QUARTERLY REPORT

of the

COLORADO COOPERATIVE FISHERY RESEARCH UNIT

April, May, June, 1951

(Not for publication)

243 Forestry Building
Colorado A & M College...Fort Collins, Colorado

QUARTERLY REPORT

This will be the last quarterly report of the Colorado Cooperative Fishery Research Unit to be generally distributed. In compliance with current policies of the Branch of Fishery Biology, U. S. Fish and Wildlife Service, and in view of the repetitious nature of the materials presented on the current projects from quarter to quarter, and further, to relieve some pressure on the limited filing facilities of most recipients, it was deemed advisable to discontinue the issuance of complete quarterly reports.

In the future, completed project material will be prepared for distribution to interested persons and agencies.

Reports will be submitted quarterly to the cooperating agencies sponsoring the Unit.

This quarter saw the completion of regularly scheduled teaching assignments on the part of the Unit Leader. In the future, supervision of the program for not more than five graduate students, majoring in fish management, will be the only teaching done by the Leader. Most of these students will be working on Unit projects.

The students on Unit projects continued their investigations during this quarter. Eugene Cook is making a survey of the parasites found in the fishes in warm-water reservoirs, together with their incidence. A part of this program will be the preparation of a key to these parasites so that others studying these waters will have a useful guide to the parasites.

Richard Moore continued his investigation on the Food Habits of the Carp. He tested various methods of stomach analysis. The one that now seems best adapted to the study of carp stomach contents is the random sample method. For the present the intestinal tract is divided into the fore, mid and hind gut and separate examinations are made of the contents of each section. The contents of the gut section are removed and put into a centrifuge tube and the water level brought up to 10 milliliters. This material is placed in a watch glass, mixed carefully, and a 1 ml. sample is removed with a wide-mouth pipette. This 1 ml. sample is analyzed in a Sedgwick-Rafter counting cell under a binocular dissecting microscope, and the number of each food item are counted.

The accuracy of this method was checked by making total counts on several stomach samples, and then 1 ml. samples were taken and counted. After three samples were counted the sampling was stopped for the three samples gave no greater accuracy than one sample.

Upon discussion with the Head of the Mathematics Department of Colorado A & M College, it was decided that the method of counting 1 ml. samples from the stomach would provide an accurate picture of the food habits of the carp provided enough carp stomachs were analyzed. With this more rapid method of analysis, it is believed that a sufficiently large sample can be analyzed.

Two other students were working on a Masters' degree in Fish Management. Rex Taliaferro continued his study on the age and growth of yellow perch. He was employed by the State Game and Fish Department on some eastern Colorado reservoirs during the quarter. The materials he collects plus that taken on Unit projects should provide a fair picture of the growth that can be expected from yellow perch in Colorado. If there is to be a reliable basis upon which to compare various reservoirs, or for later evaluation of improvement work, it would seem indicative that a knowledge of what growth rate is to be expected for the various species is of paramount importance.

Bert Thomas began a problem on plankton production, but during the quarter decided to transfer to the Zoology Department and take his Masters' degree in Zoology. He will continue the plankton study, using samples collected on Unit surveys, but his problem will be supervised by the professor of Limnology.

During this quarter some netting was done to determine the time of spawning of various species. With fluctuating water levels in irrigation reservoirs, which comprise the vast majority of local impoundments, it has appeared that one possible contributing cause to poor fishing has been inadequate spawning of game fishes. With water levels rising or falling at a rate of 6 inches a day (as happened at Lone Tree Reservoir last year) it is possible for many nests to be left high and dry before sufficient time has elapsed for the eggs to hatch and the fry to develop enough to be able to swim as the level drops, or if the level rises, the nests become too deep for good spawn production. If the period of spawning can be delineated, it might be possible to come to some arrangement with the water companies for a period of stable water levels in some reservoirs.

This might be possible where companies own several reservoirs in a chain. They could hold the level steady in one or two impoundments while the others take all the water and fill at a faster rate. Then, when the fry are sufficiently developed, all of the water could be let into these reservoirs where the level had been stabilized. This would give the other reservoirs a period of stable levels and might catch the late spawners.

The time and duration of spawning must be known before it will be possible to approach the owners of the reservoirs about cooperating in a stabilization program. First consideration is always to the farmer who needs the water for irrigation of crops, but it is hoped that a mutually beneficial agreement can be reached with some water companies.

Another problem under the direction of the Unit Leader is the utilization of rough fish. Carp and suckers are the dominant species of rough fish found in Colorado reservoirs. A program of netting is underway to determine what sizes of gill nets can be used for the capture of these species without reducing the game and panfish populations. It is hoped eventually that the general public can be permitted to use gill nets for taking rough fish. At present a large segment of the fish population is not being utilized, or is inadequately harvested by hook and line fishing. Early results indicate that the 2 and 2½ inch bar measure mesh gill nets are the most effective for taking carp and suckers and are not dangerous to game fish. However, a great deal of additional netting needs to be done before conclusive statements can be released.

Three men were added to the staff of assistants for the summer months. Leonard Fisk and Dale Hoffman were assigned to the survey crews and Joe Kutkuhn is working with the Unit Leader.

Fisk is assigned to the Lone Tree Reservoir party, with Eugene Cook as party leader. He is a graduate of Colorado A & M in Game Management and plans to continue his study for a Master of Science degree in Fish Management. His problem for the summer is to learn what becomes of the fry of fishes. Are they eaten by other fish? Or do they die of other causes?

Hoffman is a senior at A & M and is majoring in Fish Management. He was assigned to the Jackson Lake Survey party, headed by Moore. Jackson Lake Reservoir near Fort Morgan, Colorado, is the second impoundment to be intensively studied.

Kutkuhn is a junior and plans to major in Fish Management also.

The emphasis this summer on the lake inventory will be on the biological interrelationships rather than on the physico-chemical data. Special emphasis will be placed on the effects of the removal of fishes by netting.

In cooperation with the Rocky Mountain Forest and Range Experiment Station, a thermograph was installed on Fool Creek in the Fraser Forest Experiment station at Fraser, Colorado. The effect of various types of timber cutting on stream temperatures will be checked. During the summer, a brief survey of the Fool Creek area will be made. At present it is reported that the stream temperature remains too cold to permit trout production. Other factors may be the cause and these will be checked during the survey. Should the Fool Creek area prove unsatisfactory, another stream in the Forest will be selected. The Unit is furnishing the thermograph and will conduct the stream survey. The station runs the thermograph in conjunction with other meteorological instruments and all other details of the project.

Another thermograph has been installed on the South Branch of the Poudre River at Pingree Park. Pingree Park is the location of the Colorado A & M Forestry School summer camp. Again it is reported that water temperature is the limiting factor to fish growth. In the future some stream improvement work may be done in an attempt to better fishing conditions in this area. The instructor in charge of Game Management work at camp, together with help from interested students, will carry out this program. The Unit furnishes the thermograph and technical advice.

The death of Dean J. Lee Deen on April 24, 1951, constituted a great loss to the Cooperative Fishery Research Unit. Dean Deen was always willing to help in the solution of problems confronting the Unit. He did much to ease the Unit through its growing pains, and greatly aided the Unit Leader in establishing himself in a new community and surroundings. Besides his personal friendship, his valued judgment and help will always be remembered.

Respectfully submitted,

William C Beckman

William C. Beckman
Unit Leader

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Volume 1 No. 4

April, May, and June, 1950

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Colorado A & M College Fort Collins, Colorado

The highlight of this quarter was an extended field trip through Colorado. The Seniors majoring in Game Management or Forest Recreation were taken on a 5-week field course. This trip is required for all men majoring in Game Management or Forest Recreation and is included in the curriculum for Fish Management Majors for next year.

This quarter seven students majoring in Game Management needed additional work in Fisheries Biology in order to qualify for the Fishery Biologist option on Federal Civil Service Exams. Therefore a special problems course was organized and included in their course of study for the spring quarter.

In addition to giving this course the trip also afforded an excellent opportunity to get acquainted with the State of Colorado and to collect fishes from various waters along the route.

It is the present plan to write a book on the Fishes of Colorado. M. M. Ellis' book published in 1914 is out of print and many taxonomic changes have occurred as well as some changes in the fish fauna. Thus the spring trip was utilized to begin the work of collecting more specimens on which to base this new volume.

A 3,400 mile circuit of central, southwestern, western, and northwestern Colorado was made from April 11 through May 19, 1950. Twenty students, Harold Steinhoff, Ass't. Professor of Game Management, and I made the trip. A suburban carryall, two sedans, and a ton and a half stake body truck provided the transportation. Tents were taken along and used where other shelter was not available. For the most part state or government housing at various project areas was available for our use. The Federal Forest Service and the State Game and Fish Department were particularly cooperative both in providing their facilities for our use and especially for the time of their employees in explaining their work and conducting trips through their areas.

I believe this spring field trip is excellent and should be continued and expanded. It provides the students with an opportunity to get away from their textbooks to a large extent and put to work the knowledge accumulated during their past 3 and 2/3rds years of classroom work.

They saw the problems that would be theirs when they got jobs and saw how some of these were being handled. They made observations and surveys of some problem areas and made up management plans and suggestions. During the last two weeks of the Spring term these reports were gone over by the Professor in charge and suggestions and comments made. Thus the last professorial critique was obtained before embarking into the professional field.

The summers' work program also got under way in June. On June 16 camp was set up at Lone Tree Reservoir and biological, chemical and physical investigations of the Reservoir were begun. Eugene Cook and Richard Moore are the assistants on this survey. They will be at the reservoir until late September. A regular Lake Inventory program has been set up.

In the last quarterly report mention was made of the Castolite plastic process for mounting fishes. Jesse Williams, a student in Game Management, took a problems course under my direction and worked on the technique of mounting a series of eggs and fry in plastic. In the castolite plastic he mounted unfertilized, fertilized, eyed and hatching eggs, 1, 12, 18 and 24 day old fry. This plaque makes an excellent demonstration piece and is useful both in the classroom and for public meetings and particularly could be used in state fish hatcheries.

Directions that come from the Castolite Company of Woodstock, Illinois, when followed produce excellent results. Minor techniques of pouring the liquid and adding the hardener, etc., are soon developed and probably can only be acquired by doing.

Water reacts with the plastic to give a minor opaqueness to the specimens, and various agents should be tried to get the best media. Best results were obtained from specimens that were taken from 10% formaldehyde solutions, although they gave a slight cloudy appearance. Absolute alcohol does not work well with small specimens because they shrivel up on exposure to air. It is quite probable that a formalin solution in alcohol would be the best media for the mounting technique.

Personnel and Cooperating Agencies

For a list of personnel and cooperating agencies, the reader is referred to Vol. 1, No. 2, in this series of reports.

Size of Quarterly Report

Following a directive from the Central Office of the Fish and Wildlife Service in Washington, only the highlights of the work have been given. Should anyone wish additional information on any items mentioned in the quarterly reports I shall be pleased upon request to send the additional details.

Respectfully submitted,

William C Beckman

William C. Beckman,
Leader

Instream Flows to Assist the Recovery of Endangered Fishes of the Upper Colorado River System: Review and Synthesis of Ecological Information, Issues, Methods and Rationale

by

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A Report Prepared for the
Instream Flow Subcommittee
of the
Endangered Fishes Recovery Program
Upper Colorado River

and

U.S. Fish and Wildlife Service
P.O. Box 25486
Denver Federal Center
Denver, CO 80225

28 June 1993

Second Draft Report

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Corrections if necessary

8-9
5 pgs 17, 22-25, 40, 56

THESIS

SYSTEMATICS OF NATIVE COLORADO CUTTHROAT TROUT

Submitted by

Gary R. Wernsman

In partial fulfillment of the requirements
for the Degree of Master of Science
Colorado State University
Fort Collins, Colorado
August, 1973

Statement from Colorado Division of Wildlife's Non-Game Advisory Council

Rehabilitation of the Douglas Creek Watershed and Restoration of Native Cutthroat Trout

The Douglas Creek watershed in northwestern Colorado covers approximately 220,000 acres. The present state of the watershed is characterized by deep arroyos and expanses of greasewood. One hundred years ago this watershed was characterized as . . . "the best grazing land you ever seen -- grass up to the stirrups of a horse" (see attached paper by Behnke). The Douglas Creek watershed is a classic example of accelerated erosion due to past overgrazing by domestic livestock. The process of accelerated erosion can be reversed and, concomitantly, riparian vegetation re-estalished, sedimentation levels greatly reduced, stream channels stabilized and intermittant flows can become perennial (for documentation see attached paper) to again create favorable trout habitat.

The native trout of Douglas Creek is the Colorado River cutthroat trout, <u>Salmo clarki pleuriticus</u>, presently an extremely rare fish and recognized by the Colorado Division of Wildlife as a "threatened species." In the headwaters of Douglas Creek, several tributary streams have trout populations representing various degrees of hybridization between the native cutthroat trout and the introduced rainbow trout. One tributary, Soldier Creek, has a trout that is quite typical of <u>S. c. pleuriticus</u> in appearance (there is no outward indication of hybridization).

The opportunity for the Division of Wildlife and the BLM to enter into a cooperative arrangement to rehabilitate the Douglas Creek watershed for the benefit of native fish and wildlife and recreation is strongly endorsed by the Non-Game Advisory Council.

Of the 110 miles of perennial and intermittant streams in the watershed, 64 miles are on BLM lands and 46 miles on private or state lands. The private land is owned by the Tippery Oil Co. which, hopefully, will cooperate in the effort to rehabilitate the watershed through strict controls on livestock grazing. Some of the private lands are leased by the American Sportsman's Club. The Club has constructed several dams in the arroyo of West Creek to create ponded areas. These have been stocked with rainbow trout which reach a large size. Perhaps similar techniques could be used in other parts of the watershed to reduce erosion, raise the water table, and create habitat for cutthroat trout.

Once the watershed is revegetated, particularly with riparian vegetation, erosion and sediment loads should be tremendously reduced, the intermittant streams should become perennial with clean, cool water of good quality -- suitable for native cutthroat trout. With vigorous stands of riparian vegetation, a great diversity of birds, mammals, reptiles and amphibians, not now present (or in low numbers) should become established on the watershed.

The major significance of the proposal, however, would be to demonstrate that the process of accelerated erosion, which has converted millions of acres of grassland into virtual wasteland in the Southwest during the last 100 years, is reversible and the original values of fish, wildlife and a dependable quantity of quality water emanating from this watershed can be restored.

This rehabilitation project could be completely justified, if for no other reason, solely on the basis of the BLM's mandate to reduce salinity in the Colorado River basin (see BLM 1977 Status Report: The effects of surface disturbance [primarily livestock] use on the salinity of public lands in the upper Colorado River basin).

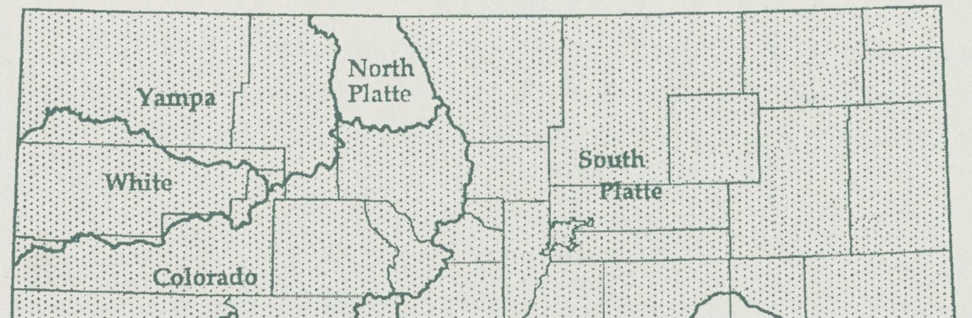
A River Runs Through It

With the close of the 1997 field season, CNHP has sampled and classified vegetation in nine of the ten major watersheds in Colorado (see inset). This project will generate a complete statewide description of riparian plant communities in Colorado.

CNHP employees Tom Stephens and Jennifer Zoener overcame unseasonal rains, high water, impenetrable vegetation and biting insects to visit approximately 35 miles of the San Miguel River main stem and 50 miles of tributary streams. This project will help identify impacts of flow alterations in the river, and provide information on the condition of riparian areas, helping to guide management decisions in the watershed.

The CNHP riparian ecology team finished sampling the Upper Rio Grande and Closed Basin watersheds. During these surveys, we discovered three new riparian communities, including what is "probably the most pristine cottonwood stand in the state," according to ecologists Gwen Kittel and Renée Rondeau. This is a three-mile-long occurrence of the globally imperiled narrowleaf cottonwood/Drummond's willow-Rocky Mountain maple plant type which is found in the Rio Grande National Forest.

The multi-year effort has been possible through support of the CO Dept. of Natural Resources, EPA, BLM, BOR, willing landowners, and other partners.



CNHP has sampled vegetation in nine Colorado watersheds (grey areas)

A New Spin on Riparian Know-How

An interactive CD-ROM of Colorado riparian plant communities and the western United States vegetation classification, recently adopted as the federal standard, is scheduled for completion and distribution to land managers in March 1998.

Users will be able to search information on over 2200 plant communities, including the scientific and common names of each community, and its global and state Natural Heritage rarity ranks. More information on Colorado riparian communities includes distribution, habitat, and a description of the surrounding vegetation. The interactive format will take the user to photographs of each community type, cross-sectional diagrams, and management information.

The CD-ROM is the result of a collaboration between CNHP, the Biological Resources Division of the US Geological Survey, and the Environmental Protection Agency.

New Features Now Available in Colorado Natural Heritage List

The latest edition of CNHP's Rare and Imperiled Animals, Plants, and Plant Communities is now available with updates and new features. This complete list provides the scientific and common name, the global and state Natural Heritage rarity ranks, and the federal and state legal protection status for more than 1,200 plants, animals, and plant communities tracked by CNHP. The list catalogs those species with a state rarity rank of S1 (critically imperiled or extremely rare), S2 (imperiled or very rare), or S3 (vulnerable, rare, or found in a restricted range).

Two new critically imperiled plant species: Among the new plant listings are two new G1 (critically imperiled globally) : the skyrocket (*Gilia sedifolia*) found in the San Juans, and the bladderpod (*Lesquerella vicina*) found in the Uncompahgre River Valley.

Lesquerella vicina
Illustration by D. Baker

Cross-reference by county: New to this edition is a cross-reference that lists rare and imperiled species and significant plant communities by the Colorado counties from which they have been documented. This is a new twist on last year's cross-reference by Bailey's ecoregions.

Complete Plant Community List: As a new feature, the list reflects the work of CNHP ecologists to develop a statewide plant community classification scheme. This latest edition is the first to list all plant communities found in Colorado.

Updated listings: Since the April 1996 edition, 31 plant, 11 vertebrate, and 1 invertebrate species have been ranked as rare or imperiled and added to the list. Twenty-nine vertebrate and three plant species have been dropped from the list due to field surveys clarifying their relative degree of imperilment in the state.

Peer reviewed rankings of vertebrate species: Vertebrate state rarity ranks have been updated as the result of an intensive expert peer review process. Experts were drawn primarily from the Colorado Division of Wildlife, federal agencies, the academic community and non-governmental organizations.

The Natural Heritage List, Rare and Imperiled Animals, Plants, and Plant Communities Vol 3, No. 1 is available on the internet via anonymous FTP from: **ftp://ftp.heritage.tnc.org/pub/nhp/us/co/rarelist.txt** or via our homepage at: **http://www.colostate.edu/orgs/CNHP**. Hard copies will be available upon request from CNHP. Contributions of $10 to cover printing and shipping costs are appreciated.

Thank You For Your Gift

Dave Armstrong	Loveland
Cate Werner	Boulder
Vince McElligott	Fort Collins
Randall Ferguson	Golden
Buck and Barbara Ingersoll	Colorado Springs
Bob Barford	Alma
Caroline H. Coleman	Fort Collins
Susan Sheridan	Denver
Paula Lehr	Gunnison
Robert Poole	Salida
Odell's Brewery	Fort Collins

Saving Butterflies on Both Sides of the Divide

CNHP inventories are helping land managers understand the conservation needs of globally significant butterflies in the San Juan Mountains, and for the City of Boulder Open Space and Mountain Parks.

San Juan Mountains: In 1997, CNHP built on 19 years of monitoring and search efforts for the federally endangered Uncompahgre fritillary *(Boloria acrocnema)*. This species was believed to be approaching extinction, but CNHP scientists Aaron Ellingson and Mundy Hackett visited 54 potential colony sites and confirmed the persistence of all previously known populations, and located one new colony site. This brings the total number of colonies to 7 with 14 populations.

The Uncompahgre fritillary is known to occur only in high-elevation, moist alpine meadows within the San Juan Mountains. CNHP has spent much time and effort attempting to survey these remote areas, and our success in 1997 indicates that such efforts are justified. Continued monitoring will be critical to understanding the causes of population fluctuations that could lead to extinction, potentially indicating a need for additional management.

Boulder: For the second year in a row, CNHP scientists have surveyed the City of Boulder Open Space and Mountain Parks for rare and imperiled butterflies. This field season Zoologist Phyllis Pineda discovered 11 new locations and updated four others.

Most exciting was encountering the Regal fritillary *(Speyeria idalia)*, a large and beautiful butterfly that has seen a serious decline in both numbers and habitat across North America since the early 1980's. Only one colony in eastern Colorado is confirmed; however, CNHP's encounter of a fresh individual during the peak of its breeding season suggests the presence of a small colony in the Boulder Foothills.

We also discovered three new locations of the state rare Ottoe skipper *(Hesperia ottoe)*, an important indicator of xeric tallgrass prairies, which have been declining along Colorado's Front Range.

Big Survey—small subject

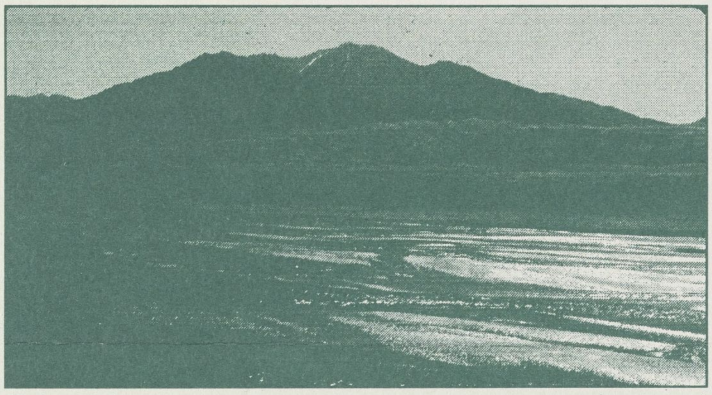
CNHP's largest single-species inventory this year was for the proposed endangered Preble's meadow jumping mouse *(Zapus hudsonius preblei*). Zoologists found numerous locations of the mice in Douglas County, one new location in Jefferson County, and conducted radio telemetry studies of jumping mice on the U.S. Air Force Academy. The telemetry studies were the first successful attempt to understand the mouse's life history patterns in order to facilitate better land-use planning.

Be our Secret Santa.
We've been really good this year. CNHP is wishing for:

Laptop computers for WP 5.1 or better
486 computers or better
Color Printer
Dissecting Microscope
Reliable refrigerator
Legal File Cabinets
Large Walk-in Tent
Bookshelves

Beetles, Birds, Bats and Other Fun Species in Saguache County Closed Basin

This summer, CNHP field teams conducted a rapid ecological assessment in Saguache County Closed Basin. Numerous mountain streams drain into this large and high mountain valley, creating Colorado's most extensive wetlands, one of its largest aquifers, and the world's highest sand dunes. CNHP biologists found over 60 imperiled animals, plant species, and plant communities between the extensive sand dunes, playa lake wetland complex, and a diverse foothill/montane ecosystem.


Sand Creek and the Great Sand Dunes

In the San Juan Mountain foothills, scientists discovered the first Colorado location of the Wyoming ground squirrel (*Spermophilus elegans*), significantly extending its known range. They also found Colorado's fourth known breeding colony of Townsend's big-eared bat (*Plecotus townsendii*) in an abandoned mine shaft on private land. The landowner is very interested in protecting this location. CNHP botanists located several new populations of slender spiderflower (*Cleome multicaulis*), and a new popluation of Smith's whitlow grass (*Draba smithii*), bringing the total number of known locations for this species to eight. They also found two new San Luis Valley locations of milkvetch (*Astragalus cerussatus*) and grass fern (*Asplenium septentrionale*), and significantly extended the known range of several populations of rock-loving neoparrya (*Neoparrya lithophila*).

While conducting wetland inventories, teams discovered a new county location for the plains spadefoot toad (*Spea bomifrons*), and a new population of the Rio Grande chub (*Gila pandora*)—a declining fish that is a concern of regulatory agencies. But despite their efforts, the team was unable to find any locations for the northern leopard frog (*Rana pipiens*). This frog, reported to be abundant in the San Luis Valley during the 1970s, has been declining over much of its range and will continue to be a concern of CNHP.

As you travel south toward the lowest part of the Closed Basin, the lakes and wetlands become very salty. These saline lakes and wetlands provide an important habitat for the last large and healthy populations of slender spiderflower (*Cleome multicaulis*), and are very important for shore birds and waterfowl.

Adjacent to this extensive and diverse playa lake wetland system are the Great Sand Dunes. Here, zoologists found new locations for the endemic and globally restricted San Luis Dunes tiger beetle (*Cicindela theatina*). They also discovered the first location in Saguache County for a solitary tiger beetle (*Cicindela purpurea cimarrona*), and four species of newly discovered insects that are still unnamed.

This wealth of information, partnered with two other CNHP efforts in the area--riparian area inventory and wetland inventory, will be given to Saguache County commissioners and citizens to identify areas suitable for protection and restoration in the San Luis Valley. These support The Nature Conservancy's program to work with local landowners and agencies to develop conservation strategies that incorporate local economic interests.

pleuritica

Colo. R. basin

WY 1987 collections

Uinta Co

Archie Crk. Trib. W. Fk. Smith, R116W, T12N, S21

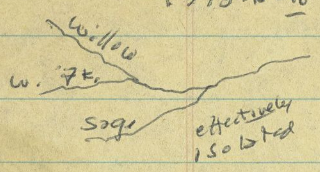
July 29, 1987, N=10, 99-216mm T.L.

teeth 3 no teeth 7 w/ 1-9 (~~3.4~~ 3.24) [2 no 14 w/ 0-11 (4.5)]

1975 N=16

40-46 (43) (42)

162-179 (173) (176) ~~34-45~~ 35-45 (40) caeca - 31-46 (39)



1975 Rep. N=16 16-21 (19.1) [14-22 (19.5)]

- No change 'B' - no obvious hybrids

Uinta Co

Willow Crk. → Smith Fk. R116W, T12N S6

Aug. 19, 1987 N=11 144-186mm T.L.

similar but - one specimen distinctly S.R. like in caudal peduncle (Sage Crk). 16-21 (18.8) . 39-44 (42)

168-182 (173)

S.R. in Willow not Archie

why S.R. infl. cutt greater than RB

3 no teeth 8 w/ 1-5 (3, 2.3) - typical 'B' but 27-36 (33)

if S.R. int. increa—

Lead Crk.? (Label faded .. U.S. for Bm - prob.

Trib. N. Horse Crk. R113W T35N S31 - 'A' - uniform

but N=15 102-205 mm. 13 pure S.R. smaller spots not clear

siruan ~~p~~ pleuritica. - . not hybrid swarm as Sage - explanation? -

as if barren stocked S.R. - dominate - not logical .. how

could so completely dominate? - barrier? -

Little Snake - foil. Dirtyman Crk. Carbon Co. Trib. E. Fk. Savery Crk.

Sept. 23, 1987 N=50 hybrid spots - smaller below lat. li

3 no teeth 7 2-6 (3.3) 20 + 10 1-5 (3.2)

1980 N=10

17-21 (19.0) 17-21 (19.3) 41-46 (43.5) 41-50 (44.7)

172-187 (177)

166-192 (182)

31-40 (36) 'B' no change

RB - inv

7 yrs - invasion? isolated?

but perhaps trend.

trib. Clark Fk. Yellowst

N Fk. Crandall Park Co. –

S. c. bouvieri – only S. Paintrock – but days as little collected in park – status unclear but could at com

great condit~

N=26 148-242mm extremely robust, heavy fat depress

pure? ~~one~~ variability – w/ Paintrock. – smaller p

not obvious hyb one spec. or RB X – but at ..

slight all 26 w/ basibranch.

N=26 17-21 (19.2)

2-14 (6.7)

40-47 (43.7)

168-187 (178)

29-41 (35.9) 36

gravity - drop back.
- constraints - not absolute.

pleuriticus

Archie Crk. → W. Fk. Smith Fk.

R 116 W, T 12N S 21 S 1/4. No obvious hybrids!

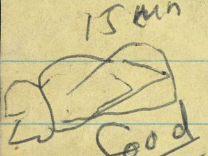
July 29, 1987 - W. G. F. Crew Kevin Johnson

	S.L. T.L.		teeth				
①	185, 216	- typical pleuriticus	5	7/13=20	43/177	-9	- 36
②	151, 181	- "	2	7/11=18	45/179	-9	- 45
③	119		3	7/13=20		-9	
④	99		2	8/13=21		9	
⑤	201		9	8/11=19	44/162	9	— 44
6	180		0	7/13=20	42/166	9	- 35
7	172		0	6/10=16		9	
8	154		2	6/12=18		9	
9	132		0	8/11=19		9	
10	126		0	8/12=20		9	

ca. 4 in teeth 43/172 - 41

recall! evidently
hybrid not listed on Wyo. map.

15 mm



Good

15-20 mm
nematode
parasites
in stomach

~~43/175~~ - N Fk Crandall

42/168 44/169 41/181 41/178 40/186 46/182 47/184 41/170

36 35 37 31 38 35 39 36

45/179 43/178

36 36

40-47 (43.7)
168-187 (178)

31-39
30-40
29-41

(

Willow Crk. → Smith Fk.
Uinta Co. WY R116W T12N S6, NE¼
next to Archie Crk Aug 19, 1987 - coll. by Green R. crew

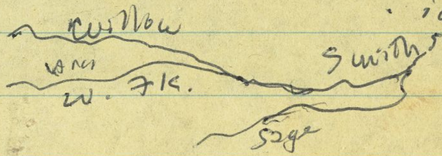
Dirtyman Crk., Carbon Co. trib. E. Fk. Savery Cr
Sept. 23, 87 - Stabler & Oberholtzer.

? label faded
USFS boundary Lead Crk 9/11/87
- pure fine-spotted S.R. cutts
1 pleuriticus spotted

Sage Crk. 50/50 hybrids

- N. Fk. Crandall Crk. Yellow
Park Co. trib. Clark Fk. of Yellowstone.

Willow - Archie .. should be identical if pure?



- 1986 Stone Rep. Colo R. cutts
Dirtyman Crk. - 'B'
Archie Crk. 'B
Willow - unknown

Archie - 1975 Rep. I -
19-22 31-46 40-46 42.4 2 of 16 no teeth
19.5 39.4 158-187 175.9 0-11 (4.5) -

Dirtyman - examined 1981.
near Hell Canyon Crk.
N=10 17-21 (19.3) 166-192 (182) 41-50 (44.7) -
31-38 (35) 2 of 10 no teeth 1-5 in 8 (3.2) -
coll. July 29, 1980 - F. Stabler & J. Blackwell

Snake R. 103-297mm N=15

only one (156mm) resemble pleuriticus

often appear pure S. R. – 103 mm may be pleuriticus

vs. Sage Crk

Dirtyman N=10 117-212 mm

obvious hybrid spotting – great variants

some 2s Little-Snake

Willow Crk. N=11 144-186mm

good cutt – but not pleuriticus – prob

one spec. distinct fine-spots on peduncle one S.R. like

3 no teeth

Willow

~~teeth~~ 1, 2, 2, 3, 5, 3, 0 5, 0, 2, 0

7/12 6/12 8/12 7/13 4/12 7/12 5/11 7/14 7/13 7/12 7/11 16-21 (18.8)

19 18 20 20 16 19 18 21 20 19 18

16 12

pelvic 9 9 9 9 9 9 9 9 9 9 9

44 41/170 42/172 39/182 39-44 42

168-182 173

168

39-44

caeca: 36, 34, 27, 32, 36, 32 27-36 (33)

Dirty man N = ~~9~~ 10 117-212 mm

stone pass for - pine - spots small below l.l. ? now - invasion: residual genes or gradual stabiliz. of old hyb. (1951)? is - no typical R.B. no. 71

·3 - 0 - 0 - 2 - 0 - 3 · 3 - 6 - 3 - 0 2-6 (3.3)

~~3~~ 4 no teeth

6/12 7/12 6/12 8/13 5/12 7/12 7/13 6/12 7/13

18 19 18 21 17 19 20 18 20 17-21 (~~19~~ 19.0)

9 9 9 9 8 9 9 9 9

43/175 41/174 44/180 42/177 45/183 41-46 43.5

41-45 (42.5) 17~~2~~-187 (177)

172-187

31-40

31, 37, 41, 34, 40, 31, (36.3)

36.8

S.R. cutt. N = 15 size: Lead Crk.

? 113N 113 W US75 boundary

~ W S31

N = 15 155 mm

Spr. Col. R. (?) - 192-205 mm ~~typical~~ no S.R. spin

N. Horse Crk. drainage

Lead Crk. 'A' B in stone's key

R113 T~~35~~ S~~3~~4

	N
Archie	10
willow	11
Dirtyarm	10
Lead	15 ——?
N. Pk. Crandall	46 26
	72

$950 ca $10 + [illegible]
25

5261y1 thru June 30 1959

- . 1988 - up to 13 coll. 250 ≈ 200 s m .

not exceed $ 1800 .

150

19

rept next week

few spec. - Small, profess

S.R. ??

X one other
1 in S.R.

good condition

'robust'

c[illegible] fat

N 7Ki Crandall N=26

148-242 mm

, one [illegible]

RBX

6	9	5	4	4	7	10
6/11	7/13	7/12	7/12	6/12	8/13	7/13
17	20	19	19	18	21	20

3	5	6	16	4	5	12	4	8	6	5	8
8/12	7/11	7/12	7/11	7/12	8/11	7/13	9/12	7/13	7/13	8/12	7/13
20	18	19	18	19	19	20	21	20	20	20	20

2	4	14	14	4	12	6	5
7/11	7/10		7/12	7/11	7/12	7/13	7/12
18	17		19	18	19	20	19

4

17	18	19	20	21
2	5	8	0	

17-21 (19.2)

/ +26 4

17-21 (19.2)

2-14 (6.7)

45
82
147
26|174

26|174 = 6.7
156
180
182

40-47 (43.7)

168-187 (178)

29-41 (35)

Danny M. Regan

Colorado drainage

FISH DISTRIBUTION

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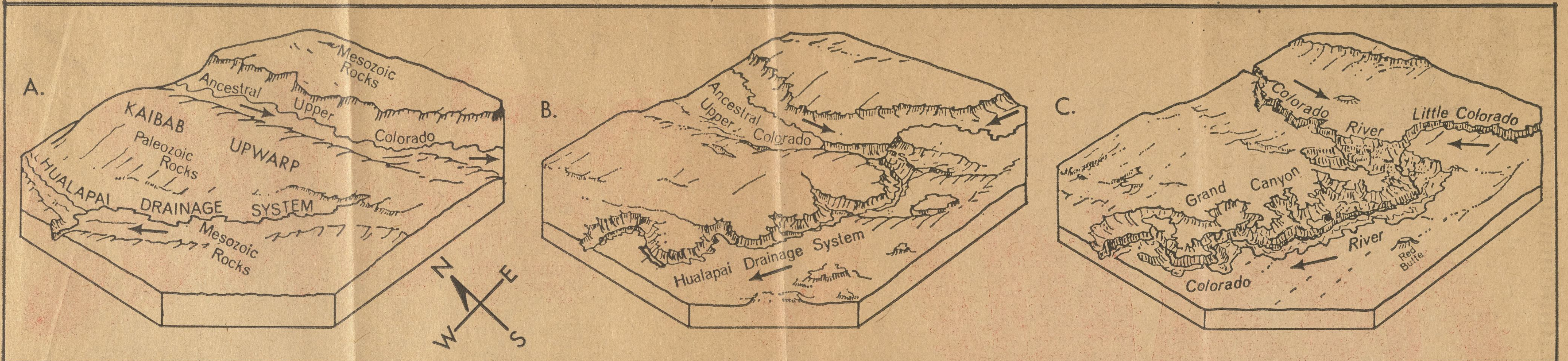

A new hypothesis of the origin of the modern Colorado River and its Grand Canyon in northern Arizona is graphically set forth in this chart prepared by the Museum of Northern Arizona in Flagstaff. Some 35 million years ago (A), the uplifted Kaibab Upwarp separated two river drainage systems east and west of the present Grand Canyon. Subsequently (B), the western system's headwaters eroded headward, or eastward through the Upwarp, and "captured" the eastern system sometime after 10.6 million years ago. Downcutting of the eastern Grand Canyon and other features of the modern Colorado River system (C) occurred since this "capture," the hypothesis holds. Arrows indicate probable direction of primary drainage. (Chart Courtesy Museum of Northern Arizona)

Was Grand Canyon Carved by 2 Rivers Rather Than 1?

FLAGSTAFF—A new theory on the creation of the Grand Canyon has been advanced by 21 geologists and geophysicists in the recently published Museum of Northern Arizona bulletin entitled "Evolution of the Colorado River in Arizona."

The new hypothesis was evolved at a special symposium held at the museum's research center here during the summer of 1964. The basic premise of the new theory is that 11 million years ago there were two "Colorado Rivers" in northern Arizona, in contrast to the one river remaining in the canyon today.

THE CONCEPT is at sharp variance with the long-held idea that the Grand Canyon was carved by a single, swift, abrasive river as it cut downward along its full course at a rate roughly the same as that of the uplift of the land.

The new theory states that the major uplifting of land occurred millions of years before what is now the Grand Canyon began to form and created two separate river drainage systems to the east and west of the uplifted area now known geologically as the Kaibab Upwarp and geographically as the Kaibab Plateau.

The initial uplifting began 70 million years ago and raised what had been a gently sloping alluvial plain, draining to the northeast, to altitudes of about 10,000 feet. Faulting accompanying the uplift created great escarpments, the remnants of which are still visible today in such features as the Grand Wash Cliffs and the Hurricane Cliffs west of the Grand Canyon.

BY 35 million years ago, the geologic evidence indicates, the two separate river systems were well established. The eastern system, labeled the Ancestral Upper Colorado at the symposium, probably drained to the southeast while the so-called Hualapai River system to the west drained northwestward into present-day Utah.

The modern Colorado River was established, the new hypothesis holds, when the western system "captured" the eastern system by the process of headward erosion. The western system gradually extended its headwaters eastward across the intervening Kaibab Plateau until the eastern system was reached and diverted into the single course that exists today.

Once the single river system was established, geologic events in the area principally concerned downcutting by the river with the formation of the eastern Grand Canyon, Glen Canyon, Marble Canyon and the San Juan canyons, and with the development of various erosion surfaces of the modern river system.

THE symposium report says that 1.2 million years ago the "Lower Canyon" lavas dammed the river at Toroweap Point.

"By this time the gorge of the Colorado River and Grand Canyon itself were essentially cut, for the channel of the river today is only a few tens of feet below these lavas," the bulletin points out.

"Why the Colorado should have downcut only a few tens of feet in approximately the last million years, whereas during the preceding several million years it downcut some thousands of feet, is uncertain," the bulletin adds.

THE MAJOR factor in the rapid initial downcutting, it suggests, may have been continued uplifting of the area and a substantial increase in the amount of water in the river after capture of the eastern drainage system.

The slow rate of downcutting in more recent times might have resulted from a cessation of the uplifting, recurrent damming of the river

(Continued on Page 2-C, Col. 6)

Japanese Buddhist Festival Today

Travel

Farm

THE A REPUBLIC

More About

Law School to Be Full-Fledged

(Continued from Page 1-C)

with a firmly established national reputation.

Prosperous even before it has opened its doors, the college has a fat wallet containing $25,000 donated by 204 members of the Law Society, a nonprofit corporation formed to provide private support essential for a first-class school.

A portion of these funds, plus the income from a $90,000 estate left in trust to ASU, will provide around 10 scholarships in the college's first year.

THE FIRST scholarship will be awarded to an American Indian, in keeping with Pedrick's pledge to help tribes of the Sotuhwest help themselves.

A federally financed program at the University of New Mexico now is preparing Indians to embark upon careers in law. After they finish this readiness course, Indians will be eligible to enroll in law colleges at New Mexico, the University of Arizona and ASU.

"As far as I know, Arizona, New Mexico and Utah have never graduated an Indian attorney," Pedrick said. "Now, we're on our way to doing something about it."

THE NUMBER of inquiries (1,418) the college of law has received for admission strengthens Pedrick's contention that there is room in Arizona for two medium-sized law schools.

He anticipates a "friendly competition, but cooperation on a wide variety of matters" with the 40-year-old law college at the UofA. Although the UofA has graduated 85 per cent of the members of the State Bar of Arizona, some of its alumni have helped ASU pave the way for its law school.

At least a decade will pass fore the ASU law college will

Among Pedrick's first catches was Richard C. Dahl, a bespectacled karate and judo expert who was law librarian for the State of Washington four years. Dahl also served with the U.S. Department of Justice, Judge Advocate General's Office, U.S. Department of Navy and the U.S. Treasury Department.

He looks forward to the day when the ASU college of law will fill its shelf space of 200,000 books.

William C. Canby Jr., a former Peace Corps director in Africa, personifies the kind of legal scholar Pedrick sought. Canby was first in the University of Minnesota law school graduating class of 1956.

A MEMBER of the Air Force Judge Advocate General's Corps and a law clerk to Justice Charles E. Whittaker of the U.S. Supreme Court, Canby later was a special assistant to Sen. Walter Mondale of Minnesota, a law school classmate at the University of Minnesota.

Pedrick also lured to ASU Dr. Edward W. Cleary, former professor of law at the University of Illinois and recently the reporter for the committee appointed by Chief Justice Earl Warren to prepare rules of evidence for the federal courts.

Dr. Harold C. Havighurst was named the first faculty member of the college of law after he retired as a professor at Northwestern University last month. Havighurst formerly was dean of Northwestern's law school. His governmental experience includes stints with the Anti-Trust Division, U.S. Justice Department, and the State Department.

COMPLETING ASU's first law faculty is Richard W. Effland, former professor at the University of Wisconsin. He was one e principal architects of

ity that springs up in a big institution," Pedrick said.

All classrooms and ancillary facilities are focused toward this central meeting area or rotunda. Crescent-shaped wings accommodate classrooms and administrative offices. Circular areas will house the library and moot court, where Pedrick expects the Arizona Supreme Court to hear some cases.

Seating 400 persons, the court is one of the striking features of the Law Building. It provides a dramatic setting for final arguments before a full bench.

MOOT COURT also will be used for meetings of the Student Bar Association, for occasional class sessions, programs of continuing education by the organized bar and for public lectures.

From a central well, rows of elevated tiers of benches with broad desk tops rise to the front and both sides in a fashion somewhat reminiscent, though in modern circular form, of the British House of Commons.

Sidewalk superintendents watching construction of the building refer to two circular domed rooms joined by a plexiglass-domed rotunda as a miniature astrodome.

Some students have nicknamed the law building "Miss Maidenform" because an aerial view suggests a brassiere.

PEDRICK describes the 79,950 square-foot building as "unusual in shape, rich-looking and economical." It was built for $19.70 a square foot, as contrasted to a cost of $40 a square foot for a law college under way at the University of Southern California.

A third of the cost was paid by federal funds.

Members of the law faculty will welcome in September a diverse group of students (who must have undergraduate degrees) now pursuing careers in accounting, baseball, medicine, radio-TV, real estate, forestry, insurance, theater, military and the Internal Revenue Service.

Their ages vary from 19 to 72, but 79 of the 110 are in the 21-to-25 age bracket.

THEY'LL embark on studies leading to practice in a profession that Pedrick considers the most noble in the world.

In the future, attorneys will find themselves increasingly occupied with the legal problems of the poor, according to Pedrick. Therefore, they must know more about social and economic problems and psychology and sociology, too, he said.

"Lawyers are trained to be contentious and to become acclimated to the adversary process and verbal combat," Pedrick said. "There is room for a variety of tasks to be done in the law profession. The nation is in short supply of lawyers, a fact about which it became acutely aware a few years ago. Since then, construction of new colleges of law has been accelerated."

THE LAW curriculum, Pedrick said, will "bridge the gap between the school and its ivory tower and the hard facts of life."

After two years of books and study, students will participate in a Legal Aid Clinic, working under the supervision of licensed lawyers. They'll be introduced to casework and assist the Maricopa County Public Defenders Office.

Following graduation in 1970, the first law class will be quickly employed in private practice, government, business, banking, insurance, law enforcement and the Internal Revenue Service, Pedrick said.

Our Laws

Safety of Children Homeowner Liability

In a recent case Suzie Strauss, 8, and her mother were visiting one of mother's old friends. Her new home had lots of glass sliding doors, a big patio and a swimming pool.

Suzie had a time at the pool. After dinner she went for a short swim again.

Mother went into the house and later called Suzie in. It was getting cold. Running into the house, Suzie collided with the sliding glass door, shattered it and cut herself badly.

THIS WAS the first time that Suzie had used the glass

it was

social guests of dangerous or hidden "traps." A social guest takes all other risks in the house like the family.

(This legal column is issued as a public service r supervision of the

More About

Canyon

(Continued from Page 1-C)

by lava flows and the relatively greater resistence to erosion of the deep Precambrian rocks, more than 600 million years old, compared to the younger, weaker sedimentary rocks encountered by the river at higher levels during earlier cutting.

JACKIE IN IRELAND

DUBLIN (UPI) — Jacqueline Kennedy returned to Ireland yesterday after a six-day visit in Italy. She immediately left Dublin Airport by car for Waterford where she rejoined her two vacationing children.

NEWSPAPER STRUCK

UTICA, N.H. (AP) — A pressmen's strike prevented publication of the Utica Observer-Dispatch yesterday, as four other unions vowed not to cross picket lines.

For 'Your Money's Worth,' it's Sylvia Porter.

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INTRODUCTION

The history of Colorado ichthyology traces its origins to the early U.S. Geological and Geographical Surveys. Fishes were collected by the naturalist on the survey and sent to E.D. Cope who examined the specimens and identified them. - cite (—) Often as not, many of the specimens would be described as new species. An example of such license can be illustrated by the synonymy of Notropis stramineus missuriensis. In 1864, Cope described Hybognathus stramineus, In 1871, Hybopsis missuriensis and Hybopsis scylla all three of which are synonyms of the aforesaid species (Suttkus 1958:313). Collections from the Arkansas River (Cope and Yarrow 1875) and the North Platte River(Cope 1870) are the earliest collections from eastern Colorado. The next survey of Colorado fishes was taken in 1889, when Jordan(1891) collected and examined specimens from the area. Very little investigation succeded Jordan's report. Scarcely a dozen papers were published from 1904 to 1929. The papers that were published are Juday(1904),(1905); Ellis(1914); Ellis and Jaffa (1918); Jaffa (1917); Cockerell (1908),(1911a), (1911b), (1927); Evermann and Cockerell(1908); and Smith (1929). Unfortunately none of these investigators was highly specialized in the intracacies ~~in~~ of systematic ichthyology. The quality of the work during this time span was therefore, not uniformly high. A gap of three decades elasped before Beckman (1952) published a key to Colorado fishes, based on a survey of the literature at that time. Significant taxonomic studies have since made his list of fishes inadequate. Only one subsequent investigation has been published after 1952, Diffenbach(1966) on the taxonomy of ~~the~~ Salmo clarkii stomias.

In general one may say that very little is known about the fishes of eastern Colorado and that most of the literature is dated and highly inadequate to describe present conditions of the species in this area.

PROGRESS REPORT

Collections

Collections have been made at the following locals. South Platte River:at Ford, north of Kersey, past Greeley, south of Goodrich, Platteville, one mile above Cargy, South of Ovid, southwest of Sterling, above Eleven mile reservoir, south of Crook, one mile below Tarryall road, near Watertown, between Weldona and Narrows Bridge, between Orchard and Goodrich bridges, outside of Beetwood.

Pawnee Creek: twelve miles west of Sterling on H.W. 14, five miles north of Raymer, on the Leslie M. Beck ranch.

Crow Creek: off H.W. 14, east fork on the Pawnee National Grasslands.

Beaver Creek: below Brush, Colo.

Wildcat Creek

Big Thompson River: eight miles west of Loveland, near Palisades mountain, north fork above Drake, twenty miles west of Loveland, one mile south of Loveland, two miles east of the Vaally Highway.

Little Thompson River: southeast of Milliken.

Clear Creek at the confluence of the Big Thompson River.

Saint Vrain River: south of Hygiene, Colo., west of Gowanda

Lefthand Creek: one mile northwest of Niwot, on N.63rd and Niwot road.

Boulder Creek: at junction with Highway 287, northeast of Boulder, in Boulder in the childerns park.

South Boulder Creek on highway 7.

Little Dry Creek near Fort Lupton

Coal Creek: east of Lafayette

Boxelder Creek: two miles north of Highway 14, two miles northwest of Buckeye.

Cache la Poudre River: east of Fort Collins, three miles east of interstate 25, east of Windsor.

Fossil Creek: seven miles south of Fort Collinsl

Park Creek: three miles south of Fort Collins.

Irrigation ditbh southeast of Fort Collins.

Irrigation ditch south of Trilby Corners.

North Boulder Farmer's ditch

Boulder and Weld Co. ditch one-half mile north of Layner.

Mail Creek six miles south of Fort Collins.

Sterling Reservoir

Jackson Reservoir

Seaman's Reservoir

Reservoir #9 outside of Waverly

M
Larimer Co. ditch south of Neyer's Corner

Terry Lake inlet

Irrigation ditch from Terry Lake

Further collection will be done on the stretch of the South Platte River from Iliff to Nebraska. Tributaries south of Denver and southwest of Denver will also be sampled next year. A list of the fishes collected is given.

Fishes not yet caught but known or suspected in the drainage basin are *Carpiodes forbesi*, *Chrosomus eos*, *Chrosomus neogaeus*, *Hybopsis aestivalis tetranemus*, *Hybopsis biguttata*, *Hybopsos* (i) *gracilis*, *Hybopsis*

FISHES COLLECTED

PAWNEE CREEK

Notropis lutrensis lutrensis
Notropis stramineus missuriensis
Pimaphales promelas
Catostomus catostomus griseus
Ictalurus melas
Fundulus kansae
Fundulus sciadicus
Lepomis cyanellus
Lepomis humilis

Beaver Creek

Notropis stramineus missuriensis
Catostomus commersoni suckleyi
Fundulus sciadicus
Lepomis humilis
Lepomis cyanellus

Wildcat Creek

Notropis dorsalis dorsalis
Notropis stramineus missuriensis
Pimaphales promelas
Ictalurus melas
Fundulus kansae

Big Thompson River

Notropis dorsalis dorsalis
Notropis stramineus missuriensis
Rhinichthys cataractae
Pimaphales promelas
Semotilus atromaculatus atromaculatus
Campostoma anomalum pullum
Catostomus catostomus griseus
Catostomus commersoni suckleyi
Ictalurus melas
Fundulus kansae
Fundulus sciadicus
Percina caprodes
Etheostoma nigrum nigrum
Micropterus salmoides salmoides
Lepomis cyanellus
Perca flavescens

Park Creek
- Semotilus atromaculatus atromaculatus
- Rhinichthys cataractae
- Catostomus commersoni suckleyi
- Fundulus kansae
- Etheostoma exile

Saint Vrain River
- Notropis cornutus frontalis
- Notropis dorsalis dorsalis
- Notropis stramineus missuriensis
- Rhinichthys cataractae
- Campostoma anomalum pullum
- Semotilus atromaculatus atromaculatus
- Pimaphales promelas promelas
- Cyprinus carpio
- Hybognathus hankinsoni
- Catostomus commersoni suckleyi
- Catostomus catostomus griseus
- Fundulus sciadicus
- Fundulus kansae
- Etheostoma nigrum nigrum
- Percina caprodes
- Lepomis cyanellus

Boulder Creek
- Pimaphales promelas
- Semotilus atromaculatus atromaculatus
- Cyprinus carpio
- Rhinichthys cataractae
- Catostomus catostomus griseus
- Catostomus commersoni suckleyi
- Fundulus sciadicus
- Lepomis cyanellus
- Lepomis humilis

Lefthand Creek
- Semotilus atromaculatus atromaculatus
- Pimaphales promelas
- Rhinichthys cataractae
- Catostomus catostomus griseus

Little Dry Creek
- Pimaphales promelas

Coal Creek
    Fundulus kansae
    Pimaphales promelas

South Platte River
    Notropis dorsalis dorsalis
    Notropis stramineus missuriensis
    Notropis lutrensis lutrensis
    Notropis blennius
    Semotilus atromaculatus atromaculatus
    Pimaphales promelas
    Rhinichthyes cataractae
    Cyprinus carpio
    Campostoma anomalum pullum
    Catostomus catostomus griseus
    Catostomus commersoni suckleyi
    Fundulus kansae
    Fundulus sciadicus
    Hybognathus hankinsoni
    Dorosoma cepedianum
    Lepomis cyanellus
    Lepomis humilis
    Micropterus salmoides salmoides

Boxelder Creek
    Catostomus catostomus griseus
    Catostomus commersoni suckleyi
    Pimaphales promelas
    Cyprinus carpio carpio

Cache la Poudre River
    Notropis stramineus missuriensis
    Semotilus atromaculatus atromaculatus
    Pimaphales promelas
    Cyprinus carpio
    Campostoma anomalum pullum
    Catostomus commersoni suckleyi
    Etheostoma nigrum
    Micropterus salmoides salmoides

Mail Creek
    Semotilus atromaculatus

Lewis creek
    Notropis stramineus missuriensis
    Notropis dorsalis dorsalis
    Pimaphales promelas
    Catostomus commersoni suckleyi
    Fundulus kansae
    Lepomis cyanellus
    Lepomis humilis

Cedar Creek
- Notropis lutrensis lutrensis
- Notropis stramineus missuriensis
- Notropis sp.
- Semotilus atromaculatus atromaculatus
- Pimaphales promelas
- Hybognathus SP.
- Catostomus commersoni suckleyi

Fossil Creek
- Semotilus atromaculatus atromaculatus
- Cyprinus carpio
- Notropis stramineus missuriensis
- Pimaphales promelas
- Lepomis cyanellus
- Lepomis machrochirus machrochirus
- Pomoxis nigromaculatus
- Etheostoma nigrum nigrum
- Ictalurus melas
- Micropterus salmoides SALMOIDES
- Catostomus catostomus griseus
- Catostomus commersoni suckleyi
- Rhinichthys caratactae
- Fundulus kansae

Boulder Co. Irrigation Ditch
- Pimaphales promelas
- Cyprinus carpio
- Semotilus atromaculatus atromaculatus
- Rhinichthys cataractae

Eaton Ditch
- Etheostoma nigrum nigrum
- Fundulus kansae
- Pimaphales promelas
- Catostomus commersoni suckleyi
- Semotilus atromaculatus atromaculatus
- Notropis stramineus missuriensis
- Catostomus catostomus griseus

Inlet to Terry Lake
- Fundulus kansae
- Semotilus atromaculatus atromaculatus
- Catostomus catostomus griseus

Farmer's Ditch
- Ictalurus melas

Larimer Co. Ditch
- Perca flavescens
- Semotilus atromaculatus atromaculatus
- Rhinichthys cataractae
- Catostomus commersoni suckleyi
- Etheostoma exile

North Poudre Canal
- Notropis dorsalis dorsalis
- Notropis stramineus missuriensis
- Pimaphales promelas
- Rhinichthys cataractae
- Catostomus catostomus griseus
- Catostomus commersoni suckleyi
- Fundulus kansae
- Perca flavescens
- Etheostoma nigrum nigrum
- Etheostoma exile

Crow Creek
- Ictalurus melas
- Pimaphales promelas
- Etheostoma exile

Clear Creek
- Catostomus catostomus griseus

Boulder and Weld Co. Ditch
- Pimaphales promelas
- Rhinichthys cataractae

Sterling Reservoir
- Carpiodes ~~carpio~~ cyprinus
- Micropterus salmoides salmoides
- Pimaphales promelas
- Notropis lutrensis lutrensis
- Notropis stramineus missuriensis
- Etheostoma exile

Boxelder #3 Lake
- Pimaphales promelas
- Percina caprodes
- Micropterus salmoides salmoides
- Pomoxis nigromaculatus
- Perca flavescens
- Catostomus catostomus suckleyi

Stewart's Lake
- *Lepomis gibbosus*
- *Etheostoma exile*

Reservoir #9
- *Etheostoma exile*
- *Ictalurus melas*
- *Pimaphales promelas*
- *Etheostoma nigrum nigrum*

plumbea, *Hybopsis storeiana*, *Phenacobius mirabilis*, *Gambusia affinis affinis*, *Etheostoma spectabile pulchellum*, Notropis heterolepis or any sculpins. Scupins , in particular, are of great interest. There has been no record of them in the headwaters of the eastern slope. They are native to the headwaters of the western slope and with the number of water diversions of western water to eastern drainages one would suspect transfer of these fish to the eastern slope. Of the fish caught, it is of interest to note that the common shiner, *Notropis cornutus*, was only collected in the Saint Vrain River. This fish is becoming quite *uncommon* as its range has been severly depleted because of water pollution. Noted on members of the species *Etheostoma exile* was the high degree of variability in the character of cheek scalation. This caused much confusion as it is one of the characters one uses to distinguish between it and *Etheostoma spectabile*. The cheek of the Iowa Darter is not always fully scaled. In fact some specimens are ascalous in that region, while others have one or two minute scales which can only be detected under a microscope. It is best to separate the two species on the degree of separation of the soft and spiny dorsal fins. The Iowa Darter has a separation of approximately two to three scales, while the dorsal fins are connected on *Etheostoma spectabile*.

An unidentified cyprinid of the genus *Notropis* is being studied. The meristic characters are quite indistinguishable from that of the *N. stramineus* complex, but differences in the size of the mouth, shape of the head and a more elongate shape differentiate it from the sand shiner. Quite distinctive is the higher number of radii on the scales. It is also very similar to *N. volucellus volucellus* (see table 1).

TABLE OF COMPARISONS

N. volucellus volucellus	Unknown *Notropis*
1.Anal rays normally 8, range from 7-9.	1.Anal rays 7 for 14 specimens.
2.Middorsal stripe faint or irregular.	2.Distinct and regular.
3.Mouth reaches orbit.	3.Mouth does not reach orbit.
4.Length of upper jaw shorter than diameter of eye.	4.Jaw is equal or smaller than diameter of eye.
5.Lateral line stripe normally prominant.	5.Absent, but may be due to preservative.
6.Peritoneum silvery.	6. Silvery.
7.Length of gut is equal to standard length.	7. Equal to standard length.
8.Infraorbital canal complete.	8.?
9.Teeth: 0,4-4,0	9.0,4-4,0
10.Black diamond shaped scales	10. present
11.Depth/standard length=4.5	11.Depth/standard length=4.66
12.Depth/width=1.7	12.Depth/width=1.33
13.Depth caudal peduncle/head =more than 2.5	13.Average for seven specimens is 2.74
14.Predorsal length/dorsal fin =more than 2.5	14.Average for eight specimens is 1.98
15.Anterior lateral line scales are 2.5-3.8 times as high as they are wide for the exposed portion of scale	15.Not yet able to measure accurately.
16.Lateral line count is 35-37.	16.Lateral line count is 35

(data for N. v. volucellus from Trautman, 1957)

TABLE 1

Taxonomy

Beckman has been revised in accordance with present taxonomic thinking. The revisions are noted in a subsequent list. Other taxonomic problems are listed in greater detail below.

Leuciscus evermanni Juday

This species is a synonym of *Semotilus atromaculatus atromaculatus*, creek chub. The characteristics given in the original description (Juday 1905) is consistanct with the characters of the creek chub. The tooth formula, dorsal and anal fin ray numbers are the same and the number of scales in the lateral line of 47 is reasonably close to the range of *Semotilus atromaculatus*(50-60). Dr. Behnke (personal communication) counted the scales on the type specimen at the National Museum and counted 47 scales to the standard length plus two additional scales with lateral line pores to total 49. He furthermore found a note in the bottle from ~~Reeves Bailey~~ R. R. miller stating that the specimen was *Semotilus atre maculatus*. Juday based his description of a new species on the lack of barbels and robustness of the specimen stating that it differed from *S. atromaculatus* in that respect. Trautman (1957:317) states that a barbless condition, although uncommon, does occur. Metcalf (1966:102) found a cline towards a more robust form in western specimens, although not of significance to merit taxonmoic recognition.

Notropis universitatus Evermann and Cockerell

Carl Hubbs identified the type specimen as *Notropis cornutus frontalis* based on the meristic characters and later Cockerell believed the specimen to be a color varient of the species(Smith 1929: 7. unpublished Master's Thesis).

Notropis horatii Cockerell

This species is based on a single specimen caught at Julesburg on the South Platte River. Efforts to collect more specimens at the exact station have been fruitless. Dr. Behnke (personal communication) examined the type specimen at the National Museum. He described the specimen as being beyond recognition. The meristic characters were badly damaged. He managed to sketch the specimen and salvage some meristic characters. The tooth formula of 1-3 is unique within the genus although this may have been an anomaly. The sketch superficailly resembles *Notropis dorsalis*.

Carpiodes velifer(Rafinesque)

Ellis (1914) reported specimens of this species caught from the Cache la Poudre River near Greely. This fish has had its range radically reduced because of the increase in silty, polluted water in the Kansas River System. The specimen may have been ~~mistaken--and-a~~ a misidentified specimen of *C. carpio carpio*. Bailey and Allum (1962:82) feel that there are no valid accounts of this species in the upper and middle waters of the Missouri Drainage. The young of both species are extremely difficult to separate.

Chrosomus erythrogaster

Ellis (1914) lists specimens from Saint Vrain Creek at Longmont and Boulder. Metcalf (1966) is certain that this species doesn't exist in the Platte. It was impossible to determine from Ellis's description whether or not, in fact, the specimen was *C. eos* . It is highly probable that it is.

Hybognathus Agassiz

Work will be done to determine of the *Hybognathus* of this drainage IS *H. placitus* or *H. nuchalis*. The shape of the Weberian apparatus and the basioccipital bone will be used to identify the specimens (Bailey and Allum 1962).

Pimaphales promelas Rafinesque

Vandermeer (1966) decied that the subspecific names of *P. promelas* should not be recognized as there are several clines which he recognized. While there were distinct separations, he felt that the taxonomy of this species would become too unwieldy by naming many subspecies.

Campostoma anomalum pullum

Metcalf 's study(1966) indicated that *C. anomalum plumbeum* WAs not well defined and that it was a synonym of *C. anomalum pullum*.

Carpiodes forbesi Hubbs

Carpiodes forbesi is a questionable species. Hubbs, himself, was not positive that it was a "good species", but decided to give it full species status because of its distinctive pheno type. *C. forbesi* is more attenuated than *C. cyprinus* and has a shorter first principal ray. Bailey and allum (1962) decided that C. forbesi was a synonym of C. cyprinus and the phenotypic differences between the two forms was due to an environemntal response. Metcalf (1964) feels that the distinct phenotype of *C. forbesi* is attributable partially to a different genotype and that the variable size of the dorsal fin in specimens from the Kansas River System represent a mosaic type of intergradation between the two forms.

Hybopsis gracilis (Richardson)

Oland and Cross (1961) distinguished two subspecies of *H. gracilis*: *H. gracilis gracilis* and *H. gracilis gulona*. This decision was based on geographic distribution of vertebral count differences. Bailey and Allum (1962) feel that the differences in vertebral counts are due to environmental conditions. They state, for example, that northern poulations will have more vertebrae because of the phenotypic respone to the cold water by the young developing fry. Similarly, fish in shallow waters will have lower counts because of the phenotypic response to warm water. Bailey and Allum (1962) further believe that the geographic pattern of the intergradation is inconsistant with genetic principles. Metcalf (1966) disagrees, noting that *H. gl gulona* (low vertebrae form) is found in the cold melt waters of the upper North Platte River. Intergrades are found downstream, gradually giving way to *H. g. gracilis* (high vertebrate form) in the warmer lowland waters of the same river.

BECKMAN'S LIST WITH REVISIONS

CYPRINIDAE

Cyprinus carpio Linnaeus, carp

Carassius auratus (Linnaeus), goldfish

Tinca tinca Linnaeus, tench

Notemigonus crysoleucas auratus, Western Golden Shiner

Chrosomus eos Cope, Northern Redbelly Dace

Semotilus atromaculatus atromaculatus (Mitchell), Northern Creek Chub

Hybopsis aestivalis tetranemus Gilbert, Arkansas River Speckeled Chub

Hybopsis biguttata (Kirtland), horneyhead chub

Hybopsis gracilis gracilis (Girard), Plains Flathead Chub ✓

In Beckman: *Hybopsis gracilis communis*

Hybopsis gracilis gulona (Cope), Southern Flathead Chub ✓

In Beckman: *Hybopsis gracilis physignathus*

Both subspecies also considered by Bailey and Allum(1962) to be phenotypic responses to environment of *Hybopsis gracilis*.

Hybopsis plumbea (Agassiz), lake chub

Hybopsis storeiana (Kirtland), silver chub

Rhinichthys cataractae (Valenciennes), longnose dace

Rhinichthys osculus (Girard), speckled dace ✓

In Beckman: *Rhinichthys nubilus yarrowi* (Jordan and Everman)

Phenacobius mirabilis (Girard), suckermouth minnow

Notropis blennius,(Girard), river shiner good

Notropis cornutus frontalis (Agassiz), Northern Common Shiner

Notropis stramineus missuriensis (Cope), sand shiner ✓

In Beckman: *Notropis deliciosus missuriensis* (Cope)

(N. d. syn, *N. texanus* (Cope))

LIST 1

~~*Notropis dorsalis* (Agassiz), bigmouth shiner~~ ✓

[redacted] *Notropis dorsalis dorsalis*(Agassiz)

Notropis dorsalis piptolepis (Cope)

Notropis lutrensis lutrensis(Baird and Girard), Plains Red Shiner

Hybognathus hankinsoni Hubbs, brassy minnow

Hybognathus placitus Girard, plains minnow ✓

In Beckman: *Hybognathus placita placita* Girard

More work is needed to determine if this species has been misidentified and is not in fact, *Hybognathus nuchalis nuchalis*.

Pimaphales promelas Rafinesque, fathead minnow ✓

In Beckman: *Pimaphales promelas promelas* Rafinesque

Pimaphales promelas confertus(Girard)

Campostoma anomalum pullum (Agassiz), central stoneroller ✓

In Beckman: *Campostoma anomalum plumbeum* (Girard), plains stoneroller

addition

Richarsonius balteatus (Richardson),

specimens collected by A. Kent Andrews in the [redacted] Yampa River

ICTALURIDAE ✓

In Beckman: AMERIURIDAE

Ictalurus furcatus (LeSueur), blue catfish

Ictalurus punctatus (Rafinesque), channel catfish + nebulosus

Ictalurus melas (Rafinesque), black bullhead ✓

In Beckman: *Ictalurus melas catulus* (Girard)

Ictalurus melas melas (Rafinesque)

Pilodictis olivaris(Rafinesque), flathead catfish

Noturus flavus Rafinesque, stonecat

ANGUILLIDAE

Anguilla rostrata (LeSueur), American Eel

CYPRINODONTIDAE

Fundulus kansae Garman, plains killifish

Fundulus sciadicus Cope, plains topminnow

POECILIIDAE

Gambusia affinis affinis (Baird and Girard), western gambusia

SERRANIDAE

Roccus chrysops (Rafinesque), white bass ✓

In Beckman: *Lepibema chrysops* (Rafinesque)

CENTRARCHIDAE

Micropterus dolomieui dolomieui (Lacepede), smallmouth bass

Micropterus salmoides salmoides (Lacepede), largemouth bass

Chaenobryttus gulosus (Cuvier), warmouth bass ✓

In Beckman: *Chaenobryttus coronarius* (Bartram)

Lepomis cyanellus Rafinesque, green sunfish

Lepomis gibbosus (Linnaeus), pumpkinseed

Lepomis humilis (Girard). orangespotted sunfish

Lepomis macrochirus macrochirus Rafinesque, bluegill

Ambloplites rupestris rupestris (Rafinesque), rock bass

Pomoxis annularis Rafinesque, white crappie

Pomoxis nigromaculatus (LeSueur), black crappie

Fishes of the Colorado River Basin

The total area drained by the Colorado River and all of its tributaries is approximately 244,000 square miles. This represents approximately one-fifteenth the total area of the fifty States of the Union.

The Colorado River has its origin in the high mountains of Colorado, Utah, and Wyoming. The length of the Colorado River, measured up the Green River branch, is exceeded by only three United States rivers. Distance from the headwaters of the Green River to the mouth of the Colorado at the Gulf of California is approximately 1700 miles.

Average annual runoff for the Colorado River is approximately thirteen million acre feet. The flow varies from a low of three thousand cubic feet per second to over two hundred thousand. Most of this flow originates in the various mountain ranges that form an almost continuous border around the outermost rim of the basin. The basin itself makes up three-quarters of the rivers drainage area but contributes nothing more than an undependable and fluctuating water supply derived principally from rainfall.

The volume of flow reaches a low point in the winter. The flow starts to rise as the mountain snowpack melts and reaches a peak in late May or June. This is followed by minor fluctuations until the flow reaches its winter minimum.

Some of the important tributary rivers are the Green, San Juan, Little Colorado, Gila, Santa Cruz and White.

The construction of dams on the Colorado River and its tributaries will bring about important ecological changes. Seven major dams plus many smaller impoundments on tributary streams have been completed or are currently under construction.

The fish fauna of the basin consists of sixteen families, fourty-nine genera and eighty-two species. Thirty-five of the species are native and twenty-eight are endemic to the Colorado River Basin.

The following list gives the species distribution in the states of Arizona, New Mexico, Colorado, Utah and Wyoming. The origin is listed as introduced or native and endemic.

FISHES OF THE COLORADO RIVER DRAINAGE IN ARIZONA

FAMILY	GENUS	SPECIES	COMMON NAME	ORIGIN*
Elopidae	Elops	affinis	Machete	N
Clupeidae	Dorosoma	petenense	Threadfin shad	I
Salmonidae	Salmo	~~clarki~~ gilae	Cutthroat trout	N,E,I
"	Salmo	gairdneri	Rainbow trout	I
"	Salmo	trutta	Brown trout	I
"	Salvelinus	fontinalis	Brook trout	I
~~O. nerka~~	~~O. kisutch~~	~~tshawytscha~~		
- Characidae	Astyanax	mexicanus	Mexican tetra	N
Cyprinidae	Agosia	chrysogaster	Longfin dace	N,E
- "	Campostoma	ornatum	Mexican stone roller	N,E
"	Carassius	auratus	Goldfish	I
"	Cyprinus	carpio	Carp	I
"	Gila	atraria	Utah chub	I
"	Gila	cypha	Humpback chub	N,E
- "	Gila	ditaena	Sonora chub	N,E
- "	Gila	nigrescens	Rio Grande chub	N,E
- "	Gila	purpurea	Yaqui chub	N,E
"	Gila	robusta	Bonytail	N,E
- "	Lavinia	exilicauda	Hitch	I
"	Lepidomeda	albivallis	White River spinedace	N,E
"	Lepidomeda	altivelis	Paharanagat spinedace	N,E
"	Lepidomeda	mollispinis	Virgin River spinedace	N,E
"	Lepidomeda	vittata	Little Colorado spinedace	N,E
"	Meda	fulgida	Spikedace	N,E
"	Moapa	coriacea	Moapa dace	I
"	Notemigonus	crysoleucas	Golden shiner	I
"	Notropis	lutrensis	Red shiner	I
"	Pimephalis	promelas	Fathead minnow	I
"	Plagopterus	argentissimus	Woundfin	N,E
"	Ptychocheilus	lucius	Colorado squawfish	N,E
"	Rhinichthys	oscules	Speckled dace	I
"	Richardsonius	balteatus	Redside shiner	I
"	Tiaroga	cobitis	Loach minnow	N,E
Catostomidae	Catostomus	ardens	Utah sucker	I
"	Catostomus	commersoni	White sucker	I
"	Catostomus	insignis	Sonora sucker	N,E
"	Catostomus	latipinnis	Flannelmouth sucker	N,E
"	Pantosteus	clarki	Gila sucker	N,E
"	Pantosteus	delphinus	Bluehead sucker	N,E
"	Pantosteus	platyrhynchus	Mountain sucker	I
"	Pantosteus	plebeius	Rio Grande sucker	I
"	Xyrauchen	texanus	Humpback sucker	N,E

FISHES OF THE COLORADO RIVER DRAINAGE IN ARIZONA (CONT.)

FAMILY	GENUS	SPECIES	COMMON NAME	ORIGIN*
Ictaluridae	Ictalurus	catus	White catfish	I
"	Ictalurus	melas	Black bullhead	I
"	Ictalurus	natalis	Yellow bullhead	I
"	Ictalurus	nebulosus	Brown bullhead	I
"	Ictalurus	punctatus	Channel catfish	I
Cyprinodontidae	Crenichthys	baileyi	White River killifish	N,E
"	Cyprinodon	macularius	Desert pupfish	N,E
"	Fundulus	parvipinnis	California killifish	N
"	Fundulus	zebrinus	Rio Grande killifish	I
Poeciliidae	Gambusia	affinis	Mosquitofish	I
"	Poeciliopsis	occidentalis	Gila topminnow	N,E
Serranidae	Roccus	chrysops	White bass	I
Centrarchidae	Chaenobryttus	gulosus	Warmouth	I
"	Lepomis	cyanellus	Green sunfish	I
"	Lepomis	gibbosus	Pumpkinseed	I
"	Lepomis	macrochirus	Bluegill	I
"	Lepomis	microlophus	Redear sunfish	I
"	Micropterus	dolomieui	Smallmouth bass	I
"	Micropterus	punctulatus	Spotted bass	I
"	Micropterus	salmoides	Largemouth bass	I
"	Pomoxis	annularis	White crappie	I
"	Pomoxis	nigromaculatus	Black crappie	I
Percidae	Perca	flavescens	Yellow perch	I
Eleotridae	Eleotris	picta	Spotted sleeper	N
Cottidae	Cottus	bairdi	Mottled sculpin	N
Mugilidae	Mugil	cephalus	Striped mullet	N

* I Introduced
N Native
E Endemic to the Colorado River Drainage

TOTAL: Families - 16
Genus - 41
Species - 68

FISHES OF THE COLORADO RIVER DRAINAGE IN COLORADO

FAMILY	GENUS	SPECIES	COMMON NAME	ORIGIN*
Salmonidae	Oncorhynchus	kisutch nerka	Sockeye salmon	I
"	Prosopium	williamsoni	Mountain whitefish	N
"	Salmo	clarki	Cutthroat trout	N,I,E
"	Salmo	gairdneri	Rainbow trout	I
"	Salmo	trutta	Brown trout	I
"	Salvelinus	fontinalis	Brook trout	I
"	Salvelinus	namaycush	Lake trout	I
Cyprinidae	Cyprinus	carpio	Carp	I
"	Gila	cypha	Humpback chub	N,E
"	Gila	robusta	Bonytail	N,E
"	Hybopsis	gracilis	Flathead chub	I
"	Pimephalis	promelas	Fathead minnow	I
"	Ptychocheilus	lucius	Colorado squawfish	N,E
"	Rhinichthys	cataractae	Longnose dace	I
"	Semotilus	atromaculatus	Creek chub	I
Catostomidae	Catostomus	catostomus	Longnose sucker	I
"	Catostomus	commersoni	White sucker	I
"	Catostomus	latipinnis	Flannelmouth sucker	N,E
"	Pantosteus	delphinus	Bluehead sucker	N,E
"	Xyrauchen	texanus	Humpback sucker	N,E
Poeciliidae	Gambusia	affinis	Mosquitofish	I
Cottidae	Cottus	annae	Eagle sculpin	N,E
"	Cottus	bairdi	Mottled sculpin	N

* I Introduced
N Native
E Endemic to the Colorado River Drainage

TOTAL: Families - 5
Genus - 16
Species - 23

FISHES OF THE COLORADO RIVER DRAINAGE IN NEW MEXICO

FAMILY	GENUS	SPECIES	COMMON NAME	ORIGIN*
Salmonidae	Salmo	clarki	Cutthroat trout	N,E,I
"	Salmo	gairdneri	Rainbow trout	I
"	Salmo	gilae	Gila trout	N,E
"	Salmo	trutta	Brown trout	I
"	Salvelinus	fontinalis	Brook trout	I
Cyprinidae	Agosia	chrysogaster	Longfin dace	N,E
"	Campostoma	anomalum	Stonroller	I
"	Cyprinus	carpio	Carp	I
"	Gila	robusta	Bonytail	N,E
"	Meda	fulgida	Spikedace	N,E
"	Notropis	lutrensis	Red shiner	I
"	Pimephalis	promelas	Fathead minnow	I
"	Ptychocheilus	lucius	Colorado squawfish	N,E
"	Tiaroga	cobitis	Loach minnow	N,E
Catostomidae	Catostomus	commersoni	White sucker	I
"	Catostomus	insignis	Sonora sucker	N,E
"	Catostomus	latipinnis	Flannelmouth sucker	N,e
"	Pantosteus	clarki	Gila sucker	N,E
"	Pantosteus	delphinus	Bluehead sucker	N,E
"	Pantosteus	plebeius	Rio Grande sucker	I
Ictaluridae	Ictalurus	melas	Black bullhead	I
"	Ictalurus	natalis	Yellow bullhead	I
"	Ictalurus	punctatus	Channel catfish	I
Poeciliidae	Gambusia	affinis	Mosquitofish	I
"	Poeciliopsis	occidentalis	Gila topminnow	N,E
Centrarchidae	Lepomis	cyanellus	Green sunfish	I
"	Lepomis	macrochirus	Bluegill	I
"	Micropterus	dolomieui	Smallmouth bass	I
"	Micropterus	salmoides	Largemouth bass	I
"	Pomoxis	annularis	White crappie	I
"	Pomoxis	nigromaculatus	Black crappie	I
Percidae	Stizostedion	vitreum	Walleye	I
Cottidae	Cottus	bairdi	Mottled sculpin	N

* I Introduced
N Native
E Endemic to the Colorado River Drainage

TOTAL: Families - 8
Genus - 21
Species - 33

FISHES OF THE COLORADO RIVER DRAINAGE IN UTAH

FAMILY	GENUS	SPECIES	COMMON NAME	ORIGIN*
Salmonidae	Prosopium	williamsoni	Mountain whitefish	N
"	Salmo	clarki	Cutthroat trout	N,E,I
"	Salmo	gairdneri	Rainbow trout	I
"	Salmo	trutta	Brown trout	I
"	Salvelinus	fontinalis	Brook trout	I
Cyprinidae	Cyprinus	carpio	Carp	I
"	Gila	atraria	Utah chub	I
"	Gila	cypha	Humpback chub	N,E
"	Gila	robusta	Bonytail	N,E
"	Lepidomeda	mollispinis	Virgin River spinedace	N,E
"	Pimephalis	promelas	Fathead minnow	I
"	Plagopterus	argentissimus	Woundfin	N,E
"	Ptychocheilus	lucius	Colorado squawfish	N,E
"	Rhinichthys	cataractae	Longnose dace	I
"	Rhinichthys	oscules	Speckled dace	I
"	Richardsonius	balteatus	Redside shiner	I
Catostomidae	Catostomus	ardens	Utah sucker	I
"	Catostomus	latipinnis	Flannelmouth sucker	N,E
"	Pantosteus	delphinus	Bluehead sucker	N,E
"	Pantosteus	platyrhynchus	Mountain sucker	I
"	Xyrauchen	texanus	Humpback sucker	N,E
Ictaluridae	Ictalurus	melas	Black bullhead	I
"	Ictalurus	punctatus	Channel catfish	I
Cyprinodontidae	Fundulus	zebrinus	Rio Grande killifish	I
Poeciliidae	Gambusia	affinis	Mosquitofish	I
Centrarchidae	Lopomis	macrochirus	Bluegill	I
"	Micropterus	salmoides	Largemouth bass	I
"	Pomoxis	nigromaculatus	Black crappie	I
Percidae	Perca	flavescens	Yellow perch	I
"	Stizostedion	vitreum	Walleye	I

* I Introduced
N Native
E Endemic to the Colorado River Drainage

TOTAL: Families - 8
Genus - 23
Species - 30

FISHES OF THE COLORADO RIVER DRAINAGE IN WYOMING

FAMILY	GENUS	SPECIES	COMMON NAME	ORIGIN*
Salmonidae	Prosopium	williamsoni	Mountain whitefish	N
"	Salmo	clarki	Cutthroat trout	N,I,E
"	Salmo	gairdneri	Rainbow trout	I
"	Salmo	trutta	Brown trout	I
"	Salvelinus	fontinalis	Brook trout	I
"	Thymallus	arcticus	Arctic grayling	I
Gyprinidae	Cyprinus	carpio	Carp	I
"	Gila	robusta	Bonytail	N,E
"	Ptychocheilus	lucius	Colorado squawfish	N,E
"	Rhinichthys	oscules	Speckled dace	I
"	Richardonius	balteatus	Redside shiner	I
"	Semotilus	atromaculatus	Creek chub	I
Catostomidae	Catostomus	latipinnis	Flannelmouth sucker	N,E
"	Pantosteus	delphinus	Bluehead sucker	N,E
"	Xyrauchen	texanus	Humpback sucker	N,E
Ictaluridae	Ictalurus	punctatus	Channel catfish	I
Centrarchidae	Micropterus	dolomieui	Smallmouth bass	I
Cottidae	Cottus	bairdi	Mottled sculpin	N

* I Introduced
N Native
E Endemic to the Colorado River Drainage

TOTAL: Families - 6
Genus - 16
Species - 18

ANNOTATED LIST OF FISHES NATIVE TO THE COLORADO RIVER BASIN

Colorado Cooperative Fishery Unit
Colorado State University
Fort Collins, Colorado

INTRODUCTION

The following accounts attempt to concisely summarize the current state of our knowledge of the native fish fauna of the Colorado River basin and to call attention to those forms which are most in need of further study.

The geologic history of the Colorado River basin, indicates the present basin was once a series of independent basins providing areas for fishes to isolate and differentiate in diverse environments. The diversity, high degree of endemism, and marked distinctions of the faunal components of various segments of the basin support such a view.

For this report, the term Colorado basin includes several independent desiccating basins without present connection to the Colorado River system; however, the fishes found in these basins were derived from previous connections with the Colorado system.

It is significant to note that of the 22 fishes listed by the U.S. Department of Interior as rare or endangered in the most recent checklist (1967) - 10 are endemic to the Colorado basin, as construed in this paper.

The following notations are used:

U - Denotes a distribution restricted to the upper basin, above the Grand Canyon, but not including the Little Colorado River.

L - Includes the Little Colorado River, the Grand Canyon and below to the mouth of the Colorado.

V - For the Virgin and White River section of the basin containing a number of small desiccating basins with relict populations derived from previous connections with the Colorado River.

E - Endemic species whose natural distribution is limited to the confines of the basin.

R - Includes the species reported on the most recent rare and endangered species list.

Family Salmonidae: Trouts, Whitefishes, Graylings

Salmo clarkii pleuriticus Cope. Colorado River cutthroat trout - U

The native trout of the Colorado basin closely resembles the Yellowstone subspecies, *S.c. lewisi* which has been widely introduced throughout the basin. Pure populations of the native trout, uncontaminated by hybridization with introduced Yellowstone cutthroat or rainbow trout undoubtedly are rare. Current studies by the Colorado Cooperative Fishery Unit are investigating the systematics of the native subspecies, attempting to discover differentiating characters allowing recognition and separation from hybrid populations and Yellowstone cutthroat. The original downstream distribution of the cutthroat trout included the San Juan River system, but probably not the Little Colorado or the Grand Canyon area.

Salmo gilae Miller. Gila trout - L E R

The native trout of the upper Gila River system is quite distinct from the upper Colorado River cutthroat. The origin and true affinities of this trout are not known. Its range has been drastically reduced, the only pure population identified with any degree of certainty occurs in a tiny headwater section of Diamond Creek, Gila National Forest, New Mexico. Populations of native trout are known from the headwaters of the Black and White rivers, tributaries to the Salt River of the Gila basin in eastern Arizona, and from the headwater tributaries of the Little Colorado River near Mt. Baldy in the same general vicinity. These trout, sometimes referred to as Apache trout, show relationships to *S. gilae* but are differentiated sufficiently to be regarded at least as a subspecies, indicating long separation from the Gila trout of New Mexico. The Apache trout is also included on the rare and endangered species list.

Prosopium williamsoni (Girard). Rocky Mountain Whitefish - U

This species, as the cutthroat trout, is widespread throughout the western United States. The original distribution in the Colorado River system apparently was restricted to the Green River division of the basin. No study has yet compared the Colorado basin whitefish with populations from other basins to indicate the amount of variability and divergence occurring in the whitefish of the Colorado system.

Family Catostomidae: Suckers

Catostomus latipinnis Baird and Girard. Flannelmouth sucker - U L E

Once widespread in all of the larger streams of the basin, it has disappeared from many areas particularly in the lower basin.

Catostomus insignis Baird and Girard. Sonora sucker - L E

The common coarse scaled sucker of the Gila River division of the basin. The complete distribution has not been authoritatively established.

Pantosteus delphinus(Cope). Northern bluehead mountain sucker - U L

A recent publication by Smith (1966) revised the taxonomy of the suckers of the genus Pantosteus. Smith considers Pantosteus as a subgenus of Catostomus, and his research changes many former conclusions concerning correct names, distribution of species, and endemic species. For this report it is not critical if Pantosteus is considered as a genus or subgenus, but Smith's findings on nomenclature, distribution, and relationships are followed in the following accounts of Pantosteus. Smith stated the correct species name for the bluehead sucker should be discobolus Cope and not delphinus. The species discobolus is not endemic to the Colorado basin but occurs in the Bonneville basin and the Snake River. The bluehead sucker is known from the Little Colorado basin but not below the Grand Canyon. Former records of the bluehead sucker from the Virgin River basin and the Bill Williams River of Arizona actually belong to the species P. clarki, according to Smith.

Pantosteus clarki (Baird and Girard). Gila sucker - L E

Formerly considered only from the Gila River division, but the populations previously considered as P. utahensis (Tanner) and P. intermedius (Tanner) from the desiccating White and Virgin basins are in reality P. clarki.

Pantosteus platyrhynchus (Cope). Mountain sucker - U

Smith greatly enlarged the limits of the species platyrhynchus to include the Bonneville, Lahontan, and upper Missouri mountain suckers previously considered as the species virescens, lahontan, and jordani. He found platyrhynchus in the Green River division of the upper Colorado basin, together with the bluehead sucker P. delphinus (= discobolus). This makes a new addition to the native fish fauna of the Colorado basin. It is believed the species name delphinus actually was based on the species platyrhynchus and thus is not available for use as the specific name for the bluehead sucker.

Xyrauchen texanus (Abbott). Humpback sucker - U L E

This highly modified sucker has suffered a great decline in abundance due to the changing environment of the basin. Little is known of its ecology or taxonomy.

Family Cyprinidae: Minnows

Gila robusta-elegans-intermedia complex. Roundtail and bonytail chubs - U L E

This group of chubs, including Gila cypha, comprises one of the most fascinating problems in systematic ichthyology. The extreme variability in morphologies found in the roundtail and bonytail chubs have been described as no less than 12 species. The true situation is not known concerning the actual number of species and subspecies which should be recognized and the pattern of geographical differentiation and intergradation. Do two or more distinct types of Gila occur together without interbreeding? Are there consistant patterns of differentiation associated with geographical divisions? To what degree does environmental modification control the phenotype? The genus Gila of the Colorado basin is attracting well deserved attention as a fruitful field of biological study; however, an immense amount of work will be necessary before this genus is fully understood.

Gila jordani Tanner, described from Pahranagat Valley, Lincoln Co., Nevada, a glacial relict of the disrupted White River, is probably more correctly considered a subspecies of G. robusta.

Gila cypha Miller. Humpback chub - U L E R

This fish parallels the humpback sucker in the development of a peculiar morphology, evidently adapted for bottom living in rapid water. Some specimens indicate a transitional series and perhaps gene flow from the Gila robusta-elegans type to Gila cypha. The specimen on which the name is based came from the Grand Canyon. Further collections from the Grand Canyon should provide significant information on Gila cypha, and how it relates to the robusta-elegans complex. Recent humpback chub specimens from Lake Powell resemble G. cypha, but are fully scaled.

Ptychocheilus lucius Girard. Colorado River squawfish - U L E R

The largest North American species of the minnow family. This species has disappeared through most of its range. Little is known of its life history and ecology.

Rhinichthys osculus (Girard). Speckled dace - U L V

This species has a broad distribution in western North America. Interspecific variability throughout its range is not well known.

Agosia chrysogaster Girard. Longfin dace - L

This genus and species cannot strictly be called endemic to the Colorado system because it is found in the headwaters of the Rio Yaqui. The origin and evolution of Agosia most probably occurred in the lower Colorado basin. It is locally abundant in the Gila River system. The variability of Agosia and the existence of more than a single species or subspecies has not yet been established.

Tiaroga cobitis Girard. Loach minnow - L E

This genus and species is known only from the Gila River system. It has declined greatly in abundance.

Moapa coriacea Hubbs and Miller. Moapa dace - V E R

This genus and species is endemic to warm springs of the Moapa River, a tributary in the White River system, in Clark Co., Nevada. A relict species now restricted to warmer waters, typically of 87° - 93°F.

Tribe Plagopterini - The Spinedaces.

This group consisting of three genera and six species is found only in the lower Colorado basin and its disrupted tributary, the Virgin River system. They are the only North American cyprinid fishes with spinous fin rays. It is believed they were derived from the genus Gila.

Lepidomeda mollispinis Miller and Hubbs. Middle Colorado spinedace - V E

Miller and Hubbs recognized three subspecies of this species: m. mollispinis of the Virgin River system; m. pratensis, known only from a spring in Lincoln Co., Nevada, now believed to be extinct; and m. albivallis, from the White River segment of the Virgin River basin.

Lepidomeda altivelis Miller and Hubbs. Pahranagat spinedace - V E

This species was known only from two sites in Pahranagat Valley, Nevada. It is now believed extinct due to introductions of carp and mosquitofish.

Lepidomeda vittata Cope. Little Colorado spinedace - L E R

The known range of this species is limited to the upper Little Colorado River system in eastern Arizona. It was once believed extinct, but a few populations have been discovered in recent years.

Meda fulgida Girard. Spikedace. - L E

This genus and species is known only from the Gila River system.

Plagopterus argentissimus Cope. Woundfin - V E

Apparently now restricted to the Virgin River system; once inhabiting the Gila River, but the last specimens known from the Gila basin were collected in 1894.

Family Poeciliidae: Topminnows

Poeciliopsis occidentalis (Baird and Girard). Gila topminnow - L E R

Once widespread in the Gila River system, now found only in a few localities.

Family Cyprinodontidae: Killifishes

Cyprinodon macularius Baird and Girard. Desert pupfish - L

Formerly wide ranging in the lower Colorado basin, this species is rapidly declining. One inimical factor is competition from the introduced mosquitofish, Gambusia affinis.

Perhaps during the Pliocene, connections of streams and lakes of the now desert areas of Death Valley and contiguous basins of California and Nevada, to the lower Colorado system, allowed Cyprinodon access to these basins.

Subsequent isolation has produced an array of species and subspecies. The described forms include: C. salinus Miller, the Salt Creek pupfish of Death Valley; C. radiosus Miller, the Owens Valley pupfish - R; C. nevadensis Eigenmann and Eigenmann, the Amargosa pupfish with six subspecies recognized; and C. diabolis Wales - R, the Devil's Hole pupfish, restricted to a single tiny pool.

Also in the Amargosa desert on the California-Nevada border, the Ash Meadows poolfish, Empetrichthys merriami Gilbert, (now believed extinct) was found. Three subspecies of Empetrichthys latos Miller - R, the only other known species in this genus, occurred in three springs (two springs now destroyed) in Pahrump Valley, Nye Co., Nevada.

The genus Crenichthys has two known species, C. baileyi (Gilbert), the White River springfish found in warm springs along the White River drainage of Nevada, and *C. nevadae* Hubbs, the Railroad Valley springfish from a desiccating basin just west of the White River system, Nye Co., Nevada.

The cyprinodont fishes of the desert areas of the western United States reveal information on past conditions and connections of the Colorado basin and provide insight into the mechanisms and rates of evolution.

Family Cottidae: Sculpins

Cottus bairdi Girard. Mottled sculpin - U L

A widespread species across the northern United States.

Cottus annae Jordan and Starks. Eagle sculpin - U

This sculpin formerly believed endemic to headwater areas in the upper Colorado River basin, is considered identical to *Cottus beldingi* Eigenmann and Eigenmann, of the Lahontan basin, middle and upper Columbia River system and the lower Bear River of the Bonneville basin, by Bailey and Bond (1963).

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Native Fishes of the Upper Colorado River Basin with Particular Reference to the Effects of Endangered and Threatened Species on Future Development in the Basin

Prepared for the Colorado River Water Conservation District

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Introduction

During millions of years of isolation the fish fauna of the Colorado River basin evolved to fit specific roles in the existing environment. Four large, somewhat bizarre appearing species became specialized for life in the main river channels, an environment characterized by enormous fluctuations in flows and turbidities. Perhaps for millions of years these species flourished in the harsh environment of the Colorado and Green rivers and in some of the larger tributaries. In recent times land use patterns, initiated in the Nineteenth Century, construction of main stream dams, begun in 1935, and the widespread introduction of non-native fishes, better adapted to the changing environments, have contributed to the catastrophic decline of all four of the large, mainstream fishes native to the basin (Behnke, 1976).

Under the Endangered Species Act of 1973 (PL 93-205), the U.S. Department of Interior lists the squawfish, *Ptychocheilus lucius*, and the humpback chub, *Gila cypha*, as endangered. The Endangered Species Office of the U.S. Fish and Wildlife Service is currently proposing that the bonytail chub, *Gila elegans*, be listed as endangered and the razorback (or humpback) sucker, *Xyrauchen texanus*, be listed as threatened. It is likely that these proposals will be accepted and the bonytail chub and razorback sucker will join the squawfish and humpback chub in the federal register as federally recognized endangered or threatened species with all of the ramifications of environmental protection as stipulated in the Endangered Species Act. All of these four species are presently listed as endangered by the Colorado Wildlife Commission.

A proposal by the Albuquerque regional office of the U.S. Fish and Wildlife Service to declare the Yampa Basin to Milk Creek (about 15 miles downstream from Craig) as critical habitat for squawfish, will undoubtedly be a significant obstacle to any federal involvement promoting any project in the basin which may have a negative impact on "critical habitat" of an endangered species.

Some of the confrontations that may be in store in the battle of the Endangered Species Act versus water development in the Yampa River basin became apparent to me at a Resources for the Future Symposium in Albuquerque (October, 1976), where it was related that full scale energy development cannot occur in the basin without major dams for water storage.

The key question is can endangered species, contrary to all past experience, coexist with dams (no negative impact) and can mitigation measures be an integral part of a development project not only to preserve endangered species but to enhance their abundance and restore them to areas where they do not now exist?

The emphasis of this report is on the squawfish because of the proposed critical habitat and because it is the only endangered species with authentic records from the Yampa River above Maybelle. Comprehensive information is included on the humpback and bonytail chubs, on the razorback sucker, and on the native cutthroat trout, as well as an annotated list of all native species of the upper Colorado River basin to provide a basis of information to answer questions and make predictive assumptions basic to any future water development projects in the Upper Colorado basin.

Historical Perspectives

It is somewhat ironic that the squawfish, humpback and bonytail chubs are species of the minnow family (*Cyprinidae*) and the razorback sucker is of the sucker family (*Catostomidae*) -- fishes of these families historically have been considered as "trash" fish, or "rough" fish by state and federal fisheries agencies to be eradicated by pest control programs. Indeed, all of the native species including large numbers of the presently endangered species were eradicated by massive poisoning of the Green River (down to Dinosaur National Monument) in 1962 prior to the closure of Flaming Gorge Dam to make the environment more hospitable for the introduced rainbow trout (Miller, 1963). According to Miller, 100 men and $157,000 ($173,000 according to the N. Y. Times, Aug. 11, 1963) were used to kill all the fishes from about 500 miles of river. A pre-impoundment study of the Flaming Gorge Reservoir site by Wyoming Game and Fish Department (1960, Fish. Tech. Rept. 9) commented that game fish were scarce and trash fish such as squawfish and bonytail chubs were abundant.

In a 1971 booklet published by the Colorado Division of Wildlife, entitled, "Fishes of Colorado," the following statement is found under Colorado Squawfish: "Because the squawfish are such predators on game fish, control has long been a fisheries management problem. Everything from dynamite to chemical control has been tried. The most recent development is a specific chemical called 'Squoxin' for the control of these predators." This embarrassing statement resulted from a lack of information on the Colorado squawfish. The author evidently based the comments on a closely related species, the Columbia River squawfish, *Ptychocheilus oregonensis*, an adaptable and abundant squawfish that is often considered a pest species. Although the fate of the native fish fauna of the Colorado River basin and that of their original environment may be lamented the fact remains that a multimillion dollar recreational fishery has resulted from the creation of reservoirs and these fisheries are based entirely on non-native fishes. Thus, it is understandable why a state fish and game agency, funded by license sales, may not seem enthusiastic to back a program to protect or enhance survival of endangered species of minnows and suckers, particularly where conflicts with sport fishing interests could develop. The Endangered Species Act, however, becomes a decisive advocate for any species listed by the U.S. Department of Interior as endangered or threatened by directing all federal agencies to prohibit any action which would be negative to the survival of endangered or threatened species. Environmental groups (Sierra Club, Wilderness Society, Audubon Society, Trout Unlimited, etc.) have found a potent new weapon in The Endangered Species Act for battles against certain projects and will initiate legal action on their own to enforce certain provisions of the law. For example, Audubon Society and Sierra Club lawyers have petitioned the U.S. Fish and Wildlife Service (the agency charged with enforcement of the Endangered Species Act) to the effect that the U.S. F.W.S. failed to fulfill its responsibilities in regard to Bureau of Reclamation irrigation projects in North Dakota, South Dakota and Nebraska in relation to potential negative impacts on critical habitat of the endangered whooping crane (although critical habitat of the whooping crane has not yet been determined).

A basic question may be asked: Are the squawfish, humpback chub and bonytail chub truly endangered (in danger of extinction)? The answer is probably yes, or at least it is not likely that new evidence will be found which could serve as a basis to remove these species from the endangered list. This matter is treated in more detail under each species account, but all indications are that the squawfish, razorback sucker, humpback and bonytail chubs have suffered great declines in abundance and distribution and are very rare, occurring only sporadically in a few areas of their former range. Such areas of occurrence then assume great significance as "critical habitat." The disappearance of these species occurred first in the lower basin (below Grand Canyon) (Minckley and Deacon, 1968) and their rapid decline in the upper basin is correlated with the completion of Flaming Gorge Reservoir (1962) and Lake Powell (1963).

It is difficult to document the original abundance and distribution of these four species or to quantify their decline because so little detailed information exists. Of all the early literature, only the expedition of David Starr Jordan in 1889 (Jordan, 1891) provided information based on collections from several localities in the upper Colorado River basin. Evermann and Rutter (1895) reviewed all of the literature to that time on the fishes of the Colorado basin.

Jordan and Evermann (1896, 1902) stated that the squawfish was "very abundant in the river channels as far north as the base of the Rocky Mountains in Colorado." Essentially this same comment was repeated for the razorback sucker and the bonytail chub.

In some areas, particularly in the lower basin, squawfish and razorback suckers were harvested by commercial fishermen. Confusion has always surrounded the three chub species of the genus *Gila* of the upper Colorado River basin. The roundtail chub, *G. robusta*, is still a common species in tributary streams, but specimens have long been known which appear intermediate between *G. robusta*, *G. cypha* (humpback chub) and *G. elegans* (bonytail chub) and these intermediate types apparently became more common in the 1960's, indicating hybridization was stimulated by the environmental changes. Several authors have used the term "bonytail chub" for the common roundtail chub. Thus, the former abundance and present occurrence of *G. elegans* and *G. cypha* is not well understood. The humpback chub was probably always restricted in its distribution to deep water canyon areas of the Colorado and Green rivers. It was not officially discovered and described until 1945 (Miller, 1946). The bonytail chub may have been an important food source for the squawfish. The decline of the bonytail chub apparently coincided with the decline of the squawfish and the present known maximum size of squawfish is only about 15 lbs., far less than the 80 lbs. reported by Jordan for the Nineteenth Century.

All ichthyologists and fisheries biologists familiar with the Colorado River basin in recent years agree that squawfish and razorback suckers have been greatly reduced in distribution and abundance and fish which appear to be typical bonytail chub or typical humpback chub are even rarer.

The construction of Flaming Gorge Reservoir and Lake Powell stimulated studies on the native fishes of the upper basin. Smith (1960) reported collecting 18 humpback chub from Hideout Flats of the Green River (now under Flaming Gorge Reservoir) in 1959. The data of Taba, et al. (1965) indicated squawfish were still common and reproduction was successful in the Green River near Moab, Utah in 1962-64. Vanicek (1967), Vanicek and Kramer (1969) and Vanicek, Kramer and Franklin (1970) documented data on the native fishes in the Green River following the closure of Flaming Gorge dam in 1962 (from the dam through Dinosaur National Monument). Holden and Stalnaker (1970, 1974, 1975) discussed the chubs of the genus *Gila*, the fishes of the Dolores and Yampa rivers and the fishes of the upper Colorado River basin, respectively. Holden and Stalnaker (1974, 1975) have emphasized the point that the

Yampa River, as the only major tributary in the Colorado River basin without a mainstream dam, holds great significance for the preservation of endangered and threatened species.

Early documentation of the former existence of any of the presently endangered species in the Yampa River does not exist to my knowledge. This, however, is due to the lack of early collections. Holden and Stalmaker (1974, 1975) summarized data from fish collections made from 1967-1973 and documented the presence of squawfish, razorback sucker and "humpback chub complex" in the Yampa River during that time. Only the squawfish was found upstream from Dinosaur National Monument, the other species were confined to an area near the confluence with the Green River. The upstream limit of squawfish distribution in the Yampa River is based on a specimen collected in 1971 from near Milk Creek by Paul Holden (thus, the basis for the proposed critical habitat). Although systematic and comparable fish collection data is lacking for the Yampa River, it does appear from studies of 1975-76 that a continued trend of decline in squawfish abundance and success of reproduction (as well as the other species) is in progress. This has led me to suggest that the squawfish may become extinct in about 25 years, even if no further environmental alterations occur in the upper basin (Behnke, 1976). I based this assumption on the history of extinctions of other animal species and the rapid extinction of squawfish from the lower basin (Miller, 1961; Minkley and Deacon, 1968). Once the curve of abundance reaches a certain inflection point, the extinction process is greatly hastened.

In any event, it must be admitted that no one really knows how "critical" the Yampa River is for squawfish survival. Do the squawfish presently inhabiting the Green River below the mouth of the Yampa depend on the Yampa for reproduction? If so, to what extent? Where are the spawning and nursery grounds? Why has there been no indication of successful reproduction of squawfish in the Yampa River since 1969 (finding young-of-the-year fish)?

Definitions, Interpretations and Ramifications

Before treating the biology of the fishes, it may be useful to discuss certain aspects of the Endangered Species Act in more detail. The intent of the Act is, of course, to prevent species of animals and plants from becoming extinct. The intent is carried out by a listing of endangered and threatened species by the Office of Endangered Species of the Fish and Wildlife Service (Dept. Interior). No federal agency can expend funds or cooperate in any activities which would be detrimental to species on this list. States are encouraged to initiate management programs designed to enhance survival of endangered species by a grant of federal funds (Colorado will receive $100,000 this fiscal year).

Section 3 of the Act defines terminology. Endangered species is defined as any species in danger of extinction throughout all or a significant portion of its range. Species is defined to include subspecies and smaller units of a species. Thus, arguments over the validity of the humpback and bonytail chubs -- are they two separate species or only subspecies of one species -- is not pertinent to their classification as "endangered species." The same reasoning applies to the native Colorado River cutthroat trout, *Salmo clarki pleuriticus*, where the species as a whole is not endangered or threatened, but some subspecies of the species are. Threatened species means any species which is likely to become an endangered species within the foreseeable future.

Section 7 (Interagency Cooperation) charges the Secretary of Interior to review all Interior programs and to use these programs for the furtherance of the Act. All other federal agencies are to utilize their authorities in furtherance of the Act by carrying out programs for the conservation of endangered and threatened species. These agencies are also to insure that actions authorized, funded, or carried out by them do not jeopardize the continued existence of these species or result in the destruction or modification of these species' habitat that is determined to be critical by the Secretary of Interior after consultation with the affected states.

Critical habitat mentioned in the last sentence is a most important and complex issue.

As of July, 1976, only one species had its "critical habitat" defined and that was an obvious example -- the snail darter, a small fish known only from a small area of the Little Tennessee River about to be inundated by a TVA dam under construction. The case of TVA vs. the snail darter and the Endangered Species Act is likely to go to the Supreme Court. The Sixth Circuit Court of Appeals (Oct. 1976) has allowed TVA to proceed with construction of the dam but has forbidden its closure (scheduled for January, 1977). TVA rests its case on the fact that the snail darter was not discovered and described until after dam construction was underway and on their attempts to establish new populations into new habitat.

The following is a reproduction of a brief article from "The Endangered Species Technical Bulletin" (Aug., 1976) written by the Director of the Office of Endangered Species, Keith M. Schreiner, entitled: "Critical habitat: what it is -- and is not."

> In recent months, my staff and I have been barraged with innumerable queries and comments concerning critical habitat. It is clear that Federal and State administrators, Congressmen, biologists, reporters, and private citizens are wondering about the meaning of critical habitat and its potential effects on their own activities and interests.
>
> The most important point I can make about critical habitat is that in no way does it place an iron curtain around a particular area; that is, it does not create a wilderness area, inviolable sanctuary, or sealed-off refuge. Furthermore, I would stress that it does not give the Fish and Wildlife Service or any other government agency an easement on private property nor will it affect the ultimate jurisdiction regarding any public lands.

Critical habitat is provided for by section 7 of the Endangered Species Act of 1973, which charges Federal agencies--and only Federal agencies--with the responsibility for ensuring actions authorized, funded, or carried out by them do not either 1) jeopardize the continued existence of Endangered or Threatened Species or 2) result in destruction or adverse modification of the habitats of these species. (State and private actions that do not involve Federal money or approval do not come under the terms of the Act.)

Simply stated, critical habitat is the area of land, water, and airspace required for the normal needs and survival of a species. As published in the *Federal Register* on April 22, 1975, the Service has defined these needs as space for growth, movements, and behavior; food and water; sites for breeding and rearing of offspring; cover or shelter; and other biological and physical requirements. Determination of a critical habitat may include consideration of certain biological, physical, or human elements of a species' environment, if--but only if--the element is required for the continued survival or reasonable recovery of the species.

We are taking special pains to make sure that every shred of biological data is obtained and analyzed before any critical habitat is determined. Federal and State agencies are being contacted in writing prior to publication of a proposal. Once the proposal has been published, written comments on its biological adequacy are actively sought from all interested parties. In some cases, if the situation warrants, public hearings are being held in the affected States to seek the views of local residents. It is only after all of this biological information has been collected and carefully analyzed that a final determination is made.

Once the final determination has been published, its only effect is to cause Federal agencies managing lands or administering programs within the area to examine their actions in light of section 7.

The actions of private individuals (farmers, ranchers, trappers, etc.), firms, and State agencies are not affected unless funding or approval from a Federal agency is involved.

If an action does require Federal funds or approval, then the particular Federal agency having jurisdiction must decide whether or not the action would "jeopardize the continued existence of the species or result in destruction or modification" of its critical habitat.

There is no way to predict how Federal agencies will decide about particular actions in particular areas. The agencies simply consider them on a case-by-case basis as they arise. Nevertheless, I should emphasize that there are many types of existing land uses that are compatible with the continued survival of species and maintenance of the quality of their habitats. In addition the Service is prepared to provide assistance and consultation on the biological impacts of proposed activities whenever such consultation is needed. However, the final decisions will be made by the appropriate Federal agencies.

In short, the determination of critical habitat is a means of helping all Federal agencies meet their responsibilities under the Endangered Species Act of 1973. It is a tool to help save and restore species, not a weapon to hinder economic or social progress.

Critical habitat is typically recommended first by the endangered species "recovery team," an advisory board charged with developing a plan to restore an endangered species to an abundance where it is no longer endangered. The recommendation of the squawfish recovery team included the Yampa River from its confluence with the Green River upstream to Craig, Colorado. As mentioned above, the recommendations of the Albuquerque regional office of the Fish and Wildlife Service has slightly reduced the Yampa River critical habitat by placing the upstream limits at Milk Creek. Besides the Yampa River, the current recommendations for critical habitat for squawfish includes the Colorado River from Lake Powell to Plateau Creek (about 10 miles above Palisades, Colorado), the Gunnison River to Delta, Colorado and the Green River to its confluence with the Yampa.

A Memorandum of Understanding was signed in March, 1976, by the Directors of the Fish and Wildlife Service, the BLM and the Bureau of Reclamation to the effect that all three agencies must agree on the designation of critical habitat before it is published in the federal register.

Because of the threat of embarrassing law suits, however, it is likely that even without official designation, federal agencies are likely to treat the Yampa River as "de facto" critical habitat for squawfish unless it can be adequately demonstrated that the Yampa River is not significant for the survival of the species or that a project can actually enhance the survival potential of an endangered species.

The other species, razorback sucker, bonytail and humpback chubs are known only from specimens taken near the confluence with the Green River. The confluence of the Yampa and the Green rivers is a highly significant area because this is now the upstream limits of the endangered species of the Green River after the cooling effect of Flaming Gorge Reservoir release eliminated these species from the Green River upstream from this point. Any potential alteration in the flow and temperature patterns of the Yampa River from a proposed development project which could upset the delicate balance which now exists would be vigorously fought. A logical question, however, is can the flow regime be improved in the lower Yampa River to benefit the endangered species?

The Endangered Species Act is a relatively new law, adequate precedents do not yet exist to serve as guidelines in relation to mitigation for critical habitat.

Colorado Squawfish *Ptychocheilus lucius*

Taxonomy and Identification. The Colorado squawfish has been reputed to attain a size of 80-100 lbs., although I believe a maximum of 55-60 lbs. is more realistic. In any event, the Colorado squawfish is by far the largest species of the minnow family native to North America. The jaw extends to the rear margin of the eye. Scales 80-95 in the lateral line, dorsal and anal rays typically 9. Body elongate, tail deeply forked. Young squawfish can be easily confused with the roundtail chub, *Gila robusta*. The presence of a wedge-shaped spot at the base of the caudal fin of young squawfish (absent in adults) can serve to distinguish young squawfish from the roundtail chub.

Three other species of squawfish are known from other rivers in the western North America. The other squawfish species, unlike *P. lucius*, are highly adaptable, responding favorably to changing environments to such an extent that they are commonly considered as pest species to be controlled.

Distribution. Although not documented with precise records, the original range of the squawfish included the main channel areas of the Green and Colorado rivers and the larger tributaries from Wyoming to Mexico.

This range was shared with the razorback sucker and the bonytail chub. Presently the squawfish may be extinct from the lower basin (below Glen Canyon Dam), no records that I know of exist after 1968. In the upper basin the major stronghold of the squawfish appears to be the Green River from the confluence of the Yampa River downstream to its confluence with the Colorado River (but occurrence is sporadic). Recent records in the Colorado River include small numbers around Grand Junction as far upstream as Plateau Creek. Holden collected squawfish from the Gunnison River in 1971, but Bureau of Reclamation collections in the Gunnison in 1976 found none. For the Yampa River it should be pointed out that the data are difficult to interpret in relation to actual abundance of squawfish in any particular area and to detect real trends in abundance because collections were made by different people at different times using different gear with varying degrees of time and effort involved. That is, collections were not systematically planned for long term comparisons, but rather sporadic in time, place and effort and it is only possible to interpret these data as suggestive of the real situation. The collection sites of Holden (Holden, 1973; Holden and Stalnaker, 1975) from the lower Yampa River encompasses about 45 miles of river in the Yampa Canyon of Dinosaur National Monument. Of a total of 300 squawfish collected by Holden from the Upper Colorado River basin from 1968 to 1971, 269 came from the Yampa Canyon. More than 90% of these 269 squawfish were ripe males, no ripe females were taken. The squawfish found in the Yampa River evidently are not a resident population but probably represent a fish moving up from the Green River for spawning. Movement begins in June with rising water temperatures and typically reaches a peak in late July at water temperatures of 68°-70° F. Just where the spawning areas are located in the Yampa and the success of reproduction are not known. Apparently reproductive success is low. Holden found juvenile squawfish abundant in the Echo Park area (near confluence) in 1968, but found very few in 1969 and none in 1970 despite an intensive search. Further studies in 1975-76 in the Yampa River by Karl Seethaler (Utah State University, funded by U.S. Fish and Wildlife Service) and Charles Prewitt (Colorado State University, funded by BLM) also failed to find young-of-the-year squawfish. Based on the collection of spawned-out adults, Seethaler believes the area of the Yampa River in Lily Park, about two miles above the confluence with the Little Snake River is a spawning site. Prewitt collected a spawned out female, August 8, 1975, from the Yampa River at Maybelle. Prewitt also collected three adult squawfish from the mouth of Cross Mountain Canyon on August 21, 1975. One specimen was taken right at the mouth of the canyon and two taken about 100 yards into the canyon. These specimens and one taken by Paul Holden near the mouth of Milk Creek on June 23, 1971, represent the known upstream records of squawfish in the Yampa River.

Holden collected 113 adult squawfish in 1970 but only 12 in 1971. Based on notes from conversations with Seethaler, I believe he captured more than 20 adult squawfish in the Yampa River in 1975; 13 were taken in the Lily Park area (two miles above mouth of Little Snake) August 6, 7, and 8, 1975. He captured only two specimens in 1976. Prewitt collected no squawfish from the Yampa in 1976 but refrained from using gillnets (the most effective gear) for fear of mortality.

Intensive seining of young fry and fingerling fish to validate the success of squawfish reproduction in 1975-76 failed to find any young squawfish in the Yampa River. Young were found only in the Green River (near Jensen, Utah, in Desolation Canyon and in Canyonlands National Park).

In summary, my interpretation of the limited data, indicates to me that squawfish from the Green River migrate up the Yampa River for reproduction, the runs peaking when water temperature reaches 68°-70° F (males and females probably migrate separately and most movement is during the night). The mass migration, in part, extends to Cross Mountain Canyon with occasional specimens penetrating further upstream. The number of squawfish participating in this migration has been steadily declining and there is no indication that successful reproduction has occurred in the Yampa River since 1969.

It is probable that after the closure of Flaming Gorge Dam and the cooling of the Green River for 65 miles (to its confluence with the Yampa), spawning squawfish which formerly migrated up the Green River to the Flaming Gorge area were shunted into the Yampa by the colder waters. However, squawfish probably historically have used the Yampa for reproduction. "Old timers" living in the Maybelle and Juniper Hot Springs area (allowing for fish story reminiscing) recall that 15-20 years ago squawfish were much more abundant and of a much larger size than they are now. Mr. Wayne Seaman, Director Fish Research, Colorado Division of Wildlife, recalls catching 3-6 lb. squawfish in 1969 by angling in the Yampa River between Cross Mountain Canyon and Dinosaur National Monument.

It could be mentioned that the creation of a 65 acre backwater area, the Walter Walker Wildlife Area, by gravel excavation for interstate highway construction, promoted a "boom" in squawfish reproduction for the small population inhabiting the Colorado River near Grand Junction. This matter will be discussed more fully under reproduction, but is mentioned here as a clue concerning creation of habitat for squawfish reproduction and a possible method for restoring squawfish to parts of their range where they no longer exist.

Recent collections indicate the squawfish no longer exists in the San Juan, Dolores or White rivers, but occasionally migrates up the Duchense River, Utah.

Life History, Ecology and Reproduction. Little detailed data exists because the squawfish was already rare by the time it became an important subject for study. Based on the literature cited above, personal communications and observations and making some evolutionary interpretations based on millions of years of specializing as a large, main river predator in the original environment of the Colorado River basin, I propose the following scenario to explain why the evolutionary heritage of the squawfish makes it ill-adapted to survive (why it is endangered).

Originally the squawfish probably made major upstream spawning migrations particularly into the larger tributaries (hence the common name of "salmon"). Spawning and nursery areas were probably quiet, backwater areas and oxbows of the lowland tributaries and main rivers. Such areas were changed early by land use practices, vegetation removal, erosion and irrigation, changing flow regimes and the alteration of the physical characteristics of the river channels. Thus, much of the original prime spawning habitat and nursery grounds were lost. Dams blocked migration routes not only by their physical structure but more importantly by the creation of a clear, coldwater environment below the dams. A minimum temperature of 68°-70° F seems critical for squawfish reproduction. The most abundant native fish originally living in the main river channels with adult squawfish was probably the bonytail chub and as such, was likely the major food source of the squawfish. Presently the squawfish must depend on a variety of introduced fishes for its food and evidently it is not so well adapted to capture these fishes as are the non-native predators. That is, the squawfish is probably at a competitive disadvantage. Dead squawfish have been found with channel catfish lodged in their esophagus (the catfish spines prevented their being swallowed or regurgitated).

Vanicek (1967) and Vanicek and Kramer (1969) studied squawfish food habits. Young squawfish up to 100 mm. fed on invertebrates. I envision that at present the young squawfish face intense competition for the invertebrate food supply from introduced minnows such as the redside shiner (*Richardsonius*), the creek chub (*Semotilus*), and the red shiner (*Notropis*) which are rapidly proliferating throughout the upper basin. Between 100 and 200 mm. the squawfish begins to consume more fish in its diet and after a size of 200 mm., fish become its major food source.

From the above, it would appear that the key to an effective program of squawfish restoration would be to create environments where squawfish can be raised to about 200 mm. in the absence of competition from the non-native fishes (and predation from non-native predators) and then released to feed on the abundant non-native minnows.

Little is known about squawfish reproduction except that a minimum water temperature of 68°-70° F seems critical and that sexual maturity is not attained until the age of 6-8 years (maximum life span may be about 20 years). Quiet backwater areas seem to be preferred for spawning although no one has yet observed squawfish spawning in nature (Squawfish spawning was induced at the Willow Beach, Nevada, National Fish Hatchery, by pituitary hormone injections--they spawned over gravel beds in a hatchery raceway).

It is highly significant that an abundance of young squawfish were noted in 1975 in the Walter Walker Wildlife area lake--a backwater off the main Colorado River created by gravel excavation. This man-made habitat evidently closely approximates areas originally preferred by squawfish for reproduction. The success of squawfish reproduction here will probably be limited by the abundance of non-native fishes but raises the question: Can similar habitats be created specifically for squawfish and designed to exclude the non-native fishes?

Spawning in the Yampa River probably occurs from late July to early mid-August.

Current Management and Research

As mentioned above, the construction of Flaming Gorge Reservoir and Lake Powell stimulated studies on the native fish fauna of the upper Colorado River basin. In recent years, the endangered status of the squawfish endowed the species with great significance in respect to any federal water development project in the upper basin. The Fish and Wildlife Service has funded the studies of Karl Seethaler (squawfish) and Charles McAda (razorback sucker) through the Utah Cooperative Fishery Unit. The BLM has funded a project on the native fish fauna of the Yampa and White rivers through Colorado State University (Mr. Charles Prewitt's work). The Bureau of Reclamation has funded fish collections in the Colorado and Gunnison rivers (Mr. George Kidd). Colorado squawfish were successfully propagated at the Willow Beach National Fish Hatchery in 1974 and 1975 (young feed on trout pellets and adults feed on rainbow trout). However, no reproduction occurred in 1976 at the hatchery and the young squawfish raised at the hatchery have not been stocked because of a lack of agreement on where to plant them.

The Squawfish Recovery Team was established in 1975 (expanded to also include the bonytail and humpback chubs and razorback sucker in 1976). This is an advisory board of people representing various state and federal agencies whose task is to design a recovery program to preserve and increase the abundance of squawfish.

The Office of Biological Services of the Fish and Wildlife Service has recently awarded contracts on habitat requirements of endangered fishes (project 24) of the upper Colorado River basin. Ecology Consultants, Inc. (Fort Collins) will undertake phase 1, essentially a literature review and planning, while Paul Holden's group (BioWest) will probably handle phase 2, the field investigation. Holden plans intensive sampling of 63 stations covering 630 miles of river (Yampa, Green, Colorado and Gunnison) to find where squawfish exist and where they reproduce successfully and correlate this information with physical, chemical and biological parameters of the environment.

These research efforts are characterized by a lack of coordination, central authority or unified direction. Propagation of squawfish has been proven feasible but is carried out at the Willow Beach Hatchery more as a hobby than as a priority program of the Fish and Wildlife Service. Who should be responsible for funding and directing endangered species projects? The Office of Endangered Species is the obvious answer, but their original intent to develop endangered species management programs concerns granting funds to individual states to assist in state programs. With the number of states in the Colorado River basin, it is doubtful that they could all agree on a common, centrally directed program.

It would appear from the great amount of environmental impact analysis going on in the region that adequate data on native fishes should be available. Despite the great bulk of literature produced by Environmental Impact Statements, I find the work, particularly in relation to fishes, to be superficial and without ichthyological expertise. For example, the USDI recently released a "Draft Environmental Impact Statement on Northwest Colorado Coal," consisting of five large volumes and two large appendices (weighing about 25 lbs.). In looking up information on the status of the squawfish in the Yampa River in these volumes I read that squawfish comprise 15% of all fishes in the lower Yampa River (from the Green River to Maybelle). Who said this? What is the statement based on? When were these collections made? How good are the data? Such critical information is not given. I also note in Table IX-2 that in the Yampa River from Lily Park to Maybelle, cutthroat trout make up 10%, brook trout 80% and rainbow trout 10% of the fishes. The fact is that these species do not occur (except as random strays) in the lower Yampa.

The lack of a coordinated and unified program of funding and direction while the squawfish continues to decline has led me to propose that squawfish restoration become an integral part of future water development projects similar to mitigation for the blocking of salmon runs on the West Coast by dams (Behnke, 1976). My ideas were presented to the Squawfish Recovery Team (March, 1976) but were rejected as being defeatist (if one plans for defeat, he will be defeated). I appreciate the members' points of view as firm advocates of the squawfish, but I maintain that some positive action should be taken such as the creation of a habitat to insure successful reproduction, and I see no other way, at present, to fund such projects. The squawfish can be literally researched to death (or to extinction). By the time a viable plan to save this species is ready, it may be too late.

The key to squawfish restoration is their reproduction and survival in their first and second year of life (until they are large enough to feed on other fishes). Reproduction, at least in the early stages of recovery, can be accomplished in a hatchery as is already known. But where are the young fish to be stocked? The creation of habitat similar to the off-channel lake in the Walter Walker Wildlife area should provide ideal rearing sites for young squawfish, but controls must be designed to prevent their infestation with non-native fishes. This would be my idea of a positive action of a recovery program. There is no way that squawfish abundance can be increased by studying the areas where it exists and reproduces and where it does not, unless an attempt is made to create an environment similar to that where successful reproduction occurs in areas that lack such environments. In respect to this, the Walter Walker Wildlife lake as a model for future floodplain excavations to create squawfish nursery areas assumes a great significance.

Much more information is necessary before it can be determined just how "critical" the Yampa River is for the survival of the species. How many squawfish enter the Yampa River? Where do they spawn? What happens after the eggs are laid? Why have no young been found since 1969? If reproduction is actually a complete failure, it would be better to force the squawfish to spawn elsewhere than allowing them to make fruitless attempts at reproduction in the Yampa.

Since 1969, the proliferation of non-native fishes in the Yampa River, particularly the redside shiner and the creek chub, may be the explanation for lack of reproductive success of the squawfish. Creation of off-channel environments free of these non-native fishes is a logical course of action.

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October 9, 1979

Dr. Robert J. Behnke
Colorado State University
Department of Biology
Fort Collins, CO 80526

Dear Bob:

I have enclosed copies of two reports summarizing data collected in four major drainages of The Geysers Known Geothermal Resources Area (KGRA). The 1975 Annual Report, "An Inventory of Fishery Resources in the Upper Putah Creek, Kelsey Creek, and Cole Creek Drainages," is only a part of a larger inventory of fishery resources in KGRA being conducted by PGandE. The other report, "An Investigation of Unique Water Quality Conditions in the Big Sulphur Creek Watershed Related to Natural Geothermal Activity, Stream Flow and Geothermal Development," is an analysis of a study initiated in 1968.

Also included is a copy of "Evaluation of the Effects of Flows on Trout Stream Ecology" by D. R. Hooper.

I enjoyed the opportunity we had to meet at the Wildtrout Symposium last month. If you have any questions or would like additional reports, please contact me.

Sincerely,

Don

D. G. Price
Biologist

Enclosures

5~

Hale

brown TT

iMcIntosh 2+

Spearman Glenn

Shaw Frey Bm

March 3, 1849

United States Department of the Interior
FISH AND WILDLIFE SERVICE
AREA OFFICE COLORADO—UTAH
1311 FEDERAL BUILDING
125 SOUTH STATE STREET
SALT LAKE CITY, UTAH 84138-1197

IN REPLY REFER TO:

March 31, 1983

Robert Behnke
Colorado State University
Fort Collins, Colorado 80523

Dear Robert:

Enclosed are two copies each of the following reports per your request.

First Annual Report Colorado River Fishes Monitoring Project

Windy-Gap Fishes Study First Annual Report

Sincerely yours,

Bill Miller
/s/cjs

Bill Miller

Enclosures (4)

WINDY-GAP FISHES STUDY
FIRST ANNUAL REPORT

January, 1983

Submitted in accordance with provisions of Cooperative Agreement No. 14-16-0006-82-959 (R) between the U.S. Fish and Wildlife Service and the Northern Colorado Water Conservancy District, Municipal Subdistrict

W.H. Miller
Project Leader

L.R. Kaeding
Field Supervisor, Grand Junction

H.M. Tyus
Field Supervisor, Vernal

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INTRODUCTION

The fish community of the Colorado River was historically dominated by endemic species -- species found nowhere else (Miller 1959). Because of limited distribution, survival of these species is more tenuous than it is for species with wider distributions. Alteration of the Colorado River ecosystem has greatly reduced the populations of some of these endemic species, and continued alterations of the river could reduce a few species to extinction.

The recent decline in abundance of three endemic fishes; Colorado squawfish (*Ptychocheilus lucius*), humpback chub (*Gila cypha*), and bonytail chub (*G. elegans*); has been significant enough to justify classifying them as endangered by the United States Fish and Wildlife Service.

Under the provisions of the Endangered Species Act of 1973, endangered species designation dictates that Federal agencies involved in development must assure that their actions do not further reduce populations of endangered species. Proposed developments that would further reduce populations of endangered species might be modified or canceled. Thus, the presence of an endangered species can greatly influence the development of natural resources and this has been a particularly controversial issue affecting proposed Colorado River water projects.

Information on the distribution, abundance, and habitat associations of endangered Colorado River fishes was required in order to determine the effects that proposed water development projects might have on these endangered species. In 1979 the Fish and Wildlife Service (FWS) and the Bureau of Reclamation (BR) cooperated in the development of the Colorado River Fishery Project (CRFP) in order to collect and interpret information on endangered Colorado River fishes. Among the many findings of CRFP was that the endangered Colorado squawfish and humpback chub apparently experience an unusually high rate of mortality during the first few years of life (Miller et al. 1982). If these causes of early mortality could be determined, it might be possible to lessen or eliminate their influence on the survival of Colorado squawfish and humpback chub.

The intent of the present Windy-Gap work program includes determining the factors that affect the survival of Colorado squawfish and humpback chub during their first year of life. Knowledge of these limiting factors would then be used in an attempt to increase the population size of these species, perhaps to the extent that the endangered species designations can be removed.

The specific objectives of the Windy-Gap work plan are:

1) to locate and describe reproductive habitats for Colorado squawfish and humpback chub in the Grand Junction area,

2) to locate and quantify rearing areas for young Colorado squawfish and humpback chub,

3) to identify the major factors that affect the survival of Colorado squawfish and humpback chub during the first year of life,

4) to modify river backwaters and gravel pits, between Debeque Canyon and the mouth of the Green River, in a way that might enhance the survival of endangered fishes.

5) to evaluate natural and modified river backwaters as habitat for young Colorado squawfish and humpback chub, and

6) to determine the extent that Colorado squawfish and humpback chub move within the Colorado River and its tributaries.

These objectives are largely interrelated and the achievement of some is prerequisite to the successful completion of others. The objectives consists of two major work elements: 1) movement, spawning, and rearing studies (objectives 1,2,3, and 6) and 2) backwater and gravel pit investigations (objectives 4 and 5). Although a distinction is made between these work elements for the purpose of clarity, it is recognized that work elements themselves are also interrelated.

Investigations during 1982 were carried out in the Colorado River between Palisade, Colorado and Hite, Utah; the Gunnison River between the Redlands diversion structure and the confluence of the Gunnison and Colorado rivers; the lower 20 miles of Yampa River; and the Green River from the confluences of the Yampa downstream to Gray Canyon (Figure 1).

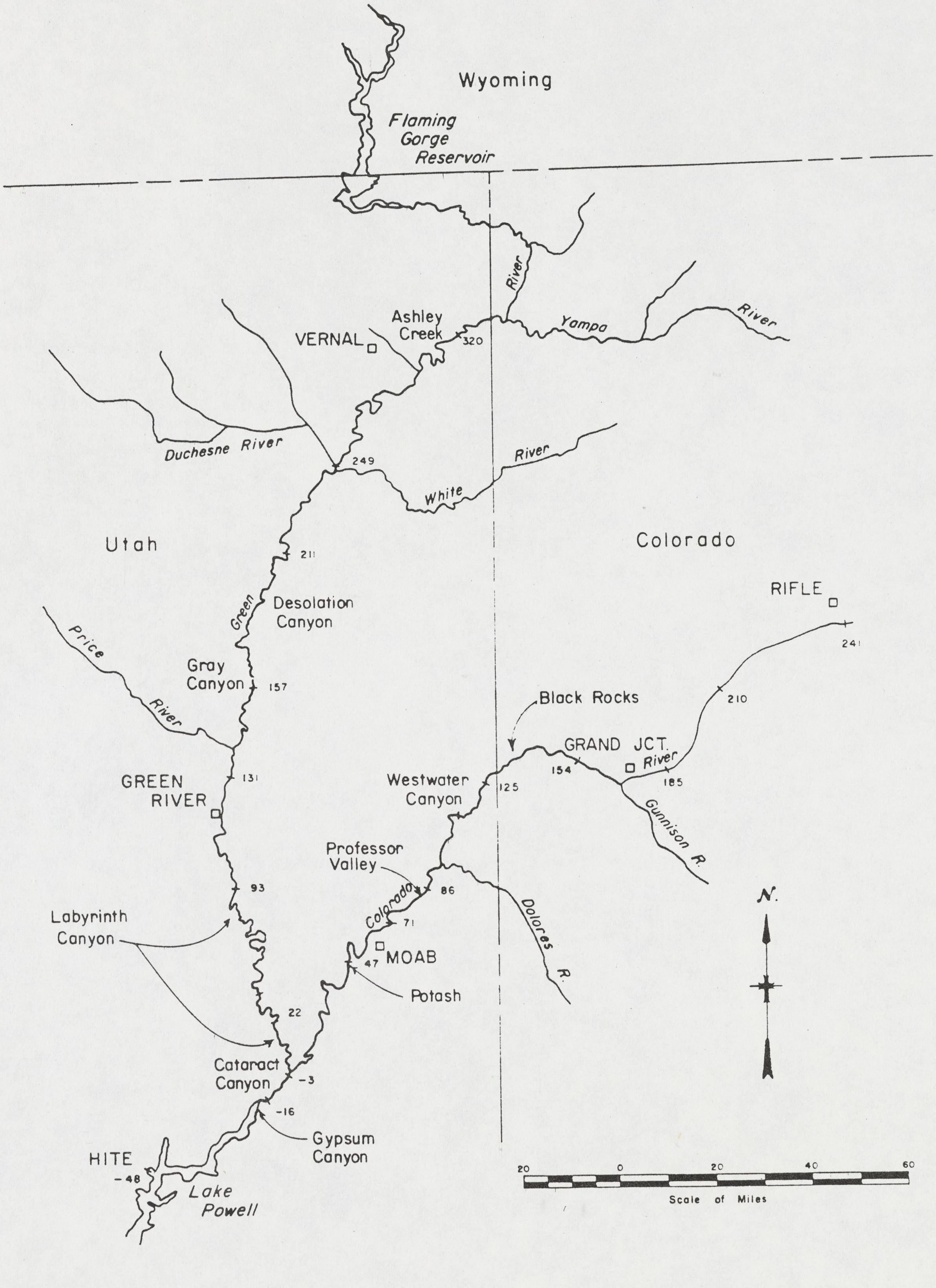


Figure 1 . Map of the study area.

METHODS

Movement, Spawning and Rearing Investigations

The movement of adult Colorado squawfish was followed using radiotelemetry. Fish were collected using electrofishing, gill nets, trammel nets, and traps. Colorado squawfish longer than 500 mm total length (TL) were surgically implanted with radio transmitters following procedures outlined by Tyus (1982). Transmitters weighed about 10-11 grams in air and had a life expectancy of approximately 6 months. All rare fishes collected were weighed (grams) and measured (TL, mm).

River reaches where radio-equipped Colorado squawfish were released were searched for the presence of these radiotagged fish at least biweekly. A larger area was searched at times when fish could not be located in the immediate study area. The majority of the search effort was conducted using boats; however, airplanes and helicopters were also employed. Location and movement of fish was identified by river mile (RM) with the confluence of the Green and Colorado rivers starting as RM 0. Other tributary river mileage was calculated using the tributary mouth as RM 0.

Possible spawning areas for Colorado squawfish were identified using radiotelemetered fish, and by analysing collections of larval fish. The radio tracking effort was intensified during the suspected Colorado squawfish spawning season (July-August). When more than one radio-equipped fish were found at a particular location -- a possible indication of pre-spawning or spawning activities in that area -- trammel nets were actively fished (drifted) there to determine if other Colorado squawfish might be present. Collected Colorado squawfish were measured in the usual manner, and observations were made for sexual products and any external reproductive characteristics of the fish.

During July and August radio tracking efforts were accompanied by qualitative sampling of the larval fish community. Larval fishes were collected from backwaters and shoreline areas at 2-5 river mile intervals, using fine-mesh hand nets. All larval fishes collected were preserved in formaldehyde and sent to the Larval Fishes Laboratory, Colorado State University, Fort Collins, for identification.

A special Colorado squawfish young-of-the-year (YOY) survey was conducted each fall to identify nursery areas, river regions occupied by YOY Colorado squawfish of fingerling size (25-60 mm). These surveys were done with seines (3x5 mm-mesh) from mid-September through October. The YOY surveys were quantitative; the areal extent of each seining effort was recorded, as were the water depth, water velocity, and substrate characteristics of the areas sampled (Archer et al. 1980). Sampling sites were river backwaters selected at about 5 mile intervals. At least two seine hauls were made in each backwater, and one similar haul was made along the adjacent river shoreline.

Backwater and Gravel Pit Investigations

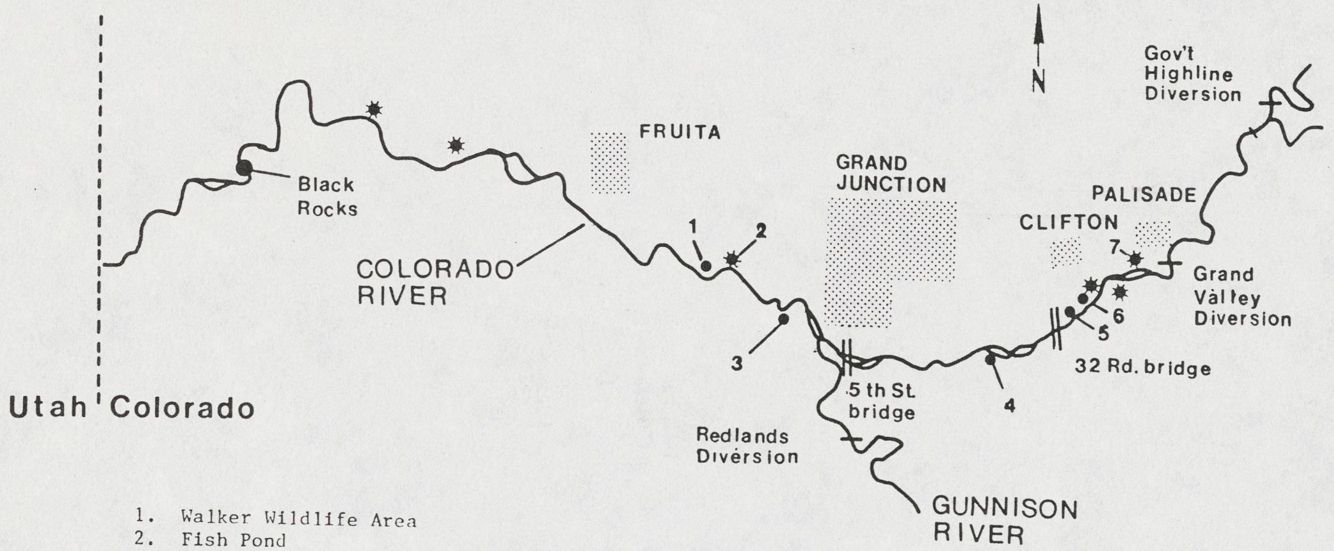
Earlier CRFP investigations suggested that river backwaters -- naturally indented areas with little or no water current -- are a particularly important habitat for young Colorado squawfish and humpback chub, and that the limited availability of such habitat could limit the survival of these young endangered fishes. If the relative scarcity of river backwaters is limiting, then an increase in backwater availability might appreciably increase the rate of survival for young endangered fishes.

Gravel pits are defined in this study as man-made habitats constructed within the river floodplain. They communicate with the river during periods of high river flow but may or may not communicate when river discharge is low. Gravel pits can be hydraulically similar to some natural backwaters. As gravel pits are common in the Colorado River floodplain of the Grand Valley and since such pits will continue to be developed in the future, it seems prudent to investigate the usefulness of these gravel pits as habitat for the spawning and rearing of endangered fishes.

During 1982 routine physicochemical and biological surveys were completed on several river backwaters and gravel pits along the Colorado River in the Grand Valley (Figure 2). These investigations were performed to determine the characteristics of habitats used by endangered fishes. Four river backwaters and seven gravel pits were examined on an approximate weekly schedule. Physicochemical analyses included dissolved oxygen (DO), salinity, conductivity, turbidity, and observations on water elevation (stage) and communication between the study area and the Colorado River.

Biological sampling of gravel pits was performed using trammel nets and seines during daylight (3x5 mm-mesh), electrofishing during darkness, and qualitatively sampling for larval fishes with a fine-mesh hand net.

The biological sampling program for river backwaters differed somewhat from that for gravel pits. Because river backwaters that contain young Colorado squawfish normally contain too few squawfish to allow extensive study of the interactions of fishes and their environment, the natural squawfish populations in study backwaters were supplemented using Colorado squawfish raised at Dexter (New Mexico) National Fish Hatchery. These hatchery fish were about 3 months old and 35-85 mm long when stocked into the experimental backwaters on 6 October 1982. Each fish was marked with a coded-wire microtag before stocking. The microtags consisted of a small (1x0.5 mm) piece of magnetized wire that was mechanically inserted in the cartilage of the fish's head. An electronic device detected the presence of a tag when the fish was passed through the detector. The fish need not be killed in order to detect the presence of a tag. Some of these tagged hatchery Colorado squawfish were also planted in gravel pits.



1. Walker Wildlife Area
2. Fish Pond
3. Connected Lakes
4. Island Backwater
5. Clifton Pond
6. Little Pond
7. Labor Camp

✸ young-of-the-year study sites

Figure 2 . Locations of river backwater and gravel pit study areas along Colorado River near Grand Junction, CO, 1982. Young-of-the-Year study sites* are those areas (4 river backwaters and 2 gravel pits) where hatchery-reared Colorado squawfish were stocked in early October, 1982.

Microtags contain physical marks on their surface that can be interpreted under a microscope. Because individual microtags are not unique and all tags from a given group contain the same information, such microscopic analysis allows the researcher to determine only of which group a tagged fish is a member. Decoding requires that the fish be killed and the tag removed. About 30,000 Colorado squawfish received microtags. Fish were separated into two groups of 10,000 each and 4 groups of 2,500 each. Each group received microtags unique to that particular group.

The smaller groups of Colorado squawfish were stocked into each of the four river backwaters (Figures 3-6), whereas the two larger groups were separately stocked into two gravel pits (Figures 7 & 8). Blocking nets were placed in the entrance to each river backwater at time of stocking; the next day the backwaters were sampled to obtain baseline catch per unit effort values after which block nets were removed. Before stocking the gravel pits as many predatory fishes as could be collected from one pit were removed using mechanical means (seining, trammel netting, trawling, and electrofishing).

Experimental backwaters were regularly examined as described above. Gravel pits and river backwaters were sampled once or twice a week. All predatory fishes collected were passed through the tag detector to determine the presence of tagged Colorado squawfish within the stomach of the predator. Six predators of each species were killed initially to validate the accuracy of this dectection technique. Collected fish were measured and marked with a pelvic fin clip. Recaptured fish were noted; data were used in cumulative census techniques of population estimation (Ricker 1975).

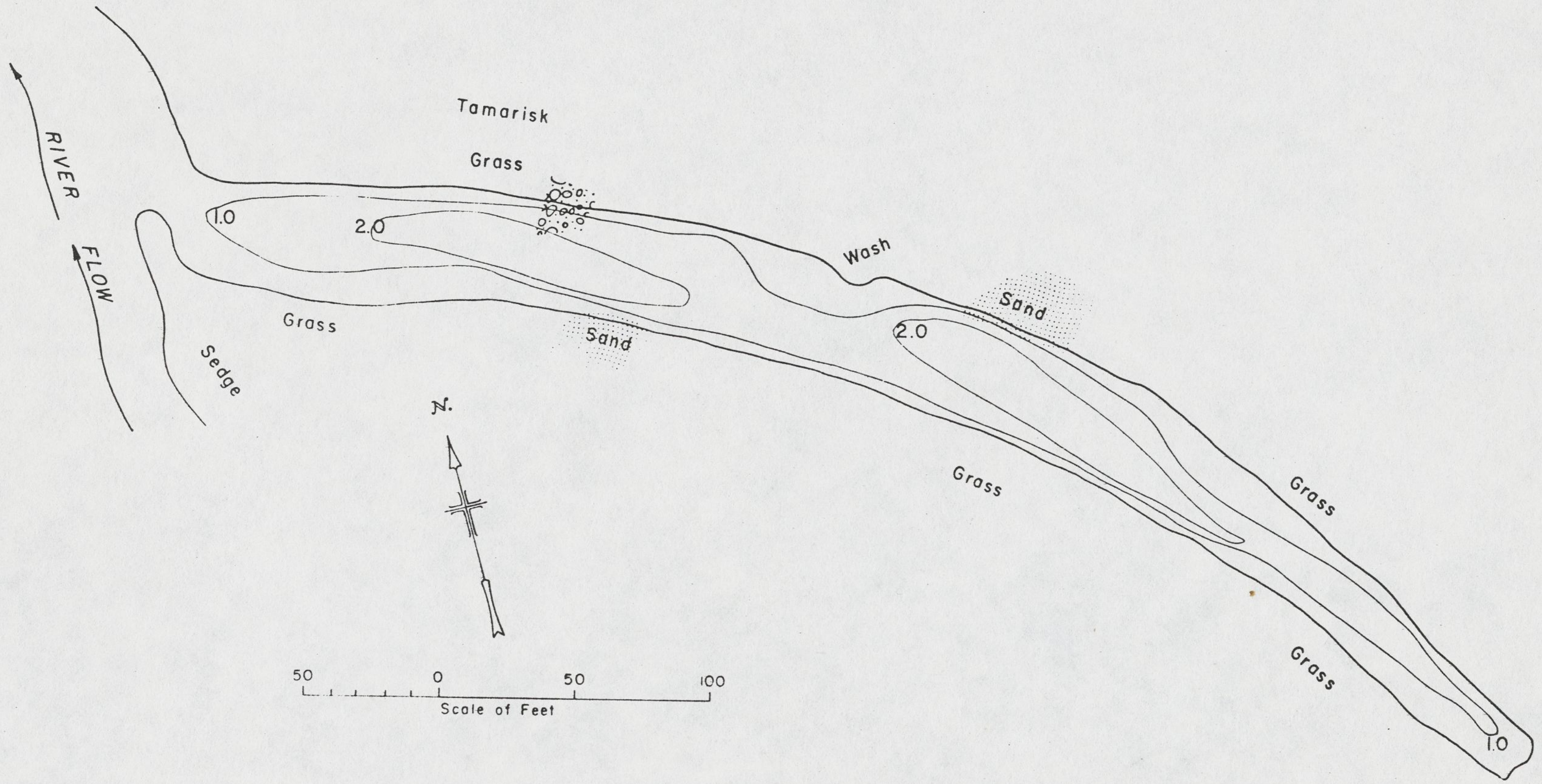


Figure 3 . Bathometric map of Colorado River backwater at river mile 146.9 (0.2 ha). Contour interval is in feet.

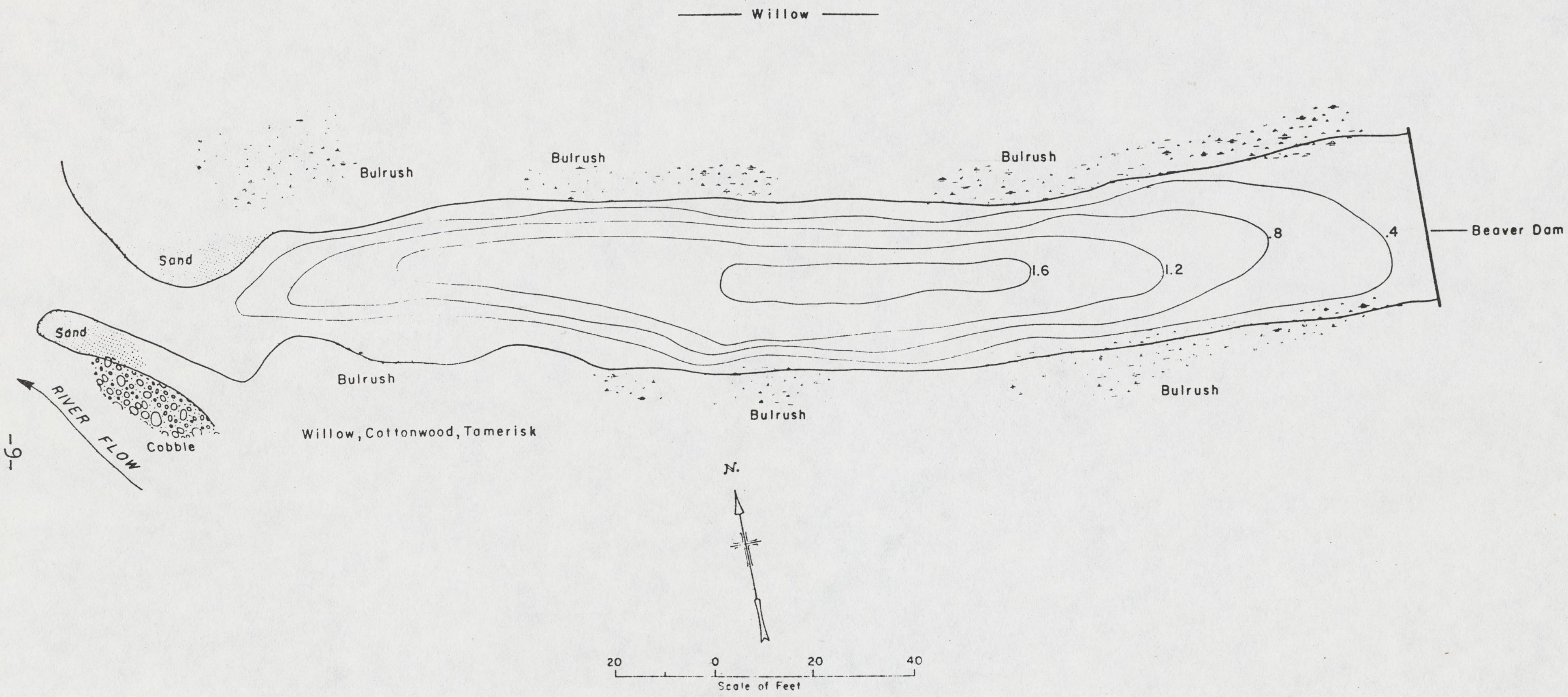


Figure 4 . Bathometric map of Colorado River backwater (0.1 ha) at river mile 151.6. Contour interval is in feet.

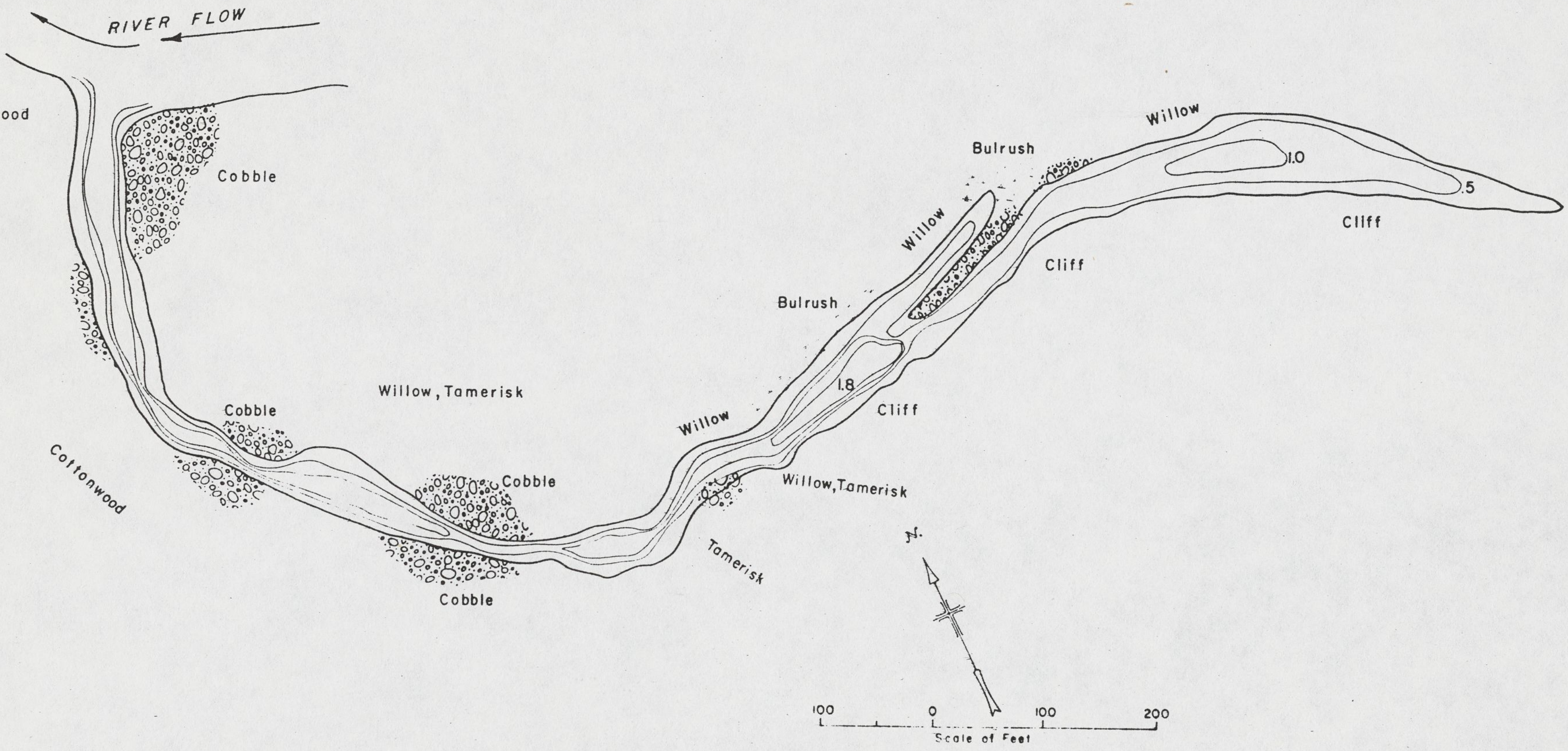


Figure 5 . Bathometric map of Colorado River backwater (0.6 ha) at river mile 179.5. Contour interval is in feet.

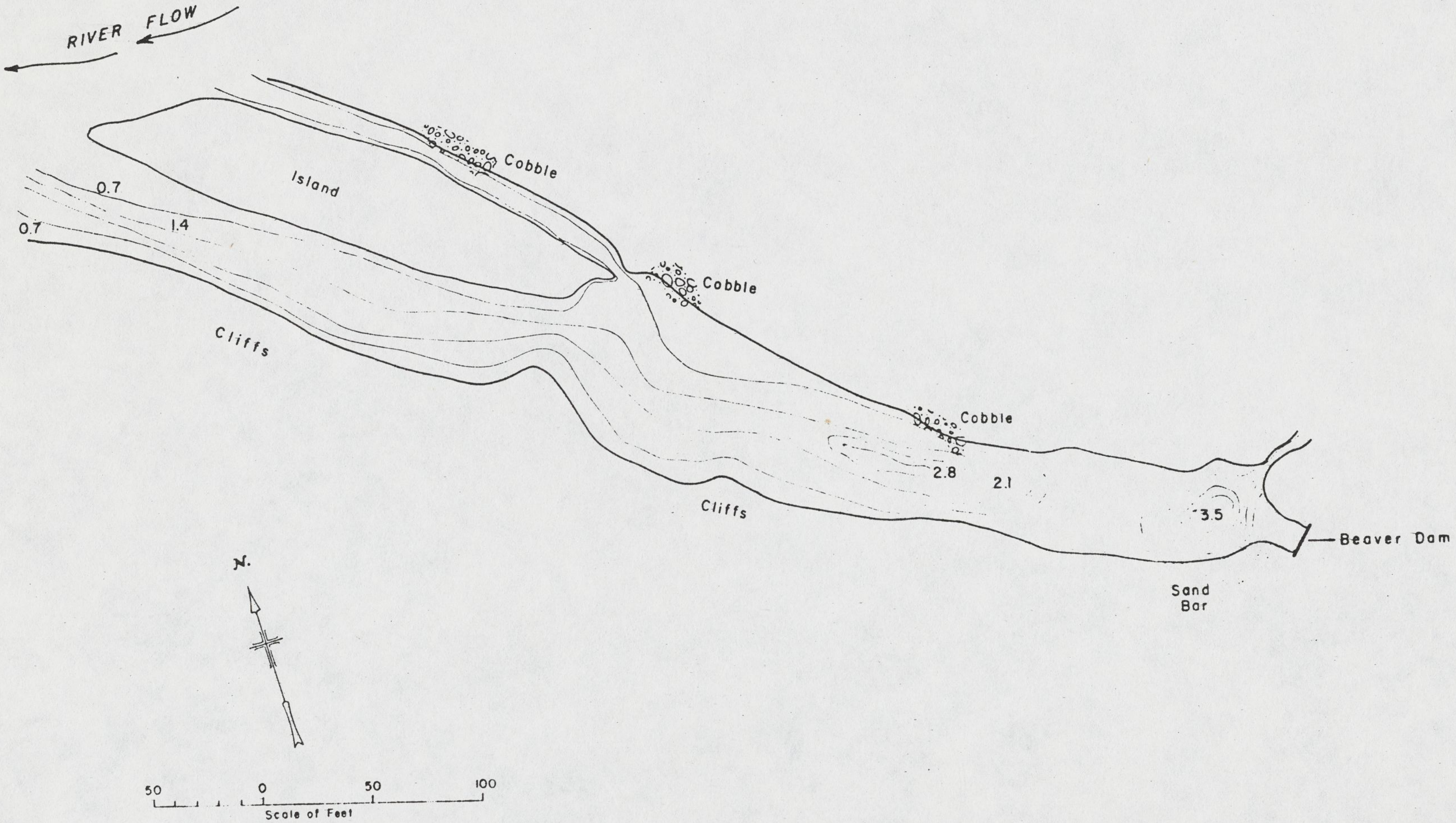


Figure 6. Bathometric map of Colorado River backwater (0.3 ha) at river mile 181.8. Contour interval is in feet.

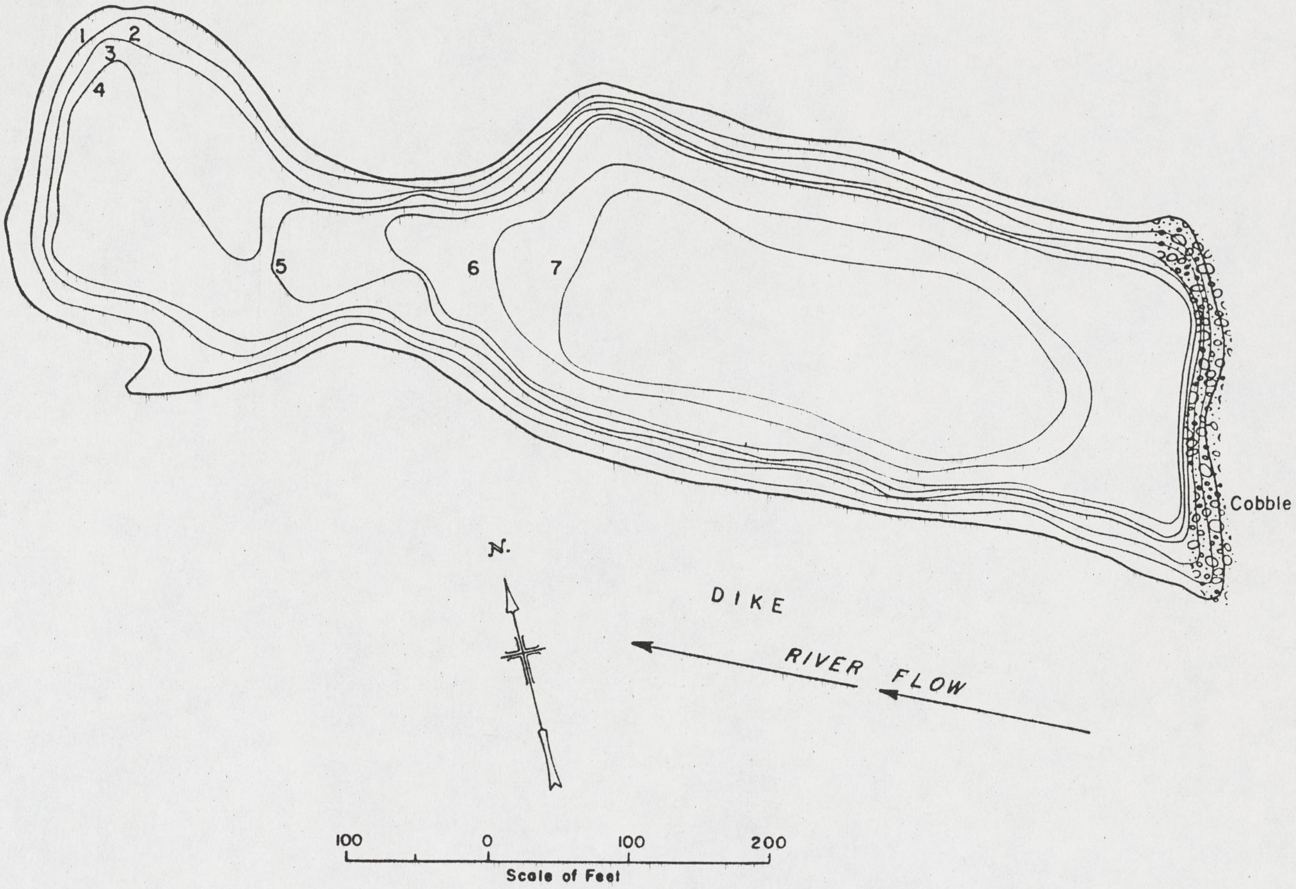


Figure 7 . Bathometric map of Fish Pond (1.7 ha). Contour interval is in feet.

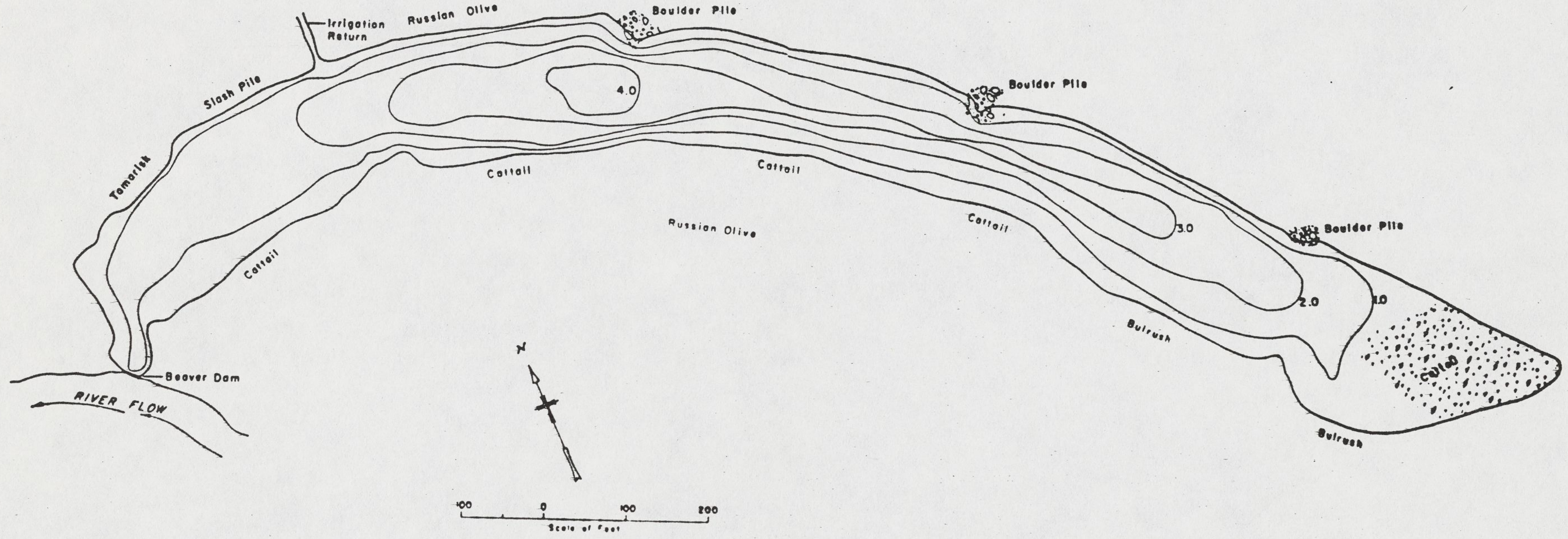


Figure 8 . Bathometric map of Labor Camp Pond (2.6 ha). Contour interval is in feet.

RESULTS AND DISCUSSION

Radiotelemetry

Six Colorado squawfish collected from upper Lake Powell near Gypsum Canyon were implanted with radio transmitters, between April 6 and May 28 (Table 1). One additional fish was implanted with an ultrasonic transmitter on April 6. Contact was lost with three fish, including the ultrasonic unit, as soon as the fish were released. However, the remaining four radio-equipped fish were periodically located over periods of time ranging from 5 days to 6 months after release. Three of these fish were followed downstream into the reservoir in April where contact was lost in deep water (Figure 9). Although one of these fish was never recontacted, the remaining two fish were recontacted in the Gypsum Canyon area in May and June. The fish that was relocated in June was again found in the Gypsum Canyon area at the end of July when radio tracking efforts were terminated in the upper reservoir.

The most noteable movement was exhibited by the radiotelemetered fish that remained in the vicinity of Gypsum Canyon until early July. In mid-August this fish was found at RM 140, about 4 miles upstream from Black Rocks; an upstream movement of about 160 miles. In September the same fish was located near Clifton, Colorado, an additional 40 miles upstream.

Four Colorado squawfish collected from the Gunnison River (1 fish), Colorado River (1 fish), and the region of the confluence of the two rivers (2 fish), were implanted with radio transmitters. Twelve additional Colorado squawfish collected from flooded gravel pits connected to the Colorado River; eight from Walker Wildlife area (RM 163.6), two from Island Backwater (RM 175.3), and two from Labor Camp (RM 183.2) were implanted with radios. Fish were implanted with radio tags and released between May 14 and June 18 (Table 2). Radio contact was maintained with most fish through August, and with some fish into October. Of the fish collected and tagged within gravel pits, nine were released inside the pits whereas three were released outside the pits in the river proper. Fish were released into the river because they were apparently leaving the pits when captured in trap nets. All fish released within gravel pits subsequently moved into the Colorado River. One of the fish released in Walter Walker Wildlife Area (WWWA) subsequently entered Connected Lakes pit for a short time while the fish was moving upstream. A Gunnison River fish apparently died sometime after implantation; its movement is not reported herein.

No long distance (>50 miles) movements were observed for Colorado squawfish released in the Grand Junction area. However, total movement equaling about 40 miles was observed for some fish. In general, fish collected from WWWA (Figure 10) moved farther than did fish tagged in upstream areas (Figure 11). Most of the radio-equipped fish remained in the Grand Junction area during the study period; however, one Colorado squawfish released in the Gunnison River and four fish from WWWA moved to the Black Rocks region (RM 136) before contact was lost. Although

Table 1. Radiotelemetered Colorado squawfish in upper Lake Powell, Colorado River, spring 1982

Tag No.	Total Length(mm)	Weight(g)	Sex	Capture Site (RM)[b]	Monitored Period
3212	545	1200	-	CØ 198.5	4/06 - 10/25
3109	660	1900	-	CØ 189.5	4/22 - 6/08
2506	646	1840	-	CØ 190.5	5/10
3220	550	1000	-	CØ 193.5	4/11 - 4/16
3141	671	2100	-	CØ 195.9	4/04 - 7/28
3198	690	2420	-	CØ 182.8	5/28
2582[a]	660	2600	-	CØ 190.2	4/26

[a] Fish implanted with ultrasonic transmitter.

[b] Numeric data are river miles (RM) locations; CØ = Colorado River

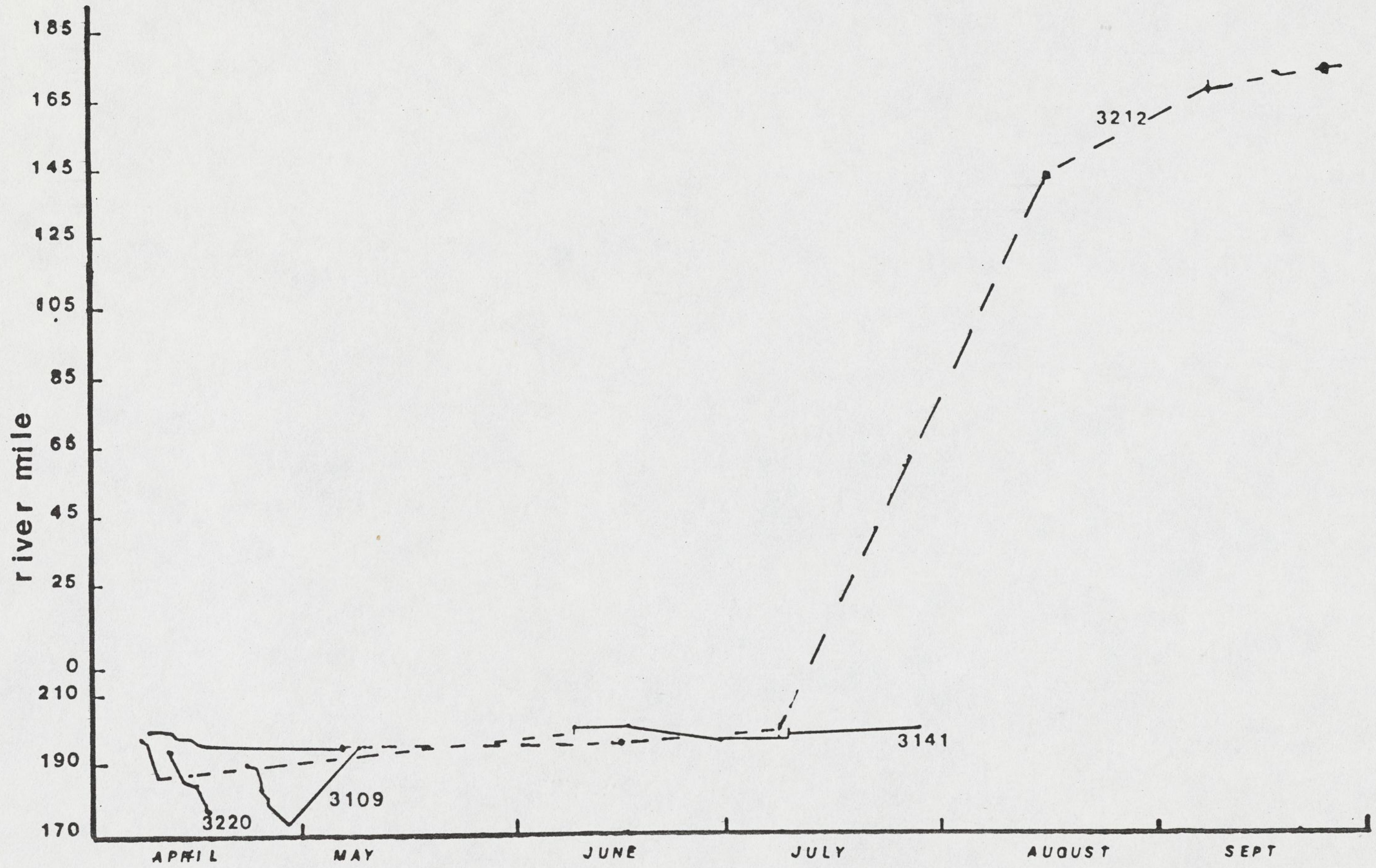


Figure 9. Movement of four radio-equipped Colorado squawfish released near upper Lake Powell, Utah, 1982.

Table 2. Data for 16 Colorado squawfish implanted with radio transmitters in the Grand Junction area during 1982.

Tag No.	Total Length (mm)	Weight (g)	Sex	Capture Site (RM)[b]	Monitored Period
3127	732	4240	-	Island BA (175.3)	6/02 - 8/26
3180	611	1630	-	GU 002.0	5/19 - 9/29
3139	726	3620	-	CO 184.1	5/24 - 8/19
2728[a]	774	5000	-	GU 000.0	5/26 - 8/27
3134	749	3680	-	GU 000.0	5/26 - 7/27
3160	523	1400	-	Walker WA (163.4)	5/21 - 11/03
2531	570	1600	-	Walker WA (163.4)	5/14 - 9/03
3170	828	5714	-	Walker WA (163.4)	5/14 - 9/21
3187	766	4342	-	Walker WA (163.4)	5/14 - 8/04
3100	616	2360	-	Island BA (175.3)	6/16 - 11/03
3144	570	1600	Ripe Male	Walker WA (163.4)	6/16 - 9/29
2522	754	3840	Ripe Male	Walker WA (163.4)	6/15 - 8/10
2905	555	1300	-	Walker WA (163.4)	6/14 - 9/29
2579	572	1340	-	Walker WA (163.4)	6/14 - 8/20
3119	705	3200	-	Labor Camp (163.4)	6/18 - 6/23
3190	739	3590	-	Labor Camp (163.4)	6/18 - 7/30

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[a] Based on our observations in the field, this fish probably died sometime after implantation

[b] Numeric data are river mile (RM) locations;
BA = backwater; GU = Gunnison River;
CO = Colorado River; WA = Wildlife Area (Walter Walker Wildlife Area)

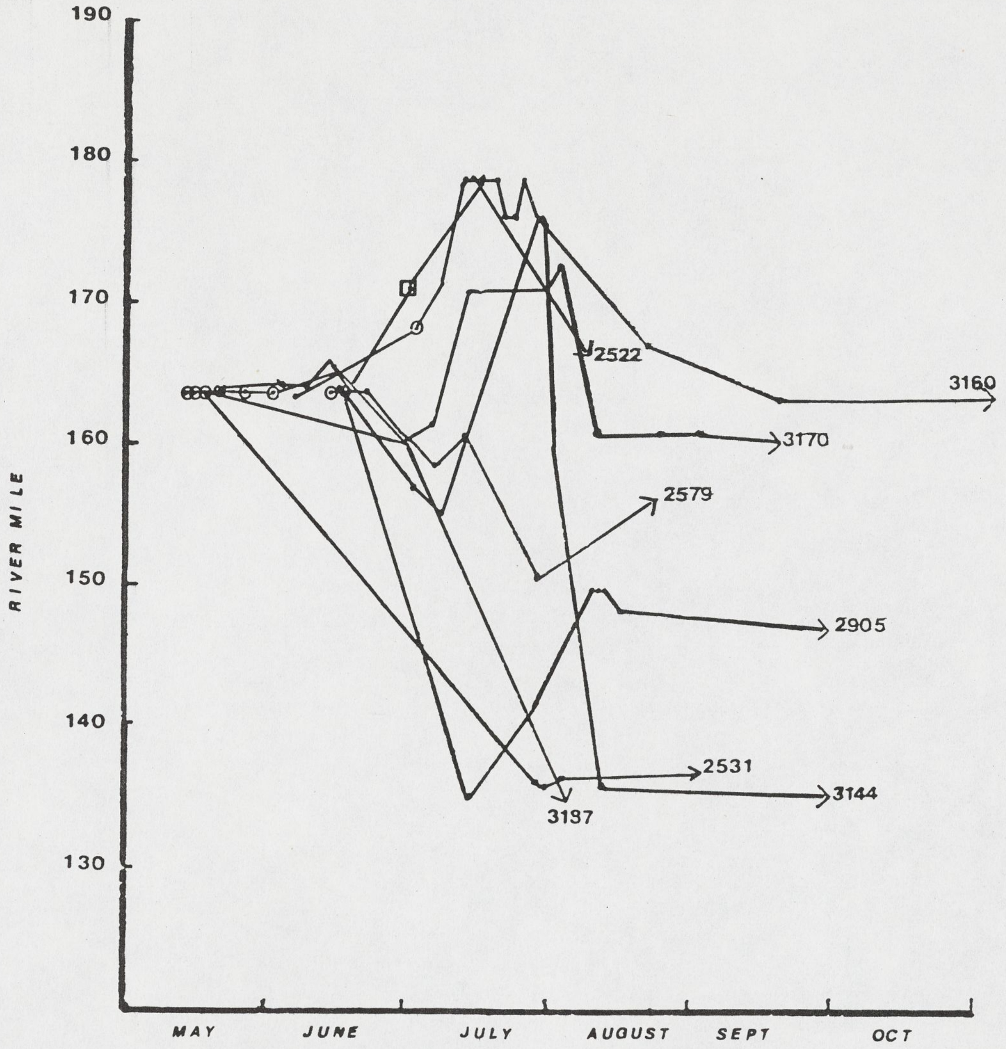

Figure 10 . Movement of radio-equipped Colorado squawfish released in or near Walter Walker Wildlife Area, 1982. Tag number for each fish is given.

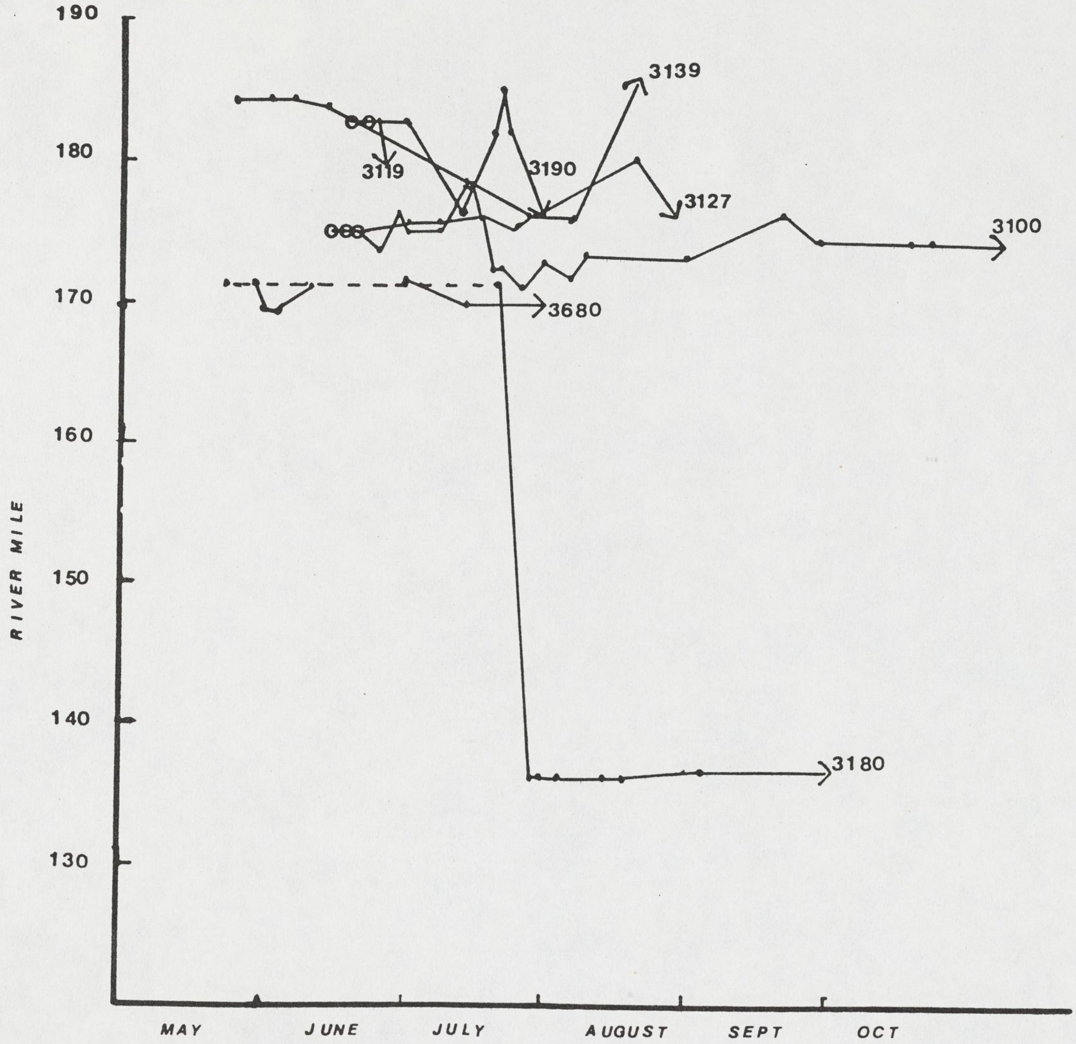

Figure 11 . Movement of radio-equipped Colorado squawfish released near Grand Junction, 1982. Tag number for each fish is given.

contact was lost with most fish by the end of August, intensive searches between Palisade and Westwater continued through November; one search was made below Westwater in September. The radio transmitters were near the end of their expected battery life about the time contact was lost; however, the possibility that the fish left the study area cannot be ruled out.

Movement of radio-equipped Colorado squawfish was closely monitored during the spawning period in an attempt to locate spawning areas. On July 13 three radio-tagged fish were found in a small pool in a side channel at RM 178.3 near Clifton, Colorado. Trammel nets drifted through the pool collected nine Colorado squawfish including one radio-tagged fish; five of these fish were ripe males. The remaining fish were tuberculated in a pattern believed typical of mature females, but sex products could not be produced when pressure was applied to the abdomen. An additional radio-equipped Colorado squawfish was subsequently observed in the vicinity of this pool.

A large eddy at RM 176 was independently visited by five radio-telemetered Colorado squawfish during the subsequent two weeks. A ripe male Colorado squawfish was collected from this location. A radio-tagged Colorado squawfish recaptured from a nearby side channel had a distended abdomen and had gained about 500g in the six weeks since it was released. Although sex products were not expressed from this fish, it was most likely a maturing female.

Although an aggregation of ripe males is a significant observation, it does not necessarily indicate that spawning occurred in the immediate vicinity. Males of most minnows ripen earlier than females, and they can move considerable distances after ripening before spawning occurs (Breder and Rosen 1966). We encountered ripe males in WWWA (RM 163.6) one month before the aggregation at RM 178.3 was noted. We equipped two of these fish with radios; one radiotagged fish was subsequently found among the group of radiotelemetered fish that constituted the aggregation described above. One of these fish moved 10 miles, and the other 15 miles, during the time they were ripe.

Although spawning did not necessarily occur in the immediate vicinity of RM 176.0 or 178.3, it did occur in the Grand Junction area as demonstrated by the collection of larval Colorado squawfish in August. The aggregation of mature Colorado squawfish near Clifton, Colorado occurred when river flows were receding and water temperatures were near 20 C (Figure 12).

In addition to the radio tracking effort in the Grand Junction area the FWS also conducted similar radio tracking work in the Green River. Green River work was a continuation of the previous 2 years radiotelemetry to further define movement and spawning for Colorado squawfish. Eleven adult Colorado squawfish were radio-tagged and tracked by FWS in the Green River during 1982. Collection of adult fish for tagging began on May 4th and by May 20th eleven fish ranging in size from 522 to 810 mm

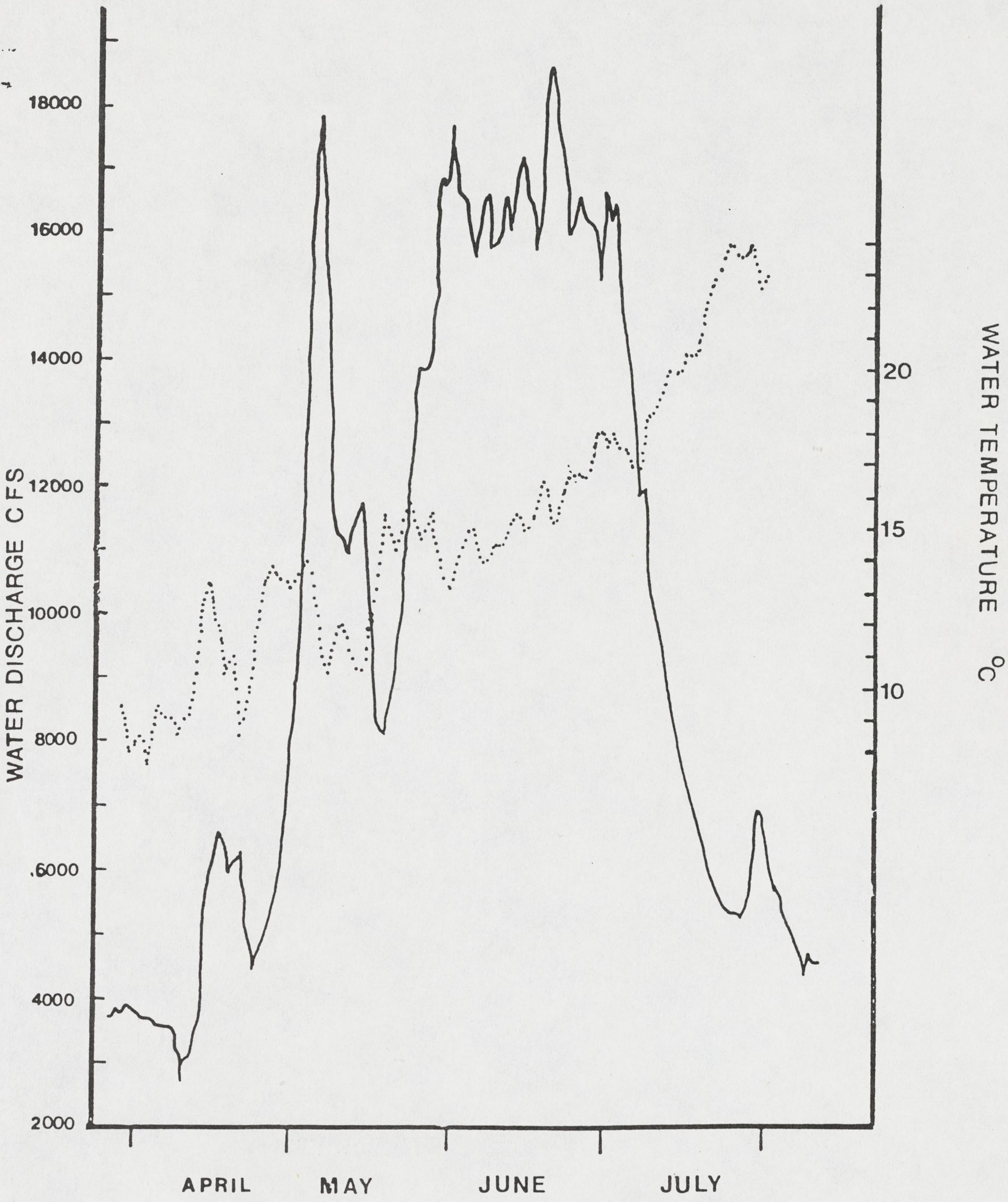

Figure 12 . Colorado River discharge (solid line) and temperature (dotted line) at the State Line gauge, 1982.

TL had been implanted. Movement patterns of these fish were somewhat different than those observed in the Green River in 1980 and 1981; with larger fish moving into or remaining in whitewater canyon areas after the spawning season. In addition, radio-tagged fish lead us to a previously suspected spawning site in Gray Canyon. Collections of ripe fish in Gray Canyon and subsequent young-of-the-year studies provide the first documentation of this spawning site. One 810 mm fish (No. 3001) moved about 322 miles during the study period. Colorado squawfish implanted in the Green and White rivers apparently used the lower Yampa and Gray canyons for spawning in 1982. The movement patterns of radio-telemetered Green River fish are shown in Figure 13.

During the 1982 spawning season (July-August) the Vernal Station conducted sampling in Yampa Canyon, on the Yampa River and in Split Mountain and Gray canyons on the Green River. A total of seven ripe Colorado squawfish were collected in the vicinity of radio-tagged fish in Gray Canyon between July 13 and July 22. Only one collecting trip was made to the lower Yampa River where one ripe fish was collected. The reason for the comparative absence of ripe fish in the Yampa was provided by co-workers doing a Yampa River fish study (Stoneburner, 1983), which indicated that spawning occurred about 3 to 4 weeks later than our sampling in 1982 (also 3-4 weeks later than spawning in 1981). Study results indicated that spawning occurred in Gray Canyon about 3 weeks earlier than spawning in Yampa Canyon.

Larval and Young-of-the-Year (YOY) Surveys

Larval sampling in the Colorado River was initiated in mid-July and performed on a weekly basis between Palisade and the Westwater Ranger Station through August. Two sampling trips were made during August in the river reach between Westwater Canyon and Potash, Utah. An attempt was made to sample below Potash in late August; however, this effort was canceled because of equipment failure. Sampling was also accomplished in upper Lake Powell in July, concurrent with radio-tracking work.

Larval Colorado squawfish (148 individuals) were found throughout the study area (Figure 14). Colorado squawfish larvae (107 individuals) were most frequently encountered and were in highest relative abundance in samples taken from the river reach below Westwater Canyon (Westwater Canyon itself was not sampled). Colorado squawfish larvae were first collected from the river reach above Loma, Colorado later in the season than from the downstream river reach; this might reflect marked differences in the spawning time between river reaches.

Larval data for the Green River have not been completely analyzed at this time.

In mid-September through October, when YOY Colorado squawfish were large enough to be identified in the field, the Colorado River and Green River were quantitatively sampled using 3x5 mm mesh seines. Colorado River YOY (30-40 mm TL) Colorado squawfish were only collected below

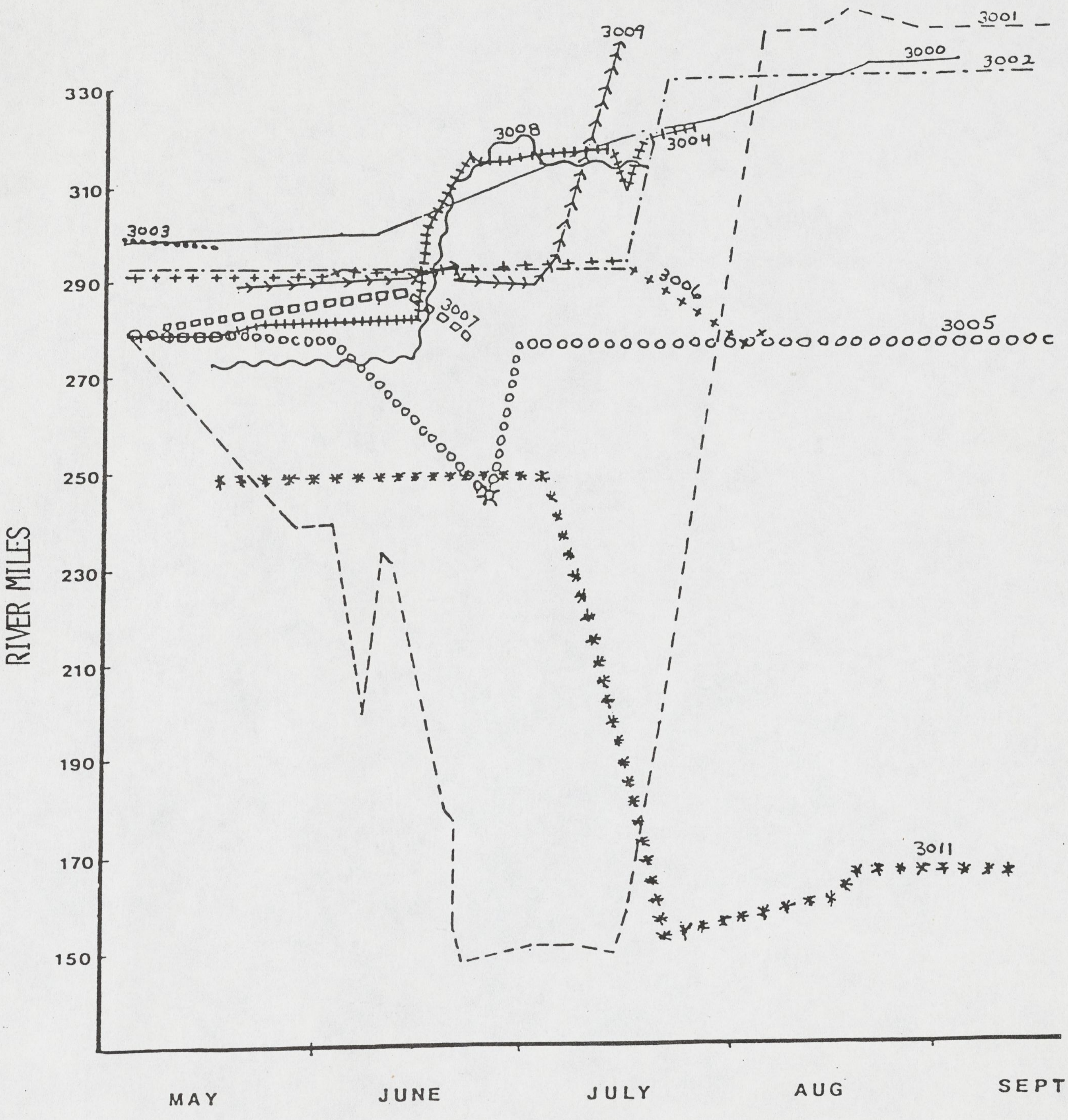

Figure 13 . Movement of radiotelemetered Colorado squawfish in the Green River, 1982, FWS Study. River miles given from the confluence.

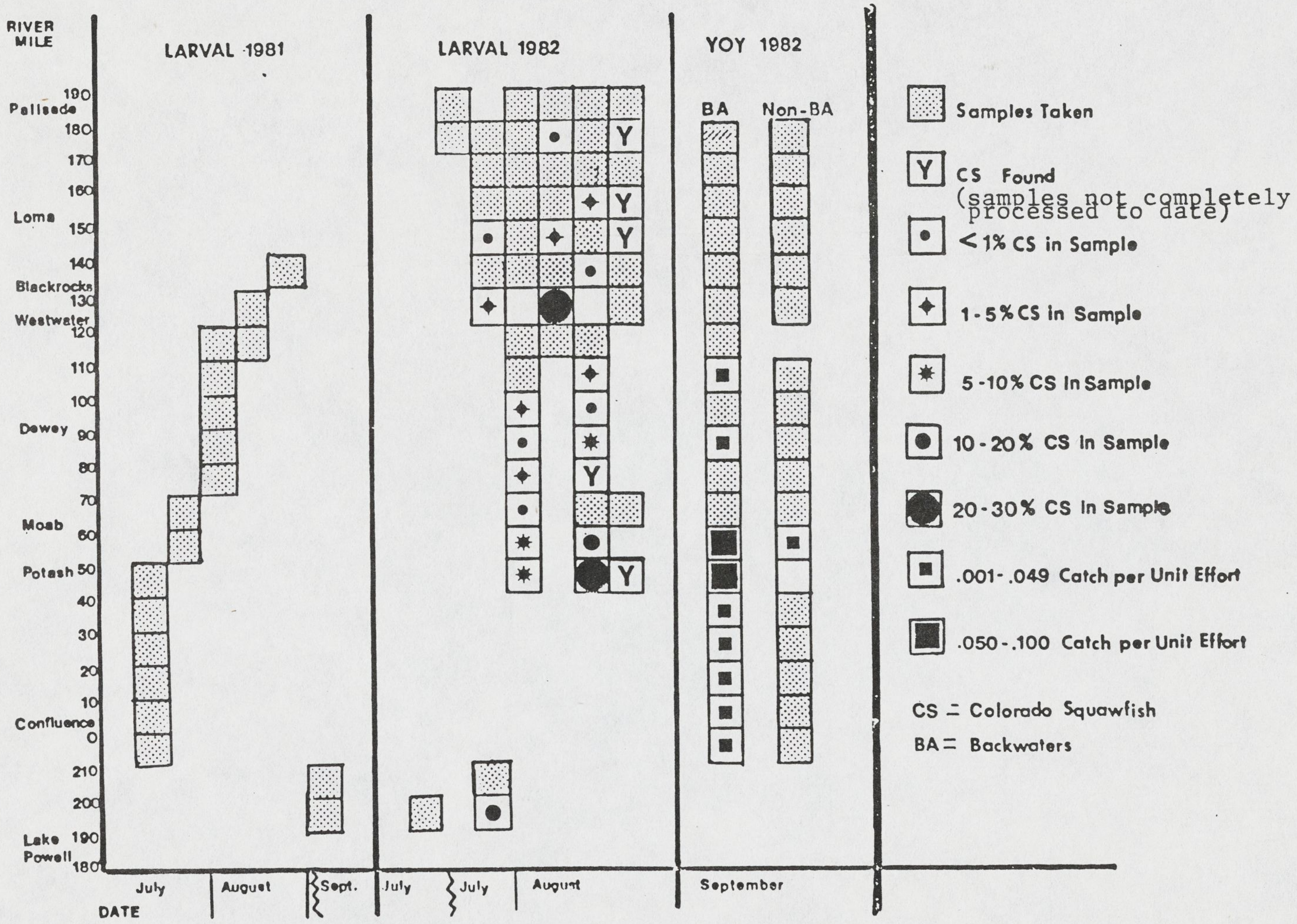

Figure 14 . Distribution and relative abundance of larval and fingerling Colorado squawfish, Colorado River, 1982. Larval data from 1981 are also provided. CS = Colorado squawfish

Westwater Canyon; areas with high YOY Colorado squawfish abundance were correlated with earlier high relative abundance of larval fish (Figures 14 and 15). YOY Colorado squawfish catch per effort for the Green River is shown in Figure 16. In the Green River catch per effort of YOY Colorado squawfish was reduced to about one-half the average obtained in previous years. This reduction no doubt reflects the very high water levels in 1982 and does not indicate a poor spawning year. Shallow backwater habitats were virtually non-existent during the YOY collections on the Green River. Indeed, it is surprising that our collections produced 637 YOY fish in the Green River and we interpret these data to mean that reproduction was as high as in previous years. However, it is possible that YOY survival may be decreased due to the unfavorable water conditions.

Backwater and Gravel Pit Investigations

Adult Colorado squawfish and razorback sucker were collected from nearly all of the gravel pits investigated (Table 3). When river runoff subsided and gravel pits became isolated from the river, Colorado squawfish were no longer found in the pits; however, razorback sucker continued to be collected from four gravel pits (numbers 1,2,4, and 7 in Table 3). Colorado squawfish evidently moved out of the gravel pits before the pits became isolated. Fyke nets set in the entrance of WWWA caught 12 Colorado squawfish leaving WWWA in late June, when the river began receding. Another Colorado squawfish was caught leaving WWWA in early July. Fyke nets collected two adult Colorado squawfish leaving and one entering Labor Camp pit during that same period. Post-runoff sampling resulted in the collection of two larval Colorado squawfish in Island Backwater pit (Table 3) on August 11. No larval Colorado squawfish were collected from the remaining gravel pits.

Largemouth bass (Micropterus salmoides) and green sunfish (Lepomis cyanellus) were the dominant predators in both Fish Pond (Figure 17) and Labor Camp (Figure 18). However, Fish Pond also had large numbers of bluegill (L. machrochirus) and black crappie (Pomoxis nigromaculatus).

Before Colorado squawfish were stocked, 155 largemouth bass, 247 green sunfish, 881 bluegill and 1483 black crappie were removed from Fish Pond. Population estimates made after small squawfish were stocked showed appreciably larger populations of largemouth bass in Labor Camp than in Fish Pond (Table 4).

In spite of our removal effort, green sunfish remained common in Fish Pond. Largemouth bass less than 350 mm in length were the predators that most frequently contained stocked Colorado squawfish. The frequency of largemouth bass containing stocked Colorado squawfish was high early in the study, and diminished over time (Table 5). This decrease is probably a result of decreased numbers of available Colorado squawfish and a decline in water temperature (Figure 19) with an attendant decline in largemouth bass feeding rate.

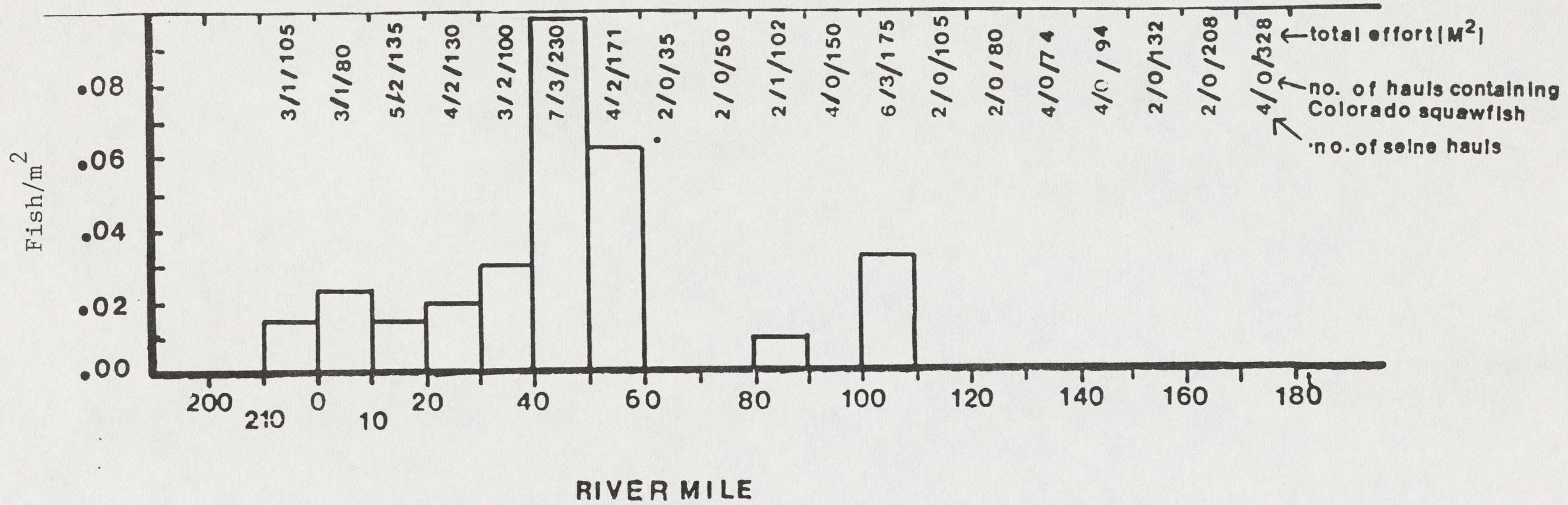

Figure 15 . Mean catch per unit effort (fish/m^2 seined) of young-of-the-year Colorado squawfish, Colorado River (Spanish Bottom, Utah to Palisade, Colorado) September 1982.

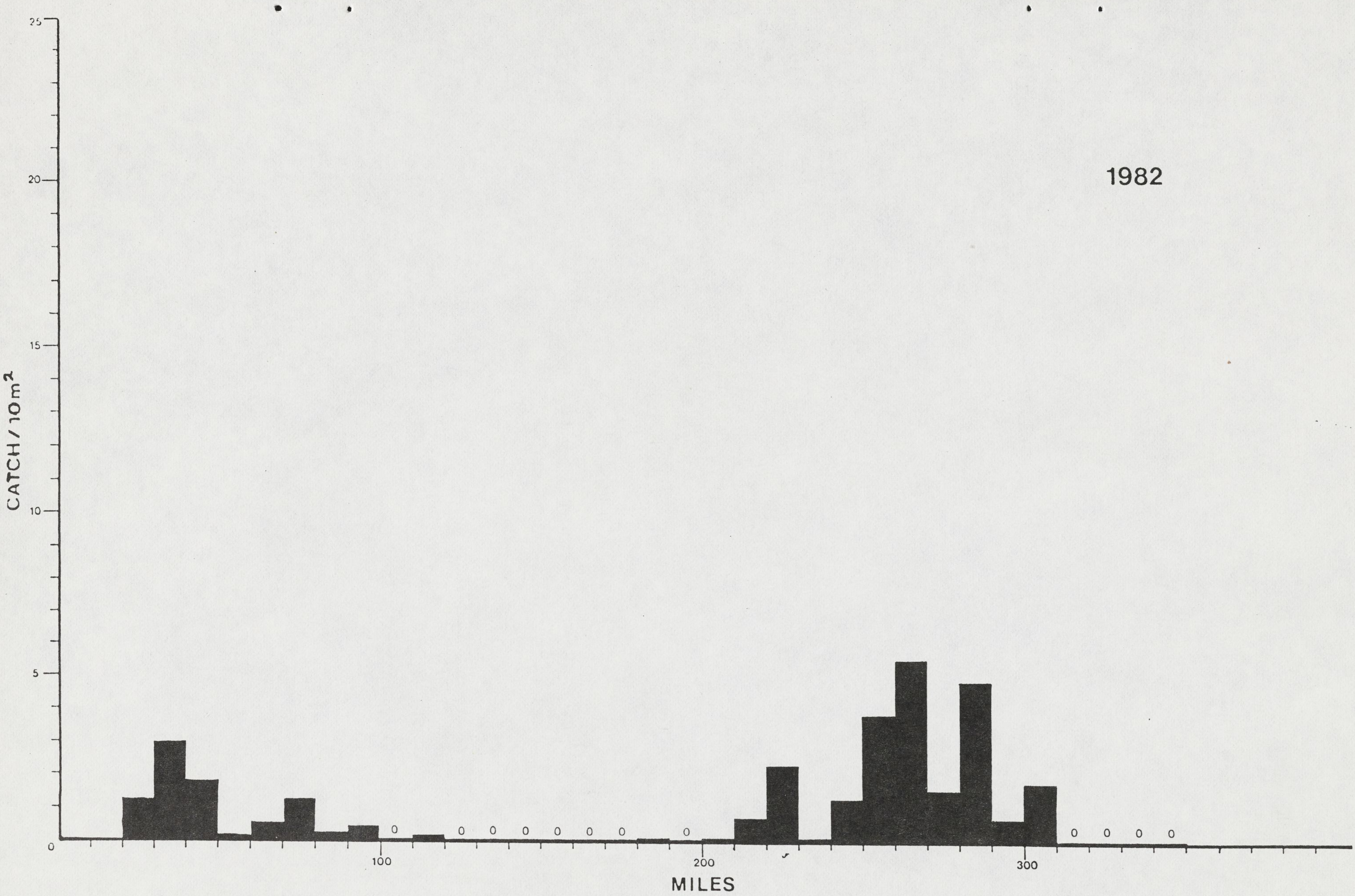

Figure 16 . Catch per effort of young-of-the-year Colorado squawfish, special investigation, backwater habitat, Green River, 1982. One unit of effort equals $10m^2$ sampled with seines.

Table 3. Total number of Colorado squawfish and razorback sucker collected from gravel pits connected to the Colorado River, 1982.

Gravel pit	River mile (RM)	Colorado squawfish	Razorback suckers
1. Walter Walker Wildlife Area (WWWA)	163.6	23[ab]	6[a]
2. Fish Pond	165.2	0	1[a]
3. Connected Lakes	167.8	0[c]	5[a]
4. Island Backwater	175.3	2	1
5. Clifton Pond	177.8	0[c]	8
6. Little Pond	179.2	1	0
7. Labor Camp	183.2	10	0[c]

a. Some of these fish were later recaptured in the same pond.

b. Collection effort was about equal in pits 2-7; collection effort was considerably greater in pit 1 than in other areas.

c. Although not collected during the gravel pit monitoring program, 1982, these species were collected in these pits during earlier CRFP efforts, or by earlier workers from other agencies.

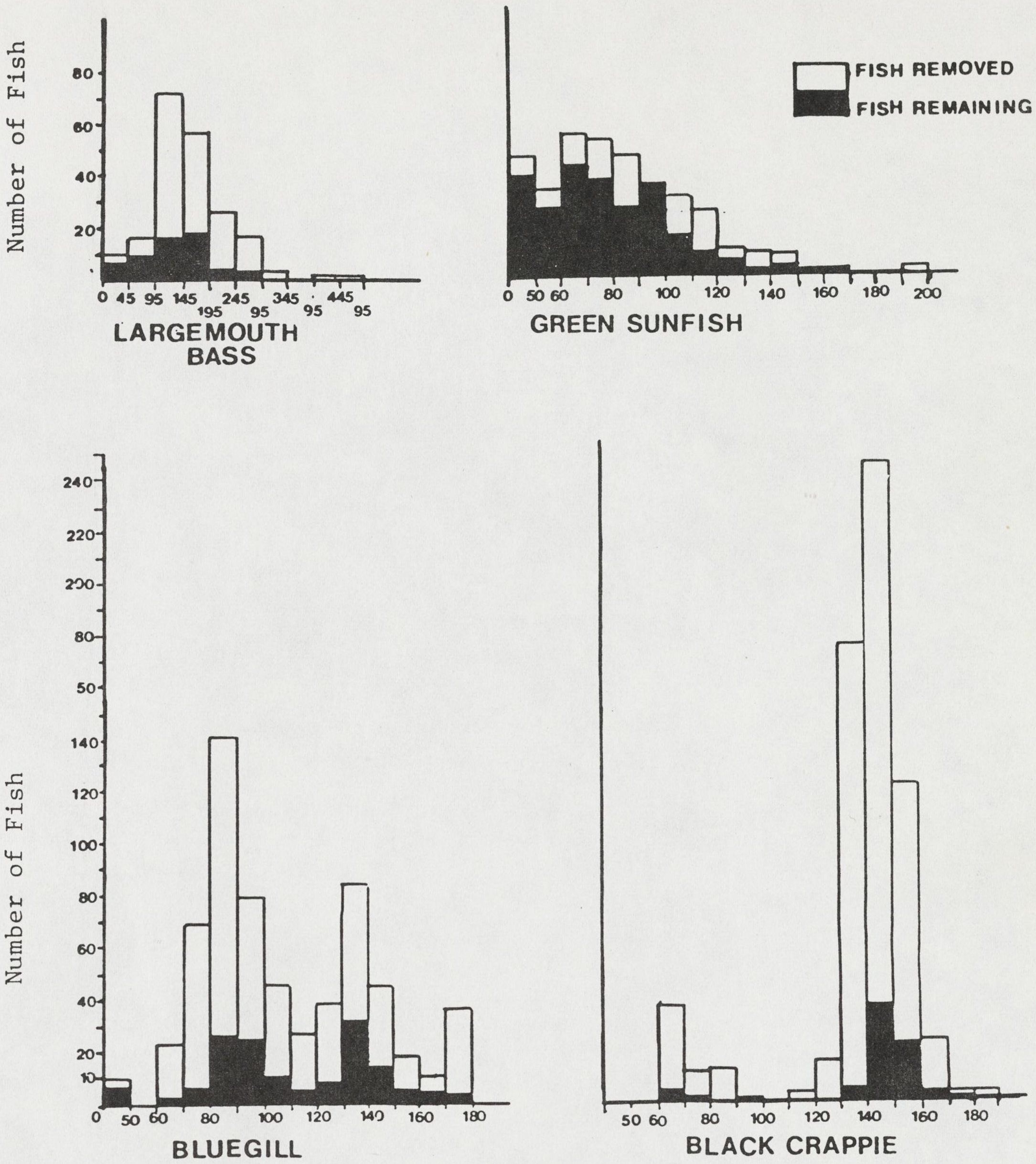

Figure 17 . Length frequency of four species of predator fish in Fish Pond. Open bars represent fish removed from Fish Pond before Colorado squawfish were stocked. Closed bars represent fish collected after Colorado squawfish were stocked. X-axis is total length in mm.

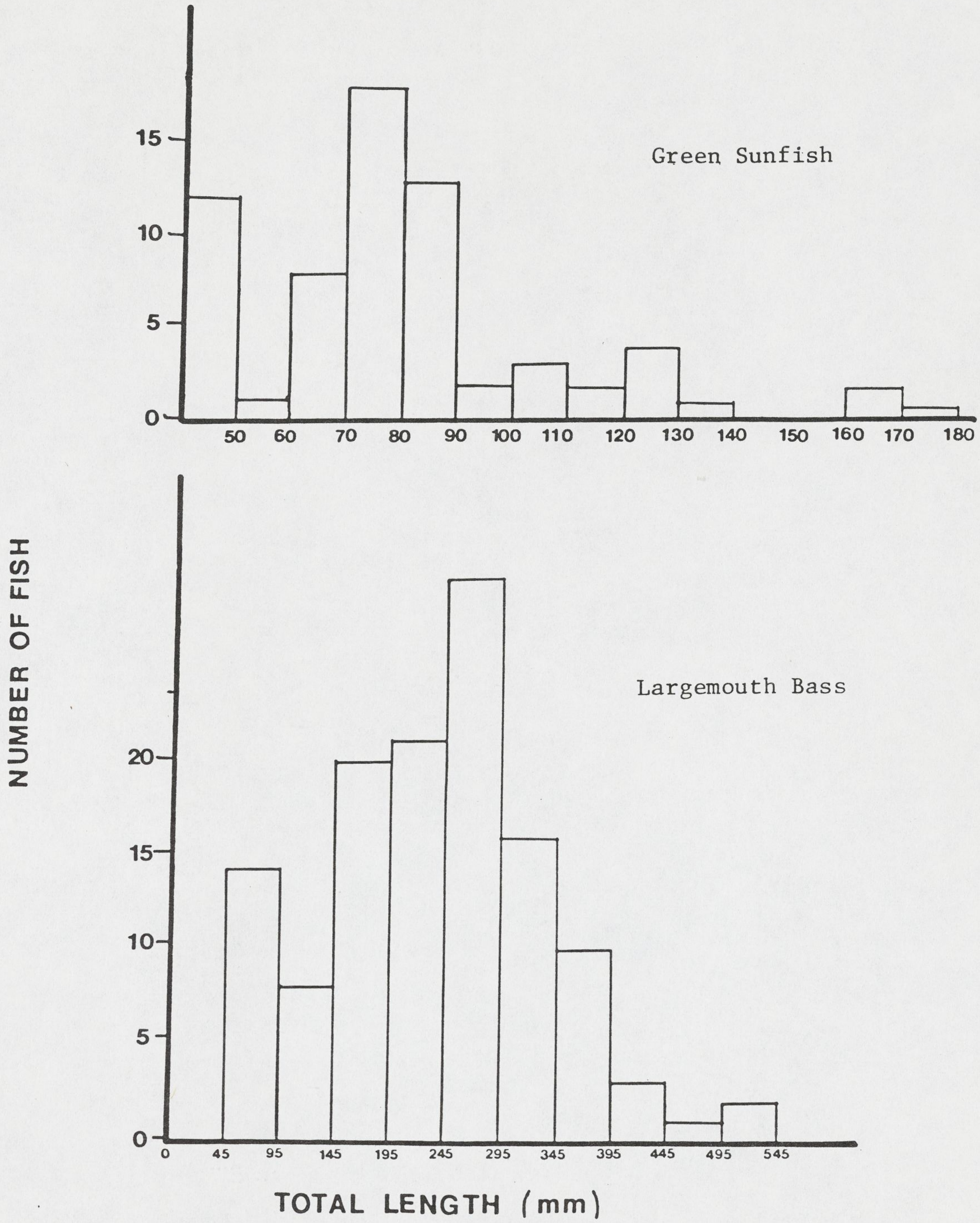

Figure 18 . Length frequency of green sunfish (above) and largemouth bass (below) in Labor Camp, fall, 1982.

Table 4. Population estimates derived from multiple capture data on predatory species in Labor Camp and Fish Pond, fall, 1982.

Species[a] Size range (mm)	FISH POND Number (N)	FISH POND 95% Confidence	LABOR CAMP Number (N)	LABOR CAMP 95% Confidence
GS < 100	3569	159-14306	1548	171-9842
GS > 100	108	62-442	59	44-88
LG < 151	68	42-168	1032	351-4576
LG 151-350	30	21-52	226	211-246
LG > 350	--	--	17	13-23
BC < 130	4	3-6	--	--
BC > 130	164	79-1998	--	--
BG < 115	632	43-1226	--	--
BG > 115	246	103-640	--	--

[a] GS = green sunfish; LG = largemouth bass;

BC = black crappie; BG = bluegill

Table 5. Percent of predators containing Colorado squawfish, Labor Camp and Fish Pond, fall, 1982.

Date	Gear type[b]	Green sunfish				Largemouth bass					
		<100 mm TL[a]		>100 mm TL		<150 mm TL		150 - 350 mm TL		>350 mm TL	
		FP[c]	LC[d]	FP	LC	FP	LC	FP	LC	FP	LC
10/06-07	EL	10	0	17	100	150	83	100	67	--	25
10/07	SB	--	--	--	--	--	--	--	--	--	--
10/12-13	SB	0	0	17	17	25	100	67	--	--	--
10/12-13	EL	0	0	100	--	0	50	100	--	--	40
10/14-15	SB	0	0	--	67	--	0	--	100	--	--
10/18-19	SB	0	0	--	0	0	0	--	60	--	--
10/19-20	EL	0	0	0	--	58	--	100	41	--	0
10/21-22	SB	--	0	--	0	0	0	--	--	--	--
10/25-26	SB	0	0	--	0	0	--	--	19	--	--
10/25-26	EL	0	0	0	--	100	20	0	33	--	0
10/28-29	SB	0	0	--	--	--	40	--	25	--	--
11/1-02	SB	--	0	0	--	--	0	--	--	--	--
11/02-03	EL	0	0	0	0	0	14	--	20	--	11
11/04-05	SB	0	0	--	--	0	--	--	--	--	--
11/09-10	SB	0	0	--	--	0	0	--	0	--	--
11/15-18	SB	--	0	--	--	0	0	--	--	--	--

a - TL = total length

b - EL = electrofishing; SB=25-m long, 1/4-inch mesh bag seine

c - FP = Fish Pond

d - LC = Labor Camp

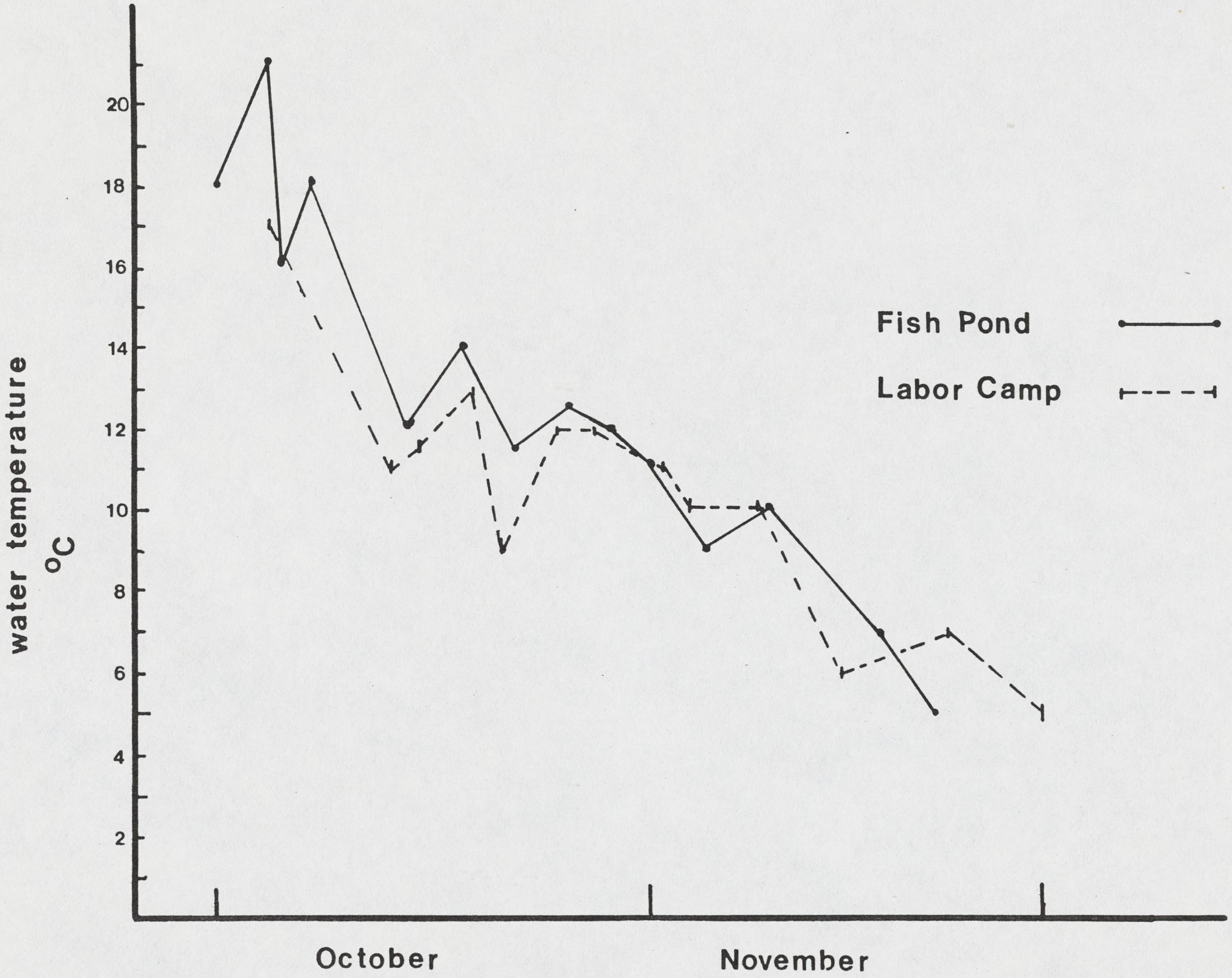

Figure 19 . Water temperature in Fish Pond and Labor Camp, fall, 1982.

Catch per unit effort of Colorado squawfish from Fish Pond was highly variable; much less variation was evident in the data from Labor Camp (Figure 20). The difference in catch rates between pits and the variation within pits probably reflect, in part, the greater ease of sampling Fish Pond and the clumped distribution of small Colorado squawfish. It is still uncertain whether catch per effort statistics showing fewer Colorado squawfish in Labor Camp than Fish Pond is a valid statistic.

Catch per unit effort was also quite variable in the river backwaters. In two backwaters, catch rate was sometimes higher after the blocking nets were removed and Colorado squawfish were no longer confined, than during the period when the blocking nets were in place (Figure 21). Catch rate generally declined in the backwaters until early November when rates were near zero; no Colorado squawfish were found in backwaters in late November. Some Colorado squawfish had left study backwaters by late October when two tagged Colorado squawfish were collected from the river about 3 miles downstream from the nearest study backwater. We have not yet examined these microtags to determine of which study group these fish are members.

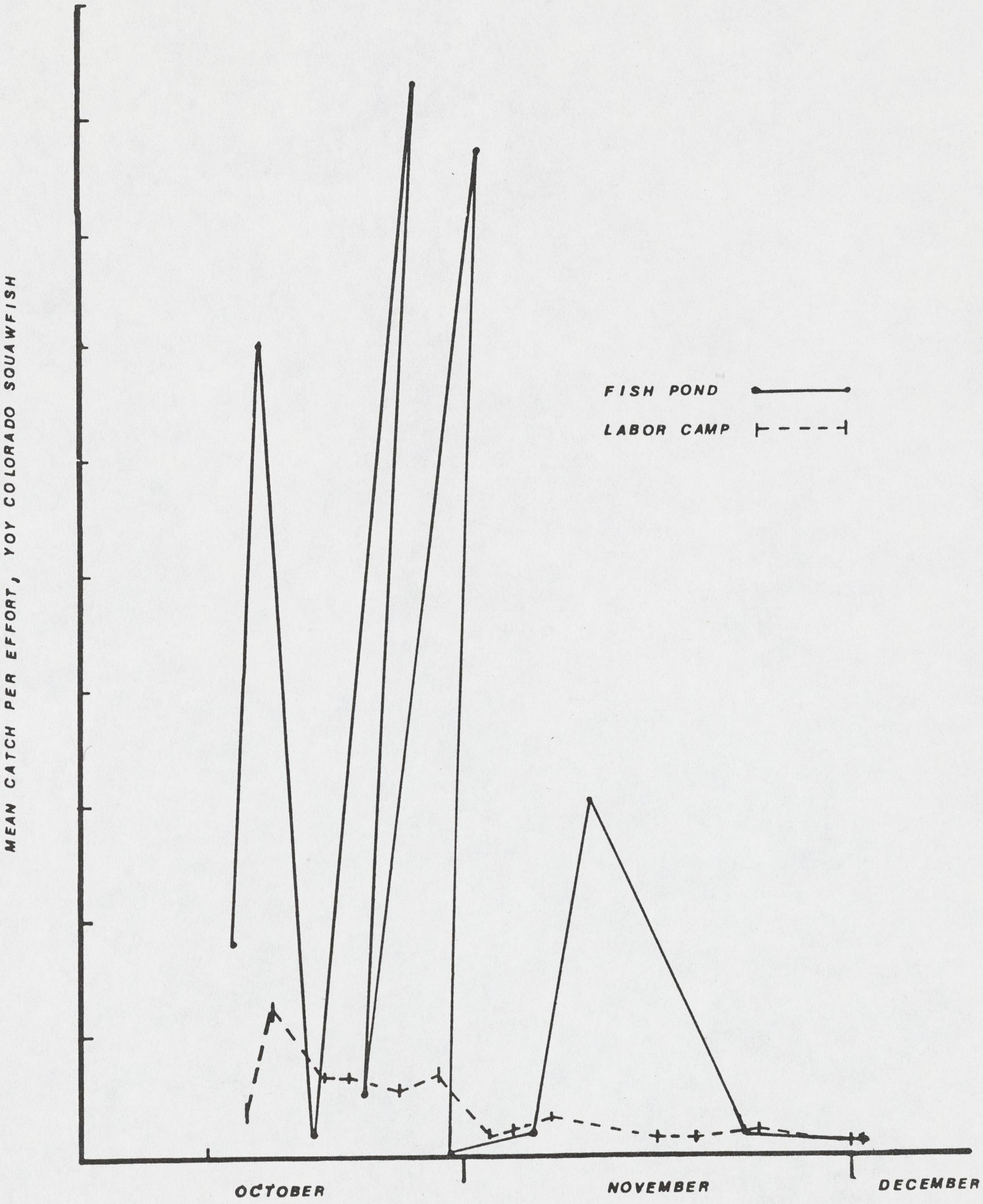

Figure 20 . Mean catch per unit effort (fish per m^2 seined) of stocked Colorado squawfish in Fish Pond and Labor Camp, fall 1982.

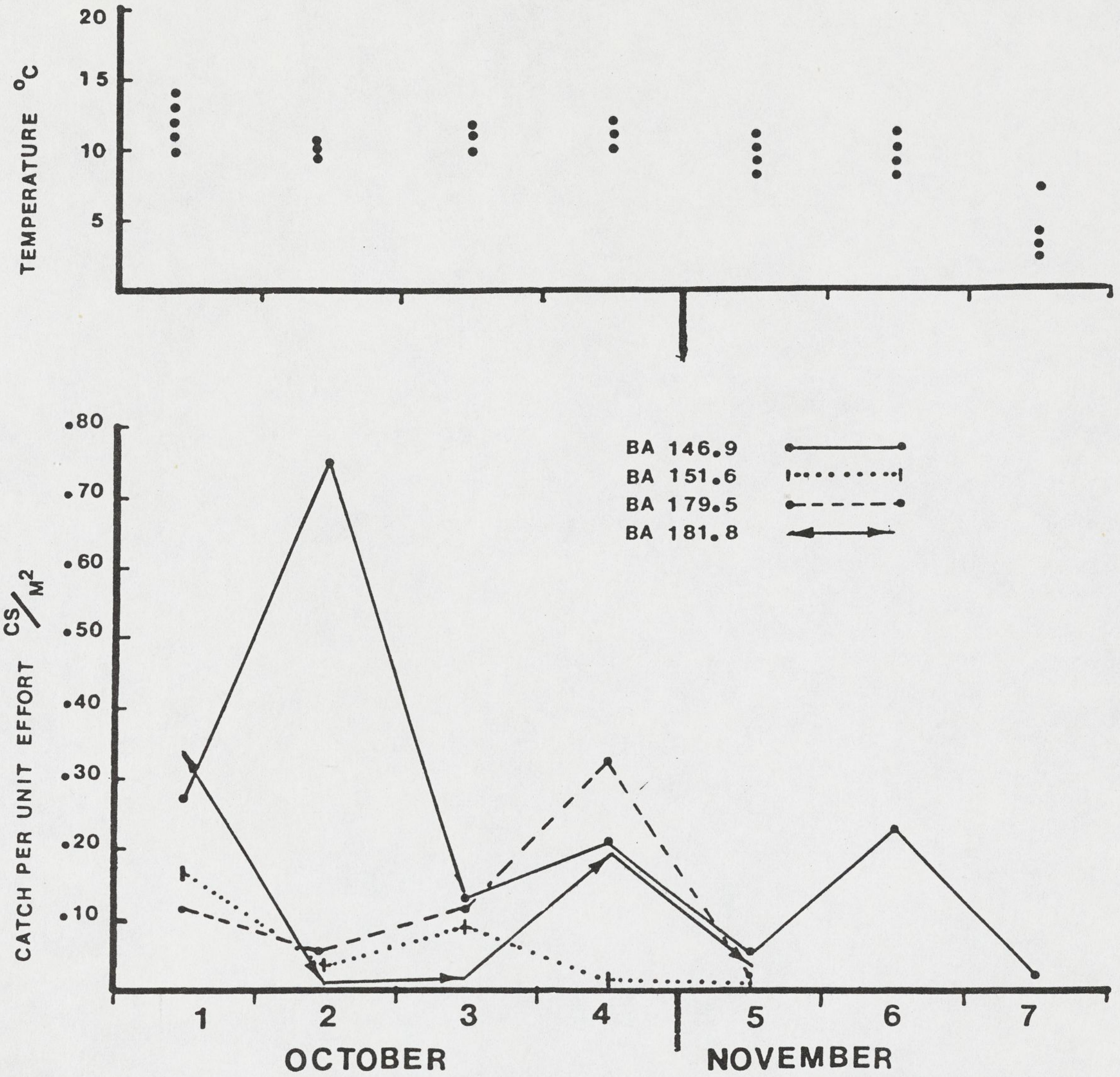

Figure 21 . Spot temperature data for river backwaters stocked with hatchery-reared Colorado squawfish in 1982 (above). Mean catch per effort of stocked Colorado squawfish in river backwaters, fall, 1982 (below). Initial collections (below) were made when blocking nets were in place, whereas subsequent collections were made after blocking nets were removed.

1983 WORK PLANS

Each of the gravel pits investigated during 1982 contained adult Colorado squawfish, razorback sucker, or both species, during the period of high river discharges. As there was considerable variation between gravel pits in their physicochemical and biological characteristics, the observation that rare fishes used each of these areas indicates that new gravel pits constructed in a manner similar to that of existing pits will most likely also be used by rare fishes. However, use of such gravel pits by adult rare fishes should not be taken as evidence for enhancement of rare fish populations by such physical features. Only one gravel pit contained larval Colorado squawfish, a possible indication of reproduction in the area, but these small fish might have entered the pit from reproductive areas in the river.

We will not perform the gravel pit monitoring program of 1982 in 1983. A more detailed program on a smaller number of pits will be executed. WWWA is used extensively by Colorado squawfish and razorback sucker during the period of high river flows. The environmental clues used by these fishes to locate and enter WWWA, as well as to depart WWWA before the gravel pit becomes isolated from the river, are unknown. Residence in the warm WWWA environment could influence gonadal maturation (and thus spawning time), subsequent movement within the river system, and the physical condition of the fish because of exposure to pathogens in the pit that are not normally encountered in the river. These areas of concern could be addressed if detailed studies were performed on WWWA, and on similar areas. However, an effective means of collecting fish with minimal expenditure of manpower must be developed. If we can determine what clues are used by these endangered species we can better manage the species to increase populations.

We plan, with the cooperation of the Colorado Division of Wildlife (CDOW), to install a semi-permanent weir in the outlet of WWWA during winter 1982-1983. This weir will separately trap fish moving into and out of WWWA. Detailed measurements of fish will be made, including analyses to determine the occurrance of important pathogens. Concurrent measurement of physical variables such as water temperature and river dishcarge should allow us to determine the environmental clues used by rare fishes to locate gravel pits of this type. A similar structure might be constructed in the outlet of Labor Camp pit, where comparative data could then be collected.

Further plans are being developed, in concert with CDOW and Corn Construction Company of Grand Junction, to create a spawning pond in an existing or planned gravel pit in the Grand Valley. The spawning pond concept includes separate inlet and outlet structures between the pond and the river. These structures would control the passage of fishes using weirs, and the flow of water through the pond using a headgate structure. Water flow through the pond would be necessary, based on observations made in the hatchery, for successful reproduction by Colorado squawfish. Colorado squawfish, and perhaps razorback sucker, would be allowed into the pond, whereas potential competitor/predator would be excluded. The pond would be contructed to allow for natural seasonal draining, mechanical pumping, or chemical treatment to aid in the removal of undesirable fishes. Rare fishes would be held in the pond and obligated to spawning in that area.

The spawning pond concept would allow us to control environmental variables to a large extent. We should be able to examine: 1) spawning site selection, 2) spawning success under various physical conditions and under different densities of adult fish, 3) the effects of competitor/predator species on spawning success, 4) the drift of larval Colorado squawfish from reproductive areas, 5) the environmental clues that influence the use of gravel pits by Colorado squawfish as discussed above for WWWA, and 6) numerous other aspects of the reproductive ecology of rare Colorado River fishes.

Radiotelemetry of Colorado squawfish will again be performed in 1983. Our field effort will include a systematic combined radio-tracking and larval sampling program in the Colorado and Green rivers. The Colorado River will be divided into two separate reaches for the 1983 study; the Colorado River between Palisade, Colorado (RM 185), and Westwater Canyon (RM 124-116), Utah; and the Colorado River between Westwater and Spanish Bottom, Utah (below confluence with Green River at RM-3). Equal sampling effort will be expended in each of these reaches. Each river reach will be surveyed biweekly. Radio tracking and larval sampling will also be performed in the Gypsum Canyon area of Lake Powell, as time and manpower permit. We plan to install a continuously monitoring radio receiving station on the Gunnison River upstream from Redlands Diversion. This station could detect the passage of radio-tagged Colorado squawfish over the diversion, as well as record signals from the one telemetered fish (implanted and released in the Upper Gunnison River in September 1982) which might move downstream. Eleven Colorado squawfish were implanted in the fall of 1982 with 18-month radio transmitters as part of this 1983 study effort. Radiotelemetry work on humpback chubs in the Black Rocks area will begin in March 1983. We are investigating the possibility of using pressure-sensitive transmitters that would reveal the depth of the fish. As many as ten humpback chubs will be equipped with radios in 1983.

In the Green River Colorado squawfish radio-tagging will emphasize the lower Green River and determine if additional spawning areas exist there. Up to 20 Colorado squawfish will be radio tagged between the Gray Canyon area and the confluence with Colorado River. Work in the lower Green River will also aid in determining possible movement of Colorado squawfish between the Green and Colorado rivers. Detailed information on known spawning areas will be taken to expand our knowledge on spawning needs of Colorado squawfish.

The Colorado squawfish YOY monitoring program will continue during 1983 in the Colorado and Green rivers. All known spawning sites will be checked and evaluated during 1983. Success of spawning and adult movement will be correlated to 1983 river flows.

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Brown and Rainbow Trout Populations in a Section of the North Fork Cache la Poudre River during September 1983

by

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During early fall 1983, we were invited to investigate the trout population in a short section of the North Fork of the Cache la Poudre River located on lands of the North Fork Recreation Association. The purpose of this study was to provide basic information about the abundance, age, growth, and biomass of trout residing there, and to describe and measure habitat so that estimates of density and standing crop could be made. Using the man- and womanpower of students in Colorado State University's Fisheries Science course, we measured the trout population during late September and measured habitat during late October 1983.

STUDY AREA AND METHODS

We chose a 262-meter (860 ft.) stream section for study, located within the first half mile downstream from the Halligan Reservoir dam where the first access road from the west reaches the river. The river runs through a narrow, rock-faced gorge downstream from the reservoir which makes access difficult. The stream bed in the section we studied was predominately cobble and boulders interspersed with small pockets of gravel in flowing areas, and silt along the margins where flow was reduced.

Stream width averaged 17 meters (59 ft.) and depth varied from 5 centimeters (2 in.) in riffles to more than 2 meters (6.6 ft.) in pools. Pools in this stream are often quite deep, especially along cliff faces, and those we measured ranged in area from 79-360 square meters (850-3875 ft^2). The stream discharge, measured at only one transect during the morning of 28 October, was 1.74 m^3/sec (61.4 ft^3/sec). The area of the study section was 0.47 hectares (1.17 acres).

The stream bank vegetation in the riparian zone was abundant and not degraded by over-grazing, which contributed to excellent stream bank stability. Periphyton (algae) was abundant on rocks in the stream bed. The water was slightly turbid, which may be due either to detached periphyton or to phytoplankton from the reservoir, but did not appear to be caused by suspended inorganic sediment.

The general method used to estimate trout abundance is termed a mark-recapture population estimate, and involves capturing as many trout as possible from the stream section on a first run, and marking these fish by clipping the tip from one of the lobes of the tail before returning them to the stream. Fish are captured by electrofishing using direct current, which stuns but rarely harms them. We anesthetized trout with a compound called MS222 (tricaine methanesulfonate) which reduces the likelihood of damage during measurement and weighing. After about a week a second electrofishing run is made, and both recaptured (previously marked) and unmarked fish are caught. The proportion of recaptured to unmarked fish in the second sample is assumed to be the same as the proportion of fish originally marked to the entire population, allowing a population estimate to be made.

Because our electrofishing equipment malfunctioned during our first attempt on 19 September, we captured only a few young-of-the-year trout. We made our two main electrofishing runs on 23 and 28 September. Each fish captured was measured and weighed, and scales were removed from about half of the fish for analysis of age and growth. We calculated population estimates of fish larger than 6 inches according to 50 millimeter length groups for brown trout, rainbow trout, and all trout combined. We also calculated the statistical 95 percent confidence limits around the total number of fish for each of the three estimates. Because the number of young-of-the-year (YOY) trout born in 1983 was estimated using a slightly different formula, this size group (74-149 mm, 3-6 in) is treated separately.

RESULTS AND DISCUSSION

We captured 237 fish during all electrofishing, of which 111 were less than 6 inches (150 mm), 57 were rainbow trout larger than 6 inches, and 69 were brown trout larger than 6 inches. All trout smaller than 6 inches were young-of-the-year. We estimated there to be 293 rainbow and 5 brown trout of this 3-6-inch size class (Table 1). We estimated the population of over-6-inch trout to be 123 rainbow and 123 brown trout, or 250 trout when a total estimate was made. We emphasize that population estimates using this mark-recapture method are always statistically rather imprecise. Thus the reader should understand that the 95% confidence limits shown in Table 1 indicate that if 100 similar samples were drawn from this population, 95 of the estimates for all trout over 6 inches in the section would fall between 176 and 395 trout.

The density of trout in terms of numbers and biomass (Table 2), reveals that the trout population in this section of the North Fork is much larger than that measured in the best sections of the main stem of the Cache la Poudre River in October 1982 by Nehring and Anderson (1983). Trout biomass in the North Fork is comparable to the best sections of other trout rivers in Colorado, such as the Colorado and Fryingpan rivers. Trout biomass in the best sections of the South Platte River below Cheesman Dam is much larger than the North Fork, for both catch-and-release and standard-regulation sections (Table 2).

A striking characteristic of the North Fork trout population we studied is the unusual number of large fish in the population (Table 1 and Fig. 1). Whereas few fish in the main stem of the Cache la Poudre River exceed 12 inches (Nehring and Anderson 1983), we estimated that 151 of the 250 trout over six inches, were larger than 12 inches. The average length of the brown trout over 6 inches was about 12.5 inches and of similar-sized rainbow trout about 13.1 inches. The largest brown trout we captured was 20 inches (502 mm) and the largest rainbow trout was 18 inches (460 mm). This large number of larger trout is likely due to two factors: relatively fast growth and reduced or no harvest by fishermen.

The most precise way to estimate age and growth of fish is to clip the YOY fish each fall with a different finclip each year. After a number of successive years of recapturing these known-age fish, a complete growth history can be calculated. Given only a sample of fish from one time period, we used two less precise methods to estimate age and growth. The first method is to simply examine the length-frequency histogram for modes or "peaks" that represent age groups of fish (see Fig. 1). The approximate distribution of lengths of fish of each age are shown by the brackets, but overlap of distributions for fish older than age II prevents determining their mean lengths. It is evident from these histograms that age-0 or YOY trout are distinct from older fish, and that age-I and age-II fish of each species form fairly distinct modes.

The second method involves ageing the fish by magnifying their scales and determining periods of fast (summer) and slow (winter) growth, much as one would age a tree. The distribution of lengths of fish of each age (Table 3), indicates that average lengths of North Fork trout during late September for ages 0 through III are about 4, 9, 12, and 14 inches (125, 225, 300, and 350 mm) respectively. We emphasize that reading scales requires much practice, is more of an art than a science, and that scales from old trout are notoriously difficult to assess. However, the agreement between the two methods lends credence to our finding that these trout grow relatively rapidly, and that few fish are older than five or six years.

This rate of growth is faster than that measured by Nehring and Anderson (1982) for fish in most of Colorado's trout rivers, including the South Platte River at Deckers during fall 1981 where lengths of age I through IV brown trout were 208, 274, 317, and 333 mm respectively, and lengths of age I through III rainbow trout were 201, 264, and 317 mm. By comparison, growth of trout in the main Cache la Poudre River is poor. Brown trout grow faster than rainbow there, and averaged 97, 168, 231, 277, and 305 mm for ages 0 through IV in fall 1981.

We used the lengths and weights of the trout captured to calculate a relationship between length and weight separately for brown and rainbow trout (Fig. 2). Rainbow trout are slightly heavier for a given length than brown trout, which we had noticed while handling the fish. The length-weight relationship for fish is typically a steeply rising curve, and usually fits the data quite well. We found that 98% of the variation in the data for each species was explained by the mathematical equations shown in Fig. 2. We prepared Table 4 to aid in interpreting the weights of fish of a given length in metric and English units. Trout of both species reach one pound at 13-14 inches and two pounds at 17-18 inches.

In summary, several facts are evident from the data we collected and our analysis. First, the short section of the North Fork of the Cache la Poudre River we studied is populated about equally with adult brown and rainbow trout of relatively large size. Second, these fish are growing relatively rapidly in what appears to be productive habitat, reaching catchable size of 8 inches during their second year of life (age I), and 12 inches during their third or fourth year (age II or III). Few fish appear to live longer than 5-7 years (age IV-VI). Third, rainbow trout are slightly heavier than brown trout for a given length. Fourth, because only a few age-0 brown trout were captured it appears that brown trout did not reproduce in this section during 1982-83, and we suggest that brown trout may move in from upstream or downstream if reproductive failure is common. Natural reproduction of rainbow trout did occur judging from the relatively small number of age-0 rainbow trout captured. These fish were concentrated in the area near the entrance of a very small stream from the west, probably because some suitable spawning gravel was available in the main river near there. All of these fish could easily have been produced by only one or a few pairs of spawning rainbow trout. By and large, the trout population and stream habitat in the section we studied appear to be healthy and productive.

Many other aspects of trout populations in the North Fork gorge below Halligan Reservoir deserve further study. For instance, the effects of flow fluctuations on stream habitat and trout populations along the canyon would be an interesting and challenging topic for further research.

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Table 1. Population estimates of rainbow, brown, and all trout in a 262-m section of the North Fork Cache la Poudre River.

Total length		Population estimate		
mm	in	Rainbow	Brown	All trout
74-149	3-6	293		
100-149	4-6		5	
150-199	6-7.9	0	2	2
200-249	8-9.9	24	11	34
250-299	10-11.9	28	34	63
300-349	12-13.9	41	30	71
350-399	14-15.9	17	32	52
400-449	16-17.9	9	7	16
450+	18+	4	7	12
Total >6 in		123	123	250
95% CI		74-282	84-213	176-395
Ave. length (in)		12.5	13.1	

Table 2. Density and biomass of all trout in a 262-m section of the North Fork Cache la Poudre River, and standing crop estimates for the best sections of other Colorado trout rivers.

	Trout per lineal distance		Trout per area	
	per km	per mi	per ha	per acre
Number	950	1529	530	214
Biomass (kg)	369 kg/km	-	205 kg/ha	-
Biomass (lb)	-	1308 lb/mi	-	183 lb/acre

Standing crop estimates for all trout from other Colorado trout rivers (from Nehring and Anderson 1983)

1.	Arkansas River - Tezak section, March 1983	98 kg/ha
2.	Cache la Poudre River - 3 mi above Rustic, Oct. 1982	100 kg/ha
3.	Colorado River - Parshall to Sunset Ranch bridge, Oct. 1982 (C & R 12-20 in.)	226 kg/ha
4.	Fryingpan River - Old Faithful section, Sept. 1982	204 kg/ha
5.	S. Fk. Rio Grande - above Beaver Creek bridge, Sept. 1982	118 kg/ha
6.	South Platte River - Lower canyon (0.2 mi above Wigwam Club, C & R) Dec. 1982	469 kg/ha
	Below Deckers (8 trout/day)	358 kg/ha

Table 3. Length of brown and rainbow trout at each age as determined by reading scales.

Total length		Brown					Rainbow				
(mm)	(in)	0+	I+	II+	III+	IV+ and older	0+	I+	II+	III+	IV+ and older
80-99							4				
100-119	4 in	1					21				
120-139							9				
140-159							2				
160-179											
180-199			1								
200-219	8 in		1					2			
220-239			2					4	1		
240-259			2					6	1		
260-279				6				2	3		
280-299				4					2		
300-319	12 in			3	3				1		
320-339					2				4		
340-359					3				4	2	1
360-379					4				1	2	
380-399						4				1	
400-419	16 in					1				1	
420-439											2
440-459						1					1
460-479											1
480-499											
500-519	20 in					1					
Total		1	6	13	12	7	36	14	17	6	5

Table 4. Metric-English equivalents of average length and weight of brown and rainbow trout.

Total length		Weight			
		Brown		Rainbow	
mm	in	g	lb	g	lb
153	6	36	0.1	37	0.1
204	8	85	0.2	89	0.2
254	10	162	0.4	174	0.4
305	12	277	0.6	305	0.7
356	14	436	1.0	491	1.1
407	16	646	1.4	740	1.6
458	18	914	2.0	1063	2.3
509	20	1247	2.7	1470	3.2

Fig. 1. Lengths of fish captured.

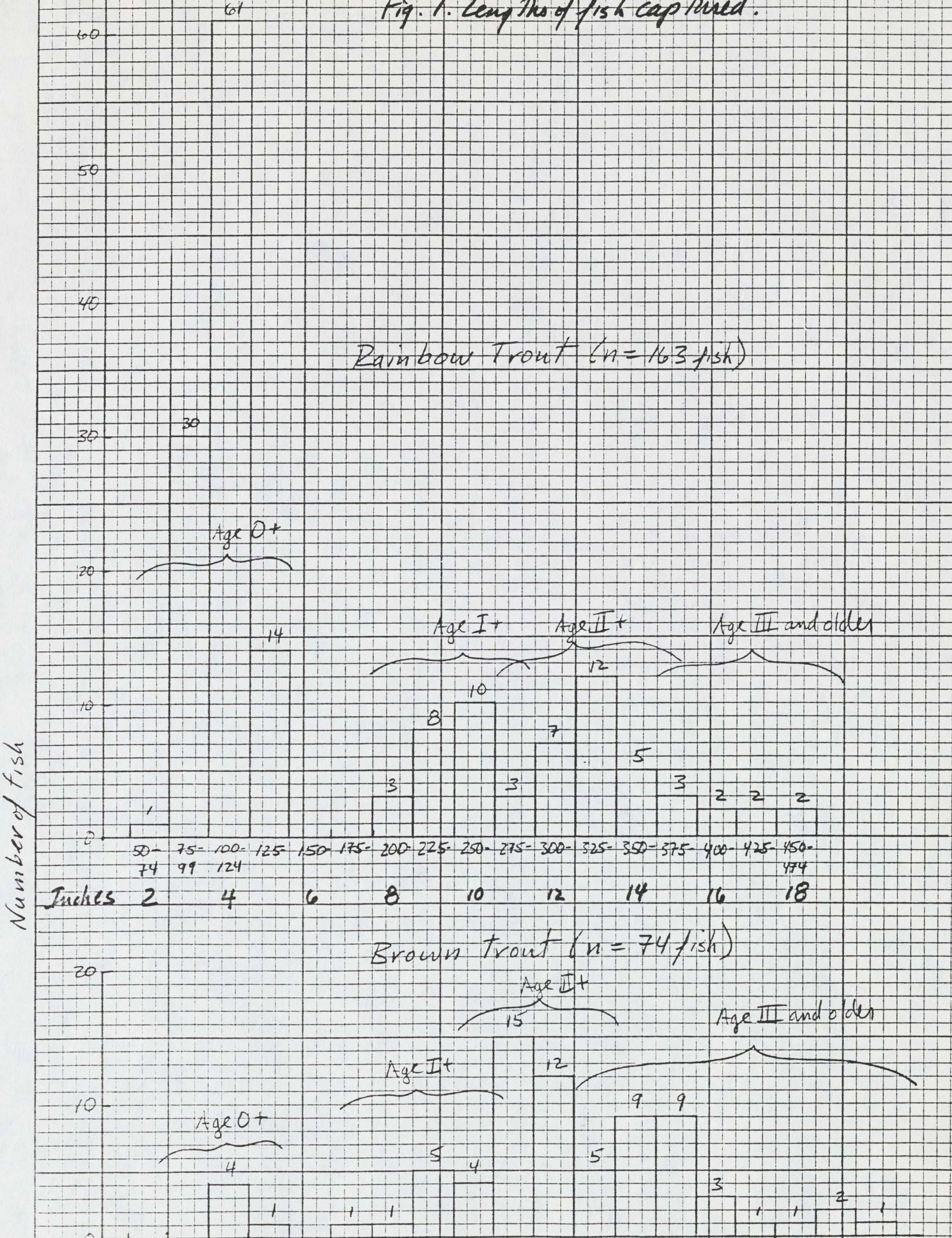
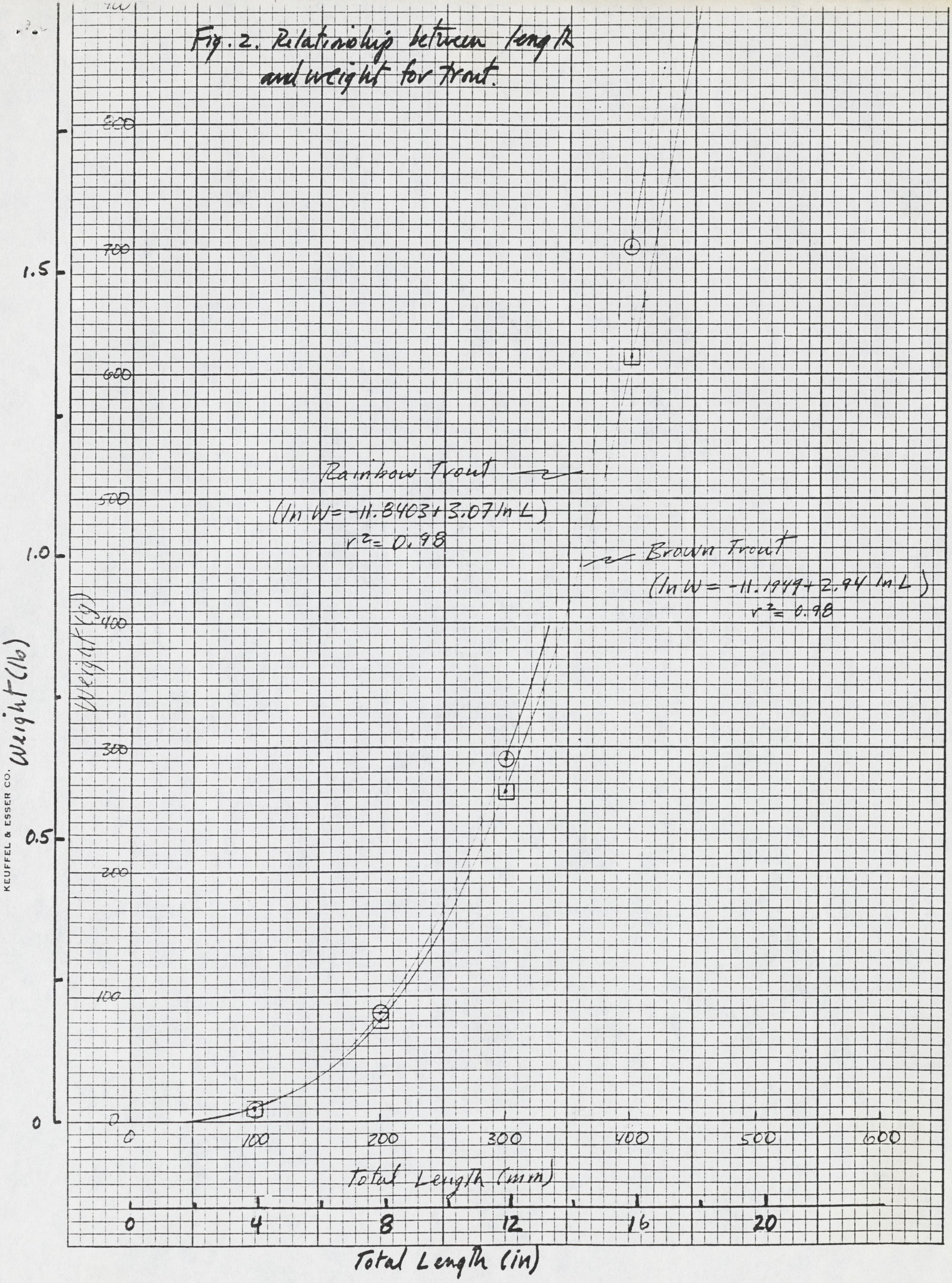


Fig. 2. Relationship between length and weight for trout.



NOTES ON TROUT POPULATIONS IN THE NORTH FORK OF THE POUDRE RIVER IN PHANT~~HOM~~OM CANYON

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July, 1984

The following information is based on data collected in September, 1983, by Dr. Kurt Fausch and fishery students sampling ~~an~~ 860 ~~feet~~ linear feet ~~section~~ of the river ~~a~~ near the dam of Hallig~~en~~an Reservoir, ~~and~~ my observations during a fishing trip on ~~the river~~ June 27, and discussions with Mr. Steve Goto and Mr. Donn Johnson who regularly fish the river. ~~With~~ These limitations ~~of~~ on the ~~comp~~ degree of completeness and depth of the data base do not allow for precise quantification but there is sufficient information to make the following conclusions: ~~The~~ The ~~section~~ N. Fork ~~of the~~ Poudre ~~River~~ River in Phantom Canyon is an excellent trout fishery based on the numbers and size of the rainbow and brown trout. Natural reproduction apparantly is poor in most years due to flows regulated by the reservoir. Rainbow trout have successful reproduction in some years but virtually all brown trout are recruited into the population by escapement from the reservoir. The poor recruitment (poor spawning success) results in a situation of high survival and rapid growth of trout and a "top heavy" size-age structure with a high proportion of large fish (> 14 inches). The abundance of deep pool habitat in the canyon also favors a build-up of large trout in the population. However, such a size-age structure is highly vulnerable to overexploitation (removal of large fish more rapid than replacement by recruitment) if this section of the

~~Fig. 2 – tax loss value decl. 54 – 203~~
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river were to be open to public fishing without special protective regulations designed to recycle the catch.

The September, 1983, sampling collected 250 brown and rainbow trout more than six inches in length. Of these, 151 (60%) were more than 12 inches and 37% of the brown trout and 25% of the rainbow trout were 14 inches or greater. These size statistics ~~are about~~ ~~the~~ that define a quality fishery are about the best known from any rivers in the state. Comparing size statistics from Colorado's best trout streams compiled ~~over~~ during ~~the past~~ recent years by Colorado Division of Wildlife biologists ~~reveals~~ the ~~t~~ quality of the N. Fk. Poudre trout fishery, in terms of percent of fish more than 12 inches and more than 14 inches, is very similar to the South Platte River below Cheeseman Dam (in the special regulation catch-and-release area), the Black Canyon of the Gunnison ("gold medal" section below Curecanti dams, also under special regulations), and a section of the Colorado River on private lands near Kremmling (with very low angling pressure).

The "quality" of the North Fork fishery is more striking when compared to an "ordinary" trout fishery such as the main Poudre River in Poudre Canyon. The biomass of brown and rainbow trout estimated from the 1983 sampling is almost 200 pounds per surface acre of ~~river~~ the N. Poudre River. This is about three times the biomass of trout per surface acre ~~of~~ in the main Poudre River. The percentage of trout more than 12 and more than 14 inches is 20 to 30 times higher in the N. Fork compared to various sections of the main Poudre.

Obviously, the fishery in Phantom Canyon

③ → I not~~ed~~iced that the rainbow trout in the N. Poudre is actually a hybrid with the original native trout, the greenback cutthroat trout. They ~~present~~ are beautiful, highly colored fish with a deep red band, a cutthroat mark and rose colored abdomens.

is a unique and valuable resource. I would also point out the opportunities such a fishery suggest for future research ~~on~~ for learning basic information on the factors that determine a quality fishery and for gaining insight into flow-habitat relationships that determine the success of natural reproduction.

— Send to:

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4/23/84

GCC JOINT VENTURE

BIOLOGICAL ALTERNATIVES

The following is a list of possible biological alternatives that could be employed by GCC to satisfy regulatory concerns regarding the endangered fishes in the Colorado River. The two principal criteria used in making the selection were:

a) The action would directly benefit the fish and/or provide information that could be used to plan later action to benefit the fish, and

b) The action can be implemented or carried out by the GCC itself (i.e., the concurrence or cooperation of others is not required, such as would be the case in any basin-wide agreement, for example).

Factors such as cost, water rights, engineering feasibility, etc. were not considered in compiling the list. Emphasis was placed on measures to assist the squawfish, as it is the flow requirements of this species that are of principal concern to FWS.

The alternatives identified have been divided into three major types:

1) Those which can be undertaken with little or no additional research.

2) Those which can be undertaken in conjunction with some research efforts.

3) Those which are principally research or data gathering efforts.

The alternatives are as follows:

1. ACTIVITIES WITH NO RESEARCH

1a. Support Hatchery Rearing and Stocking. This alternative would require contributions to support ongoing efforts in existing hatcheries to raise and release more squawfish and/or humpback chub. Contributions could be dedicated to expand the physical facilities and/or staff or to merely taking over funding existing projects.

1b. Construct Fish Passages around Dams. This alternative would require constructing fish ladders or other appropriate structures so that squawfish could get around three existing dams that block access to upstream areas on the Colorado and Gunnison Rivers. These dams are: the Grand Valley Diversion (at Palisade), the High Line Dam (at Cameo), and the Redlands Diversion (on the Gunnison). This would increase the area into which squawfish could move to spawn, and could improve their reproductive potential.

no mly feeding
YOY downstream
Gunnison

1c. Sponsor a Symposium on T&E Fish. This alternative would require organizing, directing and funding a symposium for invited scientists to present the latest results of research in well-defined areas pertinent to the GCC situation. Biology and hydrology would be emphasized. The objectives would be to compile the latest available information and bring together the experts to evaluate such factors as status of the species, research needs to get practical answers on target flows, solutions to existing problems, etc.

1d. Sponsor Public Information Programs. This alternative would require GCC to sponsor programs to disseminate, to the local and regional population, information about the T&E fish species, their status and measures being taken for their protection. They would also educate the public with regard to how they could assist in the protection of the species. The program could involve preparing and distributing literature, presenting of seminars, providing speakers to local groups, conducting advertising campaigns, etc.

1e. Additional Storage and Release from GCC Reservoir. This alternative would require constructing the reservoir with capacity above that needed by the project and filling that capacity during peak flow periods. This water would be released during critical periods when target fish flows could not be met by existing river flows. FWS would determine release schedule on a month-by-month basis.

2. ACTIVITIES WITH SOME RESEARCH

2a. Create Backwater Nursery Areas. This alternative would require construction of backwater areas along the Colorado River between State Line and Palisade. Research would be required to determine the important characteristics of known backwater nursery sites and these would have to be duplicated in the constructed versions. Possible structures could range from tree revetments to excavations along the river banks similar to existing gravel pits. Emphasis would be placed on providing nursery habitat for naturally spawned squawfish.

2b. Create Nursery Ponds. This alternative would require construction of ponds along the river in which water level and flow could be controlled. Hatchery spawned YOY would be introducted into these ponds and reared for several weeks until they are of sufficient size to be released for movement downstream. This holding period would give the young a better chance for survival than if they were released directly as YOY. Some research would be required to define pond design, and stocking and rearing procedures.

2c. Create Spawning Structures in Natural River Channel. This alternative would involve modifying natural substrate to better accommodate squawfish spawning. This would call for hydrological as well as biological expertise. Both biological and hyrological research would be required, although some information is available from research by FWS on the Yampa River.

2d. Construct Artificial Spawning Channels. This alternative would require construction of raceway channels at selected locations along the river. Squawfish have spawned in a raceway environment in hatcheries and the objective of this alternative would be to create suitable channel environments in the river. Both biological and hydrological research would be required.

3. RESEARCH AND/OR INFORMATION GATHERING

There are innumerable possible research projects that can be identified. A number of general areas have been included in the Draft Recovery and Conservation Plans for the squawfish and humpback chub. Rather than list all possible research that could be conducted, we have focused on several projects that could yield important information on the GCC situation. Also, any research efforts would be concentrated in the reach between about State Line and Palisade.

3a. Gather Geomorphological Information. This research would gather detailed geomorphological information along numerous transects across the river in the GCC area of interest. The surveys would provide sufficient data to predict the changes in available spawning and backwater habitat that would occur at different river levels during the critical time periods. Surveys would be concentrated in known or suspected squawfish spawning and nursery areas. Efforts would also be focused in quantifying changes in known humpback chub habitats.

3b. Intensively Survey Backwater Areas. This research would gather detailed biological, physical and chemical information on backwater areas, both those known to serve as habitat for squawfish YOY and those not so utilized. Comparisons of results could identify the critical characteristics required by the YOY. The efforts would be concentrated in the critical time periods after spawning. Existing information of this nature would also be reviewed; for example, Mr. R. Valdez conducted investigations of this type on the Yampa River as part of the Colorado River Fishery Project. These data have not yet been released by FWS.

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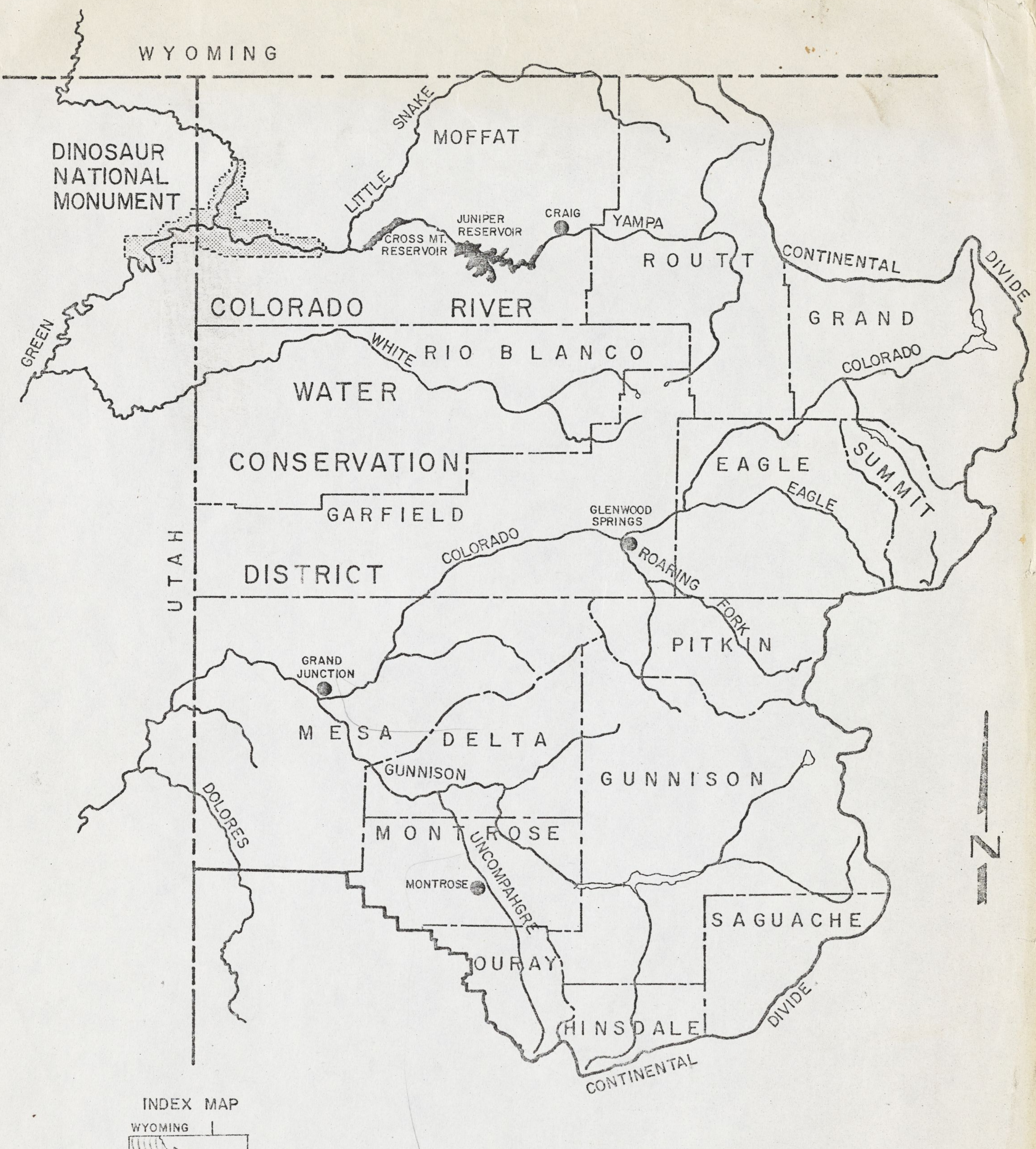
3c. Study the Role of Exotic Fishes. The research would be designed to determine the role that the non-native fishes play as competitors and/or preditors on squawfish. The study plan could involve selectively poisoning some nursery areas immediately prior to squawfish spawning and monitoring the density of YOY in these areas in comparison to unpoisoned backwaters. Also, the FWS experiment using magnetically tagged YOY could be duplicated in other nursery sites. Efforts could also be made to quantify differences in the exotic fish populations in the Green and Colorado Rivers.

3d. Study Use of Water Temperature to Define Critical Periods. This research would investigate the possibility of timing the restriction of water withdrawals to specific temperatures in selected backwater or known squawfish spawning areas. The present FWS target flow recommendations encompass a period from mid-June through August in order to account for year-to-year variations in the date of spawning and YOY entry into the nursery areas. This "vulnerability window" could be defined more accurately (and narrowed considerably) if, each year, the date of the onset of spawning could be pin-pointed. Research would focus on identifying a suitable temperature regime (e.g., three days of water temperatures of 22°C) and appropriate location(s) at which to monitor the temperature.

3e. Sponsor a Full-Time Observer Position. This alternative would require the funding of a position for a qualified fishery biologist to make and record pertinent observations at specific sites along the Colorado River in the area of interest. The observer would follow a detailed study plan which clearly defined the types of observations and measurements required and the locations and frequency at which they would be made. Efforts would be focused on one or two selected backwater areas where critical habitat parameters (water level, flow, water quality, etc.) would be monitored. The observer would have only one task: to document changes in habitat characteristics that occur with changes in flow. To date, no one has spent a continuous period of time making observations on flow-habitat relationships. The level of effort would be lower than in 3b) or 3c) above, but the research would still provide useful information.



COLORADO RIVER WATER CONSERVATION DISTRICT

FEBRUARY 1978

ss possible resource management
ts, propose alternatives, and
y available pertinent data.

s: Public scoping meetings will be
at the following locations.

st 25, 7:00 p.m.—Community Hall,
dicine Bow, Wyoming
st 26, 7:00 p.m.—BLM District
ce, Rawlins, Wyoming
st 27, 7:00 p.m.—High School
feteria, Saratoga, Wyoming
st 28, 7:00 p.m.—University of
yoming Student Union, Laramie,
yoming
mber 2, 7:00 p.m.—Senior Citizens
nter, Baggs, Wyoming
mber 3, 7:00 p.m.—West
mentary School, Wheatland,
yoming

ESS: Medicine Bow and Divide
Team Leader, P.O. Box 670,
ins, Wyoming 82301, (307) 324–

FURTHER INFORMATI
Husband, Team Lea
e address.

PLEMENTARY INFORMA
fication of places and
ing will also be publis
spapers.

y A. Oden,
Director.
Doc. 86–18284 Filed 8–11–86, 10:50 am]
G CODE 4310–22–M

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au of Reclamation

son Diversion Unit, North Dakota; nt to Prepare a Supplement to a t Supplemental Environmental tement

ursuant to section 102(2)(C) of the
onal Environmental Policy Act of
, the Department of the Interior
oses to prepare a Supplement to the
t Supplemental Environmental
ement (DES 86–9) for the Garrison
rsion Unit (GDU) in North Dakota.
supplement will address changes
the Commission Plan due to the
rison Diversion Unit Reformulation
of 1986.

he Garrison Diversion Unit will
ver Missouri River water for
culture, recreation, fish and wildlife,
municipal, rural, and industrial uses
rth Dakota. The primary features
e three reservoirs, five canals, 25
re pumping plants, 13 irrigation
s, and municipal, rural, and
strial water systems for up to 130
munities.

e supplement will amend the
ous draft environmental statement
S 86–9) to address changes in some
e features due to the Reformulation
The document will identify and assess impacts of ongoing work and describe additional studies being undertaken pursuant to the Act. The supplement will include the following: description of changes in the plan, additional studies required, and items deferred until a comprehensive report on the James River is completed and submitted to the Congress. The supplement will be provided for public review and comment. One document will then be prepared, which will respond to comments received on both DES 86–9 and the supplement, and be filed as the final supplemental environmental statement for the Garrison Diversion Unit.

There will be two scoping meetings to discuss the James River studies, the supplement, and the procedure to be used in developing the final statement. Those held on August 26, at the Doublewood marck, North Dakota , 1986 at 8:00 p.m. at Senior Citizens Main, Redfield, South

ons for this draft supplemental ement are Timothy J. , Chief, Technical Support Division, Missouri-Souris Projects Office, Bureau of Reclamation, P.O. Box 1017, Bismarck, North Dakota 58502, telephone (701) 255–4011, extension 541, or Robert Schroeder, Regional Environmental Affairs Officer, Missouri Basin Regional Office, Bureau of Reclamation, P.O. Box 36900, Billings, Montana 59107–6900, telephone (406) 657–6558.

Dated: August 7, 1986.

William C. Klostermeyer,
Commissioner.

[FR Doc. 86–18092 Filed 8–11–86; 8:45 am]

BILLING CODE 4310–09–M

Dr. Behnke
Your copy
Bob

upper Colo. River
Basin

Fish and Wildlife Service

Intent To Prepare an Environmental Assessment on a Proposed Action To Recover Rare and Endangered Fish in the Upper Colorado River Basin; Republication

[Editorial Note: The following document was originally published at page 27256 in the issue of Wednesday, July 30, 1986. The document is being republished in its entirety because of typesetting errors.]

AGENCY: Fish and Wildlife Service, Interior.

ACTION: Notice.

SUMMARY: This notice advises the public that the Fish and Wildlife Service (Service) is preparing an environmental assessment on a proposed implementation program to recover four rare and endangered fish species in the Upper Colorado River Basin. This notice is being furnished in accordance with the CEQ Regulations for implementing the National Environmental Policy Act (40 CFR 1501.7(b)(3)). We solicit public comment on impacts likely to result from the proposed action and alternatives, as well as suggestions on alternative means to protect and recover these fish species in a manner compatible with continued water development and State water allocation systems. Suggestions and information received will assist us in determining the scope of issues to be addressed and in evaluating their significance in the environmental assessment.

DATES: Written comments should be received by August 29, 1986.

ADDRESS: Comments should be addressed to: Regional Director, U.S. Fish and Wildlife Service, P.O. Box 25486, Denver Federal Center, Denver, CO 80225.

FOR FURTHER INFORMATION CONTACT: Barry Mulder, Chief, Office of Endangered Species, U.S. Fish and Wildlife Service, P.O. Box 25486, Denver Federal Center, Denver, CO 80225, (303) 236–7398, FTS 776–7398.

SUPPLEMENTARY INFORMATION:

I. Purpose and Need for Action

The purpose of the action is to protect and recover four rare fish species in the Upper Colorado River Basin in a manner that allows continued water development and that is consistent with State water rights systems, interstate compacts, and court decrees that allocate the rights to use Colorado River water among the States.

The four fish species of concern are the Colorado squawfish (*Ptychocheilus lucius*), humpback chub (*Gila cypha*), bonytail chub (*Gila elegans*), and razorback sucker (*Xyrauchen texanus*). The first three species are listed as endangered, and the fourth is a candidate for listing under the Endangered Species Act of 1973, as amended. The ultimate goal of the recovery implementation program is to delist the three endangered species and to manage the razorback sucker so it would not need the protection of the Endangered Species Act.

Though once abundant in the upper basin, these fish are now threatened with extinction. Their decline is attributed to a number of factors, ranging from habitat reduction or alteration to introduction of nonnative species. The Service has stated that ss possible resource management cts, propose alternatives, and fy available pertinent data.

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Team Leader, P.O. Box 670,
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FURTHER INFORMATION CONTACT:
Husband, Team Leader, at the e address.

PLEMENTARY INFORMATION:
fication of places and dates of ng will also be published in local spapers.

y A. Oden,
Director.

Doc. 86–18284 Filed 8–11–86; 10:50 am]

G CODE 4310-22-M

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au of Reclamation

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There will be two scoping meetings to discuss the James River studies, the supplement, and the procedure to be used in developing the final environmental statement. Those meetings will be held on August 26, 1986, at 7:00 p.m. at the Doublewood Ramada Inn, Bismarck, North Dakota and on August 28, 1986 at 8:00 p.m. at the Spink County Senior Citizens Center, 521 North Main, Redfield, South Dakota.

The contact persons for this supplement to the draft supplemental environmental statement are Timothy J. Keller, Chief, Technical Support Division, Missouri-Souris Projects Office, Bureau of Reclamation, P.O. Box 1017, Bismarck, North Dakota 58502, telephone (701) 255–4011, extension 541, or Robert Schroeder, Regional Environmental Affairs Officer, Missouri Basin Regional Office, Bureau of Reclamation, P.O. Box 36900, Billings, Montana 59107–6900, telephone (406) 657–6558.

Dated: August 7, 1986.

William C. Klostermeyer,
Commissioner.

[FR Doc. 86–18092 Filed 8–11–86; 8:45 am]

BILLING CODE 4310–09–M

Fish and Wildlife Service

Intent To Prepare an Environmental Assessment on a Proposed Action To Recover Rare and Endangered Fish in the Upper Colorado River Basin; Republication

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I. Purpose and Need for Action

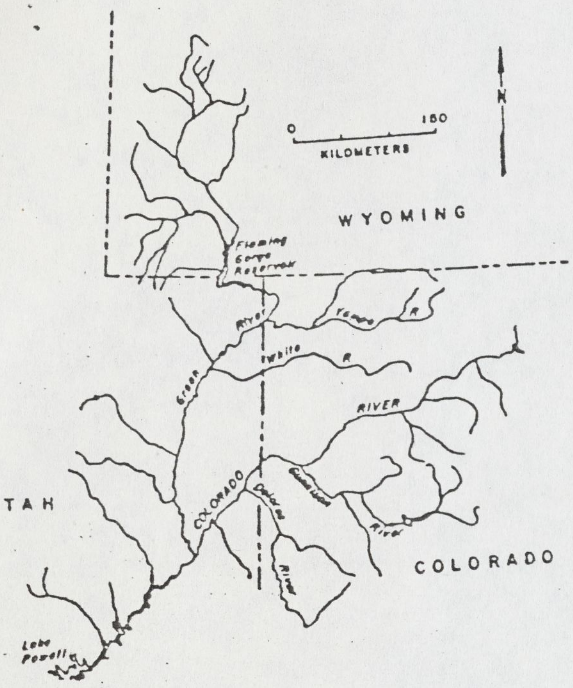
The purpose of the action is to protect and recover four rare fish species in the Upper Colorado River Basin in a manner that allows continued water development and that is consistent with State water rights systems, interstate compacts, and court decrees that allocate the rights to use Colorado River water among the States.

The four fish species of concern are the Colorado squawfish (*Ptychocheilus lucius*), humpback chub (*Gila cypha*), bonytail chub (*Gila elegans*), and razorback sucker (*Xyrauchen texanus*). The first three species are listed as endangered, and the fourth is a candidate for listing under the Endangered Species Act of 1973, as amended. The ultimate goal of the recovery implementation program is to delist the three endangered species and to manage the razorback sucker so it would not need the protection of the Endangered Species Act.

Though once abundant in the upper basin, these fish are now threatened with extinction. Their decline is attributed to a number of factors, ranging from habitat reduction or alteration to introduction of nonnative species. The Service has stated that continued water development within the upper basin is likely to further jeopardize these fishes' existence unless project impacts are offset by measures that preserve or improve these species' current status.

II. Affected Environment

The proposed action will occur in the Upper Colorado River Basin above Glen Canyon Dam, excluding the San Juan River. This area encloses the principal remaining habitat for the four fishes in the upper basin, as well as those waters (mainstem and tributaries) with potential to cause significant downstream impacts to the fish or their habitat. The affected area is located in Colorado, Utah, and Wyoming. (See map below)



III. Description of the Proposed Action and Major Alternatives

We invite public comment on impacts likely to result from the actions described below, as well as suggestions on alternative means to protect and recover the four rare and endangered fish species in a manner compatible with continued water development and State water allocation systems.

A. Proposed Action

Preamble. The proposed action was developed by a subcommittee of the Upper Colorado River Basin Coordinating Committee. The Coordinating Committee is composed of representatives from the States of Colorado, Utah, and Wyoming; Bureau of Reclamation; Fish and Wildlife Service; private water development interests; and environmental organizations. The Department of the Interior is considering adopting their draft proposal for a cooperative Federal/State/private program as the preferred means for resolving water use conflicts involving rare and endangered fish and water development actions, as follows:

1. *Administration.* A Recovery Implementation Committee representing Federal, State, private water development, and conservation interests in the upper basin would oversee implementation of recovery actions for the four rare and endangered fish species. This committee would make recommendations to the Secretary of the Interior and the States, who would use their independent authorities to make and implement final decisions.

2. *Recovery Timeframe.* 15 years, estimated.

3. *Recovery Actions.*

a. *Habitat management.* (1) Determine the locations, times, and quantities of instream flows needed to protect and recover the fish and, through cooperation, prioritize work in this area.

(2) Evaluate alternative means for providing necessary flows. Once obtained, instream flows would be appropriated, acquired and administered under State law. Federal condemnation of water rights would not occur under the proposed action. Potential sources of water may include:

(a) Allocating and releasing water from Federal storage projects. For example, through the section 7 consultation process, the Bureau of Reclamation would withhold from sale 5,000 acre-feet of water at Ruedi Reservoir. This water would tentatively be released in the months of July–September, as needed.

(b) Refining operations at Federal reservoirs. For example, the Bureau of Reclamation would refine operations at:

(i) Ruedi Reservoir—would release an additional 5,000 acre-feet in the months of July–September on an average of 4 out of 5 years (supplementing the 5,000 acre-feet withheld from sale noted in A.3.a.(2)(a) above).

(ii) Flaming Gorge Reservoir—until section 7 consultation is completed, has adopted an interim flow release schedule intended to improve rare and endangered fish spawning and survival. Ongoing research would determine a more permanent flow release pattern which would be outlined in the biological opinion planned to be completed in 1989.

(iii) Blue Mesa Reservoir—until section 7 consultation is completed, will release water to ensure that a 2,000 cubic feet/second minimum flow occurs below the confluence of the Gunnison and Colorado Rivers on an average of 9 out of 10 years. Research would determine a more permanent flow release pattern to be outlined in the completed biological opinion.

(c) Purchasing or leasing existing water rights, on a willing seller basis, and converting these rights into instream flow rights.

(d) Investigating the feasibility of acquiring "excess" water resulting from agricultural water conservation and salinity control projects and converting acquired water into instream flows.

(e) Investigating changing the point of diversion for senior water rights to downstream locations.

(f) Investigating acquisition of nontributary ground water that could be pumped and put into streams.

(g) Applying for original appropriation of instream flows in surface streams.

(3) When section 7 consultation is conducted on future projects:

(a) The Secretary of the Interior would recommend reasonable and prudent alternatives, where possible, to offset nondepletion impacts of water projects jeopardizing the endangered fish, e.g., direct impacts caused by construction, inundation, or water quality changes resulting from reservoir operations.

(b) Since the proposed action establishes a commitment and mechanism to assure instream flows are acquired and protected under State law, the Service would consider these recovery actions as offsetting depletion impacts of most projects. Projects would be considered to have addressed depletion impacts by making contributions as described in A.4.c below toward the recovery implementation program. However, if there are instances where project depletions are likely to jeopardize fish, the Service and Recovery Implementation Committee, where possible, would identify measures to offset these impacts, and implementation of these measures would be given immediate attention.

b. *Habitat development and maintenance.* The locations and degree to which any of the following techniques would be implemented would be determined after experimentation and consideration of effectiveness, cost, relationship to other recovery measures, and secondary impacts.

(1) Create backwaters to enhance young-of-year fish production. Backwaters can be created by manipulating river flow, connecting existing gravel pits/ponds to the river, or physically constructing backwaters.

(2) Increase spawning habitat by improving access to existing, unused spawning areas (e.g., fish passage structures), reintroducing eggs/larvae into suitable unoccupied habitat, modifying instream characteristics to create new spawning habitat, or constructing spawning habitat within the natural stream channel or in modified side channels.

(3) Create wintering habitat by building jetties.

(4) Build fish passage facilites to reestablish Colorado squawfish in parts of their historic range, e.g., above Redlands Diversion Dam, Taylor Draw Dam, and Palisades.

c. *Artificial propagation and stocking of rare and endangered fish species.* (1) Use hatcheries as refugia to safeguard against disease and possible extinction.

(2) Raise fish in hatcheries and/or grow-out (rearing) ponds and use them for basic research studies.

(3) Immediately introduce the bonytail chub, which appears in imminent danger of extinction in the upper basin.

(4) Augment existing populations of Colorado squawfish, humpback chub, and razorback sucker through stocking only after artificial propagation techniques have been thoroughly investigated.

d. *Nonnative species and sportfishing management.* Competition and predation from nonnative species is believed to contribute to the decline of the four rare and endangered species. In addition, fishermen have caught endangered fish while seining for bait or angling. The following actions would be carried out by Federal or State agencies, as appropriate, to reduce future losses:

(1) Confine future stocking of nonnative fish shown to pose a threat to the rare and endangered fish to areas off the mainstem where absence of potential conflict with rare and endangered fish can be demonstrated.

(2) For nonnative fish shown to pose a threat to the survival of rare and endangered fish, investigate the feasibility of selectively removing them from areas considered essential to the latter species.

(3) Review sportfishing practices and regulations to reduce the likelihood of incidental take of rare and endangered fishes, e.g., permanent or seasonal closures of fishing areas where incidental take is a serious problem; prohibition of seining in spawning areas, young-of-year habitat, and juvenile nursery areas; restrictions on use of live bait.

(4) Implement an information and education program to educate the fishing public on rare and endangered fish.

e. *Research, monitoring, and data management.* (1) Implement a comprehensive research program to provide basic biological information on the fishes, to test management approaches, and to investigate institutional or administrative actions.

(2) Track the overall status and trends of rare and endangered fish populations within the upper basin with a monitoring program.

(3) Establish a centralized data management system.

4. *Funding*—a. *Special.* Congress would be requested to establish two special funds:

(1) Water rights fund ($10 million): Used to acquire water rights to secure instream flows for the rare and endangered fishes.

(2) Construction fund ($5 million): Used for recovery actions involving capital expenditures, e.g., constructing hatchery or fish passage facilities, changing the point of diversion of a water right, or modifying habitat.

b. *Annual.* $2.4 million would be provided yearly for recovery actions. The Federal share would total $2.1 million, and the States' share, $300,000.

c. *Intermittent.* Private water developers would contribute a one-time amount of $10/acre-foot (based on average annual depletion and adjusted annually for inflation) for new water depletion projects that have not yet complied with section 7 of the Endangered Species Act. Contributions may also be made by conservation groups and private entities.

B. "No Action" Alternative

Preamble. Since the Endangered Species Act requires the Federal government to protect and recover listed species, the "No Action" alternative has been construed to mean "status quo," i.e., continuation of current actions.

For example, Federal dams in the upper basin are required to comply constantly with section 7 of the Endangered Species Act. Dam operations must not jeopardize the survival of listed species and, where possible, should help conserve these species. These dams are being studied to determine if: (a) Water is available for instream flow needs and, (b) flow releases can be modified to increase production or survivorship of rare and endangered fishes. These actions would be implemented even if the proposed action is not adopted, and will be common to all alternatives under investigation.

(Note. These actions are denoted as recovery actions A.3.a.(2)(a) and A.3.a.(2)(b) under the proposed action.)

The "No Action" alternative is as follows:

1. *Administration.* There would be no Federal/State/private oversight committee. Instead, the various agencies and developers would coordinate as needed on a project-by-project basis. The Service would review water projects through section 7 consultation and develop reasonable and prudent alternatives for projects likely to jeopardize endangered fish. The Bureau of Reclamation would ensure its projects are not likely to jeopardize the fish. The States would continue current efforts, as funds permit. It is presumed the States would not administer instream flows for the rare and endangered fishes.

2. *Recovery Timeframe.* Indefinite (greater than 15 years).

3. *Recovery Actions.* The recovery actions outlined in the proposed action would take place as described, except as follows:

a. Recovery actions that would not be undertaken due to lack of funds:

(1) Nearly all water acquisition measures [A.3.a.(2)(c)–(g)].

(2) Construction of fish passage facilities at sites other than Redlands Diversion Dam [A.3.b.(4)].

b. Recovery actions that would be undertaken, but at a slower pace than in the Proposed Action due to lack of funds:

(1) Determination of needed instream flows [A.3.a.(1)].

(2) Creation of backwaters, spawning habitat, and wintering habitat [A.3.b.(1)–(3)].

(3) All artificial propagation and reintroduction efforts, except for maintenance of hatcheries as refugia [A.3.c.(2)–(4)].

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(4) All nonnative species and sportfishing management efforts [A.3.d.(1)–(4)].

(5) All research, monitoring, and data management efforts [A.3.e.(1)–(3)].

c. Recovery actions that would be substantively different from those in the proposed action:

(1) For section 7 consultation, each project would be individually evaluated to determine the best mix of measures to offset impacts. In order to avoid jeopardy to the fish, project sponsors could be required to modify proposed structures, provide flows, and/or contribute funds for recovery implementation actions in some cases (per the existing depletion formula).

(2) The razorback sucker would likely be listed under the Endangered Species Act.

(3) Releases from Federal reservoirs would not be legally protected as instream flow rights.

4. *Funding.* The existing level of funding would continue; i.e., approximately $1.6 million annually would be directed toward recovering the rare and endangered fish, of which $1.5 million would be Federal funds and $100,000 would be State funds. Some money could continue to be contributed by water developers with small projects with correspondingly small depletions (See recovery action B.3.c.(1)).

C. "Federal Action Only" Alternative

1. *Administration.* A Recovery Implementation Committee representing only Federal agencies involved in Upper Colorado River Basin resource management would use their authorities and resources to recover the fish. It is assumed that the States would continue their current level of effort, as funds permit.

2. *Recovery Timeframe.* Indefinite (greater than 15 years).

3. *Recovery Actions.* The recovery actions outlined in the proposed action would take place as described, except as follows:

a. Recovery actions that would be undertaken, but may proceed at a lower level of effort than in the proposed action due to the need for State cooperation and/or concurrence:

(1) Reintroduction efforts [A.3.c.(3), (4)].

(2) Efforts to control nonnative fish species and sportfishing [A.3.d.(1)–(3)].

b. Recovery actions substantively different from those in the proposed action:

(1) For section 7 consultation, each project would be individually evaluated to determine the best mix of measures to offset impacts. In order to avoid jeopardy to the fish, project sponsors could be required to modify proposed structures, provide flows, and/or contribute funds for recovery implementation actions. Under this alternative, project sponsors' contributions may be used to acquire water rights.

(2) If necessary, Federal condemnation of water rights would be considered to secure water for the fish.

(3) The razorback sucker could be listed under the Endangered Species Act.

c. Recovery actions that would be managed differently from those in the proposed action:

(1) Overall, the Federal government would take a proportionately stronger role in determining and implementing recovery actions for the four fishes in the upper basin.

(2) The Federal government will encourage the States to administer water rights (obtained as described in A.3.a.(2)(a)–(g)) under State water law. However, if the States do not agree to State administration, acquisition by the United States of instream flows under section 5 of the Endangered Species Act would be investigated. Assuming these flows could be legally protected, these instream flow rights would be held in the name of the United States, and administered by the States.

4. *Funding.* The construction fund and annual funding levels would be equal to the Federal funding levels in the proposed action. Congress would be requested to authorize a water rights fund only if water acquired by the Federal government under section 5 of the Endangered Species Act could be protected as an instream flow right under State or Federal law. Private water developers could be requested to contribute toward recovery efforts as described in C.3.b.(1) above.

III. Impacts of the Proposed Action

Comments are invited on the direct, indirect, and cumulative impacts likely to result from implementing the proposed action and major alternatives. Areas of potential impact include:

A. Target species
  1. Federally listed species—Colorado squawfish, humpback chub, bonytail chub
  2. Candidate species—razorback sucker
B. Nontarget species
  1. Aquatic
    a. Native fish species other than target species
    b. Nonnative fish species
    c. Sport fish species
  2. Terrestrial
    a. Sport species
    b. Migratory birds
    c. Endangered species
C. Recreation
  1. Sportfishing
    a. Reservoir
    b. Stream
  2. Rafting/Boating
D. Electricity production
  1. Hydropower
  2. Nonhydropower
E. Energy development
F. Agricultural production
  1. Crops
  2. Livestock
G. Municipal/Industrial
  1. Urban growth
  2. Industrial development
H. Water quality
  1. Salinity
  2. Temperature
I. Visual/aesthetic
J. Historical/archaeological/cultural
K. Land management agencies
L. Habitats of Federal concern
  1. Floodplains
  2. Wetlands

A more detailed explanation of the proposed action may be obtained by calling or writing the contact person identified at the beginning of this notice.

The environmental review of this project will be conducted in accordance with the requirements of the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4371 et seq.), CEQ Regulations to implement NEPA (40 CFR Parts 1500–1508), other appropriate Federal regulations, and Department of the Interior and Service procedures for compliance with these regulations.

We estimate that the draft environmental assessment will be completed by September 1986.

Dated: July 23, 1986.

Galen L. Buterbaugh,
Regional Director.

[FR Doc. 86–17059 Filed 7–29–86; 8:45 am]

BILLING CODE 1505–01–M

National Park Service

National Register of Historic Places, Notification of Pending Nominations

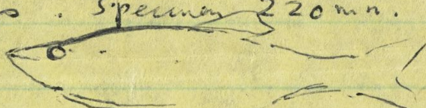
Nominations for the following properties being considered for listing in the National Register were received by the National Park Service before August 2, 1986. Pursuant to § 60.13 of 36 CFR Part 60 written comments concerning the significance of these properties under the National Register criteria for evaluation may be forwarded to the National Register, National Park Service, U.S. Department of the Interior, Washington, DC 20243. Written

Rinne, J. N. 1969. Cyprinid fishes
of the genus *Gila* f lower Colorado
River ba . St. Univ.:
77p.

G. inte cies status
& what B nuaqua Cr.).
believed in *intermedia*
considered as

G. i.

D, A bodied, darkly
pigmented (size 250? -200mm.).
fig. 4: Monkey Springs. specimen 220mm. - shows
slight humping -



+ O Donnel Crk. Babacomari R., San Carlos R.
Originally described *Tigoma intermedia* Girard 1856.
Santa Cruz R.

Verde R. - in main river and in trib.
below falls - all *G. robusta* - Big Chino
Wash (UMMZ 162834) - extreme upper trib.
above series of falls (now partially inundated
by Sullivan L. = *G. intermedia* - similar to
Santa Cruz. specimens - Juvenile specimen
from upper Oak Crk. have counts of *intermedia* but
probability of introduction in heavily fished stream.
- In trib. of Verde above rapids or falls
specimens have 70-90 (75-85) scales, w/ typical
D 9 A 8 - relatively thick body but not
as extreme as *intermedia*. - Most likely
name is *Gila grahami* B. & G. 1853c type
locality Rio San Pedro, Ariz.- and *G. r.*
grahami applied for convenience thru paper.

Cyprinid fishes of the
genus Gila from the
lower Colorado
River Basin
Arizona St. Univ.

Thesis
John N. Rinne
1969

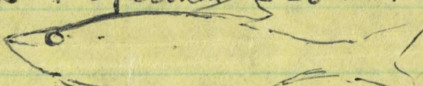
Rinne, J. N. 1969. Cyprinid fishes of the genus *Gila* from the lower Colorado River basin. M.S. thesis. Ariz. St. Univ.: 77p.

G. intermedia elevated to full species status & what Barber & Minckley 1966 (Aravaipa Crk.). believed intergrades between *robusta* & *intermedia* considered as *G. r. grahami*.

G. i. l. l. 60-80

D, A, 8 thick bodied, darkly pigmented (~~small max.~~ size 250? -200mm.).

fig. 4: Monkey Springs. specimen 220mm. - shows slight humping -



+ O Donnel Crk. Babacomari. R., San Carlos R.

Originally described *Tigoma intermedia* Girard 1856. Santa Cruz R.

Verde R. - in main river and in trib. below falls - all *G. robusta* - Big Chino Wash (UMMZ 162834) - extreme upper trib. above series of falls (now partially inundated by Sullivan L. = *G. intermedia*. - similar to Santa Cruz. specimens. - Juvenile specimen from upper Oak Crk. have counts of *intermedia* but probability of introduction in heavily fished stream. - In trib. of Verde above rapids or falls specimens have 70-90 (75-85) scales, w/ typical D 9 A 8 - relatively thick body but not as extreme as *intermedia*. - Most likely name is *Gila grahami* B. & G. 1853c type locality Rio San Pedro, Ariz.- and *G. r. grahami* applied for convenience thru paper.

fig 5 : G. r. *grahami* Upper Sycamore Ck. E. Verde R., Aravaipa Ck., Taylor Ck. Tonto Ck., Carrizo Ck. - Compared old & new samples Wet Beaver Ck. *G. r. g.* 1937-1956 stable-characters - 1964-66 changed - creek ~~po~~ rotenoned may led to invasion by *G. r. r.*

- Salt R. upstream from Roosevelt L. are *G. r. robusta*. Extreme head of Black R. slightly thicker bodies also found in several small tribs. but not typical *grahami*. Tonto Ck. major trib. of Salt R. heading in eastern margin of Verde basin - resembles *G. r. g.* of E. Verde R. - but downstream pop. reflects intergrade w/ *G. r. r.* Fish & Cave Creeks trib. to Salt downstream from its major canyon - chubs are *G. intermedia*

chubs head of San Pedro R. - identical to *G. inter.* from adjacent Santa Cruz (excluding Monkey Springs) also 17 extant spec. from upper San Simeon R. - *G. i* also from San Carlos R and *Queen Creek* (most likely extinct and likely introduced from Salt R. according UMMZ notes).

- Remainder of upper Gila basin & Aravaipa Ck. (trib. extreme lower San Pedro R. are *G. r. g.* - *G. r. r.* & *G. r. g.* may intergrade in larger waters. A blotched color pattern characteristic of many *grahami* occurs infrequently in Black R. & Bill Williams R. (whose fauna much derived from Gila) - referable to *G. r. r.* but high incidence of blotching.

- *G. r. jordani* White R. Nev. - also blotched.

G. r. r. widespread thruout Colo. basin Bill Williams, Verde mainstream and Salt R. system. - G. r. grahami. Verde tributaries + upper Gila, and G. intermedia principally in central & southern Ariz.

G. i. vert. 38-45 (- 4 webbenan = 34-41)
43-49 G. r. = 39-45

G. r. r.
- in main, larger rivers but
habitat variable - incl. small headwat.

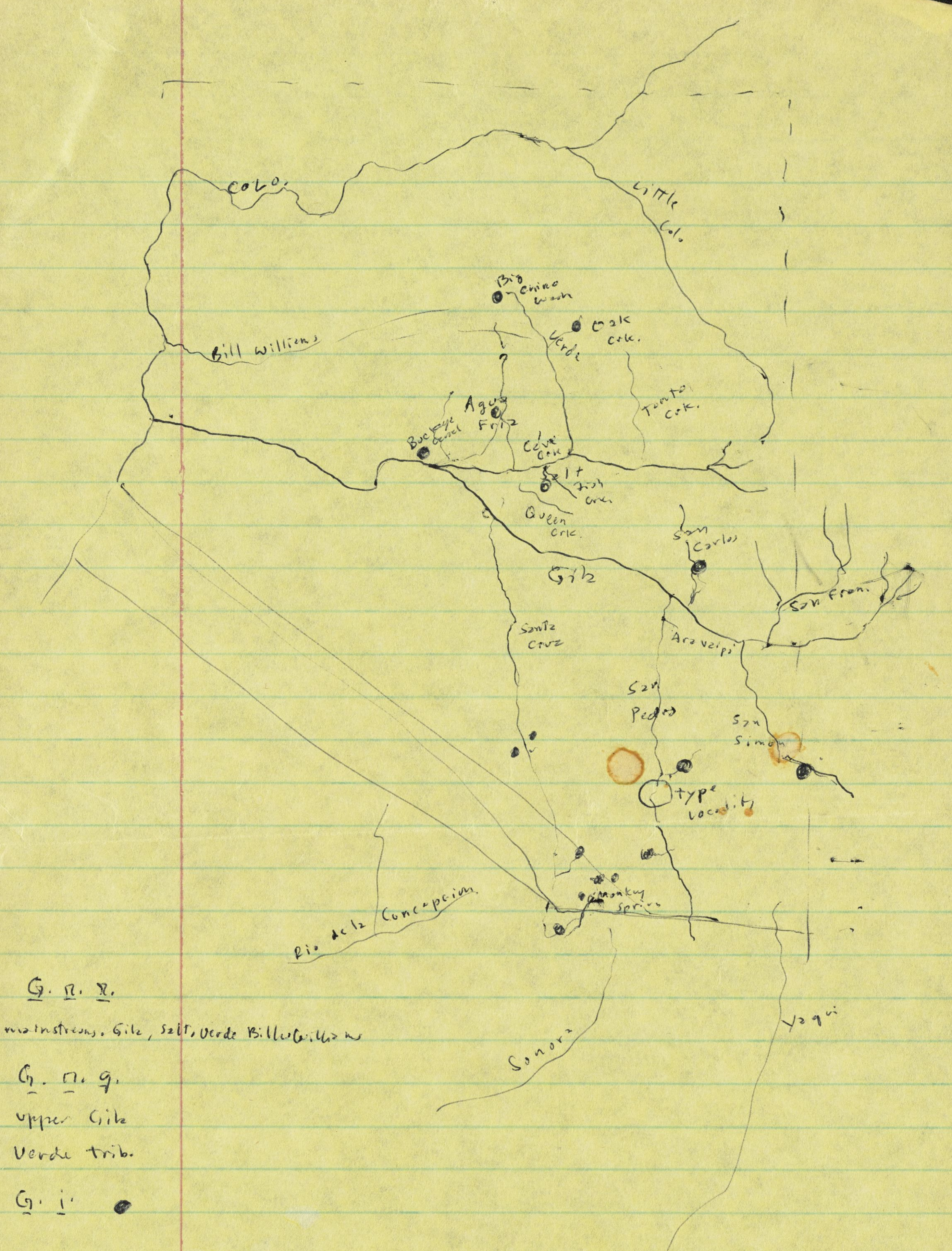
G. r. g.
small creeks -
low gradient
warm desert - Aravaipa
Fossil Crk - large, swift:
Upper Gila - mainstream
to upper trib. in mountains

*Arroyo cutting - lowered tables, drained marshy habitat - stream flow - erosion fills in pools.
irrigation abstraction diversion, pumping, dams -

— thick body (not chubby) -
Scales 80+ blotched
D. A. mostly 9
50% intermediate
- Pelvics mostly 9
almost all =

G. i.
rare - predominantly southern Ariz.
ciénegas, brooks (some impoundment)
in North - in relatively large San Carlos R.
pools of Fish Creek Canyon
& ~~pools~~ riffles of Cave Crk.
one pop. in Buckeye Canal
prefers small, quiet water habitat

Scales 60-80
D A 8
deeper caudal peduncle
dark pigment color
chubby body
Pelvics always 8



G. r. r.

mainstreams. Gila, Salt, Verde Bill Williams

G. r. g.

upper Gila

Verde trib.

G. i. ●

Question : To what extent do I give my reasoning for crossing off other tag types?

~~So I th~~

How much do I go into explaining the reasons

(ex) why Gard's place

why subcut?

* draw map of Poudre River There

1 Interest in increasing trout growth, particularly in streams exhibiting poor growth.

~~Test~~ Will ~~trout~~ stream trout utilize commercial trout pellets?

What effect on fish behavior will this have?

Act as a step in further supplementary feeding or stream enrichment studies.

① Should I include the page # for past names of G. intr.?

② What is the accepted status of G. int.?

③ more info. on Aquatic Biota of Sonota Crk.?
(see yellow sheet)

④ ~~Where is~~ ba
Did Barber & Minckley find G. int. in Aravaipa Crk.?

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13-18

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INTRODUCTION

Western cyprinid fishes of the genus *Gila* Baird and Girard have had a long, tortuous taxonomic history, which has resulted largely from a lack of understanding of their individual and geographic variation, or from erroneous interpretations of it. Geographic or ecologic allopatry, so characteristic of western fishes, prevails, and local differentiation is the rule. Interpretation of the various forms of chubs has ranged from a proliferation of generic names, to synonymization of diverse morphotypes as subspecies or "ecotypes" of a single polymorphic species. In the Gila River basin alone (Fig. 1), the forms here recognized have been placed under six generic names and have accumulated more than a dozen specific synonyms. *Gila elegans* Baird and Girard, the bonytail, has been subject to the least taxonomic confusion. It was considered a valid species until about 20 years ago, when it was placed as a subspecies of *Gila robusta* Baird and Girard (Miller, 1946b). *Gila elegans* now has been validated as a full species by the taxonomic and ecologic studies of Holden (1968)[1] and Vanicek

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[1] Holden, P. B. 1968. Systematic studies of the genus *Gila* (Cyprinidae) of the Colorado River. Unpubl. M.S. thesis. Utah State Univ., Logan, 68 pp.

(1967)[2/]. It is probably extinct in the lower Colorado River basin (Miller and Lower, 1964), and is not specifically involved in the problems discussed here. The other forms are not as easily interpreted. *Gila robusta* is widespread in the Colorado River basin, and a southern form long known as a subspecies, *G. robusta intermedia*, is restricted to the Gila River segment. *Gila intermedia* is elevated in this paper to species rank, and problematic populations in the Gila River, previously considered as intergrades between *robusta* and *intermedia* (Barber and Minckley, 1966; and others), are re-interpreted as a distinct subspecies of *G. robusta*. Emphasis is placed on temporal and spatial stabilities, habitat conditions, and the correspondence of observed patterns of variation to drainage histories and ecological information.

[2/] Vanicek, C. D. 1967. Ecological studies of native Green River fishes below Flaming Gorge dam, 1964-1966. Unpubl. Ph.D. diss., *ibid.*, 138 pp.

Figure 1. Place names in the lower Colorado River basin and in surrounding basins.

1. Phoenix
2. Buckeye
3. Florence
4. Safford
5. Prescott
6. Roosevelt Lake
7. Sullivan Lake
8. Lake Mead
9. Salton Sea
10. Guzman Basin
11. Gila River
12. Salt River
13. White River
14. Black River
15. San Francisco River
16. San Simon River
17. San Pedro River
18. San Carlos River
19. Santa Cruz River
20. Verde River
21. Agua Fria River
22. Bill Williams River
23. Virgin River
24. Little Colorado River
25. Zuñi River
26. Pluvial White River
27. Colorado River
28. Río Grande
29. Pecos River
30. Río Conchos
31. Río Yaqui
32. Río Sonora
33. Río de la Concepción
34. Monkey Springs
35. Aravaipa Creek
36. Queen Creek
37. Fish Creek
38. Cave Creek
39. East Verde River
40. Wet Beaver Creek
41. Oak Creek
42. Sycamore Creek
43. Big Chino Wash
44. Tonto Creek
45. Carizzo Creek
46. Fossil Creek
47. West Clear Creek
48. Gulf of California


115°
111°
107°
103°
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METHODS AND MATERIALS

Approximately 1500 specimens of chubs from the lower Colorado River basin and northern México (Fig. 1) were examined (see Tables 1-3 for localities and catalog numbers). Counts and measurements (the latter taken with fine-pointed dividers) were made following Hubbs and Lagler (1958). Raw data were punched on computer cards, converted to thousandths of standard length, and subjected to various statistical tests and analyses at the Arizona State University Computer Center, using principally the GE 425.

Figure 2. Allometric growth in *Gila intermedia* from Monkey Springs.

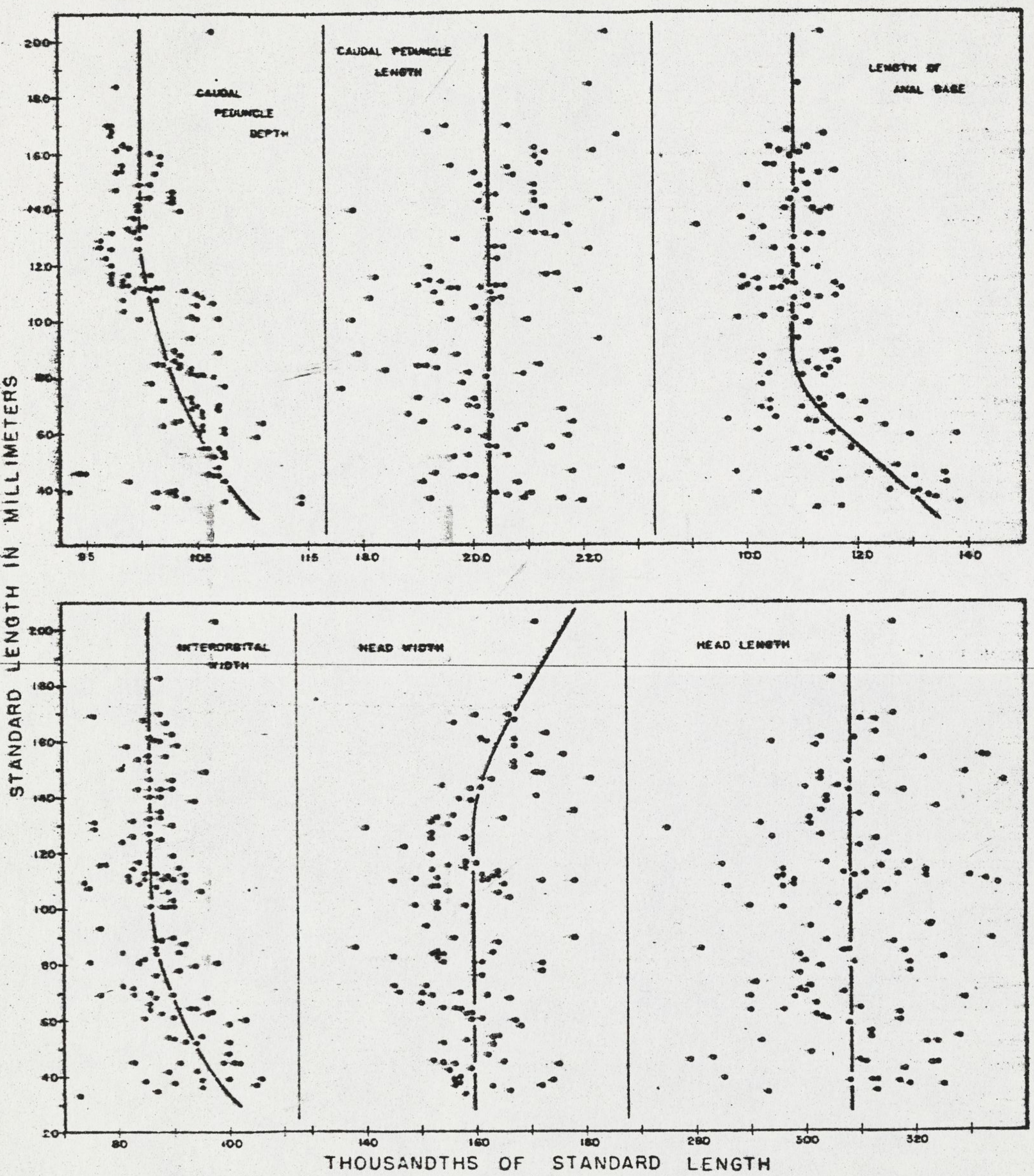
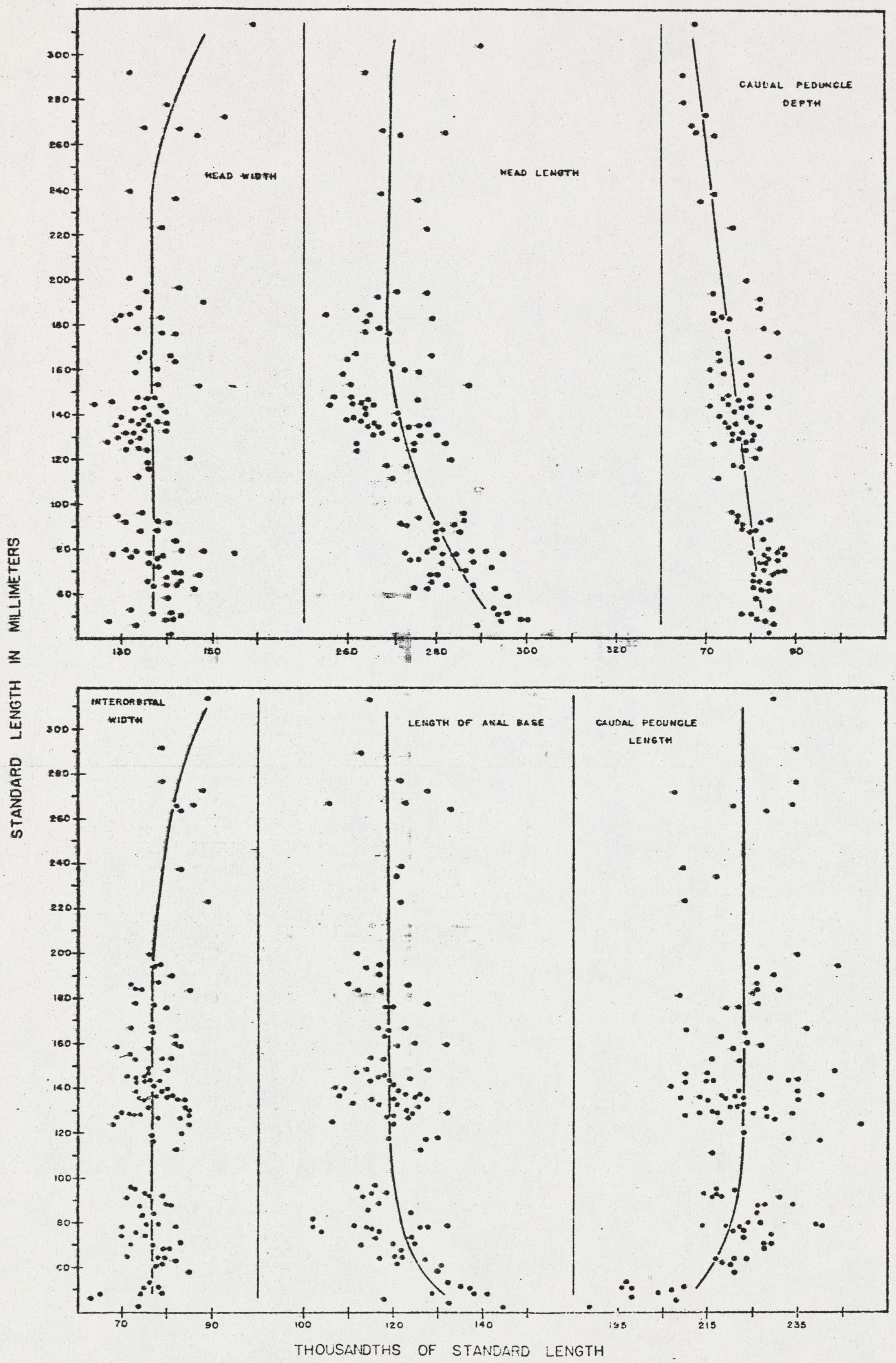

STANDARD LENGTH IN MILLIMETERS
200
180
160
140
120
100
80
60
40
20
CAUDAL PEDUNCLE DEPTH
95
105
115
CAUDAL PEDUNCLE LENGTH
180
200
220
LENGTH OF ANAL BASE
100
120
140
INTERORBITAL WIDTH
80
100
HEAD WIDTH
140
160
180
HEAD LENGTH
280
300
320
THOUSANDTHS OF STANDARD LENGTH

Figure 3. Allometric growth in *Gila robusta robusta* from the Salt River mainstream.


STANDARD LENGTH IN MILLIMETERS
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HEAD WIDTH
HEAD LENGTH
CAUDAL PEDUNCLE DEPTH
130
150
260
280
300
320
70
90
INTERORBITAL WIDTH
LENGTH OF ANAL BASE
CAUDAL PEDUNCLE LENGTH
70
90
100
120
140
195
215
235
THOUSANDTHS OF STANDARD LENGTH

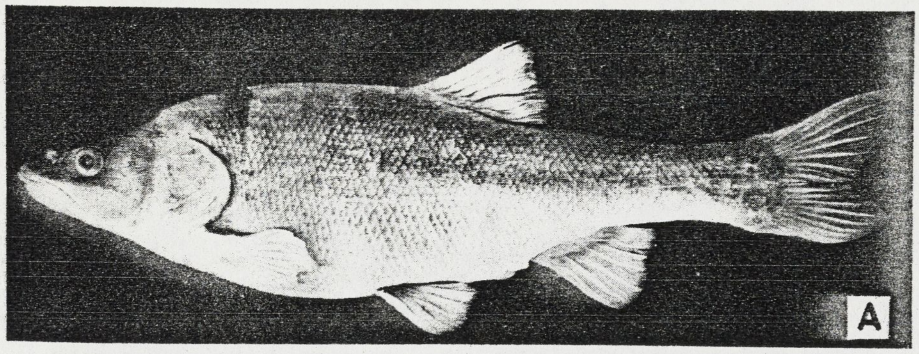
meristic features also varied with size was examined, and no such trends were evident.

Further definition of intrapopulation variability was made by morphological comparison of samples from the same place, but from different years. In series of samples where adequate material is available over a relatively long period of time (e.g., East Verde River, Black River, Monkey Springs, Cave Creek, Wet Beaver Creek, and the Gila River headwaters; Fig. 1, Tables 1, 2) marked stability year to year is indicated. A sketch by John Mix Stanley (Emory, 1848) of the "Gila trout" [=Gila robusta, but misidentified as Ptychocheilus lucius by Evermann and Rutter (1895)], the first known record of a fish from the upper Gila River, even resembles the form presently inhabiting that area.

Since allometric problems seemed minimal and temporal stability in morphology was apparent, grouping data according to major sub-basins was used to test for intra-stream variation. Significant differences were apparent within the Santa Cruz, Verde, San Pedro and upper Gila River samples, and further analyses were undertaken.

Populations from the Santa Cruz River system are modally quite similar, despite high individual variation, except for the isolated Monkey Springs fish which are uniformly distinctive over a number of years from all other samples. With that exception, lateral-line scales are invariably between 60 and 80, dorsal and anal fin-rays are both 8 (very rarely 7 or 9; Table 1). All fish are thick-bodied and darkly pigmented (Fig. 4). In all respects, they correspond to

Figure 4. Gila intermedia: (A) Monkey Springs, ASU uncat., 220 mm SL; (B) O'Donnel Creek, ASU 2720, 126 mm SL; (C) Babacomari River, ASU uncat., 150 mm SL; (D) San Carlos River, ASU uncat., 125 mm SL.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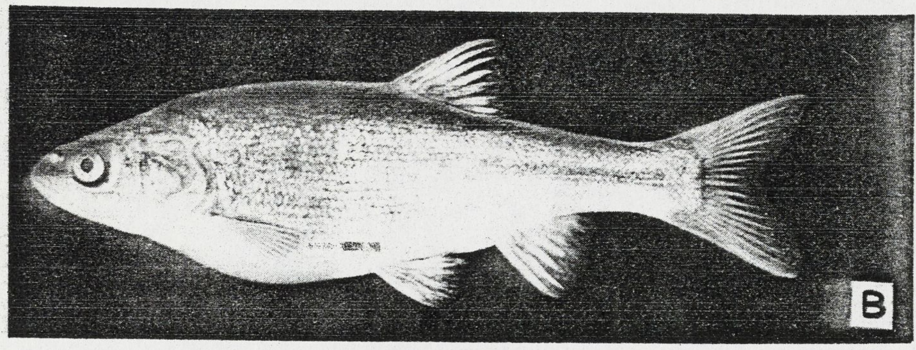
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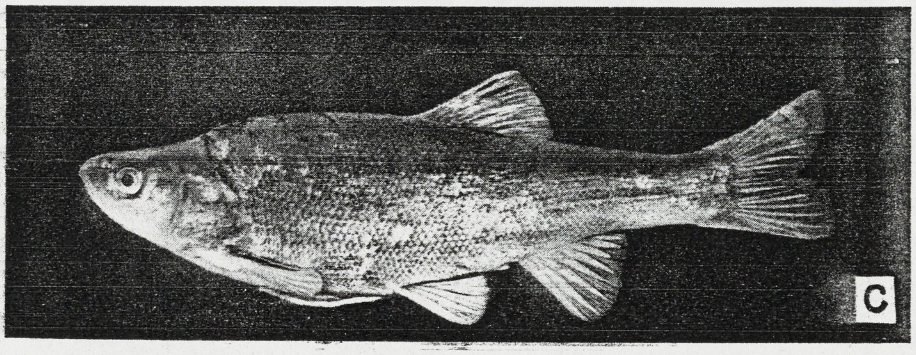
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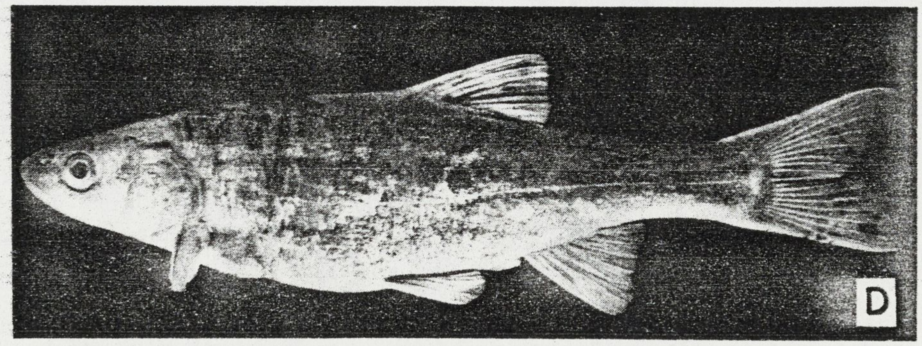
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the original description of Tigoma (= Gila) intermedia Girard (1856), and to all previous and later descriptions of chubs from the Santa Cruz basin (see synonomy, pp. 34-35).

Variation in populations of Gila from the Verde River system was exceedingly high, in almost all proportional and meristic features. However, samples from throughout the Verde River mainstream are morphometrically uniform. In tributaries, a mosaic pattern of variation occurs, with no apparent geographic coherence. Samples from tributary streams were therefore systematically examined, relative to the distance of each collection site from the Verde itself. Meristics and morphology in samples from the lower ends of tributaries, below any barrier falls or rapids (e.g., West Clear Creek, ASU 3267; Wet Beaver Creek, UMMZ 120101, UA uncat., ASU 783, 2429; and Sycamore Creek, ASU 3284, Table 2), with the exception of Wet Beaver Creek (discussed later) were the same as that of fish from the Verde River mainstream (see Fig. 6C). All correspond well to the original and subsequent descriptions of Gila robusta Baird and Girard (1853a). Fish from Big Chino Wash (UMMZ 162834), an extreme upper tributary of the Verde system, above a series of falls and rapids now partially inundated by Sullivan Lake, is G. intermedia, similar in most respects to material from the Santa Cruz system. A small sample of juvenile fish from upper Oak Creek (ASU 848) also has counts and qualitative features suggestive of intermedia. However, there is a high probability that the last population results from introduction in the intensively-managed, heavily-fished stream.

Material from above rapids or barrier falls in tributaries of the Verde River usually have lateral-line scales ranging between 70 and 90, with 75 to 85 being most common. Dorsal fin-rays are mostly 9, with the exception of Fossil Creek population (ASU 2428 and uncat.) which has 8 or 9, anal fin-rays are predominantly 8, and pelvic fin-rays are most commonly 9 on each side (Table 1). All these populations are relatively thick-bodied (Fig. 5A-B), though not as extreme as _G. intermedia_ (Fig. 4). A thorough search of the synomicon of chubs from the Gila basin, and examination of original descriptions, revealed the most-likely applicability of the name _Gila grahami_ Baird and Girard (1853c), type locality "Rio San Pedro, Arizona," and this name is applied for convenience through the remainder of this paper as _G. robusta grahami_.

It is notable that temporal stability of morphology is manifest in populations of both forms in the Verde River basin (Tables 1, 2). The only marked exception is in Wet Beaver Creek, where it appears stable (_G. r. grahami_) between 1937 and 1956, but changes in 1964-66. Wet Beaver Creek was treated with rotenone in 1962 (Bassett, 1962)[3/] and the change may reflect invasion of the lower part of the

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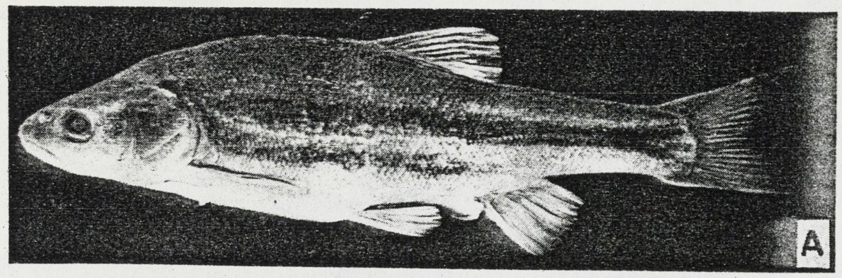
[3/] Bassett, H. M. 1962. Statewide Fisheries Investigations, Dingell-Johnson Project F-7-R-5, work plan 2, Job D-11 (compl. rept.) "A manipulation of environmental conditions pertaining to minor jobs of a developmental nature in district II," 6 pp. mimeo.

Figure 5. <u>Gila robusta grahami</u>: (A) Upper Sycamore Creek, ASU 1833, 140 mm SL; (B) East Verde River, ASU 407, 170 mm SL; (C) Aravaipa Creek, ASU 3093, 200 mm SL; (D) Taylor Creek, UMMZ 110434, 160 mm SL. <u>Gila r. robusta</u> X <u>Gila r. grahami</u>: (E) Tonto Creek, ASU 3255, 155 mm SL; (F) Carizzo Creek, ASU 3175, 150 mm SL.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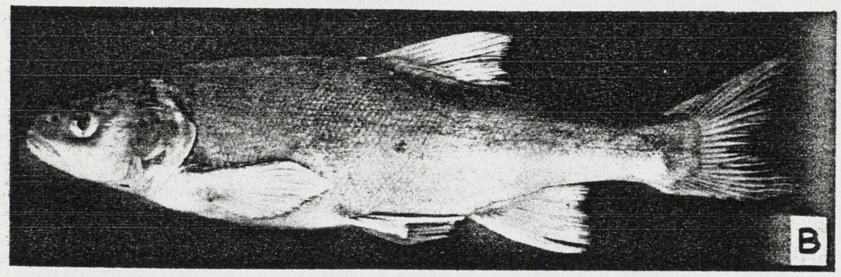
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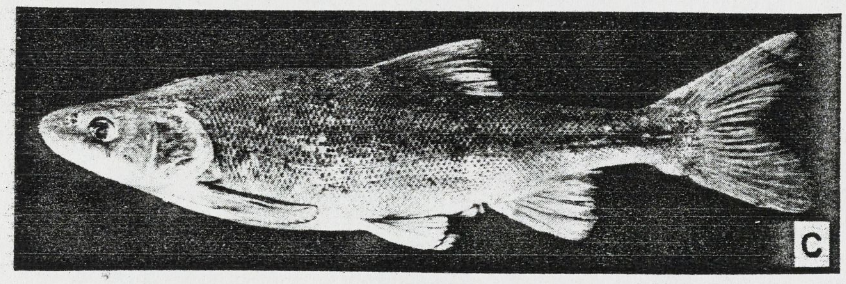
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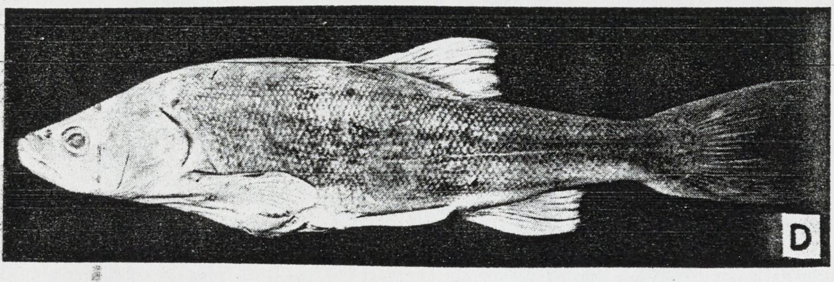
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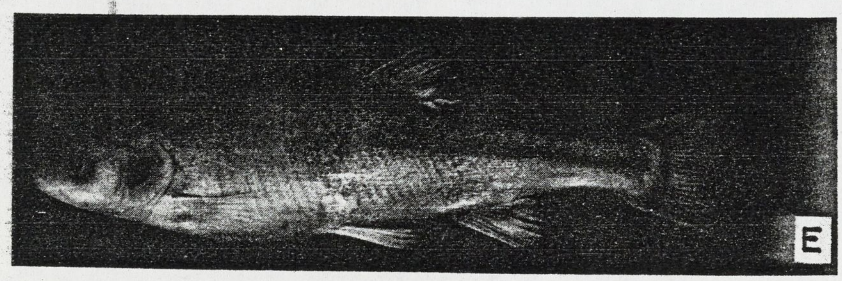
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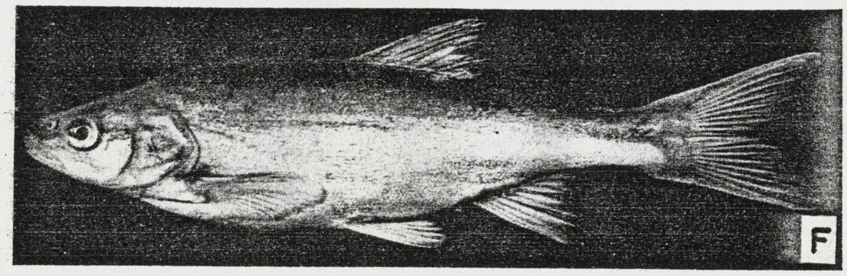
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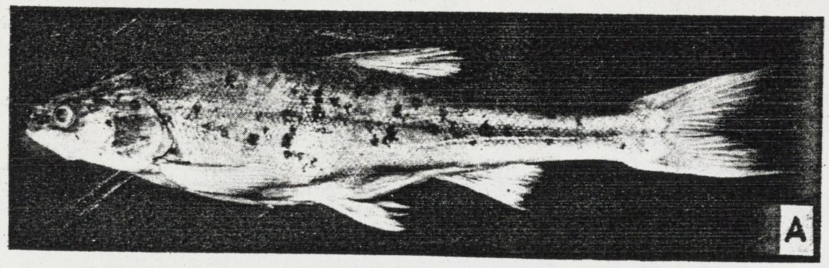
creek by Verde River G. r. robusta and intergradation of that form with remnants of the original population. Some of the indigenous fish must have survived, since Bassett indicated that limited areas in the Canyon were not treated, and Kruckenberg (1968)[4/] found Gila abundant in the upper part of the stream in the mid-1960s.

Samples from the Salt River basin, upstream from Roosevelt Lake, are G. r. robusta (Tables 1, 2; Fig. 6). Specimens from the extreme upper reaches of the Black River are slightly thicker-bodied than those downstream, and this also may be noted in several of the smaller-tributary populations. It is especially evident in Carizzo Creek (ASU 2455, et seq.; Tables 1, 2; Fig. 5F). The tendency does not, however, approach the over-all morphology of G. r. grahami. Variation of samples from Tonto Creek (Fig. 5E), a major tributary of the Salt River that heads near the eastern margin of the Verde River basin, resembles that of G. r. grahami from the East Verde River (Fig. 5B), especially in meristic features of upstream populations (UMMZ 131102), but reflects some intergradation with robusta at lower stations (Tables 1, 2). In Fish and Cave creeks that enter the Salt River downstream from its major canyon, the chubs are G. intermedia.

[4/] Kruckenberg, J. 1968. Stream survey and renovation success of Wet Beaver Creek. Typewritten report. Dept. Biology, Northern Arizona University. 32 pp.

Figure 6. *Gila robusta robusta*: (A) Bill Williams River, ASU 2774, 170 mm SL; (B) Western Canal, ASU 1513, 114 mm SL; (C) Verde River, ASU 2475, 145 mm SL; (D) Salt River, ASU 1373, 160 mm SL; (E) Salt River, ASU 3118, 195 mm SL; (F) Lower Sycamore Creek, ASU 3284, 116 mm SL.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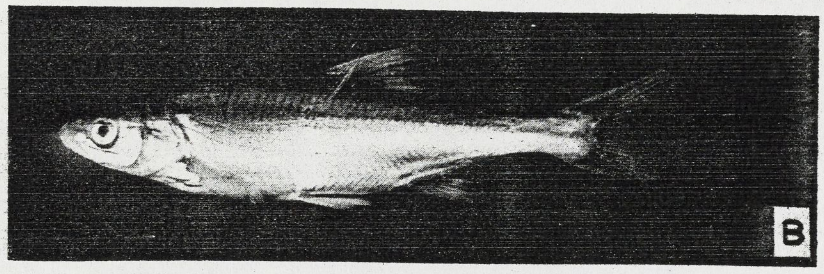
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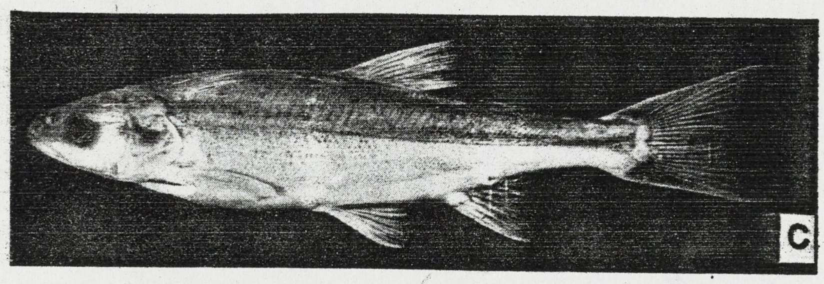
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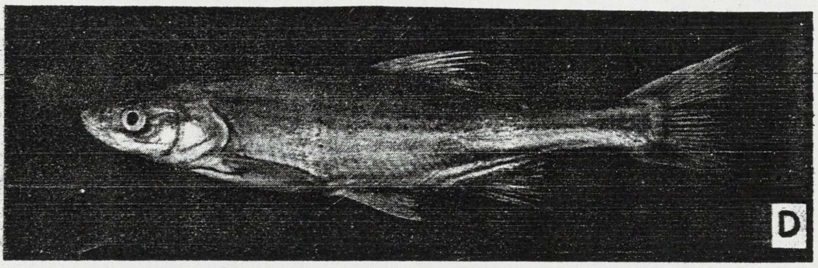
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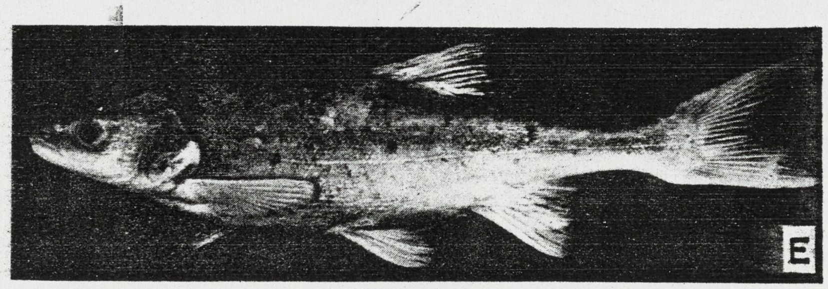
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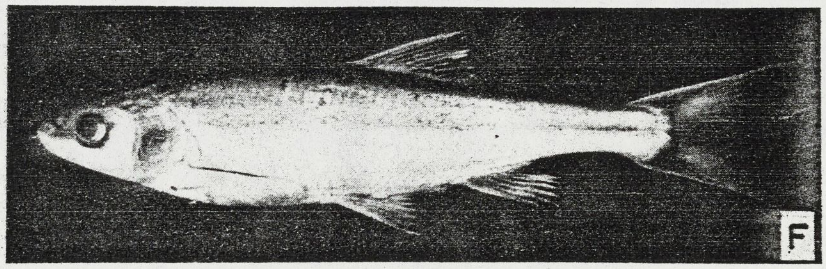
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Material from the headwaters of the San Pedro River presented no problem of interpretation. They are identical to _G_. _intermedia_ from the adjacent Santa Cruz (when Monkey Springs is excluded), as are 17 extant specimens from the extreme upper San Simon River (Tables 1, 2). Additional populations referable to _intermedia_ inhabit the San Carlos River and Queen Creek. The last population is most likely extinct, and was possibly introduced from "Salt River" according to notes on file at the University of Michigan. The remainder of the upper Gila River basin, and Aravaipa Creek (Figs. 5D and 5C respectively), a tributary to the extreme lower San Pedro River, is inhabited by _G_. _r_. _grahami_. W. J. Koster (pers. comm. to W. L. Minckley) has likewise found only one form of _G_. _robusta_ in the upper Gila River, and commented on its general uniformity. A trend toward thinner bodies and slightly higher meristic features is, however, evident in _G_. _r_. _grahami_ in the lower mainstream of the Gila River (Table 1). This parallels, in general, the trend seen in _G_. _r_. _robusta_ in the Salt drainage, and may reflect in both instances intergradation of _robusta_ and _grahami_ in the larger waters. A blotched color pattern, characteristic of many populations of _grahami_, also occurs infrequently in the Black River, and in the Gila mainstream. Specimens of _G_. _robusta_ from the Bill Williams River system, an independent tributary of the Colorado River that has derived much of its fauna from the Gila basin (Miller, 1946a; Miller and Lowe, 1964; Smith, 1966), has higher lateral-line and fin-ray counts and is referable to _G_. _r_. _robusta_; they have a high incidence of blotching (see Fig. 6A), however, that may reflect the influence of grahami or of other highly-blotched populations to the north (especially G. r. jordani Tanner, from the White River, Nevada).

It therefore appears that four forms of the genus Gila are indigenous to the lower Colorado basin (five, if an archaeological record of G. cypha Miller from Catclaw Cave, Mohave County, Arizona [Miller, 1955] is included): Gila elegans, dismissed before as not pertinent to this investigation; G. r. robusta, widespread throughout the Colorado basin and living in the Bill Williams drainage, the mainstream of the Verde, and in the Salt River system; G. r. grahami, the newly resurrected form, inhabiting the Verde River tributaries and the upper Gila River system; and, G. intermedia, principally distributed in central and southern Arizona.

ECOTYPY AND CHUBS OF THE LOWER COLORADO

Miller (1946b) referred to chubs of the Colorado River basin as "ecological subspecies" on the basis of a general trend from thick-bodies in the "small tributary and brook" form, intermedia, to the attenuate, "swift river-channel" form, elegans. These same concepts were outlined in earlier papers by Hubbs (1940, 1941, and references cited), and have appeared subsequently in a number of works (e.g., La Rivers, 1962; Beckman, 1963; Sigler and Miller, 1963; Miller and Lowe, 1964; and others). Ecotype, a term proposed by Turesson (1922) for plants, as "the product arising as a result of genotypical response of an ecospecies to a particular habitat," is generally equivalent to Miller's use of the term "ecological subspecies." The term "ecospecies," also coined by Turesson, is equivalent to the "Linnaean species from an ecological point of view [Mayr, 1963]." Mayr, et al. (1953) define ecospecies (modified from Turesson) as "a group of populations so related that they are able to exchange genes freely without loss of fertility or vigor in offspring," and ecotype as "a descriptive term applied to plant races of varying degrees of distinctness which owe their most conspicuous characteristics to the selective effects of local environments." Hubbs (1943) furthered these concepts for fishes when he stated that "in increasing numbers, subspecies are being shown to be ecological or microgeographical races [see also Hubbs, 1961]."

Another term that may pertain here is "ecotypic variation," as defined by Mayr (1963), "the formation within each geographic area of numerous localized populations that specialize in ecologically different subareas, and are not obliterated by gene exchange with adjacent, differently specialized populations." In application of such concepts to the fishes presently under consideration (excluding *G. elegans*), the ecospecies would be *Gila robusta*, with three ecotypes or eco-subspecies, "*robusta*," "*grahami*," and "*intermedia*." The "varying degrees of distinctness" would be their external morphology, in a graded series from *intermedia*, through *grahami* to *robusta*, as described before.

Habitats from which chubs have been collected by myself and other personnel from Arizona State University are generally inconsistent with an "ecotype" interpretation. For example, *G. r. grahami* has been taken in small, warm, desert streams like Aravaipa Creek (average gradient, 7.0 m/km), which consists principally of riffles and has few pools (Barber and Minckley, 1966). In contrast, Fossil Creek is a large, swift, constant-temperature spring at its source, and it drops almost 500 m in its 18 km descent to the Verde River. The subspecies also is relatively uniform in the upper Gila River basin, from the large mainstream to the high (2,500-3,000 m) mountain tributaries. Great stability in body form also exists in *G. r. robusta*, which ranges from the habitat of large, warm, strongly-flowing Phoenix Canal system (300 m above mean sea level), through the turbulent Salt River, to the cold high-gradient habitats of the

White and Black rivers (2500 m), and also is present in small, pool-riffle, low-gradient tributary creeks. In the Bill Williams drainage the fish has been taken from marshy creeks of the headwaters, and in pool-riffle habitats further downstream. The predominantly-southern _G_. _intermedia_ is rare. In the south of its range its habitats are principally lentic, in ciénegas, brooks, or (at present) in impoundments. To the north it is found in the relatively-large San Carlos River, in rock-pools of Fish Creek Canyon, and in pool-riffle situations in Cave Creek. One population lives in an artificial habitat, the Buckeye Canal.

It is apparent that each of the three forms of chubs live in different places; they are essentially allopatric. Yet the habitats of each comprise a spectrum from large to small waters, from low to high elevation, and from relative swiftness and turbulence to at least semi-lentic conditions. _Gila_ _intermedia_ prefers smaller, quiet water habitat, though it lives successfully and retains its identity in larger water like the San Carlos River and the Buckeye Canal. The forms of _G_. _robusta_, on the other hand, inhabit almost all kinds of habitats presently available to them, and remain fairly uniform in morphology over broad geographic areas; no special habitat preferences are apparent for these animals, so long as it is a stream. Slight trends toward thicker bodies and reduction of meristic features (Tables 1, 2) in populations of the upper tributaries of the Salt River (_G_. _r_. _robusta_) and of the Gila River (_G_. _r_. _grahami_), may be ecotypic response, or intergradation between those subspecies, but it is not of a magnitude that obscures distinctness of the taxa. It is highly unlikely that morphological stability of ecotypes would prevail if the animals were as plastic as ecotypic responses presumably require.

Present distribution and abundance of chubs, and other fishes, in the lower Colorado River basin, reflects the radical changes in surface water that have occurred in the last 100 years or so. Arroyo cutting has lowered water tables and drained a diversity of marshy habitats (Hastings, 1959; Miller, 1961b; Hastings and Turner, 1965; Minckley and Deacon, 1968; and references cited). Pumping from underground waters, and major and minor dams, have dried other streams. Yet, the fishes have not responded phenotypically.

ACCOUNTS OF SPECIES AND SUBSPECIES

All older literature on the "*Gila robusta* complex" that was available to me, is cited in the following accounts. More recent publications are included only if they refer to fish from the lower Colorado River basin, below Lake Mead (Fig. 1). Comparisons of critical characters of the species of the lower Colorado basin are given in the following key, compiled from original data and from the literature.

Key to Species

1a. Body highly streamlined; skull depressed on dorsum, arching smoothly into a predorsal hump in large adults. Total number of vertebrae (including one urostylar vertebrae and four in the Weberian apparatus), 47-50. Caudal peduncle thin, pencil-like, length of caudal peduncle/length of head 1.0 or greater, length of head/depth of caudal peduncle usually 5.00 or greater. Squamation often incomplete, with scales absent or highly embedded on predorsum, venter, and caudal peduncle. Fins large and falcate, origin of dorsal fin nearer to tip of snout than to caudal fin-base. Dorsal fin-rays almost always 10 or more; anal fin-rays usually 10 . . . . *Gila elegans* Baird and Girard.

b. Body thicker, not obviously streamlined; skull slightly depressed or rounded on dorsum, predorsal hump absent, or if present, fatty and rising abruptly at the nape. Total number of vertebrae 38-49. Caudal peduncle short, thick, and wide, length of caudal peduncle/length of head less than 1.0. Length of head/depth of caudal peduncle 5.0 or less (usually less than 4.0). Squamation complete. Fins smaller and rounded, origin of dorsal fin nearer to caudal fin-base than tip of snout. Dorsal and anal fin-rays 9 or fewer (very rarely 10) 2

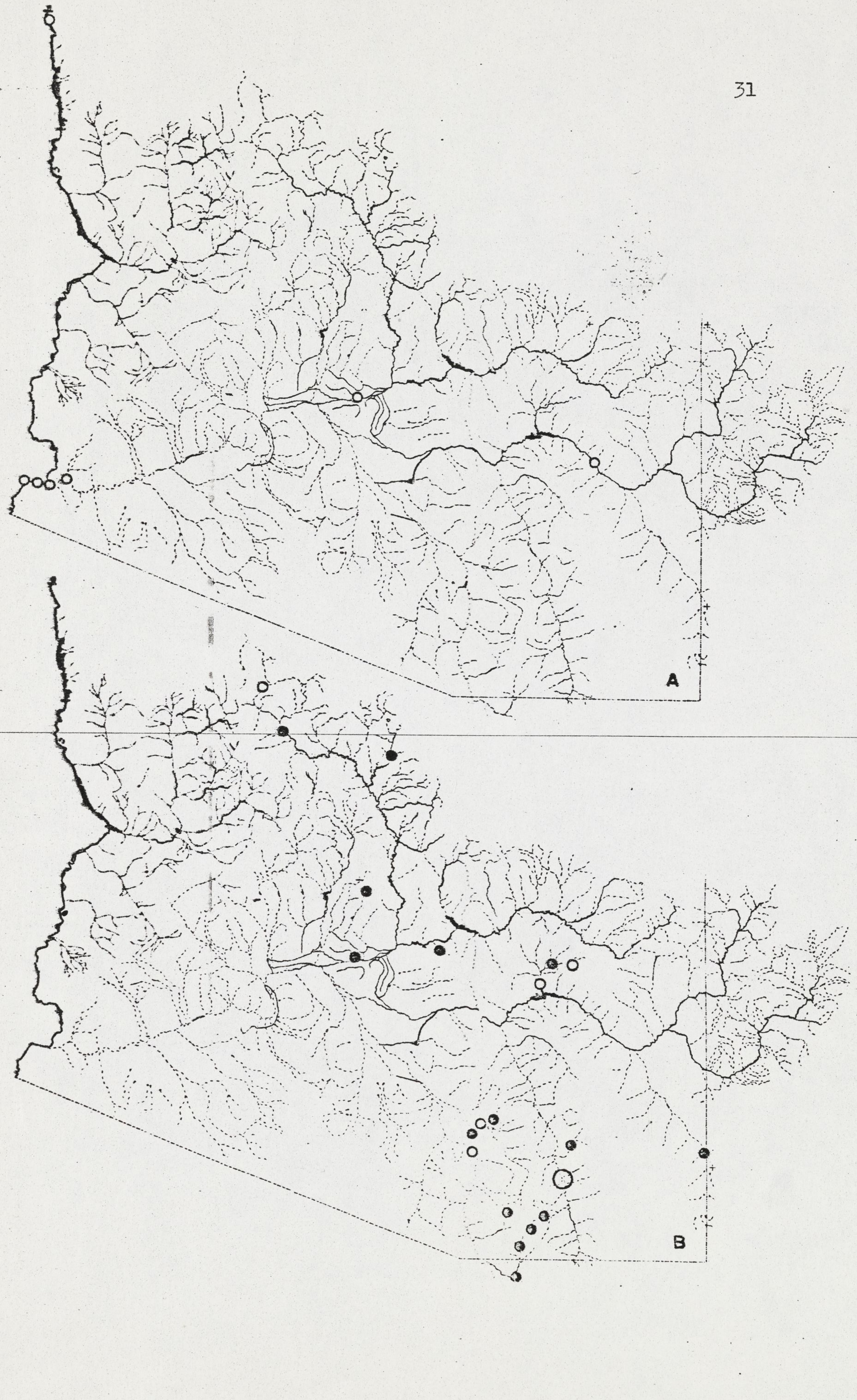
2a. Body chubby, dark in coloration. Scales large, thick, and broadly imbricate; basal radii usually present. Lateral-line scales almost always fewer than 80. Dorsal fin-rays usually 8 (rarely 7 or 9); anal fin-rays 8 (rarely 7); pelvic fin-rays 8 or 9. Length of head/depth of caudal peduncle usually 3.0 or less. An abrupt, fatty, nuchal hump develops in large females of some populations. Total number of vertebrae 38-45 . . . . *Gila intermedia* Girard.

b. Body thick, but not chubby, light to mottled in coloration. Scales smaller, thinner, and slightly imbricate; basal radii absent to weakly developed. Lateral-line scales usually more than 80 (*grahami* ranges as low as 75). Dorsal fin-rays 9, anal fin-rays mostly 9 (*grahami* has 8 or 9), pelvic fin-rays usually 9. Length of head/depth of caudal peduncle usually 3.0 or more. Fatty nuchal hump rarely developed, and if present, scarcely discernible. Total number of vertebrae, 43-49 . . . . *Gila robusta* Baird and Girard.

Gila elegans *Baird and Girard*, *Bonytail chub*.—Though once widespread in the Colorado River basin, this species is now essentially restricted to the upper part of the drainage above Lake Mead. It is extinct in the Gila River system (Fig. 7A). Literature records are from the mouth of the Gila River to as far east as Fort Thomas on the mainstream (Kirsch, 1889). This record may be questionable, especially if based on small specimens, yet "big-river fishes" like squawfish (*Ptychocheilus lucius*) and humpback sucker (*Xyrauchen texanus*) formerly moved to even higher elevations (Minckley and Alger, 1968; Minckley and Deacon, 1968), and large specimens reported from Tempe (Gilbert and Scofield, 1898), were undoubtedly *G. elegans*.

Gila elegans Baird and Girard, 1853a: 369 (orig. descr., "Zuni River, New Mexico"), 1853b: 150-51 (char., figs.); Girard, 1858: 286, 1859: 61 (char.); Cope, 1871: 441 (listed); Jordan and Gilbert, 1883: 227 (listed); Jordan, 1885: 818 (listed), 1891: 22 (dist.); Jordan and Evermann, 1896: 226-27 (synon., char.); Gilbert and Scofield, 1898: 492 (char.); Meek, 1904: 53-54 (range, char.); Snyder, 1915: 580-81 (compar.); Jordan, *et al*., 1930: 114 (synon.); Moffett, 1942: 82, 1943: 182 ("Lake Mead area"); Dill, 1945: 153-54 (dist., abun.); Minckley and Deacon, 1968: 1427 (listed).

Figure 7. Distribution of Gila elegans (A) and Gila intermedia (B) in the lower Colorado River basin. Solid circles are localities from which specimens were examined, small open circles represent literature records, and the large open circle is the type locality.


A
B

Gila emoryi Baird and Girard, 1853a: 388 (orig. descr., "Gila River"); Jordan and Gilbert, 1883: 229 (listed).

Gila emorii, Girard, 1856: 205 ("Gila River"), 1859: 62 (listed); Cope and Yarrow, 1876: 667 (listed); Jordan and Gilbert, 1883: 241 (listed); Kirsch, 1889: 558 ("Fort Thomas, Arizona").

Leuciscus elegans, Gunther, 1868: 241 (char.).

Leuciscus emorii, Gunther, 1868: 242 (char.).

Gila robusta elegans, Miller, 1946b: 414 (char., compar.), 1961b: 373-74, 78 (range, habitat); Wallis, 1951: 90 (Lake Mead National Recreation area); La Rivers, 1952: 101 (key), 1962: 391-93 (synon., char., range); La Rivers and Trelease, 1952: 116 (listed); Shapovalov, et al., 1959: 172 (listed); Miller and Lowe, 1964: 140 (compar., "ecotypy"); Uyeno and Miller, 1965: 39 (compar.); Cole, 1968: 471-72 (habitat, fig.).

Gila intermedia (Girard), Gila chub.—This species is endemic to the Gila River basin and is most abundant and widespread in the southeastern part (Fig. 7B). It commonly inhabits small creeks and ciengas. Its northernmost representation in the upper Verde system below the Mogollon Rim (e.g., Big Chino Wash and perhaps Oak Creek) may best be explained via stream capture from headwaters of the Agua Fria River (see later).

The specific identity of G. intermedia is proposed on the basis of a combination of characters. For example, 97 per cent of 390 specimens of G. intermedia have fewer than 80 scales in the lateral series (77 per cent have fewer than 75), whereas, 80 per cent of the 670 specimens of G. robusta (both subspecies) have 80 or more lateral line scales, and 96 per cent have more than 75. Strongly-inscribed basal radii were present in 63 per cent of about 70 intermedia from throughout its range, but basal radii were present in only 14.6 per cent of 137 specimens of robusta, and then were only weakly developed. Dorsal fin-rays in intermedia were 7 or 8 in 94 per cent of the specimens examined, and were 9 or more in 83 per cent of the robusta. Numbers of anal fin-rays are less reliable for separating the species because of the high incidence of 8 rays in G. r. grahami (ca. 50 per cent); 98 per cent of the G. intermedia had 7 or 8 anal fin-rays and only 13 per cent of the G. r. robusta had 8 or fewer. Pelvic fin-rays are almost always 9 in the subspecies of G. robusta (greater than 95 per cent), and are 8 or 9 in G. intermedia (ca. 50:50). Length of head/depth of caudal peduncle is more than 3.0 in 87 per cent of G. robusta, and below 3.0 in 83 per cent of G. intermedia. Of the two subspecies, G. r. robusta is more distinct (greater than 95 per cent above 3.0) from G. intermedia than is G. r. grahami (77 per cent more than 3.0).

Breeding coloration of G. intermedia from Monkey Springs has been recorded by Minckley (1968)[5]: 'The axial and inguinal regions become deep orange-red, which may develop further into a broken,

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[5] Minckley, W. L. 1968. Aquatic biota of the Sonoita Creek basin, Santa Cruz County, Arizona. Arizona State University, 28 pp., mimeo.

orange-red band along the lower sides and caudal peduncle, and extend forward to include the branchioestegal rays and cheeks. The eyes of males become yellow to yellow-orange and the body is blue-black dorsally. Fins of some individuals, especially the larger ones may be washed with lemon-yellow." Breeding colors in intermedia recorded by myself from specimens from the San Carlos were in general agreement.

Gila gibbosa Baird and Girard, 1854: 28 (orig. descr., "Rio Santa Cruz, Arizona").[6]

Tigoma intermedia Girard, 1856: 206 (orig. descr., "Rio San Pedro of the Gila [Arizona]").

Tigoma gibbosa, Girard, 1856: 207, 1859: 64 (char., figs.); Jordan, et al., 1930: 119 ("Rio Gila, Arizona").

Gila nigra Cope, in Cope and Yarrow, 1876: 663 (orig. descr., "Ash Creek, Arizona," and "San Carlos, Arizona").

Squalius intermedius, Jordan and Gilbert, 1883: 238 (listed).

Squalius niger, Jordan and Gilbert, 1883: 238 (listed).

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[6] The name "Gila gibbosa" has obvious priority for this fish, but is unavailable since it was synonomyzed with Leuciscus niger (Cope) by Jordan and Evermann (1896). The name gibbosus was twice preoccupied in Leuciscus, and Article 59 of the International Code of Zoological Nomenclature (1961) dictates continued suppression of a name that is once a homonym, even if the homonymy is incorrect. The next available name, Tigoma intermedia, is therefore applied.

Squalius lemmoni Smith, 1884: 3 (orig. descr., "Rillito Creek, near Tucson, Arizona").

Leuciscus intermedius, Evermann and Rutter, 1895: 484 ("Rio San Pedro, tributary of Rio Gila"); Gilbert and Scofield, 1898: 493-94 (in part; char., synon., "Tempe and Chino, Arizona"); Meek, 1904: 56 (char., synon.).

Leuciscus niger, Jordan and Evermann, 1896: 235 ("Rio Gila", char., synon.).

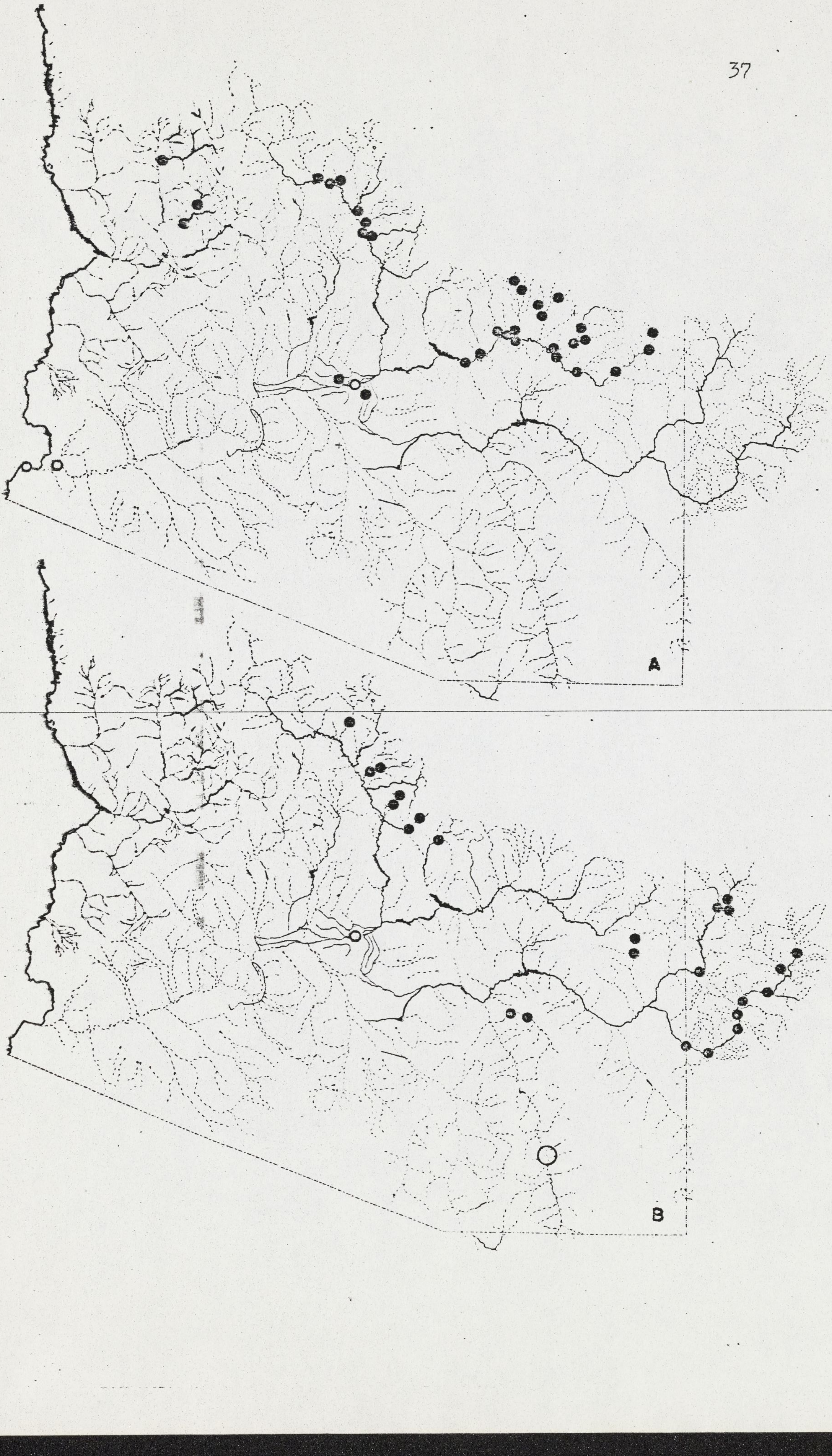
Richardsonius gibbosus, Snyder, 1915: 581-82 (in part; char., synon., "Rio Santa Cruz").

Gila robusta intermedia, Miller, 1946b: 414 (char.), 1945: 108-109 (compar.); 1961b: 377-79 (habitat, range, "ecotypy"); La Rivers, 1962: 392 (compar.); Miller and Lowe, 1964: 140 (habitat, range); Uyeno and Miller 1965: 39 (compar.); Barber and Minckley, 1966: 317-19 (compar.); Minckley and Alger, 1968: 94 (compar.); Cole, 1968: 371-72 (habitat, fig.).

Gila intermedia, Minckley and Deacon, 1968: 1427 (listed).

Gila robusta *Baird and Girard, Colorado River chub.*—This species is presently the most widely distributed chub in the Colorado River basin, where it is represented by four forms: *G. r. robusta*, throughout the basin in the larger streams; *G. r. grahami*, Gila River basin (Fig. 8B); *G. r. seminuda* Cope, Virgin River, and *G. r. jordani*, the Pluvial White River, Nevada. *G. r. grahami* is restricted to the Verde River tributaries, upper Gila River, and Aravaipa Creek. Records

Figure 8. Distribution of Gila robusta robusta (A) and Gila robusta grahami (B) in the lower Colorado River basin. Solid circles are localities from which specimens were examined, small open circles represent literature records, and the large open circle is the type locality.


A
B

of G. grahami from Utah (Evermann and Rutter, 1895) are based on misidentifications of G. r. robusta. G. r. robusta inhabits the Verde River mainstream and the Salt River system above Roosevelt Dam. Intergrading populations seem present in lower Wet Beaver Creek, Tonto Creek, Salt and upper Gila rivers, and possibly in the Bill Williams River (Fig. 8A).

On a population basis G. r. grahami has between 70 and 90 scales in the lateral series in 98 per cent of the specimens, with most (82 per cent) falling between 75 and 85 (range of means 77.0-82.4). G. r. robusta has 80 or more lateral-line scales in 97 per cent of specimens examined (range of means, 83.8-91.3). Dorsal fin-rays are 9 in 99 per cent of G. r. robusta, whereas 18 per cent of G. r. grahami had 8 dorsal fin-rays and the remainder 9. Anal fin-rays are 9 in 87 per cent of robusta while grahami has an approximate 50:50 ratio of 8 and 9 anal fin-rays. The pelvic fin-rays are almost always 9 in both subspecies (91 per cent in grahami and 97 per cent in robusta). Re-calculation of data in Table 2 gives the ratio of mean length of caudal peduncle/length of head usually less than 0.74 in grahami (44 per cent), and in robusta 84 per cent of the population had a ratio greater than 0.74. Population means of length of head/depth of caudal peduncle falls between 3.00 and 3.30 in 99 per cent of grahami, as compared to 81 per cent of robusta that fall above 3.30 (range of means 2.78-3.27 and 3.28-3.62 respectively). Blotching is commonly present in G. r. grahami (similar to that of G. r. jordani in the Pluvial White River [Tanner, 1959; La Rivers, 1962]), but is rarely developed in G. r. robusta. Breeding colors that have been noted in both robusta and grahami resemble those of G. intermedia; however, great variation in intensity exists. For example, specimens collected throughout the year from the Salt River mainstream fail to display even the slightest development of nuptial colors, even in ripe males. In contrast, colors of mature male specimens of G. r. grahami from Aravaipa Creek were well developed.

The following synonomies and key to the subspecies of G. robusta from the Gila River basin summarize my findings.

Gila robusta robusta Baird and Girard

Gila robusta Baird and Girard, 1853a: 369 (orig. descr., "Zuni River, New Mexico"), 1853b: 148-49 (char., figs.); Girard, 1856: 205 (listed); Evermann and Rutter, 1895: 483 (range, char., synon., "Babacomari Creek, Ariz."); Jordan and Evermann, 1896: 227-28 (char., synon.); Gilbert and Scofield, 1898: 493 (synon., char., compar.); Snyder, 1915: 581 (char., compar.); Jordan, et al., 1930: 114 (synon.); Miller, 1945: 104 (in part; char., range); La Rivers, 1962: 392 (char., compar.); Minckley and Deacon, 1968: 1427 (in part; listed).

Gila gracilis Baird and Girard, 1853a: 369 (orig. descr., "Zuni River, New Mexico"); Girard, 1856: 205 (listed); Baird and Girard, 1858: 287 ("White River, Arizona"); Cope and Yarrow, 1876: 665 (char.); Jordan and Gilbert, 1883: 229 (char.).

Ptychocheilus vorax Girard, 1856: 209 (listed), 1859: 301 (char.).

Gila affinis Abbott, 1860: 473-74 (orig. descr., "Kansas River", in error, locality unknown).

Leuciscus robustus, Günther, 1868: 241 (char.).

Leuciscus zunnensis Günther, 1868: 241 (replacement for *gracilis*, preoccupied in *Leuciscus*).

Gila nacrea Cope, 1871: 441 (orig. descr., possibly young of *Gila elegans*).

Gila robusta robusta Miller, 1946b: 414 (char., compar.), 1955: 131 (compar.), 1961b: 378 (listed); Simon, 1951: 79 (char., fig.); La Rivers, 1952: 100 (key), 1962: 392 (char., compar.); Beckman, 1963: 45 (char., compar., illust.); Uyeno and Miller, 1965: 39 (compar.); Barber and Minckley, 1966: 317-19 (compar.); Minckley and Alger, 1968: 93-94 (compar.); Cole, 1968: 471-72 (habitat, fig.).

Gila robusta grahami, *Baird and Girard*

Gila grahami Baird and Girard, 1853c: 389 (orig. descr., "Rio San Pedro, tributary to Rio Gila, Arizona"); Girard, 1856: 205 (listed); 1859: 61-62 (char., figs.); Cope, 1871: 441 (listed); Cope and Yarrow, 1876: 665-66 (in part; char., synon., range); Jordan and Gilbert, 1883: 228 (char.).

Leuciscus grahami, Günther, 1868: 242 (char.).

Ptychocheilus lucius, Evermann and Rutter, 1895: 476 (misident.).

Gila robusta, Evermann and Rutter, 1895: 483 (in part; "Rio San Pedro, tributary of Rio Gila, Fort Bridger, Henry's Fork of Green River, White River, Colorado Chiquito, and Ash Creek, Arizona"); Jordan and Evermann, 1896: 227 (in part; char., dist.); Gilbert and Scofield, 1898, 493 (in part); Jordan, et al., 1930: 114 (in part, listed); Miller, 1945: 104 (in part; range), 1946a: 414 (in part; compar., char.), 1961b: 376 (in part; habitat), 1963: 7 (in part; listed); Koster, 1957: 58 (char.); La Rivers, 1962: 389-90, 92 (in part; "Colorado River and tributaries," compar., synon.); Minckley and Deacon, 1968: 1427 (in part; listed).

Richardsonius gibbosus, Snyder, 1915: 582 (in part [?]; "Clear Creek 20 miles above confluence with Verde").

Gila robusta robusta, Miller, 1961b: 377 (in part); Miller and Lowe, 1964: 141 (in part); Minckley and Alger, 1968: 93-94 (in part); Cole, 1968: 471-72 (in part: habitat).

Gila robusta: robusta X intermedia, Barber and Minckley, 1966: 317-19 (char., "Aravaipa Creek, Arizona").

Key to Subspecies of Gila robusta from the Gila River Basin

1a. Scales in the lateral line usually more than 80 (78-99). Anal fin-rays almost always 9. Means of length of caudal peduncle/length of head usually more than 0.74; means of length of head/depth of caudal peduncle 3.25 or greater. Coloration most often silvery or dark gray dorsally, light ventrally, very rarely blotched . . G. r. robusta Baird and Girard.

b. Scales in the lateral line between 70 and 90, usually 75-85. Anal fin-rays 8 or 9. Means of length of caudal peduncle/ length of head usually less than 0.74; means of length of head/ depth of caudal peduncle almost always less than 3.30. Coloration darker, gray and commonly blotched . . . .
. . . . <u>G</u>. <u>r</u>. <u>grahami</u> Baird and Girard

DISCUSSION AND CONCLUSIONS

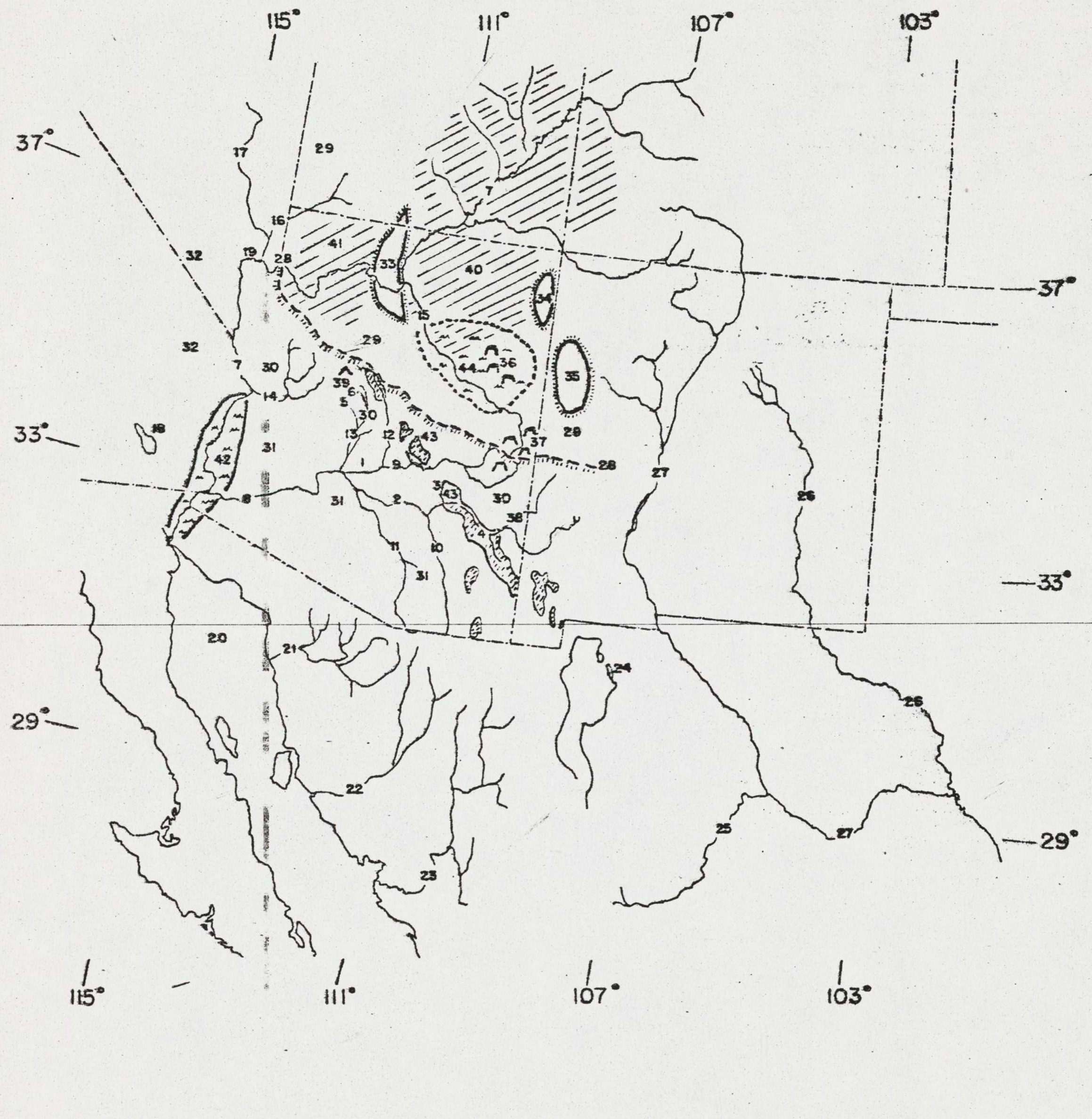
Taxonomic conclusions in preceding sections are based largely on the lack of morphologic "ecotypy" in chubs of the lower Colorado River basin, and on their distributions that are inconsistent with any conceivable pattern of intergradation. Ecotypy is discussed before, as is the general distribution of each form, but interpretation of patterns of variation necessitates examination of the history of integration in the drainage basin, and of age, origins, and affinities of its fauna. Since chubs referable to *Gila* are known from mid-Miocene to present (Miller, 1965), and species near, if not identical with, *G. robusta* are present in late Pliocene (Uyeno and Miller, 1963, 1965), it will be necessary to review much of the known Cenozoic history of the lower Colorado River basin. As orientation to the proposed sequence of differentiation of *Gila* in this area, the following events are proposed as most probable—they will be justified and expanded later: (1) The lower basin was inhabited by a form of *G. robusta* derived from the north in early stages of drainage integration with the Colorado Plateau. (2) A second form of *Gila* (*G. intermedia* or its ancestor) invaded from the south, and inhabited waters south and west of the Mogollon Highlands. (3) Completion of internal integration of the Gila basin allowed invasion of an aggressive, larger-river population of *G. robusta* into areas inhabited by both the other chubs.

(4) Ecological adjustments and displacements occurred, plus intergradation of the two forms of _G. robusta_, until complementary distributions were attained.

Interpretation of changes in drainage in this vast region center principally on the relationships of the Colorado Plateau to areas to the south and west (Fig. 9). In late Mesozoic, the Plateau most likely consisted of a low, alluvial plain, near sea level and with drainage to the east and northeast toward receding Cretaceous seas (Wilson, 1962; McKee, _et al._, 1967). In Laramide times, uplift along the western margin, and in some areas on the Plateau, was gentle, and directions of drainage remained relatively unchanged. Extensive erosional stripping of Mesozoic deposits was accompanied and followed by deposition of extensive northern and eastern beds during Eocene, in the area that now is Utah. According to McKee, _et al._ (1967), two drainage systems appeared on the Plateau by earliest Miocene, or sooner, the small Hualapai system west of the Kaibab uplift, and another, larger system to the east (Fig. 9). The Hualapai apparently flowed southwest, or possibly west. The other system ultimately drained toward the east or southeast, perhaps near the present course of the Little Colorado River. Continuing uplift south of the southern border of the Plateau, in a positive area called the Mogollon Highlands by Harshbarger, _et al._ (1957), and Central Arizona Mountains by McKee, _et al._ (1967), provided from its northern exposures extensive gravels to the southern Plateau margin (McKee, 1951).

Figure 9. Geological index map of Arizona and surrounding states with place names where appropriate.

1. Phoenix
2. Florence
3. Globe
4. Safford
5. Prescott
6. Chino Valley
7. Colorado River
8. Gila River
9. Salt River
10. San Pedro River
11. Santa Cruz River
12. Verde River
13. Agua Fria River
14. Bill Williams River
15. Little Colorado River
16. Virgin River
17. Pluvial White River
18. Salton Sea
19. Lake Mead
20. Gulf of California
21. Río de la Concepción
22. Río Sonora
23. Río Yaqui
24. Guzman Basin
25. Río Conchos
26. Pecos River
27. Río Grande
28. Mogollon Rim
29. Area of Colorado Plateau
30. Area of Mogollon Highlands
31. Area of Basin and Range Province
32. Area of Mohavia Landmass
33. Area of Kaibab Upwarp
34. Area of Defiance Uplift
35. Area of Zuñi Uplift
36. Area of Hopi Buttes Volcanic Field
37. Area of White Mts. Volcanic Field
38. San Francisco River
39. Area of Black Hills
40. Area of Upper Ancestral Colorado River
41. Area of Hualapai Drainage
42. Area of Bouse Embayment
43. Approximate limits of Pleistocene lake beds
44. Area of lower extent of Bidahochi Formation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Changes on the Plateau in Pliocene times (McKee, et al., 1967), or perhaps in Miocene (Cooley, in McKee op. cit.; Cooley and Akers, 1961; Cooley and Davidson, 1963), consisted of deposition of the extensive Bidahochi Formation (Fig. 9) in the southeastern part (Repenning and Irwin, 1954; Repenning, et al., 1958), and of integration of the eastern and western drainages of the Plateau into the through-flowing Colorado River. Question persists as to the course of the Colorado River west of the Plateau. It may have flowed west, as indicated by extensive Pliocene siltstones southwest of the Salton Sea (Woodring, 1932; Reed, 1933), and perhaps substantiated by fish distributions (Hubbs and Miller, 1948; Smith, 1966), or it may have flowed south, in or near its present channel. There is little doubt, however, that the river flowed through the area now occupied by Lake Mead in later Pliocene (McKee, et al., 1967), and extended on to the Gulf of California (Metzger, 1968).

The lands forming part of the present Gila River segment of the Colorado River basin, south of the Mogollon Highlands, were drained by southwesterly-flowing streams in post-Laramide times. The Mogollon Highlands were continuous with a landmass in what is now southern Nevada and eastern California (Fig. 9), forming during much of the Cenozoic a divide between the Plateau and the Basin and Range Province (Cooley and Davidson, 1963). Southwesterly drainage through the Highlands, from the edge of the uplifted Plateau, was disrupted in Miocene by additional uplift of the Highlands as a unit (Lance, 1960). Gorges were cut in the rising mountains, and drainages developed transverse to the superimposed systems along zones of weakness, or under structural control (Melton, 1960; 1965; Cooley and Davidson, 1963). By this time, much of the southern edge of the Plateau had been captured by south-flowing streams, and the Mogollon Rim (Fig. 9) was well established as the divide between the Gila and the Little Colorado Rivers. The Bill Williams River area has been little studied, but it lies southwest of the Mogollon Highlands in an area of relative stability, and may long have occupied its present position.

Gila robusta, or its progenitor, must have lived in the lower basin at least by Pliocene, and perhaps prior to cutting of the Grand Canyon. Early access was possible through massive headward erosion and capture of the southern part of the Colorado Plateau by the ancestral Salt and Gila rivers in late Miocene or in Pliocene (Cooley and Davidson, 1963). Establishment of a sharp drainage divide with uplift of the Mogollon Rim in mid-Pliocene may have provided effective isolation, and the Upper Verde basin was diverted south by uplift of the Black Hills (Fig. 9) at about this time (Lehner, 1958; Cooley and Davidson, 1963). Access from the west obviously could not have occurred prior to cutting of the lower Colorado River, and may have been blocked for a time by the Pliocene, Bouse Embayment (Hamilton, 1960; Metzger, 1968). Miller (1961a) suggested that the distinctive fauna of the Gila River indicates a rather recent connection with the Colorado River. However, for part of the Pliocene, the lower basin must have been accessible to chubs from that direction.

Events in later Pliocene again cut off much of the upper part of the ancestral Gila River basin from the Colorado mainstream, and provided isolation for differentiation of the chubs. Valley fills of lacustrine and fluvial nature were deposited to depths exceeding 600 meters in the extensive structural trough, partially a graben, that bounds the Colorado Plateau from the mouth of Grand Canyon to northern Chihuahua, México (Feth and Hem, 1963; Feth, 1964). Surface elevations of these deposits are remarkably similar throughout the area, and fossils included in a number of them correlate well (Taylor, 1963; Feth and Hem, 1963). Ponding of the rivers was effected by extrusion of volcanic materials and uplift in the lower Salt River area (Fig. 9) east of the present city of Phoenix (Melton, 1960; 1965). At this time the upper Gila River (not including the reach east of Safford, see later) may have joined the Salt River north of the present town of Globe. An extension of the extrusives to the north along the Verde impounded that stream (Jenkins, 1923), and to the east of Florence, the San Pedro segment of the basin was similarly isolated. The Santa Cruz and other lesser rivers entering the lower Gila valley were scarcely affected, and flowed far west to enter the drainage. The upper Gila River, above Safford, was not apparently integrated to the west until mid-Pleistocene, after the onset of incision of the volcanic dams, and prior to that time presumably flowed south into a closed basin; or perhaps into México (Morrison, 1954; Cooley and Davidson, 1963; Melton, 1965; Weber, in Kottlowski, _et_ _al_., 1965).

The ancestor of Gila intermedia could have dispersed into north-flowing tributaries of the ancestral Gila basin at almost any time in Pliocene or Pleistocene, and remained in relatively small, headwater situations to the south and west of the Mogollon Highlands, moving into that region as dissection progressed. General distribution of the fish in recent times in the southern tributaries of the Gila (Fig. 1), perhaps reflects movement over lowered divides resulting from alluviation of valleys between the Santa Cruz and San Pedro rivers in Pleistocene (Melton, 1965), and the occurrence of intermedia in the extreme upper Verde may result from a diversion of part of the Agua Fria River to the Verde in the area east-northeast of Prescott (Chino Valley). No preserved material of Gila is known from the Agua Fria, but specimens of G. intermedia from that stream were seen by W. L. Minckley (pers. comm.) in 1966.

Cutting of dams that blocked the rivers was initiated at about the same times, in early mid-Pleistocene, with cessation of volcanism and uplift at points of damming. Breaching of dams re-integrated much of the system; base levels in the alluviated valleys were high above that of the lower part of the system, and dissection progressed fairly rapidly. This degradation left remnant populations of fishes, including G. r. grahami, above falls of smaller tributaries. Movement of downstream populations, presumably G. r. robusta by this time, also was possible and they invaded upstream and largely displaced the former isolate, G. r. grahami.

An obvious alternative to the interpretations given so far is secondary contact and hybridization (Mayr, 1963) between a Gila River endemic (*G. intermedia*), and an upper basin form (*G. robusta*). This cannot be completely rejected. If true, however, the hybridization must pre-date cutting of the lake beds (mid-early Pleistocene) since *G. r. grahami* now persists in hanging tributaries of the Verde system (*i.e.*, Fossil Creek) and shows remarkable homogeneity over a diverse spectrum of habitats, and in relation to time. Present intergradation between two subspecies (*robusta* and *intermedia*) also may generally be rejected on the bases given above. No current zones of sympatry between *robusta* and *intermedia* are known but some older records (*e.g.*, Gilbert and Scofield, 1898), indicate local sympatry in complex habitats. The intermediate form, *grahami*, may show differentiation from place to place, a possible indication of isolation above dams of the different rivers during Plio-Pleistocene impoundment. These variations seem independent of the proximity of *G. intermedia*. Variation within *G. intermedia* is highly localized (*i.e.*, Monkey Springs), and in the case of *robusta* seems attributable to intergradation from *grahami* populations.

The proposed origin of *G. intermedia* from the south is substantiated by its apparent relationships to chubs of the Mexican Plateau. Related species of the adjacent, southern and eastern basins include *G. ditaenia* Miller from the basin of the Río de la Concepción, Arizona and Sonora; *G. purpurea* (Girard) from the Río Yaqui, Arizona and Sonora, and the Río Sonora, Sonora; *G. nigrescens*

(Girard) from the Guzman basin, New Mexico and Chihuahua; and G. pandora (Cope) from the Río Grande and Pecos basins, New Mexico and Texas. All are large-scaled, thick-bodied, darkly-pigmented, fishes with relatively low scale and fin-ray counts (Table 3), quite unlike G. robusta and its relatives, and very similar to G. intermedia. All of these, plus G. orcutti (Eigenmann and Eigenmann) of coastal streams of southern California, were considered by Uyeno (1961)[7] to have originated from the "ancestral form that gave rise to G. r. intermedia in the Gila ~~Ri~~ver."

If G. intermedia is more closely related to the south, as proposed here, it most likely derived from captures involving north-flowing tributaries of the Gila, or perhaps earlier as part of an ancient fauna of the original southwest-trending stream systems. Connection of the upper Gila River segment to the Guzman basin of northern Chihuahua (Cooley and Davidson, 1963; Weber, in Kottlowski, et al., 1965; Melton, 1965) is not supported by evidence from the ichthyofauna. G. nigrescens of the Guzman basin is quite similar to intermedia, however, differing mostly in having 9 dorsal fin-rays rather than 8. Yet, no species and few genera are in common between the Gila and Guzman systems, the latter having principally a Río Grande assemblage of native fishes, whereas the Gila River

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[7] Uyeno, T. 1961. Osteology and phylogeny of the American cyprinid genus Gila. Unpubl. Ph.D. diss., Univ. of Mich. 174 pp., pls., I-XXXV.

basin is occupied by a distinctive, highly-endemic fauna (Miller, 1958). One aquatic organism, a unionid clam, *Anodonta californiensis* Lea, known from a number of western drainages as fossil or living material (Taylor, 1963), is present in both the Gila and Guzman basins. Its absence from adjacent southern systems may, however, reflect a lack of collecting (D. W. Taylor, pers. comm.).

The Río Yaqui system and other minor coastal drainages of Sonora, México, share a number of ichthyofaunal elements with the Gila (Meek, 1904; Miller, 1958). These are *Agosia, cf. chrysogaster* (Girard), *Peociliopsis occidentalis* (Baird and Girard), and other pairs of species that are closely related--*Catostomus insignis* Baird and Girard and *C. bernardini* Girard; *G. robusta* and *G. minacae* Meek (= *G. robusta* [?]; Miller, 1958), and another *Gila* that may be near *G. intermedia* ("*G. nigrescens*" of Meek [1904], in part; dorsal and anal fin-rays 8, scales in the lateral series 60-75). Also, a number of Río Grande fishes have penetrated the Río Yaqui (*e.g.*, *Notropis*, *Campostoma*, *Pimephales*, *Ictalurus*, and others), presumably from the Guzman basin and/or from the Rio Conchos. The absence of these in the Gila River, especially some of the more aggressive, upland minnows, indicate an invasion of the Yaqui that post-dates any large faunal exchanges between that drainage and the lower Colorado basin.

Table 1. Meristic variations in chubs, genus Gila, from the lower Colorado River basin; data marked with an asterisk (*) are from files of the University of Michigan Museum of Zoology (see acknowledgements).

Localities, Catalog Numbers, and Years of Collection	Scales in the Lateral Line										Dorsal Fin-rays				Anal Fin-rays				Pelvic Fin-rays			
	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	n	7	8	9	n	7	8	9	n	7	8	9	n
SANTA CRUZ RIVER																						
Sabino Cr., UMMZ 146651; 1943	--	--	12	3	--	--	--	--	--	15	--	14	1	15	2	10	3	15	--	8	7	15
UA, Uncat.; 1943	--	3	5	--	--	--	--	--	--	8	--	8	--	8	--	8	--	8	--	3	5	8
UA, Uncat.; 1949	--	--	--	2	--	--	--	--	--	2	--	4	--	4	--	4	--	4	1	2	1	4
Binghampton Pond, Tucson UMMZ 146647; 1943	--	6	13	5	1	--	--	--	--	25	--	25	--	25	4	21	--	25	7	18	--	25
Monkey Spring UA, Uncat.; 1952	--	--	2	1	--	--	--	--	--	3	1	4	--	5	4	1	--	5	1	4	--	5
UA, Uncat.; 1959	2	3	--	--	--	--	--	--	--	5	--	25	--	25	--	25	--	25	1	23	1	25
ASU 599, 728; 1964	9	28	11	--	--	--	--	--	--	48	--	50	--	50	8	42	--	50	1	47	2	50
ASU 2401; 1966	5	8	4	--	--	--	--	--	--	17	--	25	--	25	1	24	--	25	--	25	--	25
Mexican tributary UMMZ 157239; 1940	--	5	4	3	--	--	--	--	--	12	--	21	--	21	--	21	--	21	--	14	7	21
Sheehy Spring *UMMZ 131103; 1939	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4	29	1	34	--	--	--	--
UMMZ 162671; 1950	--	1	5	12	7	--	--	--	--	25	--	25	--	25	1	24	--	25	1	18	6	25
SAN PEDRO RIVER																						
Aravaipa Cr., UA, Uncat.; 1943	--	--	--	--	1	1	1	--	--	3	--	--	3	3	--	1	2	3	--	1	2	3
UA, Uncat.; 1957-60	--	--	--	1	3	2	1	--	--	7	--	--	7	7	--	2	5	7	--	--	7	7
Barber and Minckley (1966)	--	--	--	--	--	--	--	--	--	--	--	10	44	54	--	16	38	54	--	--	--	--
ASU 3093, 3105; 1967	--	--	--	1	7	4	2	--	--	14	--	2	13	15	--	8	7	15	--	2	13	15
*Redfield Canyon Cr., UMMZ , 179800; 1961	--	--	--	--	--	--	--	--	--	--	1	4	--	5	--	5	--	5	--	2	3	5
Babacomari R. ASU 2724, 2763, Uncat.; 1967	--	1	10	7	--	--	--	--	--	18	--	29	--	29	2	28	--	30	--	13	15	29[1]
ASU, Uncat.; 1968	--	1	4	4	3	--	--	--	--	12	--	11	--	11	--	11	--	11	--	1	11	12
Turkey Cr., UA, Uncat.; 1952	--	--	6	1	--	--	--	--	--	7	--	7	--	7	1	6	--	7	--	3	4	7
ASU 2761; 1967	--	1	1	--	--	--	--	--	--	2	--	2	--	2	--	2	--	2	--	--	2	2
O'Donnel Cr., ASU 2761; 1967	--	1	3	--	--	--	--	--	--	4	--	6	--	6	--	6	--	6	--	6	--	6
SAN SIMON RIVER																						
San Simon Cienega UMMZ 137093; 1939	--	2	2	3	--	--	--	--	--	7	--	18	--	18	1	17	--	18	--	16	2	18
MIDDLE GILA RIVER																						
*Queen Cr., UMMZ 125041; 1938	--	--	--	--	--	--	--	--	--	--	--	--	--	--	22	127	2	151	--	--	--	--
San Carlos R. ASU, Uncat.; 1968	--	--	--	8	20	9	--	--	--	37	--	25	--	25	1	24	--	25	--	4	21	25
*Eagle Cr., UMMZ 131125; 1939	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	7	3	11	--	--	--	--
*UMMZ 162745; 1950	--	--	--	--	--	--	--	--	--	--	--	3	4	7	--	5	2	7	--	1	6	7
UA, Uncat.; 1956	--	--	1	7	9	2	1	--	--	20	--	19	8	27	--	22	5	27	--	4	23	27
ASU 1836; 1964	--	--	--	1	--	--	--	--	--	1	--	1	--	1	--	1	--	1	--	--	1	1

Table 1. Continued

Localities, Catalog Numbers, and Years of Collection	Scales in the Lateral Line										Dorsal Fin-rays				Anal Fin-rays				Pelvic Fin-rays			
	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	n	7	8	9	n	7	8	9	n	7	8	9	n
SAN FRANCISCO RIVER																						
UNM 1730-1, 1738; 1948	--	--	--	--	1	3	--	--	--	4	--	3	14	17	--	7	10	17	--	2	15	17
GILA RIVER, NEW MEXICO																						
Mainstream, Redrock area UNM 1739, 2010; 1949	--	--	--	--	--	--	--	--	--	--	--	--	3	3	--	--	3	3	--	1	2	3
Mainstream, Cliff area UMMZ 124744; 1938	--	--	--	3	6	4	--	4	--	17	--	7	18	25	--	14	11	25	--	6	19	25
UNM 1732, 1752; 1949	--	--	--	1	9	3	1	1	--	15	--	2	21	23	--	5	18	23	1	1	21	23
UNM 1743, 1745, 1747, 1751; 1953	--	--	--	2	8	5	5	2	--	22	--	6	17	23	--	10	13	23	--	3	20	23
Mainstream, Lyon's Lodge UNM, Uncat.; 1966	--	--	--	--	--	1	--	--	--	1	--	1	2	3	--	1	2	3	--	--	3	3
Headwater tributaries UMMZ 110434; 1935	--	--	--	--	5	2	--	--	--	7	--	4	4	8	--	6	2	8	--	--	8	8
UNM 2007; 1949	--	--	--	2	2	1	--	--	--	5	--	10	5	15	--	13	2	15	--	1	14	15
UNM 1729, 1748; 1951-52	--	--	--	7	2	--	--	--	--	9	--	4	5	9	--	7	2	9	--	3	6	9
VERDE RIVER																						
Mainstream, near Camp Verde ASU 496; 1963	--	--	--	--	--	3	2	1	--	6	--	--	6	6	--	--	6	6	--	1	5	6
Mainstream, Perkinsville area *UMMZ 162827; 1950	--	--	--	--	--	--	--	--	--	--	--	--	16	16	--	--	16	16	--	--	16	16
ASU 2389, 2400, 2475; 1966	--	--	--	--	1	6	10	4	1	22	--	--	22	22	--	--	22	22	--	1	20	22[1/]
Upper East Verde R. UMMZ 94886; 1926	--	--	--	--	8	14	3	--	--	25	--	3	22	25	--	19	6	25	--	5	20	25
*UMMZ 162823; 1950	--	--	--	--	--	--	--	--	--	--	--	--	20	20	--	14	6	20	--	5	15	20
ASU 407; 1963	--	--	--	1	7	6	2	--	--	16	--	1	18	19	--	15	4	19	--	2	17	19
ASU 1065; 1964	--	--	--	--	4	4	5	--	--	13	--	1	12	13	--	7	6	13	--	1	12	13
ASU 2299; 1965	--	--	--	--	1	3	--	--	--	4	--	1	19	20	--	20	--	20	--	3	17	20
ASU 3261; 1967	--	--	--	--	1	2	2	--	--	5	--	--	10	10	--	3	7	10	--	2	8	10
Lower Fossil Cr. *UMMZ 120088; 1937	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	12	31	53	--	--	--	--
*UMMZ 162820; 1950	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8	7	16[1/]	--	--	--	--
Upper Fossil Cr. ASU 2482; 1966	--	--	--	--	4	4	1	--	--	9	--	3	6	9	--	2	7	9	--	--	9	9
ASU, Uncat.; 1968	--	--	--	--	14	5	--	1	--	20	--	11	9	20	--	16	4	20	--	2	18	20
Lower West Clear Cr. ASU 3267; 1967	--	--	--	--	--	3	3	--	--	6	--	--	6	6	--	1	5	6	--	--	6	6
Lower Wet Beaver Cr. UMMZ 120101; 1937	--	--	--	--	1	3	--	--	--	4	--	3	1	4	--	4	--	4	--	1	3	4
UA, Uncat.; 1956	--	--	--	--	1	8	1	--	--	10	2	6	2	10	1	7	2	10	1	3	6	10
ASU 783; 1964	--	--	--	--	--	--	1	1	--	2	--	--	2	2	--	--	2	2	--	--	2	2
ASU 2429; 1966	--	--	--	--	--	--	1	1	--	2	--	2	1	3	--	3	--	3	--	1	2	3
Lower Oak Cr. ASU 2150, 3277; 1964, 1966	--	--	--	--	--	--	3	--	--	3	--	--	3	3	--	3	--	3	--	--	3	3
Upper Oak Cr., ASU 494; 1963	--	3	7	5	--	--	--	--	--	15	2	15	--	17	4	13	--	17	--	4	13	17

Table 1. Concluded.

Localities, Catalog Numbers, and Years of Collection	Scales in the Lateral Line										Dorsal Fin-rays				Anal Fin-rays				Pelvic Fin-rays			
	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	n	7	8	9	n	7	8	9	n	7	8	9	n
Lower Sycamore Cr. ASU 3284; 1967	--	--	--	--	--	--	--	2	--	2	--	--	6	6	--	--	6	6	--	--	6	6
Upper Sycamore Cr. ASU 1833; 1965	--	--	--	1	2	1	--	--	--	4	--	2	2	4	--	4	--	4	--	3	1	4
Big Chino Wash UMMZ 162834; 1950	--	--	7	8	7	--	--	--	--	22	--	25	--	25	--	25	--	25	--	9	16	25
PHOENIX CANAL SYSTEM																						
Tempe area, ASU 1095, 1513; 1964	--	--	--	--	2	5	7	7	1	22	--	--	22	22	--	--	22	22	--	--	22	22
Buckeye area, ASU 2229; 1965	--	--	3	10	9	2	--	--	--	24	--	25	--	25	--	24	1	25	--	11	14	25
SALT RIVER																						
*Mainstream, UMMZ 162760; 1950	--	--	--	--	--	--	--	--	--	--	--	--	15	15	--	--	14	15[1]	--	--	15	15
ASU 1373; 1964	--	--	--	--	--	--	2	6	--	8	--	--	18	18	--	1	17	18	--	1	17	18
ASU 2451, 3118, 3132, 3140 3149, 3159; 1966-67	--	--	--	--	1	8	36	27	4	76	--	1	105	106	--	1	105	106	--	5	101	106
Cave Cr., UMMZ 162841; 1950	--	4	13	7	1	--	--	--	--	25	--	25	--	25	7	18	--	25	--	5	20	25
ASU 480; 1963	--	1	1	--	--	--	--	--	--	2	--	7	--	7	2	5	--	7	--	1	6	7
ASU 2162, 2164; 1965	--	--	--	--	--	--	--	--	--	--	--	3	--	3	1	2	--	3	--	1	2	3
Fish Cr., ASU 474; 1963	--	--	--	5	11	6	--	--	--	22	1	24	--	25	2	23	--	25	--	3	22	25
ASU 2246; 1965	--	--	--	--	3	2	--	--	--	5	--	7	--	7	--	7	--	7	--	--	7	7
*Tonto Cr., UMMZ 131102; 1937	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	19	--	20	--	--	--	--
UMMZ 162803; 1950	--	--	--	--	3	14	3	2	--	22	--	1	24	25	--	2	23	25	--	--	25	25
ASU 3255; 1967	--	--	--	1	1	2	4	--	--	8	--	--	14	14	--	3	11	14	--	--	14	14
Cherry Cr., ASU 3241; 1967	--	--	--	--	--	--	1	1	--	2	--	--	2	2	--	--	2	2	--	--	2	2
Canyon Cr., ASU 3186; 1967	--	--	--	--	2	13	8	2	--	25	--	--	25	25	--	--	25	25	--	--	25	25
Salt Cr., ASU 3165; 1967	--	--	--	--	--	--	--	1	--	1	--	--	3	3	--	1	2	3	--	--	3	3
Cibeque Cr., ASU 2445; 1966	--	--	--	--	--	2	2	4	--	8	--	--	8	8	--	--	8	8	--	--	8	8
ASU 3127, 3152; 1967	--	--	--	--	2	14	9	3	--	28	--	--	28	28	--	--	28	28	--	--	28	28
Carrizo Cr., ASU 2455, 3175 3179, 3196, 3199, 3202; 1966-7	--	--	--	--	1	18	13	5	1	38	--	--	82	82	--	32	48	80	--	4	78	82
Corduroy Cr., ASU 2459; 1966	--	--	--	--	--	7	3	--	--	10	--	--	20	20	--	12	8	20	--	--	20	20
White R., UNM 1744; 1950	--	--	--	--	--	--	2	2	--	4	--	--	5	5	--	--	5	5	--	--	5	5
UNM 1753; 1957	--	--	--	--	--	--	--	4	1	5	--	--	5	5	--	1	4	5	--	--	5	5
ASU 2464, 3183, 3186; 1966-7	--	--	--	--	--	3	7	14	5	29	--	--	--	60	--	2	58	60	--	4	56	60
Lower Black R. UNM, Uncat.; 1965	--	--	--	--	--	--	2	4	--	6	--	1	6	7	--	1	6	7	--	--	7	7
ASU 2507, 3203, 3217; 1967	--	--	--	--	--	1	9	5	6	21	--	2	33	35	--	10	25	35	--	--	35	35
Upper Black R., UMMZ 121628, 121651, 121660; 1937	--	--	--	--	--	--	4	7	--	11	--	--	13	13	--	5	8	13	--	--	13	13
ASU 2434; 1966	--	--	--	--	--	--	--	1	--	1	--	--	1	1	--	--	1	1	--	--	1	1
BILL WILLIAMS RIVER																						
ASU 2222, 2353, 2359, 2774; 1965-66	--	--	--	--	1	19	25	16	1	62	--	4	60	64	--	44	20	64	--	6	58	64

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[1] N includes one fish with 10 fin-rays.

Table 2. Morphometric variations in chubs, genus Gila, from the lower Colorado River basin. Data in the first six columns are expressed as thousandths of standard length ± 0.95 per cent confidence limits. The last column is the ranges of ratios, with means in parentheses, for the total number of fish from a given locality or stream.

Localities, Catalog Numbers, Years of Collection, and Number of Fish (in Paren.)	Width of Interorbital	Width of Head	Length of Head	Depth of Caudal Ped.	Length of Caudal Ped.	Length of Anal Fin-base	Length, Head/ Depth, Caudal Ped.
SANTA CRUZ RIVER							
Sabino Cr., UMMA 146651; 1943 (15)	89± 3	164± 3	321± 6	117± 3	217± 5	115± 3	2.17-3.16 (2.71)
UA, Uncat.; 1943 (3)	94± 2	161± 3	313± 5	111± 3	204± 4	116± 3	
UA, Uncat.; 1943 (3)	83± 4	157± 5	312±11	106± 6	209± 8	112± 7	
UA, Uncat.; 1949 (2)	93± 7	165± 9	305± 5	123± 9	227±14	126± 9	
Binghampton Pond, Tucson UMMZ 146647; 1943 (25)	93± 2	169± 3	315± 5	119± 2	210± 4	114± 3	2.42-2.90 (2.59)
Monkey Spring UA, Uncat.; 1952 (5)	74± 9	164±18	287±15	110±12	227±30	113±17	
UA, Uncat.; 1954 (25)	82± 5	162±10	287±11	102± 6	196±14	105± 7	

Table 2. Continued.

Localities, Catalog Numbers, Years of Collection, and Number of Fish (in Paren.)	Width of Interorbital	Width of Head	Length of Head	Depth of Caudal Ped.	Length of Caudal Ped.	Length of Anal Fin-base	Length, Head/ Depth, Caudal Ped.
ASU 599; 1964 (25)	85± 2	155± 7	310± 5	99± 2	202± 6	107± 4	2.43-3.58 (2.98)
ASU 728, 1964 (25)	88± 2	161± 8	307± 5	101± 2	207± 6	108± 3	
ASU 2401, 1966 (25)	85± 2	156± 8	305± 5	106± 3	198± 6	111± 3	
Mexican Tributary UMMZ 157239; 1940 (21)	98± 2	164± 3	317± 5	117± 3	212± 4	116± 4	2.52-2.90 (2.65)
Sheehy Spring UMMZ 162671; 1950 (25)	89± 2	157± 3	304± 5	115± 3	219± 3	111± 3	2.31-3.04 (2.59)
SAN PEDRO RIVER							
Aravaipa Cr., UA, Uncat.; 1943 (2)	92± 7	148± 9	291±18	91±10	228±14	119±11	2.41-3.78 (3.12)
UA, Uncat.; 1957 (4)	90± 6	150± 8	289±13	92± 7	217±20	119±15	
UA, Uncat.; 1957 (2)	84± 7	143±11	278±18	84± 9	215±14	124±10	
ASU 3105; 1967 (7)	92± 4	150± 6	278±10	92± 8	211± 8	119± 6	
ASU 3093; 1967 (9)	93± 4	154± 6	296± 9	91 ± 5	215± 8	118± 5	

Table 2. Continued.

Localities, Catalog Numbers, Years of Collection, and Number of Fish (in Paren.)	Width of Interorbital	Width of Head	Length of Head	Depth of Caudal Ped.	Length of Caudal Ped.	Length of Anal Fin-base	Length, Head/ Depth Caudal Ped.
Babacomari R. ASU 2724; 1967 (9)	93± 4	157± 5	291± 8	114± 4	204± 7	118± 5	2.30-3.07 (2.60)
ASU 2763; 1967 (4)	91± 5	175± 8	295±12	97± 7	203± 9	103± 7	
ASU, Uncat.; 1967 (16)	90± 2	158± 4	303± 6	111± 3	203± 5	119± 3	
ASU, Uncat.; 1968 (12)	99± 3	165± 4	290± 7	115± 4	211± 6	108± 4	
Turkey Cr., UA, Uncat.; 1952 (6)	85± 6	159± 7	302±14	119± 7	205±10	122± 8	1.84-3.13 (2.58)
ASU 2761; 1967 (2)	95± 8	168±11	291±19	124± 9	224±14	124± 9	
O'Donnel Cr., ASU 2720; 1967 (6)	93± 4	162± 7	312±10	114± 5	197± 6	114± 6	
SAN SIMON RIVER							
San Simon Cienega, UMMZ 137093; 1939 (7)	95± 7	159±11	305±20	114± 9	210±15	114± 9	2.55-2.87 (2.63)

Table 2. Continued.

Localities, Catalog Numbers, Years of Collection, and Number of Fish (in Paren.)	Width of Interorbital	Width of Head	Length of Head	Depth of Caudal Ped.	Length of Caudal Ped.	Length of Anal Fin-base	Length, Head/ Depth Caudal Ped.
MIDDLE GILA RIVER							
San Carlos R. ASU, Uncat.; 1968 (25)	84± 4	154± 2	289± 3	109± 2	214± 2	109± 3	2.37-2.85 (2.60)
Eagle Cr. UA, Uncat.; 1956 (16)	78± 2	146± 5	290± 4	103± 3	208± 4	121± 3	2.63-3.40
UA, Uncat.; 1956 (11)	75 ± 3	168± 4	294 ± 5	95± 3	199± 4	110± 4	(2.90)
SAN FRANCISCO RIVER							
UNM 1731; 1948 (15)	80± 2	140± 4	285± 9	84± 3	209± 4	121± 4	3.04-3.74 (3.27)
GILA RIVER, NEW MEXICO							
Mainstream, Redrock area UNM 2010; 1949 (2)	75± 6	137± 9	310±14	82± 9	196±12	130±16	2.52-4.00 (3.75)
Mainstream, Cliff area UMMZ 124774; 1938 (25)	84± 2	147± 2	299± 4	96± 3	209± 4	115± 5	
UNM 1732; 1949 (6)	84± 4	139± 5	289± 8	83± 5	206±13	138±16	
NUM 1752; 1949 (17)	84± 2	146± 3	295± 5	86± 4	212± 5	132± 5	

Table 2. Continued.

Localities, Catalog Numbers Years of Collection, and Number of Fish (in Paren.)	Width of Interorbital	Width of Head	Length of Head	Depth of Caudal Ped.	Length of Caudal Ped.	Length of Anal Fin-base	Length, Head/ Depth, Caudal Ped.
UNM 1743; 1953 (8)	76± 3	136± 4	281± 7	82± 5	211± 6	110± 9	2.78-3.79 (3.30)
UNM 1745; 1953 (5)	80± 4	133± 6	281± 9	81± 6	221± 8	118±10	
UNM 1751; 1953 (9)	81± 3	135± 5	276± 6	89± 4	207± 6	119± 8	
UNM, Uncat.; 1966 (2)	84± 6	148± 9	304±14	87_10	225± 7	118± 8	
Headwater tributaries							
UMMZ 110434; 1935 (8)	86± 4	148± 5	289± 7	99± 5	225± 7	118± 8	2.47-3.53 (2.90)
UNM 2007; 1949 (15)	80± 2	142± 3	294± 5	93± 3	213± 5	117± 6	
UNM 1729; 1952 (8)	76± 5	136± 4	281± 4	98± 5	213± 6	113± 5	
VERDE RIVER							
Mainstream, near Camp Verde ASU 496; 1963 (6)	78± 4	129± 4	277± 7	77± 4	214±11	122± 5	3.18-3.90 (3.45)
Mainstream, Perkinsville area, ASU 2389; 1966 (3)	78± 5	134± 7	266±11	76± 5	215±15	126± 7	

Table 2. Continued

Localities, Catalog Numbers, Years of Collection, and Number of Fish (in Paren.)	Width of Interorbital	Width of Head	Length of Head	Depth of Caudal Ped.	Length of Caudal Ped.	Length of Anal Fin-base	Length, Head/ Depth, Caudal Ped.
ASU 2474; 1966 (18)	77± 2	139± 2	283± 5	82± 3	212± 6	118± 3	
Upper East Verde R.							
UMMZ 94886; 1926 (25)	87± 2	157± 2	306± 4	96± 3	205± 6	107± 3	2.74-3.90 (3.02)
ASU 407; 1963 (19)	88± 2	152± 3	301± 4	97± 3	213± 6	118± 3	
ASU 1065; 1965 (13)	86± 3	154± 4	289± 5	98± 2	218± 7	111± 3	
ASU 2299; 1965 (20)	83± 2	153± 3	302± 4	96± 2	203± 6	111± 2	
ASU 3261; 1967 (10)	84± 3	158± 3	301± 6	97± 2	213± 6	118± 3	
Upper Fossil Cr.							
ASU 2482; 1966 (9)	85± 3	153± 4	294± 6	92± 3	218± 8	110± 6	2.82-3.65 (3.15)
ASU, Uncat.; 1968 (20)	87± 2	152± 3	309± 4	97± 3	213± 6	118± 3	
Lower West Clear Cr.							
ASU 3267; 1967 (6)	81± 4	145± 5	287± 7	78± 4	206± 9	114± 5	3.31-3.89 (3.62)

Table 2. Continued.

Localities, Catalog Numbers, Years of Collection, and Number of Fish (in Paren.)	Width of Interorbital	Width of Head	Length of Head	Depth of Caudal Ped.	Length of Caudal Ped.	Length of Anal Fin-base	Length, Head/ Depth Caudal Ped.
Lower Wet Beaver Cr.							
UMMZ, 120101; 1937 (4)	93± 4	151± 5	292± 9	97± 3	226±13	108± 6	
UA, Uncat.; 1956 (10)	80± 3	150± 3	304± 6	89± 3	208± 8	106± 4	2.95-3.74 (3.27)
ASU 783; 1964 (2)	77± 2	121± 8	262±13	76± 7	216±18	122± 8	
ASU 2429; 1966 (3)	78± 5	143± 6	292±11	92± 5	208±15	103± 7	
Lower Oak Cr.							
ASU 3277; 1967 (2)	96± 7	159± 3	300± 1	91± 3	212±23	126±12	3.26-3.31 (3.29)
Lower Sycamore Cr.							
ASU 3284; 1967 (6)	72± 4	137± 5	283± 8	78± 4	200±11	117± 5	3.44-3.82 (3.63)
Upper Sycamore Cr.							
ASU 1833; 1965 (4)	82± 5	138± 5	281± 9	99± 4	202±13	120± 6	2.56-3.02 (2.84)
Big Chino Wash							
UMMZ 162834; 1950 (25)	88± 2	147± 2	294± 4	102± 2	216±19	122± 9	2.47-2.98 (2.70)

Table 2. Continued.

Localities, Catalog Numbers, Years of Collection, and Number of Fish (in Paren.)	Width of Interorbital	Width of Head	Length of Head	Depth of Caudal Ped.	Length of Caudal Ped.	Length of Anal Fin-base	Length, Head/ Depth, Caudal Ped.
PHOENIX CANAL SYSTEM							
Tempe area, ASU 1095; 1964 (2)	81± 5	129±12	263±13	69± 8	224±16	128± 6	3.40-3.89
ASU 1513; 1964 (20)	78± 2	128± 4	270± 5	75± 2	214± 5	124± 3	(3.59)
Buckeye area, ASU 2229; 1965 (25)	89± 2	138± 3	264± 4	97± 2	225± 5	123± 3	2.51-3.09 (2.68)
SALT RIVER							
Mainstream, ASU 1373; 1964 (18)	79± 2	136± 4	288± 6	80± 2	210± 5	130± 3	
ASU 2451; 1966 (22)	78± 2	134± 3	266± 5	78± 2	222± 7	119± 2	
ASU 3118; 1967 (25)	77± 2	136± 5	271± 4	75± 2	222± 4	119± 3	3.13-4.86
ASU 3132; 1967 (21)	77± 2	135± 3	277± 5	80± 2	228± 5	116± 3	(3.51)
ASU 3140; 1967 (6)	75± 4	135± 4	270± 9	74± 4	223± 8	111± 6	
ASU 3149; 1967 (24)	77± 2	140± 3	282± 6	81± 2	222± 4	121± 3	

Table 2. Continued.

Localities, Catalog Numbers, Years of Collection, and Number of Fish (in Paren.)	Width of Interorbital	Width of Head	Length of Head	Depth of Caudal Ped.	Length of Caudal Ped.	Length of Anal Fin-base	Length, Head/ Depth, Caudal Ped.
ASU 3159; 1967 (9)	75± 3	130± 4	260± 8	75± 3	230± 7	113± 4	
Cave Cr.							
UMMZ 162841; 1950 (25)	89± 1	150± 3	294± 6	117± 2	211± 5	109± 3	2.33-2.73 (2.48)
ASU 480; 1963 (7)	84± 3	160± 4	304±12	121± 3	208± 8	123± 6	
ASU 2162; 1965 (2)	80± 6	158± 9	304±21	108± 7	199±16	129±10	
Fish Cr.							
ASU 474; 1963 (25)	82± 2	146± 3	297± 6	103± 2	221± 5	120± 3	2.05-3.04
ASU, 2246; 1965 (7)	83± 4	148± 4	291± 8	107± 3	219± 8	129± 5	(2.81)
Tonto Cr.							
UMMZ 162803; 1950 (25)	82± 2	137± 3	289± 6	95± 2	214± 4	111± 3	2.76-3.38
ASU 3255; 1967 (14)	84± 3	149± 4	285± 8	93± 3	218± 6	114± 3	(3.01)
Cherry Cr.							
ASU 3241; 1967 (2)	81± 6	140± 9	268±22	75± 8	224±16	126±10	3.51-3.62 (3.55)

Table 2. Continued.

Localities Catalog Numbers, Years of Collection, and Number of Fish (in Paren.)	Width of Interorbital	Width of Head	Length of Head	Depth of Caudal Ped.	Length of Caudal Ped.	Length of Anal Fin-base	Length, Head/ Depth, Caudal Ped.
Canyon Cr.							
ASU 3186; 1967 (25)	99± 2	142± 2	289± 6	80± 2	218± 4	115± 3	3.17-3.89 (3.56)
Salt Cr.							
ASU 3165; 1967 (3)	74± 5	138± 7	286±18	78± 5	221±12	111± 8	3.62-3.70 (3.65)
Cibeque Cr.							
ASU 2445; 1966 (8)	79± 3	136± 4	245±11	79± 3	226± 8	118± 5	2.14-3.78 (3.42)
ASU 3127; 1967 (25)	77± 2	135± 2	287± 6	80± 2	223± 5	123± 2	
ASU 3152; 1967 (3)	83± 4	141± 7	288±17	83± 5	226±13	128±18	
Carizzo Cr.							
ASU 2455; 1966 (5)	82± 4	149± 6	282±14	83± 5	203±10	109± 6	2.41-3.98 (3.28)
ASU 3175; 1967 (25)	82± 2	149± 3	298± 6	89± 2	215±11	120± 3	
ASU 3179; 1967 (25)	80± 2	155± 2	322± 7	90± 2	214± 5	116± 3	
ASU 3196; 1967 (8)	85± 3	152± 5	285±11	87± 3	217± 7	105± 5	
ASU 3199; 1967 (10)	86± 3	154± 3	306±10	89± 3	211± 7	111± 4	
ASU 3203; 1967 (10)	88± 3	155± 4	317±10	87± 3	216± 7	113± 4	

Table 2. Continued.

Localities, Catalog Numbers, Years of Collection, and Number of Fish (in Paren.)	Width of Interorbital	Width of Head	Length of Head	Depth of Caudal Ped.	Length of Caudal Ped.	Length of Anal Fin-base	Length, Head/ Depth, Caudal Ped.
Corduroy Cr.							
ASU 2459; 1966 (20)	90± 2	155± 3	299± 7	98± 2	212± 5	120± 3	2.82-3.37 (3.06)
White R.							
UNM 1744; 1950 (5)	77± 4	133± 3	271± 9	81± 5	230±10	125± 6	2.86-4.17 (3.39)
UNM 1750; 1954 (5)	82± 4	133± 6	276± 3	83± 4	221±10	116± 7	
ASU 2464; 1966 (20)	79± 2	143± 3	282± 5	84± 2	219± 4	127± 3	
ASU 3183; 1967 (16)	74± 2	136± 3	274± 6	78± 2	220± 5	116± 3	
ASU 3186; 1967 (25)	79± 2	146± 3	286± 5	87± 2	224± 4	124± 3	
Lower Black R.							
UNM Uncat.; 1965 (7)	80± 4	129± 6	284± 9	69± 3	208± 7	109± 5	2.46-4.34 (3.58)
ASU 2507; 1967 (6)	77± 4	137± 7	271±10	74± 4	224± 8	115± 6	
ASU 3203; 1967 (4)	82± 5	139± 7	279±11	85± 5	218±11	118± 7	
ASU 3217; 1967 (25)	74± 2	137± 4	276± 5	82± 2	219± 4	114± 3	

Table 2. Concluded.

Localities, Catalog Numbers, Years of Collection, and Number of Fish (in Paren.)	Width of Interorbital	Width of Head	Length of Head	Depth of Caudal Ped.	Length of Caudal Ped.	Length of Anal Fin-base	Length, Head/ Depth, Caudal Ped.
Upper Black R.							
UMMZ 121628; 1937 (5)	80± 4	135± 6	282±10	89± 4	214± 9	115± 6	2.86-4.46 (3.34)
UMMZ 121651; 1937 (5)	77± 4	138± 6	284±11	92± 4	218± 9	102± 4	
UMMZ 121669; 1937 (3)	84± 5	131± 7	303± 4	80±10	218±21	134±14	
BILL WILLIAMS RIVER							
Burro Cr.							
ASU 2222; 1965 (19)	79± 2	139± 2	288± 5	94± 2	217± 6	114± 4	2.73-3.67 (3.18)
ASU 2774; 1966 (25)	82± 2	147± 2	291± 4	88± 2	220± 5	107± 5	
Conger Cr.							
ASU 2353; 1966 (11)	83± 2	146± 3	299± 5	93± 3	220± 7	107± 5	
Trout Cr.							
ASU 2359; 1966 (9)	83± 3	145± 4	296± 6	90± 3	215± 8	108± 6	

Table 3. Meristic variations in chubs, genus *Gila*, from river systems south and east of the lower Colorado River basin.

Localties and Catalog Numbers	Scales in the Lateral Line							Dorsal fin-rays				Anal fin-rays				Pelvic fin-rays			
	50-54	55-59	60-64	65-69	70-74	75-79	n	7	8	9	n	7	8	9	n	7	8	9	n
GILA DITAENIA--Rio Sonora basin, Arizona and Sonora. ASU 2729 and 2749	--	—	16	13	1	—	30	--	29	1	30	1	29	—	30	1	29	--	30
GILA PURPUREA--Rio Yaqui basin, Arizona and Sonora. ASU 1649, 2233, 2284, Uncat.	7	21	—	—	—	—	30	1	29	—	30	4	26	--	30	--	30	--	30
GILA NIGRESCENS--Guzman basin, Chihuahua, Rio Casas Grandes. ASU 816	—	—	2	7	5	—	14	—	--	25	25	—	25	—	25	--	—	25	25
Rio Piedras Verdes. ASU 821	—	--	1	10	9	5	25	—	1	24	25	—	25	--	25	--	—	25	25
Rio del Carmen. ASU 709	—	--	9	8	2	—	19	--	1	24	25	—	25	--	25	—	2	23	25
Rio Santa Maria. ASU 838	--	—	1	3	2	—	6	—	--	6	6	—	6	—	6	—	—	6	6
GILA PANDORA--Rio Grande basin, New Mexico, Hondo Cr. ASU 1323	3	12	2	--	--	--	17	—	22	—	22	2	20	—	22	--	20	2	22
Jemez R. ASU 2362	—	10	8	—	--	—	18	—	18	—	18	2	16	—	18	—	4	14	18

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Leuciscus lineatus, common to mountain tribs. of Colo. basin & Bonneville. - occurrence in Colo. unexplained anomaly & contradicts all the other fact - bespeaking long & absolute isolation of Col. basin.

- *Pantosteus arizonae* Gilbert, new sp. taken at Tempe.

check type - *Catostomus discobolus* Cope - from Green R. Wyo. - not found in lower Colo. - evidently replaced by *latipinnis*. - mouth as in *latipinnis* except posterior tubercles on lower lip are long & not nearly so closely set, 9-10 rows. - specimens fm. Delta Colo. - differ slightly - Scales Green R. 18-20; 101-113
Delta ~~- 21-25~~; 112-128

length	D	Scales	before dorsal	~~scales front of dorsal~~	
5-8 in.	12-13	18-21; 101-113	56-63	Green R.	} *discobolus*
5-8 in	12-13	21-25; 112-128	60-65	Delta.	
5-24 in	2 2 14 | 15	N=4 N=4 19-20 89-102	46-50	Salt R. Ariz. - *latipinnis*	

Closely resembles *discobolus* of Green & Grand r. - but w. larger scales, more dorsal rays - confused in J. & E. (96) - Their description of *C. l.* based on *discobolus* fm. Green & Grand. - fins very large - D concave - recorded fm.

ba

- numerous 3 in. specimen at Temp

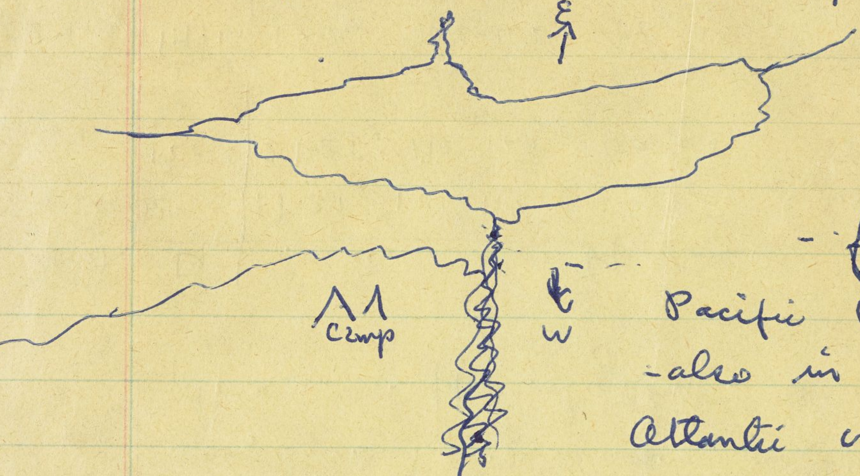
intermedius

Salt R. at Te

Dist. of Fishes. Ann. Rept. Smithson. for 1927: 355-85.

- Plate 2 - drawing of Two Ocean Pass looking east. - from Pop. Sci. Monthly June 1895.

- See also Evermann - Recon. St. Mont. Wyo. Bull. U.S. Fish Comm. 11, 1891 : 24-28.



- found trout in Pacific Crk. at every pt. - also in Pass and in Atlantic crk. - Almost certain Yellowstone L. stocked w/ trout from the west via Two-Ocean Pass:

- Ev. - Gil. - comments on trout spotting.

- footnote p. 373 "A most striking case of species formed by isolation is found in 3 Calif. golden trout S. a., S. r., S. w. shut off centuries ago by a trap dyke from Kern R. Each is apparently derived from the Shasta rainbow, S. shasta, not from the present Kern trout. S. gilb."

- Evermann 1-893 Bull. U.S. Fish. Comm. Vol. 11: (for 1891). Reconn. Streams & lakes of western Mont. & NW Wyo. - fact that trout can pass back-forth on 2 Ocean Pass - 'show can't even be regarded as geogr. forms.' - color notes - description of spotting - * - Pac. Crk. 20 mi. below large trout separated into 2 groups: one more s ish-star shaped spots more common among e.

found round & star shaped spots in Pac. C

Behnke

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October 13, 1977

Enclosed: revised & corrected ms.

R.B.

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Dear Robert:

Enclosed please find the edited copy of your paper on fish faunal changes which will appear in Vol. 6, No. 2 of the GREAT PLAINS-ROCKY MOUNTAIN GEOGRAPHICAL JOURNAL. Please have the manuscript retyped, following all my penciled notations as closely as possible. Note especially my comment about providing examples of research on the effects of dams, channelization, etc. (p. 3), which would strengthen your argument (of course, these should be then referenced in the reference section). Also, please note the change to first order heading, p. 2.

Please return the final copy by First Class Mail by October 27, 1977.

Thank you for your contribution to the Journal and to the GP-RM Division.

Sincerely yours,

R. G. Reider

Richard G. Reider, Editor and
Associate Professor of Geography

FISH FAUNAL CHANGES ASSOCIATED WITH LAND-USE AND WATER DEVELOPMENT

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ABSTRACT. Non-native fishes have commonly replaced native species throughout the Southwest. Man-induced changes in the environment have been responsible for rapid alterations in drainage basins which have favored the non-native fishes.

INTRODUCTION

Fish species have optimum habitat characteristics. A species needs more than water of suitable quality to live in and more than an adequate food supply to meet nutritional requirements if it is to coexist successfully with other species, particularly non-native species. Such habitat characteristics include channel morphology, substrate, depths, velocities, turbidity, and cover in relation to optimal habitat for all life history stages of a species.

Man-induced changes of the landscape of the American Southwest during the last 100 years have radically altered many major river systems and caused a rather dramatic change in the fish fauna, mainly by the replacement of native species by non-native species. This phenomenon has been especially manifested in the Colorado River Basin.

One consequence is that several native fishes of the Colorado River Basin are presently recognized or proposed for recognition as endangered or threatened species under the 1973 Endangered Species Act, and they in turn now pose a threat to certain proposed water and energy development projects in the basin.

To explain the replacement of indigenous fauna by non-native species in an evolutionary perspective, it may be simply surmised that the environmental changes occurred at a rate far outpacing the rate of genetic change through evolution and natural selection. Man's influence on the fluvial geomorphic processes has condensed thousands of years of natural change into less than 100 years. Essentially, the environment in which the native species have been evolving and adapting during millions of years is no longer there, and non-native fishes have largely supplanted the native species throughout most of the Colorado River Basin.

In general, fisheries biologists are only dimly aware of the ramifications to fish habitat caused by various land-use practices as they influence, or greatly accelerate, fluvial geomorphic processes in a river basin. On the other hand, fluvial geomorphologists may accurately predict the physical consequences of changes in the flow regime, sediment loads, and channel morphology, but are unable to predict all significant biological changes without an understanding of the fish fauna and its species associations by habitat types. Interdisciplinary cooperation and understanding are necessary if future environmental analysis of water and energy development projects and land-use practices are to achieve more authoritative predictive values.

EXAMPLES OF MAN-INDUCED IMPACTS ON AQUATIC ECOSYSTEMS

In relation to the survival status of native fishes and their replacement by non-native species, impacts on river systems are categorized as "sudden and catastrophic " or "gradual and cumulative" (Behnke, 1977a). Sudden and catatrophic impacts cause a great rearrangement of the environment in a relatively short period of time. They are typically irreversible and site-specific. Such changes can be readily observed and documented. Massive mainstream dams converting warm, turbulent river sections into enormous impoundments, and their cold, clear tailwaters are examples of sudden and catastrophic impacts. In all such reservoirs and tailwaters of the Colorado River Basin, there has been virtually a complete replacement of native fishes by introduced species -- although it must be admitted that the introduced fishes form the bases of multi-million-dollar recreational fisheries.

The disappearance of endangered species, such as the Colorado River squawfish, from reservoirs and tailwater areas of the Colorado River is not difficult to comprehend. They lack the evolutionary programming for lacustrine life in the reservoirs and require a minimum temperature of 20 degrees C for reproduction. The tailwaters below the dams are too cold.

The squawfish has not been found in the lower Colorado River Basin (Grand Canyon and below) since 1968. It has also disappeared or drastically declined in numbers in major tributary rivers which lack large, mainstream dams. In these areas, it has been the gradual, cumulative impacts acting to favor dominance of non-native fishes.

It is more difficult to quantify cause and effect relationships resulting from gradual, cumulative impacts. They are dispersed in time and place; they act through changes in flow regimes, channel morphology (physical habitat), depth, velocity, turbidity, temperature, etc.

The Gila River of New Mexico and Arizona may be cited as an example of the replacement of native fishes by introduced species as the result of environmental changes from land-use practices. Originally the Gila was a clear river with stable banks and channels averaging 100 to 200 feet in width, flowing through rich bottomlands with associated quiet backwater marshes and lagoons. Dense vegetation and an abundance of fish and wildlife, including the presently endangered squawfish, characterized the original environment. Beginning in the late nineteenth century, the period of the open range began (the "tragedy of the commons"). Overgrazing by livestock destroyed the vegetation cover throughout much of the basin, accelerating erosion and peak run-offs and setting the stage for greatly amplifying the effects of floods. As we now know, the fluvial geomorphic consequences of vegetation removal from arid and semiarid watersheds, such as the Gila, is quite predictable (Schumm, 1969).

A flood in 1916 devastated the Gila drainage, obliterating the bottomlands and associated farms and converting the environment into a barren expanse of shallow, braided stream channels. The channel of the Gila River expanded from 138 feet to 1,935 feet at Solomon, Arizona. A similar sequence of events occurred in other tributary rivers of the lower Colorado Basin -- the Little Colorado, the San Simeon, the Blue, the San Pedro, etc. (Chapman, 1933; Miller, 1961).

In the upper Colorado River Basin, the changes have been less dramatic, but the squawfish continues to decline in numbers in areas of former abundance, such as the Gunnison and Yampa Rivers. Here roads, railroads, urban areas, and agricultural irrigation have caused changes in channel morphology and loss of quiet backwater habitat which is important for early life history stages of the squawfish.

FINAL COMMENTS

The degree of awareness of land- and water-use impacts on fishes can be gauged from the number of symposia stimulated by the problem. Thus, there has been considerable literature generated in recent years on the effects of dams and reservoirs, channelization, logging, and in-stream flow requirements (Hall, 1971; Fish, 1968; Arner et al., 1976; Corning et al., 1975; Gibbons and Salo, 1973; Osborn and Allman, 1977). The most pervasive man-induced influence on watersheds in the West, however, is livestock grazing, but the first symposium examining the impact of livestock on fishes was held only this year (Behnke, 1977b). One reason for this lack of awareness is due to the gradual, cumulative impact of livestock grazing. Many degraded streams have been in that condition so long that it is commonly assumed that only natural forces are responsible. The problem of livestock grazing accelerating the erosional process and destroying optimal fish habitat is particularly acute in arid and semiarid regions. It is, essentially, a problem of range management, or the failure of range management to consider all effects on the aquatic ecosystem caused by range management practices. The solution to this problem is to remove streams and their associated riparian vegetation from the standard grazing allotments and to manage such areas with a different set of priorities.

With the increasing demand on fisheries biologists to provide input to predict the consequences of water and energy development projects and land-use practices, it is essential that they become familiar with certain principles of fluvial geomorphology, particularly as they relate to ramifications throughout a drainage area, as regards changes in flow regimes, channel morphology, and bank stability.

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