most appeared to be quite old, suggesting a razorback population that is having limited reproductive success.

Other investigations estimate that adult razorbacks may exceed 20 yr of age, and weights have been reported greater than 10 lb (Behnke and Benson 1980). Historical accounts indicate that the razorback sucker was common and a desirable food fish in the lower basin to the extent of supporting some commercial fisheries. The fish is thought to have been less common in the upper basin, but used on a limited commercial basis such as food for mink in fur farms.

Distribution and Abundance

The razorback sucker once occupied about 1,500 miles of the Colorado River system, and is now limited to about 600 miles, mostly in the upper basin. Sample efforts by the GJFS have documented the scattered presence of razorbacks throughout the study reach (Figure 30, Table G-1). One fish was captured in Lake Powell at the downstream end of the study by the Utah Division of Wildlife Resources (RM -48, Hite Marina). The upstream extent of razorback captures represents a range extension for the species in the upper Colorado River. These fish were taken in July 1981 at RM 220.7 and 223.5, between Debeque and Rifle, Colorado.

Thirty-seven of the 52 razorbacks captured (71 percent) occurred in two abandoned gravel pits adjacent to the Colorado River near Grand Junction, Colorado. These pits communicate with the river during runoff, and apparently are attractive areas for a variety of non-native and native fishes. The gravel pits are locally known as Walter Walker Wildlife Area (WWWA) and Clifton Pond (CP), and are located at RM 163.6 and 117.8, respectively.

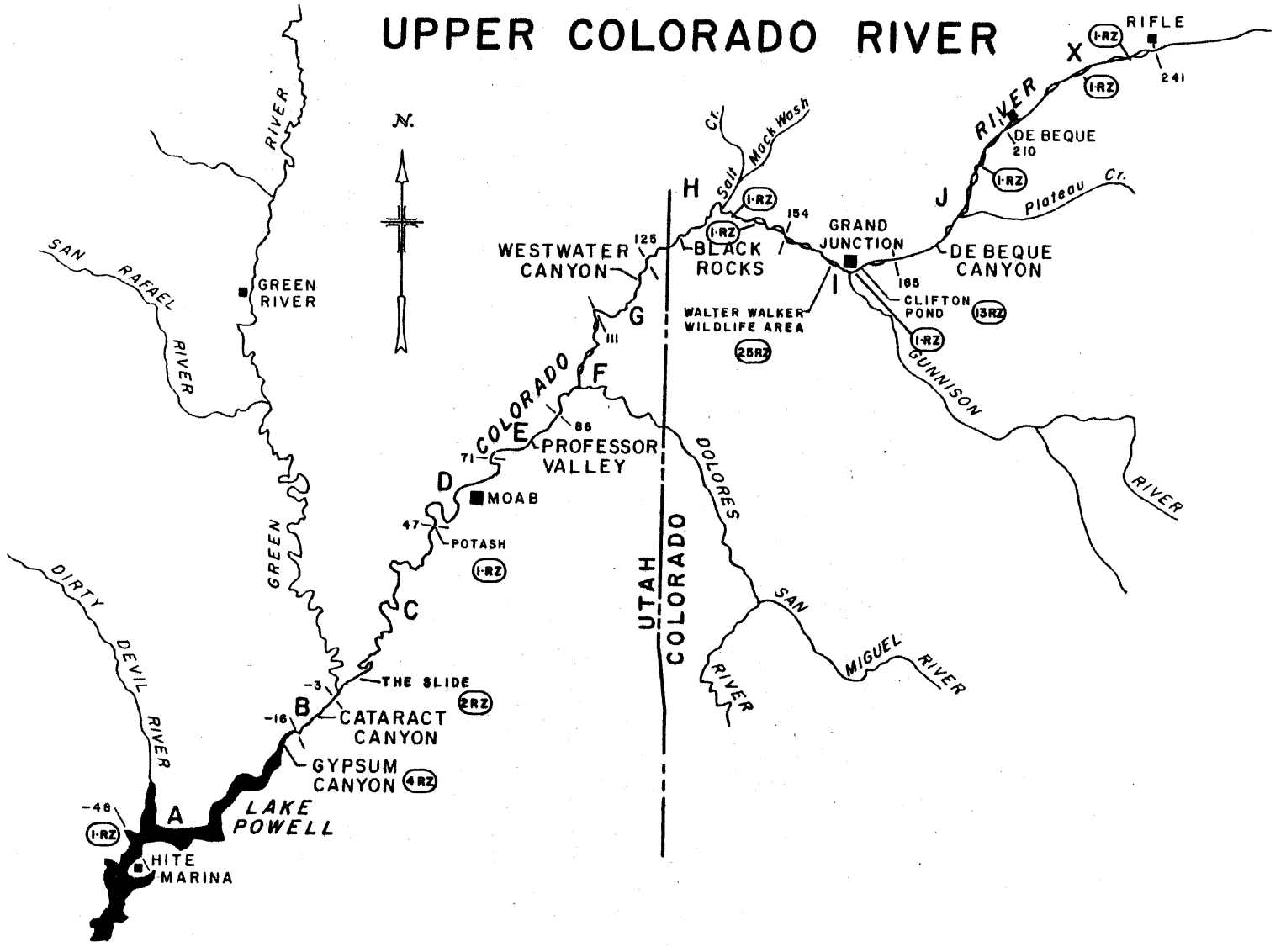
Six specimens were taken in natural backwaters along the river corridor, and five were captured in Lake Powell. Only four razorbacks were found in flowing riverine habitats. The small number of captures from flowing habitats could reflect an inefficiency in our gear to sample relatively deep fast-flowing water or an ability by razorbacks to avoid sampling gear in those conditions.

Catch per unit effort (CPE) was calculated for razorbacks caught with all hour-based gears. No razorbacks were captured with area gears. The CPE statistic is utilized as a measure of relative abundance in various partitions chosen by GJFS personnel. In many of these partitions, the number of razorbacks was too small for statistical analyses.

CPE was uniformly small for razorbacks in all strata, indicating rarity of the species throughout the study area (Table 47). Razorbacks were taken in strata A, C, D, H, I, J and M; with catch rates (fish/10 hours) of 0.06, 0.06, 0.04, 0.07, 0.16, 0.08, and 0.86, respectively. The highest rate, 0.86 fish/10 hours in stratum M, was recorded in WWWA.

Catch values were low for razorbacks in 5 of the 6 habitats in which they were found, indicating scarcity of the species (Table 48). The atypically high CPE value (14.29) for main channel habitat is deceptive, because it is based on the capture of one fish in a habitat type that was inefficiently sampled due to gear limitations. CPE did not differ significantly (.01) for the three habitats in which razorbacks were most frequently caught. These habitats were gravel pits, backwaters and runs; with catch rates (fish/10 hours) of 0.28, 1.22 and 0.22, respectively.

Figure 30



Locations and numbers of razorback sucker captured in the upper Colorado River, 1979-81.

Table 47
Ranked catch per 10 hours of effort for fishes of the upper Colorado River by 12 sample strata (gear = trammel nets, gill nets, electrofishing)

	Regular Strata 1/												
Rank	A	B	C	D	E	F	G	H	I	J	K	M	N
1	CP(2.80)	CC(4.71)	CP(2.43)	CP(23.16)	CP(25.06)	FM(28.73)	RT(13.34)	FM(15.43)	FM(47.74)	FM(70.34)	RT(95.54)	BB(12.34)	RT(72.44)
2	BG(1.67)	CP(2.33)	FM(1.20)	FM(6.37)	FM(17.89)	CP(12.54)	CC(5.47)	RT(8.48)	BH(39.82)	RT(66.67)	HB(39.58)	CP(10.84)	CP(33.07)
3	LG(1.67)	FM(0.84)	CC(0.93)	CC(3.71)	CC(7.43)	CC(7.19)	BH(4.62)	CP(7.54)	CP(19.87)	BH(16.75)	CP(34.23)	GS(7.24)	CC(22.83)
4	GS(1.37)	BH(0.05)	RS(0.57)	GS(0.56)	BH(4.24)	BH(3.21)	CP(3.51)	BH(6.50)	RT(15.27)	WS(8.50)	FM(25.89)	FM(6.27)	HB(18.11)
5	CC(0.66)	HB(0.05)	BH(0.42)	BB(0.53)	LG(1.26)	RT(1.56)	HB(3.25)	CC(4.83)	BB(9.05)	CP(6.94)	BH(9.82)	CC(2.82)	BH(15.75)
6	WE(0.24)	RT(0.05)	CS(0.42)	LG(0.53)	RT(0.91)	LG(0.29)	FM(1.11)	LG(1.22)	CC(2.75)	RH(2.86)	CS(8.93)	RT(2.21)	RH(3.15)
7	FM(0.18)	WF(0.05)	GS(0.24)	BH(0.49)	CS(0.35)	CS(0.21)	GS(0.51)	CS(0.56)	WS(2.02)	BB(1.06)	GS(4.46)	RZ(0.86)	BC(2.36)
8	RS(0.18)		BB(0.15)	RT(0.45)	BB(0.30)	BB(0.16)	RH(0.51)	GS(0.45)	LG(1.62)	MS(0.90)	CC(3.27)	WS(0.86)	CS(2.36)
9	BC(0.12)		RT(0.12)	RS(0.38)	GS(0.30)	CH(0.12)	LG(0.43)	BB(0.24)	GS(1.13)	SD(0.90)	RH(1.49)	CS(0.29)	FM(0.79)
10	TC(0.12)		FH(0.06)	CS(0.34)	BN(0.05)	RB(0.08)	RS(0.26)	HB(0.21)	WF(0.24)	GS(0.57)	LG(0.60)	LG(0.29)	
11	BB(0.06)		RZ(0.06)	WS(0.15)	RS(0.05)	BN(0.04)	SD(0.26)	FH(0.10)	GS(0.16)	RB(0.25)	BC(0.30)	BC(0.11)	
12	RZ(0.06)		BC(0.03)	BC(0.04)	WS(0.05)	FR(0.04)	BN(0.09)	RZ(0.07)	RZ(0.16)	BN(0.08)		BG(0.11)	
13	SB(0.06)		BN(0.03)	FH(0.04)		GS(0.04)	CS(0.09)	WF(0.07)	BG(0.08)	FH(0.08)		RS(0.07)	
14			LG(0.03)	RZ(0.04)		RS(0.04)	FH(0.09)	BC(0.03)	FR(0.08)	FR(0.08)		BH(0.04)	
15				SS(0.04)		SS(0.04)		SD(0.03)		LG(0.08)		FR(0.04)	
16								WB(0.03)		RZ(0.08)		NP(0.04)	
17										RW(0.08)			
18										WF(0.08)			

1/ See Table 2

Table 48
Ranked catch per 10 hours of effort for fishes of the upper Colorado River by 11 habitat types (trammel nets, gill nets, electrofishing)

Rank	Habitats[1]										
	BA	ED	GP	PO	RI	RU	SH	SC	MC	ID	LK
1	CP(11.68)	RT(6.15)	BB(11.45)	RT(25.50)	FM(1000)	FM(23.01)	FM(87.04)	CP(11.17)	FM(14.29)	BH(170.00)	CP(2.75)
2	FM(7.69)	FM(4.93)	CP(10.06)	FM(21.39)	BH(861.11)	CP(17.13)	CP(28.72)	RT(5.05)	RZ(14.29)	FM(120.00)	BG(1.64)
3	RT(7.22)	CC(3.53)	GS(6.72)	BH(3.25)	RT(188.89)	BH(9.70)	CC(18.39)	FM(3.72)		RT(80.00)	LG(1.64)
4	WS(4.17)	CP(1.34)	FM(5.82)	WS(1.81)	CP(16.67)	RT(9.29)	BH(18.04)	WS(2.39)		CP(70.00)	GS(1.35)
5	BB(2.91)	BH(1.16)	CC(2.61)	CC(1.15)	MS(16.67)	CC(4.89)	RT(8.58)	BB(2.13)		CC(50.00)	CC(0.64)
6	BH(2.77)	HB(0.51)	RT(2.05)	CP(1.05)	WS(16.67)	WS(0.44)	CS(1.05)	GS(1.60)			CS(0.18)
7	LG(2.02)	RH(0.24)	RZ(1.22)	RB(0.57)	CC(5.56)	LG(0.38)	WS(0.88)	LG(1.65)			RM(0.18)
8	CC(0.84)	WS(0.22)	WS(0.79)	HB(0.38)	RB(5.56)	RS(0.36)	BB(0.53)	BH(0.53)			RS(0.18)
9	CS(0.84)	CS(0.10)	CS(0.43)	FB(0.29)		GS(0.33)	GS(0.53)	CS(0.53)			WE(0.23)
10	GS(0.84)	BB(0.08)	LG(0.26)	BN(0.10)		RH(0.31)	FR(0.18)				BC(0.12)
11	RZ(0.28)	LG(0.08)	BC(0.10)	CS(0.10)		SD(0.23)	RB(0.18)				TS(0.12)
12	FH(0.19)	CH(0.04)	BG(0.10)	FR(0.10)		CS(0.19)	SD(0.18)				BR(0.06)
13	RB(0.19)	FR(0.04)	RS(0.07)			BB(0.17)					RZ(0.06)
14	BC(0.09)	GS(0.04)	BH(0.13)			HB(0.16)					SB(0.06)
15	BN(0.09)	RB(0.02)	FR(0.03)			RB(0.16)					
16		RZ(0.02)	NP(0.03)			MS(0.14)					
17		SD(0.02)				BN(0.10)					
18		WF(0.02)				FH(0.05)					
19						WF(0.05)					
20						WB(0.03)					
21						RZ(0.02)					
22						SS(0.02)					

1/ See Appendix A

Migration and Movement

Findings from previous studies demonstrate that razorbacks can move 20 miles or more over a span of several months, and up to 80 miles in a few years (McAda and Wydoski 1980). Recapture data from this study demonstrated a lack of movement in five individuals. Four of the five razorbacks were caught initially and recaptured in the gravel pit at WWWA (RM 163.6). The fifth razorback was caught and subsequently recaptured in the CP gravel pit, near RM 177.8. Time frames from initial capture to recapture ranged from 1 day to 1 year.

A total of 24 fish captured from these two gravel pits indicates an affinity by these fish for such "artificial backwaters". The fact that all five individuals captured were subsequently recaptured in the same area also indicates a sedentary mode on the part of these individuals. Captures of razorbacks in spawning condition in lentic habitats suggests that the fish move to and use these areas for resting and feeding or perhaps for staging or spawning.

During an extended effort to capture razorbacks at or near spawning condition, an apparent sensitivity to changes in flow was noted in one of the gravel pits. Clifton Ponds gravel pit was electrofished intermittently from May 10, 1980 through June 11, 1980. This time frame included the peak of runoff, manifested by daily fluctuations in flow.

GJFS biologists noted that razorbacks were present in the gravel pit during ascending flows, but absent from samples during decending flow. Water enters and leaves the gravel pit via a 24-inch culvert, and the direction of flow (into or out of the gravel pit) could be determined by the presence of a vortex (outflow) or bubbles (inflow) at the end of the culvert extending into the gravel pit. Razorbacks apparently swam through the culvert and into the gravel pit during rising water levels and out of the pit during descending flows.

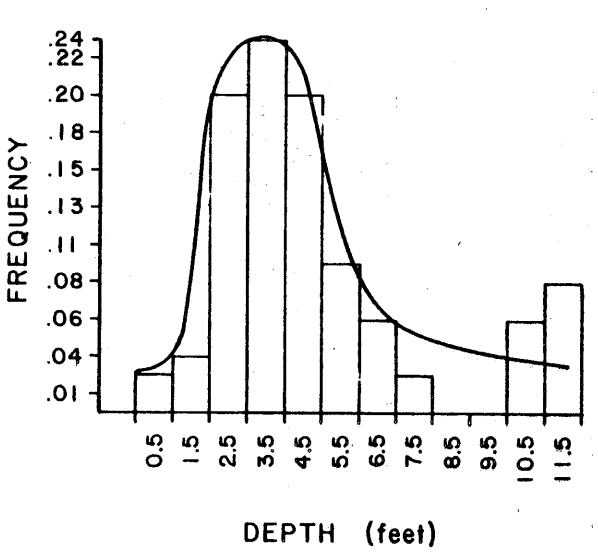
Habitat Preference

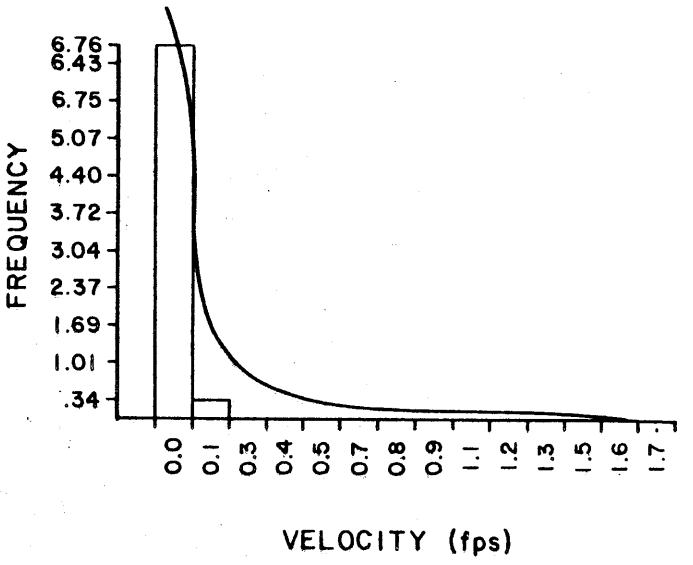
Habitat preferred by razorback sucker was evaluated using histograms of actual data, and smooth curves developed from these data. Habitat information was taken on all razorbacks captured (48 individuals, 4 recaptures), including depth, velocity and substrate. Reliable assessments of habitat conditions preferred by razorback sucker in the upper Colorado River were impossible because of the small number of observations. It should be noted that all razorbacks caught were adults, thus preferences for depth, velocity and substrate for other life stages cannot be assessed from this investigation. Assessments of habitat preferred by adults are further biased since 67% of fish captured came from one habitat (gravel pits) in two distinct pit features (WWWA and CP).

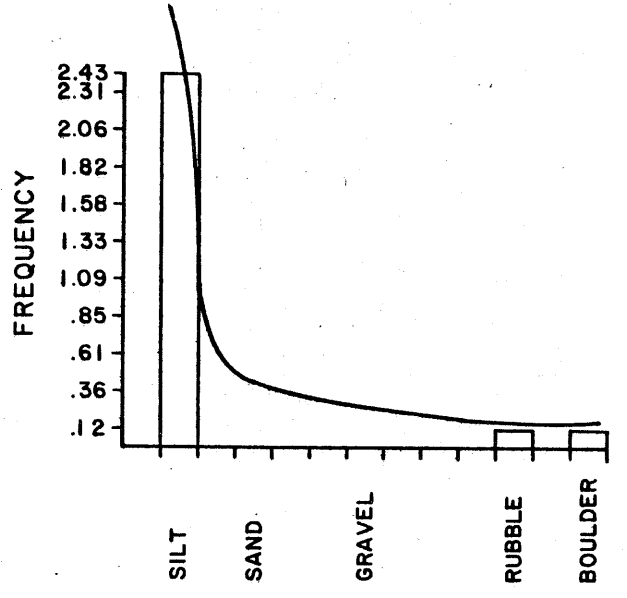
Depth

Figure 31 depicts the frequency distribution of all razorbacks captured over a range of water depths. The majority of fish (approximately 62 percent) were at depths between 2.5 and 6.5 feet, with a peak distribution between 3.5 and 5.5 feet.

Figure 31







Depth, velocity and substrate used by all (n=52) razorback sucker (adults) captured in the upper Colorado River, 1979-1981.

Velocity

The majority of razorbacks (90.4 percent) were caught in flow conditions at (or immeasurably near) 0.0 fps, and the remaining individuals (9.6 percent) were taken in velocities ranging from 0.1 to 2.0 fps. The velocity histogram and curve (Figure 31) show the dominant frequency of fish captured at or near zero velocity. One factor in the high percentage of low velocity captures is that the majority of these fish were caught in habitats that characteristically have little or no flow (gravel pits, backwaters).

Substrate

Substrate type and percentage of razorback captures associated with each type are shown below:

Substrate Type	Percentage of total number of razorbacks captured
Sand	1.9
Boulder	3.9
Rubble	5.8
Silt	88.4

The histogram and curve for substrate (Figure 31) show the predominance of captures associated with silt bottoms, and the small frequency associated with rubble and boulder substrates. The high frequency of razorback captures in lentic habitats serves to explain the high incidence of silt as the primary substrate associated with these fish, because still-water features are natural settling areas for fine-textured, suspended solids.

CPE and Habitat Use

CPE values for habitats in which razorbacks were found lend additional support to velocity, substrate and depth uses indicated by histograms and curves. The three habitats in which razorbacks were captured most frequently, and for which CPE did not differ significantly (.01), were gravel pits, backwaters and runs. The majority of captures (82.7 percent) were in gravel pits and backwaters; habitats typically with velocities near zero and silt substrates. Histograms and curves for velocity and substrate indicate these conditions are preferred by razorbacks.

Average depth for a representative sample of gravel pits and backwaters in the study area were 2.6 and 3.6 feet, respectively. These depths fall within the peak distribution indicated by the depth histogram (2.5 - 6.5 feet). The curve for depth shows a similar high probability density for razorbacks in this range, which includes average depth values for gravel pits and backwaters.

Spawning

Razorbacks were observed near spawning conditions during the runoff period of 1980 and 1981, usually in late May or early June. Over 80

percent of fish that displayed late stages of sexual maturity were captured in two gravel pits; WWWA and CP. One tuberculate male in spawning condition was captured in Lake Powell near Dark Canyon by the Utah Division of Wildlife Resources (Ottenbacker 1980).

An attempt was made by the Colorado Division of Wildlife to artificially spawn razorbacks, using fish captured from these flooded gravel pits. On June 7, 1980 a tuberculate male was netted in CP and placed in a holding pen in the 20° C pond water. The fish was injected with carp pituitary extract at 0900 and again at 1730 hours. After holding the fish for 24 hours, a more distinct tuberculate condition was noted, as well as an increase in red pigmentation on the lateral aspect of the body. Swelling of the region around the papillae was evident.

On June 8, 1981 a gravid female was captured in CP that shed eggs readily and required no pituitary injection. The "dry fertilization" method was used, and eggs and milt were stripped into a plastic cup. The eggs were smaller than those of flannelmouth sucker, and lighter in color (Hufziger 1981).

The eggs were shipped to the Larval Fish Laboratory, Colorado State University (CSU), Fort Collins, Colorado, after water hardening. Temperature of the water and eggs was kept between 19 and 20° C during shipment. Eggs were held at the CSU facility in incubation trays at 18.5° C,, and these hatched on June 15, 1980, 192 houra after fertilization. Hatching continued for about 16 houra. Newly-hatched fry were 9-10 mm long. On June 23, 1980 the fish averaged 11 mm in length. The yolk sac was completely absorbed by June 25, 1980. Young razorbacks then began feeding on zooplankton, and accepted fish food ("starter") after several months. One year after hatching the fish were 100-150 mm long, and had developed a distinct hump (Hufziger 1981).

It should be reiterated that no evidence of successful reproduction in the wild was found at any time during this study. Razorback suckers are apparently having extremel poor reproductive success, perhaps to the point of warranting recovery efforts via artificial propagation.

Recent studies are supportive of the theory that early life stages may be completely destroyed. Ulmer (1981) and Loudermilk (1981) observed spawning activities of razorbacks in two impoundments in the lower basin. In all cases where actual spawning was observed, the substrate preferred was at least 50% gravel with intermixed sand. Silt content in each of the spawning areas was approximately 1 percent. Under present conditions in the upper basin, few (if any) still-water areas exist with this primary substrate composition. Lentic habitats within the study area all have silt as the primary substrate, thus a lack of suitable spawning substrate may be a major factor contributing to poor reproductive success.

Predation by other fishes appeared to be a cause in the demise of viable eggs and larvae, as reported by Ulmer and Loudermilk in the lower basin. An attempt was made to examine the stomach contents of fishes

captured in the spawning areas. In the same study, it was noted that predation on razorback larvae had the potential of being equally devastating. Young razorback fry are planktonic, swimming weakly near the water surface after the swim-up stage. During this time the young fish are extremely susceptible to predation. The combination of egg and larval predation by non-native fishes such as largemouth bass, bluegill and channel catfish was a major factor in the total lack of young razorback survival reported in the lower basin study.

Associated Species

Fourteen species were collected with razorback suckers in four habitat types (Table 49). Since the majority of razorbacks were captured in lentic habitats, many of the associated species are those typically found in still-water features along the upper Colorado River. Number of associated species found in each habitat type is shown on the following page.

Habitat type	Number of species associated with razorback suckers
Backwater	11
Eddy	3
Gravel Pit	11
Run	4

Nine of the 14 species found with razorbacks were non-native (64.2 percent). The percentage of non-native and native fishes is nearly the same as that for the entire upper basin, which is 65.5 percent and 34.5 percent, respectively. The presence of these large numbers of non-natives and coincidental demise of the native species suggests that the introduction and establishment of non-natives has had a detrimental impact on native fishes through such factors as predation and competition for space and food. Non-natives may be responsible for the near destruction of complete life stages through predation on eggs or young fry.

Large numbers of piscivorous non-natives (black bullheads, green sunfish) were observed in WWWA, which was also a primary capture site for target species. Thirteen razorbacks captured from this area were in near spawning condition, which suggests that some of these fish may actually spawn in or near the gravel pit. Most of the adult razorbacks are thought to leave the gravel pits as the runoff period ends. The gravel pits are isolated from the river during the remainder of the year. It appears that any reproduction by a species that does not guard eggs or young would be highly vulnerable to concentrated predation in this lentic habitat.

Age and Growth

Five recaptured razorbacks provided limited information on short-term growth. One specimen (Tag No. 0513) was captured in WWWA on August 16, 1979, and recaptured in the same location on September 25,

Table 49
Species found in association with razorback sucker, upper Colorado River, 1979-1981

Species*	Numbers		Percent Composition for each habitat type#				Total Percentage of associated species caught
	Juveniles	Adults	BA	ED	GP	RU	
Black bullhead	34	13	11		14		25
Black crappie	1		<1				<1
Bluegill	4				2		2
Bluehead sucker	1	14	3	1	<1	3	8
Common carp	1	40	18	<1	2	2	22
Channel catfish		2			1		1
Colorado squawfish	3	8	4		2		6
Flannelmouth sucker	14	13	3	5	3	3	14
Flannelmouth X razorback sucker		2	<1		<1		1
Green sunfish	5	1	1		2		3
Largemouth bass		1				<1	<1
Rainbow trout	4		2				2
Roundtail chub	18	3	10		1		11
White sucker	3	5	3		1		4

*See Table 5 for scientific name, status, etc.
#See Glossary of Terms, Table A-1.

1979. This fish grew 2 mm and gained 347 g in 40 days. Another fish gained 16 g over 10 days with no detectable change in length in a gravel pit during late May and early June 1980 (Tag No. 0680). This fish was a female, and it is possible that the weight gain can be attributed to the onset of spawning condition.

Three recaptured razorbacks showed no changes in length or weight. One fish (Tag No. 9947) had the same length and weight measurements after 1 year. The other two fish were recaptured after 1 and 3 days, periods too short to assess changes.

Mean length for all razorback suckers captured was 553.7 mm, and mean weight was 1773 g. No significant differences (.01) were found in length-weight relationships between males and females. The relationship for all razorbacks captured in the upper Colorado River is described by the equation:

$$WT = -2665 + 8.016TL \quad (r^2 = 0.58)$$

where: WT = weight in grams,
TL = total length in millimeters and
r^2 = coefficent of determination.

The coefficent of condition (K factor) was computed using the formula $K = (WT \times 10^5)/TL^3$. K factors for 50 razorbacks ranged from 0.7 to 1.3, with a mean of 1.04. No significant differences (.01) in K factor were observed between sexes, years of capture, habitat types, or flow periods.

A field observation common to the majority of razorback suckers is that they appeared to be quite old. Many fish were missing the pupil pigmentation in one eye, a condition thought to be caused by invading protozoa, Myxobolus sp. (Valentine 1981). Some specimens exhibited scars, edema and irregular patches of regenerated scales. Anchor worms (Lernaea cyprinacea) were observed on 10 percent of the fish, with some individuals heavily infested with up to 28 worms. Anchor worms were usuall found attached on or between fin-rays, or at the base of fins. Individuals remaining in backwaters or gravel pits through the spring and summer appear to be more heavily infested with anchor worms than those in the main channel. Leeches were noted on about 5 percent of the razorbacks observed, usually attached on the fins.

Samples of scales were collected during this investigation for age and growth information. The subcontractor that examined these scales estimated maximum ages of 5 years. There is a strong possibility that these analyses are in error since other investigators report difficulty in distinguishing annuli past the 5th to 7th year of life (McAda and Wydoski 1980, Minkley 1981).

Bonytail Chub

No bonytail chub were caught during this investigation in either the Colorado River above Lake Powell or two of its tributaries, the Dolores

and Gunnison Rivers. All chubs captured were thoroughly examined for any evidence of bonytail chub. None were found that exhibited the features seen in collections on the Green River. Only influences of roundtail chub and humpback chub were seen in this region of the Colorado River.

Non-Target Species

Distribution and Abundance

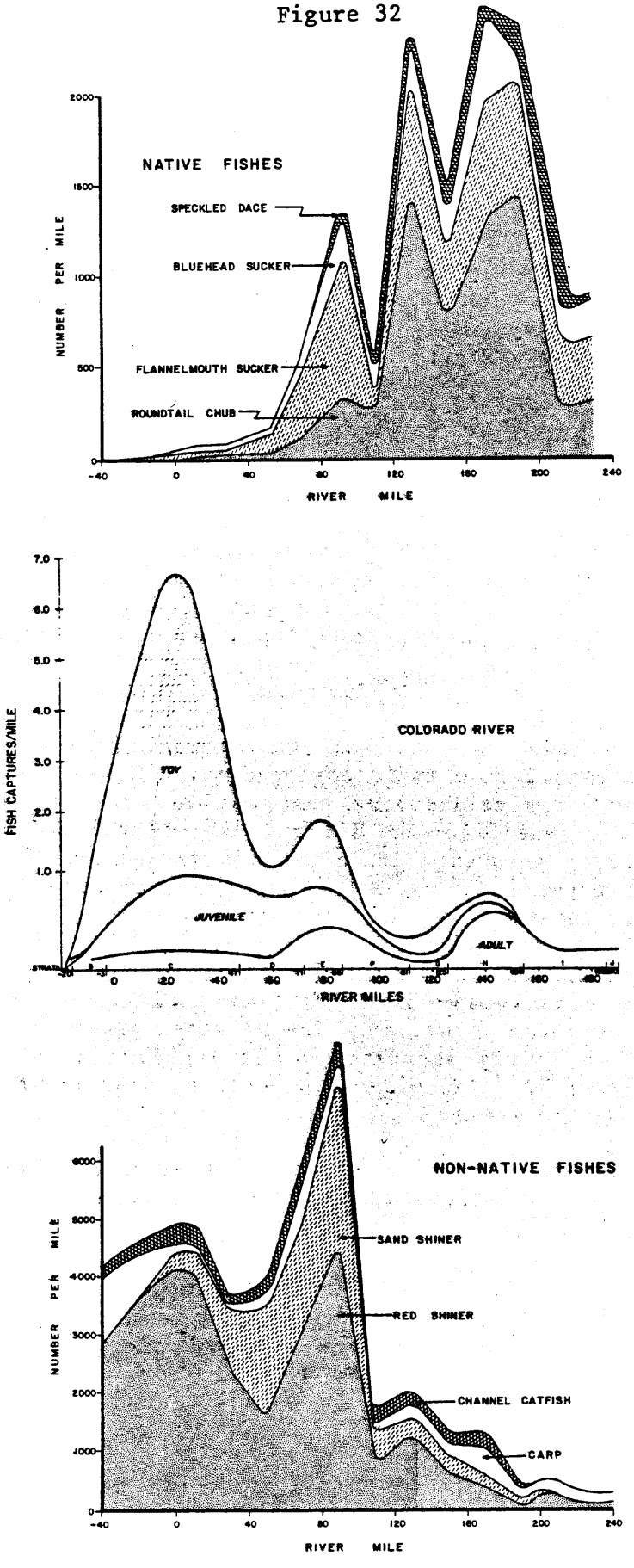
The four most common native fishes in the upper Colorado River (roundtail chub, flannelmouth sucker, bluehead sucker and speckled dace) were unevenly distributed (Figure 32). Increasing numbers of these species were generally encountered progressively upstream from Lake Powell to a point near Debeque, Colorado where cool water temperatures apparentl kept the numbers of all these species down--except for speckled dace. Although total numbers of these native species appeared to decrease in the extreme upper reaches of this study area, the general size, health and vigor of individuals seemed greater than that of the same species further downstream.

Roundtail chub exhibited a close association with rocky substrates. Few roundtail chub were caught below Moab (RM 60) on the predominately sand bottom. The species became progressively abundant further upstream on the predominately rock substrate. The same trend was true of bluehead sucker, but the total numbers were not as great. Flannelmouth sucker were associated with most substrate types, although they were most commonly found on rocky bottoms. This species became very abundant near Moab (RM 60-80) and was also abundant from the Utah state line upstream to Plateau Creek and the Government Highline Dam. This structure is probably preventing upstream movement of flannelmouth and bluehead sucker and may account for the paucity of the two species above the structure.

The distribution of the four most common non-native fishes (red shiner, sand shiner, channel catfish and carp) shows a trend opposite to that of the native fishes; the numbers of non-native fishes generally increased downstream (Figure 32).

Red shiner was the most abundant fish species in the upper Colorado River. The species was abundant in upper Lake Powell, and numerous in Cataract Canyon and the sandy reaches to Moab. Above Moab (RM 60-100), red shiner became abundant, but progressively decreased in numbers further upstream. Sand shiner were closely associated with sandy substrates and were abundant in the reach between the Green River confluence (RM 0) and Moab. Common carp were distributed fairly uniformly throughout the study area, but were numerous in Lake Powell and the upstream reaches near Grand Junction (RM 160). Channel catfish were distributed in clumped fashion and were most abundant in Lake Powell and Cataract Canyon, as well as the area from the Dolores River confluence (RM 110) to Grand Junction.

Figure 32



Relative abundance of Colorado squawfish compared to that of the common native and non-native fishes in the upper Colorado River from Lake Powell, Utah to Debeque, Colorado.

A comparison of the distribution of squawfish, native and non-native fishes in the upper Colorado River shows the non-native fishes (especially red shiner and sand shiner) in similar distribution with YOY squawfish (Figure 32). Much greater numbers of red shiner occurred between Lake Powell and Moab, where the catches of YOY squawfish were also greatest. This similar distribution suggests competition on the young squawfish from at least one species--red shiner. The presence of channel catfish with young squawfish also represents the possibility of predation. These associations were also discussed in Fish Species Composition by Habitat in this report.

Juvenile squawfish were distributed in similar fashion to red shiner and sand shiner as well as flannelmouth sucker and some roundtail chub and bluehead sucker. Food habits studies on squawfish show that juveniles probably eat large numbers of shiners.

Adult squawfish, with higher relative abundance in the upper reaches, were distributed with roundtail chub, flannelmouth sucker and bluehead sucker. Competition for food and perhaps habitat is probably only between large roundtail chub and subadult Colorado squawfish.

Spawning

Spawning periods for selected endangered, native and non-native fishes were determined from field observations. Windows for each species were established from collections that yielded ripe or gravid fish in apparent spawning condition and did not extend to times when fish were only tuberculate or colored. These periods varied between years and for regions of the upper Colorado River and are presented in Figure 33 to encompass all of these variations.

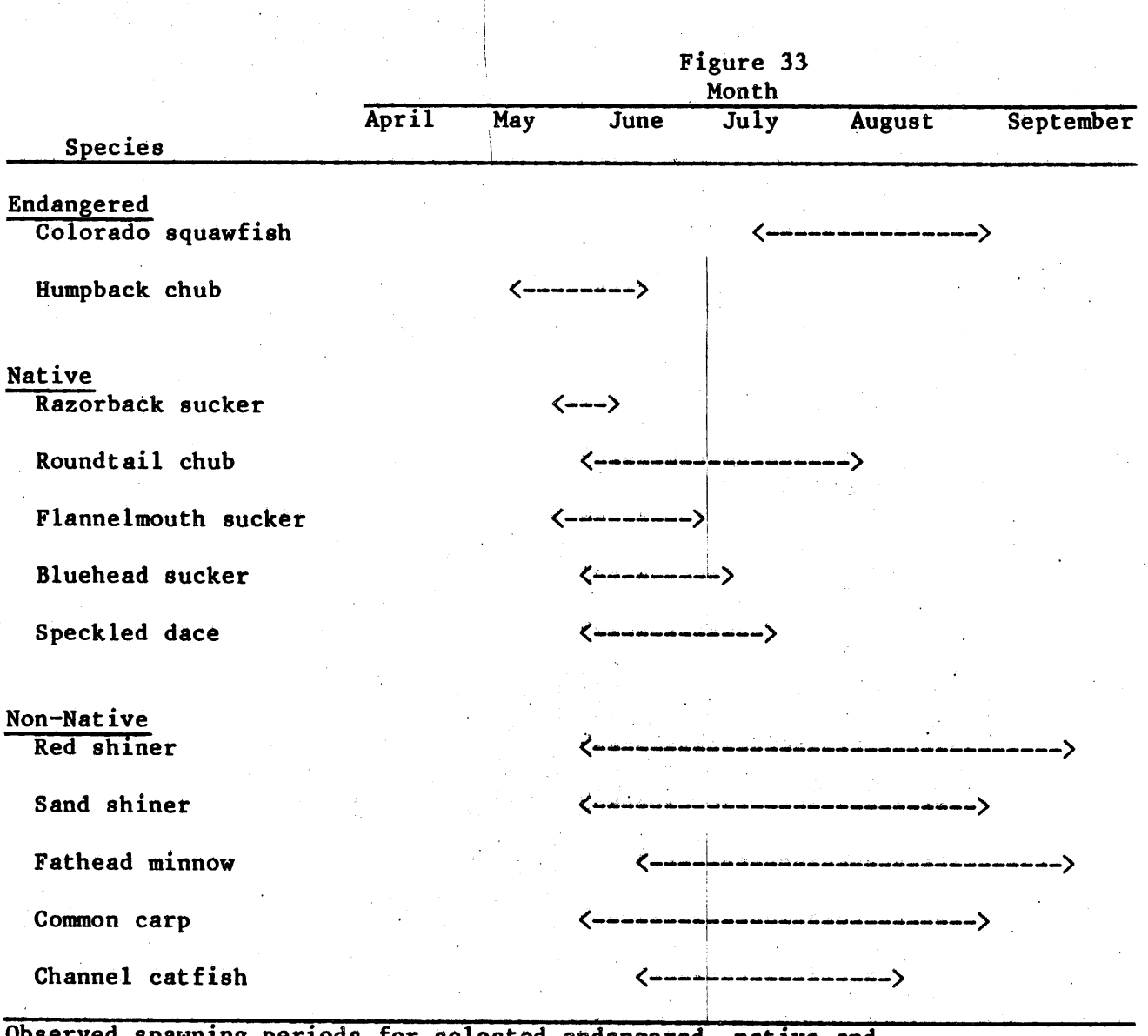
Colorado squawfish were not observed as ripe or gravid fish, but a spawning window of July 15- 31 August was established based on temperatures and historical information. The spawning period for humpback chub is believed to be fairly accurate and is smaller in any one year than indicated in Figure 33. The window is based on spawning in 1980 and 1981 which differed by 2-3 weeks.

Spawning periods for the native fishes appear to be keyed to post-runoff flows and temperatures, although ripe fish were often found during runoff.

The non-native fishes--especially red shiner, sand shiner, fathead minnow and carp--were usually in spawning condition from June to September. These species often spawned more than once in the period and young fish were usually abundant in small, shallow backwaters throughout the summer.

It is evident from Figure 33 that Colorado squawfish are the last of the principle river fishes to inititiate spawning. All of the other principle river species have spawned at least once by the time squawfish spawn in mid-July. The large numbers of non-native cyprinids have heavily populated many of the primary microhabitats of Colorado squawfish and introduced a new population pressure not inherent to the Colorado River ecosystem.

Figure 33



Observed spawning periods for selected endangered, native and non-native fishes of the upper Colorado River.

Larval Sampling

A program designed to sample larval Colorado squawfish and humpback chub was initiated in the upper Colorado River in 1981. The objectives of the program were to:

(1) determine distribution of endangered yearling fishes in the upper Colorado River, and

(2) determine the relative abundance of endangered yearling

Methodology

One team of 2-3 biologists conducted the larval sampling from July 21 to September 10, 1981. Sampling was conducted only in the upper Colorado River within the State of Utah. The Colorado Division of Wildlife conducted sampling in Colorado.

Sampling was initiated in the lower reaches of the river near the Green River confluence, where water temperatures warmed earliest and presumably Colorado squawfish spawned earliest. Sampling was conducted according to a methodology agreed upon by participants of the program in the upper basin.

Sampling stations of 0.5-mile lengths were established at 5-mile intervals within each exiting sample stratum. Collections were made at each of these stations with a meter-long seine of coarse, plankton net cloth in the following habitats:

(1) shoreline: rocky, sandy and grassy area,

(2) eddy: deep and shallow areas, and

(3) backwater: deep and shallow areas.

Collections from each habitat type were preserved separately in bottles, and total area of each sample haul was recorded.

A dip-net sample was taken from a variety of habitats under a "search and collect" method within each 0.5-mile sample reach. This entailed a search for schools of fry, but when large numbers of what appeared to be the same species were encountered, a subsample was taken to avoid excessive numbers. All samples were preserved in 5-10 percent buffered formalin. The formalin was buffered with 1 teaspoon of borax per quart of preserving solution. Labels were enclosed within the bottles to insure proper sample identification.

The samples were packed and shipped to the Larval Fishes Laboratory at Colorado State University, Fort Collins, for analyses. Results were returned to the GJFS for interpretation.

Results and Discussion

A total of 81 larval samples were collected and examined for fish species composition. Of the 2,803 specimens examined from these samples, all but 17 were non-native. The native species included speckled dace, humpback chub and roundtail chub. The non-natives were red shiner, sand shiner, fathead minnows, channel catfish and plains killifish.

The specimens were classified as young-of-the-year (YOY) and immature (IMM) based on lengths found in literature (see Appendix B). The immature fish were generally 6-19 mm long.

The percentage composition of larval fishes caught in each stratum is presented in Tables 50-56. Red shiner was the dominant species found in all strata. Sand shiner and fathead minnow were usually the second and third most abundant fishes, respectively. Red shiner were particularly prevalent in backwaters, generally less abundant in shorelines, and least in eddies. Sand shiner were usually more common in shorelines and eddies than in backwaters, while fathead minnows were generally associated with backwaters. Channel catfish YOY were caught in few numbers but about equally in eddies, backwaters and shorelines. This was also true of speckled dace. The two plains killifish taken in backwaters of stratum D (Table 52) is a significant finding since the species is apparently a recent introduction into the upper Colorado River. This indicates that reproduction by the killifish is taking place and that, if conditions are favorable, it may soon be a more common species in the upper basin.

Five of the seven roundtail chub and both of the humpback chub collected were from shorelines (Tables 54 and 55). This suggests that the two species have similar early life stage requirements for shallow shorelines. The presence of two YOY humpback chub in shorelines of stratum G (Table 55) is significant because it does confirm the presence of reproduction by the species in Westwater Canyon. The sample that yielded these two specimens was taken near steep rock walls in shallow quiet water, adjacent to swift currents and deep water.

No YOY Colorado squawfish were recovered in this larval sampling program on the upper Colorado River. Several hypotheses are offerred to explain this absence of fish:

(1) Colorado squawfish failed to spawn in the upper Colorado River in 1981.

(2) The random sampling scheme failed to sample near spawning sites.

(3) YOY squawfish use habitats other than those sampled during this program.

(4) Spawning may have occurred much earlier and the fish were in deeper water than expected.

(5) Spawning may have not yet occurred at the time of sampling.

Table 50
Number and percentage of larval fishes caught between river miles -16.5 and -4.5 (stratum B) in the upper Colorado River

Species	Eddy				Backwater				Shoreline			
	YOY		IMM		YOY		IMM		YOY		IMM	
	No.	Per	No.	Per:	No.	Per.	No.	Per.	No.	Per.	No.	Per.
Red shiner					67	(93.06)			26	(96.30)	4	(100)
Sand shiner					5	(6.94)						
Fathead minnow									1	(3.70)		
Total					72	(100.00)			27	(100.00)	4	(100)

Table 51
Number and percentage of larval fishes caught between river miles -4.0 and 42.0 (stratum C) in the upper Colorado River

Species	Eddy				Backwater				Shoreline			
	YOY		IMM		YOY		IMM		YOY		IMM	
	No.	Per.	No.	Per.	No.	Per.	No.	Per.	No.	Per.	No.	Per.
Red shiner	218	(85.83)	1	(33.33)	1,060	(79.82)			123	(51.90)		
Sand shiner	28	(11.02)	2	(66.67)	186	(14.01)	7	(33.33)	103	(43.46)	5	(83.33)
Fathead shiner	7	(2.76)			82	(6.71)	14	(66.67)	9	(3.80)	1	(16.67)
Channel catfish									2	(0.84)		
Speckled dace	1	(0.39)										
Total	254	(100.00)	3	(100.00)	1,328	(100.00)	21	(100.00)	237	(100.00)	6	(100.00)

Table 52
Number and percentage of larval fishes caught between river mile 51.0 and 66.3 (stratum D) in the upper Colorado River

Species	Eddy				Backwater				Shoreline			
	YOY		IMM		YOY		IMM		YOY		IMM	
	No.	Per	No.	Per.	No.	Per.	No.	Per.	No.	Per.	No.	Per.
Red shiner	35	(62.50)			311	(78.34)	6	(37.50)	22	(33.33)		
Sand shiner	15	(26.79)			42	(10.58)	9	(56.25)	31	(46.97)	2	(66.67)
Fathead minnow	5	(8.93)			43	(10.33)			12	(18.18)		
Speckled dace	1	(1.79)			1	(0.25)	1	(6.25)	1	(1.51)	1	(33.33)
Plains killifish					2	(0.50)						
Total	56	(100.00)			397	(100.00)	16	(100.00)	66	(100.00)	3	(100.00)

Table 53
Number and percentage of larval fishes caught between river miles 71.5 and 76.5 (stratum E) in the upper Colorado River

Species	Eddy				Backwater				Shoreline			
	YOY		IMM		YOY		IMM		YOY		IMM	
	No.	Per.	No.	Per.	No.	Per.	No.	Per.	No.	Per.	No.	Per.
Red shiner					2	(66.7)	1	(100.00)				
Sand shiner					1	(33.3)						
Total					3	(100.00)	1	(100.00)				

Table 54
Number and percentage of larval fishes caught between river miles 86.0 and 110.4 (stratum F) in the upper Colorado River

	Eddy				Backwater				Shoreline			
	YOY		IMM		YOY		IMM		YOY		IMM	
Species	No.	Per	No.	Per.	No.	Per.	No.	Per.	No.	Per.	No.	Per.
Red shiner	2	(100.00)			18	(68.97)	7	(58.33)	2	(66.67)	1	(100.00)
Sand shiner					8	(31.03)	5	(41.67)				
Speckled dace												
Roundtail chub*									1	(33.33)		
Total	2	(100.00)			26	(100.00)	12	(100.00)	3	(100.00)	1	(100.00)

* possibly humpback chub (G. cypha)

Table 55
Number and percentage of larval fishes caught between river miles 115.0 and 125.0 (stratum G) in the upper Colorado River

	Eddy				Backwater				Shoreline			
	YOY		IMM		YOY		IMM		YOY		IMM	
Species	No.	Per.	No.	Per.	No.	Per.	No.	Per.	No.	Per.	No.	Per.
Red shiner	3	(42.86)	1	(33.33)	5	(21.74)	2	(66.67)	4	(23.53)		
Sand shiner	2	(28.58)	1	(33.33)					2	(11.76)	4	(66.67)
Roundtail chub*	1	(14.28)					1	(33.33)	4	(23.53)		
Fathead minnow					17	(73.91)			5	(29.41)	1	(16.67)
Speckled dace			1	(33.34)							1	(16.67)
Channel catfish	1	(14.28)			1	(4.35)						
Humback chub+									2	(11.76)		
Total	7	(100.00)	3	(100.00)	23	(100.00)	3	(100.00)	17	(100.00)	6	(100.00)

* tentative identification
\+ smaller of two specimens in questionable, possible a roundtail chub (G. robusta)

Table 56
Number and percentage of larval fishes caught between river miles 132.5 and 137.5 (stratum H) in the upper Colorado River

Species	Eddy				Backwater				Shoreline			
	YOY		IMM		YOY		IMM		YOY		IMM	
	No.	Per	No.	Per.	No.	Per.	No.	Per.	No.	Per.	No.	Per.
Red shiner	19	(76.00)	2	(100.00)	74	(77.08)			6	(75.00)	1	(100.00)
Sand shiner	4	(16.00)			9	(9.38)			1	(12.50)		
Fathead minnow	2	(8.00)			13	(13.54)			1	(12.50)		
Total	25	(100.00)	2	(100.00)	96	(100.00)			8	(100.00)	1	(100.00)

The presence of large numbers of young non-native species strongly suggests that competition upon native Colorado River fishes should be examined more thoroughly. One of the factors limiting survival of the target species may be competition and predation in the early life stages.

SUMMARY

Colorado Squawfish

The Colorado squawfish is rare throughout the upper Colorado River between upper Lake Powell, Utah and Rifle, Colorado. The species appears to be distributed by age groups such that most adults were found in the upper reaches, juveniles in the middle reaches, and YOY in the lower reaches. This distribution and the occurrence of larval fish suggests that spawning occurs in the middle to upper reaches (Moab to Grand Junction) where the substrate is predominantly rock. The young apparently drift or migrate downstream into the sandy reaches where backwaters and other shallow-water nurseries are available.

Young Colorado squawfish reside in backwaters for most of their first year of life and frequently occupy these their second year of life. In their second year of life and afterward, squawfish appear to use this habitat primarily for food and rest.

Squawfish of all ages appear very sensitive to flow levels and temperatures, and often occupy the warmest, shallow backwaters available, but rarely become entrapped by normal receding flows.

Young and juvenile Colorado squawfish were usually associated with large numbers of non-native species, while the adults were more commonly associated with native fishes. The apparently low reproductive success of the species suggests competition and possibly predation by these non-native fishes.

Equally important to reproduction by squawfish is the presence of silt-free cobble and gravel areas. There appear to be numerous such areas in the upper Colorado River for spawning. But, altered flows have allowed silt to accumulate in these gravel bars that may smother eggs or larvae. These changes have also substantially reduced the energy of the river for creating new backwaters and similar nurseries.

Critical Areas

Spawning and Incubation. Two areas of the upper Colorado River appear critical to spawning and incubation by Colorado squawfish:

(1) Loma (RM 154) to Utah Line (RM 132): a 22-mile stretch of river in which most adults and some larvae were found in 1980 and 1981 by the Colorado Division of Wildlife.

(2) Big Bend (RM 71) to Nine Mile Bottom (RM 90): a 19-mile reach of Professor Valley in which adults were often found in the spring and young in late summer. The area also contains many gravel bars and some backwaters since it occurs in the transition between the upper gravel substrate and the lower sand substrate.

Nurseries.--Three areas appear critical as nurseries for larvae and YOY:

(1) Potash (RM 47) to Spanish Bottom (RM -3): a 50-mile reach of river from near Potash to below the confluence of the Green River (RM 0). This reach of river yielded the greatest number of young squawfish.

(2) Big Bend (RM 71) to Nine Mile Bottom (RM 90): a 19-mile reach of river that yielded numerous adults, juveniles and some YOY.

(3) Loma (RM 154) to Utah Line (RM 132): a 22-mile reach of river that yielded some larvae, but few YOY or juveniles. Either survival of young is poor in this area or the fish are moving downstream. However, downstream movement from this reach would mean going through Westwater Canyon, an area of swift deep water with many rapids and turbulent areas that could be difficult for larvae and small YOY to safely negotiate. No juveniles or YOY and very few adults were found in Westwater Canyon.

Juvenile Maintenance.--The majority of juvenile squawfish in the upper Colorado River were caught in one reach of river:

(1) Spanish Bottom (RM -3) to Big Bend (RM 71): a 74-mile reach of river supporting the greatest number of juveniles in the upper Colorado River. The reach has many more backwaters than any other reach of the river.

Adult Maintenance.--Adults were found distributed throughout the upper Colorado River although slightly greater numbers were found in the upstream reaches. The area between upper Lake Powell (RM -20) and Palisade (RM 185) appears critical to adults. This area is about 200 miles of river in which adult squawfish apparently move freely and perhaps throughout the entire reach.

Critical Periods and Conditions

Spawning and Incubation

June 15 to August 30 appears critical to spawning and incubation by Colorado squawfish. In 1980, mean daily water temperatures reached 20° C about mid-June and spawning apparently occurred the last week of July at 23-25° C and 3000-4000 cfs flow, based on the size of larvae captured in early August by the Colorado Division of Wildlife. Thus, it appears critical that mean daily water temperatures are 20° C for about 1 month before spawning. Adult squawfish appear to stage for spawning in the sheltered areas like side channels, backwaters and even gravel pits during and after runoff. Since no spawning sites were located in this study, little can be said about the other conditions critical to reproduction.

Nurseries

Colorado squawfish appear most sensitive in the egg or larval stage of development which occurs July 1 to August 30, depending on flow and water temperature. Although young squawfish appear sensitive to flow fluctuations and temperatures, sudden changes in flow level can desiccate or inundate important nurseries and force the young to compete with non-native fishes or to face the physical rigors of the river.

Juvenile and Adult Maintenance

Juvenile and adult squawfish require median river flow 2 of every 3 consecutive years to flush sediments from spawning and feeding areas and maintain deep resting areas. Water temperatures above 28° C apparently become detrimental to Colorado squawfish.

Prospects for Survival and Recovery

The Colorado squawfish may have never been abundant as a resident in the upper Colorado River above Moab. The rock substrate in this upper reach does not easily allow the river to develop many backwaters and side channel nurseries as are found in the lower sandy reach, below Moab. However, the rocky upper reach may have been an important spawning area, along with the similar reaches of the Dolores and Gunnison Rivers. The success of larvae and YOY moving or drifting through turbulent areas like Westwater Canyon and Professor Valley can only be speculated upon. Spawning in the intermittent gravel bars of the lower reach is also possible, as indicated by a large number of YOY in one seine haul from a backwater adjacent to a gravel bar at RM 34.8 in 1979. The relatively large numbers of YOY and juveniles in the lower reach near the Green River confluence also indicates the possibility of squawfish moving into the Colorado River from spawning areas in the Green River.

Radiotelemetry studies are needed on Colorado squawfish in the upper Colorado River to monitor the movement of adults prior to and during spawning. It now appears that the fish overwinter in deep holes in the upper third of the reach and leave these during spring runoff. The adults appear to stage for spawning in sheltered areas on the descending limb of runoff. The exact locations, sites and conditions for spawning by Colorado squawfish in the upper Colorado remain unknown.

Humpback Chub

This investigation revealed that the humpback chub is rare throughout the upper Colorado River above Lake Powell, but is locally common in two restricted areas; Black Rocks, Colorado, and Westwater Canyon, Utah. The occurrence of all age groups in these two areas suggests reproducing and self-sustaining populations. The species is concentrated in areas of the river with greater than average depths and velocities and with bedrock, boulder and sand substrates. This clumped distribution in resticted habitats probably reflects the historic distribution of the species in the Colorado River System. These restricted areas also harbor fewer fish species--especially non-natives--than most areas of the river, suggesting that the humpback chub evolved in a specialized environment conducive to few other species. Tagging studies and radiotelemetry also suggest that individuals of the species rarely leave these restricted areas and appear to perform all of their life functions in a short reach of river.

Although this highly-adapted fish inhabits areas with swift current, it is rarely found in the swift water and apparently prefers to occupy

the slower pools and eddies. This phenomenon appears to have given the humpback chub an advantage over other riverine species incapable of navigating the deep swift waters. However, flow alterations-particularly reductions in peak flows--have weakened these isolating mechanisms and allowed encroachment by other fishes, both natives and non-natives.

The native fish that has probably most impacted the humpback chub is the closely-related roundtail chub. Still abundant in the upper Colorado River above Moab, Utah, the roundtail chub is usually found in shallower, less swift water than the humpback chub. However, reduced flows have allowed encroachment by the more generalist roundtail chub into the areas of the more specialized humpback chub and resulted in competition and possibly hybridization. The presence of many forms intermediate between the two species strongly suggests the latter. Reproductive isolation has also been weakened by lowered flows and altered water temperatures. Humpback chub now spawn at 14-16° C in late May and early June while the roundtail chub spawn shortly after in warmer water and on the descending limb of runoff. Continued encroachment by the roundtail chub could seriously alter and endanger gene pool integrity for the humpback chub in the upper Colorado River. The existence of hybridization between humpback chub and other species of the genus Gila in the wild needs to be verified. This cross has been performed successfully in a hatchery.

Several management options exist by which to enhance the survival and recovery of the species. Knowledge of critical areas, periods and conditions is vital to a beneficial water management scheme. The following discusses these topices as they apply to the humpback chub.

Critical Areas

Two areas are identified as critical to the survival of the humpback chub in the upper Colorado River between Lake Powell, Utah and Rifle, Colorado:

(1) Black Rocks Area, Colorado: a 12 mile reach of river between Salt Creek (RM 144) and Utah Line (RM 132).

(2) Westwater Canyon, Utah: a 15 mile reach of river between Westwater (RM 125.0) and Agate Wash (RM 110)

These two areas are critical because they support the only known concentration of humpback chub in the upper Colorado River. The presence of ripe adults and various ages in both areas strongly suggests that Black Rocks and Westwater Canyons support reproducing and probably self-sustaining populations of the species.

Two other areas are identified as important for possible supplemental introductions of humpback chub:

(1) Cataract Canyon, Utah: an 18 mile reach of river between Spanish Bottom (RM -3) and Gypsum Canyon (RM -21).

(2) Moab Canyon, Utah: a 15.0 mile reach of river between Onion Creek (RM 86) and Big Bend (RM 71).

Area 1 above is important because it is the site of the only release of hatchery-reared humpback chub in the wild. Approximately 7600 marked age group I fish were released in December 1981 near the site where one adult humpback chub was captured in 1980. Area 2 is important because a juvenile was captured in what was documented historic habitat and is now habitat similar to that used by the species elsewhere in the basin.

The status of one area remains undetermined because the fish inhabiting it are a humpback chub-like form tentatively identified as hybrids:

(1) Debeque Canyon, Colorado: a 3-mile reach of river from above Beavertail Mountain (RM 197) to the Government Highline Dam (RM 194).

This area is important because it harbors a concentration of humpback chub-like fish that are tentatively identified as intermediates between G. cypha and G. robusta. These fish probably represent the remnants of a population of humpback chub whose habitat was modified and invaded by large numbers of roundtail chub. This situation may be a foreteller of other populations of humpback chub in the basin facing habitat or flow alterations.

Critical Periods and Conditions

Critical time periods and conditions are identified for spawning and incubation, rearing for larvae and young-of-the-year (YOY), juvenile maintenance, and subadult and adult maintenance.

Spawning and Incubation

Based on observations of ripe and spent adults in Black Rocks and Westwater Canyon in 1980 and 1981, the critical spawning period for humpback chub appears to be May 1 to June 30; during and shortly after peak spring flows. This time period applies to both Black Rocks and Westwater Canyon because of the proximity of the areas to each other and the absence of any intervening significant water inputs. Spawning of the intermediates in Debeque Canyon probably occurs later since the reach is upstream from Black Rocks in a cooler region of river.

Spawning in Moab Canyon and Cataract Canyon has not been documented but a reasonable time period is probably before the May 1 to June 30 period because of the warmer downstream conditions.

Water temperatures appeared to be the key factor to spawning in Black Rocks in 1980 and 1981. Temperatures both years were 14-16.5° C when evidence of spawning was observed. Flows for the same periods were 21,500-26,000 cfs in 1980 and 3000-5000 cfs in 1981. Incubation temperatures are probably 16-20° C. It appears important that mean daily water temperatures reach 12° C by April 1 and warm to 18° C by June 1. The relative strengths of the 1980 and 1981 year classes have not been evaluated to assess relative spawning success under different flow levels.

Data gaps exist regarding spawning time, sites and preferred conditions. But, silt accumulation is undoubtedly detrimental to the eggs and larvae. The species could be experiencing reduced reproductive success because reduced peak flows have allowed silt accumulation in spawning areas. Flows are needed at least once every 3 years of a magnitude sufficient to flush silt and sediments.

Nurseries.--Too few larvae and YOY humpback chub are documented from the upper Colorado River to adequately assess critical periods and conditions. Based on spawning time, the period from May 15 to June 30 is probably critical to the young fish. Critical maximum water temperature for YOY is about 28° C.

The few young chub caught were in shallow waters and shoreline depressions near swift water. Dramatic changes in flow could reduce shallow-water habitats for these fishes and subject them to the rigors of the river. This is a potentially detrimental situation in areas like Black Rocks and Westwater Canyon of the steep canyon walls and few shelves which could become desiccated with reduced flow.

The indirect effects of physical changes on the young fish could be equally detrimental. Habitat degradation apparently allows large numbers of competitive and predaceous non-native as well as native fishes to encroach upon the habitat of these young fish. Data gaps exist for assessing preferred nursery areas and conditions for young humpback chub.

Juvenile Maintenance.--Juvenile humpback chub appear to use waters intermediate in depth with low velocity. Shallow embayments, backwaters and pockets in the canyon walls are important to this age of fish. Median flows are needed at least 2 of every 3 consecutive years with no flow below the predominant shelf. Few shallow water habitats would be left if the river were dewatered to form the shoreline on steep, swift, rock canyon walls. Water temperatures above 28 C are reported detrimental to juveniles.

Adult Maintenance.--Adult humpback chub are generally associated with deep swift water, although suitability-of-use criteria and radiotelemetry indicate that adults rarely position themselves in the swift water. The fish are often found in all depths, but at relatively low velocity, coared to what is available. Adults appear to prefer cool, shaded water as indicated by raiotelemetry. Water temperatures above 28 C could be detrimental to adults. Median flows at least 2 of every 3 consecutive years is recommended for maintaining adults.

The deep and swift regions occupied by humpback chub are very critical to their existence. These areas exclude large numbers of competive native and non-native fishes. As habitats are altered by flow modifications these isolating mechanisms break down and allow encroachment by other species. The occurrence of humpback x roundtail hybrids is probably strong evidence of this habitat degradation.

Humpback chub are apparently very suseptible to competition and possibly hybridization since the species evolved in a rigorous environment that excluded most other fishes and reduced the humpback's ability to compete. Present conditions appear for the continued existence of humpback chub. But, hybridization may be diluting the gene pool. Median flow is needed for adults at least 2 of every 3 consecutive years.

Water quality conditions, especially pesticide levels, also might be affecting the well-being of the species. A large variety and volume of pesticides is used in the Grand Junction area that probably drain into the river via irrigation returns, and possibly affect insect populations in the river. These pesticides could result in decreased food supplies for the species or a concentrated effect of pesticides in the fish that may affect gonadal development or survival of the eggs or larvae.

Prospects for Survival and Recovery

Prospects for survival by the humpback chub are favorable--at least to maintain the species at its present distribution and abundance in the upper Colorado River. However, recovering the populations can only be accomplished by recovering the habitat lost to mainstem dams and water uses. Supplemental stocking in two areas in Utah may also enhance this recovery. Several management options exist by which to enhance the survival and recovery of the species. Knowledge of critical areas, periods and conditions is vital to a beneficial water management scheme.

Razorback Sucker

The razorback sucker appears to be uniformly rare throughout the upper Colorado River from Lake Powell, Utah, to Rifle, Colorado. Only the bonytail chub appears to have lower total numbers of the native Colorado River fishes. The capture of only adults in this 3-year study indicates limited reproductive success. It is unlikely that young razorbacks are being misidentified as other suckers since the species can be distinguished as a very young fish. All razorbacks captured appear to be old adults suggesting that individuals of the present population are probably dying of old age without successful recruitment.

Nearly all razorback sucker were caught in still water over silt substrate in either gravel pits or large backwaters. Many of these fish were taken in spawning condition during peak flow indicating that razorback sucker either stage for spawning or spawn in large backwaters--or gravel pits in lieu of large backwaters--in the upper basin. Studies of razorback sucker in the lower basin show that the species spawn in quiet shallow gravel bars of low silt content. These studies also show that larval razorbacks are very suseptible to predation by other fishes, especially non-natives.

In the upper Colorado River, it appears that the failure of the egg or larval stage is severely hampering the chances for continued survival by the species. Since the fish is believed to spawn during peak spring flows in relatively silt-free gravel, it is reasonable to assume that

much of the spawning habitat--high flood-plain gravel bars--is no longer available. Ripe adults are probably attracted to large backwaters or gravel pits because of the presence of gravel, but these areas have high silt composition and high densities of predators. Razorback sucker probably spawn in Walter Walker Wildlife Area and Clifton Pond, as indicated by ripe and gravid fish, but they are probably unsuccessful because high silt levels in the poorly-flushed gravels likely smother the eggs and larvae, and the predators consume the few that survive. These gravel pits support a large complement of green sunfish, black bullhead, channel catfish, largemouth bass and common carp. These and other non-native fishes account for 65 percent of the species associated with razorback sucker. Razorbacks in gravel pits are often infested with numerous external parasites, especially the copepod Lernaea cyprinacea.

The razorback sucker appears further threatened as a species by hybridization with flannelmouth sucker. Approximately 10 percent of the razorbacks collected were intermediates, suggesting that there is some weakening or breakdown in reproductive isolation between the species. Apparently the razorback sucker is being forced to encroach upon the spawning habitat of the flannelmouth sucker as a result of reduced river flows and habitat alterations such as channelization and extensive gravel pit excavations. Flannelmouth generally spawn in the gravel bars near stream inlets.

The unique morphology of the razorback sucker (sharp keel, tapered head) suggests specialization for isolationism. Habitat alteration, especially reduced peak flows, have apparently forced the razorback to use marginal habitats with resulting low reproductive success.

Critical Areas

Since most razorback sucker caught during this investigation were near Grand Junction, Colorado, the river reach between Palisade (RM 185) and Black Rocks (RM 136) warrants consideration as a critical area. Although spawning appears unsuccessful, the fish are still attracted to this reach of river during runoff, although they may migrate from a long distance.

Critical Periods

The majority of razorback sucker were captured from late May to early June during runoff and while the fish were in spawning condition. Periods critical to other life aspects can not be evaluated because of the paucity of fish.

Critical Conditions

Studies in the lower basin indicate that razorback sucker select quiet gravel bars with low silt content for spawning. This condition is rarely found in the upper Colorado River, and it appears that the fish are finding quiet gravel areas mostly in gravel pits. Silt content in these, however, is probably too high for success, and predation probably eliminates the few eggs and larvae that do survive.

Razorback sucker in spawning condition move from the main channel (water temperatures of 16-18° C) to warm backwaters and gravel pits (19-20° C) during spawning at runoff. Relatively warmer temperatures and quiet silt-free gravel bars appear critical to reproduction.

Prospects for Survival and Recovery

The razorback sucker is rapidly approaching extinction in the upper Colorado River. The only fish caught recently are adults with no evidence of recruitment. However, the razorback is a species that may lend itself well to management, particularly in the critical stages of reproduction, egg survival and larval success.

The presence of razorback sucker in gravel pits near Grand Junction especially during spawning indicates that fish are seeking quiet silt-free gravel areas and need predation-free nurseries. Walter Walker wildlife Area and Clifton Pond do not provide these needs. But, construction of gravel pits or modification of existing ones could provide these critical conditions for the species.

A gravel pit adjacent to the river but with its lowest point higher than the level of median river flow will flood only during runoff and provide razorbacks with quiet off-channel gravel areas. The pit should be sloped about 1:4 (deepest near the river) with one or two 16-20-inches culverts leading to the river. A berm separating the pit from the river channel is necessary to prevent the river from changing its course or creating a large eddy during runoff. A pit of this design should desiccate in pre and postrunoff periods to preclude establishment of predaceous lentic non-native fishes. The presence of a free-flowing spring in the pit may help to flush the gravel of silt accumulated during flooding.

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APPENDICES

Appendix	
A	Glossary of terms used by the Colorado River Fishery Project
B	Computerized field data sheets used by the Grand Junction Field Station of the Colorado River Fishery Project to record physical and chemical data
C	Widths and depths of selected cross sections of the upper Colorado River in regular and special strata
D	Chemical characters of the upper Colorado River in regular and special strata.
E	Data associated with Colorado squawfish captured in the upper Colorado River, 1979-1981
F	Data associated with humpback chub captured in the upper Colorado River, 1979-1981
G	Data associated with 52 razorback sucker captured in the upper Colorado River, 1979-1981

Table A-1
Glossary of terms used by the Colorado River Fishery Project

Life history terms	
Larva	Newly hatched fish with yolk sac visable (synonym: prolarva, fry).
Postlarva	Fish with yolk sac absorbed; loss of larval and gain of adult appearance.
Young-of-year	Fish up to one year of age.
Juvenile	Fish one year old up to but not including adult (synonyms: immature and subadult).
Adult	A fish capable of reproduction.
Spawning Condition	A sexually mature state at or near the actual time of spawning. Mature eggs and milt run with slight pressure.
Field terms	
RM	River miles upstream and downstream from the confluence of Green and Colorado Rivers.
Braided	Multiple side channels forming an interlacing network in a section of river.
Stratum	Geomorphologically homogeneous section of river selected for random statistical sampling of fishes.
Habitat types	
Backwater (BA)	A body of water off the main channel with no measurable velocity; often created by a drop in water level which stops the flow through a former side channel or low-lying area.
Eddy (ED)	A portion of the stream with a distnnct whirl-pool effect.
Gravel pit (GP)	Excavated gravel bar adjacent to or in the river channel inundated by the river to form a small lake or large backwater.
Irrigation return flow (IR)	Water entering the river from irrigation collector system.
Lake (LK)	Large body of impounded river water; i.e. Lake Powell.

Main channel (MC)	Primary river course that carries the major water flow throughout most of the year.
Pool (PO)	A portion of the stream that is deep and quiet relative to the main channel.
Riffle (RI)	A shallow fast-flowing area where the water surface is broken into waves by obstructions wholly or partly submerged.
Run (RU)	A stretch of relatively deep, fast flow with the surface essentially nonturbulent.
Shoreline (SL)	The shallow, low-to-negligible velocity waters next to shore.
Side channel (SC)	A secondary channel which carries appreciable flow during high water and provides a low velocity habitat or backwater during low flow.

Substrate types

Silt (SI)	Fine gritty material
Sand (SA)	Less than 3 mm diameter
Gravel (GR)	3 mm to 6 mm
Rubble (RU)	76 mm to 305 mm (synonym: cobble)
Boulder (BO)	305 mm and larger
Bedrock (BE)	Solid, continuous rock layer

Table B-1
Computerized field data sheet used by the Grand Junction Field Station of the Colorado River Fishery Project to record physical and chemical data.

COLORADO RIVER FISHERY PROJECT

DATASET 1: PHYSICAL

River __ __ (1 2) Stratum __ (3) RMI __ __ __ . __ (4 5 6 7 8) Type __ (9) Date . y y m m d d (10 11 12 13 14 15)

Time __ __ __ __ (16 17 18 19) Water Temp __ __ . __ °C (20 21 22 23) Air Temp __ __ °C (24 25) DO __ __ mg/l (26 27)

Cond __ __ __ __ umhos/cm (28 29 30 31) Sal __ __ ppth (32 33) Turb __ __ __ __ J.U. (34 35 36 37)

CROSS SECTIONS:

Width 1 __ __ __ ft. (38 39 40) Max Depth 1 __ __ ft. (41 42) Ave Depth 1 __ __ ft. (43 44)

Width 2 __ __ __ ft. (45 46 47) Max Depth 2 __ __ ft. (48 49) Ave Depth 2 __ __ ft. (50 51)

Width 3 __ __ __ ft. (52 53 54) Max Depth 3 __ __ ft. (55 56) Ave Depth 3 __ __ ft. (57 58)

SKETCH OF SAMPLE SITE:

Table B-2
Computerized field data sheet used by the Grand Junction Field Station of the Colorado River Fishery Project to record fish captures and associated data.

COLORADO RIVER FISHERY PROJECT

DATASET 2: CATCH

River __ __ (1 2) Stratum __ (3) RMI __ __ __ . __ (4 5 6 7 8) Type __ (9) Date y y m m d d (10 11 12 13 14 15)

Start Time __ __ __ __ (16 17 18 19) End Time __ __ __ __ (20 21 22 23) Hours __ __ . __ (24 25 26 27) Gear __ __ (28 29)

Habitat __ __ (30 31) Area __ __ __ __ m^2 (32 33 34 35) Depth __ __ . __ ft. (36 37 38 39) Velocity __ . __ fps (40 41 42)

Substrate 1 __ __ (43 44) 2 __ __ (45 46)

Species	YOY	Immature	Adult	Parasites (%)
B H	(<60)__ __ __	(60-300)__ __ __	(>300)__ __ __	__ __ __
F M	(<60)__ __ __	(60-410)__ __ __	(>410)__ __ __	__ __ __
R Z	(<60)__ __ __	(60-400)__ __ __	(>400)__ __ __	__ __ __
G S	(<45)__ __ __	(45-210)__ __ __	(>210)__ __ __	__ __ __
L G	(<50)__ __ __	(50-250)__ __ __	(>250)__ __ __	__ __ __
C P	(<70)__ __ __	(70-250)__ __ __	(>250)__ __ __	__ __ __
C S	(<60)__ __ __	(60-400)__ __ __	(>400)__ __ __	__ __ __
F H	(<20)__ __ __	(20-35) __ __ __	(> 35)__ __ __	__ __ __
H B	(<55)__ __ __	(55-260)__ __ __	(>260)__ __ __	__ __ __
R S	(<20)__ __ __	(20-30) __ __ __	(> 30)__ __ __	__ __ __
R T	(<55)__ __ __	(55-260)__ __ __	(>260)__ __ __	__ __ __
S S	(<20)__ __ __	(20-30) __ __ __	(> 30)__ __ __	__ __ __
S D	(<20)__ __ __	(20-32) __ __ __	(> 32)__ __ __	__ __ __
B B	(<52)__ __ __	(52-250)__ __ __	(>250)__ __ __	__ __ __
C C	(<60)__ __ __	(60-300)__ __ __	(>300)__ __ __	__ __ __
(47 48)	(49 50 51)	(52 53 54)	(55 56 57)	(58 59 60)

DEPTH-VELOCITY-SUBSTRATE:

		1	2	3
A	D(ft.)			
	V(fps)			
	S(1&2)			
B	D(ft.)			
	V(fps)			
	S(1&2)			
C	D(ft.)			
	V(fps)			
	S(1&2)			

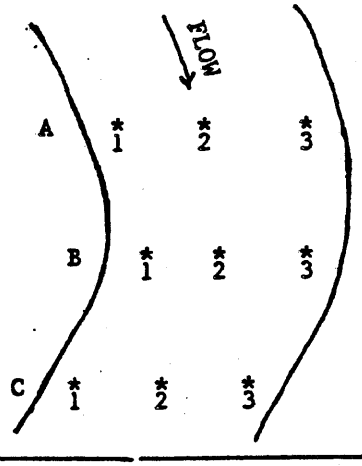

Table B-3
Computerized field data sheet used by the Grand Junction Field Station of the Colorado River Fishery Project to record endangered fish data.

DATASET 3: RARE

River __ __ (1 2) Stratum __ (3) RMI __ __ __ . __ __ (4 5 6 7 8) Type __ (9) Date y y m m d d (10 11 12 13 14 15)

Start Time __ __ __ __ (16 17 18 19) End Time __ __ __ __ (20 21 22 23) Hours __ __ . __ __ (24 25 26 27) Gear __ __ (28 29)

Habitat __ __ (30 31) Area __ __ __ __ m² (32 33 34 35) Depth __ __ . __ __ ft. (36 37 38 39) Velocity __ . __ __ fps (40 41 42)

Substrate 1 __ __ (43 44) 2 __ __ (45 46)

Species	Sex	TL(mm)	WT(g)	Tag No.	Co	Si	Rec	Lernea(#)	Disp.
47 48	49	50 51 52	53 54 55 56	57 58 59 60	61	62	63	64 65 66	67 68

Table B-3 (continued)
Computerized field data sheet used by the Grand Junction Field Station
of the Colorado River Fishery Project to record endangered fish data

ONLY FOR HUMPBACK CHUB (HB), ROUNDTAIL-HUMPBACK HYBRID (RH), UNIDENTIFIED GILA (GI), BONYTAIL CHUB (BT), some ROUNDTAIL CHUB (RT)

Species	Sex	TL(mm)	WT(g)	Tag No.	Tag Co	Tag Si	Tag Rec	Lernea(#)	Disp.	P_1-P_2	Hump	Ray Count D Fin	Ray Count A Fin	1
47 48	49	50 51 52	53 54 55 56	57 58 59 60	61	62	63	64 65 66	67 68	69 70 71	72 73 74	75 76	77 78	79
														1
														1
														1
														1
														1
														1
														1
														1
														1
														1
														1
														1
														1
														1

HABITAT PARAMETERS FOR ENDANGERED FISHES

Species	Tag No.	Depth	Velocity	Substrate 1	Substrate 2

Table B-4
Field names associated with the Dataset PHYSICAL from the
Data Storage and Retrieval System MANAGE, used by CRFP

NO.	FIELDNAME	TYPE	LENGTH	SEARCHABLE?	NO. VALUES	MV
1	RIVER	CHAR	2	YES	3	20
2	STRATA	CHAR	1	YES	22	30
3	RMI	DEC	5	YES	119	200
4	TYPE	CHAR	1	YES	3	10
5	DATE	CHAR	8	YES	111	200
6	TIME	INT	4	YES	39	40
7	WATERT	DEC	4	YES	45	80
8	AIRT	INT	2	YES	35	50
9	DO	INT	2	YES	10	20
10	COND	INT	4	YES	58	150
11	SAL	INT	2	YES	4	30
12	TURB	INT	4	YES	34	50
13	W1	INT	3	YES	46	60
14	MAX1	INT	2	YES	31	100
15	AVG1	INT	2	YES	23	100
16	W2	INT	3	YES	50	60
17	MAX2	INT	2	YES	35	100
18	AVG2	INT	2	YES	24	100
19	W3	INT	3	YES	51	60
20	MAX3	INT	2	YES	28	100
21	AVG3	INT	2	YES	19	100

Table B-5
Field names associated with the Dataset CATCH from the
Data Storage and Retrieval System MANAGE, used by CRFP

NO.	FIELDNAME	TYPE	LENGTH	SEARCHABLE?	NO. VALUES	MV
1	RIVER	CHAR	2	YES	3	20
2	STRATA	CHAR	1	YES	23	30
3	RMI	DEC	5	YES	575	1000
4	TYPE	CHAR	1	YES	4	10
5	DATE	CHAR	8	YES	210	250
6	START	INT	4	YES	116	120
7	END	INT	4	YES	122	200
8	HR	DEC	4	YES	119	200
9	GEAR	CHAR	2	YES	24	30
10	HAB	CHAR	2	YES	13	20
11	AREA	INT	4	YES	122	300
12	DEPTH	DEC	5	YES	142	150
13	VEL	DEC	4	YES	36	100
14	SUB1	CHAR	2	YES	8	20
15	SUB2	CHAR	2	YES	8	20
16	NAME	CHAR	2	YES	35	100
17	YOY	INT	3	YES	86	200
18	JUV	INT	3	YES	77	200
19	ADULT	INT	3	YES	118	200
20	PAR	INT	3	YES	39	100

Table B-6
Field names associated with the Dataset RARE from the Data Storage and Retrieval System MANAGE, used by CRFP

NO.	FIELDNAME	TYPE	LENGTH	SEARCHABLE?	NO. VALUES	MV
1	RIVER	CHAR	2	YES	2	20
2	STRATA	CHAR	1	YES	19	30
3	RMI	DEC	5	YES	110	500
4	TYPE	CHAR	1	YES	3	10
5	DATE	CHAR	8	YES	122	250
6	START	INT	4	YES	84	120
7	END	INT	4	YES	81	120
8	HR	DEC	4	YES	48	100
9	GEAR	CHAR	2	YES	16	30
10	HAB	CHAR	2	YES	10	20
11	AREA	INT	4	YES	41	300
12	DEPTH	DEC	4	YES	119	150
13	VEL	DEC	3	YES	29	100
14	SUB1	CHAR	2	YES	7	20
15	SUB2	CHAR	2	YES	7	20
16	NAME	CHAR	2	YES	5	100
17	SEX	CHAR	1	YES	5	5
18	TL	INT	3	YES	313	500
19	WT	INT	4	YES	271	500
20	TAG	INT	4	YES	415	500
21	COLOR	CHAR	1	YES	3	10
22	SIZE	CHAR	1	YES	3	10
23	RECAP	CHAR	1	YES	2	5
24	LERN	INT	3	YES	20	100
25	DISP	CHAR	2	YES	7	10
26	P1P2	DEC	4	YES	71	250
27	HUMP	DEC	4	YES	50	250
28	DFIN	INT	2	YES	4	30
29	AFIN	INT	2	YES	4	30

Table C (1-15)

Widths and depths (in feet) of selected cross sections of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	cross section 1 width	cross section 1 Depth-max	cross section 1 Depth-ave	cross section 2 width	cross section 2 Depth-max	cross section 2 Depth-ave	cross section 3 width	cross section 3 Depth-max	cross section 3 Depth-ave
Table C-1, Stratum A											
POSTRUNOFF											
178.0	9/1/80		990	99	76	980	99	99	990	99	96
173.0	9/2/80		820	99	99	980	99	99	980	99	99
Table C-2, Stratum B											
PRERUNOFF											
212.0	4/4/81		660	38	22	300	36	20	820	8	4
207.0	4/5/81		300	13	7	400	37	21	330	10	7
POSTRUNOFF											
213.0	9/27/79		240	52	16	190	36	12	200	26	10
208.0	9/28/79		180	26	8	200	25	10	240	32	12
212.0	8/30/80		110	62	40	390	92	65	360	52	44
207.0	8/30/80		160	61	35	490	60	36	-	9	8
Table C-3, Stratum C											
PRERUNOFF											
37.0	4/1/81		660	10	3	660	6	4	314	14	7
32.0	4/2/81		660	4	2	460	10	4	690	5	2
RUNOFF											
34.0	6/10/80		390	21	9	400	27	14	380	21	13
39.0	5/26/81		300	10	6	220	12	4	190	7	3
34.0	5/27/81		390	20	8	390	25	12	360	20	12

Table C (1-15) (Continued)

Widths and depths (in feet) of selected cross sections of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	cross section 1			cross section 2			cross section 3		
			width	Depth-max	Depth-ave	width	Depth-max	Depth-ave	width	Depth-max	Depth-ave
Table C-3, Stratum C (Continued)											
POSTRUNOFF											
27.0	9/24/79		250	16	3	240	14	3	180	12	6
22.0	9/25/79		220	14	4	260	12	2	160	14	5
9.0	8/27/80		660	6	5	300	10	7	660	7	4
4.0	8/27/80		620	12	4	520	6	4	720	8	5
Table C-4, Stratum D											
RUNOFF											
67.0	5/4/80		670	10	7	850	11	8	660	19	12
62.0	5/5/80		720	13	9	660	12	8	820	11	7
68.0	4/30/81		460	4	2	530	4	2	590	7	4
63.0	5/1/81		400	6	3	360	6	4	600	6	2
POSTRUNOFF											
65.0	9/19/79		190	16	3	200	15	4	200	14	4
60.0	9/22/79		210	12	2	200	14	3	220	12	2
54.0	10/6/80		260	11	4	720	5	3	720	9	3
49.0	10/7/80		720	6	4	360	15	6	460	5	4
Table C-5, Stratum E											
PRERUNOFF											
76.0	5/1/80		450	32	17	340	26	11	650	10	6
71.0	5/2/80		590	23	13	720	46	25	650	22	12
80.0	4/28/81		360	4	2	190	6	3	170	10	4
75.0	4/29/81		250	13	6	200	22	10	470	28	12

Table C (1-15) (Continued)

Widths and depths (in feet) of selected cross sections of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	cross section 1			cross section 2			cross section 3		
			width	Depth-max	Depth-ave	width	Depth-max	Depth-ave	width	Depth-max	Depth-ave
					Table C-5, Stratum E (Continued)						
					RUNOFF						
78.0	7/10/80					330	15	10	490	11	7
73.0	7/11/80		540	13	7	310	9	5	260	9	6
82.0	6/3/81		200	10	4	230	12	5	460	4	2
77.0	6/4/81		130	18	6	230	18	6	300	18	5
					POSTRUNOFF						
80.0	9/18/79		180	15	3	190	18	4	240	10	3
75.0	9/18/79		200	18	2	180	16	2	220	16	2
84.0	10/1/80		330	7	3	360	9	5	560	10	6
79.0	10/2/80		480	10	7	430	9	5	390	10	6
					Table C-6, Stratum F						
					PRERUNOFF						
93.0	4/29/80		660	14	7	520	35	17	260	10	6
88.0	4/30/80		620	22	16	660	14	9	590	16	10
110.0	4/21/81		270	6	3	500	8	2	118	10	5
105.0	4/22/81		360	6	3	290	7	6	260	16	9
					RUNOFF						
91.0	7/8/80		160	20	9	420	11	7	490	11	7
86.0	7/8/80		660	11	4	650	12	7	590	17	12
107.0	6/1/81		270	12	5	210	6	3	200	10	4
102.0	6/2/81		200	14	4	180	8	3	400	6	2

Table C (1-15) (Continued)
Widths and depths (in feet) of selected cross sections of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	cross section 1			cross section 2			cross section 3		
			width	Depth-max	Depth-ave	width	Depth-max	Depth-ave	width	Depth-max	Depth-ave
Table C-6, Stratum F (Continued)											
POSTRUNOFF											
93.0	10/29/79	210	13	2	160	19	3	140	10	3
88.0	10/31/79	160	12	3	170	18	2	210	16	6
95.0	9/29/80	330	7	4	260	6	4	230	19	11
90.0	9/30/80	330	13	8	200	16	6	260	22	12
Table C-7, Stratum G											
RUNOFF											
116.0	5/6/81	130	20	10	120	13	6	130	30	14
113.0	5/6/81	400	-	-	300	-	-	300	-	-
POSTRUNOFF											
126.0	10/9/79	170	12	3	180	16	4	240	16	2
121.0	10/10/79	210	10	2	160	12	3	110	12	4
122.0	9/9/80	200	15	8	130	11	9	130	13	17
116.0	9/9/80	130	20	11	160	60	29	180	19	15
125.0	7/14/81	145	18	5	145	15	6	155	18	4
120.0	7/15/81	160	9	5	200	7	3	-	-	-
Table C-8, Stratum H											
PRERUNOFF											
143.0	5/12/80	820	11	6	720	5	3	920	7	3
138.0	5/13/80	430	11	6	390	18	12	490	11	6

Table C (1-15) (Continued)

Widths and depths (in feet) of selected cross sections of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	cross section 1			cross section 2			cross section 3		
			width	Depth-max	Depth-ave	width	Depth-max	Depth-ave	width	Depth-max	Depth-ave
Table C-8, Stratum H (Continued)											
RUNOFF											
140.0	7/22/80	140	9	6	230	14	6	390	9	6
135.0	7/23/80	300	10	5	360	5	4	140	5	3
147.0	5/13/81	250	7	5	280	15	6	280	5	3
142.0	5/14/81	380	6	2	320	5	2	400	5	2
POSTRUNOFF										
153.0	8/23/79	190	8	2	210	10	4	190	11	4
148.0	8/23/79	220	16	6	200	12	3	200	10	4
131.0	10/14/80	-	4	3	360	8	6	430	8	6
126.0	10/15/80	460	6	5	360	4	3	460	6	4
149.0	6/23/81	220	10	2	250	10	2	260	10	4
144.0	6/24/81	130	8	2	190	6	2	260	9	4
Table C-9, Stratum I										
PRERUNOFF										
183.0	4/14/81	140	6	2	150	5	2	160	6	1
178.0	4/14/81	140	4	1	150	6	2	160	5	2
RUNOFF										
159.0	6/18/80	330	14	6	320	12	7	300	13	7
154.0	6/18/80	500	12	8	400	16	8	330	9	6
181.0	6/9/81	400	14	4	300	13	5	460	12	5
176.0	6/11/81	400	18	4	300	6	1	300	4	1

Table C (1-15) (Continued)

Widths and depths (in feet) of selected cross sections of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	cross section 1			cross section 2			cross section 3		
			width	Depth-max	Depth-ave	width	Depth-max	Depth-ave	width	Depth-max	Depth-ave
Table C-9, Stratum I (Continued)											
POSTRUNOFF											
170.0	8/7/79		180	12	3	210	14	3	190	14	4
165.0	8/7/79		210	10	4	200	12	3	190	10	3
177.0	9/16/80		130	6	4	130	13	7	330	6	4
172.0	9/17/80		200	3	3	150	8	5	200	6	4
Table C-10, Stratum J											
PRERUNOFF											
197.0	4/22/80		260	14	9	260	17	12	360	11	7
192.0	4/23/80		660	5	3	820	8	5	660	9	5
RUNOFF											
200.0	7/17/80		220	11	7	250	11	5	310	8	4
195.0	7/17/80		160	17	8	410	8	6	330	12	8
210.0	5/19/81		230	7	3	300	5	1	330	-	-
205.0	5/20/81		250	22	8	280	13	6	300	22	10
POSTRUNOFF											
191.0	7/19/79		220	16	4	180	12	4	200	12	5
186.0	7/20/79		200	12	3	190	14	5	190	10	2
201.0	9/22/80		180	5	4	210	5	4	300	4	3
196.0	9/23/80		140	6	3	210	5	3	210	6	2
205.0	6/29/81		170	9	4	130	9	3	220	6	3
200.0	7/1/81		150	8	1	200	6	2	170	14	6

Table C (1-15) (Continued)

Widths and depths (in feet) of selected cross sections of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	cross section 1 width	Depth-max	Depth-ave	cross section 2 width	Depth-max	Depth-ave	cross section 3 width	Depth-max	Depth-ave
Table C-11, Stratum K											
RUNOFF											
136.4	6/3/80	200	20	11	180	42	26	210	22	12
136.3	6/4/80	140	60	28	140	38	17	160	54	18
POSTRUNOFF											
136.6	8/24/79	90	36	18	110	42	16	120	25	12
136.4	10/13/79	110	58	28	140	36	20	140	32	12
Table C-12, Stratum M											
RUNOFF											
163.6	5/28/80	990	6	4	990	5	3	950	5	3
163.6	6/2/81	960	5	3	980	4	3	930	5	3
Table C-13, Stratum N											
POSTRUNOFF											
115.8	10/10/79	140	32	12	160	28	10	180	20	10
Table C-14, Stratum O											
RUNOFF											
177.8	6/3/80	320	10	2	260	8	2	260	9	2
177.8	6/4/80	300	10	1	280	6	1	250	10	3

Table C (1-15) (Continued)

Widths and depths (in feet) of selected cross sections of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	cross section 1			cross section 2			cross section 3		
			width	Depth-max	Depth-ave	width	Depth-max	Depth-ave	width	Depth-max	Depth-ave
Table C-15, Stratum P											
					RUNOFF						
196.6	5/22/80		600	30	18	690	30	20	650	30	15
196.4	5/22/80		600	25	12	660	30	15	680	26	14

Table D (1-15)
Chemical characters of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	Temperature °C Air	Water	Dissolved Oxygen (mg/l)	Conductivity (umhos/cm)	Turbidity J.U.
Table D-1, Stratum A							
PRERUNOFF							
191.0	3/31/80		1	8.0	10	800	-
186.0	3/31/80		8	9.0	-	-	-
POSTRUNOFF							
178.0	9/1/80		36	26.0	9	1000	-
173.0	9/2/80		27	26.0	9	900	-
Table D-2, Stratum B							
PRERUNOFF							
206.0	3/29/80		12	8.0	10	740	-
200.8	3/29/80		8	9.0	-	800	-
212.0	3/4/81		15			800	-
207.0	4/4/81		21			900	-
POSTRUNOFF							
213.0	9/27/79		25	21.0	9	1000	18
208.0	9/28/79		25	18.0	9	1000	20
212.0	8/30/80		25	20.0	8	1375	-
207.0	8/30/80		25	20.5	8	1390	-

Table D (1-15) (Continued)
Chemical characters of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	Temperature ° C Air	Water	Dissolved Oxygen (mg/l)	Conductivity (umhos/cm)	Turbidity J.U.
			Table D-3, Stratum C				
			PRERUNOFF				
10.0	3/27/80		17	12.0	11	750	60
37.0	4/1/81		22	12.5	10	1100	-
32.0	4/2/81		24	11.5	10	1190	-
			RUNOFF				
34.0	6/10/80		24	16.0	10	285	120
39.0	5/26/81		27	20.0	10	1250	-
34.0	5/27/81		25	23.0	8	1200	-
			POSTRUNOFF				
27.0	9/24/79		20	23.5	10	1200	16
22.0	9/25/79		29	22.5	9	1000	15
9.0	8/27/80		25	22.0	7	1720	-
4.0	8/27/80		27	23.5	7	1720	-
			Table D-4, Stratum D				
			RUNOFF				
67.0	5/4/80		21	12.5	8	315	350
62.0	5/5/80		23	12.5	8	325	275
68.0	4/30/81		26	18.7	8	790	-
63.0	5/1/81		29	21.0	8	820	-

Table D (1-15) (Continued)
Chemical characters of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	Temperature ° C Air	Water	Dissolved Oxygen (mg/l)	Conductivity (umhos/cm)	Turbidity J.U.
			Table D-4, Stratum D (Continued)				
			POSTRUNOFF				
65.0	9/19/79		27	20.0	10	990	20
60.0	9/22/79		16	17.0	9	1100	18
54.0	10/6/80		38	18.0	5	1030	-
49.0	10/7/80		30	17.0	9	1230	-
			Table D-5, Stratum E				
			PRERUNOFF				
76.0	5/1/80		15	11.0	8	290	500
71.0	5/2/80		22	12.0	9	295	575
80.0	4/28/81		25	16.5	8	850	-
75.0	4/29/81		29	18.0	9	800	-
			RUNOFF				
78.0	7/10/80		30	22.0	9	800	78
73.0	7/11/80		27	22.0	8	700	60
82.0	6/3/81		20	18.8	8	650	-
77.0	6/4/81		27	20.0	7	650	-
			POSTRUNOFF				
80.0	9/18/79		25	20.0	9	1000	25
75.0	9/18/79		26	20.0	10	1000	24
84.0	10/1/80		32	22.0	9	1200	-
79.0	10/2/80		22	18.0	9	1250	-

Table D (1-15) (Continued)
Chemical characters of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	Temperature ° C Air	Water	Dissolved Oxygen (mg/1)	Conductivity (umhos/cm)	Turbidity J.U.
			Table D-4, Stratum D (Continued)				
			POSTRUNOFF				
65.0	9/19/79		27	20.0	10	990	20
60.0	9/22/79		16	17.0	9	1100	18
54.0	10/6/80		38	18.0	5	1030	-
49.0	10/7/80		30	17.0	9	1230	-
			Table D-5, Stratum E				
			PRERUNOFF				
76.0	5/1/80		15	11.0	8	290	500
71.0	5/2/80		22	12.0	9	295	575
80.0	4/28/81		25	16.5	8	850	-
75.0	4/29/81		29	18.0	9	800	-
			RUNOFF				
78.0	7/10/80		30	22.0	9	800	78
73.0	7/11/80		27	22.0	8	700	60
82.0	6/3/81		20	18.8	8	650	-
77.0	6/4/81		27	20.0	7	650	-
			POSTRUNOFF				
80.0	9/18/79		25	20.0	9	1000	25
75.0	9/18/79		26	20.0	10	1000	24
84.0	10/1/80		32	22.0	9	1200	-
79.0	10/2/80		22	18.0	9	1250	-

Table D (1-15) (Continued)
Chemical characters of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	Temperature °C Air	Water	Dissolved Oxygen (mg/1)	Conductivity (umhos/cm)	Turbidity J.U.
Table D-7, Stratum G (Continued)							
POSTRUNOFF							
126.0	10/9/79		25	17.0	10	1100	15
121.0	10/10/79		26	15.0	9	960	30
122.0	9/9/80		21	20.0	8	1350	-
116.0	9/9/80		17	19.0	9	1300	-
125.0	7/14/81		30	24.0	8	1400	-
120.0	7/14/81		38	25.0	8	1490	-
Table D-8, Stratum H							
PRERUNOFF							
143.0	5/12/80		10	9.5	8	280	85
138.0	5/13/80		29	10.5	-	490	85
RUNOFF							
140.0	7/22/80		40	25.0	9	1100	35
135.0	7/23/80		32	24.5	8	1100	45
147.0	5/13/81		22	15.0	7	900	-
142.0	5/14/81		19	15.0	9	1000	-
POSTRUNOFF							
153.0	8/23/79		38	27.0	10	900	15
148.0	8/23/79		36	25.0	10	950	16
131.0	10/14/80		20	23.0	10	1050	-
126.0	10/15/80		7	11.0	8	1100	-
149.0	6/23/81		35	26.0	8	500	-
144.0	6/24/81		34	25.0	8	1100	-

Table D (1-15) (Continued)
Chemical characters of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	Temperature ° C Air	Water	Dissolved Oxygen (mg/1)	Conductivity (umhos/cm)	Turbidity J.U.
			Table D-9, Stratum I				
			PRERUNOFF				
183.0	4/14/81		24	17.0	9	1000	-
178.0	4/14/81		23	14.0	9	850	-
			RUNOFF				
159.0	6/18/80		21	14.0	9	280	10
154.0	6/18/80		38	15.5	10	280	59
181.0	6/09/81		29	17.5	9	250	-
176.0	6/11/81		30	21.0	8	500	-
			POSTRUNOFF				
170.0	8/7/79		35	21.0	7	500	16
165.0	8/9/79		39	26.0	9	990	12
177.0	9/16/80		34	21.0	6	1000	-
172.0	9/17/80		21	22.0	8	1100	-
			Table D-10, Stratum J				
			PRERUNOFF				
197.0	9/22/80		18	13.0	8	650	360
192.0	4/23/80		13	11.4	8	650	350
			RUNOFF				
200.0	7/17/80		21	14.0	9	495	10
195.0	7/17/80		38	15.5	10	450	10
210.0	5/19/81		29	17.5	9	650	-
176.0	5/20/81		30	21.0	8	650	-

Table D (1-15) (Continued)
Chemical characters of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	Temperature °C Air	Water	Dissolved Oxygen (mg/l)	Conductivity (umhos/cm)	Turbidity J.U.
			Table D-10, Stratum J (Continued)				
			POSTRUNOFF				
191.0	7/19/79			-			
186.0	7/20/79			-			
201.0	9/22/80		21	22.5	10	900	-
196.0	9/23/80		22	15.0	9	850	-
205.0	6/29/81		31	21.0	8	700	-
200.0	7/1/81		22	20.0	8	800	-
			Table D-11, Stratum K				
			RUNOFF				
136.4	6/13/80		20	11.5	10	290	100
136.3	6/4/81		31	19.0	8	600	-
			POSTRUNOFF				
136.6	7/24/79		25	24.0	9	1200	48
136.4	10/13/79		16	14.0	9	1000	20
			Table D-12, Stratum L				
			RUNOFF				
163.6	5/28/80		25	20.0	9	880	65
163.6	6/2/81		29	24.5	8	1650	-

Table D (1-15) (Continued)
Chemical characters of the Upper Colorado River

River Mile RM	Date	Flow (cfs)	Temperature ° C Air	Water	Dissolved Oxygen (mg/l)	Conductivity (umhos/cm)	Turbidity J.U.
			Table D-13, Stratum M				
			POSTRUNOFF				
115.8	10/10/79		9	14.5	10	920	18
			Table D-14, Stratum N				
			RUNOFF				
177.8	6/3/81		19	13.5	8	1100	-
177.8	6/3/81		20	14.0	8	1100	-
			POSTRUNOFF				
115.8	10/10/79		9	14.5	10	920	18
			Table D-15, Stratum O				
			RUNOFF				
196.6	5/22/80		21	12.0	-	-	-
196.4	5/22/80		19	11.0	-	-	-
			POSTRUNOFF				
115.8	10/10/79		9	14.5	10	920	18

Table E-1
Data associated with 337 young-of-the-year Colorado squawfish (<60 mm TL) captured in the Upper Colorado River, 1979-1981

River mile*	Date	YOY number	Habitat type	Depth (f)	Velocity (fps)	Primary substrate#
-11.0	04/05/81	001	BA	01.4	0.0	SI
-10.7	03/29/80	001	BA	01.2	0.2	SI
-09.0	09/28/79	001	BA	02.6	0.0	SI
-09.0	09/28/79	008	BA	02.6	0.0	SI
004.0	08/28/80	002	RU	00.6	0.1	SA
004.0	08/28/80	002	BA	00.3	0.0	SA
004.5	09/26/79	017	BA	01.7	0.1	SI
005.0	03/27/80	008	RU	01.2	0.5	GR
005.0	03/27/80	001		01.2	0.0	SI
005.2	09/26/79	001	BA	01.3	0.0	SI
008.5	08/27/80	001	BA	00.5	0.0	SI
008.6	09/26/79	015	BA	01.5	0.0	SI
008.7	08/27/80	003	RU	00.2	0.2	SA
009.9	03/27/80	004	RU	00.3	0.2	SI
009.9	03/27/80	002	RU	00.9	0.4	SI
016.9	09/25/79	045	BA	00.7	0.0	SI
021.5	09/25/79	030	BA	00.3	0.1	SI
026.8	09/25/79	006	BA	01.5	0.0	SI
026.8	09/25/79	016	BA	01.5	0.0	SI
026.9	09/24/79	001	BA	01.5	0.0	SI
034.1	09/24/79	005	BA	00.7	0.0	SA
034.8	09/24/79	106	BA	00.6	0.0	SA
038.5	05/27/81	015	BA	03.0	0.0	SI
041.0	05/27/81	003	BA	02.0	0.0	SI
042.4	05/28/81	002	BA	01.0	0.0	SA
053.9	10/06/80	001	BA	00.7	0.0	SI
054.0	10/07/80	007	BA			
054.5	07/15/80	001	RU	01.1	0.3	SI
054.5	07/15/80	006	BA	00.8	0.1	SI
067.0	04/30/81	001	BA	00.6	0.2	SA
067.0	04/30/81	001	BA	00.7	0.0	SA
078.7	10/02/80	001	SC	00.6	0.5	SA
083.6	10/01/80	002	BA	00.4	0.0	SI
083.7	10/01/80	012	BA	00.4	0.0	SI
086.0	07/09/80	001	BA	00.3	0.0	RU
086.7	07/09/80	001	BA	01.0	0.0	SA
092.5	10/29/79	001	BA	00.6	0.0	SA
110.4	10/11/79	006	BA	00.7	0.1	SI

*Miles upstream or downstream (-) from the Green River confluence.

Table E-2
Data associated with 50 juvenile Colorado squawfish captured in the Upper Colorado River, 1979-1981

River Mile*	Date	Red Tag Number	Total Length (m)	Weight (g)	Sex+	Habitat Type#	Depth (f)	Velocity (fps)	Primary Substrate#
-20.5	05/29/80	0686	163	0030	U	LK	06.0	0.0	SI
-20.5	05/29/80	0604	228	0090	U	LK	06.0	0.0	SI
-19.5	05/29/80	0620	224	0080	U	LK	04.0	0.0	SI
-03.5	09/26/79		164	0020		BA	33.2	0.0	SI
000.1	09/26/79		137	0014		BA	02.0	0.0	SI
000.1	09/26/79		134	0014		BA	02.0	0.0	SI
000.1	09/26/79		127	0013		BA	02.0	0.0	SI
001.5	04/03/81	2586	296	0220	U	BA	12.0	0.0	SI
001.5	04/03/81	3824	381	0420	U	BA	12.0	0.0	SI
001.5	04/03/81	0864	381	0420	U	BA	12.0	0.0	SI
008.6	09/26/79		110	0009		BA	01.5	0.0	SI
016.9	09/25/79		178	0012		BA	00.7	0.0	SI
026.8	09/24/79		120	0010		BA	01.8	0.0	SI
026.8	09/24/79		160	0010		BA	01.8	0.0	SI
026.8	09/25/79		154	0010		BA	01.5	0.0	SI
026.8	09/24/79		152	0010		BA	01.8	0.0	SI
026.8	09/24/79		128	0010		BA	01.8	0.0	SI
026.8	09/24/79		158	0010		BA	01.8	0.0	SI
026.8	09/24/79		127	0006		BA	01.8	0.0	SI
026.8	09/24/79		171	0010		BA	01.8	0.0	SI
026.8	09/24/79		127	0010		BA	01.8	0.0	SI
026.8	09/24/79		157	0010		BA	01.8	0.0	SI
026.8	09/24/79		165	0008		BA	01.8	0.0	SI
026.8	09/24/79		125	0010		BA	01.8	0.0	SI
026.8	09/24/79		145	0010		BA	01.8	0.0	SI
026.8	09/24/79		165	0010		BA	01.8	0.0	SI
026.8	09/24/79		172	0010		BA	01.8	0.0	SI
026.8	09/24/79		151	0010		BA	01.8	0.0	SI
031.6	04/02/81	2825	369	0380	U	RU	04.0	0.7	SI
048.2	06/11/80	3507	340	0340	U	BA	05.6	0.0	SI
048.2	05/06/80	2584	301	0200	U	BA	01.5	0.0	SI
048.2	05/06/80	2332	297	0200	U	BA	01.5	0.0	SI
048.2	06/11/80	2418	330	0340	U	BA	04.1	0.0	SI
048.2	06/11/80	3966	305	0270	U	BA	01.0	0.0	SI
053.4	09/21/79		124	0007		BA	02.4	0.0	SI
065.2	09/20/79		116	0020		RU	01.9	1.5	SI
065.2	09/20/79		139	0020		RU	01.9	1.5	SI
065.3	09/20/79		095	0009		RU	00.7	0.3	SI
067.0	05/04/80	0425	145	0060		BA	04.9	0.1	SI
075.0	04/29/81	3222	381	0580		RU	06.8	0.1	SI
075.0	04/29/81		205	0060		BA	00.9	0.0	SA
075.0	09/18/79		102	0008		BA	01.1	0.0	SI
075.0	04/30/81		185	0050	U	RU	00.5	0.0	SA
075.0	05/01/80	0648	400	0600	U	RU	10.6	0.5	RU
077.5	07/10/80		095		U	ED	01.3	0.1	SA
115.8	10/10/79	0565	366	0932		ED	09.6	0.1	RU
121.8	09/09/80		102			RU	01.4	1.0	RU
125.5	10/17/80		145			BA	03.5	0.0	SI
135.8	11/03/79	0831	383	0425		RU	04.2	0.4	BO
138.8	08/24/79		079			PO	02.2	0.0	SI

*Miles upstream or downsteam (-) from the Green River confluence.
+M = Male, F = Female, U = Undetermined
#See Glossary of Terms, Appendix A

Table E-3
Data associated with 144 adult Colorado squawfish captured in the Upper Colorado River, 1979-1981

River Mile*	Date	Red Tag Number	Total Length (m)	Weight (g)	Sex+	Habitat Type#	Depth (f)	Velocity (fps)	Primary Substrate#
-20.5	05/26/80	0662	471	0806	U	LK	06.0	0.0	SI
-20.1	06/12/80	0679	577	2183	U	LK	10.0	0.5	SI
-20.1	06/17/80	0679	577	2013	U	LK	15.0	0.2	SI
-20.1	06/17/80	0628	573	1559	U	LK	03.0	0.3	SI
-20.1	06/12/80	0625	406	0652	U	LK	10.0	0.5	SI
-20.1	05/09/80		624	2381	U	LK	03.0	0.3	SI
-20.1	05/09/80		464	2041	U	LK	03.0	0.3	SI
-20.1	05/09/80		610	2296	U	LK	03.0	0.3	SI
-20.0	04/30/80		677	2041	U	LK	10.0	0.3	SI
-20.0	06/04/80	0644	621	2353	U	LK	15.0	0.1	SI
-20.0	05/29/80		664	3050	U	LK	10.0	0.1	SI
-19.9	05/15/80		734	3685	U	LK	03.0	0.0	SI
-19.9	05/16/80	0642	656	2325	U	LK	03.0	0.0	SI
-19.9	05/03/80		560	1729	U	LK	05.0	0.1	SI
-19.9	05/03/80		672	2722	U	LK	05.0	0.1	SI
-19.9	08/27/80	0673	639	2070	U	LK	10.0	0.2	SI
-19.9	05/16/80		631	2608	U	LK	03.0	0.0	SI
-19.9	05/24/80	0612	595	2807	U	LK	12.0	0.1	SI
-19.9	05/27/80	0640	618	2041	U	LK	10.0	0.2	SI
-19.9	05/16/80		630	2268	U	LK	03.0	0.0	SI
-19.9	05/04/80		569	1758	U	LK	33.0	0.0	SI
-19.9	05/31/80	0670	585	1559	U	LK	18.0	0.5	SI
-19.8	05/21/80	0697	578	2211	U	LK	10.0	0.5	SI
-19.8	05/11/80		625	2637	U	LK	10.0	0.5	SI
-19.8	05/11/80		690	3062	U	LK	10.0	0.5	SI
-19.8	05/10/80		653	2580	U	LK	12.0	0.5	SI
-19.8	05/11/80		526	2041	U	LK	10.0	0.5	SI
-19.8	05/23/80	0656	409	0652	U	LK	10.0	0.5	SI
-19.8	05/15/80		580	2183	U	LK	15.0	0.5	SI
-19.8	04/30/80		677	2040	U	LK	10.0	0.3	SI
-19.8	05/02/80		610	1928	U	LK	06.0	0.2	SI
-19.8	04/27/80		532	2211	U	LK	10.0	0.3	SI
-19.8	05/10/80		532	1474	U	LK	12.0	0.5	SI
-19.8	04/27/80		667	2948	U	LK	10.0	0.3	SI
-19.8	05/01/80		590	2068	U	LK	10.0	0.3	SI
-19.5	05/02/80		580	1814	U	LK	08.0	0.5	SI
-19.5	05/09/80		587	1871	U	LK	10.0	0.5	SI
-19.5	04/26/80		660	2494	U	LK	07.0	0.5	SI
-19.3	06/01/80	0666	575	1956	U	LK	10.0	0.3	SI
-19.3	05/04/80		586	2041	U	LK	05.0	0.1	SI
-19.3	06/01/80	0681	650	2183	U	LK	10.0	0.3	SI
-19.3	05/03/80		636	2637	U	LK	77.0	0.2	SI
-19.3	05/04/80		419	0680	U	LK	05.0	0.1	SI
-19.3	05/02/80		571	2070	U	LK	05.0	0.1	SI
-18.0	05/01/80		555	1726	U	LK	10.0	0.5	SI
-18.0	05/01/80		586	1844	U	LK	10.0	0.5	SI
-18.0	05/02/80		580	1758	U	LK	10.0	0.5	SI
-18.0	05/01/80		579	1670	U	LK	10.0	0.5	SI
-03.0	05/20/80	0614	600	1702	U		00.5		
-03.0	05/20/80	0607	693	2383	U		07.5		
-03.0	05/20/80		602	1674	U		07.5		
001.4	04/03/81	0846	613	1640		BA	04.5	0.0	SA
001.5	04/03/81	2993	498	0900	U	BA	12.0	0.0	SI
031.5	04/02/81	2577	645	2200	U	RU	06.0	0.0	SA
036.0	05/27/81	2544	625	2180	F	RU	08.0	0.2	SA
048.2	06/11/80	0614	468	1000	U	BA	06.1	0.0	SI
062.0	05/06/80	0636	586	1750	U	RU	04.3	1.1	SI
065.2	09/20/79	0524	562	1640		SH	06.4	1.4	BO
075.0	05/01/80	0655	575	1830	U	RU	05.9	1.0	RU
076.6	06/04/81	3409	412	0680	U	RU	05.4	1.1	SA

Table E-3 (continued)

River Mile*	Date	Red Tag Number	Total Length (m)	Weight (g)	Sex+	Habitat Type#	Depth (f)	Velocity (fps)	Primary Substrate#
076.7	06/04/81	2417	409	0500	U	RU	01.5	0.5	SI
076.8	06/04/81	2585	539	1380	U	RU	04.4	1.3	RU
088.8	10/29/79	0811	566	1540		ED	05.1	0.2	SI
088.8	10/29/79	0889	532	1230		ED	05.1	0.2	SI
088.8	10/29/79	0803	575	1450		ED	05.1	0.2	SI
088.8	10/29/79	0810	584	1580		ED	05.1	0.2	SI
107.0	06/02/81	2590	541	1640	U	ED	03.5	0.1	SA
115.8	10/10/79	0507	515	1310		ED	09.6	0.3	RU
116.0	08/13/81		450	1500	U	ED	01.0	0.0	SA
121.9	09/10/80	2914	505	1100	U	RU	11.0	1.0	BE
135.5	10/13/79	0528	543	1100		RU	06.6	0.9	BO
135.5	05/01/81	0746	726	3060	M	BA	02.5	0.0	RU
135.5	10/14/79	0552	558	1246		RU	06.8	0.7	BO
135.5	10/14/79	0862	582	1550		RU	06.8	0.7	BO
135.5	10/13/79	0545	444	0750		RU	04.0	0.3	BO
135.8	10/13/79	0503	495	0925		RU	09.1	0.8	BO
135.6	08/26/79	0597	502	0900		RU	07.0	0.3	BO
135.6	08/25/79	0506	578	1210		RU	06.0	0.2	BO
135.6	11/03/79	0801	795	4640		RU	06.0	0.6	BO
135.7	10/13/79	0506	560	1300		RE	07.2	0.3	BE
135.7	11/01/80	0788	525	0794	U				
135.7	11/01/80	0766	631	1588	U				
135.7	11/01/80	0729	447	0635	U				
135.7	10/13/79	0541	541	1240		ED	07.2	0.3	BE
135.7	11/04/79	0723	578	1400		RU	05.0	0.8	BO
135.7	11/01/80	0746	718	2948	U				
135.7	08/15/80	0708	510	1361	U	ED	15.0	.8	BO
135.7	11/01/80	0707	542	0907	U	SH	04.0	1.5	BO
135.7	10/13/79	0596	664	2220		ED	07.2	0.3	BE
135.8	11/03/79	0827	526	1100		RU	06.9	0.8	BO
135.8	11/03/79	0819	540	1100		RU	05.2	0.2	BO
135.8	11/03/79	0503	493	0890		RU	04.1	0.1	BE
135.8	11/03/79	0814	542	1280		RU	12.8	1.1	RU
135.8	11/03/79	0801	795	4640		RU	04.1	0.1	BE
135.8	10/14/79	0528	543	1100		PO	20.0	0.2	SA
135.8	11/03/79	0825	510	1000		RU	04.1	0.1	BE
135.8	11/03/79	0805	602	1860		RU	04.2	0.2	BO
135.8	11/03/79	0528	545	1140		RU	04.1	0.1	BE
135.8	11/03/79	0820	553	1180		RU	04.1	0.1	BE
135.9	08/29/79	0508	586	1400		RU	02.6	3.8	BO
135.9	08/29/79	0537	554	1230		PO	02.6	3.8	BO
136.0	04/23/79	9904	494		U	RU		3.0	
136.0	04/22/79	9902	460		U	SH			
136.0	04/23/79	9903	670		U	SH			
136.0	04/24/79	9905	705		U	PO	04.6		SA
136.1	10/13/79	0582	566	1400		RU	07.9	1.3	BE
136.2	10/14/79	0579	589	1362		ED	24.4	0.2	BE
136.2	10/14/79	0526	528	1135		ED	24.4	0.2	BE
136.6	07/22/80	2548	690	2400	F	RU	06.5	1.0	SA
139.5	11/03/79	0842	700	3220		RU	04.4	0.4	BO
142.5	05/14/81	2535	S85	1860		RU	03.0	1.0	SA
143.4	03/25/80	0516	595	1542	U	RU	04.4	0.0	BO
143.7	11/03/79	0739	465	0760		RU	05.5	0.4	BO
143.8	10/13/79	0516	595	1550		SH	05.8	1.0	BO
143.8	10/13/79	0521	530	1100		SH	06.4	0.7	BO
143.8	10/13/79	0578	535	1200		SH	07.1	0.7	BO
146.6	05/12/81	2520	760	5200	F	RU	12.7	0.3	SI
146.9	05/12/81	2599	659	2700	F	BA	01.0	0.1	SI
147.0	08/13/80	0703	668	2268	U	SH	6.0	1.7	BO
148.4	08/23/79	0501	870	6050		RU	04.6	0.9	SI
153.0	06/18/80	0610	688	3420	F	SC	03.2	0.8	SI
163.6	09/23/79	9951	495	1130	U	GP	04.0	0.0	SI
163.6	09/21/79	9944	457	0960	U	GP	05.0	0.0	SI

Table E-3 (continued).

River Mile*	Date	Red Tag Number	Total Length (m)	Weight (g)	Sex+	Habitat Type#	Depth (f)	Velocity (fps)	Primary Substrate#
163.6	08/16/79	0509	525	0820		GP	05.4	0.0	SI
163.6	05/17/79	9906	820	5902	U	GP	05.0	0.0	SI
163.6	09/25/79	9954	465	0890	U	GP	05.0	0.0	SI
175.2	06/10/81	2562	572	1620	F	BA	06.0	0.0	SI
175.2	06/10/81	2509	528	1480	F	BA	04.0	0.5	SI
177.8	06/08/80	0657	586	1460	U	GP	04.0	0.0	SI
177.8	06/08/80	0657	586	1754	U	GP	02.2	0.0	SI
177.8	06/05/80	0882	590	1645	U	GP	03.2	0.0	SI
185.1	09/13/79	9934	513	1200	U	RU	08.0	0.5	GR
185.1	09/12/79	9936	559	1350	U	RU	06.0	1.0	GR
185.1	09/13/79	9935	554	1400	U	RU	08.8	0.5	GR
185.1	09/12/79	9937	495	0465	U	RU	06.0	1.0	GR

*Miles upstream or downstream (-) from the Green River confluence.
+M = Male, F = Female, U = Undetermined
#See Glossary of Terms, Appendix A

Table F-1
Data associated with two young-of-the-year humpback chub captured in the upper Colorado River, 1979-1981

River Mile*	Date	Red Tag Number	Total Length (m)	Weight (g)	Sex+	Habitat Type#	Depth (f)	Velocity (fps)	Primary Substrate#
110.4	10/11/79		042	0003		BA	00.9	0.0	SI
110.4	10/11/79		045	0003		BA	00.9	0.0	SI

*Miles upstream or downstream (-) from the Green River confluence
+M = Male, F = Female, U = Undetermined
#See Glossary of Terms, Appendix A

Table F-2
Data associated with 34 juvenile humpback chub captured in the upper Colorado River, 1979-1981

River Mile*	Date	Red Tag Number	Total Length (m)	Weight (g)	Sex+	Habitat Type#	Depth (f)	Velocity (fps)	Primary Substrate#
072.5	07/11/80		127	0010	I	ED	03.0	0.2	SI
116.0	08/20/80	2581	155	0030	I	ED	22.0	2.0	BE
116.0	08/20/80		170	0020	I	ED	16.0	1.6	BE
116.0	08/20/80	2526	245	0100	M	ED	22.0	2.0	BE
118.5	08/13/81		180	0120	I	ED	10.0	0.6	BO
118.5	08/13/81		145	0065	I	ED	10.0	0.6	BO
118.5	08/13/81		173	0090	I	ED	10.0	0.6	BO
120.5	10/09/79	0542	247	0126		ED	05.7	0.5	SA
121.5	09/10/80		188	0030	I	ED	35.0	0.8	BE
121.9	09/10/80	2913	222	0140	I	RU	05.6	0.6	GR
122.0	07/15/81		085	0015	I	RU	02.5	0.1	BO
122.0	08/12/81		167	0046	I	ED	10.0	0.5	BO
122.0	08/12/81	2527	213	0102	I	ED	10.0	0.5	BO
122.0	09/09/80		119	0028	I	RU	01.4	1.0	RU
123.6	04/08/80	0840	240	0140	M	ED	12.7	0.7	BE
123.7	04/08/80	0891	210	0076	M	RU	05.6	1.0	BE
123.7	04/08/80	0857	210	0078	M	RU	05.6	1.0	BE
123.7	04/08/80	0841	220	0102	M	RU	05.6	1.0	BE
123.8	04/08/80	0857	210	0078	M	ED	03.0	0.3	SA
124.4	07/14/81		093	0020	I	RU	01.2	0.5	BO
135.6	10/13/79	0408	205	0104		ED	27.3	0.2	BE
135.9	08/25/79	0543	230	0100		RU	07.6	0.2	BO
135.9	08/25/79	0534	255	0125		PO	20.0	0.2	SI
136.0	06/02/80	0838	217	0080	M	RU	12.5	0.8	BE
136.0	06/02/80	0886	255	0165	F	RU	12.5	0.8	BE
136.0	07/23/80		149	0028	I	PO	28.0	1.0	SA
136.1	10/13/79	0592	229	0280		RU	17.9	1.3	BE
136.1	08/25/79		099			ED	01.9	0.2	SI
136.3	08/24/79		131	0010		RU	17.8	1.8	BO
136.4	10/13/79	0529	257	0160		RU	05.4	1.0	BO
136.5	04/30/81	0923	256	0389	M	RU	28.0	1.0	BO
136.5	04/30/81	0901	202	0200	I	RU	22.0	1.8	SA
139.7	07/22/80	2573	196	0007	I	RU	05.7	1.0	GR
139.8	07/22/80	2511	250	0100	I	RU	06.6	0.4	GR

*Miles upstream or downstream (-) from the Green River confluence
+M = Male, F = Female, U = Undetermined
#See Glossary of Terms, Appendix A

Table F-3
Data associated with 203 adult humpback chub captured in the upper Colorado River, 1979-1981

River Mile*	Date	Red Tag Number	Total Length (m)	Weight (g)	Sex+	Habitat Type#	Depth (f)	Velocity (fps)	Primary Substrate#
-10.8	03/29/80	0893	316	0216		PO	17.7	0.6	SA
116.0	08/20/80	2012	351	0300	M	ED	16.0	1.6	BE
117.5	10/11/79	0548	323	0258		ED	09.6	1.1	BO
118.5	08/13/81	0853	332	0280	M	ED	10.0	0.6	BO
119.8	04/09/80	0890	360	0420	M	RU	06.5	0.2	SA
120.0	04/09/80	0663	338	0320	M	ED	05.5	0.9	SI
120.0	04/09/80	0879	322	0264	F	ED	05.5	0.9	SI
120.5	10/09/79	0585	324	0258		RU	07.0	0.3	BO
120.5	10/09/79	0589	329	0274		ED	02.4	0.8	SA
120.5	10/09/79	0540	335	0300		ED	05.2	0.1	SA
120.5	10/09/79	0518	323	0248		RU	10.0	0.2	BO
120.5	10/10/79	0584	341	0297		RU	10.0	0.2	BO
120.5	10/09/79	0598	299	0240		ED	05.7	0.5	SA
120.5	10/09/79	0591	326	0240		ED	06.2	0.8	SA
120.5	10/09/79	0566	366	0384		ED	02.4	0.8	SA
120.5	10/09/79	0517	362	0330		ED	05.7	0.5	SA
121.0	04/09/80	0828	297	0184	F	ED	13.1	0.7	BE
121.0	04/09/80	0897	268	0326	F	ED	13.1	0.7	BE
121.5	09/10/80	2918	334	0290	M	ED	35.0	0.8	BE
121.5	09/10/80	2906	345	0300	F	ED	40.0	0.5	BE
121.5	09/10/80	2947	342	0280	F	ED	35.0	0.8	BE
121.5	09/10/80	2952	290	0210	F	ED	35.0	0.8	BE
121.5	09/10/80	2944	320	0280	M	ED	40.0	0.5	BE
122.0	08/19/80	2501	345	0380	F	RU	28.6	1.2	BE
122.0	08/19/80	2534	345	0350	F	RU	28.6	1.2	BE
122.0	08/19/80	2595	352	0355	F	RU	28.6	1.2	BE
122.0	08/19/80	2574	300	0220	F	RU	28.6	1.2	BE
122.0	08/19/80	2513	297	0260	F	RU	28.6	1.2	BE
122.5	04/09/80	0823	325	0260	F	ED	04.8	0.3	SI
122.5	04/09/80	0866	317	0272	F	ED	04.8	0.3	SI
122.5	04/09/80	0896	359	0360	F	ED	44.8	0.3	SI
122.5	04/09/80	0866	326	0228	F	ED	04.8	0.3	SI
123.3	08/19/80	2510	340	0320	M	RU	36.0	0.8	BE
123.3	08/19/80	2588	320	0290	I	RU	36.0	0.8	BE
123.6	04/08/80	0858	327	0285	M	ED	12.7	0.7	BE
123.6	04/09/80	0873	371	0381	F	ED	12.4	0.6	BO
123.7	04/08/80	0833	307	0244	M	RU	31.0	0.9	BE
123.7	04/08/80	0818	309	0252	M	ED	29.4	0.2	BE
123.7	04/08/80	0871	356	0386	M	RU	31.0	0.9	BE
123.7	04/19/80	2552	368	0430	M	RU	15.6	1.0	BE
123.7	08/19/80	2542	359	0440	M	RU	15.6	1.0	BE
123.7	08/19/80	2523	331	0320	F	RU	15.6	1.0	BE
124.1	08/19/80	2538	331	0345	F	RU	22.5	1.5	BE
124.1	08/19/80	2533	330	0300	F	RU	22.5	1.5	BE
132.0	08/26/79	0536	381	04*0		PO	05.0	1.8	BE

Table F-3 (continued)

River Mile*	Date	Red Tag Number	Total Length (m)	Weight (g)	Sex+	Habitat Type#	Depth (f)	Velocity (fps)	Primary Substrate#
135.6	10/13/79	0546	343	0300		ED	27.3	0.2	BE
135.6	05/01/81	0934	352	0364	M	RU	07.0	1.0	BO
135.6	10/13/79	0544	303	0220		ED	27.3	0.2	BE
135.6	10/13/79	0575	335	02*0		ED	27.3	0.2	BE
135.6	10/13/79	0595	325	0240		ED	27.3	0.2	BE
135.6	11/01/80	0586	326	0113	I	SH	2.5	0.0	BO
135.7	08/15/80	0808	337	0340	I	ED	11.0	0.6	BO
135.7	08/15/80	0706	312	0454	I	ED	11.0	0.6	BO
135.7	08/15/80	0705	285	0113	I	ED	13.0	.7	BO
135.7	10/13/79	0527	272	0200		ED	07.2	0.3	BE
135.8	10/13/79	0580	351	0344		RU	11.6	0.6	BE
135.8	10/14/79	0588	335	0310	I	PO	18.6	0.4	BO
135.8	10/14/79	0539	390	0444		PO	20.0	0.2	SA
135.8	10/13/79	0550	345	0300		RU	06.5	0.1	BE
135.8	11/01/80	0755	359	0272	I	ED	5.0	0.0	BO
135.8	03/26/80	0716	340	0272	I	PO	20.0	0.0	SI
135.8	11/01/80	0799	337	0272	I	ED	5.0	0.0	BO
135.8	11/01/80	0782	349	0340	I	ED	5.0	0.0	BO
135.8	10/14/79	0533	302	0244		PO	20.0	0.2	SA
135.8	10/14/79	0573	343	0274		PO	20.0	0.2	SA
135.8	10/14/79	0576	321	0270		PO	20.0	0.2	SA
135.8	03/26/80	0719	299	0181	I	RU	05.0	1.0	BO
135.8	05/02/81	0903			I	PO			
135.8	03/26/80	0718	307	0227	I	PO	20.0	0.0	SI
135.8	03/26/80	0719	299	0181	I	PO	20.0	0.0	SI
135.8	10/13/79	0523	351	0360		RU	06.5	0.1	BE
135.8	03/26/80	0*00	331	0318	I	RU	05.0	1.0	BO
135.8	10/13/79	0574	330	0208		RU	06.5	0.1	BE
135.8	10/14/79	0571	315	0212		PO	20.0	0.2	SA
135.8	03/26/80	0717	346	0363	I	PO	20.0	0.0	SI
135.8	10/14/79	0564	351	0340		PO	04.6	0.6	BO
135.8	03/26/80	0715	367	0290	I	PO	20.0	0.0	SI
135.8	08/20/80	0514			I	PO			
135.9	08/25/79		318	0210		PO	20.0	0.2	SI
135.9	04/29/81	0975	339	0701	F	RU	07.0	0.5	BO
135.9	11/04/79	0804				PO	40.0	0.2	SA
135.9	03/26/80	0714	298	0184	I	ED	15.0	0.1	BO
135.9	11/04/79	0815				PO	30.0	0.2	SA
135.9	08/25/79	0556	340	0330		PO	20.0	0.2	SI
135.9	08/26/79	0567	373	0410		RU	07.6	0.2	BO
135.9	11/04/79	0813	287			PO	18.0	0.9	SI
135.9	08/25/79	0586	321	0240		PO	02.6	3.8	BO
135.9	08/25/79	0551	347	0285		PO	20.0	0.2	SI
135.9	08/25/79	0599	338	0280		PO	20.0	0.2	SI
135.9	08/25/79	0583	372	0380		RU	07.6	0.2	BO
135.9	08/25/79	0530	325	0240		OO	20.0	0.2	SI
135.9	08/25/79	0559	345	0275		PO	20.0	0.2	SI
135.9	08/25/79	0550	342	0300		RU	07.6	0.2	BO
135.9	08/25/79	0522	329	0565		PO	20.0	0.2	SI
135.9	08/25/79	0588	331	0300		PO	20.0	0.2	SI
135.9	08/25/79	0525	326	0240		RU	07.6	0.2	BO
135.9	08/26/79	0570	282	0204		RU	07.6	0.2	BO
135.9	08/25/79	0567	373	0410		PO	20.0	0.2	SI
135.9	04/29/81	2974	319	0496	M	RU	07.0	0.5	BO
135.9	08/25/79	0538	370	0376	I	PO	20.0	0.3	BO
135.9	08/25/79	0587	380	0390		PO	20.0	0.2	SI
135.9	08/25/79	0515	310	0240		PO	20.0	0.2	SI
135.9	08/26/79	0554	336	0222		PO	20.0	0.2	SI
135.9	08/25/79	0519	325	0245		PO	20.0	0.2	SI
135.9	11/04/79					PO	35.5	0.2	SA
135.9	03/26/80	0712	332	0272	I	ED	15.0	0.1	BO
135.9	08/25/79	0514	290	0210		PO	20.0	0.2	SI
135.9	11/04/79	0821				PO	16.0	0.3	SA
135.9	08/25/79	0562	308	0204		RU	07.6	0.2	BO
135.9	11/04/79					PO	35.5	0.3	SA
135.9	11/04/79	0806				PO	35.0	0.3	SA

Table F-3 (continued)

River Mile*	Date	Red Tag Number	Total Length (m)	Weight (g)	Sex+	Habitat Type#	Depth (f)	Velocity (fps)	Primary Substrate#
135.9	11/04/79					PO	30.0	0.3	SA
135.9	08/25/79	0549	322	0304		RU	07.6	0.2	BO
135.9	04/29/81	0994	296	0416	M	RU	05.0	0.2	SA
135.9	08/25/79	0593	344	0225		PO	20.0	0.2	SI
135.9	08/25/79	0532	321	0220		PO	20.0	0.2	SI
135.9	03/26/80	0713	338	0318	I	ED	15.0	0.1	BO
135.9	08/26/79	0535	325	0260		RU	07.6	0.2	BO
135.9	08/25/79	0512	310	0240		PO	20.0	0.2	SI
135.9	03/26/80	0711	333	0272	I	ED	15.0	0.1	BO
135.9	04/29/81	0912	336	0500	F	RU	03.0	0.1	SA
135.9	08/25/79	0581	360	0300		PO	20.0	0.2	SI
135.9	08/25/79	0560	369	0380		RU	02.6	3.8	BO
135.9	11/04/79	0809				PO	45.0	0.1	SA
135.9	08/25/79	0515	310	0240		RU	07.6	0.2	BO
135.9	11/04/79					PO	30.0	0.2	SA
135.9	08/26/79	0577	312	0260		RU	07.6	0.2	BO
135.9	08/25/79	0560	369	0380		PO	20.0	0.2	SI
136.0	10/13/79	0590	314	0180		RU	06.6	0.7	SA
136.0	06/03/80	0847	370	0440	F	RU	07.0	0.5	SA
136.0	10/13/79	0594	342	0260		RU	06.0	0.7	SA
136.0	06/03/80	0646	343	0365	M	RU	07.0	0.5	SA
136.0	06/03/80	0802	352	0400	M	RU	07.0	0.5	SA
136.0	06/02/80	0863	340	0400	M	RU	10.0	0.5	BE
136.0	06/02/80	0835	362	4030	F	RU	09.2	0.7	BE
136.0	06/02/80	0861	333	0265	M	RU	10.0	0.5	BE
136.0	10/13/79	0562	293	0120		RU	06.6	0.7	SA
136.0	04/29/81	0929	293	0266	F	RU	03.0	0.4	SA
136.0	04/29/81	0905	330	0397	M	RU	20.0	0.9	BE
136.0	07/23/80	0837	332	0270	M	PO	22.0	0.5	BO
136.0	10/13/79	0553	327	0260		RU	06.6	0.7	SA
136.0	06/03/80	0683	380	0540	F	RU	07.0	0.5	SA
136.0	10/13/79	0572	364	0280		RU	06.6	0.7	SA
136.0	06/03/80	0650	372	0420	M	RU	07.0	0.5	SA
136.0	06/02/80	0850	372	0500	F	RU	12.5	0.8	BE
136.0	06/02/80	0899	363	0370	M	RU	09.2	0.7	BE
136.0	06/03/80	0699	350	0340	M	RU	07.0	0.5	SA
136.0	06/03/80	0839	325	0300	I	RU	07.0	0.5	SA
136.0	06/02/80	0829	371	0425	M	RU	12.5	0.8	BE
136.0	08/01/80	0595			I				
136.0	06/02/80	0881	392	0580	F	RU	09.2	0.7	BE
136.0	07/23/80	0645	364	0330	I	PO	28.0	1.0	SA
136.0	07/23/80	0830	345	0320	M	PO	32.0	0.5	BO
136.0	10/13/79	0568	375	0270		RU	06.6	0.7	SA
136.0	06/03/80	0844	364	0460	F	RU	07.0	0.5	SA
136.1	10/13/79	0557	275	0225		RU	07.9	1.3	BE
136.1	11/04/79	0816				PO	22.5	0.2	BE
136.1	11/04/79	0553	321	0275		PO	17.5	0.3	SA
136.1	03/26/80	0702	322	0272	I	PO	12.0	0.2	SA
136.1	11/04/79	0832				PO	22.0	0.5	SA
136.1	08/25/79	0510	335	0300		PO	04.6	1.8	SA
136.1	11/04/79	0812				PO	15.0	0.2	SA
136.1	11/04/79	0807				PO	36.0	0.4	BE
136.1	10/13/79	0555	336	0320		RU	07.9	1.3	BE
136.1	08/25/79	0500	383	0410		PO	07.5	0.2	BO
136.1	08/25/79	0505	328	0250		PO	07.5	0.2	BO
136.1	11/04/79	0800				PO	45.5	0.6	SA
136.1	11/04/79	0817				PO	26.5	0.1	BE
136.1	11/04/79	0822				PO	40.0	0.3	SI
136.1	05/14/80	0511	352	0376	M	RU	07.1	0.5	BO
136.2	08/24/79	0502	335	0275		RU	15.1	1.5	BO
136.2	07/17/81		350		U	PO	17.0	0.3	BE
136.2	04/29/81	0903	352	0576	M	RU	05.0	0.2	BO
136.2	05/26/81	2911	286	0280	M	RU	02.5	0.4	BE
136.2	04/29/81	0967	366	0525	F	RU	05.0	0.2	SA
136.2	05/26/81	0884	320	0300	F	RU	02.5	0.4	BE
136.2	05/26/81	2980	326	0310	F	RU	02.5	0.4	BE

Table F-3 (continued)

River Mile*	Date	Red Tag Number	Total Length (m)	Weight (g)	Sex+	Habitat Type#	Depth (f)	Velocity (fps)	Primary Substrate#
136.3	08/24/79	0504	350	0320		RU	18.0	1.5	BO
136.3	08/24/79	0511	347	0305		RU	17.8	1.8	BO
136.3	08/24/79	0558	371	0330		RU	18.0	1.5	BO
136.4	05/15/80	0684	358	0520	F	RU	02.7	0.6	SA
136.4	10/13/79	0569	402	0408		RU	05.4	1.0	BO
136.4	05/15/80	0504	354	0420	F	RU	11.4	0.8	BE
136.4	05/15/80	0569	395	0605	F	RU	11.4	0.8	BE
136.4	05/15/80	0647	360	0400	M	RU	11.4	0.8	BE
136.4	05/15/80	0682	312	0350	I	RU	10.2	0.8	BE
136.4	05/15/80	0617	370	0450	M	RU	11.4	0.8	BE
136.4	05/15/80	0627	339	0370	M	RU	02.7	0.6	SA
136.4	05/15/80	0685	310	0320	M	RU	16.5	1.0	BE
136.4	05/15/80	0682	312	0350	M	RU	16.5	1.0	BE
136.4	05/15/80	0630	322	0340	M	RU	02.7	0.6	SA
136.4	10/13/79	0531	292	0280		RU	05.4	1.0	BO
136.4	05/15/80	0895	375	0500	F	RU	16.5	1.0	BE
136.5	04/30/81	0959	315	0410	M	RU	03.0	0.9	BO
136.5	04/30/81	0979	352	0470	F	RU	03.0	0.9	BO
136.6	05/14/80	0667	328	0345	I	ED	02.7	0.6	SI
136.6	05/27/81	2960	280	0280	M	RU	02.9	0.6	SA
136.6	05/14/80	0694	359	0320	I	ED	02.7	0.6	SI
136.6	05/27/81	2500	321	0380	F	RU	02.9	0.6	SA
136.6	05/14/80	0635	312	0280	I	ED	02.7	0.6	SI
138.8	08/24/79	0561	300	0340		ED	06.8	0.2	BO
139.8	08/14/80	0704	350	0454	I	PO	08.0	2.9	BO
143.9	08/24/79	0S20	365	0300		RU	08.8	1.5	BO

* Miles upstream or downstream (-) from the Green River confluence

\+ M = Male, F = Female, U = Undetermined

\# See Glossary of Terms, Appendix A

Table G-1
Data associated with 52 razorback sucker captured in the upper Colorado River, 1979-1981

River Mile*	Date	Red Tag Number	Total Length (m)	Weight (g)	Sex+	Habitat Type#	Depth (f)	Velocity (fps)	Primary Substrate#
-48.0&	06/10/80	0651	557	1990	M	LK	12.0	0.0	RU
-19.5	05/16/80		526	1530	U	LK	07.0	0.0	SI
-19.5	05/17/80		500	1244	U	LK	03.0	0.0	SI
-19.5	05/18/80		458	1620	U	LK	08.0	0.0	SI
-19.5	05/21/80		520	1832	U	LK	06.0	0.0	SI
001.4	04/03/81	0609	483	1060	U	BA	04.5	0.0	SA
001.5	04/03/81	2991	594	2260	U	BA	12.0	0.0	SI
048.2	06/11/80	0615	610	2280	U	BA	05.7	0.0	SI
146.9	05/13/81	2598	522	1660	F	BA	01.0	0.1	SI
150.1	03/24/80	0710	588	2722	F	RU	06.0	0.9	BO
163.6	08/16/79	0513	557	1383	U	GP	05.8	0.0	SI
163.6	09/21/79	9943	597	2210	U	GP	05.0	0.0	SI
163.6	09/21/79	9945	572	1325	U	GP	05.0	0.0	SI
163.6	09/23/79	9949	546	2050	U	GP	04.0	0.0	SI
163.6	09/23/79	9950	610	2025	U	GP	04.0	0.0	SI
163.6	09/23/79	9947	566	2330	U	GP	04.0	0.0	SI
163.6	09/23/79	9946	584	1700	U	GP	04.0	0.0	SI
163.6	09/23/79	9953	566	1900	U	GP	04.0	0.0	SI
163.6	09/23/79	9948	432	0865	U	GP	04.0	0.0	SI
163.6	09/24/79	9946	584	1700	U	GP	05.0	0.0	SI
163.6	09/24/79	9945	572	1325	U	GP	05.0	0.0	SI
163.6	09/25/79	0513	559	1730	U	GP	05.0	0.0	SI
163.6	09/26/79	9958	635	2530	U	GP	05.0	0.0	SI
163.6	09/26/79	9959	559	1550	U	GP	05.0	0.0	SI
163.6	09/27/79	9955	533	1765	U	GP	04.0	0.0	SI
163.6	09/27/79	9956	483	1200	U	GP	04.0	0.0	SI
163.6	09/28/79	9961	597	2080	U	GP	05.0	0.0	SI
163.6	05/28/80	0638	550	1850	M	GP	10.6	0.0	SI
163.6	05/28/80	0664	570	2120	F	GP	11.3	0.0	SI
163.6	05/28/80	0605	584	2400	F	GP	11.0	0.0	SI
163.6	05/28/80	0621	557	2240	M	GP	11.0	0.0	SI
163.6	05/28/80	0639	500	1300	M	GP	11.3	0.0	SI
163.6	09/25/80	9947	566	2330	U	GP	05.0	0.0	SI
163.6	08/21/81	2953	604	2500	F	GP	06.0	0.0	SI
175.0	06/10/81	2505	550	1710	F	BA	06.6	0.0	SI
177.8	05/23/80	0691	544	1840	F	GP	02.8	0.0	SI
177.8	05/23/80	0624	564	1580	F	GP	02.8	0.0	SI
177.8	05/29/80	0675	506	1440	M	GP	03.0	0.0	SI
177.8	05/29/80	0680	571	1800	F	GP	03.0	0.0	SI
177.8	05/29/80	0659	575	1920	F	GP	03.0	0.0	SI
177.8	06/05/80	0865	545	1660	M	GP	01.8	0.0	SI
177.8	06/05/80	0856	563	1400	F	GP	02.6	0.0	SI
177.8	06/06/80	0888	591	1872	F	GP	02.1	0.0	SI
177.8	06/08/80	0869	500	1362	M	GP	03.5	0.0	SI
177.8	06/08/80	0680	571	1816	F	GP	03.5	0.0	SI
177.8	06/08/80	0836	565	2040	F	GP	03.0	0.0	SI
177.8	06/08/80	0855	586	2382	F	GP	03.5	0.0	SI
177.8	06/08/80	0852	545	1538	M	GP	03.5	0.0	SI
178.0	06/10/81	2532	571	1700	F	RU	07.0	2.0	RU
205.5	06/29/81	2517	529	1400	F	ED	02.6	0.2	BO
220.7	07/15/81	2587	471	1180	U	BA	01.2	0.0	SI
223.5	07/15/81	2529	524	1620	U	MC	06.0	1.4	RU

* Miles upstream or downstream from the Green River confluence

\+ M = Male, F = Female, U = Undetermined

\# See Glossary of Terms, Appendix I

Lake Powell Records Supplied by Bill Persons, Cooperative Fishery Research Unit, Utah State University

& Lake Powell Record Supplied by Mike Ottenbacher, Utah Division of Wildlife Resources

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REPORT 3

LIFE HISTORY AND POPULATION ECOLOGY OF THE HUMPBACK CHUB IN THE LITTLE COLORADO AND COLORADO RIVERS OF THE GRAND CANYON, ARIZONA

by

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INTRODUCTION

Because of the difficulty and expense encountered in sampling its relatively inaccessible habitat, the humpback chub, Gila cypha, was among the last large North American freshwater fish described by science (Miller 1946). Therefore, the life history and population ecology of the species until recently was largely unknown. It is believed that the humpback chub was historically distributed throughout much of the Colorado and Green Rivers and their major tributaries. Contemporary humpback chub are known only from relatively unaltered portions of its former range (Minkley 1973, Holden and Stalnaker 1975, U..S. Fish and Wildlife Service 1979).

Losses of humpback chub habitat were most evident following closure of Flaming Gorge Dam on the Green River and Glen Canyon Dam in the Upper Colorado River. These dams inundated major riverine canyon environments and adversely impacted native fish reproduction by direct inundation and, elimination of reproduction in tailwater areas, because of cool water releases (Vanicek and Kramer 1969, Vanicek et al. 1970, Holden and Stalaker 1975).

While physical and chemical modifications of the river ecosystem are clear consequences of the many dams operating on the Colorado River which have been deliterous to some native fishes, competition with introduced species, as demonstrated for numberous southwestern fishes, may also be a significant factor (Miller 1961, Minckley and Deacon 1968). Its markedly reduced range and uncertainty for its survival in the face of continuing alteration of the Colorado River ecosystem resulted in the designation of the humpback chub as an endangered species in 1967.

Fishery surveys of the 450 km reach of Colorado River in the Grand Canyon were not conducted until several years after the closure of Glen Canyon Dam in 1963. These early investigations were largely qualitative in nature and clearly indicated the adverse effects of Glen Canyon Dam on the native fishes, which was similar to the effects documented after closure of Flaming Gorge Dam on the Green River. Several native fishes believed formerly common in Grand Canyon were no longer found, while the humpback chub persisted in low numbers with the only reproduction evident near the mouth of the Little Colorado River, a major tributary (Miller 1975, Minckley and Blinn 1976, Suttkus et al. 1976, Carothers and Minckley 1981).

Proposed operational changes for Glen Canyon dam prompted concern that a new flow regimen might adversely affect the humpback chub population in the Grand Canyon. The present study was developed to learn more about the life history and population ecology of the humpback chub and to determine what effects the proposed flow changes may have on these fish.

METHODS

Study Area and Sampling Scheme

The study area included the 32 km segment of the Colorado River encompassing the mouth of the Little Colorado River and the 20 km reach of the Little Colorado River between its confluence with the Colorado River and Blue Spring. Blue Springs is the uppermost source of perennial flow in the Grand Canyon. The rivers were divided into strata approximately 5 km in length with the exception of the confluence stratum (CR 4) which totaled 3 km and included parts of both rivers (Figure 1). Because no chub were collected by any gear from stratum LCR 1 in July 1980 or during a preliminary effort in May 1980, this uppermost Little Colorado River stratum was dropped from subsequent sampling.

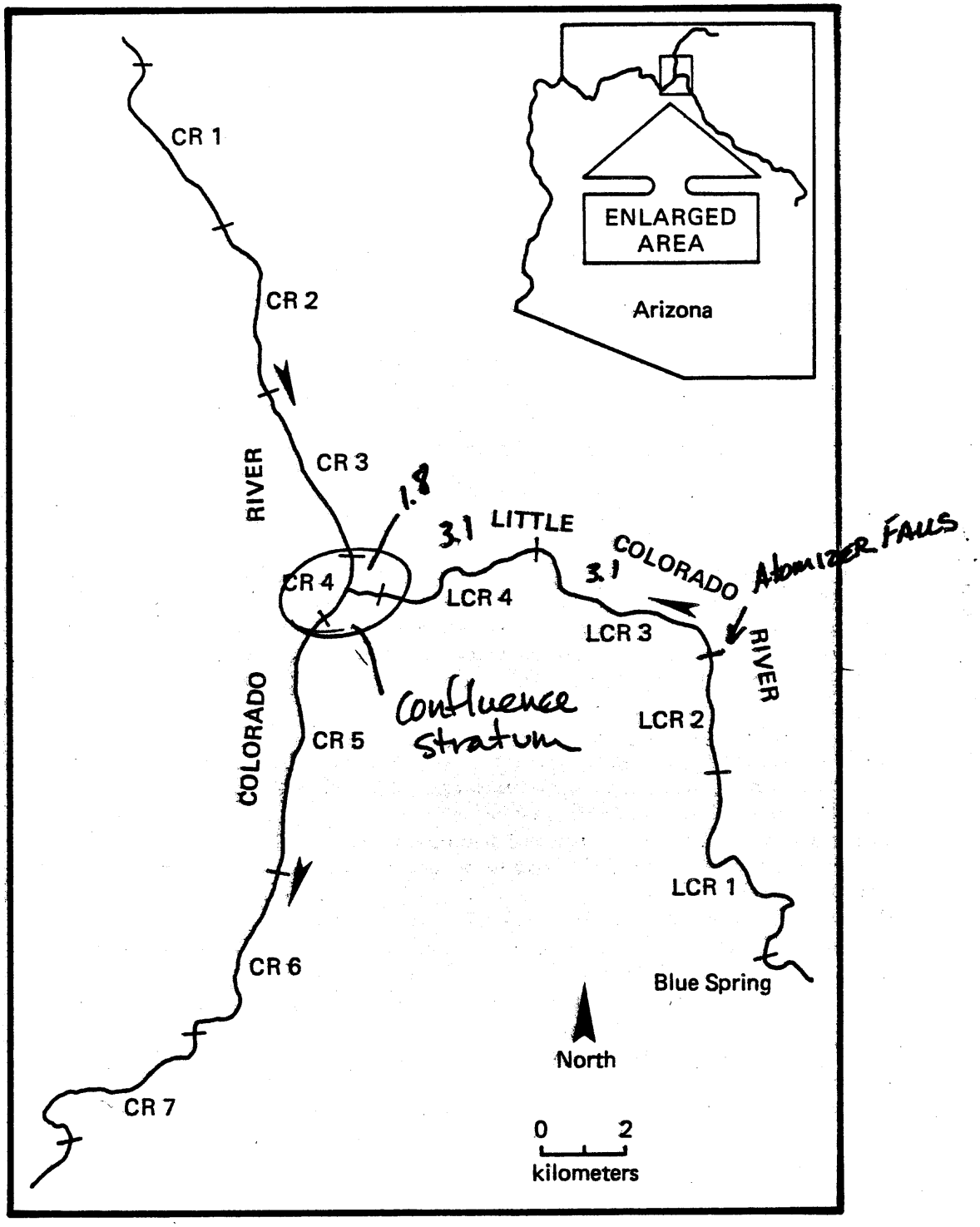
After the July 1980 sampling trip, one study site was randomly selected from within each stratum using aerial photographs prior to field activities. On the Colorado River sampling was conducted from inflatable rafts, which often precluded upstream movement in turbulent waters. Access on the Little Colorado River was by helicopter. Therefore, study sites corresponded with areas suitable for reasonably safe movement during sampling and for helicopter landing.

Temporal stratification of effort was accomplished by periodic sampling throughout the year and by distributing the daily effort of most gear types within the three periods of (1) AM daylight between sunrise and noon, (2) PM daylight between noon and sunset, and (3) darkness. Sampling at each site encompassed approximately 1 km of river and was normally performed for 2 days before moving to the next stratum.

Physicochemical

Three depth profiles were made electronically at all Colorado River study sites to grossly characterize available habitat, while four similar profiles were made manually at one study site in each of the Little Colorado River strata. Water analyses performed in the field between 1000 and 1400 h included pH, dissolved oxygen, specific conductance, turbidity, and temperature. Continuous recording thermometers were installed at two locations in the Little Colorado River, 5 and 13 km above the confluence, and at one location in the Colorado River at the USGS gage 23 km below the study area. Temperature data collected at that gage were representative of the study area since Cole and Kubly (1976) showed the river warms no more than 0.3° C over this reach. Mean daily temperature was computed as a mean of the maximum and minimum readings in the 24-hour period from midnight to midnight. Mean daily temperatures for each month were averaged within six periods, the first five consisting of 5 days each and the sixth containing the remaining days of the month.

Figure 1



Map of study area with locations of sampling strata.

Colorado River discharges (Q, in ft^3/s) measured at the USGS gage were converted to relative water surface elevations (EL, in meters) at a reference point in the confluence stratum using the equation $EL = 0.02032 \sqrt{Q} - 0.6426$ developed by the U.S. Bureau of Reclamation. The procedure used to summarize these data was the same as that for temperature.

Biological

Fishing gears

Although a number of fishing gears were tried early in the study, five principle types were found effective and used throughout: double funnel-type minnow traps (45 X 23 cm, 6 mm hardware cloth), beach seines (9.1 X 1.8 m, 3 mm mesh), trammel nets (45.7 X 1.8 m, 2.5 cm wall, 25.4 cm trammel), and gill nets (30.5 X 0.9 m, 1.9 cm bar mesh). DC electrofishing was used only in the Colorado River and some of these data are incomplete because mechanical problems and hazardous river conditions sometimes precluded systematic use of this gear.

Field data and laboratory analyses

Initiation and termination times for individual fishing activities and the areal extent of beach seining efforts were quantified. An elapsed time clock measured actual electrofishing time. General habitat type sampled was recorded following criteria provided by Archer et al. (1980). Measurements of water depth, velocity, and principle substrate types were made at regular intervals along transect lines within beach seine area, and at minnow trap locations. Mean values were used to characterize the habitat sampled.

Collected fish were weighed (g), measured in total length (TL,mm) and examined for gross ectoparasites and external characteristics of seasonal reproductive development. Humpback chub dorsal and anal ray counts were made on chub larger than 100 mm TL, a size where no disagreement over counts occurred among workers. Several chub scales were removed from the caudal peduncle above the lateral line and later permanently mounted on microscope slides for age estimation. Fish larger than 200 mm received a numbered Carlin dangler tag prior to release. Multiple census methods (Ricker 1975) were used to estimate the abundance of chub larger than 200 mm within the total study area. Data were stratified into 2-month time intervals for these analyses.

External urogenital characteristics as described by Suttkus and Clemmer (1977), in all but one instance proved accurate for selecting female chubs with good representative characters for subsequent laboratory analyses; however, in some cases determination of sex was difficult, particularly after spawning. No attempt was made to separate sexes in age and growth, movement, or catch rate analyses.

Seasonal gonadal development of female chubs was determined by monitoring the gonadosomatic indices (GSI) and mean ova diameters (MOD) of fish of mature size. Gonads were preserved in Bouin's fixative in the field and later weighed to the nearest 0.1 g in the laboratory where the maximum diameter of 20 of the largest ova were measured with an ocular micrometer. Histological analyses of gonads were made at the Fish Cultural Development Center (FWS), Bozeman, Montana.

Tissues from sacrificed fish and accidental mortalities, and skin scrapings from fish exhibiting external symptoms of bacterial or fungal disease, were collected for routine pathologic analyses at the Fish Disease Control Center (FWS), Fort Morgan, Colorado. Digestive tracts were preserved in formalin for subsequent diet analyses.

Statistical analyses of catch data

Catch per unit of fishing effort (CPE) was calculated for each species collected during the use of each gear. Chub were divided into broad age categories; length frequency was effective in identifying young-of-the-year (YOY) chub, while juvenile and adult fish were separated at 200 mm (TL). Minnow trap CPE was calculated as fish per trap night; seining CPE as fish per 100 m^2 seined; trammel net CPE as fish per hour of netting; electrofishing CPE as fish per hour of shocking time. Gill nets were used too infrequently to be included in these analyses.

Preliminary analysis revealed seining catch rates differed markedly between daylight and darkness periods and data were consequently grouped for analysis on this basis. Because trammel nets were checked every 1-2 hour and fished much of the day and night in the Little Colorado River while those in the Colorado River were only fished, unattended, overnight, the Little Colorado River data provided resolution of differences in CPE among diel periods not possible with data from the Colorado River. After preliminary analysis, data from the Little Colorado River were stratified into three diel periods; daylight, sunset (sundown $\pm$ 3 h), and darkness.

Due to the extreme variability in catch rates among efforts, CPE was averaged within gears, strata, individual sampling trips, diel periods, and occasionally chub age categories. Mean values were then used in trend analyses to examine relationships between CPE and seasons, strata, and diel period. The obvious difference in vulnerability to capture by various gears between rivers dictated that statistical comparisons be made within rivers only, and include the confluence stratum where appropriate.

Where sufficient data were available, trend analysis was used to test for relationships between mean CPE for individual species within rivers as an indication of interspecific associations. These analyses were made between species caught in one gear and occasionally between species caught by separate gears used simultaneously. Data points consisting of zero values for both species being tested, and strata where data indicated one species did not occur because of factors other than interspecific associations, were excluded from these analyses.

RESULTS AND DISCUSSION

Physicochemical

The physicochemical characteristics of the study strata differed markedly between rivers but little within rivers (Table 1). Besides being much smaller than the Colorado River, the Little Colorado River contains numerous boulder field riffles and travertine dams ranging in height from about 0.1 to 2 m. Numerous travertine structures occur in each of strata LCR 2 to 4 with the highest located in upstream areas where a dam with a vertical drop of approximately 2 m forms the boundary between strata LCR 1 and LCR 2. The height of these structures affected both the depth and length of interveining pools. Aerial photographs revealed that 70 percent of the LCR 2 thalweg, 54 percent of LCR 3, and 34 percent of LCR 4 consisted of pool habitat.

Mean water temperatures in the Colorado River and strata LCR 4 on the Little Colorado River differed by about 9° C throughout the year (Figure 2). Thermograph data supplemented with spot temperature readings indicated progressive downstream cooling of Little Colorado River water in winter and warming in summer. Temperature variation within 5-day periods was much greater in the Little Colorado than in the Colorado River. Unlike pre-dam water temperatures, present Colorado River temperatures vary little through the year.

The 5-day ranges in relative Colorado River water surface elevations at the confluence stratum reference point varied between 0.6 and 1.9 m during the study while little short-term variation was evident in pre-dam data from 1954-55 (Figure 2). Dolan et al. (1974) summarized the effects of Glen Canyon dam operation on the hydrology of the Colorado River.

Midday dissolved oxygen concentrations were near saturation in all samples except those from LCR 1 where springs charged with carbon dioxide and low in dissolved oxygen provided the major stream flow. The release of dissolved gases into the atmosphere begins at Blue Spring and results in the precipitation of travertine ($CaCO^3$), primarily in the region between 10 and 16 km above the confluence (Cooley et al. 1969). The rate of deposition in this region (LCR 2 and lower LCR 1) was demonstrated by the deposition of an 8 mm thickness of travertine on the upstream thermograph over a 3 1/2 month period.

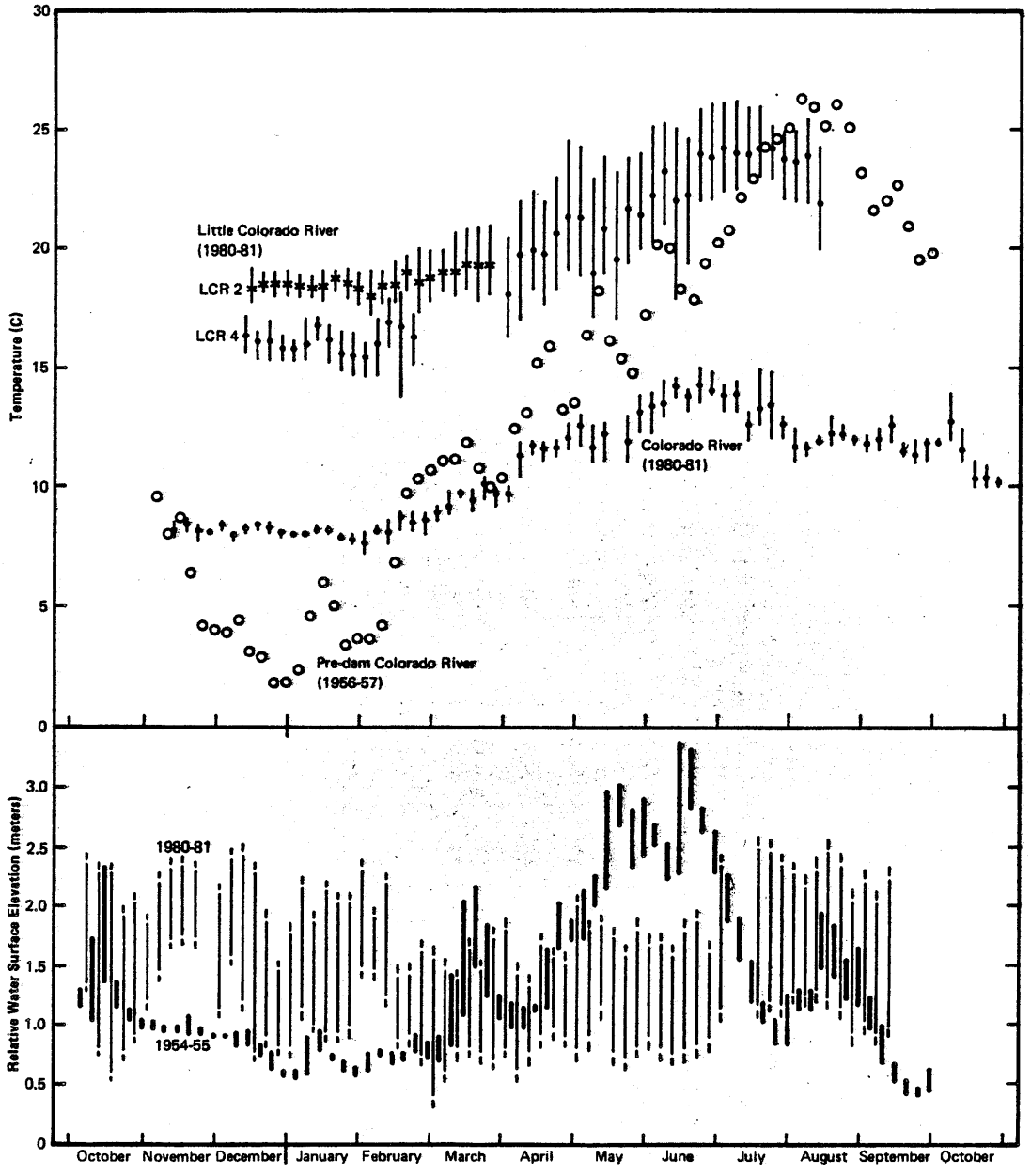
The high specific conductance and salinity of the Little Colorado River is due in part to sodium chloride (Cooley et al. 1969). Although a number of periods of high turbidity occurred during the study, field data included only one sample taken during the high turbidity runoff period and that was from the confluence stratum. The Little Colorado River in flood greatly increases the turbidity of the Colorado River downstream but, because of its relatively small volume, the Little Colorado River has little effect on the chemical composition of the Colorado River (Cole and Kubly 1976). A detailed account of Little Colorado River basin hydrogeology is provided by Cooley et al. (1969).

Table 1
Range of physicochemical characteristics measured at Colorado and Little Colorado study strata.
Number of observations (cross sections or chemical determinations) is given in parentheses.

River, Stratum	Width(m)	Mean Depth(m)	Max. Depth(m)	Dissolved Oxygen(ppm)	Conductivity[a]	Salinity(0/00)	Turbidity[b]	pH
Little Colorado								
LCR1	-	-	-	2- 8(4)	4161 - 5161(3)	2.1-3.3(3)	-	-
LCR2	18.0- 35.1(5)	1.0- 1.5(5)	1.4- 2.6(5)	7-10(9)	3772 - 6017(9)	2.0-3.1(7)	12- 16(2)	7.6-8.0(4)
LCR3	29.3- 50.0(4)	0.5- 0.9(4)	1.0- 1.2(4)	8-10(8)	3973 - 5012(9)	2.0-3.5(9)	0- 7(4)	7.3-7.7(4)
LCR4	20.1- 27.4(4)	0.7- 0.9(4)	1.0- 1.7(4)	8-10(7)	3548 - 6018(6)	1.7-3.0(6)	2- 7(4)	7.5-8.2(5)
Confluence Stratum								
CR4	75.6-132.0(9[c])	4.9- 9.1(6[c])	6.1-13.7(6[c])	7-11(12)	503 - 4990(18)	0.1-3.1(17)	0-310(9)	8.1-8.5(5)
Colorado								
CR1	81.2-205.6(9)	3.3- 8.5(9)	4-6.15.2(9)	10-11(5)	567 - 1160(6)	0.0-0.4(6)	0- 10(5)	7.5-8.0(3)
CR2	77.7-193.5(9)	4.0- 8.3(9)	5.2-17.1(9)	9-10(6)	483 - 787(6)	0.1-0.4(6)	2- 36(5)	7.1-7.8(2)
CR3	51.1-132.8(9)	4.3- 6.4(9)	4.6-11.9(9)	10-11(7)	397 - 787(7)	0.1-0.5(6)	0- 5(3)	7.9-8.0(2)
CR5	71.5-190.6(9)	4.0-11.3(9)	4.9-18.6(9)	9-11(5)	436 - 920(5)	0.2(5)	0- 10(5)	8.0(2)
CR6	65.2-124.6(9)	3.8- 6.5(9)	6.4-10.4(9)	9-11(5)	534 - 778(6)	0.1-0.4(6)	2- 5(4)	7.5-7.8(2)
CR7	83.2-192.8(9)	3.4- 7.1(8)	5.5- 9.8(8)	9-11(6)	551 - 778(7)	0.1-0.5(7)	4- 60(4)	7.9-8.0(2)

[a]Micromhos per centimeter[2]
[b]Jackson turbidity units
[c]All measurements taken in Colorado River

Figure 2



(Top) Chronolgy of Little Colorado and Colorado River 5-day mean water temperatures. Ends of vertical bars indicate extreme temperatures observed during the 5-day periods of the present study. (Bottom) Chronology of pre-dam (1954-55) and post-dam (present study 1980-81) fluctuations in relative Colorado River water surface elevation at the confluence stratum reference point. The zero value equates with a stream discharge of 28.3 m^3/sec (1,000 cfs).

Distribution and Relative Abundance

Young-of-the-year (YOY) and juvenile Humpback chub

Minnow traps almost exclusively collected YOY chub while seines collected YOY and juvenile fish. Mean total length of chub collected by these respective gears was 80 ± 23 mm SD and 92 ± 46 mm SD. Mean CPE for chub varied considerably between strata within sampling trips and between sampling trips within strata.

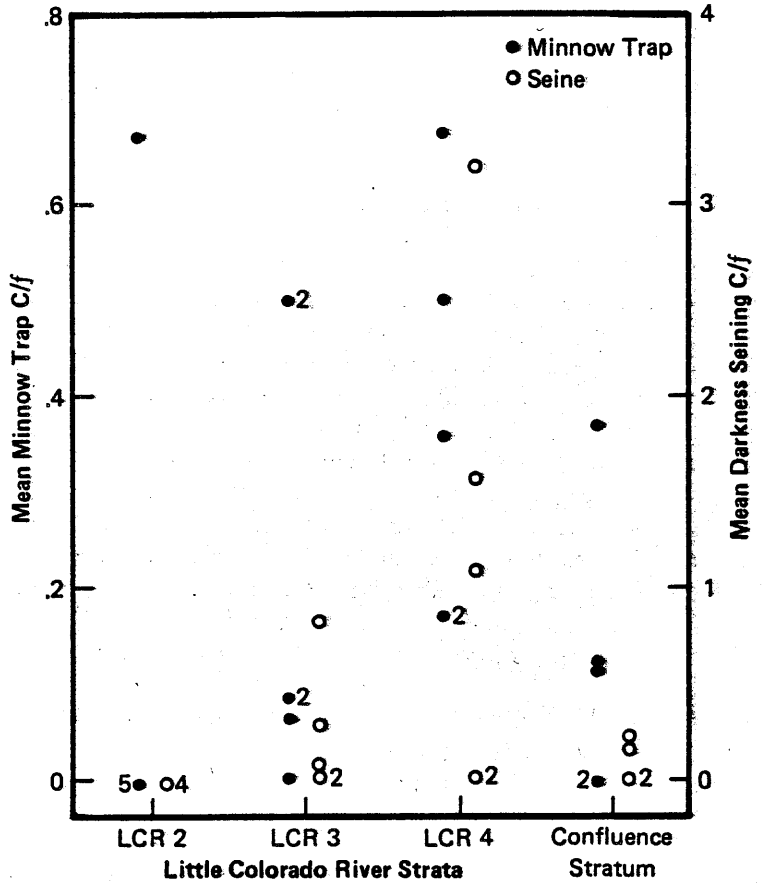
Trend analyses revealed mean CPE for YOY in minnow traps and seine hauls during darkness from the Little Colorado River were significantly correlated with stratum; mean CPE increased with proximity to the confluence (Figure 3). Although these correlations are significant, analyses used predominantly 1981 data and may, to some degree, reflect downstream movement of young chub (See section on Reproduction). Comparisons of postspawning period CPE during July 1980 and August 1981 reveal this longitudinal trend may not occur consistently each year. Seine CPE in stratum LCR 2 during July 1980 were appreciably higher than in any other stratum during the study, while rates were generally much higher throughout the Little Colorado River in July 1980 than in August 1981. In marked contrast with the high seining CPE in July 1980, no YOY were collected in August 1981 from stratum LCR 2, the region where the high rate of travertine deposition forms dense layers of precipitate on bottom substrates. A springtime runoff occurred in 1980 during the chub reproductive season of April and May (see section on Reproduction) but not in 1981. Runoff removes fine sediments and precipitates that could otherwise suffocate developing embryos and may also ameliorate possible negative effects of high salinity or other chemical constituents on embryos by dilution of base flows with runoff waters.

The difference in CPE for YOY chub between years is deemed largely attributable to marked differences in reproductive success between years. Although the geographical trend in mean CPE for YOY chub suggests downstream strata were most important to chub reproduction in 1981 (Figure 3), this trend may be reversed in years where runoff is coincident with spawning. Moreover, such marked differences in reproductive success between years may not have occurred historically. Prior to the late 1800's the Little Colorado River immediately above the study area was a perennial stream (Miller 1961) and these flows may have moderated the presumed negative effects of the present physicochemical environment on chub reproduction in the Little Colorado River study area.

Low mean CPE in the confluence stratum (Figure 3) resulted from this stratum being partially in the main Colorado River where catch rates tended to be low. In this confluence stratum 48 of 89 total trap-nights and 43 of 132 total seine hauls were expended in the Colorado River portion with the remainder in the Little Colorado River portion. As a chub reproductive area, the Little Colorado River part of the confluence stratum appears approximately equal to an adjacent reach of similar length in stratum LCR 4.

YOY and juvenile chub in the Colorado River were almost exclusively collected from strata downstream from the Little Colorado River and were more frequently encountered in 1981 than in 1980. This distribution

Figure 3



Mean catch rates for humpback chub collected by minnow traps and seines during darkness from Little Colorado River strata LCR 2, 3, and 4, and the confluence stratum, 1980-81. Numbers designate multiple observations.

reflects the inability of chub to reproduce in the Colorado River part of the study area, as discussed in the section on reproduction. Differences in the catch rates for small chub in the Colorado River between years may depend largely upon: (1) reproductive success in the Little Colorado River, (2) the rate small fish emigrate from the Little Colorado River which may vary with discharge, and (3) the survival rate of small chub in the Colorado River.

Electrofishing collected 19 chub classified as juveniles and six as adults from the Colorado River. Mean total length was 163 mm + 64 SD. Electrofishing CPE are quite variable in part because all individual efforts as well as many total, within strata, efforts lasted less than 1 hour. The capture of one or two chubs during an electrofishing session may yield an hourly catch rate above what would likely result if an hour of effort was actually expended.

Adult chub

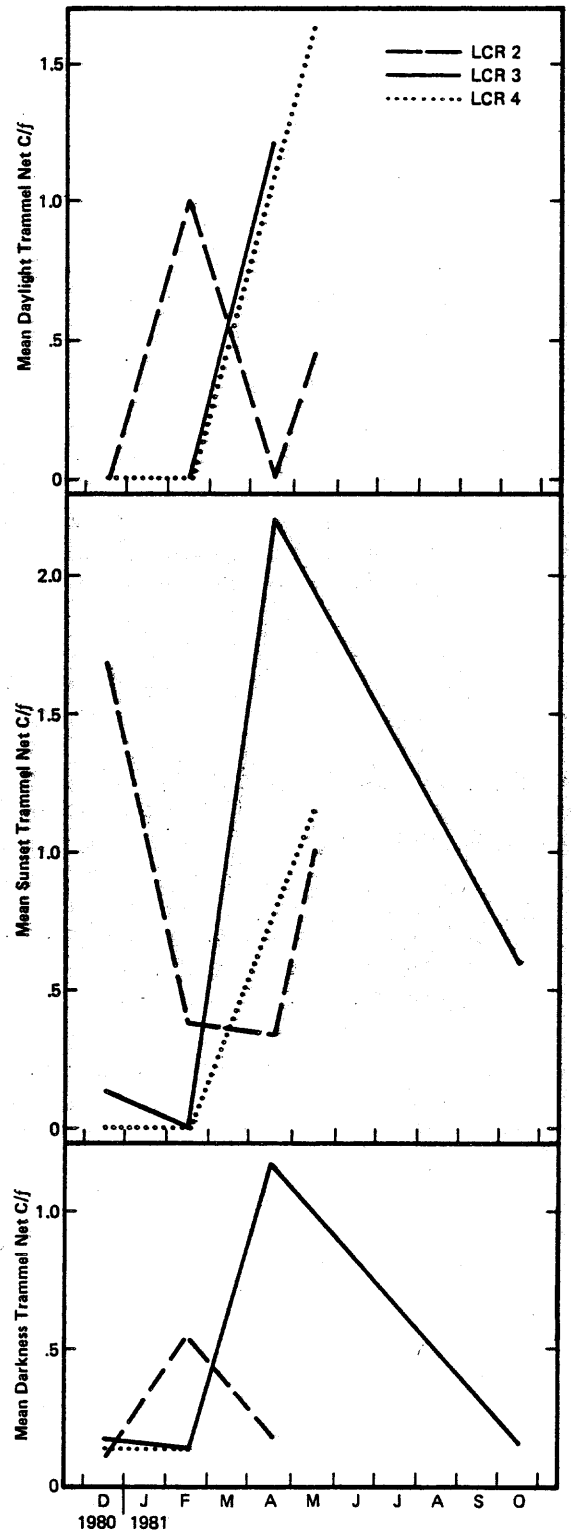
Trammel nets collected 504 humpback chub with a mean total length of 278 mm + 54 SD; 93 percent were classified as adults. CPE in the Little Colorado River varied considerably among strata, diel periods, and collection trips. Although some of the highest mean catch rates were evident in strata LCR 2 and 3, there was no consistent relationship between mean catch rate and stratum within the river. High catch rates during July 1980 may, in part, reflect the lack of randomized systematic sampling.

A seasonal pattern of change in mean CPE, however, was evident within Little Colorado River strata when mean catch rates in all diel periods increased between February and April/May in strata LCR 3 and 4 (Figure 4) . Mean catch rates in the confluence stratum also showed seasonal highs in May. These higher catch rates perhaps resulted from increased activity during spawning and/or an influx of mature fish from the Colorado river. Additional discussion of chub movement is provided in the section on migration and movement.

No appreciable within strata differences in mean CPE for humpback chub collected from the Colorado River by trammel nets were evident between years or seasons. However, the distribution of mean catch rates among Colorado River strata was normal about the confluence stratum, indicating chub densities in the Colorado River are greatest near the confluence stratum and decrease at a simlar rate with movement up and downstream (Figure 5). This distribution contrasts markedly with that of small chub and strongly suggests many adult chub in the Colorado River maintain an association with the Little Colorado River, most probably because of the importance of this area as reproductive habitat.

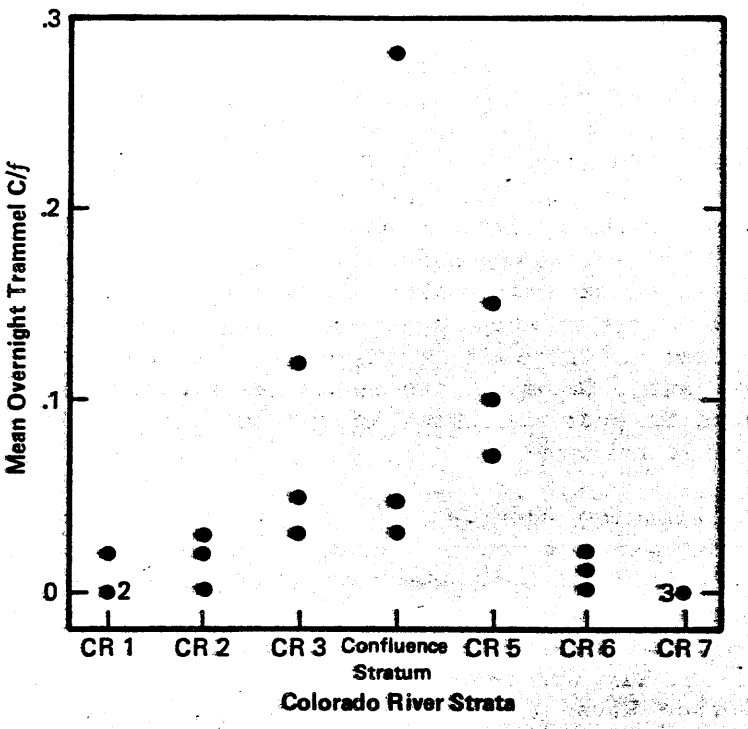
Although several criteria for application of multiple census methods for population estimation where not met in the study, a rough estimate, using the Schnable, Modified Schnabel, and Schumacher/Eschmeyer method of population estimateion were employed to provide a "ball park" figure. These analyses suggest the adult humpback chub (TL > 200 mm) population of the study area probably numbers around 7,000-8,000. Inclusion of fish smaller than 200 mm would conservatively increase the above estimate by a factor of two or three.

Figure 4



Mean catch rates for humpback chub collected by trammel nets during three diel periods from Little Colorado River strata LCR 2, 3, and 4. Inflection points indicate collection date.

Figure 5



Mean catch rates for humpback chub collected by trammel nets fished overnight in Colorado River strata and the confluence stratum. Numbers designate multiple observations.

Movement and Migration

Tagged and released humpback chub in the Little Colorado River, confluence stratum, and Colorado River numbered 433, 242, and 45 while subsequent recaptures totaled 17, 13, and 2, respectively. One tagged chub from the Little Colorado River was recaptured twice, first 5 months after tagging and again 15 months after the first capture. Three chubs tagged in the confluence stratum by earlier researchers from the Museum of Northern Arizona where among those recovered. Five additional fish collected from the confluence stratum and Little Colorado River showed evidence of tags that had detached.

Recaptured fish were at large between one day and 16 months and exhibited movement up to 17.1 km from the original tagging site (Figure 6). Recaptures in the immediate area of initial release (± 0.3 km) accounted for 13 of the 32 fish recovered, while 19 others moved an average distance of 3.8 km. No relationship between time at large and distance moved was evident.

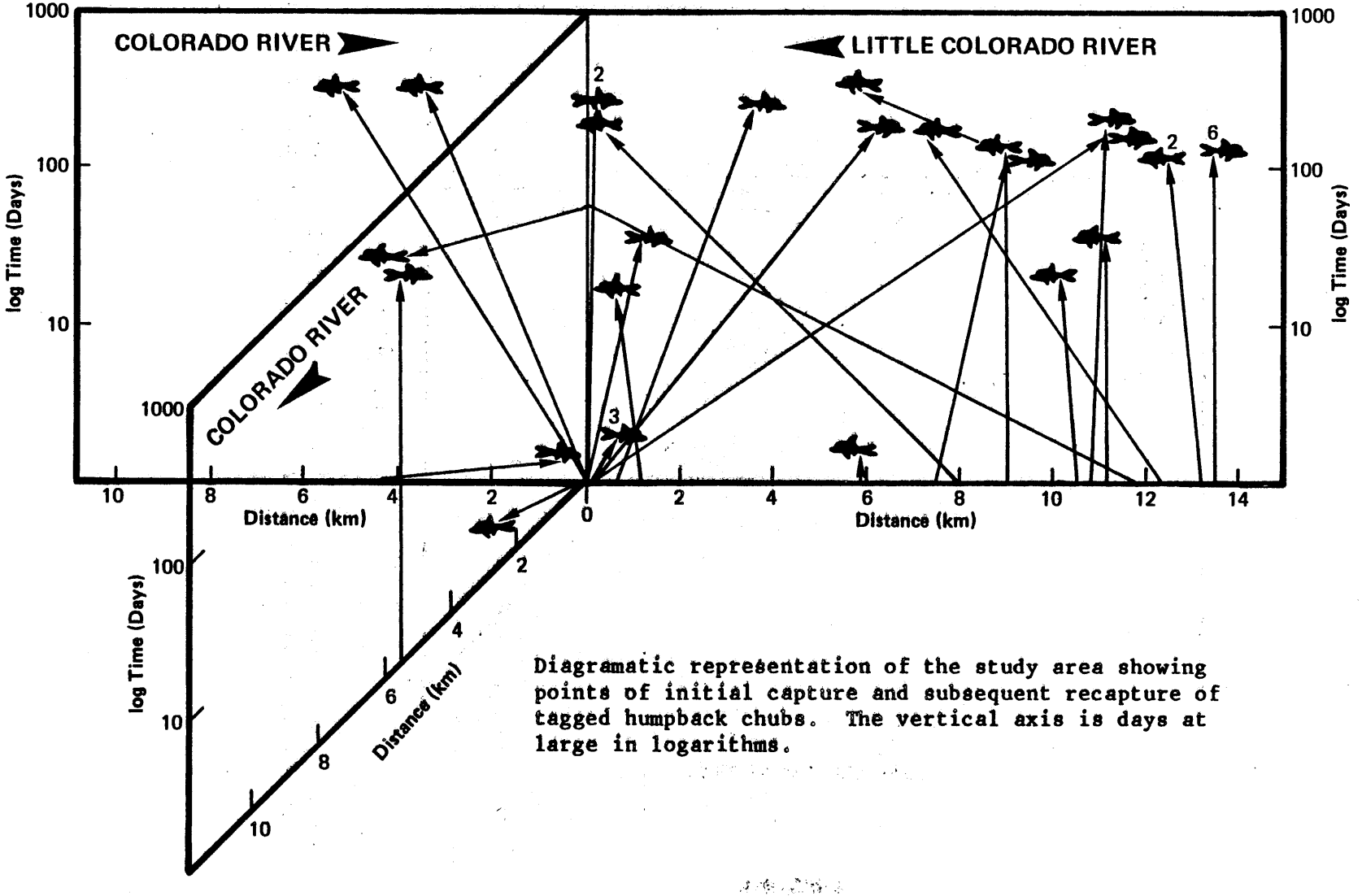
Tagging can subject fish to immediate stress and latent debilitation due to handling or secondary infection, problems that may be manifest in downstream movement or drift and could bias analysis of movement data. Many chubs were recaptured near their original tagging site after considerable time at large which suggests that the effect of tagging may not be significant. However, two instances were noted where tagged fish were recaptured in poor condition an appreciable distance downstream one or two days after release.

Fish experiencing adverse effects of tagging are unlikely to make significant upstream movements, however; of the 10 recaptured chub that moved more than 0.3 km upstream from their original point of release, nine were tagged in April - June, the time of chub reproduction. Seven of the nine were recaptured during that same or the subsequent spawning season in the Little Colorado River while the other two were recovered from the Colorado River upstream from the confluence stratum during the post-spawing season. This evidence indicates some substantial chub movement which may, in large part, be related to spawning, and may sometimes occur between rivers.

Physical Habitat Use

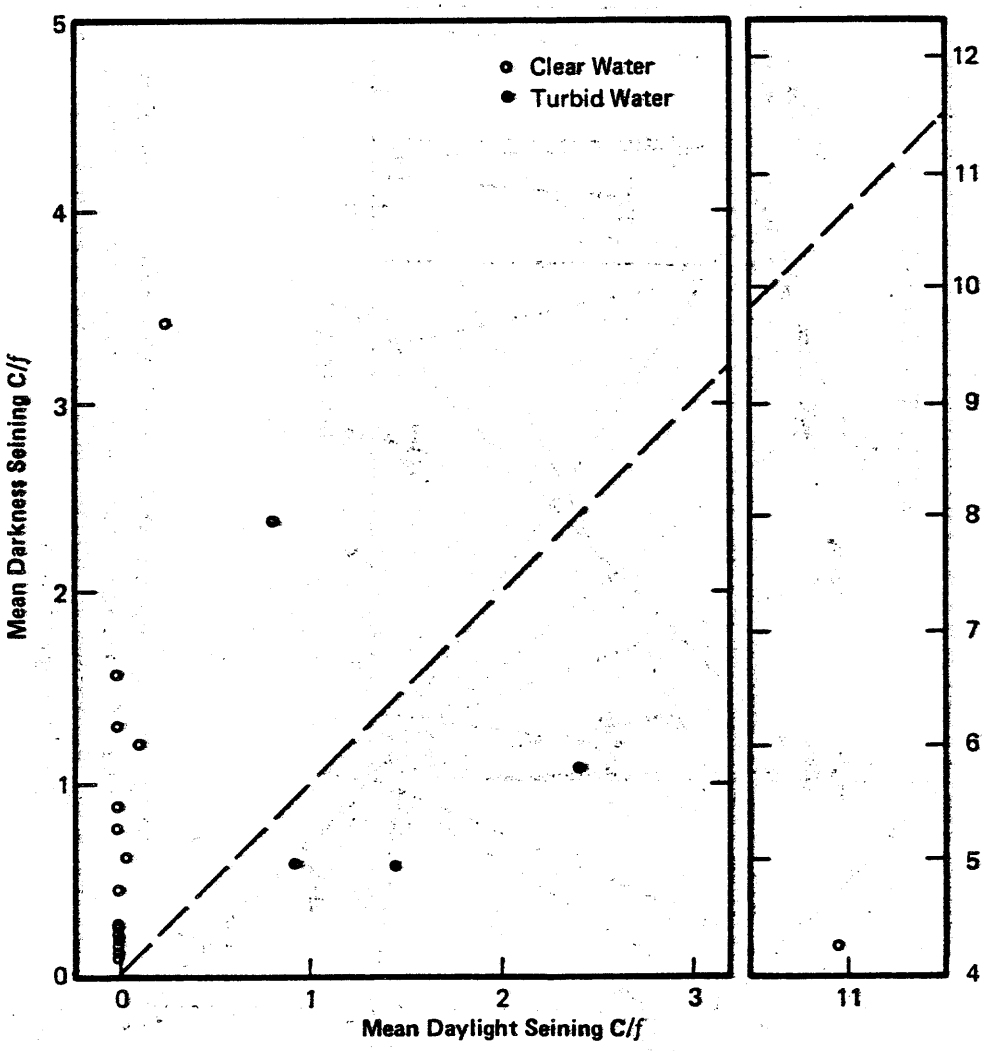
Physical habitat use by YOY and juvenile humpack chub was most markedly affected by light intensity; 16 of 20 comparisons of mean catch rates by seines revealed rates higher during darkness than during daylight (Figure 7). Exceptions occurred in the Little Coloado River and confluence stratum in August and October 1981 when waters were very turbid and in July 1980 when small chub may have been particularly abundant. It may be speculated that chub were able to elude nets in clear water during daylight. However, it is highly unlikely that escaping chub would go unnoticed by workers. Water clarity in both the Colorado and Little Colorado Rivers generally facilitated observation of fish escaping seines during daylight. The absence of chub in daylight collections from clear, shallow water is best explained as an avoidance of these areas during daylight periods. The collection of chub during

Figure 6



Diagramatic representation of the study area showing points of initial capture and subsequent recapture of tagged humpback chubs. The vertical axis is days at large in logarithms.

Figure 7



Relationship between mean catch rates for young-of-the-year and juvenile humpback chub collected by seining during darkness and during daylight.

daylight in shallow areas but during highly turbid water conditions, supports this hypothesis. From these observations it is concluded that the drastically increased clarity of the Colorado River that accompanied the closure of Glen Canyon dam may have significantly modified the behavior of small humpback chub.

YOY and juvenile chub were collected by minnow traps and seines from the Little Colorado River over most of the range of depths and velocities sampled. No evidence was obtained to indicate selection of preferred depth or velocity on the basis of these criteria alone (Figures 8 and 9). Chub were most commonly seined from shoreline/run and shoreline/eddy habitats which had relatively homogeneous bottoms, principally of sand or silt. Minnow traps were fished over a wider range of physical habitat types than were seines, but again, no selection of physical habitat on the basis of specific water depth or velocity was indicated (Figures 10 and 11).

A significant positive correlation ($r^2 = 0.25$, $n=10$) occurred between mean catch rates of YOY chub seined during darkness and captured by minnow traps. Of the efforts that collected chub, 16 of 24 minnow traps were set among boulder or bedrock substrates while 88 of 90 seine hauls were made over sand-silt substrates. Since both gears successfully collected chub in the respective habitats where they fish most effectively, the relative importance of these substrates to chub cannot be established.

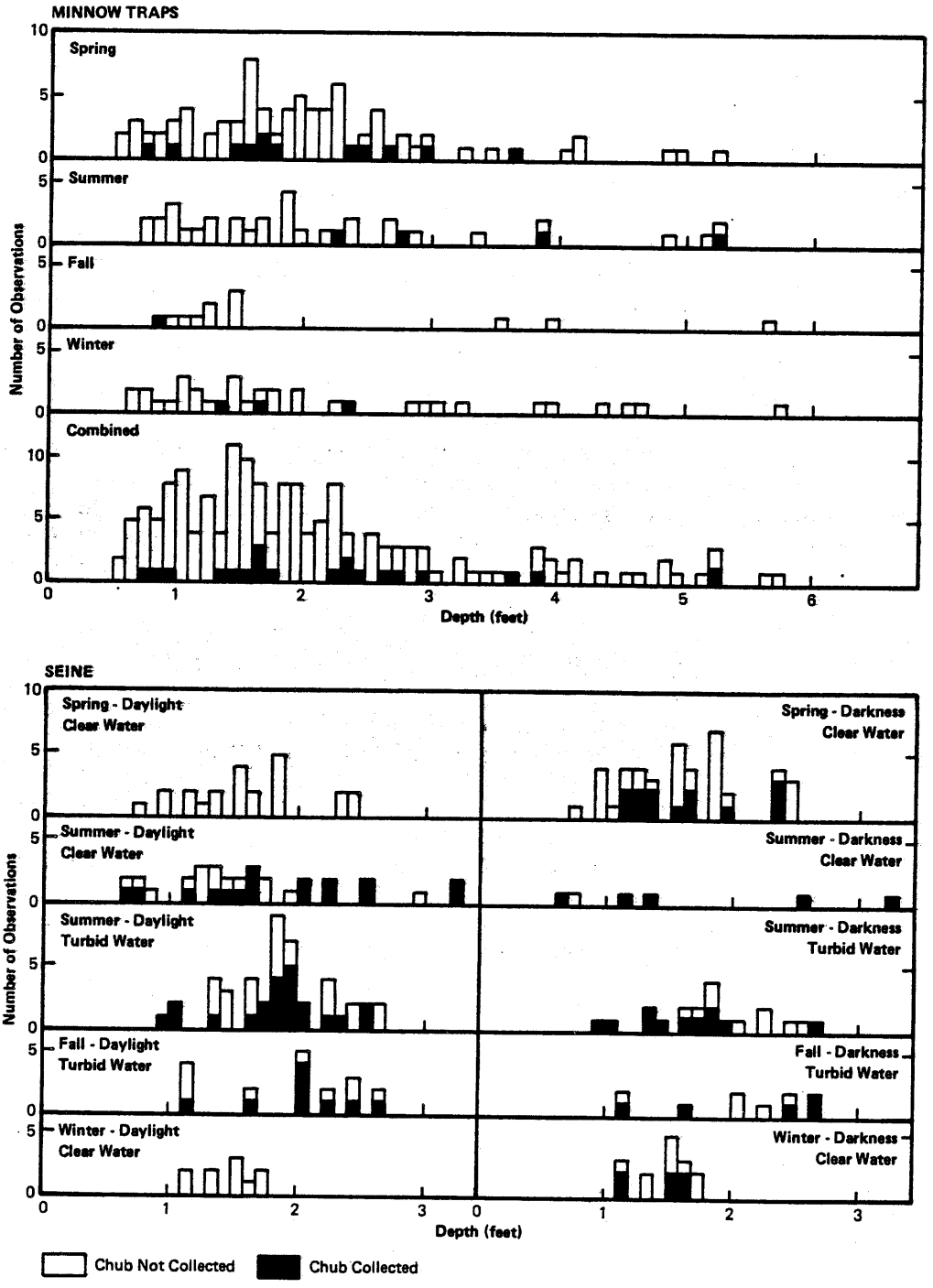
Available information indicates Little Colorado River water quality may have a more significant influence on humpback chub reproductive success, and subsequent habitat use by small fish, than do the depth, velocity and substrate parameters found useful in other regions.

An effect of light intensity, though less dramatic than that with seines, was also evident in the catch rates of adult chub by trammel nets in the Little Colorado River. Mean catch rates during sunset were greater than during daylight in 6 of 9 cases while the difference between sunset and darkness catch rates was less apparent. Although these observations suggest chub activity may increase with diminishing light intensity, the possibilty that chub avoid passive entangling gears during daylight cannot be discounted.

Age and Growth

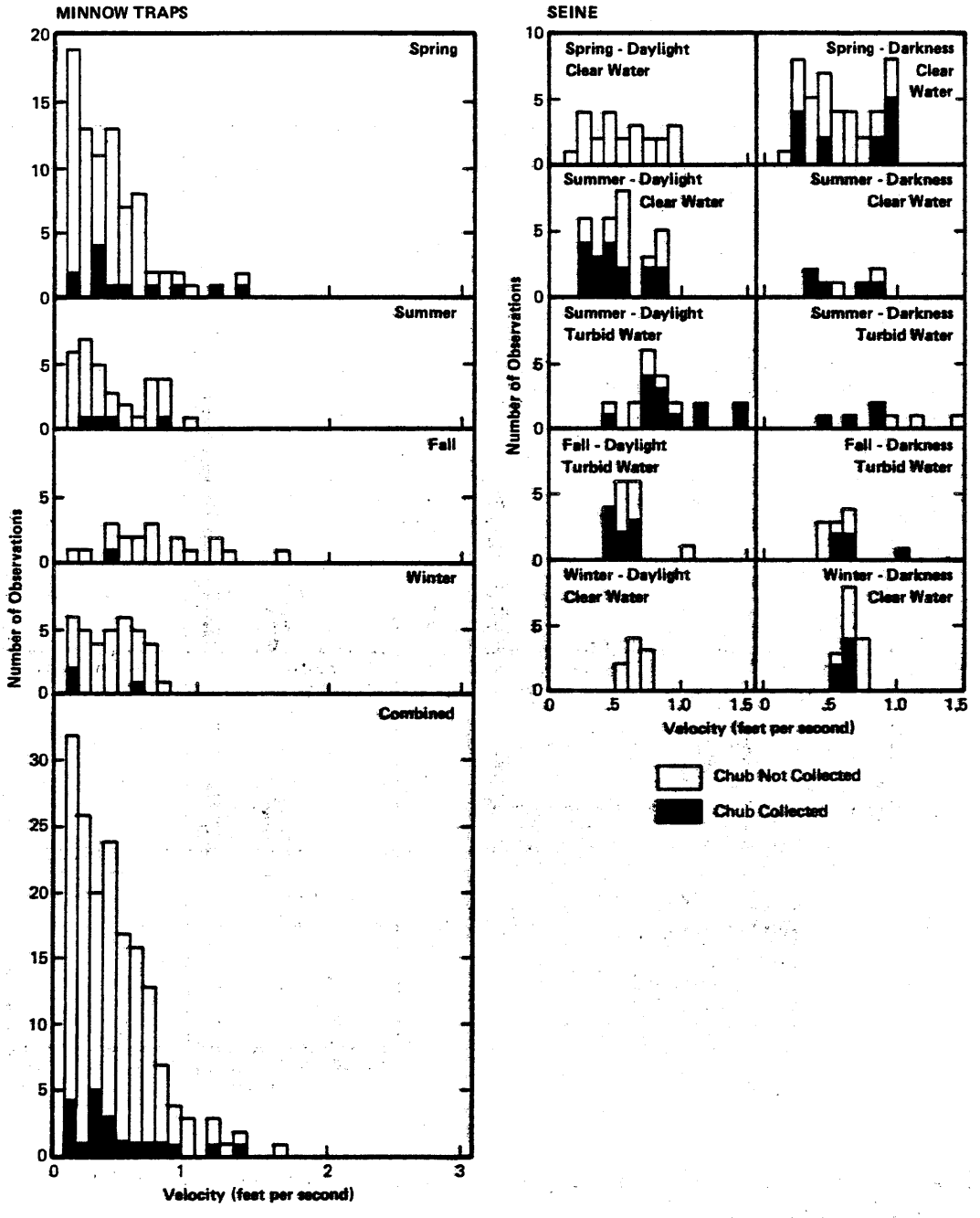
Examination of scales taken from chub showed scale annuli were useful indicators of age for Little Colorado River fish. Newly formed annuli, those near the scale margin, were observed on few scales collected in February but were present on most scales in May. For fish up to about 250 mm (approximately 3 years old), the number of scale annuli correlated well with age estimated by length-frequency (Figure 12). There was no evidence for the formation of false annual. The first annulus formed at approximately 100 mm TL and one year of age. Growth of chub from the Little Colorado River was rapid during the first 3 years of life while older fish exhibited relatively little annual growth. Where concurrent observations were available, age and growth characteristics of chub from the confluence stratum did not differ appreciably from those of Little Colorado River fish.

Figure 8



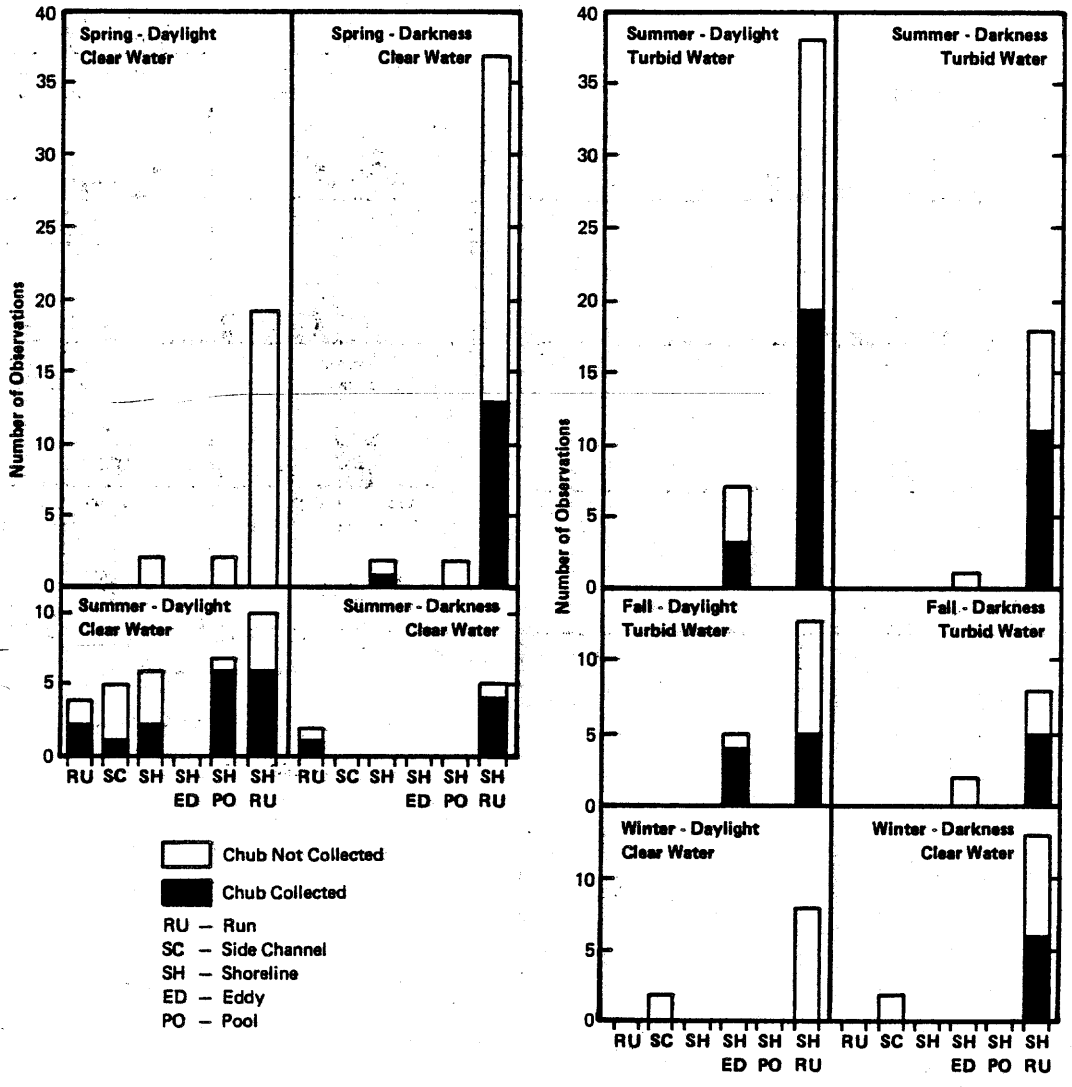
Frequency of humbpack chub captures over the range of depths sampled with minnow traps and seines.

Figure 9



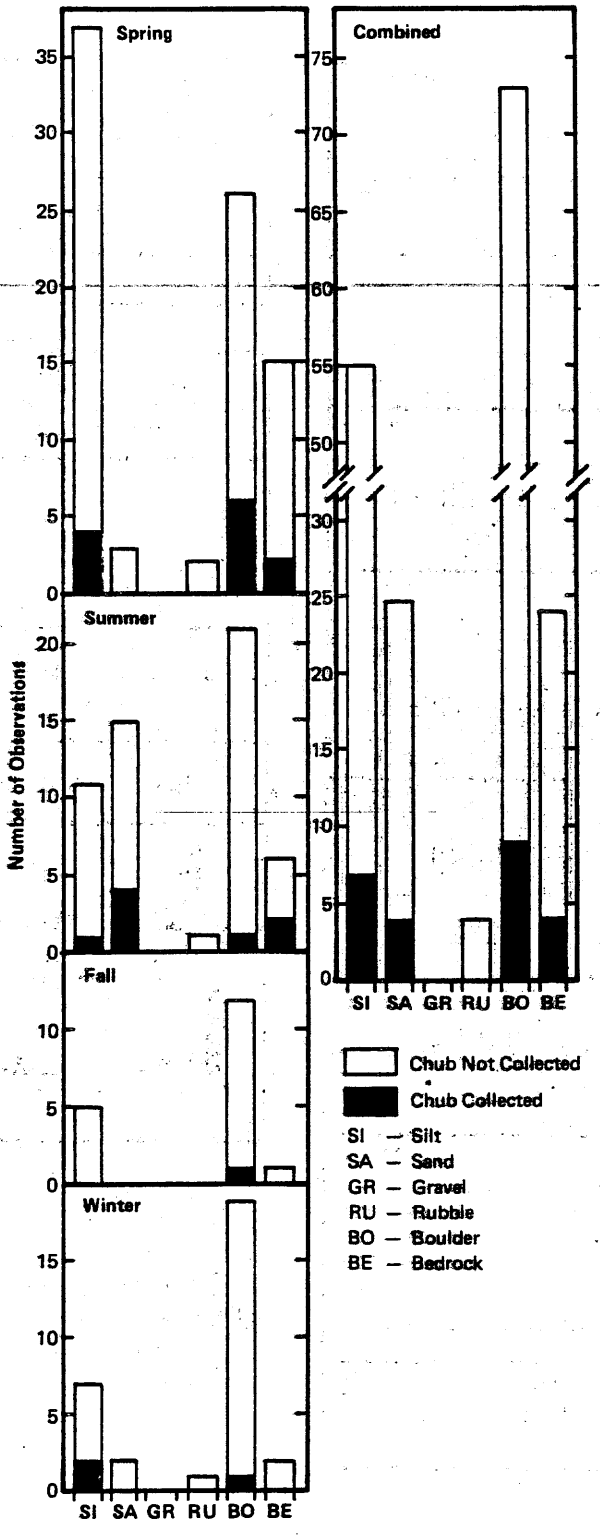
Frequency of humpback chub captures over the range of velocities sampled with minnow traps and seines.

Figure 10



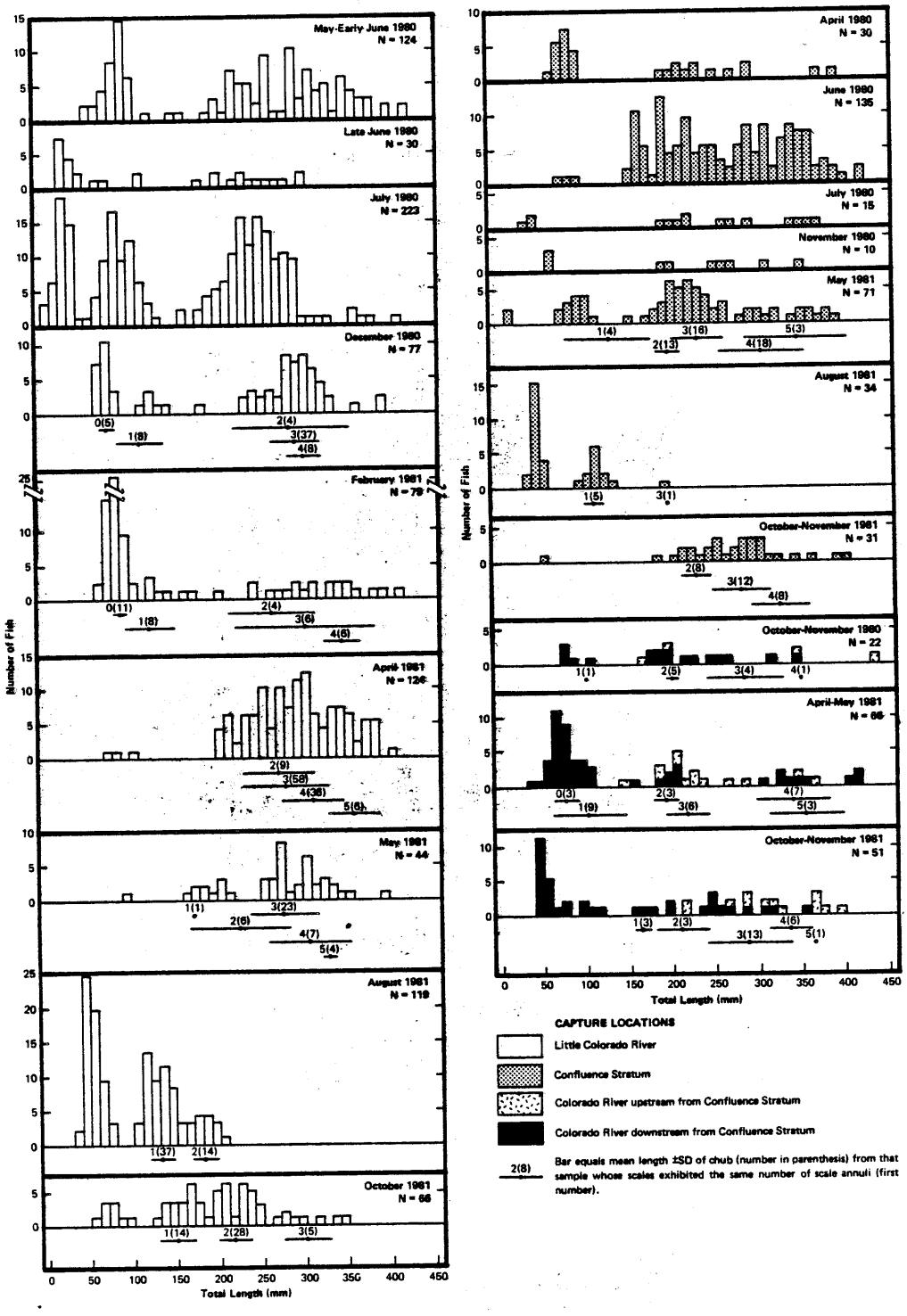
Frequency of humpback chub captures over the range of habitat types sampled with seines.

Figure 11



Frequency of humpback chub captures over the range of substrate types sampled with minnow traps.

Figure 12



Length-frequency distributions and summation of scale characteristics for humpback chub collected from the Little Colorado River, confluence stratum, and Colorado River.

Although chub length-frequency distributions did not differ markedly between the three semiannual Colorado River sampling efforts, chub growth is implicit in size class segregation and scale characteristics (Figure 12). The onset of seasonal growth was indicated by newly formed marks near the margins of many scales collected in April-May 1981, while relatively slow growth was evidenced by packing of circuli at the margins in October-November 1980 and 1981. However, within a well defined 30-120 mm size class from April-May 1981, many of the larger fish clearly possessed one annulus while some of the smaller individuals had yet to develop scales large enough to exhibit circuli. This strongly intimates that all these specimens were yearlings and casts doubt on the reliability of age and growth estimates derived from Colorado River humpback chub scales because the smaller fish would probably not form an annulus that year. Further evidence for designation of these small Colorado River chub as yearlings is provided in the section on reproduction.

Reproduction

Age at maturity

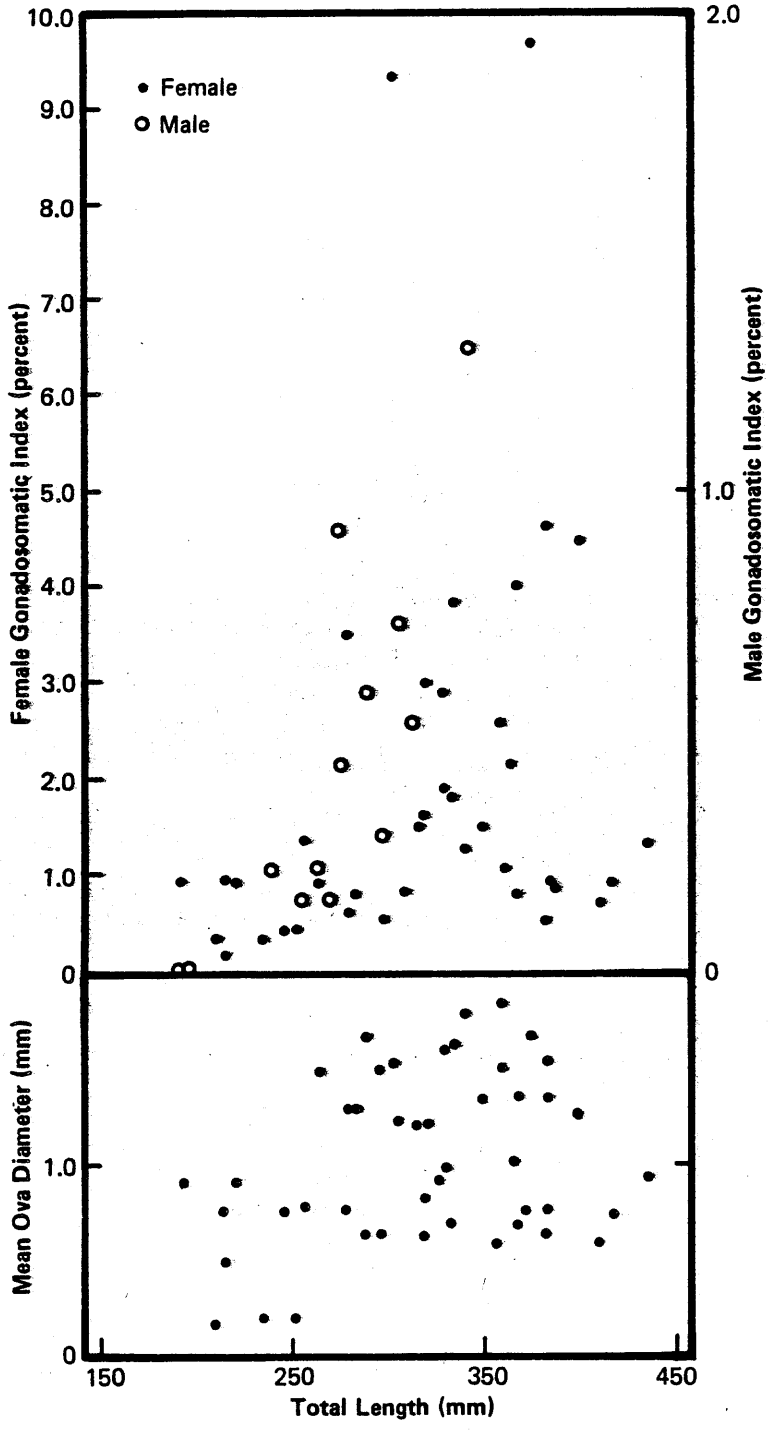
Relationships between gonadosomatic index (GSI) and fish length and between mean ova diameter (MOD) and fish length indicated sexual maturity of female chubs begins at approximately 250 - 280 mm TL (Figure 13), or about 3 years of age for chub in the Little Colorado River (Figure 12). However, Colorado River chub may be older at the onset of sexual maturity. While the relatively small number of GSI values for male chubs suggests male sexual maturity commences at lengths similar to those of female fish (Figure 13), field observations indicated mature males of smaller size. Of the male chubs collected in April 1981, 15 of 19 (79 percent) between 200 and 249 mm and 26 of 35 (74 percent) between 250 and 300 mm expressed milt when external pressure was applied. The smallest male to express milt was 205 mm.

Seasonal gonadal development

Seasonal fluctuations in GSI and MOD for female chubs from the Little Colorado River were similar, although within sample MOD generally exhibited less variation than did GSI values (Figure 14). Significant seasonal differences were evident between sample MOD values but not between GSI values. Gonadal development of Little Colorado River chub was rapid between December and February/April when indices attained seasonally high levels, while rapid declines in both MOD and GSI between April and May indicated spawning had occurred (Figure 14).

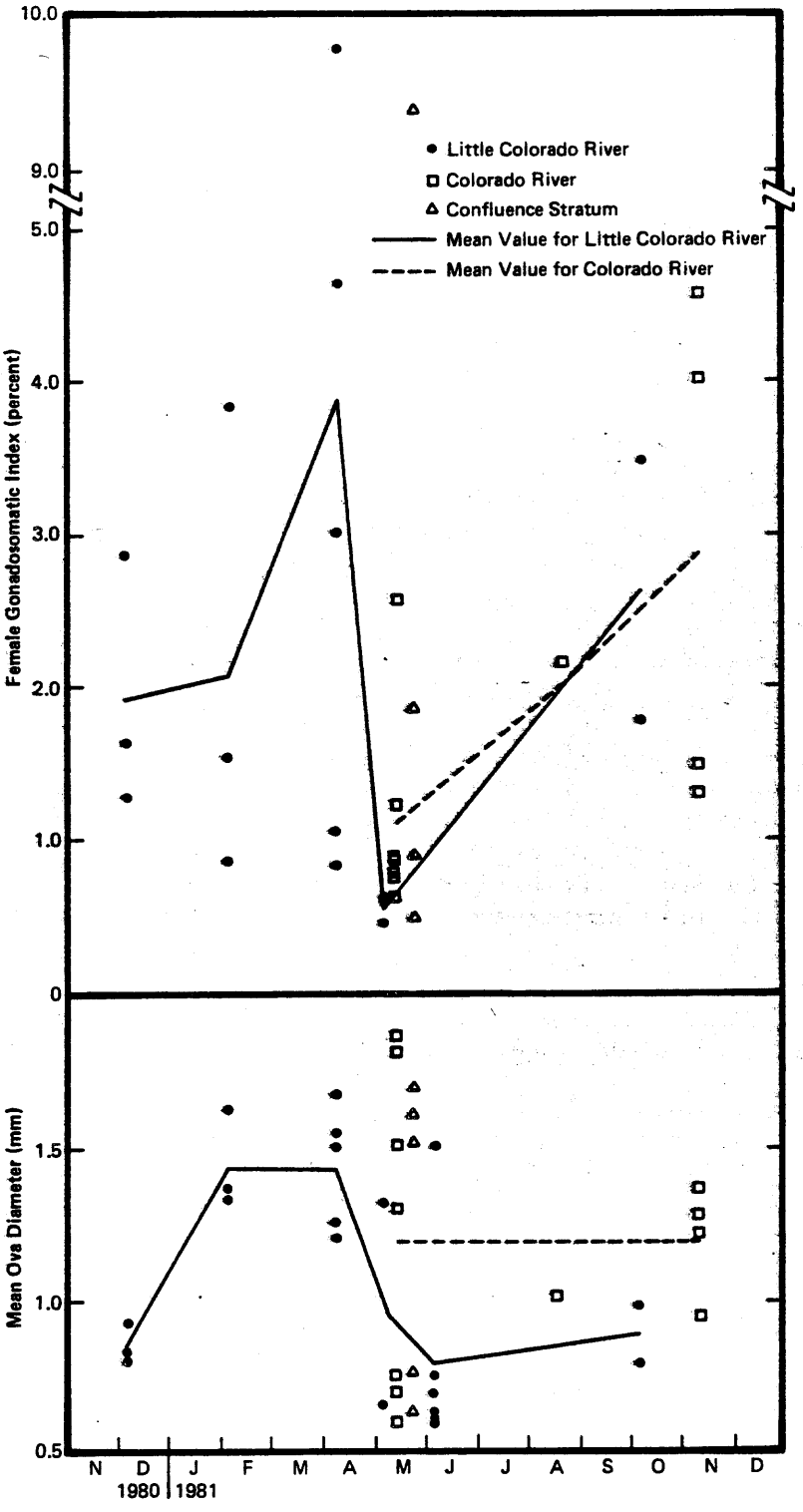
Little Colorado River, confluence stratum, and Colorado River chubs in May exhibited relatively low mean GSI while MOD values varied extensively (Figure 14). This suggests a post ovulatory condition where spent or partially spent ovaries exhibited low GSI but large, residual ova resulted in high MOD values. No statistical differences were found between samples taken in May. Histological analysis corroborated observations on gross gonadal characteristics, indicating chub gonadal development was similar between concurrent collections from the Little Colorado, confluence stratum, and Colorado River (Charlie Smith, Fish Cultural Development Center, FWS, personal communication). These observations indicate chub undergo normal seasonal gonadal development in the

Figure 13



Relationships between gonadosomatic index and fish length and between mean ova diameter and fish length for humpback chub.

Figure 14



Seasonal changes in gonadosomatic indices and mean ova diameter for humpback chub. Six specimens collected in June 1980 are included in the mean ova diameter data.

Colorado River in preparation for spawning, an observation that is not remarkable in that water temperatures during the time of most rapid gonadal development were similar to those that chub historically experienced (Figure 2).

Seasonal gonadal development of Little Colorado River males larger than 250 mm paralleled that of female chub. Milt was expressed with external pressure in 25 percent of 12 fish in February, 74 percent of 57 fish in April, and 17 percent of 23 fish in May. Nuptial tubercles were observed on 50, 23, and 22 percent of the males in these respective samples.

Occurence of young-of-the-year (YOY)

YOY chub were first collected from the Little Colorado River in late June 1980 and August 1981 and from the confluence stratum in July 1980 and May 1981 (Figure 12). Chubs from the latter sample measured 14-21 mm and were probably spawned only two or three weeks prior to collection. Length-frequency distributions for YOY chub in 1980 and 1981, when viewed in the context of incubation times, fry size at emergence, and the rate of subsequent growth observed in the hatchery (Hamman 1982), suggested spawning peaked in April-May of both years, the same reproductive period indicated by gonadal analysis.

The complete absence of chub less than 145 mm from any of the Colorado River collections upstream from the confluence (Figure 12), although adult fish were present, provided evidence of no chub reproduction in the Colorado River and demonstrated chub movement from spawning and/or nursery areas in the Little Colorado River into the Colorado River. The smallest chub collected from the Colorado River in April-May 1981 measured 38 mm and was probably not produced in the Colorado River. This small Colorado River chub was nearly twice the size of the largest YOY chub collected concurrently from the confluence stratum and no YOY were found at this time in the Little Colorado River. Poor growth of small Colorado River chubs is attributable to low temperatures and frequent water level fluctuations which severely limit production of food organisms in littoral areas, the presumed habitat of these small fish.

Recent thermal tolerance tests demonstrated that water temperatures in the Colorado River are too cold for successful chub reproduction. At 12-13° C, temperatures slightly warmer than the seasonal highs of the Colorado River in April-May 1981, only 12 percent of fertilized chub eggs hatched and only two percent survived to the feeding larval stage (Hamman 1982). Limited reproduction of humpback chub in the Colorado River has been reported by earlier workers based on their collection of small fish (Suttkus et al. 1976, Suttkus and Clemmer 1977, Carothers and Minckley 1981). Some of these earlier observations were made only a few years after the closure and subsequent filling of the reservoir of Glen Canyon Dam, and discharge temperatures were somewhat warmer. However, caution must be exercised when the capture of small fish is taken as an indication of successful reproduction in an area. Small chub exhibit a general downstream movement as clearly demonstrated by the occurrence of these fish in the Colorado River and fish as small as 38 mm have been determined to be 1 year old. Although reproduction may occur in places within the Grand Canyon other than the Little Colorado River (other warm

Table 2

Mean percentage of sample total and mean percent of sample frequency of groups of food organisms found in the stomachs of humpback chub collected from the Little Colorado and Colorado Rivers. Ranges are given in parentheses. T = 0.05.

Food Item	Little Colorado 4 samples / 26 fish	Colorado 2 samples / 18 fish
Chironomidae		
% Numbers	36.1(5.6-92.3)	27.5(0.1-54.8)
% Frequency	36.7(20.0-50.0)	50.0(11.1-88.9)
Simuliidae		
% Numbers	22.4(0.0-89.7)	71.1(42.9-99.3)
% Frequency	5.0(0.0-20.0)	55.6(33.3-77.8)
Other Diptera[a]		
% Numbers	12.3(0.0-35.7)	0.1(T-0.2)
% Frequency	22.1(0.0-50.0)	11.1(11.1)
Tricoptera		
% Numbers	17.9(0.0-66.7)	T(0.0-T)
% Frequency	15.8(0.0-50.0)	5.6(0.0-11.1)
Neuroptera		
% Numbers	2.4(0.0-9.5)	0
% Frequency	6.7(0.0-26.7)	0
Coleoptera		
% Numbers	1.8(0.0-5.6)	0.1(T-0.2)
% Frequency	17.5(0.0-50.0)	11.1(11.1)
Gammarus		
% Numbers	0	1.0(0.4-1.6)
% Frequency	0	22.2(11.1-33.3)
Other[b]		
% Numbers	7.3(0.0-16.7)	0.2(0.1-0.2)
% Frequency	35.0(0.0-100.0)	11.1(11.1)

[a]Ceratopogonidae, Hemerodromia, Ephydridae, Limnophora

[b]Ephemeroptera, Orthoptera, Hymenoptera, Oligochaeta, Nemotoda, Pimephales promelas

T = Trace, less than 0.05%

Table 3

Seasonal incidence of *Lernaea cyprinacea* infection of humpback chub of three age categories from the Little Colorado River, confluence stratum, and Colorado River. Data are given as number of fish examined/number infected (mean intensity of infection).

Season, size class	Little Colorado	Confluence	Colorado
Winter (Dec)			
100 mm	20/9 (1.2)	-	-
100-200 mm	7/5 (4.6)	-	-
200 mm	50/25(1.7)	-	-
total	77/39(2.0)	-	-
Spring (Feb-May)			
100 mm	50/4 (1.5)	11/1 (1.0)	34/0(0)
100-200 mm	16/1 (3.0)	12/0 (0)	10/1(1.0)
200 mm	178/8 (1.8)	48/3 (1.0)	22/1(2.0)
total	244/13(1.8)	71/4 (1.0)	66/2(1.5)
Summer (Jul-Aug)			
100 mm	57/7 (1.1)	21/0 (0)	-
100-200 mm	61/21(1.9)	12/6 (1.3)	-
200 mm	1/0 (0)	-	-
total	119/28(1.7)	33/6 (1.3)	-
Fall (Oct-Nov)			
100 mm	9/1 (3.0)	4/1 (1.0)	21/1(1.0)
100-200 mm	28/7 (1.4)	2/2 (3.5)	16/0(0)
200 mm	29/10(1.5)	35/16(2.0)	32/3(2.3)
total	66/18(1.6)	41/19(2.1)	69/4(2.0)

tributaries), the attainment of suitable reproduction requirements in the Colorado River is improbable because of the frequent water level fluctuations that would desiccate fertilized eggs deposited in shallow areas where waters are warmest.

How does flow affect tributary spawning + doesn't affect LCR upstream spawning

Stomach Contents

Stomach contents of humpback chub collected from both the Little Colorado and Colorado Rivers were numerically dominated by Dipterans of the families Chironomidae and Simuliidae with other food items present in low numbers and frequencies (Table 2). Comparision of Little Colorado River chub stomachs and concurrently collected drift samples suggested a moderate selectivity for Chironomid larvae and pupae and an avoidance of Chironomid adults (Jacobi 1982, Part 3). The amphipod Gammarus, although common in many areas of the Colorado River, was infrequently consumed by chub residing in the Colorado River.

This doesn't support previous statement of flow fluctuation slow growth problem

Food items of chubs collected in the Little Colorado River were somewhat more varied than those collected in the Colorado River, with the Neuropteran Corydalus being the most significant on the basis of size. Not normally found in drift collections, the occurrence of Corydalus suggests that chub may selectively feed on the river bottom. Two Little Colorado River chub contained fish remains, including a fathead minnow (Pimephales promelas) approximately 50 mm TL.

what's size of fish

Of the chub stomachs collected, 42 percent from the Little Colorado River and 28 percent from the Colorado River were empty, perhaps resulting from digestion during retention in holding pens before sacrifice. Detailed accounts of stomach contents and drift samples are provided by Jacobi (1982, Part 3).

Parasites and Disease

Metazoan parasites

The copepod Lernaea cyprinacea, the most conspicuous metazoan parasite of the humpback chub, exhibited a seasonal cycle of incidence in the Little Colorado River and confluence stratum with infections most widespread in winter and least common in spring (Table 3). Incidence in Colorado River chub did not differ between spring and fall samples, and no relationship between fish size and incidence of infection was apparent in any of the collections.

Site of infection was usually near the fin base although buccal and opercular cavities were not regularly examined. Observations on 271 copepods revealed 32 percent associated with the dorsal fin, 24 percent with the pelvic fins, 21 percent with the pectoral fins, 13 percent with the anal fin, 2 percent with the caudal fin, and 8 percent with other body parts. Mean intensity of infection was 1.7 copepods per infected fish; 63.6 percent of 162 infected fish hosted only one parasite while the maximum burden was seven.

The capture of six Colorado River chub infected with L. cyprinacea implies movement between the Little Colorado and Colorado rivers. Development of Lernaea is optimized at tempertures between 23° and 30° C

and cannot be completed below 14° C (Bauer 1959). These temperatures requirements are not met in the Colorado River (Figure 2). Infected chub in the Colorado River probably contracted the parasite in the warmer Little Colorado River.

The intensity of Lernaea infection of humpback chub within the study area is well below that reported in cases where significant mortality of other host species has occurred (Bauer 1959, Bulow et al. 1979). The high incidence of low intensity infection in small Little Colorado River chubs during December 1980, however, could be a cause of mortality.

Routine pathological analysis revealed an additional metazoan parasite, the nematode Philometra, in one chub from the confluence stratum (Flagg 1981, Part 3).

Microparasites

Thirteen species of bacteria, six protozoans, and the fungus Saprolegnia were identified in routine pathological analyses of humpback chub (Flagg 1981, Part 3). While these data are largely qualitative, the low incidence of most of these pathogens suggests disease due to microparasites is generally not a major cause of chub mortality.

Although the bacterium Aeromonas hydrophila occurred in low incidence in collected specimens throughout the year, field observations revealed acute symptons of Aeromonas in many chub collected from the confluence stratum and Little Colorado River during the 1981 spawning season. At that time, humpback chub were generally in poor condition and tolerated little handling. Stress associated with spawning, thermal and osmotic changes experienced by chub that moved from the Colorado River into the Little Colorado River, and possible crowding, are factors that could cause acute expression of this pathogen. It appears that conditions of stress in the Little Colorado River during late spring may not be unlike those in hatcheries where significant mortality has occurred (Flagg 1981, Part 3).

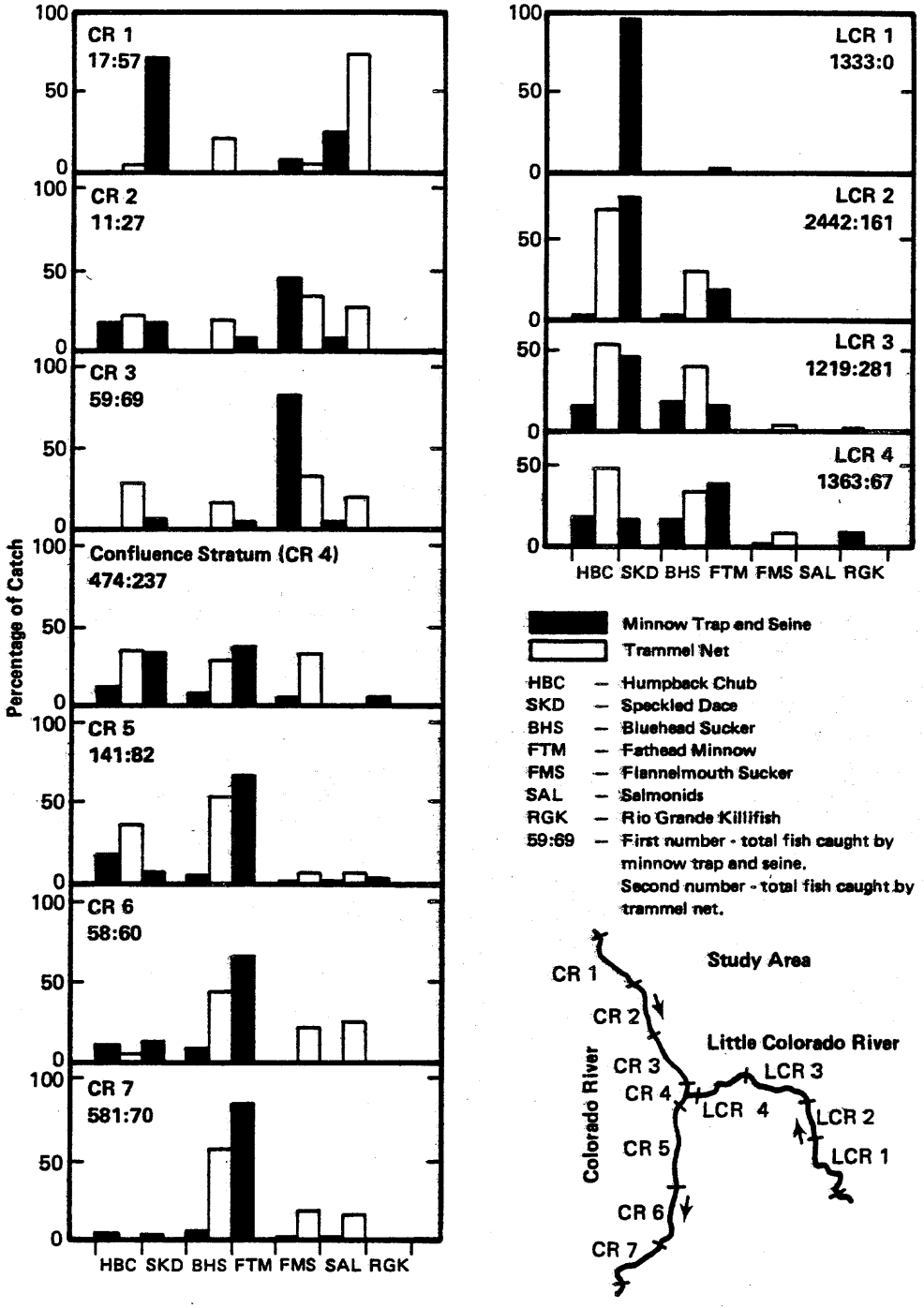
Interspecific Associations

In addition to humpback chub, thirteen other fish species and one hybrid were collected from the study area. The catch rates for these fishes varied considerably between rivers and strata (Figure 15). Of the species that attain relatively large size, YOY and juveniles were most frequently collected by minnow traps and seines while adults were collected by trammel nets. The incidental catch of redside shiner (Richardsonius balteatus) from the Colorado River is the first known within the study area. Although caught in numbers too low to allow for detailed analysis, black bullhead (Ictalurus melas) and channel catfish (I. punctatus) were also found. Angling suggested channel catfish may be particularly common in some areas of the Colorado River.

No significant relationships were found between mean catch rates for humpback chub and sympatric species which suggested that interspecific associations alone did not significantly affect the distribution and relative abundance of chub within the study area. Several chub from the Little Colorado River, however, were observed with apparent catfish bite

Why catfish

Figure 15



Relative abundance of the dominant species caught by minnow traps, seines, and trammel nets from Little Colorado River, confluence, and Colorado River strata.

marks; some of which were received during entanglement in nets while many others were older and showed various degrees of healing and infection. These observations suggested that catfish may be an important predator on chub in the Little Colorado River.

Of the fourteen fish species collected from the study area, each a potential colonizer of the Little Colorado River, only humpback chub, speckled dace (Rhinichthys osculus), bluehead sucker (Catostomus discobolus), and fathead minnow (Pimephales promelas) were collected from the river in substantial numbers. Physicochemical parameters appear to limit the range of other fishes within the Little Colorado River: species diversity in the catch decreased with distance from the confluence which clearly demonstrated an inability of many species to develop populations in the river. Only speckled dace and fathead minnow were collected from the uppermost Little Colorado River stratum (LCR 1), perhaps because low dissolved oxygen and the effects of travertine precipitation make the habitat unsuitable for reproduction of other species. The large travertine dams separating LCR 1 from the other Little Colorado River strata prevent, except perhaps during the highest of river discharges, upstream movement of humpback chub. It is possible that the significance of the Little Colorado River to humpback chub is in large part attributable to the unsuitability of the harsh river environment for other potential competitor species. Laboratory studies suggest humpback chub may tolerate higher levels of total dissolved solids than do bonytail chub (Gila elegans) and Colorado squawfish (Ptychocheilus lucius), former residents of the Colorado River in Grand Canyon (Bulkley et al. 1981, Part 3).

Limited sampling upstream - Tributary spawning - not just LCR

Bluehead sucker and fathead minnow within the Colorado River apparently resulted from reproduction in the Little Colorado River. No evidence of reproduction by these species within the Colorado River was obtained and their distribution below but not above the confluence stratum, like that of juvenile humpback chub, indicated recruitment occurred from the Little Colorado River. The habitat requirements of the Rio Grande killifish (Fundulus zebrinus) are evidently met only near the confluence stratum or stratum LCR 4.

Speckled dace were commonly encountered throughout the Colorado River strata while flannelmouth suckers (Catostomus latipinnis), including young, occurred predominately in the upstream strata of the Colorado River and in the confluence stratum. Some level of reproductive success within the Colorado River was suggested by these data.

Eighty-six percent of all salmonids collected were rainbow trout (Salmo gairdneri), while the remainder consisted of cutthroat trout (S. clarki), rainbow trout X cutthroat trout hybrids, brown trout (S. trutta), and brook trout (Salvelinus fontinalis). Fingerling rainbow trout were captured on rare occassions during the spring, 1981. These fingerling rainbow trout were of a size normally stocked upstream below Glen Canyon dam. The downstream movement into the study area of some salmonids was demonstrated by the recapture of a brook trout originally released below Glen Canyon dam. Based on the above information, trout reproduction is probably absent within the study area.

Carp (Cyprinus carpio) were only infrequently collected by trammel nets from the Colorado and Little Colorado Rivers. However, electrofishing demonstrated carp were abundant in the Colorado River as reported by other workers (Carothers and Minckley 1981).

Meristic Variation

None of the chub handled in the field clearly differed from published descriptions of Gila cypha (Miller 1946, Suttkus and Clemmer 1977) and all adults collected for laboratory analyses of critical taxonomic characteristics were considered representative humpback chub (Glenn Clemmer, National Fish and Wildlife Laboratory, FWS, personal communication). In some of the collected YOY fish, however, atypical characteristics were noted (Darrel Snyder, Larval Fish Laboratory, Colorado State University, personal communication).

Eight combinations of dorsal/anal fin ray counts were observed with the 9 dorsal/10 anal combination most common (Table 4). Although variation within populations is typical, pair-wise Chi-square analysis demonstrated the frequency of ray count combinations observed in stratum LCR 4 and the confluecne stratum differed significantly ($p < 0.01$) from that in the upper Little Colorado River strata, LCR 2 and LCR 3. This difference was attributable to the high frequency of the 10 dorsal/10 anal combination in stratum LCR 4 and the confluence stratum. No differences in the frequency of ray count combinations were observed among chub collected from the Colorado River strata, or between the total Colorado River sample and the individual Little Colorado River strata or the confluence stratum.

The basis for the difference in frequency of ray count combinations between LCR 4 and the confluence stratum and the Little Colorado River strata upstream cannot be explained. Effects of the physicochemical environment can cause morphologic variation but the major differences in physicochemical parameters occur between the Colorado and Little Colorado Rivers and not among strata of the Little Colorado River (Table 1). Chub movement, however, has been shown to encompass the confluence stratum and the lower Little Colorado River strata, and normal morphologic variation could be at least a partial explanation.

It is suggested that the high frequency of the 10/10 combination, characteristic of the bonytail chub Gila elegans which once inhabited the Little Colorado and Colorado Rivers of Grand Canyon (Smith et al. 1979, Miller 1963), reflects a residual influence of the bonytail genome in the humpback chub of the lower Little Colorado River. Hybridization of humpback chub and bonytail chub has been reported in wild populations (Holden and Stalnaker 1970) and has been demonstrated in the hatchery (Hamman 1981). Although an explanation for the observed differences in ray count frequencies is wanting, these differences suggest a degree of reproductive isolation between chub from the upper Little Colorado River and regions downstream which would best be resolved through electrophoretic and other detailed taxonomic examination.

Table 4

Frequency (percent) of dorsal/anal ray count combination for humpback chub (TL 100mm) collected from the Little Colorado River, confluence stratum, and Colorado River. Actual number given in parentheses.

River, Stratum	N	Dorsal/anal ray count 9/10	10/10	9/9	9/11	10/11	8/10	10/9	11/10
Little Colorado									
LCR2	168	81.0(136)	7.1(12)	7.1(12)	1.8(3)	0(0)	1.8(3)	1.2(2)	0(0)
LCR3	296	80.4(238)	7.1(21)	7.4(22)	2.0(6)	2.0(6)	0.7(2)	0.3(1)	0(0)
LCR4	57	70.2(40)	17.5(10)	7.0(4)	1.8(1)	1.8(1)	1.8(1)	0(0)	0(0)
Confluence									
Stratum	216	67.6(146)	16.7(36)	7.4(16)	3.2(7)	3.2(7)	0.9(2)	0.5(1)	0.5(1)
Colorado									
CR1	2	50. (1)	0(0)	50 (1)	0(0)	0(0)	0(0)	0(0)	0(0)
CR2	8	87.5(7)	0(0)	12.5(1)	0(0)	0(0)	0(0)	0(0)	0(0)
CR3	19	78.9(15)	5.3(1)	10.5(2)	5.3(1)	0(0)	0(0)	0(0)	0(0)
CR5	42	69.0(29)	11.9(5)	14.3(6)	2.4(1)	2.4(1)	0(0)	0(0)	0(0)
CR6	5	100 (5)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
CR7	3	33.3(1)	0(0)	66.7(2)	0(0)	0(0)	0(0)	0(0)	0(0)
Total	816	75.7(616)	10.4(85)	8.1(66)	2.3(19)	1.8(15)	1.0(8)	0.5(4)	0.1(1)

SUMMARY

A stratified systematic sampling program was conducted to investigate the life history and population ecology of the humpback chub inhabiting the Little Colorado-Colorado River confluence region of the Grand Canyon. In the Little Colorado River, chub were distributed throughout the lower 13 km river reach where spawning occurred in April-May for the two years of study. However, reproductive success differed markedly between years and was related to the timing of seasonal runoff. Relatively high reproductive success was related to runoff occurring just prior to or during the spawning period while poor success was related to runoff occurring during post-spawning.

The ratio of dorsal to anal fin rays of chub from the upper 8 km of the river were different from those in the lower 5 km reach, suggesting a degree of reproductive isolation between chub populations within the Little Colorado River. There was no support, on the basis of these meristic characters, for the suggestion that a unique humpback chub population exists in the confluence stratum or Colorado River part of the study area.

The distribution of small chub in the Colorado River, entirely downstream from the confluence, indicated that successful chub reproduction did not occur in the Colorado River part of the study area and that young fish moved downstream from spawning areas in the Little Colorado River. The year-round low temperatures of the Colorado River did not inhibit seasonal gonadal maturation but, based on recent laboratory studies, would have resulted in extremely high mortality rates for embryonic and larval chub. In marked contrast with that of small fish, the distribution of adult chub in the Colorado River was normal about the confluence, probably because of the importance of the Little Colorado River as reproductive habitat. The recapture of tagged fish and seasonal changes in adult chub catch rates from the Little Colorado River supported the hypothesis that some adult fish from the Colorado River enter the Little Colorado River for reproduction.

Physical habitat use by YOY and juvenile chub in the Little Colorado River was affected by light intensity with shallow waters occupied primarily during darkness and/or during daylight under turbid water conditions. Both sand/silt and boulder/bedrock substrates were used by small chub. Chub preference for these substrates could not be established. Little Colorado River water quality may have a more significant influence on humpback chub reproductive success, and subsequent habitat use by small fish, than do the depth, velocity and substrate parameters found useful in other regions.

Humpback chub populations inhabiting the Little Colorado - Colorado River confluence region appeared relatively stable, but continued stability is not assured. Although existing associations with sympatric species did not in themselves appear to have a significant effect on the

distribution and relative abundance of chub, the physicochemical environments of the Little Colorado and Colorado Rivers probably preclude the establishment of appreciable populations by many species presently found within the immediate drainage. The likelihood that species tolerant of these conditons will be introduced increases as management agencies bring more and varied species to the drainage, and would be significantly enhanced if, through the physical modification of Glen Canyon dam, discharge temperatures became more conducive to reproduction by certain exotics. Introduction to the Little Colorado River of species tolerant of high salinity and temperatures could have a devastating effect on the humpback chub of Grand Canyon. Although humpback chub tolerate the physicochemical environment of the Little Colorado River, pathologic analyses suggested life here may be seasonally stressful to chub. Nevertheless, maintenance of the existing phisicochemical and biological environments of the Little Colorado River is essential to the continued survival of humpback chub in the Grand Canyon.

The recapture of tagged chub after considerable upstream movement in the Little Colorado River clearly demonstrates these fish are capable of negotiating most barriers to be found in the Grand Canyon. No barriers to the upstream movement of humpback chub into the Little Colorado River were evident in the confluence stratum over the range of Little Colorado and Colorado Rivers discharges during the study period.

Future studies in the Grand Canyon are needed to monitor humpback chub reproduction and evaluate any future habitat changes.

The design for a study documenting the enhancement of chub reproduction in the Colorado River is suggested by observations made in the present study. Sampling for small chubs could be routinely carried out throughout the Colorado River of Grand Canyon by regular National Park Service river patrol personnel using minnow traps and seines. These gears were proven to be effective in collecting small chub and other small fishes, they require minimal personnel, and provide a quantifiable, replicable sampling unit. The development and implimentation of such a sampling program to collect baseline information on the distribution and relative abundance of fishes is needed so that any future efforts to enhance humpback chub reproduction in the Colorado River of Grand Canyon could be monitored over time.

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Dean Blinn and H. E. Graham of the Biology Department, Northern Arizona University, provided laboratory equipment and space. Norm Sharber designed and built the electrofishing boat and provided logistic support, as did Dr. Steve Carothers of the Museum of Northern Arizona. Jim Walters, Grand Canyon National Park, as well as numerous other park personnel, provided invaluable assistance throughout the study. Mary P. Young designed and executed the graphics.

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REPORT NO. 4

TRIBUTARY REPORT: FISHERY INVESTIGATIONS OF THE GUNNISON AND DOLORES RIVERS

by

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INTRODUCTION

General Setting

The Colorado River drainage contains fish species found nowhere else in the world. Four endemic species have declined in numbers and are threatened with extinction. The Colorado River Fisheries Project (CRFP) was originally established to assess habitat requirements of the endangered Colorado squawfish (Ptychocheilus lucius) and humpback chub (Gila cypha). The bonytail chub (Gila elegans) was added to this list of target species after being listed as endangered by the U.S. Fish and Wildlife Service (FWS) in May 1980. Razorback sucker (Xyranchen texanus) were also considered by CRFP because of their unknown status.

CRFP was established through a Memorandum of Understanding (MOU) with the Bureau of Reclamation (BR) on April 14, 1979, (Contract No. 9-07-40-L-1016). The Bureau of Land Management (BLM) supplied funding for fishery research in the State of Colorado through a MOU (Contract No. CO-910-IA9-933).

The MOU established biological criteria needed to assess the habitat requirements of the four target species, including: (a) spawning requirements, (b) habitat requirements of young-of-the-year, juveniles and adults, (c) migration and movements (d) effects of salinity, temperature and selected chemicals, (e) feasibility of propagation and rearing of endangered fish, and (f) fish pathogens and parasites.

CRFP consisted of three field stations; Vernal, Utah, Grand Junction, Colorado, and Flagstaff, Arizona. The Grand Junction Field Station (GJFS) was assigned to conduct fishery research on the upper Colorado River and lower Dolores and Gunnison Rivers.

Objectives

This report deals with the status of endangered fishes in the Dolores and Gunnison Rivers (two major tributaries of the upper Colorado River). Objectives of this research include determining use and abundance, migration and movement, habitat requirements and interspecific competition of the four target species in these tributaries. A CRFP report on the fishes of the mainstem upper Colorado River is under a separate cover.

METHODOLOGY

Study Area

Gunnison River

The Gunnison River is one of the major tributaries of the upper Colorado River, contributing approximately $2x10^6$ acre-feet of water or about 14 percent of the total average annual runoff of the Colorado River measured at Lees Ferry, Arizona. Sampling in the Gunnison River was conducted from Escalante Canyon, Colorado, to the confluence of the Colorado River at Grand Junction (Figure 1). This 42-mile reach was divided into three strata varying from 12 to 15 miles in length.

Several water diversion and power-generating structures have been constructed on the Gunnison River. Redlands Diversion, built in 1907 for irrigation purposes, is the major structure found within the study section. Unused irrigation water from Redlands Diversion flows through Redlands Canal and empties into the Colorado River, leaving the Gunnison River below the dam occasionally stagnant during the growing season. A diversion tunnel (BR Uncompahgre Project) was constructed in 1910 on the upper Gunnison above Delta, Colorado, to irrigate the Uncompahgre Valley. Unused irrigation water diverted through this tunnel returns to the Gunnison River via the Uncompahgre River. The Gunnison River is also the site of the BR Curecanti Project (completed in 1977), which consists of three water storage and hydroelectric dams above Montrose, Colorado.

Dolores River

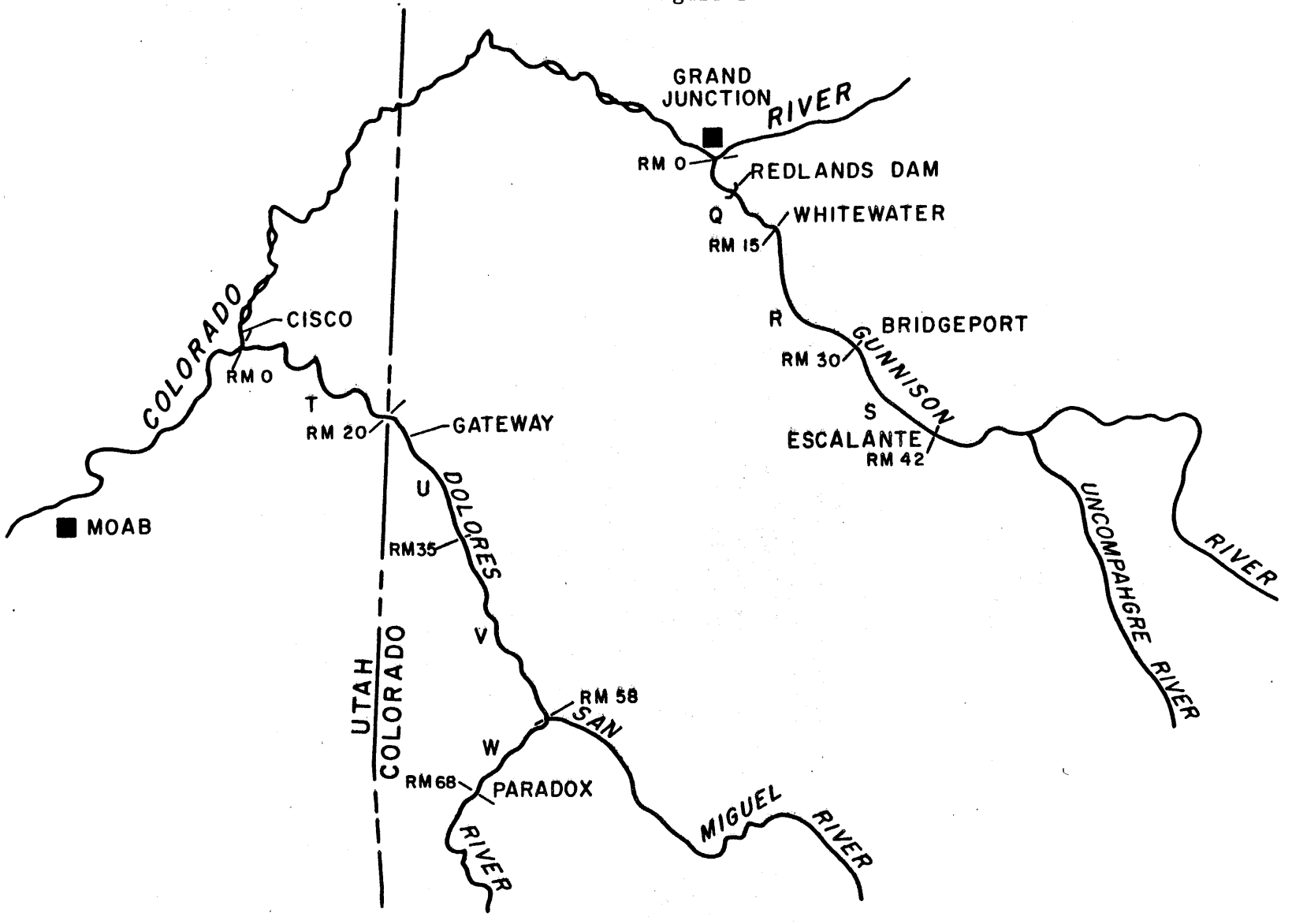
The Dolores River is a major tributary of the upper Colorado River. Sampling of the Dolores River was conducted for 67.6 miles from Paradox Valley, Colorado to the confluence with the Colorado River near Cisco, Utah (Figure 1). The study reach was divided into four strata ranging from 10 to 22.3 miles in length.

The Dolores River has several modifications associated with agriculture and mining. A dam was constructed by the Montezuma Valley Irrigation Company north of Dolores, Colorado, to irrigate arid farmland. This dam diverts nearly all of the river during times of low flow in the summer and fall (July-November). No water returns to the Dolores River after this irrigation diversion, and the river is stagnant below the dam to the San Miguel River confluence. At this point, the San Miguel River contributes nearly all the water flowing in the lower Dolores River. Uranium, gold, and salt mining operations also occur along the Dolores and San Miguel rivers. Spills from these mining operations have resulted in several fish kills (Sigler et al. 1966, Nolting 1957).

Sample Design

Sampling was conducted on the Gunnison River from July 30, 1979 through October 16, 1981. The Dolores River was sampled from April 28, 1981 through October 23, 1981. Every stratum was sampled before,

Figure 1



Study strata of the Gunnison River (Q-S) and the Dolores River (T-W)

during and after spring runoff; for two complete years on the Gunnison River and in 1981 only on the Dolores River. Sampling was not conducted from November to March because of adverse weather conditions. Field crews consisting of 2-4 investigators spent 3 days sampling each stratum, and made 8-9 field trips per year on each river.

Physical - Chemical Parameters

Physical and chemical data were collected during each sample period between 1100 and 1400 hours. River depths were recorded with a Lowrance Model LRG 1510-A sonar depth finder (graph type), except in shallow conditions (<1 ft) where a Philadelphia rod was used. Depth transects were made perpendicular to the thalweg of the river. River width was measured at the site of each depth profile using a range finder or estimated by eye. Water temperature, air temperature, specific conductance and salinity were measured with a Yellow Springs S-C-T Meter, Model 33. Dissolved oxygen content was determined with a Hach Model OX-10 analysis kit.

Watercraft

Several types of watercraft were used depending on river flow. Aluminum flatbottom boats (14 and 16 feet) were used most of the year on the Gunnison River. Hypalon rafts (16 feet) were used on the Dolores River because of dangerous rapids and low flows. Rafts were also used during low water on the Gunnison River. Low water levels in the Dolores River in August 1981 necessitated the use of a canoe for carrying sampling equipment.

Sample Gear

Active and passive gears were used to capture fishes. Electrofishing, trammel nets, gill nets, fyke nets, and beach seines were the major gears used. Several gear types were used in order to adequately sample different habitats (Table 1). These gear types were prone to differing rates of efficiency in capturing fishes.

Table 1
Principal Gears Used by CRFP to Sample Fish Habitat in the Upper Colorado River

Gear	Habitats
Electrofishing	Run, rifle, shoreline, side channel large backwater, mid-channel
Trammel and gill nets	Pool, eddy, large backwater, slow run, mid-channel
Seines	Small backwater, shoreline, run, riffle, pool

Electrofishing

Boom-type electrofishing units were built on 16 foot flatbottom boats or 16 foot hypalon rafts. A 5-kW generator was mounted on a small aluminum frame in the back compartment of the raft or bolted on wood planks in the middle compartment of the boats. Electricity was regulated with a Coffelt RF-10 electrofishing unit. Pulsed DC current was conducted through 3/8-inch stainless steel strand cable at a ratio of 1-3 cathodes to 1 anode, depending on river conductivity. Electrofishing was the most successful at output levels of 250-300 volts with 10-15 amp of current.

Trammel nets

Trammel nets used were 150 feet long and 6 feet high with 1-inch mesh on the inner panel and 10-inch mesh on outer panels. These nets were set for 1-3 hour during the day and overnight. Trammel nets fished effectively, especially during conditions of high turbidity.

Gill nets

Several sizes of gill nets were used during this study. Nets most commonly used were 150 feet long x 6 feet high, with mesh sizes of 1.5, 2.0 and 3.0 inches. Experimental, monofilament gill nets (1/2-inch and 3/4-inch mesh) were also used. Nets were set 1-3 hour during daylight hours and overnight. Gill nets were not used as extensively as trammel nets because they caused higher fish mortality.

Fyke nets

Fyke nets were used sparingly throughout this study because of limited applicability in the reaches sampled. Fyke nets with double wings were set in mouths of small streams entering the rivers. Fyke nets with one center wing were set in tranquil pools during low flows.

Seines

Three seine sizes were used in the tributary study. Small seines (8 feet x 3 feet with 1/8-inch mesh or 15 feet x 4 feet with 1/4-inch mesh) were used to capture young fishes and cyprinids of all ages in shallow areas. A larger seine (30 feet x 6 feet with 1/2-inch mesh) was used to capture juveniles and adults in deeper areas.

Fish Handling

Target species

Special precautions were taken to insure survival of the target fishes. Each endangered fish was carefully placed in a holding tub and salt added to replenish electrolytes and thus reduce stress. The fish was measured for total length (TL) in millimeters, weighed (grams), and examined for external parasites, e.g. Lernaea sp. A red Carlin tag was attached to the base of the dorsal fin of the fish. The small tag wounds were treated with Betadine to deter infection. Scales were removed and

photographs were taken. The target species were released near the original capture sites.

Other species

Fishes collected during regular sampling were processed soon after capture. Total lengths, weights, and Lernaea sp. counts were recorded for each fish collected from all gears except seining. Fish collected from seine hauls were identified, tabulated, checked for Lernaea sp. and released. Floy tags (red) were attached at the base of the dorsal fin of fish 250 mm or longer.

Habitat Parameters

Depth, current velocity and substrate data were recorded with each capture of a target fish. Depth was measured with a Philadelphia rod or a Lowrance Model LRG 1510-A sonar depth finder. Current velocities were obtained using a Marsh-McBirney Model 201 current meter. The meter sensor was placed on a Philadelphia rod and velocities were read at a point approximately 0.6 of the distance from the water surface to the river bottom, at the site where an endangered fish was captured. Primary and secondary substrate at capture sites were recorded (Appendix A).

Analyses

The Gunnison and Dolores Rivers were divided into three and four homogenous strata, respectively, to provide spatial comparisons for total fish species and numbers. Species composition and catch per unit effort (CPE) were compared between strata, habitats, and flow periods. CPE was divided into two groups, those quantified by time and area. Catches using electrofishing, trammel nets, gill nets, and fyke nets were combined to yield CPE for hour-related gears. CPE values for hour gears pertain more to larger fish (>100 mm) because the gear types used were selective for larger fish. Catches from all seines (1/8-, 1/4-, and 1/2-inch mesh) were combined to yield the area CPE. The area CPE values (because of gear selectivity) reflect catch for smaller fishes. CPE was calculated for each species captured with area and hour-based gears. Use of the two CPE combinations for comparative purposes is justified because similar field routines were employed during each sampling trip.

Data were stored and recovered in a computer sytem called MANAGE (Valdez and Wilcott, 1980). Three datasets, PHYSICAL, CATCH, and RARE, contain all data collected from the Gunnison and Dolores Rivers. Each data set has 21, 20, and 29 searchable fields, respectively. The PHYSICAL dataset has all data pertaining to water chemistry and physical characteristics of the two rivers. The CATCH dataset contains data on all fish species from each specific sample taken, and RARE has data from endangered fishes.

RESULTS AND DISCUSSION

Physical and Chemical Descriptions

The Gunnison and Dolores Rivers differed in several physical and chemical characteristics. Generally, the Gunnison River had greater channel width, higher flow rates, fewer rapids, and more floodplain area than the Dolores River. Gunnison River flows ranged from 850 to 13,200 cfs at Whitewater from 1979 through 1980 (Figures 2 and 3). Flows on the Dolores River varied from 50 to 1,890 cfs at the San Miguel confluence in 1981 (Figure 4). The 1981 flows were quite different from those of the previous 2 years (Figures 5 and 6). Large silt deposits were observed in both rivers, in backwaters and other habitats characterized by low velocities.

Conductivity and salinity values were generally lower in the Gunnison River than in the Dolores River. Several salt mining operations and salt settling ponds are located on the Dolores River, which probably contributed to higher conductivity and salinity. Conductivity and salinity values dropped during the runoff period in both rivers, presumably due to the diluting effect of snowmelt. Dissolved oxygen concentration and turbidity was nearly the same in both rivers during respective flow periods.

River temperatures were also similar for the Gunnison and Dolores Rivers. The river temperatures ranged from 13.5° C (May 5, 1981) to 28° C (June 17, 1981) in the Gunnison River and 13.4° C (May 12, 1981) to 26° C (June 10, 1981) in the Dolores River.

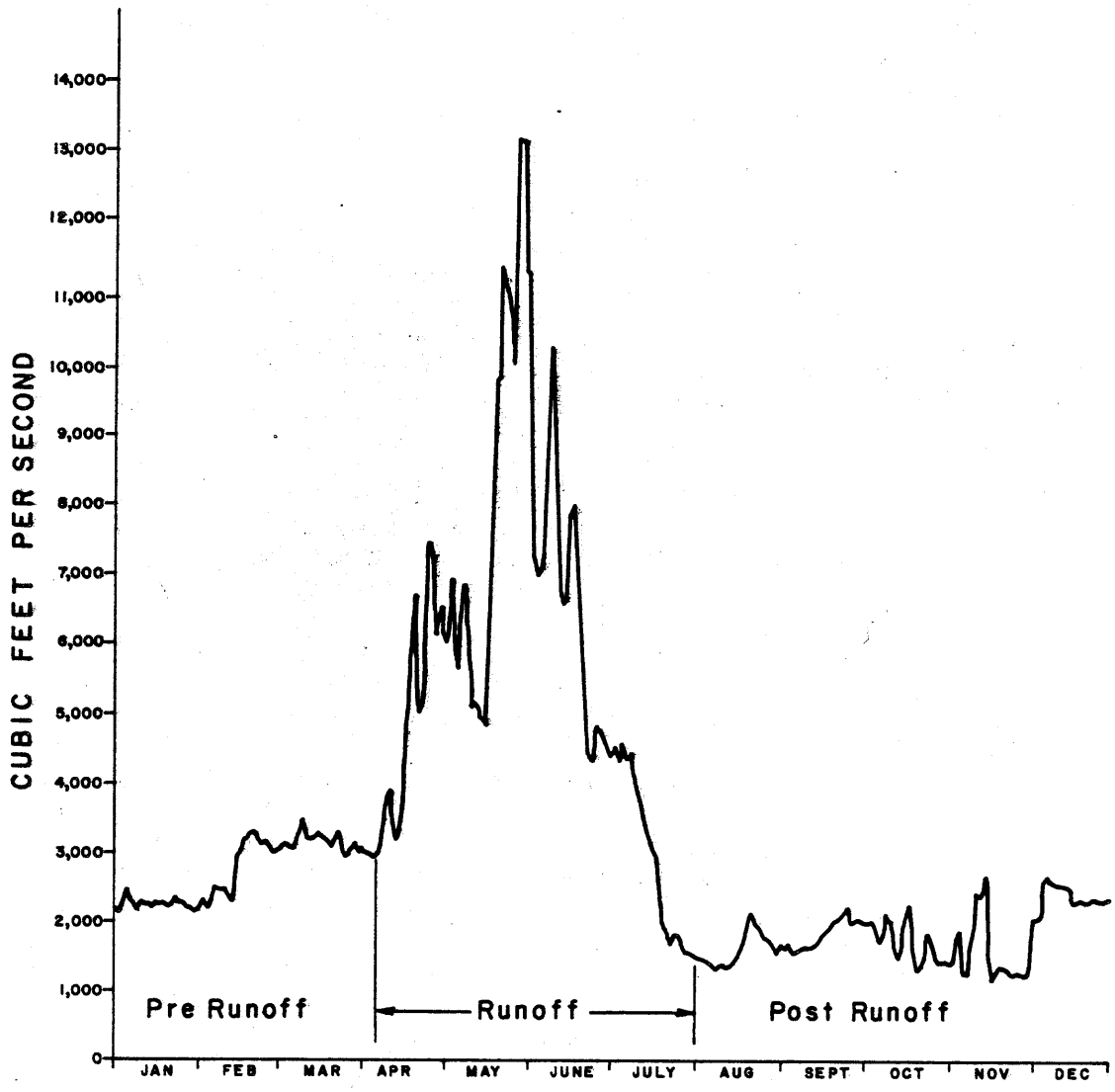
Gunnison River

Stratum Q: Colorado-Gunnison River confluence to Whitewater

The lower 3 miles of this stratum is drastically altered due to the effects of the Redlands Diversion. A large deep pool is located below the spillway (RM 3.0) before the river becomes shallower downstream. Little or no flow was observed below the structure in late summer because nearly all water is diverted through Redlands Canal, and irrigation returns bypass this lower Gunnison reach and flow directly into the Colorado River. The upper section of stratum Q has wide floodplains, few riffles and rapids, and several gravel pits and quarries along the river corridor. A long deep pool is formed directly above Redlands Diversion where water is impounded by the structure. Maximum depths reach approximately 30 feet (near the dam) with a mean stratum depth of approximately 6.6 feet. The width of the river varied from 260 to 525 feet in this stratum.

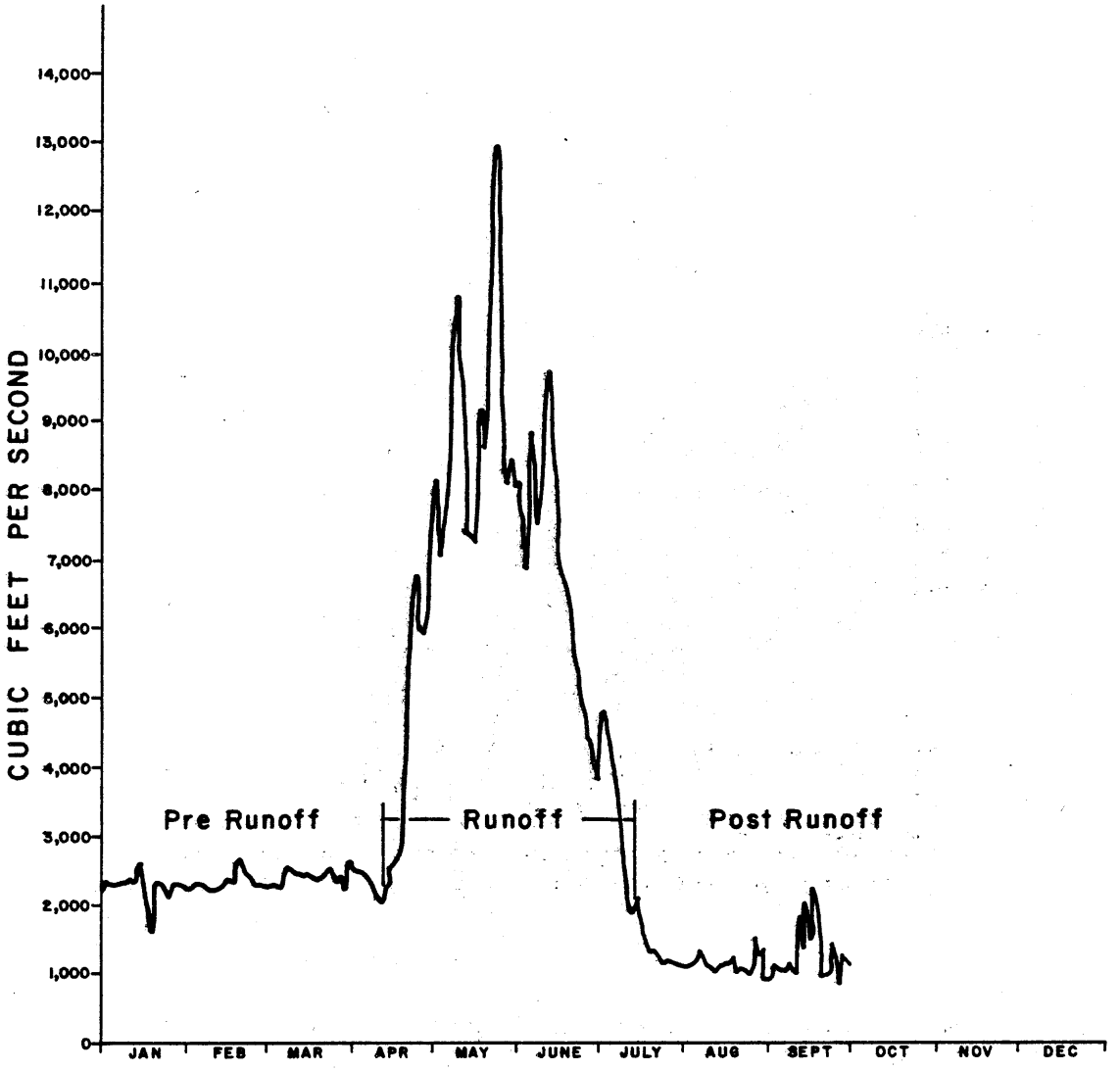
Conductivity ranged from 1,000 to 1,600 umhos cm^{-1} while salinity values were 0-1 parts per thousand (ppth). Dissolved oxygen concentrations were generally 9 to 10 mg/L. The river was turbid in this stratum during the study.

Figure 2



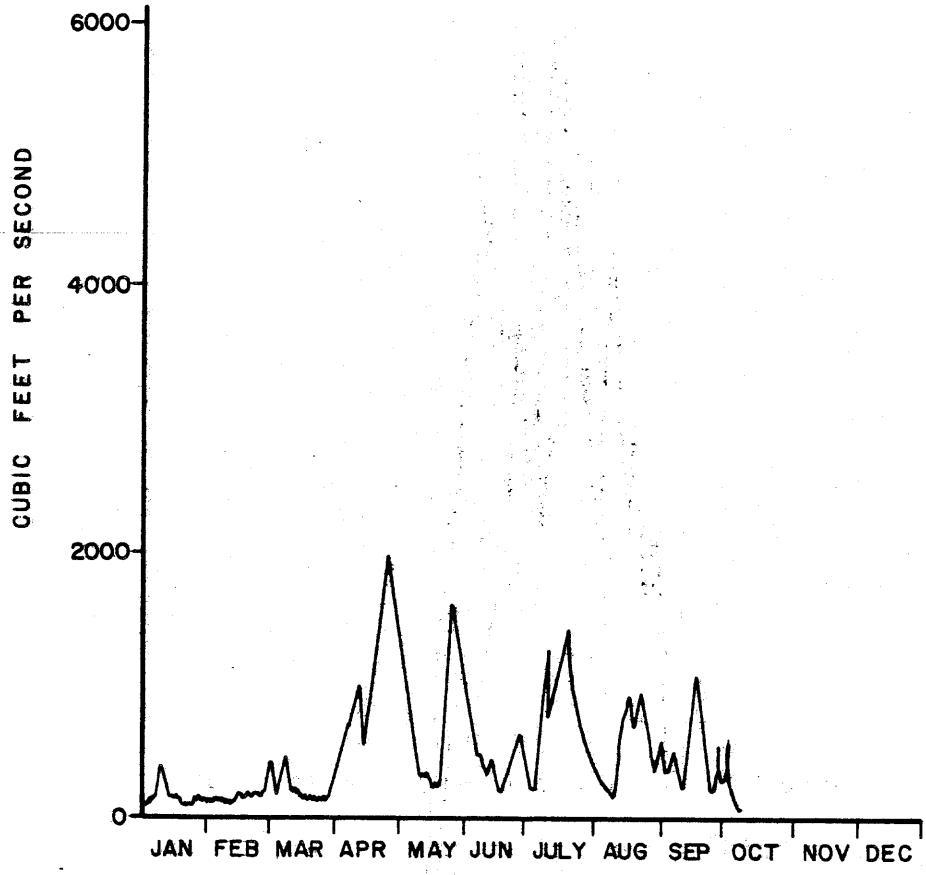
Flow of the Gunnison River at Whitewater, Colorado for 1979 (USGS records).

Figure 3



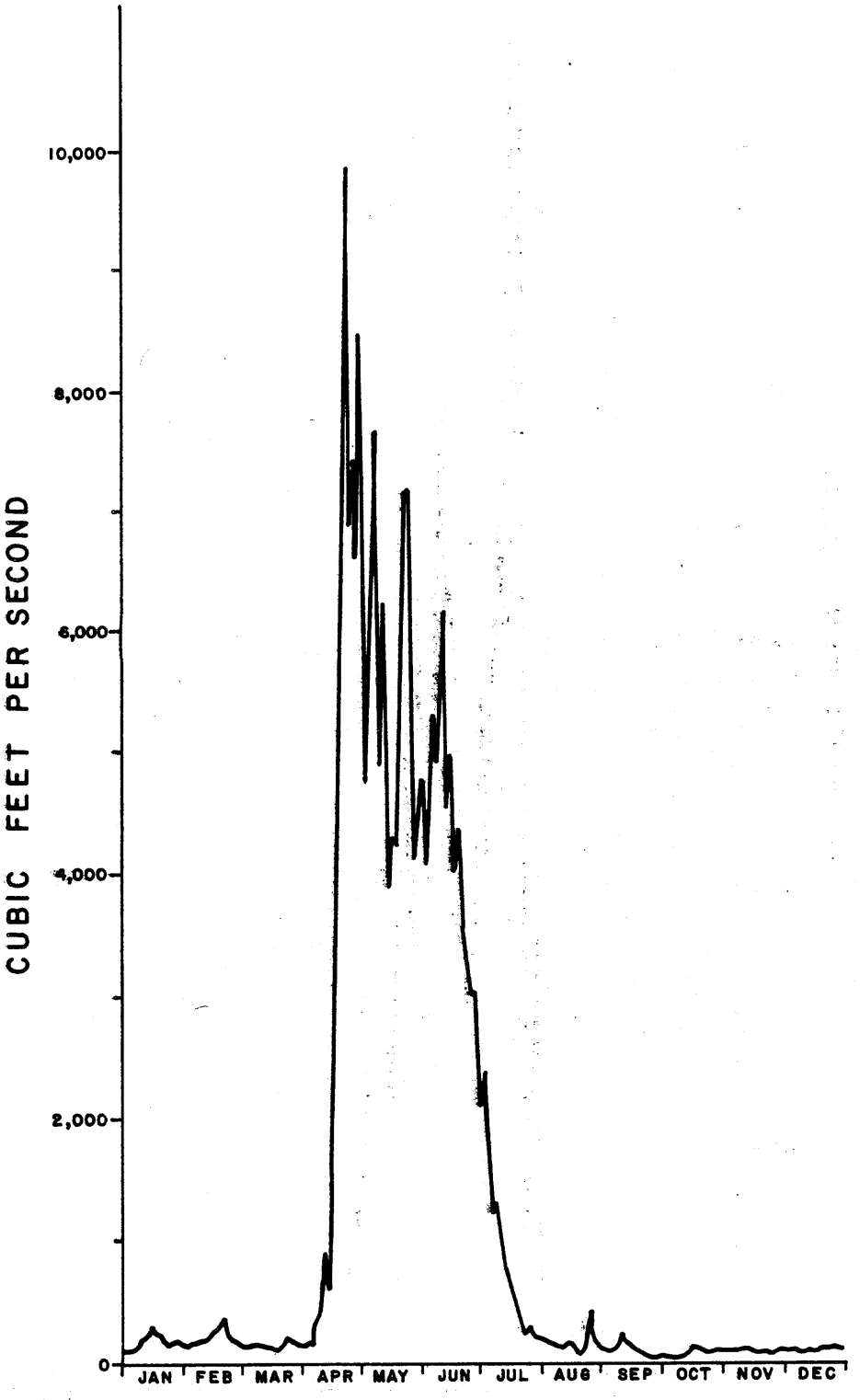
Flow of the Gunnison River at Whitewater, Colorado for 1980 (USGS records).

Figure 4



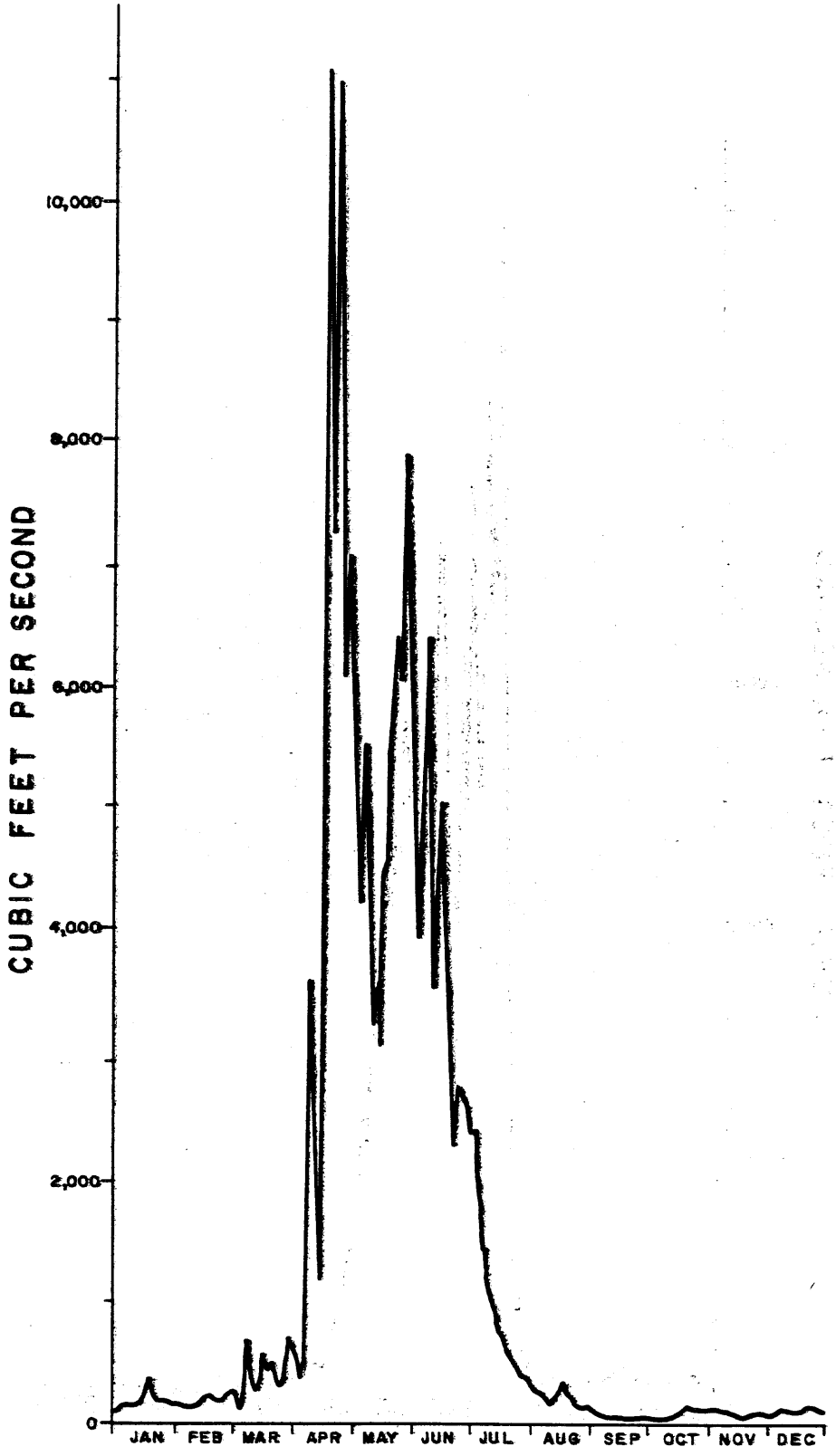
Flow of the Dolores River at the San Miguel confluence for 1981 (USGS records).

Figure 5



Flow of the Dolores River at the San Miguel confluence for 1980 (USGS records).

Figure 6



Flow of the Dolores River at the San Miguel confluence for 1979 (USGS records).

Stratum R: Whitewater to Bridgeport

In the upper portion of stratum R, the river flows through canyon topography, and the lower 2.2 miles has larger floodplain areas with gradually sloping banks. This stratum has relatively few riffles and side channels. River width varied from 200 to 260 feet, and average depth in the stratum was 4.3 feet with a maximum depth of 16.4 feet.

Conductivity was approximately 1,100 umhos cm^{-1} and salinity values varied between 0 and 1 ppth. High turbidity was observed, and dissolved oxygen readings were near 8 mg/L.

Stratum S: Bridgeport to Escalante

Stratum S was the uppermost section of the Gunnison River sampled by the GJFS. The upper and middle portions of this stratum have some floodplain areas occupied by orchards. The river is braided througout the stratum with several large islands. Other features found in the river include several rock dams designed to pool water for irrigatation. Canyon walls are prevalent riparian features in lower sections of the stratum. River widths ranged form 50 to 100 feet, and depths averaged approximately 3.3 feet with maximum depths near 10 feet.

Conductivity averaged 1,110 umhos cm^{-1} (range 600-1,600 umhos cm^{-1}) and salinity was 0-5 ppth. Turbidity was high due to silt loads held in suspension. Dissolved oxygen concentrations varied from 8-11 mg/L.

Dolores River

Stratum T: Dolores-Colorado River Confluence to Utah-Colorado State Line

Two apparently different riverine characteristics are found in stratum T. The upper portion of this stratum has several large rapids which can be treacherous during high flow. The river has fewer riffles and more floodplain area downstream near the confluence of the Colorado River. Several quarries and mining operations are located in the lower sections of this stratum. Shear canyon walls are found along the river throughout the stratum. River width varied from 33 to 100 feet and the mean depth was 3.3 feet.

Salinity was low (0-1 ppth) and conductivity ranged from 550 to 700 umhos cm^{-1}. Dissolved oxygen concentrations averaged 8 mg/L.

Stratum U: Utah-Colorado State Line to Salt Creek

This section exhibits a fairly constant pool-riffle pattern although fewer riffles are found between Gateway, Colorado, and Salt Creek. The

local topography features gently sloping floodplain areas. River width varied from 82 to 100 feet. The mean depth of this stratum was 3.3 feet with a maximum depth of 11.5 feet.

Conductivity ranged from 1,350 to 4,000 umhos cm^{-1} (mean = 1,425 umhos cm^{-1}) while the salinity range was 0-3 ppth. Turbidity was generally high during sampling periods because of silt loads. Dissolved oxygen readings were 6-10 mg/L.

Stratum V: Salt Creek to Dolores-San Miguel Confluence.

This was the longest stratum sampled on the Dolores River (23 miles). High, sheer canyon walls constitute most of the riparian topography. Instream features include several small rapids in the upper portions of the stratum while small riffles were prevalent downstream. River widths ranged from 82 to 115 feet. The mean depth was approximately 6.5 feet with a maximum depth of 33 feet.

Conductivity ranged from 700 to 2,100 umhos cm^{-1} and averaged 1,400 umhos cm^{-1} in the stratum. The San Miguel River had a conductivity of 500 umhos cm^{-1} in May 1981. Salinity values were 0-1 ppth and dissolved oxygen concentrations were 7-9 mg/L.

Stratum W: Dolores-San Miguel Confluence to Paradox Valley.

This was the uppermost stratum sampled by the GJFS. The riparian topography is similar to stratum V with high canyon walls. River features include many small rapids approximately 330-500 feet apart. Stratum W was sampled only once during May 1981. After this time flows were extremely low less than 50 cfs) due to upstream diversions for irrigation. River widths ranged from 80 to 100 feet.

Conductivity was 1,100 umhos cm^{-1} in May 1981, but dissolved oxygen and salinity data were not collected from this stratum.

Species Composition

Fish composition of the Gunnison and Dolores Rivers differed in several respects. GJFS collected 18 species from the Gunnison River and 16 from the Dolores River (Tables 2 and 3). All 16 species taken from the Dolores River were also found in the Gunnison River. Northern pike and Colorado squawfish were caught in the Gunnison River, but not in the Dolores River.

The two rivers differed considerably in percentage species composition. Sand shiner, red shiner, and fathead minnow were the most abundant species in Dolores River. Non-native species comprised 87.9 percent of the total catch in the Dolores River. Contrastingly, native fishes such as bluehead sucker, roundtail chub, and flannelmouth sucker comprised 73.1 percent of the catch from the Gunnison River.

Table 2
Fish species collected from the Gunnison River
by the GJFS from July 1979 through October 1981

Family species	Common name	GJFS code
Salmonidae		
Salmo gairdneri	Rainbow trout	RB
Salmo trutta	Brown trout	BR
Esocidae		
Esox lucius	Northern pike	NP
Cyprinidae		
Cyprinus carpio	Common carp	CP
Gila robusta	Roundtail chub	RT
Notropis lutrensis	Red shiner	RS
Notropis stramineus	Sand shiner	SS
Pimephales promelas	Fathead minnow	FH
Ptychocheilus lucius	Colorado squawfish	CS
Rhinichthys osculus	Speckled dace	SD
Catostomidae		
Catostomus commersoni	White sucker	WS
Catostomus discobolus	Bluehead sucker	BH
Catostomus latipinnis	Flannelmouth sucker	FM
C. commersoni x *c. discobolus*	White x flannelmouth hydrid	WF
	unidentified sucker	SU
Ictaluridae		
Ictalurus melas	Black bullhead	BB
Ictalurus punctatus	Channel catfish	CC
Cyprinodontidae		
Fundulus kansae	Plains killifish	PK
Centrarchidae		
Lepomis cyanellus	Green sunfish	GS
Micropterus salmoides	Largemouth bass	LG

Table 3
Fish species collected from the Dolores River
by the Grand Junction Field Station
April through October 1981

Family species	Common name	GJFS code
Salmonidae		
Salmo gairdneri	Rainbow trout	RB
Salmo trutta	Brown trout	BR
Cyprinidae		
Cyprinus carpio	Common carp	CP
Gila robusta	Roundtail chub	RT
Notropis lutrensis	Red shiner	RS
Notropis stramineus	Sand shiner	SS
Pimephales promelas	Fathead minnow	FH
Rhinichthys osculus	Speckled dace	SD
Catostomidae		
Catostomus commersoni	White sucker	WS
Catostomus discobolus	Bluehead sucker	BH
Catostomus latipinnis	Flannelmouth sucker	FM
Ictaluridae		
Ictalurus melas	Black bullhead	BB
Ictalurus punctatus	Channel catfish	CC
Cyprinodontidae		
Fundulus kansae	Plains killifish	PK
Centrarchidae		
Lepomis cyanellus	Green sunfish	GS
Micropterus salmoides	Largemouth bass	LG

The differences in species composition can be attributed to variations in water quality, flow regimes, and the relative degree of man-made modifications and perturbations. The lower Gunnison (down to Redlands Diversion at RM 3) receives relatively constant flows throughout the year, due in part to upstream regulated releases from the Curecanti Storage Unit and Redland water rights. Few backwaters or other lentic habitats exist within the study area. The Dolores River, however, loses much of its water during the summer via the Montezuma Valley Irrigation Company diversion. The Dolores below this structure becomes a series of slow-flowing pools and shallow riffles, with some small backwaters. It appears that nonnative fishes prefer still-water habitats, thus the greater number of lentic areas in the Dolores could explain the correspondingly high percentage of nonnatives. The reverse would be true for the Gunnison, with a majority of flowing habitat types contributing to a high percentage of native species.

Species Composition by Stratum

Gunnison River

Stratum Q

Seventeen species and two hybrids were caught from stratum Q during this study. Twelve nonnative, three endemic and two native species were collected from this stratum; however, endemics comprised 51 percent of the total catch. Roundtail chub (37.6 percent), bluehead sucker (18.3 percent), and flannelmouth sucker (13.2 percent) were the most common fishes. Sand shiner (8.2 percent) and fathead minnow (7.8 percent) were the most numerous nonnative species caught in stratum Q.

Eight Colorado squawfish (0.15 percent of the total catch) were captured in stratum Q, more squawfish than were observed in other strata sampled in the Gunnison River. All squawfish captured in stratum Q were found below Redlands Diversion (RM 3.0), several of which were captured by either Northwest Fisheries Research or the Colorado Division of Wildlife (DOW).

Area and hour CPE values for each species in each stratum are shown in Tables 4 and 5. CPE values were lowest in stratum Q when compared to the other Gunnison River strata. The total area CPE was 6.20 fish/10m^2 and the total hour CPE was 54.81 fish/10 hr. The presence of a dam (Redlands Diversion) within the stratum could affect fish concentrations in the reach, thus explaining the relatively low CPE values.

Stratum R

Fewer species were found in stratum R than the other Gunnison River strata. Thirteen species (eight nonnative, three endemic, and two native) were collected from stratum R during this study. Natives comprised 68.1 percent of the total catch. Bluehead sucker (43.5 percent), roundtail chub (16.2 percent), and fathead minnow (11.7 percent) were the most frequently encountered fishes.

Table 4
Ranked catch per 10 m^2 of area for fishes[1/]
of the Gunnison River by strata
(gear = 1/8-, 1/4-, 1/2-inch seines)

Rank	Strata			All strata
	Q	R	S	(averages)
1	RT(2.69)	FH(9.49)	FM(3.90)	FM(5.23)
2	FH(.96)	BH(8.72)	SS(3.18)	FH(4.25)
3	SS(.88)	SS(6.78)	FH(2.33)	BH(3.86)
4	BH(.59)	SU(6.26)	BH(2.28)	SS(3.61)
5	RS(.43)	RT(2.45)	SU(.89)	SU(2.39)
6	SD(.38)	SD(2.31)	SD(.85)	RT(1.79)
7	FM(.16)	RS(1.35)	GS(.53)	SD(1.18)
8	GS(.07)	FM(1.17)	RT(.24)	RS(.60)
9	SU(.03)	GS(.37)	CP(.13)	GS(.32)
10	CP(.009)	CP(.15)	PK(.12)	CP(.10)
11	LG(.009)	PK(.15)	RS(.03)	PK(.09)
12			BB(.008)	BB(.003)
13			WS(.008)	WS(.003)
Total CPE	6.20	39.18	14.48	

1/ See Table 2

Table 5
Ranked catch per 10 hours of effort for fishes[1/] the Gunnison River by strata (gear = trammel nets, gill nets, electrofishing)

Rank	Strata Q	Strata R	Strata S	All strata (averages)
1	RT(17.49)	BH(78.19)	BH(185.3)	BH(92.83)
2	BH(15.01)	RT(31.58)	RT(63.57)	RT(37.55)
3	FM(13.19)	FM(8.81)	FM(49.27)	FM(23.76)
4	CP(4.21)	CP(3.65)	CP(26.06)	CP(11.31)
5	RS(1.03)	SD(.97)	SD(3.92)	SD(1.68)
6	SS(1.01)	BN(.21)	BN(1.38)	BN(.71)
7	WS(.56)	CS(.11)	WS(.95)	WS(.54)
8	BN(.54)	RB(.11)	GS(.85)	GS(.43)
9	BB(.52)	WS(.11)	RB(U.32)	RS(.38)
10	GS(.44)		BB(.21)	SS(.34)
11	CC(.28)		CS(.21)	CS(.16)
12	CS(.16)		RS(.11)	RB(.16)
13	SD(.16)		WB(.11)	CC(.09)
14	LG(.06)		WF(.11)	WF(.05)
15	RB(.04)			LG(.02)
16	WS(.04)			NP(.007)
17	WF(.04)			FH(.006)
18	FH(.02)			
19	NP(.02)			
Total CPE	54.81	123.72	332.36	

1/ See Table 2

Two Colorado squawfish were observed during electrofishing by GJFS personnel on July 23, 1981, at RM 22.1, and on May 20, 1980, at RM 27.7. Another large adult squawfish was captured by DOW personnel on August 26, 1981, at RM 26.7, and this field team observed a second squawfish at this same time and location during electrofishing efforts.

Small fish were more prevalent in stratum R than the other two Gunnison River strata. The total area CPE was 39.18 fish/10m^2 (Table 4). Larger fish were also quite abundant in stratum R as indicated by a total hour CPE of 123.72 fish/10 hour (Table 5).

Stratum S

Stratum S contained the greatest number of species of the three Gunnison strata. Eighteen species including thirteen exotic, three endemic and two native were found in stratum S. Endemic species accounted for a large portion (38.3 percent) of the total catch. Bluehead sucker (31.7 percent), roundtail chub (24.2 percent), and flannelmouth sucker (14.1 percent) were the most abundant fish in the total catch. Sand shiner (8.1 percent) and fathead minnow (7.7 percent) were the most common nonnative species.

Colorado squawfish were also captured in stratum S. Two adults were captured on May 20, 1980, and May 7, 1981, at RM 33.0 and 30.8, respectively. DOW personnel captured an adult squawfish on August 25, 1981, at RM 33.8. GJFS observed an adult during electrofishing on May 20, 1980, at RM 31.4.

Small fish were quite numerous in this strata, as indicated by a total area CPE of 14.48 fish/10m^2 Table 4). Stratum S yielded the highest density of larger fish based on total hour CPE of 332.36 fish/10 hour (Table 5). This was considerably higher than the other strata in the Gunnison River.

Dolores River

Stratum T

Statum T yielded the most diverse fish fauna of all strata sampled in the Dolores River, with 14 species. Nonnatives comprised 95 percent of the total catch, and accounted for 10 of the 14 species captured. Sand shiner (40.9 percent), red shiner (38.6 percent), and fathead minnow (11.4 percent) were the most frequently collected species in stratum T. Roundtail chub was the most common native species caught.

CPE for area and hour gears for each species in each stratum sampled in the Dolores River are shown in Tables 6 and 7. The total CPE using area gear was 10.8 fish/10m^2 which was similar to strata U and V. Total CPE using hour gear was 22.29 fish/10 hour, which was low compared to the other strata in the Dolores River.

Table 6
Ranked catch per $10m^2$ of area for fishes[1/]
of the Dolores River by strata
(gear = 1/8-, 1/4-, 1/2-inch seines)

Rank	Strata			All strata
	T	U	V	(averages)
1	SS(4.68)	SS(8.65)	SS(3.72)	SS(5.68)
2	RS(4.37)	RS(5.46)	FH(2.99)	RS(3.95)
3	FH(1.31)	FH(1.95)	RS(2.02)	FH(2.08)
4	RT(.24)	RT(.44)	RT(1.56)	RT(.75)
5	FM(.06)	FM(.11)	SD(.29)	FM(.14)
6	CC(.06)	BH(.07)	FM(.26)	SD(.11)
7	BH(.03)	SD(.02)	BH(.20)	BH(.10)
8	SD(.02)	BB(.01)	CC(.01)	CC(.02)
9	WS(.01)	CP(.01)	CP(.01)	CP(.01)
10	BB(.01)	GS(.01)	GS(.01)	GS(.007)
11	CP(.01)			BB(.006)
12	GS(.002)			WS(.003)
13	PK(.002)			PK(.001)
Total CPE	10.80	16.73	11.07	

1/ See Table 3

Table 7
Ranked catch per 10 hours of effort for fishes[1/]
of the Dolores River by strata (gear = trammel nets,
gill nets, electrofishing)

Rank	Strata				All strata
	T	U	V	W	(T-V)
1	CC(7.46)	FM(4.45)	FM(29.85)	FM(25.00)	FM(13.18)
2	FM(5.25)	CP(4.05)	BH(9.81)	RT(25.00)	CP(5.28)
3	CP(4.70)	BH(3.10)	CP(7.10)	CP(16.67)	BH(4.83)
4	RS(1.84)	CC(2.46)	RT(4.80)	BH(8.33)	CC(4.49)
5	BH(1.57)	RT(1.99)	CC(3.55)		RT(2.42)
6	RT(.46)	RS(1.11)	FH(1.88)		RS(1.26)
7	BB(.37)	LG(.56)	SS(1.04)		SS(.47)
8	SS(.37)	BB(.24)	RS(.84)		BB(.41)
9	LG(.09)	BN(.16)	SD(.84)		SD(.36)
10	SD(.09)	SD(.16)	BB(.63)		LG(.22)
11	WS(.09)	FH(.08)	RB(.21)		RB(.07)
12		GS(.08)			BN(.05)
13					GS(.03)
14					WS(.03)
15					
Total CPE	22.29	18.44	60.6	75.0	

1/ See Table 3

Stratum U

Thirteen species were captured in stratum U. Nine nonnative species represented approximately 92 percent of all fishes caught. Sand shiner (50.0 percent), red shiner (28.0 percent), and fathead minnow (9.8 percent) were the three most abundant species observed. Roundtail chub, flannelmouth sucker, bluehead sucker, and speckled dace were collected but were not common.

The total CPE using area gear was 16.73 fish/10m^2 which was slightly higher than strata T and V (Table 6). Total CPE using hour gear in stratum U was the lowest (18.44 fish/10 hour) of all strata in the Dolores River (Table 7).

Stratum V

Eight of the 12 species captured from stratum V were nonnatives. These also made up three-fourths of the total catch, and included sand shiner (29.8 percent), fathead minnow (24.1 percent), and red shiner (16.3 percent).

Total CPE using area gear was 11.07 fish/10m^2 (Table 6). The total CPE for hour-based gear was greater in stratum V (60.6 fish/10 hour) than the two downstream strata (Table 7).

Stratum W

Only nine fish were collected from stratum W in May 1981. Roundtail chub, flannelmouth sucker, common carp and bluehead sucker were the four species observed. No fish were collected from this stratum after May 1981 because water levels were too low to sample. It was highly unlikely that fish inhabited this stratum during extreme low flows.

The total CPE was 75.0 fish/10 hour using hour gear (Table 7). This seemingly high value is deceptive, because it is based on a small amount of effort (1.2 hour). No fishes were collected in stratum W using area-based gear.

Flows in the Dolores River were more dramatically reduced by withdrawals than those in the Gunnison River. In 1981 (except for the runoff period--April to mid-July) the Dolores River usually flowed at less than 500 cfs (Figure 4). CPE values viewed over months in which sampling occurred illustrated some significant changes in fish abundance with corresponding changes in flow (Table 8 and 9). A similar movement of juvenile and adult native and endemic fishes was seen from May to August (Figure 7). Bluehead sucker, flannelmouth sucker, and roundtail chub increased in abundance from early May to mid-May, corresponding with runoff. These species then gradually decreased in abundance from mid-May to August, when few natives or endemics were found in the Dolores River at low flow. The Dolores River had little surface water flow after late August 1981, and a few remaining pools harbored large numbers of nonnative fishes and few natives.

Table 8
Catch per $10m^2$ of area for fishes[1/] of the Dolores River
by species and sample periods, 1981
(gear = 1/8-, 1/4-, 1/2-inch seines)

Species	Months during which sampling was conducted						
	Apr.	May	June	June	July	Aug.	Aug.
BB	0.02	.00	.02	.02	.00	.00	.00
BH	.57	.43	.12	.10	.09	.01	.04
FH	1.95	7.33	4.13	3.21	1.41	.33	.79
FM	.66	.28	.10	.03	.12	.02	.18
GS	.02	.00	.01	.02	.00	.00	.00
RS	22.45	6.11	4.38	10.02	.40	1.24	1.32
RT	5.98	1.28	.23	.82	.28	.02	.09
SS	13.40	4.26	7.11	15.50	2.50	2.77	2.41
WS	.09	.00	.00	.00	.00	.00	.00
CP	.00	.02	.04	.00	.00	.00	.02
SD	.00	.35	.06	.17	.27	.02	.03
CC	.00	.00	.12	.00	.01	.04	.00
PK	.00	.00	.01	.00	.00	.00	.00
Total CPE	45.14	20.06	16.33	29.89	5.08	4.45	4.88

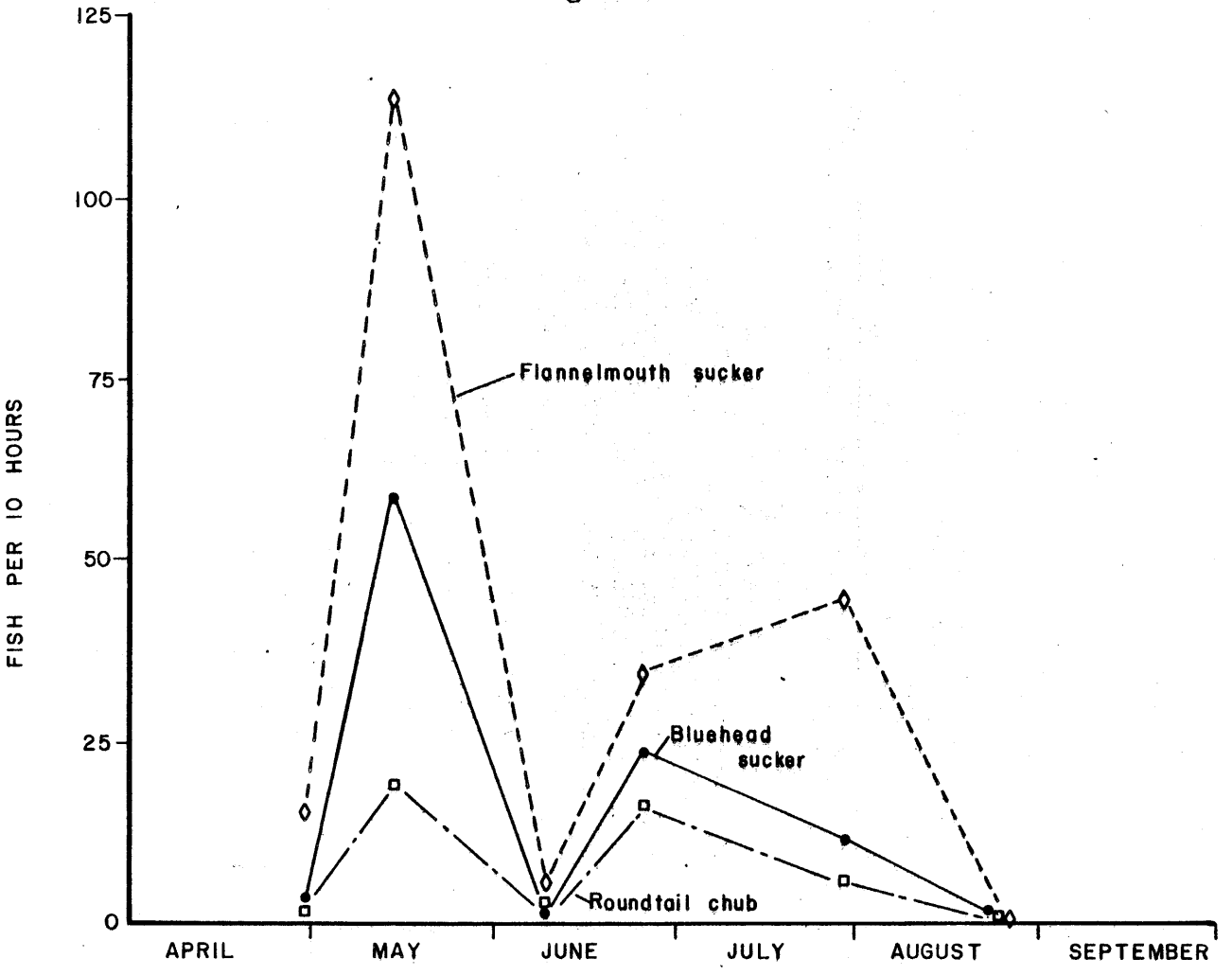
1/ See Table 3

Table 9
Catch per 10 hours of effort for fishes[1/] of the Dolores River
by species and sample periods, 1981
(gear = trammel nets, gill nets, electrofishing)

Species	Months during which sampling was conducted						
	Apr.	May	June	June	July	Aug.	Aug.
BB	0.34	2.78	0.59	1.30	0.56	0.00	0.16
BH	3.79	58.33	1.78	24.68	11.30	.25	.16
CC	2.07	11.11	7.12	16.23	6.78	7.00	.32
CP	4.48	38.89	5.93	18.83	9.04	1.00	2.78
FH	.34	22.20	.00	.65	.00	.00	.00
FM	15.51	113.89	5.49	34.41	43.50	.75	.49
RT	2.76	19.44	.74	16.23	6.21	.00	.00
SS	1.03	.00	.59	.00	1.13	.00	.00
WS	.34	.00	.00	.00	.00	.00	.00
RS	.00	5.56	2.97	9.09	1.13	.00	.00
LG	.00	.00	.15	4.54	.00	.00	.00
SD	.00	.00	.15	1.30	2.26	.00	.00
BN	.00	.00	.00	1.30	.00	.00	.00
GS	.00	.00	.00	.65	.00	.00	.00
RB	.00	.00	.00	.00	.56	.00	.00
Total CPE	30.66	272.20	25.51	129.21	82.47	9.0	3.91

1/ See Table 3

Figure 7



Catch per unit effort of three native and endemic fishes in the Dolores River from May to August 1981.

Species Composition by Habitat

Gunnison River

Backwaters, although few in number, appeared to be an important habitat in the Gunnison River. Thirteen species (nine nonnative, two endemic, and two native) were collected from Gunnison River backwaters. Backwaters were more attractive for nonnative species than any of the other habitat types. Over half (51.3 percent) of the total catch in backwaters was composed of nonnative fishes. Sand shiner (21.2 percent), fathead minnow (20.8 percent) and bluehead sucker (15.3 percent) were the most abundant species in backwaters.

CPE values (area and hour-based gears) for each species in each habitat are shown in Tables 10 and 11. CPE comparisons suggest that backwaters were less important for larger fishes, as indicated by relatively small catch values for hour-based gears. The total hour CPE was 3.24 fish/10 hour, less than all other habitats sampled. Backwaters were apparently more important areas for smaller fishes, as total area CPE was 15.24 fish/10m^2. Only side channels and eddies had higher total area CPE values.

Eddies

Nine species (five nonnative, two endemic, and two native) were found in eddies in the Gunnison River. Endemics comprised 87.1 percent of the total catch. Roundtail chub were the most abundant species caught in eddies (76.7 percent), followed by flannelmouth sucker (10.4 percent) and bluehead sucker (9.0 percent). Fathead minnow and sand shiner were the most common nonnative species, accounting for 2.5 percent and 1.3 percent, respectively.

Based on relatively high CPE values for area-based gears, it appears that eddies were important for small fishes in the Gunnison River. Total area CPE was 30.42 fish/10m^2, highest for all habitat types sampled (Table 10). Eddies did not appear as attractive for larger fish with total hour CPE of 26.6 fish/10 hour (Table 11).

Isolated Pools

Several isolated pools were sampled by GJFS in the Gunnison River. Four species were found in these pools; fathead minnow (71.6 percent), bluehead sucker (7.4 percent), green sunfish (4.9 percent), and common carp (2.5 percent). Unidentified suckers were also collected from this habitat (13.6 percent).

Most fish stranded in isolated pools probably did not survive. Several isolated pools observed did not contain any fish, and water levels did not fluctuate enough to replenish these pools. Native fishes are not often found in isolated pools since they appear to be more responsive to water fluctuations than nonnatives.

Table 10
Ranked catch per $10m^2$ of area for fishes[1/] of the Gunnison River by habitat types (gear = 1/8-, 1/4-, 1/2-inch seines)

Rank	Backwater	Eddies	Main channel	Pools	Riffles	Runs	Side channel	Shoreline	Isolated pools
1	SS(3.25)	RT(25.19)	FH(6.00)	RT(0.43)	BH(0.16)	SD(1.82)	RT(9.11)	BH(1.41)	FH(3.13)
2	FH(3.19)	BH(2.76)	SS(4.80)	SD(.17)	SD(.08)	FH(1.58)	BH(2.73)	SD(1.04)	SU(.59)
3	BH(2.34)	FM(.98)		FH(.11)	RT(.03)	SS(1.58)	RM(2.S5)	FM(.59)	BH(.32)
4	FM(2.17)	SS(.61)		RS(.08)	SS(.03)	RT(.90)	SS(1.42)	SS(.44)	GS(.22)
5	RT(1.68)	SD(.42)		SS(.06)	FM(.01)	BH(.84)	FH(.67)	RT(.37)	CP(.11)
6	SU(0.97)	FH(.23)			RS(.01)	RS(.52)	SD(.50)	PK(.22)	
7	RS(.76)	SU(.23)				SU(.35)	RS(.11)	GS(.15)	
8	GS(.46)					FM(.01)	PK(.07)	FH(.07)	
9	SD(.23)					GS(.01)	GS(.03)		
10	CP(.10)								
11	PK(.07)								
12	LG(.02)								
13	BB(.005)								
14	WS(.005)								
Total CPE	15.24	30.42	10.80	.85	.32	7.81	17.19	4.29	4.37

1/ See Table 2

Table 11

Ranked catch per 10 hours of effort for fishes[1/] of the Gunnison River by habitat types (gear = trammel nets, gill nets, electrofishing)

Rank	Backwater	Eddies	Main channel	Pools	Riffles	Runs	Side channel	Shoreline
1	RT(1.55)	RT(17.44)	BH(410.7)	FM(51.16)	FM(74.68)	BH(36.90)	RT(4.65)	BH(41.11)
2	FM(.85)	FM(6.24)	RT(140.1)	RT(33.33)	BH(33.54)	RT(22.56)	CP(0.93)	RT(9.49)
3	GS(.42)	BH(2.41)	FM(53.64)	BH(13.95)	CP(19.62)	FM(14.35)		FM(7.90)
4	BB(.14)	WB(.15)	CP(44.01)	CP(5.81)	BN(1.26)	CP(6.95)		CP(3.95)
5	BH(.14)	WF(.15)	SD(7.03)	BN(3.68)	RT(1.26)	WS(.94)		BN(1.18)
6	WS(.14)	CP(.07)	CC(0.52)	CC(1.55)	CC(.63)	SD(.75)		BB(.39)
7		GS(.07)	BB(0.26)	GS(1.16)	NP(.63)	BN(.34)		RB(.39)
8		LG(.07)	GS(0.26)	CS(.19)	RB(.63)	GS(.34)		WB(.39)
9				WS(.19)		BB(.25)		WS(.39)
10						RB(.12)		
11						CC(.09)		
12						CS(.09)		
13						RS(.03)		
14						WF(.03)		
Total CPE	3.24	26.6	657.5	111.02	194.62	83.74	5.58	65.19

1/ See Table 2

Main Channel

Main channel habitat appeared to be areas of concentration for large fishes. Ten species (six nonnative, two endemic, and two native) were caught in main channel habitat. Native species comprised 92.1 percent of the total catch. Bluehead sucker and roundtail chub were the most abundant fishes, accounting for 61.9 percent and 21.1 percent, respectively.

The highest total hour CPE for all habitats sampled in the Gunnison River was recorded in main channel. The total hour CPE was 657.5 fish/10 hour based on 21 samples and 38.4 hour of effort (Table 11). The main channel did not appear to be important to small fish as only sand shiner and fathead minnow were collected in this habitat type (Table 10).

Pools

Fourteen species (nine nonnative, three endemic, and two native) comprised the total number of species taken from pools. Bluehead sucker (11.5 percent) were the most frequently caught fish in riverine pools, and 72.6 percent of all fishes were endemic species. Common carp (4.8 percent) were the most common nonnative fish collected in Gunnison River pools.

Three Colorado squawfish were collected in pool habitat. Pools and runs were the only two habitat types in the Gunnison River where squawfish were found. The pools harboring these squawfish were 6.1-13.1 feet deep, and these fish were all captured in the autumn, suggesting that these relatively deep pools are wintering areas.

Pools appeared to be valuable habitat for larger fish, with total hour CPE of 111.02 fish/10 hour (Table 11). Conversely, pools were not preferred by smaller fishes based on a total area CPE of 0.85 fish/10m (Table 10).

Riffles

Eleven species (seven nonnative, two endemic and two native) were collected from riffles in the Gunnison River. Endemic species accounted for nearly 63.6 percent of the total catch in riffles. Flannelmouth sucker (62.0 percent) and bluehead sucker (21.2 percent) were the two major species caught, and common carp were the most frequently caught nonnative species.

Riffles were one of the most attractive habitats for large fishes. Total hour CPE was 194.62 fish/10 hour, indicating a preference for riffles by larger fish (Table 11). Total area CPE was only 0.32 fish/10m which was the lowest total area CPE value of all habitats sampled, suggesting that riffles are not attractive areas for smaller fishes (Table 10).

Runs

Fourteen species were collected from runs; more than any other habitat sampled in the Gunnison River. Nine nonnative, three endemic

and two native species were found in this habitat. Native and endemic species comprised 78.1 percent of the total catch, and included bluehead sucker (34.9 percent), roundtail chub (22.7 percent), and flannelmouth sucker (13.0 percent).

Nine Colorado squawfish were captured in runs, suggesting that runs were the preferred habitat for adult squawfish in the Gunnison River. Runs appeared to be important habitat for large and small fish. CPE values were 83.74 fish/10 hour and 7.81 fish/10m^2 for hour and area gear, respectively (Tables 10 and 11).

Side Channels

Ten species (six nonnative, two endemic, and two native) were caught in side channels of the Gunnison River. Natives comprised 86.5 percent of the total catch, with roundtail chub (53.7 percent), bluehead sucker (15.5 percent) and flannelmouth sucker (14.5 percent) the most abundant species. Sand shiner (8.0 percent), and fathead minnow (3.8 percent) were the most common nonnative species.

Side channels appeared to be attractive areas for small fishes. Total area CPE was 17.19 fish/10m^2 for side channels (Table 10), and this value represents the second greatest total area CPE of all habitats sampled in the Gunnison River. Side channels seemed less important for large fish; total hour CPE was 5.58 fish/10 hour (Table 11). Both CPE values were similar to those for backwaters, but side channels appeared to be more attractive to native species than nonnatives. Nonnatives species apparently prefer calm water over water with current, and thus are found more often in backwaters than in side channels.

Shorelines

Eight nonnative, two endemic and two native species were captured in shoreline habitat. Native species accounted for 87 percent of the total catch, with bluehead sucker (55.2 percent), roundtail chub (13.0 percent), and flannelmouth sucker (12.6 percent) the most common fishes caught along Gunnison River shorelines.

Shorelines appeared to be less attractive for most fishes when compared to other habitats. Total area CPE and total hour CPE was 4.29 fish/10m and 65.19 fish/10 hour respectively (Tables 10 and 11).

Dolores River

Backwaters

Backwaters had the second highest number of species of all habitat types sampled in the Dolores River. Nine nonnative, two endemic and two native species were taken from Dolores River backwaters. Nonnatives comprised about 92 percent of the total catch in backwaters. Sand shiner (38.5 percent), red shiner (36.8 percent), and fathead minnow (15.4 percent) were the most abundant species. The most common endemic species collected in backwaters was roundtail chub (6.9 percent).

Backwaters seemed to be attractive habitats for all fishes. Total CPE using hour gear was 23.62 fish/10 hour which was the third highest CPE value of all habitat types sampled (Table 12). Area CPE shows that backwaters contained the highest fish concentrations of all habitat types in the Dolores River (31.18 fish/10m^2) (Table 13).

Table 12
Ranked Catch per 10 hours of effort for fishes[1/] of the Dolores River by habitat types (gear=trammel nets, gill nets, electrofishing)

	Habitats					
Rank	BA	ED	MC	PO	RI	RU
1	FM(9.14)	CC(8.51)	CP(1.33)	BH(6.92)	FM(193.30)	FM(12.21)
2	CC(4.87)	FM(.71)	CC(2.67)	FM(6.92)	BH(140.00)	CP(6.25)
3	CC(4.55)	BH(.35)	FM(2.67)	CC(3.85)	CP(100.00)	CC(4.28)
4	RT(1.98)	CP(.35)		RT(2.31)	CC(93.33)	BH(3.60)
5	RS(1.34)			CP(1.54)	RT(26.67)	RT(2.53)
6	BB(.35)				BN(13.33)	FH(.56)
7	FH(.35)				RS(13.33)	SS(.51)
8	SS(.32)				BB(6.67)	LG(.45)
9	LG(.28)					BB(.34)
10	SD(.25)					SD(.28)
11	BN(.07)					GS(.06)
12	GS(.04)					RB(.06)
13	RB(.04)					WS(.06)
14	WS(.04)					
Total CPE	23.62	9.92	1.86	21.54	586.5	31.19

1/ See Table 3

Eddies

Nine species were found in eddies (five nonnative, two endemic, and two native). Nonnatives comprised the majority (96.4 percent) of the total catch in eddies. Sand shiner and red shiner were the most abundant species, representing 51.7 percent and 35.6 percent respectively. Roundtail chub was the most frequently caught endemic, but comprised only 2.2 percent of the total catch.

CPE values indicate eddies were of intermediate importance when compared with other habitats. Total hour-based CPE was 9.92 fish/10 hour while 14.46 fish/10m^2 were caught using area gears (Tables 12 and 13). Eddies appeared to be more important for smaller fish less than 100 mm.

Main Channel

Only 37 individual fishes were collected from main channel habitats. Six species, four of them nonnatives, represented the catch. Sand shiners (56.7 percent), fathead minnow (21.6 percent), and common carp (13.5 percent) were the most abundant species in main channel samples. Single captures were made of channel catfish, bluehead sucker, and roundtail chub.

Table 13
Ranked catch per $10m^2$ of area for fishes[1/] of the
Dolores River by habitat type (gear = 1/8-, 1/4-, 1/2-inch seines)

Rank	Habitats							
	BA	ED	MC	PO	RI	RU	SH	SC
1	SS(12.05)	SS(7.94)	SS(2.33)	FH(1.45)	RS(0.50)	SS(2.91)	SS(6.09)	SS(2.42)
2	RS(11.52)	RS(5.47)	FH(.89)	SS(.14)	SS(.16)	RS(1.46)	FH(2.22)	FH(1.00)
3	FH(4.80)	FH(.38)	RT(.11)		BH(.03)	FH(1.01)	RS(.80)	RS(.25)
4	RT(2.15)	RT(.34)			FM(.02)	RT(.18)	RT(.26)	CC(.08)
5	FM(.28)	CC(.21)			RT(.02)	SD(.15)	BH(.04)	SD(.08)
6	BH(.19)	FM(.06)			SD(.02)	FM(.11)	FM(.04)	
7	SD(.06)	BH(.03)				BH(.07)		
8	CC(.05)	SD(.03)				CC(.02)		
9	CP(.02)					GS(.01)		
10	BB(.02)					BB(.003)		
11	WS(.02)					CP(.003)		
12	GS(.02)					WS(.003)		
13	PK(0.01)							
Total CPE	31.18	14.46	3.33	1.59	0.75	5.93	9.45	3.83

1/ See Table 3

CPE values were low for captures in main channel habitat. The total CPE was only 1.86 fish/10 hour using hour gear while the total area CPE was only 3.33 fish/10m^2 (Tables 12 and 13). It is unlikely that gear inefficiency can explain low CPE because river depths were not great enough to hamper sampling.

Pools

Seven species were caught from pools in the Dolores River during this study. Four were nonnatives and the other three were natives. Nonnatives comprised 75 percent of the total catch. Fathead minnow (60.2 percent), bluehead sucker (10.8 percent) and flannelmouth sucker (10.8 percent) were the most numerous species captured in pools. Sand shiners comprised 6 percent of the total catch in pools.

Total hour CPE (21.54 fish/10 hour) indicate that pools were adequate habitat for larger fish (Table 12). Pools do not seem to be attractive habitat for smaller fish in the Dolores River, with total area CPE of only 1.59 fish/10m^2 (Table 13).

Riffles

Six nonnative, two endemic and two native species were found in riffles. Nonnatives comprised 56 percent of the total catch, considerably less than their composition in all other habitats sampled. This reduction could be due to constantly flowing water in riffle habitats, since nonnative species appear to prefer lentic habitats. Red shiner (24.6 percent), flannelmouth sucker (22.4 percent), bluehead sucker (17.2 percent), common carp (11.2 percent), and channel catfish (10.4 percent) were the most numerous species collected from riffles.

Riffles appeared to be important for large fishes based on total hour CPE (586.5 fish/10 hours) (Table 12). The high hour CPE is deceptive, because it was based on only 1.5 hours of effort. Riffles apparently were not important habitats for smaller fishes based on a total area CPE of 0.75 fish/10m^2 (Table 13).

Runs

More species were collected from runs than any other habitat type in the Dolores River. A total of 14 species included ten nonnatives, two endemic, and two native. Nonnatives comprised 81 percent of the total catch in runs. Sand shiner (38.9 percent), red shiner (20.5 percent), fathead minnow (13.7 percent), and flannelmouth sucker (9.4 percent) were the most numerous fish species in runs.

Runs were important habitat for large fishes based on total hour CPE of 31.9 fish/10 hours (Table 12). Small fish did not appear to prefer runs, as evidenced by a total area CPE of 5.93 fish/10m^2 (Table 13).

Shorelines

Only five fish species were caught in shoreline habitat in the Dolores River. All fishes captured in shoreline habitats were nonnative

except for one speckled dace. Sand shiner (63.0 percent), fathead minnow (26.1 percent), red shiner (6.5 percent), and channel catfish (2.1 percent) comprised the remainder of the shoreline catch. Total area CPE was only 3.83 fish/ $10m^2$ (Table 13). Shorelines were not sampled with hour gear.

Side channels

Species diversity was low in Dolores River side channels. Six species were captured in side channels during this study. Nonnatives comprised 96 percent of the total catch. Sand shiner and fathead minnow represented 64.3 percent and 23.4 percent, respectively, of the total side channel catch. Roundtail chub (2.8 percent), bluehead sucker (0.5 percent), and flannelmouth sucker (0.5 percent) comprised the native and endemic fish fauna in Dolores River side channels.

Side channels appeared to be moderately attractive areas for smaller fishes, with a total area CPE value of 9.45 fish/$10m^2$; third highest CPE for all habitats (Table 13). Hour gears were not used in side channels.

Species Composition By Flows

Gunnison River

Prerunoff, runoff, and postrunoff conditions on the Gunnison River were derived from USGS flow records for 1979 and 1980 (Figures 2 and 3). Gunnison River flow data were unavailable for 1981 at the time of this report.

No consistent changes in percent species composition occurred between prerunoff, runoff, and postrunoff flow periods on the Gunnison River when this information was compared for respective flows during the years of study. Roundtail chub and bluehead sucker were the most common fishes captured during all flow periods in the Gunnison River.

Nine Colorado squawfish were caught during postrunoff conditions in the Gunnison River. Seven of these squawfish were caught below Redlands Diversion. One squawfish was caught during runoff 1981 below Redlands Diversion.

Dolores River

Dolores River flows during the study period (Figure 4) in 1981 were atypical when compared to flows in 1980 (Figure 5) and 1979 (Figure 6). Spring runoff in 1981 was well below normal; only 43 percent of the normal inflow into Lake Powell was predicted. It does appear that most fishes leave the upper reaches of the Dolores during times of extreme low flows. Conversly, fishes are present in relatively high concentrations during peak flows. It appears that the relative abundance of fishes in the lower Dolores is a direct function of flow, and CPE comparisons for various flow periods support this contention.

Colorado Squawfish

Gunnison River

Distribution and abundance

Historically, Colorado squawfish were common to abundant in the Gunnison River. Jordan and Evermann (1896) and Jordan (1891) reported that Colorado squawfish were "very abundant" in the Uncompaghre River near Delta, Colorado, and in the Gunnison River. One specimen was reported to weigh 79 pounds and was 62.9 inches long. Squawfish were still quite common through the 1950's as indicated by catches by mink farmers near Delta (Wiltzius 1978). Squawfish numbers have declined dramatically in recent years. Kidd (1976) reported that squawfish should be considered rare between Escalante Canyon and the confluence with the Colorado River.

Sixteen adult Colorado squawfish were captured or observed in the Gunnison River during this study (Table 14). Eight squawfish were captured below the Redlands Diversion, and eight squawfish were captured or observed above the dam.

Table 14
Data collected from Colorado squawfish captured or observed by GJFS on the Gunnison River, 1979-1981

RM	Date	Length (mm)	Weight (gm)	K*	Habitat	Depth (feet)	Velocity (fps)	Substrate
			Captured below Redlands Dam					
1.5	79/09/18	485	439	0.38	pool	8.0	0.1	sand
3.0	79/09/18	668	2,400	.80	run	10.0	1.0	sand
3.0	79/09/05	566	2,720	1.50	run	10.0	1.5	sand
3.0	79/09/05	483	451	.40	run	10.0	1.5	sand
3.0	79/09/17	622	2,100	.87	run	12.0	2.0	sand
3.0	81/05/20	827	5,420	.95	pool	12.0	3.5	bedrock/sand
1.5	79/09/18	521	470	.33	pool	8.0	0.1	sand
3.0	79/09/18	480	410	.37	run	10.0	1.0	sand
			Captured above Redlands Dam					
26.7+	81/08/26	824	6,114	1.09	run	3.0	4.2	rubble
30.8	81/05/07	798	6,400	1.25	run	3.0	2.5	rubble
33.0	80/05/20	630	2,420	.97	run	8.9	.5	rubble
33.8+	81/08/25	631	2,270	.90	run	5.0	1.7	rubble
			Observed but not captured					
31.4	80/05/20	Adult						
27.7	80/05/20	Adult						
22.1	81/07/23	Adult						
26.7+	81/08/26	Adult						

* $K = W \times 10^5/L^3$

\+ Data supplied by Tom Lytle, Colorado Division of Wildlife, Grand Junction, Colorado.

Two of these squawfish were captured and tagged by the Colorado Division of Wildlife near RM 30 (Wick 1981, personal communication). All squawfish captured above Redlands Diversion were found between RM 16.0 and RM 40, the reach that would be inundated by the Bureau of Reclamation's proposed Dominguez Dam and Reservoir.

Colorado squawfish should be considered rare in the Gunnison River based on limited captures during this study. Squawfish were found below Redlands Diversion (RM 1.5 and 3.0) and upstream from the structure between RM 22 and 34.

Migration and Movement

No tagged Colorado squawfish were recaptured in the Gunnison River, therefore information on movement was not available. Several reports indicate extensive movement by squawfish. GJFS showed wild recaptures moving 0-20 miles from the original capture site in the Colorado River. Squawfish reared at Willow Beach National Fish Hatchery moved .9-45.5 miles from the release site in the Colorado River within a 1-year time frame.

Squawfish are apparently more concentrated below Redlands Diversion than in other areas in the Gunnison. Multiple captures occurred on two separate sampling attempts (September 5, 1979 and September 18, 1979). Two other squawfish were collected in the springtime at this location. The relative concentration of squawfish below Redlands Diversion could indicate (1) the tailwaters of Redlands Dam provide an attractive habitat (possibly a wintering area) or (2) squawfish attempt to migrate upstream, but are hindered by the presence of the dam. It is questionable that the structure effectively prohibits upstream movement of fishes at all flow stages. Limited tagging data on nontarget species shows no movement through Redlands Diversion (Table 15). Observations by GJFS personnel indicate possible movement of fishes over the structure during high flows by swimming through open flood gates of the dam.

Table 15
Capture and recapture data associated with nontarget species in the Gunnison River

Name	Tag No	Date of capture	RM of capture	Date of recapture	RM of recapture
Roundtail chub	7513	May 6, 1981	36.5	June 30, 1981	35.5
Roundtail chub	3397	June 30, 1981	35.5	June 30, 1981	35.5
Bluehead sucker	2554	May 5, 1980	27.5	July 21, 1981	24.5
Bluehead sucker	2208	July 30, 1980	13.5	August 5, 1981	9.0

Associated Species

Endemic and native species comprised the majority of fishes associated with Colorado squawfish in the Gunnison River. The squawfish caught on May 7, 1981, was a solitary individual. Bluehead sucker, flannelmouth sucker and roundtail chub made up 83.9 percent and 95 percent of all species associated with the squawfish captured on

May 20, 1980 and May 20, 1981, respectively. Other fish collected in association with these two squawfish were brown trout, common carp, white sucker, and a white sucker x bluehead sucker hybrid.

Spawning

A possibility exists that an enclave squawfish population is present above Redlands Diversion. If this were the case, it seems that young squawfish would be present in this reach. The absence of young could mean (1) there is an insufficient number of adults above the structure for spawning, (2) spawning habitat is scarce or absent in this reach, (3) larvae drift downstream past the Redlands structure and are not detected, (4) the relatively small number of backwaters in the Gunnison provide limited rearing areas for young to the extent that they are undetected or fall prey to other fishes. Evidence of spawning and young-of-the-year were not observed in the Gunnison River by GJFS during this study, and reproduction by Colorado squawfish in the Gunnison has not been documented.

Habitat Preference

Colorado squawfish were captured in two habitat types (pools and runs) in the Gunnison River (Table 14). Current velocities at the capture site were usually greater than 1.0 cfs. Squawfish capture sites below Redlands Diversion were deep (7.9-11.8 feet) while squawfish were collected in more shallow water (3.0-8.9 feet) above the dam. Sand was a primary or secondary substrate where most squawfish were caught.

All squawfish were captured in the spring or fall on the Gunnison River, suggesting that these areas may constitute overwintering areas for squawfish from the Colorado River. Squawfish were caught during cool water conditions in these areas and were not found when water temperatures were warmer. It is also possible that squawfish used these areas during high water, although fish were caught during low flows below Redlands Diversion in September 1979, and above the dam in late summer, 1981.

Dolores River

No Colorado squawfish were caught in the Dolores River by GJFS during this study. An effort resulting in 203.62 fish/10 hours (hour gears) and 50.34 fish/10m^2 (area gears) was expended while searching for endangered fishes.

Historically, Colorado squawfish have been captured in the Dolores River. Sigler, et al. (1966) and Nolting (1957) reported that Colorado squawfish were considered rare in the Dolores River in the early 1950's. Sigler, et al. (1966) stated that squawfish were absent by 1960 in the Dolores River above the Utah-Colorado State Line, but that squawfish were present in the Dolores River between the Utah-Colorado State Line and the confluence with the Colorado River.

Several possibilities could explain the apparent absence of Colorado squawfish in the Dolores River during this study. The reduction of squawfish numbers in the Colorado River probably also reduced squawfish numbers in the Dolores River. Near the confluence, the Dolores was larger and more difficult to sample; therefore, it is possible that individuals were not detected due to gear limitations. The Montezuma Valley Irrigation Company dam diverts much of the flow in upper reaches during low water years, making conditions poor for fishes downstream. The Dolores appears to have low productivity compared to other rivers in the Colorado system, as indicated by lower growth rates of channel catfish (Sigler, et al. 1966). Competition by nonnatives is another possibility that would serve to explain the lack of endemics; nonnatives comprised 87.9 percent of the total catch in the Dolores River compared to only 26.8 percent in the Gunnison River. A relatively large percentage of lentic habitats in the Dolores would appear to favor nonnative species. Severe water pollution has also occurred in parts of the Dolores River. Uranium mill wastes from Uravan left the Dolores River virtually sterile as far as 7 miles downstream from the point source (Nolting 1957).

The Dolores River in its present state probably cannot support any significant numbers of Colorado squawfish, with the possible exception of that reach near the confluence with the Colorado River. Modifications will have to be made to increase flows and improve water quality before recovery of the species in this river is possible. The BR Dolores Project (under construction) may provide flows necessary to support endemic fishes during critical times of the year in lower reaches near the Colorado River confluence.

Razorback Sucker

No razorback sucker were captured in the Gunnison River or Dolores River by the GJFS. One razorback sucker (gravid female) was captured in the Gunnison River on June 1, 1981, near RM 55.0, 13 miles upstream from the GJFS study area by Bio/West, Inc. (Paul Holden 1981, personnel communication).

Historically, razorback sucker were abundant in most of the Gunnison River (Jordan 1881, Jordan and Evermann 1896). Razorbacks were common as recently as the 1950's based on catches made by a mink farmer in the area. However, only one razorback (adult male) was collected in the 1970's (Wiltzius 1978). Kidd (1976) stated that the razorback was rare between Delta and Escalante. No records of razorback sucker were found for the Dolores River.

The razorback sucker should now be considered extremely rare in the Gunnison River. Young-of-the-year and juvenile razorbacks have not been collected in recent years and the likelihood of successful razorback reproduction in the Gunnison is low.

Bonytail and Humpback Chub

Jordan and Evermann (1896) reported one specimen of Gila elegans in the Gunnison River. No other records of bonytail or humpback chub are known in either the Gunnison or Dolores rivers. It is highly probable that neither humpback or bonytail were ever common in these two rivers, and both species are probably absent from these rivers today.

SUMMARY

Gunnison River

Species composition

The Gunnison River (within the study area) supports a native fish population that probably resembles historic levels. GJFS found that 73.1 percent of all fishes captured during the study period were native species, compared to 12.1 percent for the Dolores River and 65.1 percent for the upper Colorado River.

A possible explanation for the relatively high native species composition in the Gunnison River hinges on flow regimes and channel characteristics. The Gunnison has a relatively narrow, steep-sided channel morphology in most reaches, and flow rates rarely fall below 1000 cfs. This combination of constant flow and restricted channel yields few backwaters or other lentic habitats. Such still-water features are probably preferred (if not necessary) for the establishment of significant nonnative populations. Water pollution sources of the magnitude to disrupt fish communities are not apparent at this time along the lower Gunnison River.

Target fishes

Colorado squawfish and razorback sucker were the only target fishes captured from the Gunnison River during the study period. The razorback sucker was a single specimen reported by Holden (1981) and caught 13 miles upstream from Dominguez, the upper end of the GJFS study area.

Sixteen adult Colorado squawfish were captured or observed during field investigations from 1979-1981. Eight of these squawfish were found in pools and runs below Redlands Diversion, in the 3-mile reach between the dam and the Colorado River. Six of these eight specimens were captured directly below the structure, suggesting that the fish were attempting to move upstream but were hindered by the instream blockage. Flannelmouth sucker, bluehead sucker and roundtail chub were observed moving upstream during high flows along a concrete apron below an open flood gate associated with the structure. We believe that it is possible for fishes to swim past this structure during high flows when the gates

open to flush sediments, although the limited mark-recapture data from this study did not demonstrate such movement. Another possible explanation for the presence of squawfish below Redlands Diversion is that these fish came up the Gunnison from the main stem Colorado River and use the deep pools and runs below the diversion for resting, feeding, or overwintering.

Eight adult Colorado squawfish were either captured or observed (during electrofishing) 19-30 miles above Redlands Diversion. This suggests either an enclave population above the diversion or that there is indeed movement upstream past the structure under certain conditions. Since Redlands Diversion has been in place since 1907, it seems more likely that these fish moved up the Gunnison River from the Colorado in recent times, rather than their presence being deemed an enclave population isolated by the dam. The four upstream squawfish that were actually handled appeared healthy, as evidenced by relatively high condition factors (K_{TL}).

No evidence of successful reproduction was seen for Colorado squawfish or razorback sucker in the Gunnison River. Braided reaches with coarse substrate suggest that spawning habitat exists for squawfish, but no young have ever been taken in the Gunnison. It may be that too few individuals travel into the upper reaches for significant spawning success. Since backwaters appear to be important nursery areas for squawfish, the scarcity of these still-water features may preclude successful rearing of young. Another possibility is that larvae drift undetected down the Gunnison and enter the Colorado River. Larval sampling was not conducted in the Gunnison River during this study.

Razorback sucker appear to be having little or no reproductive success throughout the entire Colorado River system. It is thought that still-water areas with clean gravel substrates and an absence of nonnative predators are elements necessary for successful recruitment (Ulmer 1981, Loudermilk 1981). This combination of conditions does not exist in the lower Gunnison River.

The presence of adult Colorado squawfish and razorback sucker in the lower Gunnison suggests that this reach has the potential of supporting more of these rare fishes. The fact that native species composition approaches 75 percent of all fishes in this reach is an encouraging sign for recovery of those species that are (at present) rare or absent. This investigation indicates that Colorado squawfish may be attempting to spawn in the lower Gunnison River.

Dolores River

Drastic flow manipulations, point-source pollution, and an overwhelming majority of nonnative fishes heads the list of deterrants for the renewed presence of rare fishes in the Dolores River. None of

the target species were found during sample efforts by GJFS in 1981. It is thought that low flows brought about by irrigation diversion (Montezuma Valley Irrigation Company Dam near Dolores, Colorado) are responsible for abnormal numbers of still-water habitats. These lentic features such as slow-flowing pools and backwaters are havens for nonnative fishes, and 87.9 percent of all fishes collected from the Dolores during this study were nonnative. Competition by these nonnatives for food and space would appear to be a major obstacle to the recovery of rare endemic fishes. Spills from heavy industry along the river corridor have reportedly eradicated fishes in certain reaches (Nolting 1957, Sigler et al. 1966). Discharges from placer mines appear to be a new source of degradation in the Dolores system.

The lower reach near the confluence with the Colorado has the best chance of supporting the target species, especially Colorado squawfish and razorback sucker. It is possible that some individuals were missed during sample efforts in this reach due to difficult sampling conditions and gear limitations. At present, little chance is given to recovery of the species in upper sections of the study area, since many of these reaches are nearly dry in times of low flow. The BR Dolores Project (under construction) may provide regular flow in its tailwaters, but it is not known whether this new flow regime in the lower Dolores will be adequate for the re-establishment of endemic species.

RECOMMENDATIONS

The following recommendations for the continued existence and/or recovery of target fishes are made for each tributary, since each system has different present conditions and future needs.

Gunnison River

(1) Barriers to upstream movement appear to be a major problem for Colorado squawfish in the Gunnison River. The construction of a fish ladder around Redlands Diversion would aid in what appears to be natural migration efforts on the part of native fishes. Moyle (1981) reports the use of such ladders by Sacremento squawfish on the Sacremento River to bypass similar barriers.

(2) Artificial habitat enhancement on an experimental basis may prove helpful in recovery efforts. Specifically, the construction of backwaters with gravel substrates may be beneficial to both Colorado squawfish and razorback sucker. The backwaters should be graded in such a way as to hold water during moderate to high flows, and drain during low river water levels. It is thought that such a scheme would deter the establishment of nonnative fish populations by making these features flow-dependent and temporary. Razorback sucker and Colorado squawfish are thought to require such still-water habitat during moderate to high flows for spawning (razorbacks) and rearing of young (squawfish, razorbacks).

(3) Supplemental stocking of hatchery-reared endangered fishes is a recovery option that appears necessary for species that were historically present but are now absent, and for the razorback sucker which appears to be having critically low reproductive success. Management decisions based on habitat availability and historical presence are necessary before any reintroduction of bonytail or humpback chub in the Gunnison River. Since Colorado squawfish are present in some numbers, stocking of this endangered fish is not recommended at this time.

(4) The Bureau of Reclamation has some future proposals for water use in the Gunnison River, and several of the project alternatives would directly impact the Gunnison within the area of this study. Two alternatives involve the construction of a dam and hydroelectric facility, and the resulting reservoir would inundate 24-34 miles of the Gunnison River channel. It is not known how a reservoir or tailwater would affect existing fish fauna, but it is presumed that such an alteration would reduce numbers and percentage species composition of native fishes. In this situation, management decisions involving the use of structural modifications, supplemental stocking, or other fish management techniques must be made and implemented in order to retain these endangered fishes in the Gunnison River system.

Dolores River

Reclamation's Dolores Project is now under construction, and consists of a 200-feet high dam and a reservoir of 4,470 surface areas (active capacity). The project will impact the entire reach under the scope of this study. There may be opportunities to enhance the lower Dolores for endangered fishes, depending on flow regimes and water quality conditions in the tailwaters after project completion. Any recovery efforts will also depend on management decisions to pursue such a program, as no mitigatory measures for endangered fishes were included in the Dolores Project. Although speculative and dependent on river conditions with the project in place, these are some thoughts for enhancement of conditions for endangered fishes:

(1) Emphasis in recovery efforts should be placed in the lower reaches near the confluence with the Colorado River. This section is most likely to retain some resemblance of natural conditions. Should the artificial backwater concept prove effective in providing needed habitat for Colorado squawfish and razorback sucker, these features should be installed in the reach described above. Predictable flows from McPhee Dam may provide engineers with the elevation information necessary to allow these backwaters to drain during low-volume releases. Target fishes expected to make use of such backwaters will probably move into the lower Dolores from the Colorado River.

(2) The limited use of fish toxicants may be a management option for the elimination of nonnative fishes in that reach deemed suitable for recovery efforts. The tailwaters immediately below the dam will provide a limited trout fishery, but river water is expected to warm-up to ranges suitable for native fishes within 10-15 miles downstream from the dam. Irradication of many nonnative fishes in the lower Dolores may expedite and benefit recovery of native fishes.

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Appendix A: A Glossary of Terms

Used by the Colorado River Fishery Project

Definition of Terms

Life history terms

Fry	Newly hatched fish with yolk sac visable (synonym: prolarva).
Postlarva	Fish with yolk sac absorbed; loss of larval and gain of adult appearance.
Young-of-year	Fish up to 1 year of age.
Juvenile	Fish 1 year old up to but not including adult (synonyms: immature and subadult).
Adult	A fish capable of reproduction.
Spawning condition	A sexually mature state at or near the actual time of spawning. Mature eggs and milt run with slight pressure.

Field terms

RM	River miles upstream and downstream from the confluence of Green and Colorado Rivers.
Braided	Multiple side channels forming an interlacing network in a section of river.
Stratum	Geomorphologically homogeneous section of river selected for random statistical sampling of fishes.

Habitat types

Backwater (BA)	A body of water off the main channel with no measurable velocity; often created by a drop in water level which stops the flow through a former side channel or low-lying area.
Eddy (ED)	A portion of the stream with a distinct whirlpool effect.
Gravel pit (GP)	Excavated gravel bar adjacent to or in the river channel inundated by the river to form a small lake or large backwater.
Irrigation return flow (IR)	Water entering the river from irrigation collector system.
Lake (LK)	Large body of impounded river water; i.e. Lake Powell.

Main channel (MC)	Primary river course that carries the major water flow throughout most of the year.
Pool (PO)	A portion of the stream that is deep and quiet relative to the main channel.
Riffle (RI)	A shallow fast-flowing area where the water surface is broken into waves by obstructions wholly or partly submerged.
Run (RU)	A stretch of relatively deep, fast flow with the surface essentially nonturbulent.
Shoreline (SL)	The shallow, low-to-negligible velocity waters next to shore.
Side channel (SC)	A secondary channel which carries appreciable flow during high water and provides a low velocity habitat or backwater during low flow.

Substrate types

Silt (SI)	Fine gritty material
Sand (SA)	Less than 3-mm diameter
Gravel (GR)	3 mm to 76 mm
Rubble (RU)	76 mm to 305 mm (synonym: cobble)
Boulder (BO)	305 mm and larger
Bedrock (BE)	Solid, continuous rock layer