Department of Fishery and Wildlife Biology

Colorado State University
Fort Collins, Colorado
80523

March 21, 1983

Mr. Donald Duff
U.S. Forest Service
324 25th Street
Odgen, UT 84401

Dear Don:

Thanks for copy of final report on Utah trout. I met the two students who did the work and they impressed me as sincere and hard working fellows, but they must be incredibly naive to arrive at the conclusions they did. Essentially, cutthroat trout are classified as Snake Valley (or Colorado River) or Bear River-Yellowstone based on the allelic frequencies of a single enzyme (SDH). Where they went astray was in their belief that the frequency differences represent discrete variation (0-10% of allele 0 and 90-100% of allele 40 identifies Snake Valley or Colorado River cutthroat whereas the reverse is true for Bear River cutthroat) when in fact they were dealing with a continuous variable (allelic frequency ratios). Thus I read that one tributary of the Sevier River has Snake Valley cutthroat and a neighboring tributary has Bear River cutthroat and a third has intergrades between the two.

Evidently, they had such complete faith in Eric Loudenslager's work that they never questioned Eric's characterization of _S_. _c_. _pleuriticus_ as having 100% of the SDH 0 allele. The fact is, Loudenslager's characterization was based on one sample from a single small population. A familiarity with the literature dealing with comparable situations should have made it very predictable that as more and more samples are made from throughout the range of a subspecies or species, highly variable allelic frequency ratios will be found and this is a completely natural phenomenon and not due to hybridization or integradation. Their work demonstrated this fact, yet they considered all populations that didn't fit their preconceived notion as "atypical" and intergrades. Obviously, there are no Snake Valley cutthroat trout inhabiting the Bear River drainage no matter what the allelic frequencies show.

I remember that Terry Hickman was instructing these students in morphological examination, and I thought they would include data on such characters as scale counts, pyloric caeca and basibranchial teeth. Without such supporting data their conclusions lack credibility and any semblance of verification. How accurately they were able to detect the effects of rainbow trout hybridization is found on p. 9 where they discuss 60 specimens sampled from the Strawberry River, above Strawberry Reservoir. No indication of rainbow trout hybridization could be found by electrophoresis although they admit that some specimens appeared to be typical rainbow trout.

Anyone citing this work as an authoratative identification and classification of Utah cutthroat trout could be made to appear extremely foolish and devoid of any understanding of genetics and evolution. I suspect Utah fisheries people didn't expect much from the study -- just enough to demonstrate they are involved in "research" on native trout. The letter from Alvin Mills to Gle~~e~~nn Davis, however, indicates they will get more than they bargained for. As in Currant Creek Reservoir tributaries, "pure" native trout will turn up all over and raise problems for fishery management plans. With this in mind, it may be prudent to keep my criticisms of the report "in house" and let Don Andrians fluster awhile as a consequence of applying modern technology to native trout management.

Sincerely,

Robert Behnke

xc: Mr. Terry Hickman

Habitat
bull

- Lahontan
Soda Recr
- Utah ??

Mr. Donald Duff
U.S. Forest Service
324 25th Street
Ogden, Utah 84401

cc. Mr. Terry Hickman
U.S. Fish and Wildlife Service
1311 Federal Bldg.
125 South State St.
Salt Lake City, Utah 84138

Dear Don:

Thanks for copy of final report on Utah trout. I ~~had~~ met the two students who did the work and they impressed me as sincere and hard working fellows, but they must be incredibly naive to arrive at the conclusions they did. Essentially, cutthroat trout are classified as Snake Valley (or Colorado River) or Bear River-Yellowstone based on the allelic frequencies of a single enzyme (SDH). Where they went astray was in their belief that the frequency differences represent ~~are~~ discrete variation (0-10% of allele 0 and 90-100% of allele 40 identifies Snake Valley or Colorado River cutthroat whereas the reverse is true for Bear River cutthroat) when in fact they were dealing with a continuous variable (allelic frequency ratios). Thus ~~you~~ I read that one tributary of the Sevier River has Snake Valley cutthroat and a neighboring tributary has Bear River cutthroat and a third has ~~hybrids~~ intergrades between the two.

Evidently, they had such complete faith in Eric Loudenslager's work that they never questioned Eric's characterization of S. c. pleuriticus as having 100% of the SDH ∅ allele. The fact is, Loudenslager's characterization was based on one sample from a single small population. A familiarity with the literature dealing with comparable situations should have made it very predictable that as more and more samples are made from throughout the range of a subspecies or species, highly variable allelic ~~frequency~~ frequency ratios will be found and this is a completely natural phenomenon and not due to hybridization or intergradation. Their work demonstrated this fact, yet they considered all populations that didn't fit their preconceived notion as "atypical" and intergrades. Obviously, there are no Snake Valley cutthroat trout inhabiting the Bear River drainage no matter what the allelic frequencies show.

I remember that Terry Hickman was instructing these students in morphological examination, and I thought they would include data on such characters as scale counts, pyloric caeca and basibranchial teeth. Without such supporting data, their conclusions lack credibility and ~~verifo~~ any semblance of verification. How accurately they were able to detect the effects of rainbow trout hybridization is found on p. 9 where they discuss 60 specimens sampled from the Strawberry River, above Strawberry Reservoir. No indication of rainbow trout hybridization could be found by electrophoresis, although they admit that some specimens appeared to be typical rainbow trout.

Anyone citing this work as an authoratative identification and classification of Utah cutthroat trout could be made to appear extremely foolish and ~~ignorant~~ devoid of ~~just~~ any understanding of genetics and evolution. I suspect Utah fisheries people didn't expect much from the study -- just enough to demonstrate they are involved in "research" on native trout. The letter from Alvin Mills to Glenn Davis, however, indicates they will get more than they bargained for. As in Currant Creek Reservoir tributaries, "pure" native trout will turn up all over and raise problems for fishery management plans. With this in mind, it may be prudent to keep my criticisms of the ~~see~~ report "in house" and let Don Andriano fluster awhile as a consequence of applying modern technology to native trout management.

Sincerely.

file in Bonneville cutthroat file

COPY

Uinta National Forest

P.O. Box 1428
Provo, UT 84603

F. S. R-4
RECEIVED
FEB 3 1983
WILDLIFE MANAGEMENT

2610

FEB 02 1983

Bob—
Just recently got this memo & thought you'd like it to.
Don

Mr. Glenn Davis
Fisheries Program Coordinator
Utah Division of Wildlife Resources
1596 West North Temple
Salt Lake City, UT 84116

Dear Glenn:

Enclosed you will find the Genetic Analysis performed by Mark Martin at Brigham Young University on the sample fish collected by Chad Crosby from the four streams tributary to Currant Creek Reservoir. During the November 1982 rotenone treatment at Currant Creek (precipitated rather abruptly by Bureau of Reclamation plans), trout specimens were collected with some difficulty from the principal tributaries to the reservoir. The streams were iced over and water temperatures colder than desired for the rotenone to work quickly. Although fish expired slowly and were difficult to retrieve under the ice, enough specimens were obtained on November 3, 1982, to satisfy the needs for the electrophoretic analysis. The samples were frozen immediately and conveyed to Mark on November 4, 1982. The analysis was completed the week of January 10 and the results conveyed the week of January 17 as follows:

Electrophoretic Analysis of Currant Creek Trout

Stream and Location	Result	Number of Specimens
Low Pass Creek below FS road No. 083 and above reservoir.	All fish pure strain Colorado Cutthroat (Salmo clarki pleuriticus)	6
Currant Creek Left (south) Fork below FS road No. 083 and above reservoir.	Five fish pure strain Colorado Cutthroat (Salmo clarki pl.) One fish a cutthroat variant*	6
Currant Creek (Right Fork) below FS road No. 083 and above reservoir.	All fish pure strain Colorado Cutthroat (Salmo clarki pl.)	5
Racetrack Creek below FS road No. 145 and above reservoir.	All fish pure strain Colorado Cutthroat (Salmo clarki pl.)	

X = Action
✓ = Info

file in Bonneville cutthroat file

COPY

Uinta National Forest

P.O. Box 1428
Provo, UT 84603

F. S.
RECEIVED
FEB 3 1983
WILDLIFE MANAGEMENT

2610

FEB 02 1983

Mr. Glenn Davis
Fisheries Program Coordinator
Utah Division of Wildlife Resources
1596 West North Temple
Salt Lake City, UT 84116

Dear Glenn:

Enclosed you will find the Genetic Analysis performed by Mark Martin at Brigham Young University on the sample fish collected by Chad Crosby from the four streams tributary to Currant Creek Reservoir. During the November 1982 rotenone treatment at Currant Creek (precipitated rather abruptly by Bureau of Reclamation plans), trout specimens were collected with some difficulty from the principal tributaries to the reservoir. The streams were iced over and water temperatures colder than desired for the rotenone to work quickly. Although fish expired slowly and were difficult to retrieve under the ice, enough specimens were obtained on November 3, 1982, to satisfy the needs for the electrophoretic analysis. The samples were frozen immediately and conveyed to Mark on November 4, 1982. The analysis was completed the week of January 10 and the results conveyed the week of January 17 as follows:

Electrophoretic Analysis of Currant Creek Trout

Stream and Location	Result	Number of Specimens
Low Pass Creek below FS road No. 083 and above reservoir.	All fish pure strain Colorado Cutthroat (*Salmo clarki pleuriticus*)	6
Currant Creek Left (south) Fork below FS road No. 083 and above reservoir.	Five fish pure strain Colorado Cutthroat (*Salmo clarki pl.*) One fish a cutthroat variant*	6
Currant Creek (Right Fork) below FS road No. 083 and above reservoir.	All fish pure strain Colorado Cutthroat (*Salmo clarki pl.*)	5
Racetrack Creek below FS road No. 145 and above reservoir.	All fish pure strain Colorado Cutthroat (*Salmo clarki pl.*)	

X = Action
✓ = Info

*A single cutthroat variant exhibiting genetic deviation from pure Salmo clarki pleuriticus but exhibiting no hybridization with Rainbow trout (Salmo gairdneri). Such variants occur in nature occasionally contributing to genetic drift, natural selection, etc.

Rotenone treatment of the reservoir began in the tributary streams at culvert crossings along Forest Service System road Nos. 083 and 145 within a mile of the newly filling Currant Creek Reservoir. The streams sampled are relatively remote above the culvert locations and trout populations above the sample points should be even more reliable genetically.

The above results in my opinion have some potentially far reaching implications to our management programs (species, habitat, and recreation). The allelic frequencies represented cumulatively in the four streams are greater than .90 and as such, comprise what the geneticists would classify "pure populations" (Martin, 1982). Although one would suspect such pure populations may exist in other streams as yet untested, Behnke and Zarn (1976) in "Biology and Management of Threatened and Endangered Western Trouts" stated that "only two populations of the many examined appear to be wholly pure." They further stated that "although cutthroat trout exist in good numbers in small lakes and streams in the Colorado River basin of Colorado, Utah, and Wyoming, pure populations of Salmo clarki pleuriticus are indeed rare throughout its range."

I suspect we need to take a good look at our options for managing the reservoir, the tributaries and the fishery. We would be remiss in my opinion if we did not make an honest effort at managing to protect the genetically unique population we have here.

I suggest we need to consider and discuss fairly soon with Bureau biologists the following:

1. Can we manage the reservoir and tributaries as a Colorado Cutthroat fishery?

2. What implications would such a management scheme have to the recreational plans and development at Currant Creek?

3. Measures to protect this population from contamination through the Vat Tunnel when it begins bringing water from Upper Stillwater, West Fork Duchesne, etc.

4. Habitat measures, mitigation opportunities, and other needs for a management plan and its execution.

5. Needs to evaluate other waters that may be potential sources of genetic contamination.

6. Future monitoring of the Currant Creek Colorado Cutthroat population.

It appears at this point that projected recreation plans and use at Currant Creek do not preclude the opportunity to develop a reservoir population in an orderly program. The Uinta National Forest is willing to cooperate with you in whatever effort you feel appropriate. I will look forward to working with you and Chad Crosby in whatever program or effort is required.

Sincerely,

ALVIN D. MILLS

ALVIN D. MILLS
Zone Fisheries Biologist

Enclosure

cc:
Chad Crosby, UDWR, Vernal
Mark Martin, BYU
RHD
✓Phil Janik, RO (WL)
DTN
Dr. Dennis Shiozawa, BYU
ADM
D-1
2330

WL FILE

-5 or 90 alleles
S. Valley + Bear R
vs. Colo. R. 2 x 90
1 pop.
-3

pg 9 Strawberry R
can't detect RB
but obvious from looking at them.

-11-12
SDH!
Snake valley

Final Report

Submitted to the

Utah State Division of Wildlife Resources

Based on a Thesis on

The Electrophoresis of Isolated Trout Populations from Selected Utah Streams

15-16
dendogram
hodgepodge

By

Mark A. Martin and Dennis K. Shiozawa

18

Department of Zoology
Brigham Young University
Provo, Utah 84602

and

Heian West, Inc.
4415 Briarwood Circle
Salt Lake City, Utah 84117

Acknowledgements

We extend sincere appreciation to those who have assisted with this project. We would like to acknowledge Dr. James R. Barnes and Dr. Melvin W. Carter for the encouragement and instruction provided. Gratitude is also expressed to Dr. Jack W. Sites, Jr. (Brigham Young University), Eric J. Loudenslager (Huntsman Marine Laboratory, New Brunswick, Canada) and Boyd Bentley (U. of California, Davis) for the assistance they offered in the analysis of this research.

We are indebted to Doug Sakaguchi, Shawno May, Dave Burtoch, Allen Kimball and Louis Billedeaux for their assistance in field and lab work. We also wish to thank the biologists from the Utah Division of Wildlife Resources and the U. S. Forest Service who helped make this project possible.

Finally, the senior author will always be grateful to his wife Linda for the inspiration and support she offered throughout this study. Special thanks is also extended to his parents for the help they have provided.

THE ELECTROPHORETIC ANALYSIS OF CUTTHROAT TROUT

SUBSPECIES IN SELECTED UTAH WATERS

Abstract

Recent discoveries of native cutthroat trout (Salmo clarki Richardson) in Utah have prompted research by both State and Federal agencies. To help facilitate this research, the U.S. Forest Service located 39 Utah streams in which they suspected relict populations of native cutthroat existed. A total of 550 cutthroat from 31 streams was examined to identify strains and to investigate the degree of genetic differentiation. Horizontal starch gel electrophoresis was used to assay four protein systems from populations of Colorado River (S. c. pleuriticus), Bonneville (S. c. utah) and Yellowstone (S. c. bouvieri) cutthroat trout. Population differentiation was determined using cluster analysis. Deep Creek, North Fork of North Creek (Sevier River drainage, Beaver County), Carter Creek, Meadow Creek, Mckenzie Creek (Bear River drainage, Summit County) and Sugarpine Creek (Bear River drainage, Rich County) contain native populations of the Bonneville cutthroat trout (S. c. utah). The Middle and West Forks of Beaver Creek and Brush Creek on the north slope of the Uinta mountains in the Green River drainage are largely inhabited by populations of Colorado River cutthroat trout (S. c. pleuriticus).

Introduction

The greatest geographic distribution of the North American trout is exhibited by the cutthroat trout (Salmo clarki Richardson). Early ichthyologists (late nineteenth century) believed that the cutthroat originated in Asia (Jordan 1894). However, its origin is now uncertain because there is neither a description of an Asian counterpart to Salmo clarki nor adequate fossil evidence (Loudenslager and Gall 1980a). The original North American range of Salmo clarki extended from Alaska to Northern California, throughout the Intermountain area and east to the upper Missouri, Platt, Colorado, and Rio Grande drainages. The headwaters of the South Saskatchewan River, Alberta, Canada also contained native stocks (Sigler and Miller, 1963). Throughout this range the cutthroat is represented by distinct strains (subspecies). Ichthyologists have hypothesized that these strains developed through a series of repeated invasions and subsequent isolation during Pleistocene glacial and interglacial periods. For instance, during one Pleistocene glacial period the interior cutthroat split into two lines. One, the ancestral Westslope cutthroat trout (S. c. lewisi) occurred in the northern division of the upper Columbia, upper Missouri, and South Saskatchewan drainages. The other, the Yellowstone cutthroat trout (S. c. bouvieri) ancestor, occurred in the Southern (Snake River) division of the Columbia River Basin. This Yellowstone cutthroat ancestor ultimately gave rise to the Bonneville cutthroat trout (Bonneville Basin), the Colorado River cutthroat trout (Colorado River Basin), and the Lahontan cutthroat trout (Lahontan Basin) (Behnke 1980a).

Presently, Miller (1950) recognizes 11 cutthroat trout subspecies and Behnke (1981) recognizes 15. Until recently cutthroat trout systematics was based on morphological and meristic techniques. This includes evaluation of color and spotting patterns, and counts of gill rakers, basibranchial teeth, pyloric ceca and scales above and within the lateral line series (Behnke 1972; Hickman 1978). A study of electrophoretic patterns of proteins from inland cutthroat trout by Wydoski et al. (1976) found no protein that would successfully differentiate cutthroat subspecies (Hickman 1978). Recently Loudenslager and Gall (1980a) located 6 protein systems that aided in identifying groups of cutthroat trout subspecies and differentiated cutthroat x rainbow hybrids from cutthroat trout.

In this paper we present results of an electrophoretic comparison for several Utah cutthroat trout populations. The objectives were to identify native populations of subspecies in Utah and assess the degree of hybridization between the native and introduced strains (both rainbow and cutthroat). Identification of native populations will not only be useful in watershed management by State and Federal agencies, but will also aid in the understanding of the origins and differentiation of Utah's native trout fauna.

Prior to settlement by European man, Utah's waters supported three strains of cutthroat trout, the Yellowstone (*S. c. bouvieri*), the Colorado River (*S. c. pleuriticus*) and the Bonneville (*S. c. utah*). The Snake River and it's tributaries above Shoshone Falls, with the exception of drainages between Jackson Lake and Palisades Reservoir, harbors native Yellowstone cutthroat (Behnke 1980a). The Yellowstone cutthroat is native to Utah in the Raft River Mountain drainages but now can be found wherever man has introduced it.

The headwaters of the Colorado River Basin downstream to the Dirty Devil River, Utah, on the west and the San Juan drainage of Colorado, New Mexico and Arizona on the east comprised the original range of Colorado River cutthroat (S. c. pleuriticus) (Fig. 1). The Colorado River cutthroat trout is included in Miller's (1972) list of threatened freshwater fishes of the United States and is considered endangered by the Bonneville Chapter, American Fisheries Society (Holden et al. 1974). Only two "pure" populations of S. c. pleuriticus are described by Behnke (1976). They occur in an isolated section of Rock Creek and North Beaver Creek, Sublette County, Wyoming. Numerous other populations are morphologically good representatives of S. c. pleuriticus, but show some evidence of hybridization (Behnke 1980a). In the upper Green River Basin these populations are found in Lead Creek (a tributary of Horse Creek) and Red Castle Creek. In Colorado populations of S. c. pleuriticus occur in Northwater Creek (a headwater tributary to Parachute Creek) and Trappers Lake.

Lake Bonneville (Fig. 2) and its tributaries supported the Bonneville cutthroat trout (S. c. utah) (Duff and Hickman 1979; Hubbs and Miller 1948). This trout probably remained in the receeding Lake Bonneville until it became brackish approximately 12,000 years BP (J. Mckensie, personal communication)[1]. With the increasingly arid climate of the Bonneville Basin the major drainages gradually became

---

[1] Swiss Federal Institute of Technology, Zurich, Switzerland

isolated from each other. Final isolation occurred approximately 8,000 years BP (Broecker and Kaufman 1965). This isolated populations of Bonneville cutthroat from one another. This trout was still abundant in many rivers and streams of Utah as well as Utah Lake (Tanner 1933) when pioneers arrived in 1847. Pioneers began to deplete local fish populations by diverting water for irrigation, by eliminating spawning runs and by modifying the habitat (Heckmann, Thompson and White 1981). Associated with these impacts was the stocking of nonnative trout. Stocking resulted in both the extinction and extensive hybridization of the native trout fauna (Hickman 1977). Until recently the original Bonneville (S. c. utah) cutthroat trout was thought to be extinct or so hybridized that it was unrecognizable. However, relict populations were located in 15 streams by Hickman (1978) and fishery personnel from the Utah Division of Wildlife Resources and Forest Service now believe many other streams contain native populations. The original range of the Bonneville cutthroat trout, including the Bear River drainage, is presented in Figure 1.

The Bonneville cutthroat has been divided into several substrains, based both on electrophoresis and meristic-morphological characteristics (Behnke 1976, 1980a, 1981; Loudenslager and Gall 1980b, 1981). Behnke (1981) recognized the original Bonneville as being the predominant form throughout the Bonneville Basin. He described a variation of the Bonneville which occurs in the Snake Valley area of the Deep Creek Mountains near the Utah-Nevada border. He also noted that S. c. utah taken from the Bear River drainage were different from both the Bonneville proper and the Snake Valley strains. Loudenslager and

Gall (1981) consider the Bonneville cutthroat to have only 2 variations; the Snake Valley form, which represents the original Bonneville Basin trout and the Bear River form which they believe is a more recently derived taxon.

Methods

Thirty-nine Utah streams were examined for cutthroat trout. These were located in the Wasatch-Cache (Fig. 3), Uinta, Manti LaSal and Fish Lake (Fig. 4) National Forests. Both electrofishing and hook and line were used to collect fish. Cutthroat trout were found in 31 of the 39 streams (Table 1). Whenever possible an attempt was made to collect 25 trout from each stream. A total of 550 cutthroat were analyzed.

Fish were frozen in the field on dry ice and returned to Brigham Young University. Tissue samples were subsequently homogenized in a 0.25 molar sucrose solution and centrifuged at 30,000 x g for 15 min. The resulting supernatant was retained and used for analysis. Electrophoretic techniques as outlined by Loudenslager and Gall (1980a) were used for analysis of trout populations. This provided a means of evaluating hybridization with rainbow trout (<u>Salmo gairdneri</u>) and genetic variation within cutthroat populations. Supernatant from albino rainbow trout tissues (from the Midway Hatchery, Midway Utah) were used as control markers. Four protein systems encoded by 6 loci were examined in the sampled populations. These systems included sorbitol dehydrogenase (SDH), isocitriate dehydrogenase (IDH), malic enzyme (ME), and leucyl-glycyl-glycine (LGG). Two sorbitol dehydrogenase loci (SDH-1 and 2) were used to help differentiate cutthroat strains. Data were analyzed as described by Loudenslager and Gall (1980a). While electrophoresis successfully separates the Yellowstone (S. c. bouvieri) and Bear River Bonneville (S. c. utah) from the Snake Valley Bonneville (S. c. utah) and Colorado River cutthroat (S. c. pleuriticus), electrophoretically, the Bear River Bonneville variety does not differ in the enzyme systems examined from the Yellowstone cutthroat. Likewise, no protein system has been found to successfully separate the Colorado River cutthroat from the Snake Valley Bonneville variety. However, SDH-2 showed slight heterozygosity in Snake Valley Bonneville populations from Goshute and Pine Creeks (Deep Creek drainage) in a study by Loudenslager and Gall (1980b). The drainage from which samples were taken was used to help differentiate the Snake Valley Bonneville from the Colorado River cutthroat. Those population taken from the Bear River drainage which had no rainbow hybridization were assumed to be Bear River Bonneville. There was no difficulty in identifying rainbow trout alleles in cutthroat populations.

Allelic frequencies (Table 2) were calculated from protein bands. Similarities between populations (Table 3) were determined by Nei's (1972) genetic identity index. The resulting similarity matrix was clustered with the NTSYS statistic package. The cluster algorithm used an unweighted pair-group method of arithmetic averages (UPGMA) (Sneath and Sokal 1973). After electrophoretic analysis trout were fixed in formalin and stored in isopropyl alcohol for future reference.

Stocking records from the Utah Division of Wildlife Resources were examined to determine if trout had been planted in the sampled streams and adjoining drainages (Table 4). Stocking records were not be used as absolute indicators of the species present because not all trout introductions into area waters have been documented.

Results-Discussion

Loudenslager and Gall (1980a,b,c 1981) discovered that locus IDH-3 differentiated cutthroat from rainbow trout. Cutthroat trout alleles are expressed at allele 100 and rainbow alleles are apparent at alleles 170, 140 and 60. LGG and ME at position 100 correspond to rainbow alleles, while cutthroat had alleles at 160 and 125 respectively (Loudenslager and Gall 1981). Two criteria are used to identify F_1 rainbow x cutthroat hybrids from backcross rainbow x cutthroat hybrids. Trout heterozygous for either ME or LGG are classified as F_1 hybrids. Individuals homozygous for a cutthroat or rainbow allele at one locus and either homozygous or heterozygous for the alternate allele at the other locus were backcross hybrids. The sorbitol dehydrogenase protein system (locus 1 and 2) was found to separate cutthroat strains. At locus 1 (SDH-1) allele 40 is predominant in the Yellowstone and Bear River Bonneville cutthroat. SDH-1 (0) is predominant in Colorado River and Snake Valley Bonneville cutthroat. Loudenslager and Gall (1980b) found pure populations of Snake Valley Bonneville from the Deep Creek drainages to be homozygous for SDH-1 (0) (Goshute and Pine Creeks) or slightly heterozygous for SDH-1 (0) (Trout Creek, 0 = 0.984, 40 = 0.016). Their Colorado River cutthroat population was homozygous for the 0 allele. Variation seen in the Snake Valley Bonneville at SDH-1 implied that pure populations of this variety may be slightly heterozygous. Since Loudenslager and Gall (1980a) only examined one Colorado River cutthroat population, we feel that a slight degree of heterozygosity at SDH-1 may be expected. Therefore, populations of these two strains will be considered pure if SDH-1 (0) has a frequency of 0.90 or greater.

Stocking records indicate that the eight streams sampled in the Colorado River drainage and their downstream drainages have not been planted with cutthroat by the Utah Division of Wildlife Resources (Table 4). Thompson Creek cutthroat at locus SDH-1 (allele 0) expressed a frequency of 1.00, which when considered with the stream's drainage implied that the population is Colorado River cutthroat. However, 1 of the 17 fish examined contained a rainbow band (Me 0) indicating rainbow hybridization. Joulious Creek is inhabited by cutthroat that expressed 18 percent of allele 40 and 82 percent of allele 0 at SDH-1. This population could be pure Colorado River cutthroat or hybridized with Yellowstone (or Bear River Bonneville). It was not hybridized with rainbow. Kabell Creek contained cutthroat alleles that had frequencies of 0.63 (position 40) and 0.37 (position 0) at the SDH-1 locus. However, only 4 trout were collected from Kabell Creek. A larger sample size would have been more conclusive. This population is more like the Bear River Bonneville or Yellowstone. It may represent a hybridized population where either Bear River Bonneville or Yellowstone alleles have entered the population. No rainbow hybridization was seen. Cutthroat from the Middle Fork of Blacks Creek contained 12 percent of their alleles at position 40 and 88 percent at location 0 for SDH-1. This population may be a typical Colorado River strain. No rainbow hybridization was found. In Brush Creek (SDH-1) 2 percent of the population had alleles at 40 and 98 percent had alleles at 0. This population is typical of Colorado cutthroat. Five cutthroat trout sampled in Muddy Creek had 40 percent 40 allele and 60 percent 0 allele for SDH-1. Our analysis of Muddy Creek would have been enhanced by a larger sample size. This population may be hybridized with introduced cutthroat because of the divergence of the allelic frequency away from that found by Loudenslager and Gall (1981) for Colorado River cutthroat. Cutthroat trout expressing allele frequencies of 0.05 and 0.95 at positions 40 and 0 respectively (SDH-1) were found in the Middle Fork of Beaver Creek. Ninety-eight percent of the population sampled from the West Fork of Beaver Creek had SDH-1 alleles positioned at 0 and 2 percent had alleles located at 40. No evidence of rainbow hybridization was observed in the trout sampled from the Middle and West Forks of Beaver Creek. Both streams demonstrated what would be expected in nonhybridized, native Colorado cutthroat trout. The allelic frequencies from the Middle Fork of Beaver Creek would have been more indicative of the population if our sample size would have been larger than 9.

Stocking records indicate that Strawberry River and Strawberry Reservoir were stocked with rainbows and cutthroats. Of the 60 trout sampled from Strawberry River above Strawberry Reservoir, electrophoresis gave no indications of hybridization with rainbows. However, several fish demonstrated typical rainbow coloration and spotting. Loudenslager and Gall (1981) describe introgressed populations of cutthroat that exhibit no evidence of rainbow alleles. Introgression is the hybridization and subsequent backcrossing of alleles from one species into another. Cutthroat populations may contain rainbow trout alleles, but because of backcrossing they appear as a cutthroat genome. This may be the case with Strawberry River trout. A larger sample would have increased the chances of documenting cutthroat-rainbow hybridization in the population. Our sample indicates that rainbow lineage comprises less than 2 percent of the alleles in the population. Heterozygote cutthroat alleles existed in the Strawberry population at SDH-1. Fifty percent of the population contained cutthroat alleles at the 40 position and 50 percent expressed alleles at the 0 position. Cutthroat in the Colorado River drainage that express such heterozygosity in SDH-1 at alleles 40 and 0 are not typical for _S. c. pleuriticus_. Instead, they are intermediate and imply stocking by man, natural variation (drift, selection, etc.) within populations or a prehistoric invasion of trout containing a high frequency of SDH-1 at the 40 position. In this case man's stocking of fish has been very important.

Rainbow trout were not stocked in 6 of the 7 streams examined in the Bear River drainage. Only Woodruff Creek (below Sugarpine Creek) has been stocked with cutthroat trout by the Division of Wildlife Resources (any cutthroat trout planting during the past 25-30 years may have been with Strawberry Reservoir cutthroat trout). The Mckenzie, Carter and Sugarpine Creek populations were homozygous for the SDH-1 allele at 40. We consider this typical for both the Bear River Bonneville and Yellowstone cutthroat. Stream locations within the Bear River drainage implied that these populations were of the Bear River variety. None were hybridized with rainbow. Carter Creek was judged by

Behnke (1980b) to be 95 percent pure Bear River Bonneville (with possible cutthroat variations), while our results showed it to be 100 percent pure Bear River Bonneville because all trout from Boundary Creek contained the 40 allele at SDH-1. However, heterozygosity was noted in IDH-3 where 11 percent of the bands were positioned at allele 170 and 89 percent at allele 100. This is indicative of rainbow hybridization. Rainbow x cutthroat trout genes were noted in 25 percent of the 100 allele in ME and 32 percent of the 100 allele in LGG of Boundary Creek. Cutthroat strains located in Meadow Creek had a frequency of 1.00 at SDH-1 position 40. At the IDH-3 locus 3 percent of the population contained the 170 allele and 97 percent had the 100 allele. This variation of the IDH-3 locus indicates rainbow trout hybridization. A rainbow trout allele (LGG) appeared in 5 percent of the trout alleles sampled from Mill Creek (rainbows were stocked in Mill Creek). Heterozygous cutthroat trout alleles (locus SDH-1) existed in the Mill Creek trout population at 0.55 for 40 and 0.45 for 0. Behnke (1980b) reported this population to be 90 percent pure Bear River Bonneville (2 of 32 trout examined contained rainbow characteristics). Our study indicates the population is 95 percent cutthroat, but they are intermediate between the Bear River and Snake Valley forms. badly confused No way?

Bunchgrass Creek was the only stream sampled in the Logan River drainage. No stocking records existed for this stream. However, downstream the Logan River has been planted with rainbow and brown trout and a rainbow allele ME (100) appeared in 5 percent of the population sampled from Bunchgrass Creek. One hundred percent of this population had the SDH-1 and 2 locus at alleles 40 and 100 respectively. This

Logan R. S.C. utah
SDH-1 -40
as w/ Bear R.
not Snake Valley

SDH-1 locus is what would be expected in Yellowstone or Bear River Bonneville. No alleles of the Snake Valley form appear. The SDH-2 locus (100) is expected in either cutthroat or rainbow trout.

Moffit Creek, Greetsen Creek and Red Pine Creek were sampled from the Weber River drainage. Stocking records show that the Weber River, the Ogden River and Smith Moorehouse Creek have not been stocked with cutthroat trout by the Utah Division of Wildlife Resources. Ninety-four percent of the trout collected from Moffit Creek had allele 0 for SDH-1; the remaining had allele 40. The high frequency of the 0 allele at SDH-1 implied that the Moffit Creek population is inhabited by Snake Valley Bonneville cutthroat. Durfee Creek did not contain trout. The population from Greetsen Creek Contained 17 percent of their alleles at 40 and 83 percent at 0 for the SDH-1 locus. Stocking records show that Greetsen Creek was planted with cutthroat. Unfortunately, our sample size was only three trout, taken by hook and line. No stocking records exist for Red Pine Creek, a tributary to Smith Moorehouse Creek. It is represented by a mixture of cutthroat trout alleles at the SDH-1 locus. Twenty-five percent of the bands were located at 40 and 75 percent at 0 for this locus. Such variation of SDH-1 at 40 and 0 is not considered typical for native Snake Valley or Bear River Bonneville populations. Instead, it is intermediate and the degree of heterozygosity for these streams implies a natural Pleistocene invasion, genetic drift, selection or stocking by man.

Weber R. Utah

Yes! they show it is typical B.S.

The North Fork of the American Fork River also contained heterozygous cutthroat alleles at SDH-1. This sorbitol dehydrogenase locus was electrophoretically distinct in 25 percent of the trout at allele 40 and 75 percent at allele 0. Planting records indicated that this river has been planted with both rainbow and cutthroat trout. No indication of rainbow hybridization was found in this population. The allelic frequencies for the trout in this stream would have been more accurate if we had greatly increased our sample size. Only brook trout were found in Silver Creek above Silver Lake flat in the American Fork River drainage.

Cutthroat alleles from the Left Fork of Hobble Creek were 100 percent homozygous for the SDH-1 locus at 40. The 40 allele at SDH-1 is indicative of Yellowstone or Bear River Bonneville cutthroat. Stocking records showed that this stream has not been planted with rainbow trout. However, Hobble Creek has been stocked with rainbows by the Division.

Streams sampled in the Spanish Fork drainage contained a variety of cutthroat alleles. Stocking records indicated that higher order streams in the Spanish Fork River drainage have been stocked with rainbow and brown trout. The headwaters of Chase Creek expressed SDH-1 alleles at position 40 in 100 percent of the sample. This is what we considered typical for populations of Yellowstone or Bear River Bonneville cutthroat trout. Stocking records indicated that this drainage system has not been stocked with cutthroat by the Division. We were only able to locate 4 trout in the headwaters of Chase Creek. Shinglemill Creek was inhabited by cutthroat trout with frequencies of 0.97 (allele 40) and 0.03 (allele 0) for SDH-1. Again, this is indicative of either Yellowstone or Bear River Bonneville. The Division stocking records stated that Shinglemill and the downstream drainage of Shinglemill Creek have not been stocked with cutthroat. The Little

Diamond Creek population was heterozygous at the SDH-1 locus for alleles 40 and 0 at frequencies of 0.35 and 0.65 respectively. This population is intermediate between either Bonneville form. Wanrhodes Creek had rainbow x cutthroat hybrids identified in 8 percent of both the LGG and ME alleles of the trout collected. This stream was represented by frequencies of 0.36 and 0.64 for alleles 40 and 0 (SDH-1) respectively. Rainbow x cutthroat hybrids were collected in the upper stretch of Nebo Creek. Both LGG at 100 (0.13) and ME at 100 (0.09) were heterozygous for the rainbow allele. Planting records expressed that Nebo Creek and its drainage system has not been stocked with cutthroat trout. At SDH-1 trout from Nebo Creek had frequencies of 0.54 for allele 40 and 0.46 for allele 0. Holman Creek, a tributary to Nebo Creek, maintained cutthroat alleles at 0.85 (allele 40) and 0.15 (allele 0) for the SDH-1 locus. Fifth Water Creek cutthroat populations expressed frequencies of 0.50 for both the 40 and 0 locations of SDH-1. No stocking records existed for Holman and Fifth Water Creek. Tie Fork Creek, a tributary to Holman Creek, was dry and not inhabited by trout. Indian Creek, a tributary to the Spanish Fork River, was sampled but lacked fish. Four streams to the east of Mona Reservoir that were also checked and lacked cutthroat were Bear Canyon Creek, North Creek, Willow Creek and Mendenhall Creek.

Two of the three streams sampled in the Sevier River drainage contained no indication of hybridization with rainbows. The North Fork of North Creek and Deep Creek had SDH-1 allele 0 in 100 percent of the samples. The SDH-1 locus at allele 0 in the Bonneville Basin is considered typical for the Snake Valley Bonneville cutthroat. Records from the Utah Division of Wildlife Resources indicated that cutthroat were not planted in the North Fork of North Creek. The Deep Creek waters eventually run into the East Fork of the Sevier River which has been stocked with cutthroat trout. Hy Hunt Creek contained cutthroat alleles (LGG and ME) that indicated hybridization with rainbow trout. Twelve of the 25 trout collected from Hy Hunt Creek contained rainbow alleles. Their allelic frequencies for ME were 0.86 and 125 and 0.14 at 100 and their frequencies for LGG were 0.80 at 160 and 0.20 at 100. This is indicative of cutthroat x rainbow hybrids in F_1 and backcross generations. Heterozygosity occurred at SDH-1 for alleles 40 and 0 with frequencies of 0.20 and 0.80 respectively.

A method of illustrating complex taxonomic relationships can be found in the method of numerical taxonomy (Sneath and Sokal 1973). This method is commonly known as cluster analysis and has the advantage of being quantitative in application, thus eliminating much of the investigator induced bias. To use this technique a similarity index must be employed and a matrix of all pairwise similarities (identities) can then be clustered. A matrix of normalized genetic identity and distance values (Table 3) for all pairwise comparisons of the 31 populations of cutthroat trout sampled was calculated by using Nei's (1972) index. The genetic identity index is an estimate of the proportion of sampled alleles which are electrophoretically identical between pairs of populations. Genetic distance is a measure of the accumulated allele differences per locus between two populations.

A cluster dendogram of Nei's identity matrix depicting genetic relationships between populations is presented in Figure 5. Three distinct clusters were apparent. The first was distinct at the genetic identity level of 0.988 and contained Kabell, Mill, Fifth Water, Nebo, Wanrhodes, Little Diamond and Muddy Creeks and Strawberry River above Strawberry Reservoir. The second was distinct at the genetic identity level of 0.970 and contained Thompson, Deep, the North Fork of North Creek, and the Middle and West Forks of Beaver, Brush, Moffit, Joulious, Greetsen, and Middle Fork of Blacks, Red Pine and Hy Hunt Creeks and the North Fork of American Fork River. The third cluster was distinct at the genetic identity level of 0.893 and contained Mckenzie, Carter, Sugarpine, the Left Fork of Hobble, Chase, Shinglemill and Bunchgrass Creeks. The first cluster included a mixture of streams represented by Bear River Bonneville, Colorado River, Snake Valley Bonneville and Yellowstone cutthroat trout. Their alleles exhibited a high degree of both rainbow hybridization and heterozygosity within cutthroat strains as determined by SDH-1 (40) and (0). The second cluster contained streams with Snake Valley Bonneville and Colorado River cutthroat that had frequencies of the SDH-1 (0) allele. The third cluster included streams containing populations of either Yellowstone or Bear River Bonneville cutthroat trout. A high degree of homozygosity in SDH-1 at position 40 was dominant in this group. However, some heterozygosity existed with allele SDH-1 (0). A close genetic relationship between the Bear River drainage cutthroat populations and _S_. _c_. _bouvieri_ was evidenced by the cluster. Also, a high genetic identity was implied between Snake Valley _S_. _c_. _utah_ and _S_. _c_. _pleuriticus_ because of the clustering of the Colorado River streams with the Snake Valley Bonneville streams. This same relationship can be seen by comparing the similarities of cutthroat populations between the various drainages.

Nei's genetic identity estimates were used to demonstrate the mean genetic identity between populations within our designated subspecies (diagonal, Table 5) and contrast it to the mean genetic identity between populations from different subspecies (off diagonal, Table 5). Subspecies were designated by the drainage locations of populations and by electrophoretic findings. Populations within individual subspecies had high average genetic identities ranging from 0.9852 to 0.9808. Mean genetic identity between the combined Bear River drainage populations and the combined Snake Valley populations was only 0.9004, while the average genetic identity between the Snake Valley and the Colorado River drainage populations was 0.9847. The average identity between populations of Bear River Bonneville, Yellowstone and Snake Valley Bonneville was 0.9083. The Colorado River cutthroat had an average genetic identity of 0.8948 with the Yellowstone and Bear River Bonneville cutthroat subspecies.

Conclusions

Thirty-nine streams were examined for cutthroat trout. Eight streams, Durfee Creek in the Ogden River drainage, Silver Creek in the American Fork River drainage, Indian Creek and Tie Fork in the Spanish Fork drainage, and Mendenhall Creek, North Creek, Bear Canyon Creek and Willow Creek all above Mona Reservoir (Utah County) lacked cutthroat populations. Of the 31 streams containing cutthroat populations, hybridization with rainbow trout was evident in 7. These were Thompson Creek (ME: 0.03, Colorado River drainage), Mill Creek (LGG: 0.05, Bear River drainage), Boundary Creek (LGG: 0.32, Bear River drainage), Bunchgrass Creek (ME: 0.03, Logan River drainage), Wanrhodes Creek (ME: 0.09, Spanish Fork River drainage), Nebo Creek (LGG: 0.13, Spanish Fork River drainage) and Hy Hunt Creek (LGG: 0.20, Sevier River drainage). The remaining 24 streams contained cutthroat trout populations which showed no electrophoretical evidence of rainbow hybridization. Based on SDH-1 allelic frequency, drainage location and cluster analysis, we divided the cutthroat populations into several categories. The first major category contains populations classified as "pure". These were defined by lacking rainbow hybridization and showing complete or nearly complete (0.90) homozygous conditions with an SDH-1 allele. These pure populations were further subdivided depending upon which SDH-1 allele dominated. A dominance of SDH-1 (0) characterized the Colorado River cutthroat and the Snake Valley form of Bonneville cutthroat. A dominance of SDH-1 (40) is indicative of either Yellowstone or Bear River Bonneville populations. A final subdivision of pairs is dependent upon the drainage from which the population was sampled. The "pure" populations in the Colorado River system were in the West Fork of the Beaver River, the Middle Fork of the Beaver River and Brush Creek. All 3 streams are located in the Wasatch Forest on the north slope of the Uinta mountains. Populations which are pure Snake Valley type Bonneville were found in Deep Creek (Sevier River drainage near Antimony, Utah), North Fork of North Creek, (Sevier River drainage near Beaver, Utah) and Moffit Creek in the Weber River drainage. These populations showed complete (100 percent) homozygosity for SDH-1 (40) and were considered pure for either the Bear River form of the Bonneville cutthroat or the Yellowstone cutthroat. Populations in the

Bear River drainage fitting these criteria were found in Mckenzie, Carter, Meadow and Sugarpine Creeks. Two additional homozygous populations of cutthroat (at SDH-1 (40)) were found in Chase Creek, Spanish Fork drainage and the Left Fork of Hobble Creek, Hobble Creek drainage. Only 4 trout were sampled from the Chase Creek population so their status is questionable. These 2 populations, if truely homozygous for SDH-1 (40), are either Bear River Bonneville (native) or Yellowstone cutthroat (stocked) but there are no data on their origin.

The final group of trout have intermediate allelic frequencies (frequencies ranging from 0.11 to 0.89). The populations could also have been influenced from stocking, genetic drift, natural selection and natural variation related to the original invasion paths of trout into the Utah vicinity. In the Colorado River drainage the Strawberry River population showed a high degree of heterozygosity and was most likely influenced by stocking. Strawberry River is a major source of eggs for stocking operations and our purpose of examining it was to assess the variation in the stocked fish.

The remaining streams that showed heterozygosity in SDH-1 may have done so for a number of reasons, but the cause is uncertain. We can divide these streams into those dominated by the SDH-1 (0) allele and those dominated by the SDH-1 (40) allele. The SDH-1 (0) allele was dominant in the following streams: Joulious Creek (0.82, Colorado River draiange), the Middle Fork of Blacks Creek (0.88, Colorado River drainage), Greetsen Creek (0.83, Ogden River drainage), Red Pine Creek (0.75, Weber River draiange), North Fork of the American Fork River (0.75, American Fork River drainage), Wanrhodes Creek (0.64, Spanish

Fork River drainage), Little Diamond Creek (0.65, Spanish Fork River drainage) and Muddy Creek (0.60, Colorado River drainage). The SDH-1 (40) allele was most frequent in the following streams: Kabell Creek (0.63, Colorado River drainage), Mill Creek (0.55, Bear River drainage), Shinglemill Creek (0.97, Spanish Fork River drainage), Fifth Water Creek (0.50, Spanish Fork River drainage), Holman Creek (0.58, Spanish Fork River drainage) and Nebo Creek (0.54, Spanish Fork River drainage).

The differences seen in the SDH-1 alleles along the Wasatch front are difficult to interpret, but the pattern is more definite if one includes Loudenslager and Gall's (1980a,b 1981) data in this overview. One factor is that homozygous populations occur at the extremes of the range of the Bonneville. This may be a function of the relict populations being found in streams isolated from man. Most native populations extremes of the Bonneville cutthroat are extinct. Importantly, the type location for the Bonneville cutthroat is Utah Lake and the species is no longer extant there. The degree of hybridization with non-native cutthroat in surrounding drainages is unknown. These factors make interpretation of the uniqueness of the heterozygous cutthroat populations difficult. Should the type species be heterozygous for SDH-1 (both 0 and 40), if so, how much? Or should it be homozygous for SDH-1? If so, which allele, SDH-1 (0) or SDH-1 (40)? These questions may be more easily understood if one considers the current hypothesis existing concerning the origins and differentiation of the various cutthroat strains native to Utah.

During the Pleistocene repeated glaciation and volcanic activity impacted the invasions of cutthroat trout from costal tributaries to interior drainages. The hypothesized movement of an ancestral cutthroat trout from the Columbia River system to the upper Snake River is described by Roscoe (1974). During the Pleistocene (between 60,000 to 30,000 years BP) lava flows blocked the upper Snake River drainage creating Shoshone Falls (Malde 1965). This isolated the headwaters of the Snake River from the remainder of the Columbia drainage and prevented any further invasions of fish (May, Leppink and Wydoski 1978). The Yellowstone, Bonneville and Colorado River cutthroat subspecies were subsequently derived from the "*S. c. bouvieri* like" ancestor in the upper Snake River (Behnke 1980a; Loudenslager and Gall 1981).

Whether *S. c. pleuriticus* and *S. c. utah* differentiated from a single, common invasion of a Yellowstone ancestor within either the Bonneville Basin or Colorado drainage, or from two separate invasions within their respective water sheds is not clear. Behnke (1980a, 1981) discussed a major land disturbance that he believes was responsible for the initial cutthroat invasion into the Bonneville Basin. He hypothesized that the Bear River fish species transferred into the Bonneville Basin (35,000 to 20,000 years BP) when volcanic activity diverted the course of the Bear River (then a tributary to the upper Snake River) into the Bonneville Basin (Malde 1965). Prior to this no cutthroat trout existed in Lake Bonneville, The size of Lake Bonneville was enlarged by the expanded flow of water from the Bear River. The highest level of Lake Bonneville (5,135 feet during the Bonneville level) is represented by the highest prominent bench mark along the Wasatch Front (Bissell 1968).

Sometime between 30,000 (Malde 1968) and 18,000 (Broecker and Kaufman, 1965) years BP the lake subsequently overlfowed at its northeastern tip becoming connected to Snake River at Red Rock Pass, Cache Valley, Idaho (Wright and Frey 1965, Fig. 2). The drainage of Lake Bonneville dropped the lake to 4,800 feet in less than one year to the Provo level (Bissell 1968). Behnke (1981) argues that when the lake levels declined it provided the mechanism for isolation and "incipient" divergence of Snake Valley and Bear River forms of the Bonneville cutthroat trout. He contended that the original trout in Lake Bonneville diverged as its populations were subject to differential isolation and different selective pressures in their remaining habitat. Thus, he proposed that the Bonneville existed with at least two additional forms, the Snake Valley and the Bear River, both of which have shown this incipient divergence. Behnke (1980a) hypothesized that the Colorado River cutthroat had a separate line of invasion into the Colorado River system from the Snake River.

Loudenslager and Gall (1981) postulated that prior to the invasion of the cutthroat from the Bear River system into the Bonneville Basin an exchange of trout between the Bonneville Basin and Colorado River drainages took place. They believed the ancestral Yellowstone cutthroat gained access to the southern (Bonneville and Colorado) drainages either by a transfer from the upper Snake River to the Bonneville Basin or from the upper Snake River to the upper Green River (Colorado River drainage), Wyoming. Subsequently, the trout in either the Colorado or Bonneville drainage invaded the other. Subsequent isolation established the Bonneville and Colorado cutthroat strains.

This explained the close genetic similarity of the Snake Valley Bonneville with the Colorado cutthroat based on SDH-1 alleles. When the Bear River was diverted into the Bonneville Basin (35,000 years BP) the Yellowstone cutthroat trout in the Bear River invaded. This new invasion of Yellowstone cutthroat explains the close electrophoretic similarity between the Yellowstone and Bear River form of the Bonneville.

If we consider only "pure" populations, the Deep Creek and North Fork of North Creek Bonneville populations have the SDH-1 system identical to those found in the Deep Creek range of western Utah. This is also true of the Moffit Creek population (upper Weber River drainage). Such data tends to support the hypothesis of Loudenslager and Gall (1980b, 1981) since the SDH-1 (0) allele is found in more of the Bonneville Basin. Likewise, the similarity of our Colorado River cutthroat samples with those described by Loudenslager and Gall also supports their hypothesis. More importantly, the second invasion of the Bonneville Basin some 30,000 years BP should result in the inflow of SDH-1 (40) alleles into the resident native Bonneville (SDH-1 (0)) population. This invasion would be expected to increase heterozygosity nearer the source of the invading fish. If this spreading of the SDH-1 (40) allele (i.e. hybridization) was sufficiently slow, populations at the extremes of the basin may have been isolated before any significant level of SDH-1 (40) had built up in them. This implies that the type species in Utah Lake could reasonably have shown the heterozygous condition and the mechanism of Loudenslager and Gall is feasible. The left Fork of Hobble Creek and Chase Creek do represent foci of Bear

River/Yellowstone alleles in the headwaters of the Hobble Creek and Diamond Fork drainages. Other populations in that region also show high SDH-1 (40) frequencies. These fish appear (by spotting patterns) to be Yellowstone cutthroat and as such we will consider the status of the populations to be the result of stocking operations by man. Further studies of the fish need to be conducted before conclusions can be made. For example, more suspected relict populations need to be examined using electrophoretic techniques. Also, morphological studies should be conducted on them to determine their classification according to the criteria of Behnke (1980a, 1981). Once such studies are completed, the importance of many of the heterozygote populations will be better understood.

We recommend special management consideration be given all streams containing cutthroat trout which have not hybridized with rainbow. We recommend that no stocking of any Salmonids that could hybridize with or out compete the resident population be allowed. Land use decisions should take all non-hybridized cutthroat streams into account. Those populations which we designated as pure should receive top priority in management decisions. These populations represent known uniqueness, and as such should be carefully managed.

Literature Cited

BEHNKE, R. J. 1965. A systematic study of the family Salmonidae with special reference to the genus Salmo. Unpublished Ph.D. thesis, Univ. of California, Berkeley.

_____. 1972. The systematics of Salmonid fishes in recently glaciated lakes. J. Fish. Res. Bd. Can. 29:639-671.

_____. 1976. Summary of information on the status of the Utah or Bonneville Basin cutthroat trout, S. c. utah. Prepared for Wasatch Nat. For., Salt Lake City, Ut. Colorado St. Univ., Ft. Collins. 14 pp.

_____. 1980a. Monograph of the native trouts of the genus Salmo of Western North America. Prepared for USDA, Forest Service, Fish and Wildlife Service and Bureau of Land Management. 163 pp.

_____. 1980b. Purity evaluation of Bear River cutthroat trout from Mill and Carter Creeks, Wasatch National Forest, Summit County, Utah. Prepared for Wasatch Nat. For., Salt Lake City, Ut. Colorado St. Univ., Ft. Collins. 10 pp.

_____. 1981. Systematic and zoogeographical interpretation of Great Basin trouts. p. 255-262. In: R. J. Naiman and D. L. Soltz (eds.). Biology of fishes of the great american desert. John Wiley Pub., New York, N.Y. 552 pp.

BEHNKE, R. J., and M. ZARN. 1976. Biology and management of threatened and endangered western trouts. USDA For. Serv. Gen. Tech. Rep. RM-28, Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colorado. 45 pp.

BISSELL, H. J. 1968. Bonneville--an ice age lake. Brigham Young Univ. Geol. Studies, v. 15, part 4. 65 pp.

BROECKER, W. S., and A. KAUFMAN. 1965. Radio carbon chronology of Lake Lahontan and Lake Bonneville, II. Great Basin Bull. Geol. Soc. Amer. 76:537-566.

DUFF, D., and T. J. HICKMAN. 1979. Bonneville cutthroat trout: A summary of current status and management. Prepared for U.S. BLM, Salt Lake City, Ut. Colorado State Univ., Ft. Collins. 20 pp.

GILBERT, G. K. 1890. Lake Bonneville Monograph for the U.S. Geol. Surv. 438 pp.

HECKMANN, R. A., THOMPSON, C. W., and D. A. WHITE. 1901. Fishes of Utah Lake. Great Basin Nat. Mem. 5:107-127.

HICKMAN, T. J. 1977. Studies on relic populations of Snake Valley cutthroat trout in western Utah. Prepared for U.S. BLM, Salt Lake City, Ut. Colorado State Univ., Ft. Collins. 41 pp.

_____. 1978. Systematic study of the native trout of the Bonneville Basin. Unpublished M.S. thesis, Colorado St. Univ., Fort Collins. 122 pp.

HOLDEN, P. B., W. WHITE, G. SUMMERVILLE, D. DUFF, R. GERVAIS, and S. GLOSS. 1974. Threatened fishes of Utah. Proc. Utah Acad. Sci., Arts, Letters 51(2):46-55.

HUBBS, C. L., and R. R. MILLER. 1948. The zoological evidence, correlation between fish distribution and hydrographic history in the desert basins of western U. S. Univ. Utah Bull. 38(20):17-166.

JORDAN, D. S. 1894. How the trout came to California. Recreation 1:5-11.

LOUDENSLAGER, E. J., and G. A. E. GALL. 1980a. Geographic patterns of protein variation and subspeciation in cutthroat trout, Salmo clarki. Systematic Zoology 29:27-42.

_____. 1980b. Biochemical systematics of the Bonneville Basin and Colorado River cutthroat trout. Prepared for Wyoming Dept. of Game and Fish. Univ. of California, Davis. 16 pp.

_____. 1980c. Hybridization between cutthroat and rainbow trout: Evidence from Biochemical Genetic Loci. Univ. of California, Davis. 5 pp.

_____. 1981. Cutthroat trout: A biochemical genetic assessment of their status and systematics. Univ. of California, Davis. 89 pp.

MALDE, H. E. 1965. Snake River plains. p. 255-262. In: H. E. Wright and D. G. Frey (eds.). The quarternary of the United States. Princeton Univ. Press, Princeton, N.J. 922 pp.

_____. 1968. The catostrophic late pleistocene Bonneville flood in the Snake River Plain, Idaho. U.S. Geol. Surv. Prof. Pap. 596. 52 pp.

MAY, B. E., J. D. LEPPINK, and R. S. WYDOSKI. 1978. Distribution, systematics and biology of the Bonneville cutthroat trout. Salmo clarki utah. Utah Div. Wildlf. Res. Publ. No. 78-15. 24 pp.

MILLER, R. R. 1950. Notes on the cutthroat and rainbow trout with the description of a new species from the Gila River, New Mexico. Occas Pap. Mis. Zool. Univ. Michigan 529. 42 pp.

_____. 1972. Classification of the native trouts of Arizona with the description of a new species, Salmo apache. Copeia 3:401-422.

NEI, M. 1972. Genetic distance between population. Amer. Natur. 106:283-292.

ROSCOE, J. W. 1974. Systematics of the Westslope cutthroat trout. M.S. Thesis, Colorado State Univ., Ft. Collins. 72 pp.

SIGLER, W. F., and R. R. MILLER. 1963. Fishes of Utah. Utah Dept. of Fish and Game. Salt Lake City, Utah. 203 pp.

SNEATH, P. H. A., and R. R. SOKAL. 1973. Numerical Taxonomy. W. H. Freeman Co., San Francisco, California. 573 pp.

TANNER, V. M., and S. P. HAYES. 1933. The genus Salmo in Utah. Proc. Utah Acad. Sci., Arts, Letters 10:163-164.

WRIGHT, H. E., and D. G. FREY. 1965. The quarternary of the United States. Princeton Univ. Press. 922 pp.

WYDOSKI, R. S., G. KLAR, T. FARLEY, J. BRAMAN, Y. KAO, and C. STALNAKER. 1976. Genetic biochemical and physiological studies of trout enzymes. NMFS Final Report. Prog. No. 1-87R. 163 pp.

TABLE 1. Localities, numbers and status of trout collected in Utah.

Sample no.	Sample site	Trout present[a]	No. indiv.	Status[b]
1.	Kabell Creek	Y-BRG, CR	4	2
2.	Thompson Creek	CR	16	3
3.	M. Fk. Beaver Creek	CR	9	1
4.	W. Fk. Beaver Creek	CR	20	1
5.	Joulious Creek	Y-BRG, CR	17	3
6.	M. Fk. Blacks Creek	Y-BRG, CR	24	2
7.	Brush Creek	SVB	22	1
8.	Mckenzie	Y-BRB	12	1
9.	Mill Creek	SVB, Y-BRB, R	22	2,3
10.	Carter Creek	Y-BRB	17	1
11.	Boundary Creek	Y-BRB, R	20	3
12.	Meadow Creek	Y-BRB	19	2
13.	Moffit Creek	SVB, Y-BRB	18	1
14.	Sugarpine Creek	Y-BRB	19	1
15.	Bunchgrass Creek	Y-BRB	19	3
16.	Durfee Creek		0	
17.	Greetsen Creek	SVB, Y-BRB	3	2
18.	Red Pine Creek	SVB, Y-BRB	18	2
19.	N. Fk. American Fk. River	SVB, Y-BRB	5	2
20.	Silver Creek	EB	5	
21.	L. Fk. Hobble Creek	Y-BRB	21	1
22.	Strawberry River	Y-BRB, CR	60	2
23.	Shinglemill Creek	Y-BRB	16	2
24.	Chase Creek	Y-BRB	4	1
25.	Fifth Water Creek	SVB, Y-BRB	11	2
26.	Indian Creek		0	
27.	Wanrhodes	SVB, Y-BRB, R	11	3
28.	Little Diamond Creek	SVB, Y-BRB	17	2
29.	Tie Fork Creek		0	
30.	Holman Creek	Y-BRB	27	2
31.	Nebo Creek	SVB, Y-BRB, R	23	2,3
32.	Mendenhall Creek		0	
33.	North Creek		0	
34.	Bear Canyon Creek		0	
35.	Willow Creek		0	
36.	Muddy Creek	Y-BRB, CR	5	2
37.	Deep Creek	SVB	16	1
38.	Hy Hunt Creek	SVB, R	25	3
39.	N. Fk. North Creek	SVB	30	1

[a] Snake Valley Bonneville = SVB, Yellowstone or Bear River Bonneville = Y-BRB, Colorado River = CR, Rainbow = R, Eastern Brook = EB

[b] 1 = Pure: based on 90% or higher frequency of a single allele
2 = Heterozygous: allelic frequency between 11 and 89%
3 = Hybridized: rainbow x cutthroat cross

TABLE 2. Allelic frequencies for 31 trout populations of 6 loci.

		Streams							
Locus		Kabell	Thompson	M. Fk. Beaver	W. Fk. Beaver	Joulious	M. Fk. Blacks	Brush	Mckenzie
SDH-1	100	----	----	----	----	----	----	----	----
	40	0.63	----	0.05	0.02	0.18	0.12	0.02	1.00
	0	0.37	1.00	0.95	0.98	0.82	0.88	0.98	----
SDH-2	250	----	----	----	----	----	----	----	----
	100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
IDH-3	170	----	----	----	----	----	-----	----	----
	100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	60	----	----	----	----	----	----	----	----
IDH-4	140	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LGG	160	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	100	----	----	----	----	----	----	----	----
ME	125	1.00	0.97	1.00	1.00	1.00	1.00	1.00	1.00
	100	----	0.03	----	----	----	----	----	----

TABLE 2. Continued.

		Streams								
Locus		Mill	Carter	Boundary	Meadow	Moffit	Sugarpine	Bunchgrass	Greetsen	Red Pine
SDH-1	100	----	----	----	----	----	----	----	----	----
	40	0.55	1.00	1.00	1.00	0.03	1.00	1.00	0.17	0.25
	0	0.45	----	----	----	0.97	----	----	0.83	0.75
SDH-2	250	----	----	----	0.13	----	----	----	----	----
	100	1.00	1.00	1.00	0.87	1.00	1.00	1.00	1.00	1.00
IDH-3	170	----	0000	0.11	0.03	0.08	----	----	----	----
	100	1.00	1.00	0.89	0.97	0.92	1.00	0.97	1.00	1.00
	60	----	----	----	----	----	----	0.03	----	----
IDH-4	140	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LGG	160	0.95	1.00	0.68	1.00	1.00	1.00	1.00	1.00	1.00
	100	0.05	----	0.32	----	----	----	----	----	----
ME	125	1.00	1.00	0.75	1.00	1.00	1.00	0.97	1.00	1.00
	100	----	----	0.25	----	----	----	0.03	----	----

TABLE 2. Continued.

Locus		N. Fk. Am. Fk.	L. Fk. Hobble	Strawberry	Shinglemill	Chase	Fifth Water	Wanrhodes	Little Diamond	Holman
		Streams								
SDH-1	100	----	----	----	----	----	----	----	----	----
	40	0.25	1.00	0.50	0.97	1.00	0.50	0.36	0.35	0.85
	0	0.75	----	0.50	0.03	----	0.50	0.64	0.65	0.15
SDH-2	250	----	----	----	----	----	----	----	----	----
	100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
IDH-3	170	----	----	0.01	----	----	----	----	----	----
	100	1.00	1.00	0.99	1.00	1.00	1.00	0.95	1.00	1.00
	60	----	----	----	----	----	----	0.05	----	----
IDH-4	140	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LGG	160	1.00	1.00	1.00	1.00	1.00	1.00	0.91	1.00	1.00
	100	----	----	----	----	----	----	0.09	----	----
ME	125	1.00	1.00	1.00	1.00	1.00	1.00	0.91	1.00	1.00
	100	----	----	----	----	----	----	0.09	----	----

TABLE 2 Continued.

		Streams				
Locus		Nebo	Muddy	Deep	Hy Hunt	N. Fk. North
SDH-1	100	----	----	----	----	----
	40	0.54	0.40	----	0.20	----
	0	0.46	0.60	1.00	0.80	1.00
SDH-2	250	----	----	----	----	----
	100	1.00	1.00	1.00	1.00	1.00
IDH-3	170	----	----	----	0.04	----
	100	1.00	1.00	1.00	0.96	1.00
	60	----	----	----	----	----
IDH-4	140	1.00	1.00	1.00	1.00	1.00
LGG	160	0.87	1.00	1.00	1.80	1.00
	100	0.13	----	----	0.20	----
ME	125	0.91	1.00	1.00	0.86	1.00
	100	0.09	----	----	0.14	----

TABLE 3. Matrix of Nei's (1972) genetic identity (above) and genetic distance (below) for 31 cutthroat trout populations.

Stream	No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Kabell	1	--	.9313	.9417	.9359	.9641	.9543	.9359	.9771	.9984	.9771	.9416	.9726	.9356	.9971	.9762
Thompson	2	.0712	--	.9994	.9998	.9945	.9975	.9998	.8324	.9471	.8324	.7903	.8254	.9987	.8324	.8307
M.Fk.Beaver	3	.0601	.0006	--	.9999	.9972	.9992	.9999	.8484	.9563	.8484	.8047	.8417	.9989	.8484	.8466
W.Fk.Beaver	4	.0662	.0002	.0001	--	.9959	.9984	1.000	.8394	.9513	.8394	.7955	.8326	.9990	.8394	.8375
Joulious	5	.0366	.0055	.0028	.0042	--	.9994	.9959	.8854	.9753	.8854	.8431	.8791	.9950	.8854	.8837
M.Fk.Blacks	6	.0468	.0025	.0008	.0016	.0006	--	.9984	.8688	.9671	.8688	.8258	.8623	.9975	.8688	.8670
Brush	7	.0662	.0002	.0001	.0000	.0042	.0016	--	.8394	.9513	.8394	.7955	.8326	.9990	.8394	.8375
McKenzie	8	.0732	.1835	.1644	.1751	.1217	.1407	.1751	--	.9654	1.000	.9719	.9973	.8395	1.000	.9997
Hill	9	.0016	.0543	.0447	.0500	.0251	.0335	.0500	.0353	--	.9654	.9335	.9603	.9507	.9654	.9642
Carter	10	.0232	.1835	.1644	.1751	.1217	.1407	.1751	.0000	.0353	--	.9719	.9973	.8395	1.000	.9997
Boundary	11	.0602	.2353	.2173	.2288	.1707	.1914	.2288	.0285	.0689	.0285	--	.9671	.7970	.9719	.9738
Meadow	12	.0278	.1919	.1723	.1832	.1288	.1482	.1832	.0027	.0405	.0027	.0335	--	.8332	.9973	.9969
Moffit	13	.0666	.0013	.0011	.0010	.0050	.0025	.0010	.1750	.0506	.1750	.2269	.1825	--	.8395	.8379
Sugarpine	14	.0232	.1835	.1644	.1751	.1217	.1407	.1751	.0000	.0353	.0000	.0285	.0027	.1750	--	.9997
Bunchgrass	15	.0241	.1855	.1665	.1773	.1236	.1427	.1773	.0003	.0364	.0003	.0266	.0031	.1769	.0003	--
Greetsen	17	.0382	.0049	.0024	.0036	.0000	.0004	.0036	.1248	.0264	.1248	.1741	.1320	.0045	.1248	.1267
Red Pine	18	.0262	.0106	.0067	.0088	.0008	.0029	.0088	.1013	.0167	.1013	.1482	.1079	.0095	.1013	.1030
N.Fk.Am. Fk.	19	.0262	.0106	.0067	.0088	.0008	.0029	.0088	.1013	.1067	.1013	.1482	.1079	.0095	.1013	.1030
L.Fk.Hobble	21	.0232	.1835	.1644	.1751	.1217	.1407	.1751	.0000	.0353	.0000	.0285	.0027	.1750	.0000	.0003
Strawberry	22	.0031	.0441	.0355	.0402	.0183	.0256	.0402	.0435	.0009	.0435	.0835	.0487	.0405	.0435	.0447
Shinglemill	23	.0197	.1726	.1542	.1645	.1132	.1314	.1645	.0001	.0309	.0001	.0293	.0030	.1644	.0001	.0004
Chase	24	.0232	.1835	.1644	.1751	.1217	.1407	.1751	.0000	.0353	.0000	.0285	.0027	.1750	.0000	.0003
Fifth Water	25	.0031	.0441	.0355	.0402	.0183	.0256	.0402	.0435	.0009	.0435	.0837	.0487	.0407	.0435	.0447
Wanrhodes	27	.0166	.0236	.0185	.0216	.0080	.0122	.0216	.0770	.0088	.0770	.1035	.0841	.0222	.0770	.0773
Lt.* Diamond	28	.0143	.0211	.0154	.0185	.0051	.0091	.0185	.0752	.0077	.0752	.1194	.0813	.0191	.0752	.0767
Holman	30	.0084	.1320	.1163	.1251	.0817	.0970	.1251	.0036	.0163	.0036	.0354	.0071	.1252	.0036	.0041
Nebo	31	.0055	.0553	.0467	.0519	.0275	.0357	.0519	.0403	.0024	.0403	.0581	.0466	.0530	.0403	.0408
Muddy	36	.0096	.0278	.0211	.0247	.0085	.0137	.0247	.0637	.0045	.0637	.1065	.0695	.0254	.0637	.0650
Deep	37	.0705	.0001	.0004	.0001	.0052	.0023	.0001	.1823	.0536	.1823	.2367	.1906	.0011	.1823	.1846
Hy Hunt	38	.0466	.0138	.0123	.0137	.0096	.0102	.0137	.1320	.0317	.1320	.1436	.1410	.0144	.1320	.1328
N. Fk. North	39	.0705	.0001	.0004	.0001	.0052	.0023	.0001	.1823	.0536	.1823	.2367	.1906	.0011	.1823	.1846

Stream	No.	17	18	19	21	22	23	24	25	27	28	30	31	36	37	38	39
Kabell	1	.9625	.9742	.9742	.9771	.9969	.9805	.9971	.9969	.9836	.9858	.9916	.9946	.9904	.9319	.9545	.9319
Thompson	2	.9951	.9894	.9894	.8324	.9568	.8415	.8324	.9569	.9767	.9791	.8763	.9462	.9726	.9999	.9863	.9999
M.Fk.Beaver	3	.9977	.9934	.9934	.8484	.9651	.8571	.8484	.9651	.9817	.9848	.8902	.9543	.9791	.9996	.9878	.9996
W.Fk.Beaver	4	.9964	.9913	.9913	.8394	.9606	.8484	.8394	.9606	.9786	.9817	.8824	.9494	.9756	.9999	.9864	.9999
Joulious	5	1.000	.9992	.9992	.8854	.9819	.8930	.8854	.9819	.9920	.9950	.9216	.9729	.9915	.9948	.9904	.9948
M.Fk.Blacks	6	.9996	.9971	.9971	.8688	.9747	.8769	.8688	.9747	.9879	.9909	.9076	.9649	.9864	.9977	.9899	.9977
Brush	7	.9964	.9913	.9913	.8394	.9606	.8484	.8394	.9606	.9786	.9817	.8824	.9494	.9756	.9999	.9864	.9999
McKenzie	8	.8827	.9037	.9037	1.000	.9574	.9999	1.000	.9574	.9259	.9275	.9964	.9605	.9383	.8333	.8763	.8333
Hill	9	.9740	.9834	.9834	.9654	.9991	.9695	.9654	.9991	.9912	.9923	.9839	.9976	.9955	.9478	.9688	.9478
Carter	10	.8827	.9037	.9037	1.000	.9574	.9999	1.000	.9574	.9259	.9275	.9964	.9605	.9383	.8333	.8763	.8333
Boundary	11	.8402	.8622	.8622	.9719	.9199	.9711	.9719	.9197	.9017	.8874	.9652	.9436	.8990	.7892	.8662	.7892
Meadow	12	.8764	.8977	.8977	.9973	.9525	.9970	.9973	.9524	.9193	.9219	.9930	.9545	.9329	.8265	.8685	.8265
Moffit	13	.9955	.9905	.9905	.8395	.9603	.8484	.8395	.9601	.9781	.9810	.8824	.9484	.9750	.9989	.9857	.9989
Sugarpine	14	.8827	.9037	.9037	1.000	.9574	.9999	1.000	.9574	.9259	.9275	.9964	.9605	.9383	.8333	.8763	.8333
Bunchgrass	15	.8810	.9022	.9022	.9997	.9563	.9996	.9997	.9563	.9256	.9262	.9959	.9600	.9370	.8314	.8757	.8314
Greetsen	17	--	.9989	.9989	.8827	.9808	.8904	.8827	.9808	.9914	.9944	.9193	.9716	.9907	.9954	.9904	.9954
Red Pine	18	.0011	--	1.000	.9037	.9888	.9107	.9037	.9888	.9954	.9982	.9367	.9808	.9960	.9898	.9895	.9898
N.Fk.Am. Fk.	19	.0011	.0000	--	.9037	.9888	.9107	.9037	.9888	.9954	.9982	.9367	.9808	.9960	.9898	.9895	.9898
L.Fk.Hobble	21	.1248	.1013	.1013	--	.9574	.9999	1.000	.9574	.9259	.9275	.9964	.9605	.9383	.8333	.8763	.8333
Strawberry	22	.0194	.0113	.0113	.0435	--	.9621	.9574	1.000	.9934	.9959	.9784	.9956	.9982	.9574	.9722	.9574
Shinglemill	23	.1161	.0935	.0935	.0001	.0386	--	.9999	.9621	.9319	.9336	.9977	.9647	.9439	.8424	.8839	.8424
Chase	24	.1248	.1013	.1013	.0000	.0435	.0001	--	.9574	.9259	.9275	.9964	.9605	.9383	.8333	.8763	.8333
Fifth Water	25	.0194	.0112	.0112	.0435	.0000	.0386	.0435	--	.9934	.9959	.9784	.9956	.9982	.9574	.9722	.9574
Wanrhodes	27	.0086	.0046	.0046	.0770	.0066	.0705	.0770	.0066	--	.9973	.9539	.9929	.9969	.9764	.9917	.9764
Lt.* Diamond	28	.0057	.0018	.0018	.0752	.0041	.0687	.0752	.0041	.0027	--	.9559	.9893	.9996	.9795	.9853	.9795
Holman	30	.0841	.0654	.0654	.0036	.0218	.0023	.0036	.0218	.0472	.0451	--	.9794	.9642	.8772	.9123	.8772
Nebo	31	.0288	.0194	.0194	.0403	.0045	.0359	.0403	.0044	.0072	.0107	.0209	--	.9923	.9460	.9755	.9460
Muddy	36	.0093	.0040	.0040	.0637	.0018	.0577	.0637	.0018	.0031	.0004	.0364	.0077	--	.9731	.9818	.9731
Deep	37	.0047	.0103	.0103	.1823	.0435	.1715	.1823	.0435	.0239	.0207	.1310	.0555	.0273	--	.9854	1.000
Hy Hunt	38	.0096	.0105	.0105	.1320	.0282	.1234	.1320	.0282	.0083	.0148	.0918	.0248	.0181	.0147	--	.9854
N. Fk. North	39	.0047	.0103	.0103	.1823	.0435	.1715	.1823	.0435	.0239	.0207	.1310	.0555	.0273	.0000	.0147	--

*Little

TABLE 4. Stocking records for sampling sites and adjoining streams in Utah.

Drainage	Stream sample	*Status	Next highest order stream	*Status	Next highest order stream	*Status	Drainage basin	*Status
Colorado River	Thompson	5	Burnt Fork	5	Henrys Fork	5	Green	1,2
Colorado River	Joulious	5	Henrys Fork	1	Green River	1,2,3	Colorado	5
Colorado River	Kabell	5	Brunt Fork	5	Henrys Fork	5	Green	1,2
Colorado River	M. Fk. Blacks	5	Blacks Fork	5	Green	1,2,3	Colorado	5
Colorado River	Brush	5	Blacks	5	Green	1,2,3	Colorado	5
Colorado River	M. Fk. Beaver	5	Henrys Fork	5	Green	1,2,3	Colorado	5
Colorado River	W. Fk. Beaver	5	Beaver	1	Henrys Fork	5	Green	1,2
Colorado River	Muddy	5	Dirty Devil	5	Colorado	5		
Colorado River	Strawberry River	1,2	Strawberry Res	1,2,3				
Bear River	Bunchgrass	5	Logan	1,3	Bear	1		
Bear River	Boundary	5	E. Fk. Bear	1	Bear	1		
Bear River	Sugarpine	5	Woodruff	1,2	Bear	1		
Bear River	Meadow	5	W. Fk. Bear	5	Bear	1		
Bear River	Mckenzie	5	Mill	1	Bear	1		
Bear River	Mill	1	Bear	1				
Bear River	Carter	5	Mill	1	Bear	1		
Weber River	Moffit	5	Weber	1,2,3				
Weber River	Greetsen	2	Ogden	1,3	Weber	1,2,3		
Weber River	Red Pine	5	Smith Moorhouse	1	Weber	1,2,3		

TABLE 4 Continued.

Drainage	Stream sample	*Status	Next highest order stream	*Status	Next highest order stream	*Status	Drainage basin	*Status
American Fork River	N. Fk. Am. Fk.	1,2	American Fork	1,2				
Spanish Fork	Fifth Water	5	Diamond Fork	1	Spanish Fork	3		
Spanish Fork	Shinglemill	5	Diamond Fork	1	Sapnish Fork	3		
Spanish Fork	Little Diamond	5	Diamond Fork	1	Spanish Fork	3		
Spanish Fork	Wanrhodes	5	Diamond Fork	1	Spanish Fork	3		
Spanish Fork	Chase	5	Diamond Fork	1	Spanish Fork	3		
Spanish Fork	Nebo	1	Thistle	1	Spanish Fork	3		
Spanish Fork	Holman	5	Nebo	1	Thistle	1	Spanish Fork	3
Hobble Creek	L. Fk. Hobble	1	Hobble	5				
Sevier River	N. Fk. North	5	North	5	Beaver	1,3		
Sevier River	Deep	5	Current	5	E. FK. Sevier	1,2	Sevier	5
Sevier River	Hy Hunt	5	Lake Stream	5	Beaver	1,3		

*Planting record code: Rainbow = 1, Cutthroat = 2, Brown = 3, Brook = 4, Not stocked or no stocking record = 5

TABLE 5. Matrix of mean genetic identity among cutthroat trout populations within the Bonneville Basin, Bear River and Colorado River drainages. The number of streams in each population is in parenthesis and within subspecies population identity is on the diagonal.

	1	2	3	4
1. Snake Valley Bonneville (11) from the Bonneville Basin	.9852	.9004	.9847	.9194
2. Bear River Bonneville (7)+ from the Bear River Drainage		.9808	.8847	.9837
3. Colorado River Cutthroat (8) from the Colorado River Drainage			.9825	.9089
4. Yellowstone Cutthroat (5)* from the Bonneville Basin				.9846

+Samples taken within the Bear River Drainage may also contain Yellowstone cutthroat trout.

*Samples taken outside of the Bear River Drainage may also contain Bear River Bonneville.

Fig. 1. Ranges of the Snake Valley Bonneville (left), Bear River Bonneville (upper-middle) and Colorado River (right) cutthroat in Utah.

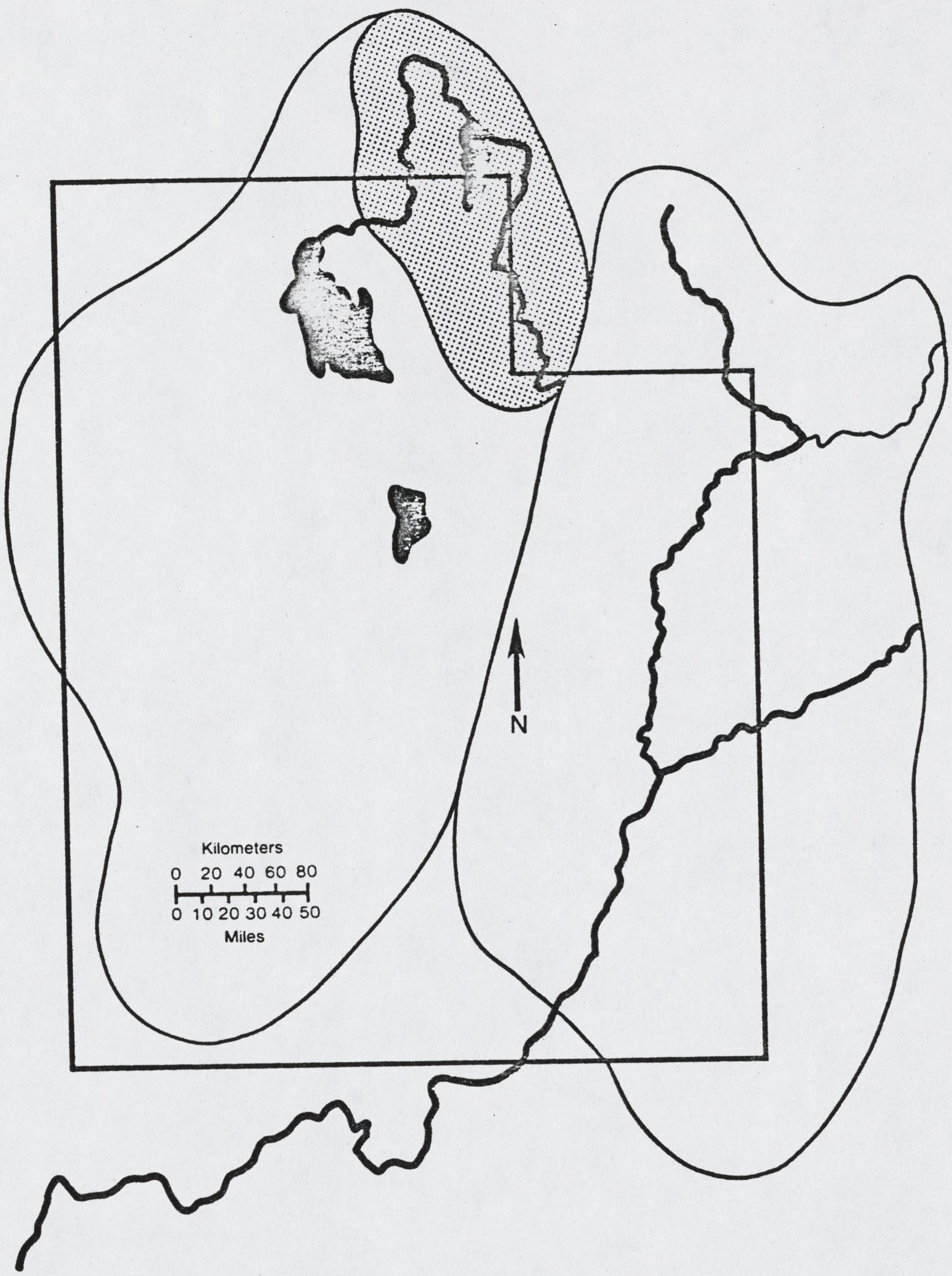
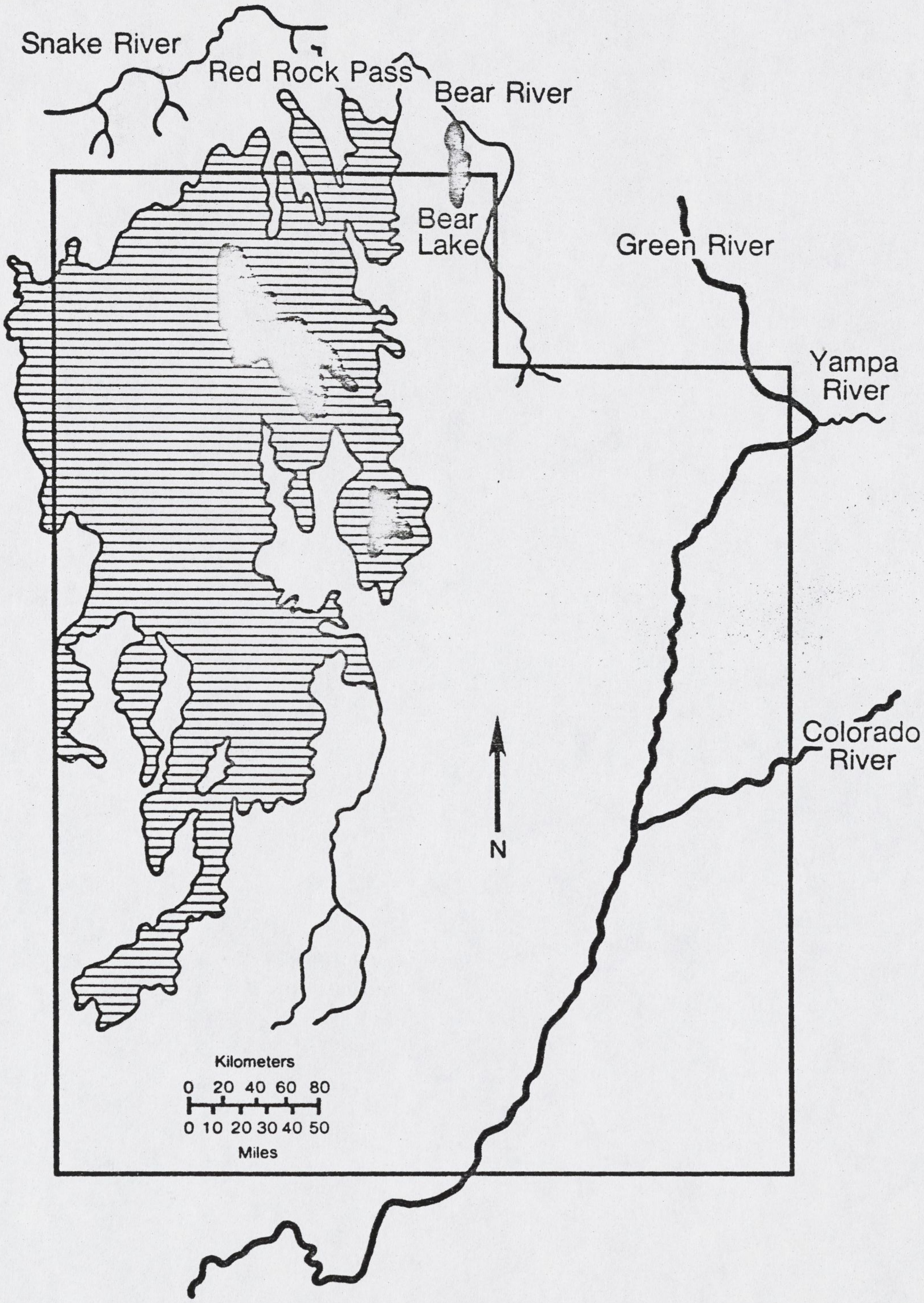
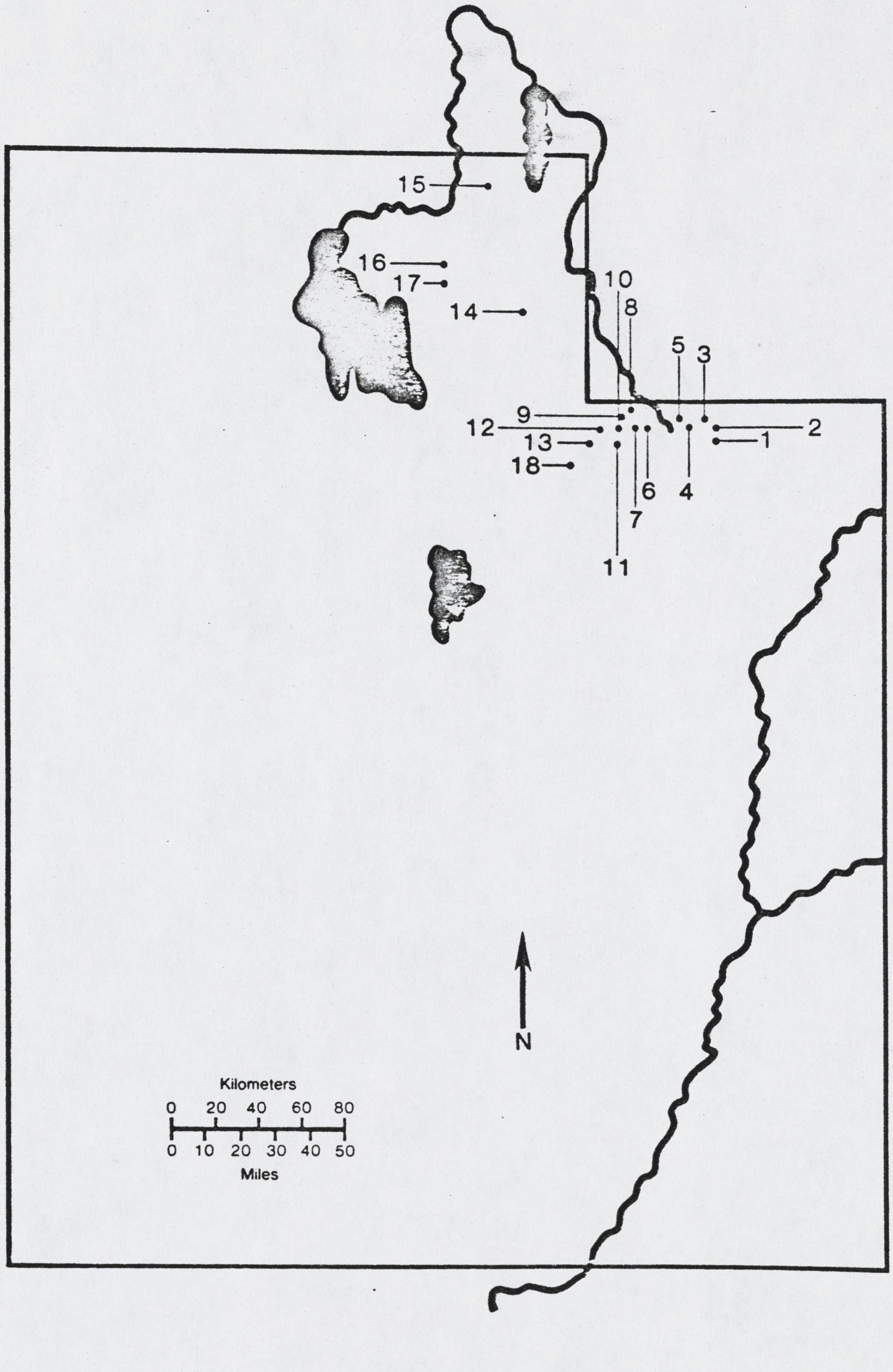

N
Kilometers
0 20 40 60 80
0 10 20 30 40 50
Miles

Fig. 2. Map of Lake Bonneville (adapted from Gilbert 1890).



Snake River
Red Rock Pass
Bear River
Bear
Lake
Green River
Yampa
River
Colorado
River
N
Kilometers
0 20 40 60 80
0 10 20 30 40 50
Miles

Fig. 3. Sampling sites from the Wasatch-Cache National Forest in Utah. Numbers refer to location listed in Table 1.



15
16
17
14
10
8
5
3
9
12
13
18
2
1
6
4
7
11
N
Kilometers
0 20 40 60 80
0 10 20 30 40 50
Miles

Fig. 4. Sampling sites from the Uinta, Manti LaSal and Fish Lake National Forests in Utah. Numbers refer to location listed in Table 1.

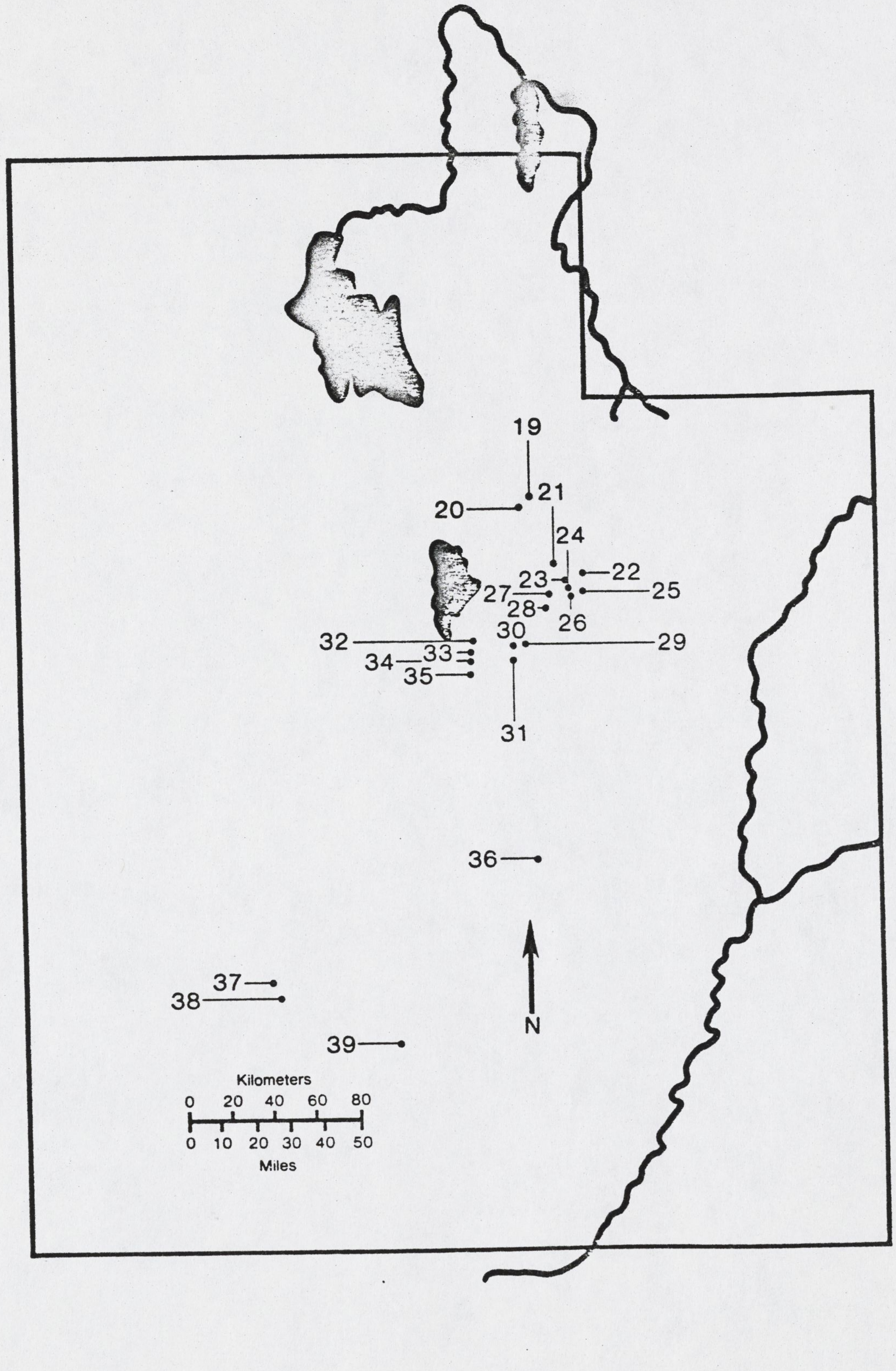
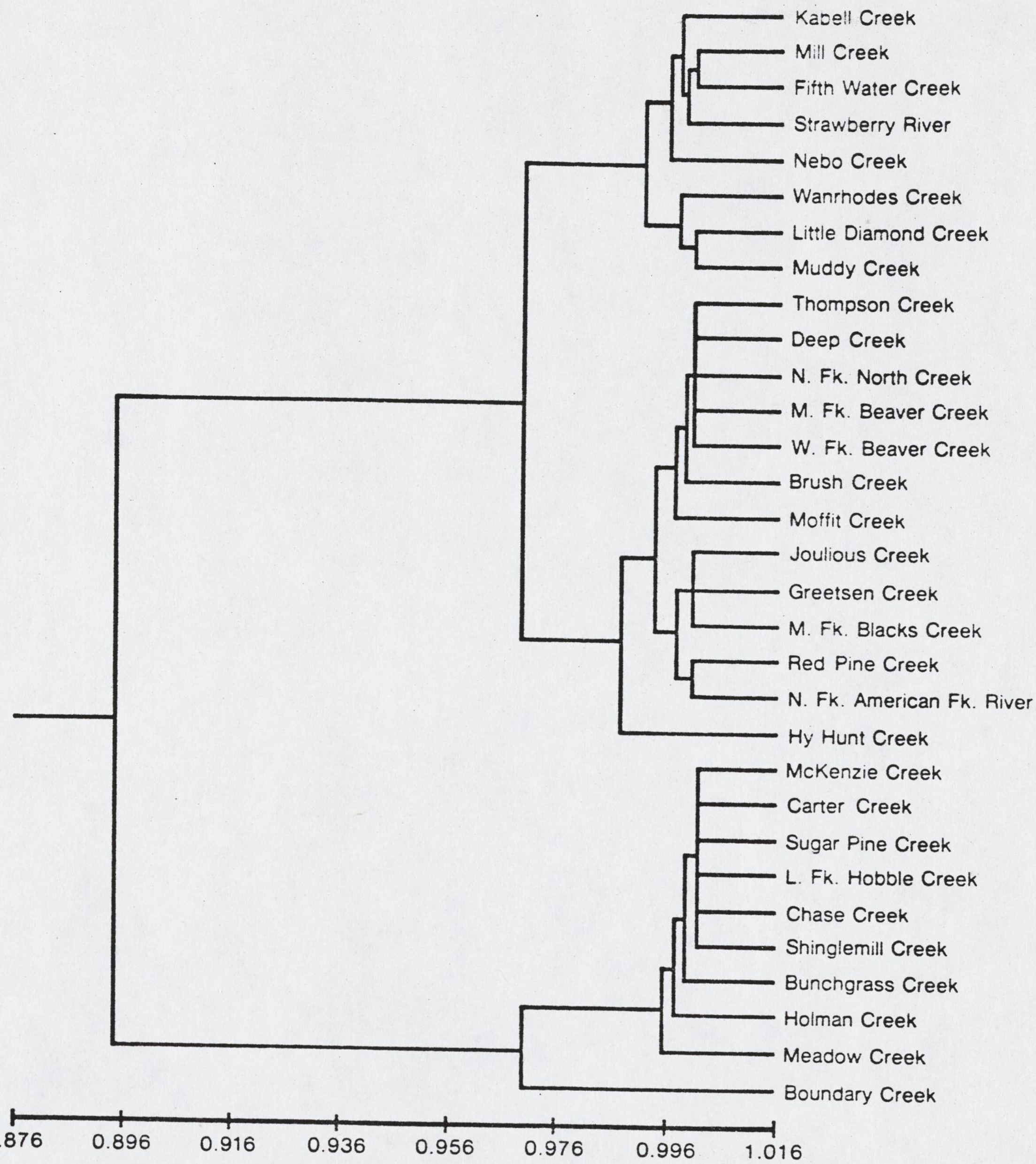

19
20
21
24
23
22
27
25
28
26
30
32
29
33
34
35
31
36
37
38
N
39
Kilometers
0 20 40 60 80
0 10 20 30 40 50
Miles

Fig. 5. A UPGMA dendrogram expressing the genetic identity (Nei 1972) of 31 cutthroat trout populations.


Kabell Creek
Mill Creek
Fifth Water Creek
Strawberry River
Nebo Creek
Wanrhodes Creek
Little Diamond Creek
Muddy Creek
Thompson Creek
Deep Creek
N. Fk. North Creek
M. Fk. Beaver Creek
W. Fk. Beaver Creek
Brush Creek
Moffit Creek
Joulious Creek
Greetsen Creek
M. Fk. Blacks Creek
Red Pine Creek
N. Fk. American Fk. River
Hy Hunt Creek
McKenzie Creek
Carter Creek
Sugar Pine Creek
L. Fk. Hobble Creek
Chase Creek
Shinglemill Creek
Bunchgrass Creek
Holman Creek
Meadow Creek
Boundary Creek
0.876
0.896
0.916
0.936
0.956
0.976
0.996
1.016

ADDENDUM

This addendum was incorporated to assist readers in interpretation of the relationships between cutthroat samples as shown by SDH-1 (0) allelic frequencies (Fig. A, B) and the cluster analysis (Fig. C, D, E). While this information is in the text, the relationships are easier to visualize with the added figures A-E.

The following points should be noted. SDH-1 (0) has a frequencies near 0 for Yellowstone and Bear River Bonneville populations. All streams (Fig. A) in the Bear River drainage with 0 are pure populations of Bear River Bonneville. In Figure B the three streams with low SDH-1 (0) frequencies (east of Utah Lake) appear to contain Yellowstone cutthroat, but determination of this will require a quantitative examination of morphological characteristics.

SDH-1 (0) frequencies of .90 or above (Fig. A, B) represent either Colorado River cutthroat or Snake Valley Bonneville. The Colorado River populations had high frequencies, as do the Southern Utah trout populations. Rather than an integrading change, we see abrupt changes across drainage divides. The change from .97 in Moffit Creek (upper Weber River) to a frequencies of 0 in Meadow Creek in the Bear River drainage just across the divide is illustrative of this phenomenon. The Bear River populations do form a unique discontinuous gene pool for SDH-1 when compared to the Colorado River and the Bonneville Basin cutthroat.

Intermediate SDH-1 (0) levels could represent hybridized fish (with rainbows) or fish that have interbred with introduced cutthroat. The introduction could be by man (stocking) or by natural invasions (as predicted by Loudenslager and Gall (1981)).

The three distinct clusters (see text for further discussion) are given in Figures C, D and E. Cluster 1 (Fig. C) represents the location of heterozygous populations of trout, especially those that were hybridized with rainbow trout. Cluster 2 (Fig. D) represents those populations which were most closely related to the Snake Valley Bonneville or Colorado River cutthroat trout. The fish in this cluster do not occur in the Bear River drainage. Figure E includes the Bear River/Yellowstone populations. Those streams in the Bear River drainage contain Bear River Bonneville. The four streams (21, 23, 24, 30) in the Bonneville Basin proper could be either Bear River Bonneville or Yellowstone cutthroat. As noted above with the discussion of the SDH-1 (0) frequencies, morphology would need to be considered in these populations.

The clusters give information similar to the SDH-1 allelic frequencies. However, the question of the status of fish with intermediate gene frequencies is still open. Final resolution of this must be based on the examination of more streams with electrophoretic techniques. This will include a comparison of morphological classification with electrophoretic based designations. At this point we can only list those populations that met our "pure" criteria, and those that were hybridized with rainbow. The remaining populations are cutthroat, but that is the limit of our designation.

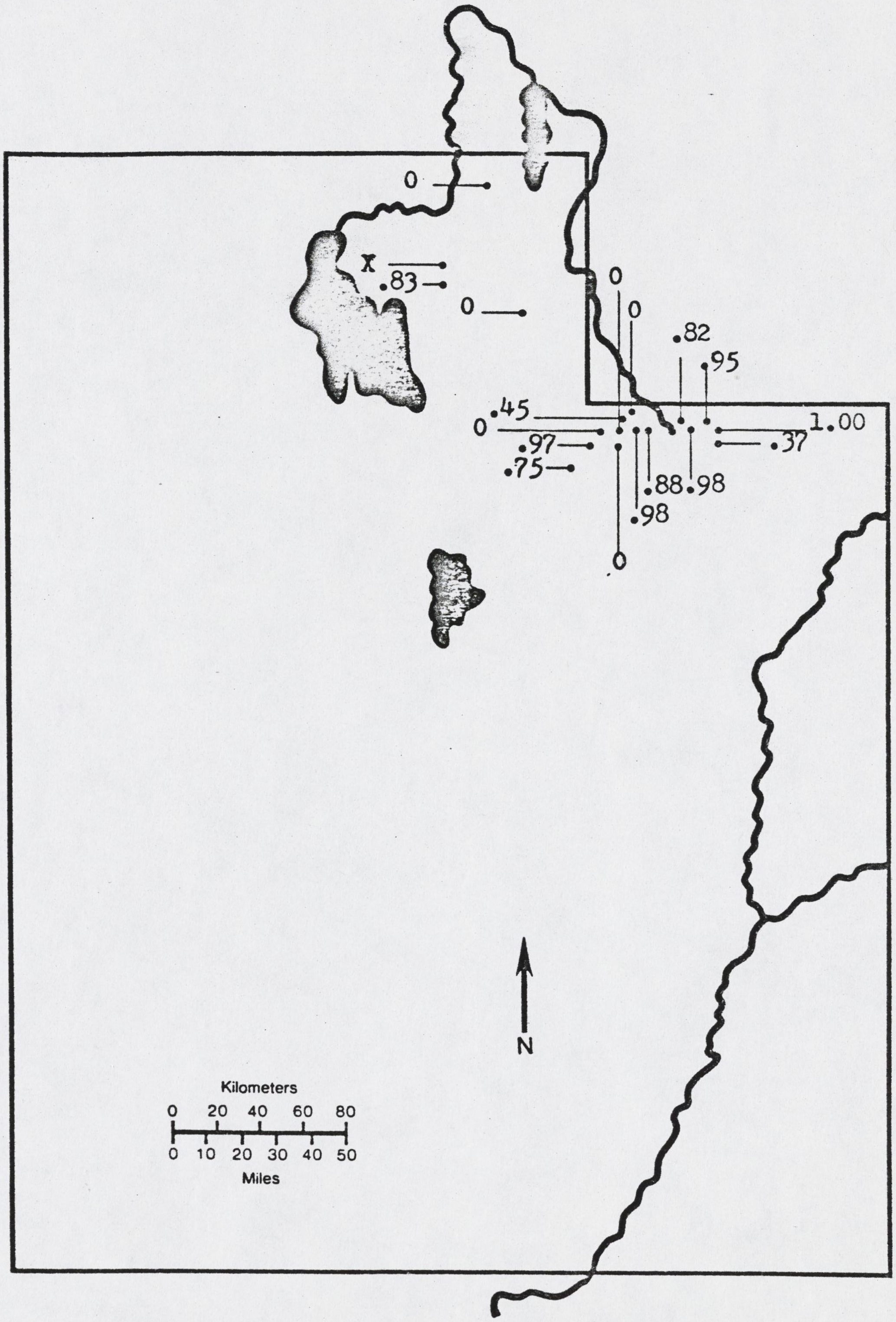
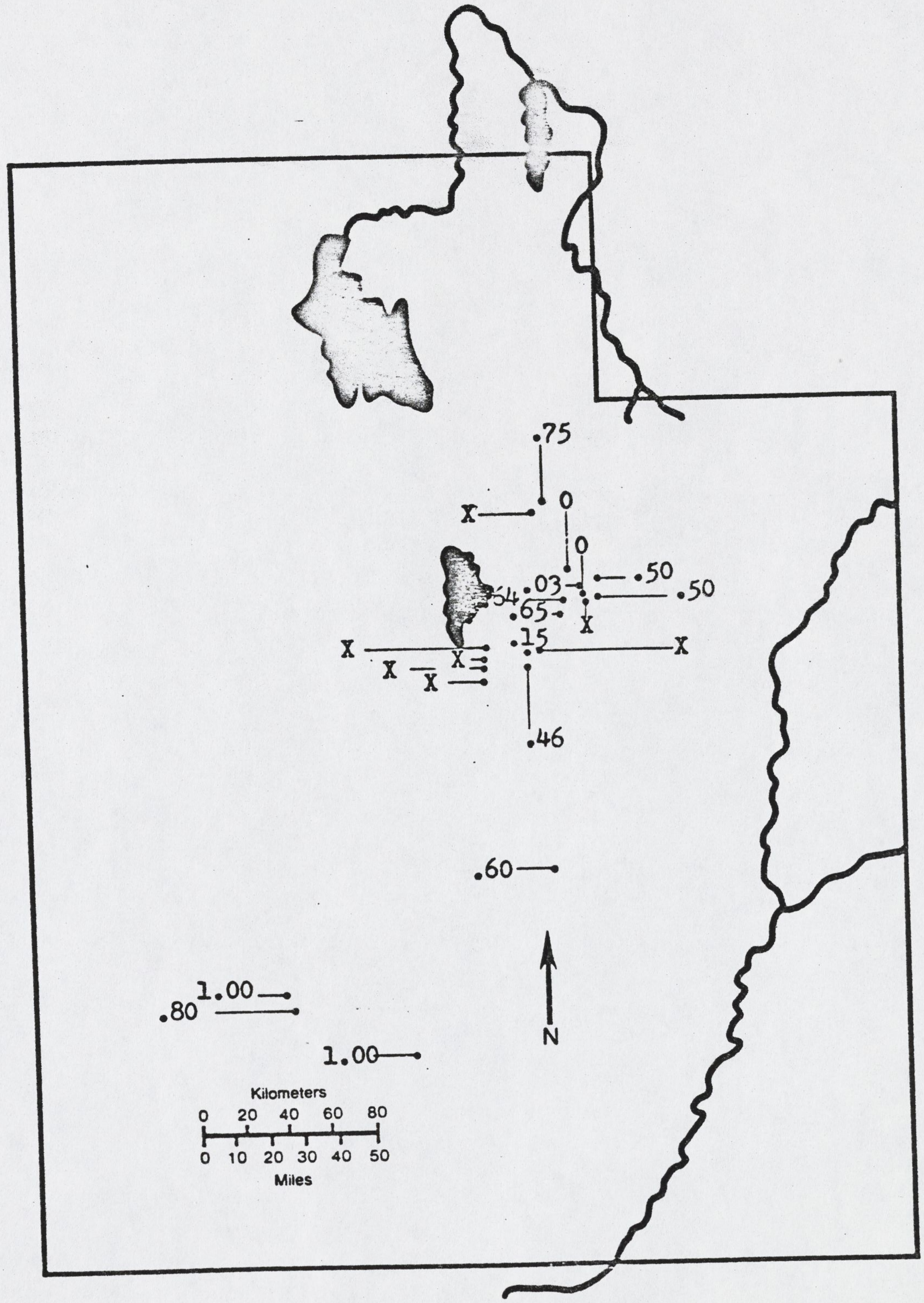

0
X
.83
0
0
0
.82
.95
.45
0
1.00
.97
.37
.75
.88
.98
.98
0
N
Kilometers
0 20 40 60 80
0 10 20 30 40 50
Miles

Figure A



.75
X
0
0
.50
.03
.50
.64
.65
X
X
.15
X
X
X
X
.46
.60
N
1.00
.80
1.00
Kilometers
0 20 40 60 80
0 10 20 30 40 50
Miles

Figure B

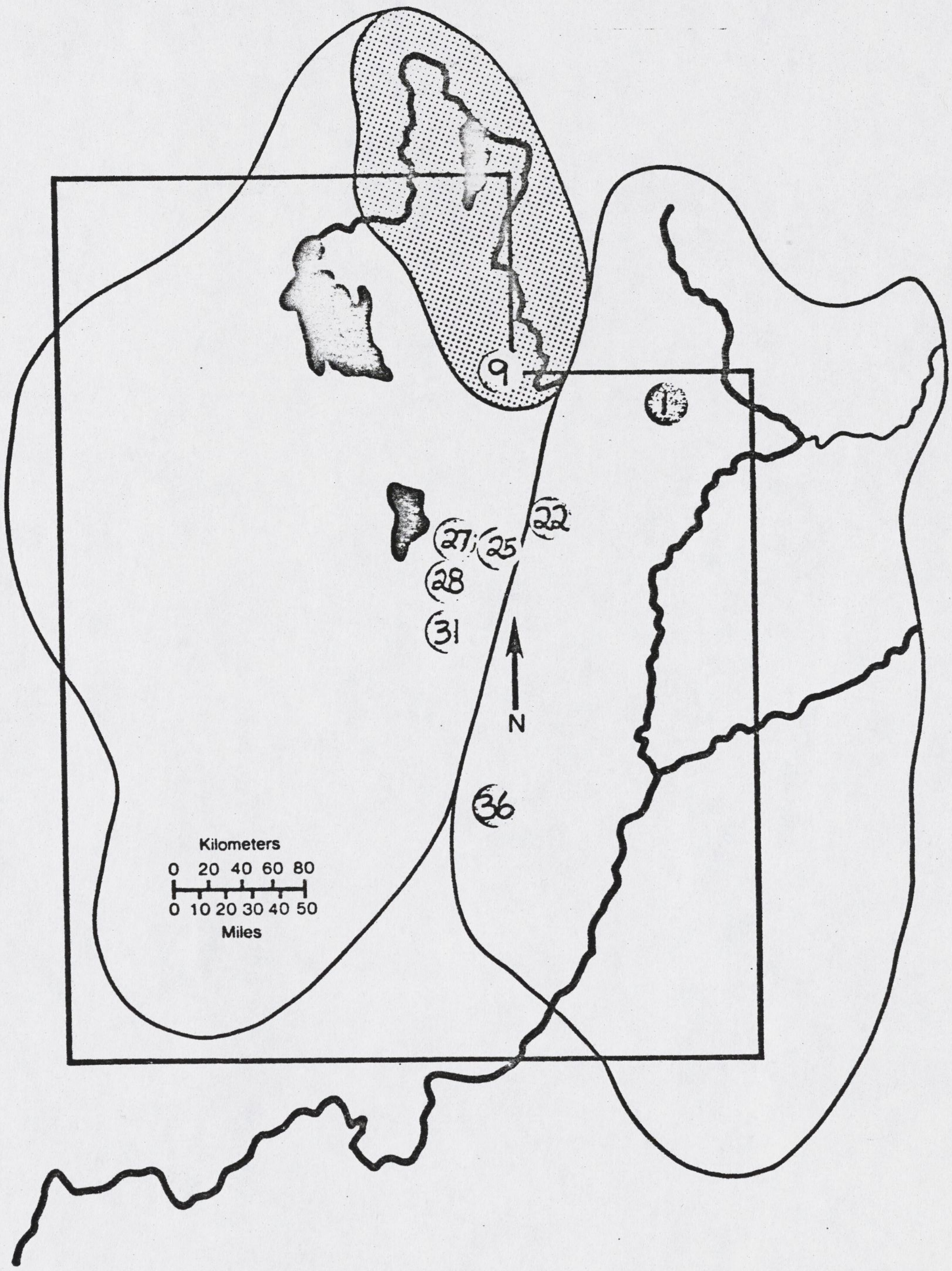

9
1
22
27
25
28
31
N
36
Kilometers
0 20 40 60 80
0 10 20 30 40 50
Miles

Figure C

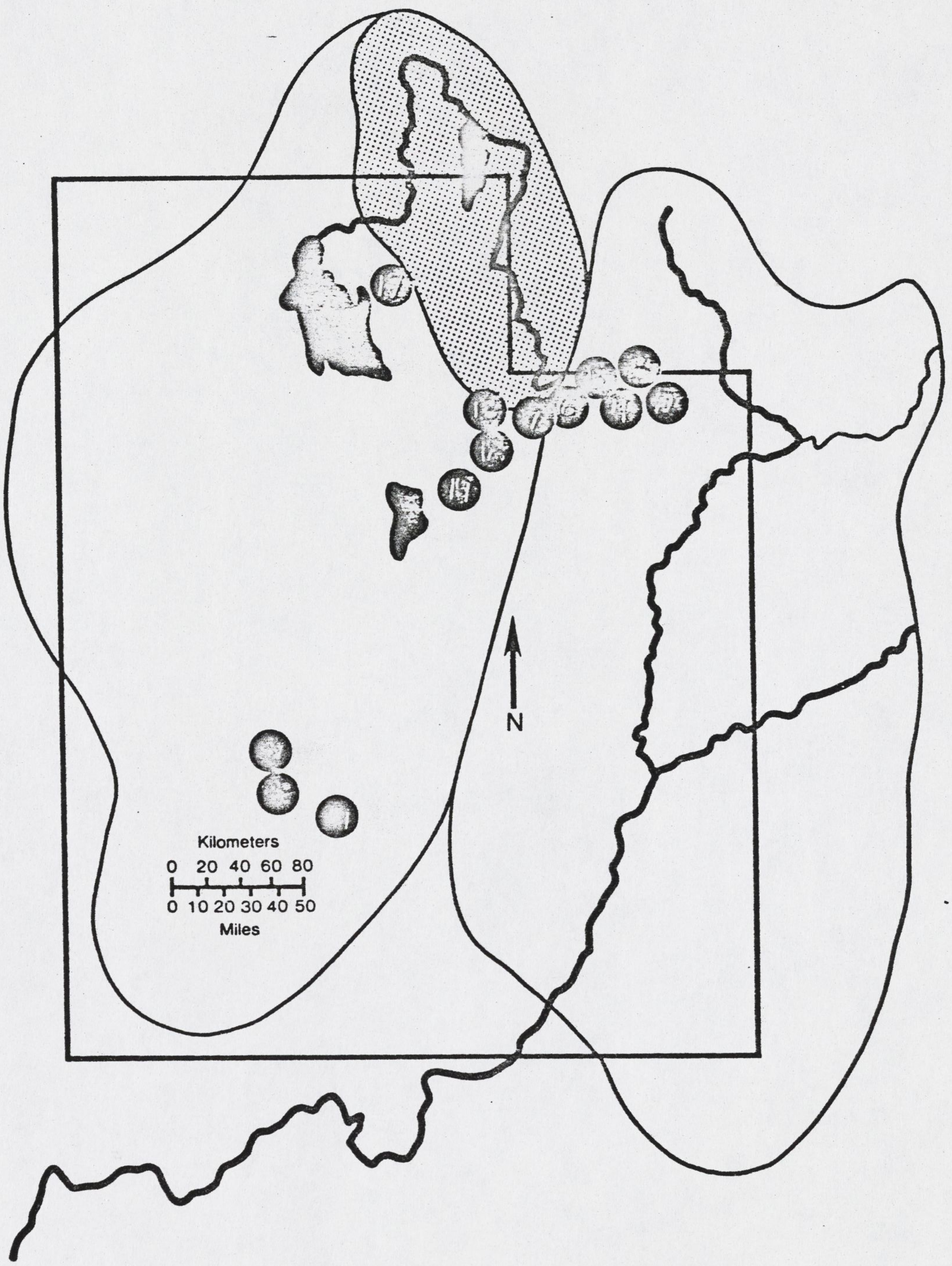


Figure D

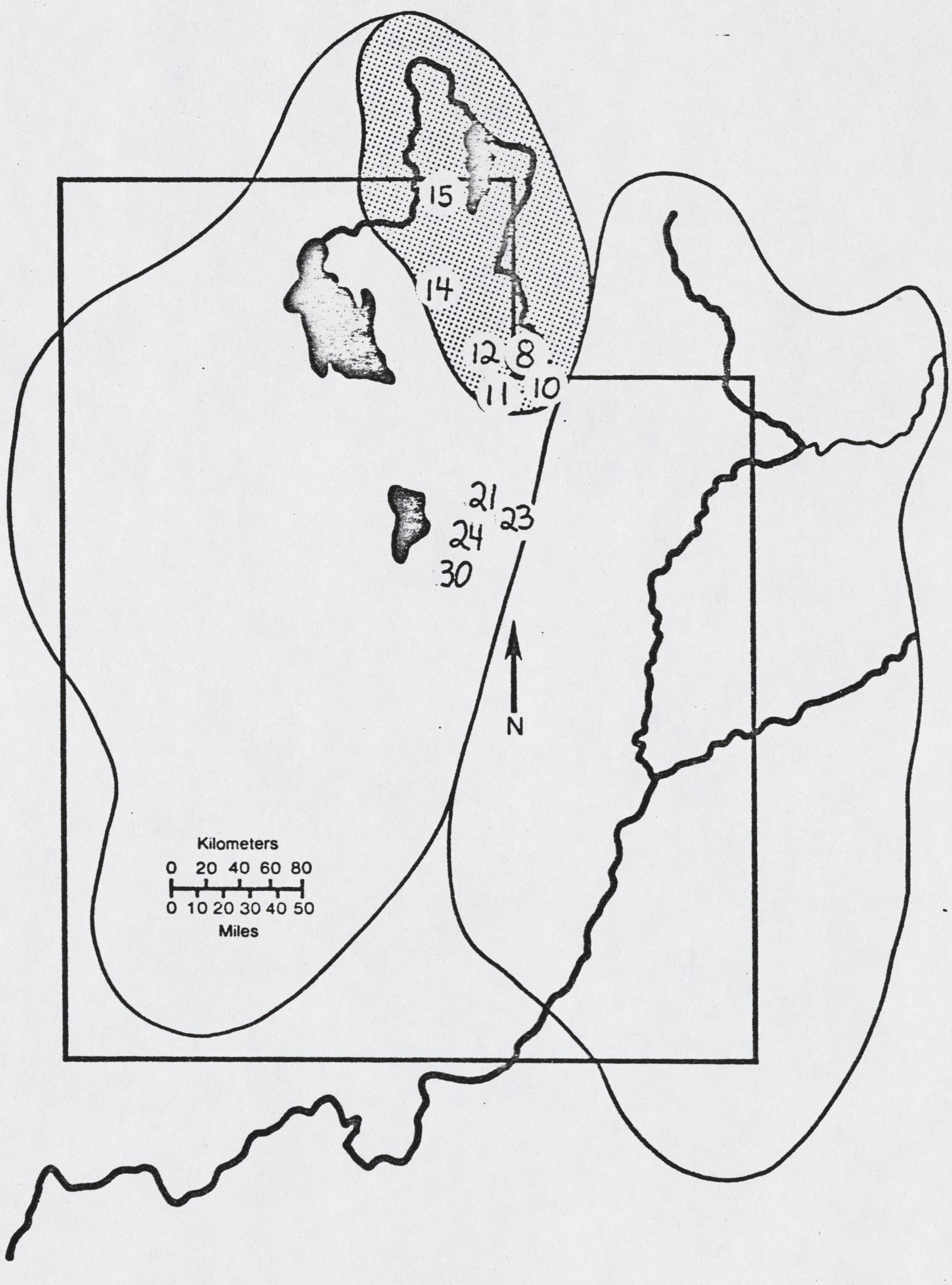

15
14
12
8
11
10
21
23
24
30
N
Kilometers
0 20 40 60 80
0 10 20 30 40 50
Miles

Figure E

Study of Fishes in the Virgin River (Utah)

Annual Report, 1984

by

Terry J. Hickman
Western Ecosystems

P.O. Box 1575
St. George, UT 84770

February, 1985

Acknowledgements

A special thanks goes to Thom Hardy for his work on the habitat model and for his assistance in field data collections and report preparation.

The following people participated in various aspects of the field work and their assistance is gratefully acknowledged: Ron and Stephenie Ellingham, Vaughn Courtney and Don Dotson.

Funding is provided by the Washington County Water Conservancy District.

The typing was done by Vicky Hickman and for this I am grateful.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
DESCRIPTION OF STUDY AREA	2
WATER USE	5
METHODS	8
BIOLOGICAL ANALYSIS	10
Woundfin	11
Virgin chub	14
EXOTIC SPECIES	17
PARASITISM	19
HABITAT MODEL	20
WATER QUALITY	21
LITERATURE CITED	23
APPENDIX A	
Figures 1-7	25
APPENDIX B	
Tables 1-21	33

Introduction

The Virgin River harbors six native fish species: woundfin, *Plagopterus argentissimus*; Virgin roundtail chub, *Gila robusta seminuda*; Virgin spinedace, *Lepidomeda mollispinis*; speckled dace, *Rhinichthys osculus*; desert sucker, *Pantosteus clarki* and the flannelmouth sucker, *Catostomus latipinnis*. The chub and spinedace are endemic to the Virgin River and the woundfin is now restricted to the Virgin River. The desert and flannelmouth suckers are restricted to the Colorado River basin and the speckled dace occurs throughout western North America (Williams 1977). The woundfin is listed federally as an endangered species and the Virgin chub is presently being considered by the U.S. Fish and Wildlife Service (FWS) for listing as an endangered species.

On December 7, 1982 the FWS issued a nonjeopardy biological opinion for the Quail Creek Reservoir Project, Washington County, Utah. One of the conditions of this opinion was that the Washington County Water Conservancy District (WCWCD) fund a study to determine the impacts of various flow regimes on the woundfin and its habitat within Utah. The study has been expanded to include an analysis of the life history and habitat requirements of the other five native fish species in the Virgin River in Utah.

The study will cover a period of five years and an annual report will be submitted to the FWS, Utah Division of Wildlife Resources (UDWR) and the U.S. Bureau of Land Management (BLM) summarizing each year's data. An annual meeting will be held with the FWS, UDWR and BLM to discuss the study and to make any necessary study adjustments.

This report includes an analysis of the data collected during 1984. The year was spent developing a study plan (which was approved by the FWS and UDWR), determining sampling techniques, obtaining the necessary equipment, locating the study stations, selecting personnel, collecting baseline biological and habitat data, initial development of the habitat model, reviewing the literature and documenting water movement within the Virgin River system in Utah. Baseline biological and habitat information was collected from July through December, 1984.

Description of the Study Area

The study area (fig. 1) encompasses the lower mainstream Virgin River from approximately one mile below the Pa Tempe Hot Springs (approximately 3100 ft. elevation), the upper limit of the woundfin and Virgin River chub, to the Arizona-Utah border (2200 ft. elevation). This is a distance of approximately 36 miles and probably contains 70% or more of the known populations of woundfin and Virgin River chub. The study area also includes the lower reaches of the tributaries to the Virgin River in Utah. Cross (1975) gives an extensive account of the history, climate, topography and vegetation of the study area.

The Virgin River, a tributary of the Colorado River prior to construction of Lake Mead in the late 1930's, is a very dynamic river typical of most desert streams. The river exhibits wide variations in flow, turbidity, salinity, and temperature and has a high sediment load with a shifting sand bottom.

The Virgin River begins from two major forks, the North and East Forks. The North Fork of the Virgin River (contributes the majority of the flow) begins at an elevation of 10,000 ft. in Iron County and flows through Zion Canyon. The East Fork of the Virgin River begins at an elevation of 8,000 ft. in Kane County, flows through Parunweap Canyon, and unites with the North Fork one mile south of Springdale (Washington Co., Utah) at an elevation of 3900 ft. Between this location and the Arizona-Utah border (approximately 54 river miles) the elevation drop is 1700 ft. All of the major tributaries (North, Ash, La Verkin and Santa Clara Creeks) enter from the north and head in the Kolob Terrace or Pine Valley mountain range at a maximum elevation of 10,000 ft.

Seven permanent habitat and population monitoring stations were established within the study area (fig. 1). Each station is approximately one-half mile in length (except La Verkin Creek which is one mile in length) and represents the various types of habitats found within the range of the woundfin and Virgin River chub. The gradient within each station decreases progressively in a downstream direction with La Verkin Creek having the most and station 6, the least. Runs with shifting sand substrate dominate (in terms of river length and width) at all stations with riffles being frequently interspersed throughout. Pools are rare and are most prevalent at stations 1, 2 and 3. Stations 1 through 4 contain the least modified habitat within the range of the woundfin and chub in Utah, while La Verkin Creek, and stations 5 and 6 contain the most modified habitat. The following is a general description of each study station; more specific data will be provided as more habitat information is collected.

Station 1 - This station is located approximately one-half mile below the confluence of Ash and La Verkin Creeks with the Virgin River at an elevation of 3,000 ft. At this point the river begins to flow through a deeply incised canyon that extends along the Virgin anticline to station 4, just above the Washington Fields diversion (approximately thirteen miles). The canyon is lined with basalt, sandstone and limestone and provides shade to the river during a significant portion of the day. As a result of the canyon walls, stations 1 and 3 have the narrowest overall channel widths of all the stations (except La Verkin Creek). There are three major pools, three major runs and three major riffle areas within the station. The pools are created by basalt and sandstone and can exceed a depth of eight ft. The riffles (more dominant at this station than at any other) are comprised of medium to large rocks, gravel or small rocks are generally absent from the area. Overhanging bank cover is limited and few vegetative snags occur in the river. One permanent side channel (about 300 ft. in length) exists within this station and consists mainly of pools and riffles. Some backwater habitats are present throughout the station.

Station 2 - This station is located approximately six and one-half miles downstream from station 1 and two miles upstream from the Quail Creek Reservoir discharge at an elevation of 2,840 ft. There are three major runs, two major riffles and two major pool areas within the station. The substrate in the riffles ranges from gravel to large rocks with medium-sized rocks dominating. The pools are formed by basalt and sandstone bedrock and are more shallow with a faster current than the pools in stations 1 and 3. The channel is generally wider than stations 1 and 3 and is more sinuous. No prominent side channels exist, although some backwater habitat occurs. Very little overhanging cover exists and no vegetative snags are found in the river.

Station 3 - This station is located approximately four and a half miles downstream from station 2 at an elevation of 2,720 ft. The Hurricane gauging station is located about one mile upstream. One of the permanent monitoring stations for the woundfin recovery team is located in the middle of this station (Berry Springs). The habitat is more diverse at this station than at any other. There are three major runs, two major pools and two major riffles. The pools are formed by boulders (basalt) and can exceed nine feet in depth. The riffles consist of an even mixture of gravel and other sizes of rock substrate. This station and station 4 contain the most gravel substrate of any other station. Some over hanging bank cover is present, although few vegetative snags occur in the river. The channel is narrower than stations 2, 4, 5 and 6, and no side channels exist, although a few backwater habitats are present.

Station 4 - This station is located approximately one and one-half mile downstream from station 3 and one and one-half mile above the Washington Fields Diversion at an elevation of 2,700 ft. At the beginning of this station, the river emerges from the canyon into a wide flood plain area. There are three major runs, one major riffle and several small pool areas. The runs are diverse, varying in depth, width, current and amount of cover. The riffles consist of gravel and small rock substrate and the pools are formed by vegetative snags in the river. More vegetative snags occur in the river at this station than at any other. The channel is wider than at any other station except station 6.

There are a few side channels present during certain flow conditions and several backwater habitats exist.

Station 5 - This station is located approximately eight and one-half miles downstream from station 4 at an elevation of 2,590 ft. One of the permanent monitoring stations for the woundfin recovery team is located about three-quarters of a mile downstream at Twin Bridges. As a result of the Washington Fields Diversion (eight miles upstream), this station experiences the lowest flows of any of the other stations. Runs dominate with two major riffles and one pool also occuring throughout the station. The runs vary in depth, width and cover, with rip-raft (deposited along the bank for stabilization) dominating the cover in runs and forming the pools. The riffles consist mainly of medium-sized rock substrate with small amounts of gravel also present. Side channels occur and some backwater habitats are present at this station. Some overhanging bank vegetation and vegetative snags are present throughout the station. A major irrigation return flow point enters the river in the middle of this section.

Station 6 - This station is located approximately five and one-quarter miles downstream from station 5 at an elevation of 2,480 ft. About eight miles downstream from this station, (about one mile upstream from the Utah-Arizona line at the mouth of the Virgin narrows) the river frequently disappears from the surface and flows underground emerging above the Beaver Dam Wash area in Arizona. The Bloomington gauging station is located approximately two and one-half miles upstream from this station. Shallow runs dominate throughout the station with one major riffle and one small pool also occurring. The riffle consists of medium-sized rock substrate and the pool is formed by a sandstone boulder. No overhanging vegetation occurs and there are a few vegetative snags in the river. The channel is braided and wider than at any other station and some backwater habitat is available. Very little stream shading occurs.

La Verkin Creek - This station is located on the lower one mile of La Verkin Creek and begins at an elevation of 3,200 ft. Extensive habitat alteration has occurred in the upper one-half mile of this station during the past two and one-half years. The average channel width is about twelve feet throughout the station. Small, shallow pools and riffles dominate with shallow runs infrequently interspersed over the length of the station. The substrate ranges from gravel to boulders. with medium-to-large rocks dominant. Overhanging vegetation is prevalent, especially in the lower half of the station where the creek is shaded most of the day.

Water Use

The history of the early settlements of Washington County, Utah, is also an outline of the history of water use from the Virgin River. Successful establishment by these early settlers directly depended upon their ability to "tame" the river. For the first fifty years it was a river that they couldn't live with or without.

Indians had been using the water from the Virgin River for irrigation for centuries prior to the time white man settled the area (Glancy and Van Denburgh 1969). One of the first records of exploration in the Virgin River basin of Utah was made by two Spanish clerics, Fathers Escalante and Dominguez. In October of 1776 they noted that the Indians along Ash Creek were irrigating small patches of corn with well-made irrigation ditches (Bolton 1950). In September of 1826 Jedediah Smith observed that the Indians on Santa Clara Creek had dammed a portion of the creek and were irrigating corn through the use of hollowed-out tree trunks (Morgan 1953). Several other historical accounts mention the use of the Virgin River system by Indians for irrigation (Crampton 1972; Steward 1938; Woodbury 1950).

White man first began using the waters of the Virgin River system in Utah for irrigation in 1854 (Hinton 1961). During this year a dam and canal system was built on Santa Clara Creek. The dam was approximately 80 ft. long, 14 ft. high and 3 ft. thick. This dam was washed out eight years later, but others were built to take its place. In 1857 a dam and canal system was built on the Virgin River near the city of Washington (a few miles downstream from the present Washington Fields Diversion Dam). This dam would wash out one to four times per year and be rebuilt each time. Between 1857 and 1865, $80,000 was spent on dams and canals at this location. Between 1854 and 1910 numerous dams and hundreds of miles of canals were built on the Virgin River and its tributaries. The cost was enormous, as many had to be rebuilt or repaired every year, often several times per year (Hinton 1961; Larson 1961).

The Washington Fields Diversion dam was completed in February, 1891 and water began flowing in the canal by mid-summer, 1891. By 1900, over $70,000 had been spent on the dam and canal system. The La Verkin canal and diversion dam were started in 1889 and water was flowing through the canal by 1901. The initial cost was $25,000. Work on the Hurricane canal and dam was started in 1893 and, after two dam failures and eleven years, water was running through the canal by August of 1904 (Hinton 1961; Larson 1961).

Between the 1850's and 1910, the Virgin River system underwent dramatic changes as a result of irrigation and livestock grazing. During the summer the demand for irrigation water exceeded the available water in the Virgin River and it was common for entire sections of the river to be diverted into canals (Hinton 1961; Larson 1961). A U.S. Department of Agriculture report in 1903 indicated that practically all of the water in tributary creeks during the summer was diverted before it reached the Virgin River. This report also concluded that more water was always diverted from the Virgin River system than was needed, due to poor management and the fact that it was necessary to continuously sluice the sand and debris from the canals (Adams 1903). By 1910, ninety-nine percent of all the major water rights to the Virgin River system in Utah were already allocated and probably being fully used.

Livestock grazing (which began in the 1850's) depleted most of the grass and shrubbery along the Virgin River drainage. As a result, the frequency and volume of flooding increased each year and the river is responsible for creating more than its share of ghost towns (Hinton 1961; Larson 1961). During this period (1850-1910) the Virgin River became wider and more shallow in many areas. Larson (1961) aptly summed up the situation when he said, "Much of the finest bottomland was carried to the Pacific by the wrathful Virgin, who struck out blindly and even viciously at those who had so thoughtlessly violated her watersheds. Like an angry pagan goddess, she turned upon her tormentors to destroy what they had built."

During the past 75 years (after 1910) there have only been slight modifications to the Virgin River in Utah and the fish present today appear to have adapted to the early environmental changes. Cross (1978), through a review of available information, determined that woundfin abundance in the mainstream Virgin River upstream from Mesquite, Nevada, had not appreciably changed since at least the 1930's (and probably earlier, but few biological records exist prior to this time).

Between the 1950's and 1970's four small reservoirs were constructed on three tributary streams to the Virgin River. These reservoirs are Kolob (5,500 af) on Kolob Creek, Ash Creek (3,500 af) on upper Ash Creek and Gunlock (11,000 af) and Baker (980 af) on Santa Clara Creek. They are mainly used for irrigation release downstream and to store water from the spring run-off. Ash Creek Reservoir is not being fully utilized due to significant leakage and structural problems. Baker Dam Reservoir, located between Veyo and Gunlock, is also used for power generation.

The main areas of water diversion affecting the woundfin and chub in Utah are the Hurricane, La Verkin and Washington Fields diversions. The main areas of augmentation are Pa Tempe Hot Springs, Ash, La Verkin and Santa Clara Creeks, Ft. Pierce Wash, returns from the diversions and spring seepage along the river. The Hurricane diversion depletes 35 cfs, the La Verkin diversion, 12 cfs and the Washington Fields diversion, 89 cfs. These are maximum values and are usually fully used during the irrigation season.

The Virgin River gauge is located about four miles upstream from the Hurricane and La Verkin diversions and approximately sixteen miles upstream from the Hurricane gauge. A comparison between the mean monthly flows of these two gauges reveals that the Hurricane readings are almost always higher for every month. This net increase in flow is due to return flows from the Hurricane and La Verkin diversions, Ash and La Verkin Creeks (about 20 cfs), Pa Tempe Hot Springs (11.5 cfs) and spring seepage. The Pa Tempe Hot Springs is located about two miles downstream from the Hurricane diversion and three miles upstream from the confluence of Ash and La Verkin Creeks. Williams (1977) indicated that during July or August the Pa Tempe Hot Springs can be accountable for over 95% of the river flow from the Springs to the Ash and La Verkin Creek Confluence area.

Over the course of the year there are differences in flow between the Hurricane gauge and the Bloomington gauge fifteen miles downstream. A comparison of the mean monthly averages for these two gauges (fig. 2) shows that the Bloomington gauge readings are higher in the winter and spring, while the summer and fall readings are essentially the same.

This is probably due to return flows from the Washington Fields diversion and augmentation of water throughout the year from Ft. Pierce Wash, Santa Clara Creek and spring seepage. Mean monthly discharges for the period of record are given for the Hurricane (fig. 3) and Bloomington (fig. 4) gauges.

During the period 1951 through 1956 a gauge was in place on the Virgin River near the Arizona-Utah border, approximately eleven miles downstream from the Bloomington gauge. Although there are no significant diversions or augmentations of water between these two gauges, the flow is significantly less at the state line gauge (no exact comparison can be made since the Bloomington gauge was established in 1977 and the Hurricane gage, in 1967 - comparisons were made by using the Virgin gauge and other information). During the period from 1951 - 1956, minimum flows at the state line gauge were zero for seven out of the twelve months (April through October) and twenty-five percent of the time during the period of record there was no flow registered at the gauge. Approximately one mile upstream from the state line gauge, the river will disappear from the surface and flow underground during certain flow conditions. The river will resurface below the Virgin River Gorge above Beaver Dam Wash. Adams (1903) noted that this occurred during the summer of 1902.

Most of the preceeding information on present day water use was taken from the U.S.G.S. gauge records or from a report published by the Utah Division of Water Resources in 1983 entitled, "Hydrologic Inventory of the Virgin and Kanab Study Units". Next year I should be able to develop a more accurate analysis of water movement in the Virgin River in Utah because new U.S.G.S. gauges were established during the fall of 1984 on Ft. Pierce Wash, and the lower portions of La Verkin and Santa Clara Creeks. In next year's report I will also include data on the filling and initial operation of Quail Creek Reservoir as it relates to water movement.

Methods

Seven population and habitat monitoring stations have been established along the Virgin River and La Verkin in Utah (refer to the section on description of study area). Each station is sampled one day per month. At each station the following habitat measurements are recorded: air and water temperature; conductivity; pH; turbidity; velocity; depth; substrate; cover and length and width of area sampled. The depth, velocity, substrate and cover measurements are taken at a minimum of nine points within each habitat segment sampled. Fish are collected either by using a 4.5m x 1.8m x 6mm mesh nylon seine or electrofishing unit. All fish measurements are expressed as total lengths to be consistent with the Woundfin Recovery Team Monitoring Program.

Fish collected with the seines are sampled in a similar manner as that used by the Woundfin Recovery Team Monitoring Program. Twenty separate areas are sampled at each station, with a representation of each available habitat type (pool, run or riffle) being sampled. Since the habitat changes monthly, the ratio of pools, runs and riffles sampled changes each month. An effort is being made to obtain a representative sample of that habitat which is present during that particular month. Where possible, a 10m x 3m segment of the habitat is sampled. The seine is hauled repetitively through this segment until 10% or less of the number of fish captured in the most successful seine haul is reached. This method provides sufficient data to make a good estimate of the fish population within a given habitat.

After each seine haul the fish are identified, counted and placed in plastic buckets until the habitat segment has been sampled. All fish captured are identified, counted, measured and returned to the river. During certain times (especially low flow conditions) several hundred fish are captured in one seine haul and, in order to avoid mortalities, it becomes necessary to hold the fish in a nylon net attached to a styrafoam lifebouy (tear-drop shape) located in the river.

The electroshocker consists of a 120 volt AC portable Kawasaki (KG1100B) generator connected to a Coffelt Model 2C variable voltage pulsating DC output. A rubber raft is used to float the generator and VVP through the sample section. The unit is set up with one large dip net (positive electrode) on the front of the raft and a trailing wire coil (negative electrode) on the rear of the raft. A large bag seine (7.5m x 1.8m x 6mm mesh nylon) is positioned at the bottom of the sample section to catch fish floating downstream. Fish are placed in plastic buckets located on the raft and on shore.

Usually three passes are made through each habitat segment and the fish are identified, counted, measured and returned to the river. Where possible, samples are made similar to the seining methods and population information for a particular habitat segment is obtained. The length of the habitat segment that is sampled varies from 10m to 50m.

Due to difficulties of electrofishing (especially during high flow conditions) and the stress exhibited by the fish from repetitive shocking, sampling by this means will only be done about four times per year.

Water chemistry data is obtained by using a Hach portable DREL/5 model kit which includes a DR/3 spectrophotometer. Current velocities are taken with a Montedaro-Whitney digital portable flow meter (model PVM-2A) and values are expressed in ft/sec.

The methods for collecting the physical habitat data for use in the development of the habitat model are similar to those outlined in the "Field Data Collection Procedures for Use With the Physical Habitat Simulation System of the Instream Flow Group", developed by the U.S. Fish and Wildlife Service Instream Flow Group, Ft. Collins, Colorado. This habitat information will be collected during the various flow periods (high, medium and low).

Biological Analysis

The biological information collected during 1984 represents baseline data and comparisons with previous studies and conclusions are preliminary. The intent of this first report is to present the data collected during 1984. Since the habitat of the Virgin River can change daily (what was a 9 ft. pool one day is a 2-inch run the next) several collections over a series of different flow conditions are necessary in order to discuss preferred habitat or other aspects of life history requirements. During July, 1984, several hundred fish were collected in one seine haul. These fish were packed into the only available habitat present under low flow conditions. Therefore, several collections are required before the difference between available and preferred habitat are determined.

The type of sampling gear used is also a factor in determining habitat and life history requirements. The seines were more effective in collecting smaller fish in shallower areas with sand substrate. Electrofishing was most effective in sampling habitats that were deeper or contained rock substrates, vegetative snags or faster currents. Seines were most effective in collecting woundfin, while electrofishing was most effective in collecting chub. More chub were collected during 1984 (1,180) than in any previous study conducted on the Virgin River and 72% of these were collected using an electroshocker. Avoidance of the seine by larger fish was frequently observed. An example of this was the collection of adult flannelmouth suckers in shallow runs. The seines rarely captured these fish while with the electroshocker fifteen to twenty were collected in the same area.

Also, the mesh size of the seines used is important. Most of the previous collections from the Virgin River were made with 0.6 mm mesh seines. I frequently noted fish under 45 mm falling through the seine onto the shore while using the 0.6 mm mesh size. The FWS in Grand Junction has switched from 0.6 mm to 0.3 mm mesh seines for some of their work on the Colorado River after observing the same problem. I intend to change to 0.3 mm mesh nylon seines in order to more efficiently collect young-of-the-year fish. There does not appear to be a significant difference in sampling efficiency between the two mesh sizes in collecting other age classes of fish. This will also allow for a comparison with the Woundfin Recovery Team Monitoring Program which uses 0.6 mm mesh seines.

Tables 1 through 6 present data on the total number of species collected at each station during the six monthly sampling periods. The density of these fish, determined by dividing the total number of fish collected by the surface area sampled, is presented in figure 5.

Density differences between stations and sampling periods are due mainly to the variability in flows that were encountered. The higher densities at station 5 during July and August are a result of low flow conditions which resulted in several thousand fish concentrating (packing) in pools. During higher flow conditions, more habitat is available and the fish become more dispersed, thus densities decrease. The monthly totals and densities of all fish species are dominated by woundfin. In general, the habitat of the Virgin River (especially the undisturbed segments) is more suited to woundfin than any other species.

Except for the spinedace, all of the native species were collected from each of the sampling stations. The spinedace occurs primarily at La Verking Creek and stations 1 and 2 and infrequently at stations 3 and 4. No spinedace were collected from stations 5 or 6. Spinedace were most frequently collected from backwater areas or side channels.

Usually speckled dace and desert suckers were collected in areas of fast current, although desert suckers were also collected in large numbers in pools and backwater areas at stations 2 and 5. Normally in seine hauls containing desert sucker and speckled dace, woundfin were absent. Flannelmouth suckers were most frequently collected in pools and other areas with a slower current. Woundfin were frequently collected with flannelmouth suckers and spinedace.

La Verkin Creek was made a sampling station during October and will be sampled regularly during the months that seines are used. The state line area was sampled one time to check presence or absence of various species at that location. Even though this section is dry part of the year, all of the native species except the spinedace were collected.

<u>Woundfin</u>

With the exception of Cross (1975), most of the studies concerning the fishes of the Virgin River have concentrated on the woundfin. Cross (1975) and Lockhart (1979) list the primary papers that have delt with woundfin taxonomy, distribution and life history and habitat requirements. With the exception of the Woundfin Recovery Team Monitoring Program, the present study is the first long-term study dealing with the fishes of the Virgin River. The Woundfin Recovering Team, under the guidance of Dr. James Deacon, has been monitoring woundfin (and chub where appropriate) during the spring and fall since 1977. Their three sampling stations in Utah are in the same areas as those from this study: Ash - La Verkin confluence area is one-half mile from station 1; Berry Springs is the same as station 3 and Twin Bridges is three-quarters of a mile downstream from station 5.

Woundfin were the most abundant species collected during each month and usually they were the most abundant species at each station (Tables 1 through 6). They were collected from virtually every habitat type available and were present in over 75% of all collections made. Woundfin comprised 40% of the fish population in July, 44% in August, 44% in September, 67% in October, 34% in November and 66% in December. The low percentage in November is a result of sampling with an electroshocker.

During October the Recovery Team (Deacon 1985) and the present study sampled the Virgin River within ten days of each other and, although the number of samples were different, the percentages of woundfin in the total catch were similar. At the Ash - La Verkin confluence woundfin comprised 37% of the population (station 1 was 32%), at Berry Springs, 86% (station 3 was 82%) and at Twin Bridges, 62% (station 5 was 52%).

Densities of woundfin populations were calculated for each sampling period at each station (fig. 6). Densities were consistantly lower at station 6 (except August), while stations 3, 4 and 5 consistantly had the highest densities. Some of the density differences between sampling periods can be explained by flow changes and sampling gear. Densities were generally lower in September and November when the electroshocker was used, while the high density for July (especially at station 5) was a result of fish "packing", due to low flows.

Size ranges for all woundfin collected during the six sampling periods at each station are presented in tables 8 through 12. Woundfin 51-80 mm in size dominated the collections. Stations 2, 3 and 4 provided the best habitat for all size classes, while station 5 seemed to provide the best habitat for adults. It appears that the best available habitat for woundfin (in Utah) occurs between stations 1 and 2 downstream to the Washington Fields Diversion dam, a distance of approximately 10 miles. This is also the least modified section of the river.

Deacon and Hardy (1982) and Deacon (1983) reported that good spawning success (recruitment of a new age class into the population) for woundfin in undisturbed areas required mean spring flows (April, May and June) at the Hurricane gauge between 200 and 800 cfs. The best spawning success occurs at flows between 400 and 800 cfs. Moderate to poor spawning success is associated with mean spring flows of less than 200 cfs or greater than 800 cfs. In the disturbed areas (below diversions) mean spring flows of approximately 200 cfs are required to insure some degree of spawning success, while flows in excess of 400 cfs are usually associated with good spawning success.

A list of the mean spring flows (April, May and June) at the Hurricane gauge from 1967 through 1984 is presented in table 13. Mean spring flows during 1984 (206 cfs) were about average for the 18-year period of record, with the highest occurring in 1983 (1082 cfs) and the lowest in 1974 (88 cfs). Mean spring flows for the undisturbed areas that were less than 200 cfs or greater than 800 cfs (poor to moderate spawning success) occurred 72% of the time; flows between 200 and 400 cfs (good spawning success) occurred 22% of the time and flows between 400 and 800 cfs (best spawning success) occurred 6% of the time. In the disturbed areas, flows associated with good spawning success (greater than 400 cfs) occurred 33% of the time, while flows between 200 and 400 cfs (some spawning success is likely) occurred 28% of the time. In the disturbed areas, spawning may not have occurred during at least seven or eight of the previous eighteen years.

Peters (1970) determined that woundfin spawning occurred between April and June. Cross (1975) indicated that spawning began about April or May and continued through August. The Woundfin Recovery Plan (1984) reports that peak spawning activity probably occurs in late May and early June. It seems likely that the spawning period is dependent upon spring and summer discharge (and related water temperatures). Multiple spawning periods probably occur between spring and fall, with later spawning possibly being triggered by summer thunderstorms. The information presented in tables 8 through 12 indicates that spawning in 1984 probably took place from May or June through August or September. These multiple spawning periods, coupled with about a six-month growing season (low water temperatures probably prevent growth from November to April or May), result in age class overlaps.

Woundfin spawning success at the seven sampling stations is presented in table 14. The months of October and December were used since it was the time period when young-of-the-year were most efficiently sampled. No mortalities were noted between the October and December collections. In fact, more young-of-the-year woundfin were collected in December. Greger and Deacon (1982) noted that woundfin reach a total length of approximately 60 mm in about five months at typical summer temperatures; therefore, I estimated that woundfin less than 51 mm (during October and December) were young-of-the-year. It is tempting to consider woundfin 51-60 mm collected in October (or later) as young-of-the-year. However, it is possible that spawning took place in August or September of the previous year and a total length of 51-60 mm may not be achieved until the following October. I consider the percentages in table 14 to be conservative since some of the woundfin in the 51-60 mm range could be young-of-the-year and due to the fact that woundfin under 45 mm were falling through the net in the October and December collections.

Spawning success was poor to non-existent at stations 1, 5 and 6 and at La Verkin Creek. Spawning success was best at stations 2, 3 and 4. This trend corresponds with the Woundfin Recovery Team collections during October. Comparing the information from Deacon (1985) and table 14, the Ash - La Verkin Creek area showed no evidence of spawning success (station 1 had 1-3% young-of-the-year, while none were collected in La Verkin Creek), at Berry Springs 17% of the catch was young-of-the-year (station 3 had 32-36% young-of-the-year) and at Twin Bridges 16% of the population consisted of young-of-the-year (station 5 had 1% young-of-the-year). At this time the difference in percent of young-of-the-year woundfin collected at stations 3 and 5 by the Recovery team and during this study cannot be explained. We sampled each station more intensively, which may explain the difference at station 3, but does not account for the difference at station 5.

Probably the main reason for the difference in spawning success between the seven stations in this study is the presence or absence of adequate spawning habitat. Greger and Deacon (1982) noted that woundfin select a substrate of rock (2-4 inches in diameter) in currents at a temperature of about 25°C for spawning. Stations 5 and 6 contain very little available spawning habitat, while stations 2, 3 and 4 contain optimum substrate for spawning. Also, poor spawning success at station 5 is probably related to the variability of flows (resulting from the Washington Fields Diversion) occurring throughout this station.

The lack of spawning in La Verkin Creek could be related to the channelization work that has been going on in this creek during the past two years. Half of the creek within the range of the woundfin has been completely rechanneled.

The virtual lack of spawning at station 1 may be attributed to a lack of good spawning substrate (rocks are generally large) and the steep gradient that occurs throughout this station. Flow does not appear to be a major factor, since it is essentially the same as stations 2, 3 and 4. Water quality, as a result of the Pa Tempe Hot Springs, may be an important factor. The information for the section from the old power plant to the Ash - La Verkin confluence area has been difficult to explain when discharge versus fish abundance data has been analyzed. Williams (1977) indicated that the discharge from the power plant (which were cooler and "cleaner" than those from Pa Tempe Hot Springs) diluted the Pa Tempe Hot Springs discharge considerably. As I mentioned earlier, Williams (1977) stated that the springs may account for as much as 90% of the flow downstream to the Ash - La Verking confluence during July and August (when the power plant was not discharging). Since the power plant has not been discharging any water the past couple of years, the influence of the springs on the fish (higher temperatures, salinity and conductivity and lower dissolved oxygen) has been extended farther downstream. This could be affecting all phases of the life history of the fish found in this area.

Deacon (1983) reported that woundfin spawning success was excellent during 1983 in nearly every segment of the Virgin River except in the Ash - La Verkin confluence area and that spawning success was poor to absent in all segments of the river during 1984 (Deacon 1985). As I mentioned previously, mean spring flows for 1983 at the Hurricane gauge were the highest (1082 cfs) since the gauge was established, while flows for 1984 were about average (206 cfs). In terms of this study, more data is needed from different flow conditions before comments on spawning success (poor, good, etc.) can be made.

Virgin roundtail chub

Unlike the woundfin, very little information exists for the Virgin chub. Most of the literature deals primarily with its taxonomy and distribution. Major discussions on taxonomy and distribution are found in Miller (1946), Holden and Stalnaker (1970), Minckley (1973), and Cross (1975). Life history and habitat requirements are discussed in La Rivers (1962), Minckley (1973), Deacon and Minckley (1973), Cross (1975), Schumann (1978) and in the Woundfin Recovery Team Monitoring Program reports.

Like the woundfin, the Virgin chub was first collected and described from the Virgin River in Washington County, Utah (Cope and Yarrow 1875). Unlike the woundfin, its historical distribution was restricted to the Virgin River system in Nevada, Arizona and Utah. Presently the Virgin chub (excluding the Moapa River chub) occurs in the Virgin River from Mesquite, Nevada upstream to the Ash - La Verkin confluence area.

Since few historical records exist for the chub, it is difficult to assess changes in abundance over the years. Cross (1975) felt that Virgin chub populations had declined drastically over the past 100 years and cited several reasons to justify this statement. I am not convinced that this is the case. Since 1910 (refer to section on Water Use), the chub in Utah have probably never been very abundant due to the lack of optimum chub habitat in the Virgin River. Schumann (1978) collected Virgin chub primarily from relatively shallow water, but noted that this was due largely to the fact that very few deep-water habitats were present in the Virgin River. Based upon his analysis, Schumann stated that the Virgin chub preferred the deeper water habitats. During the past 75 years, chub populations have probably varied as a result of the precipitation patterns. Deacon and Baugh (1984) reported that the Virgin chub population seemed to be increasing as a result of the successful hatch and survival of young in 1983 (a high water year).

More Virgin chub were probably collected in the first six months of this study (1,180) than in any of the previous studies combined. Most of the previous studies have relied on seining to capture the chub. As previously mentioned, 72% of the chub collected during this study were done so with the use of electrofishing equipment. Seining was most effective during low flow conditions when pools were seinable or when "packing" occurred in isolated habitats. In order to make defendable statements concerning the life history and habitat requirements of the Virgin chub, all habitat types should be sampled at various flow conditions.

Tables 1 through 6 present data on the total number of chub collected in each month during the six sampling periods. As flows increased (October and December) the chub become more difficult to collect, except with an electroshocker (September and November). During July the chub comprised 3% of the total fish collected; in August, 5%; in September, 10%; in October, 1%; in November, 24% and in December, 1%. During November the chub were the second most abundant species collected (Table 5).

A comparison of the sampling data for October between the Woundfin Recovery Team (Deacon 1985) and this study shows that the percent of the chub in the total catch at each area were essentially the same. At the Ash - La Verkin confluence chub comprised 1% of the total catch (station 1 was 1%), at Berry Springs, 0% (station 3 was less than 1%) and at Twin Bridges, 2% (station 5 was 4%).

Densities of Virgin chub populations at each sampling station during the six sampling periods are presented in figure 7. Again, high densities in July and August are correlated with low flow conditions, while the high densities in September and November are correlated with the use of electrofishing equipment. Like the woundfin, chub densities were generally lowest at station 6. Station 6 has only one area (backwater pool) throughout the entire section where chub were consistantly collected. Chub densities were consistantly higher at station 5, the most disturbed section of the river. One chub (96 mm TL) was captured in December from La Verkin Creek about three-quarters of a mile upstream from the confluence of the Virgin River. To my knowledge, no chub have been collected this far up La Verkin Creek.

Size ranges (TL) for all chub collected at each sampling station during the six sampling periods are presented in tables 15 through 20. The percent of chub in each size range did not change significantly from July to December. The dominant size range for every sampling period was 101-150 mm, while the 50-100 mm and 151-200 mm size ranges were next in dominance throughout the sampling periods. Only four chub larger than 351 mm were collected, while no chub less than 50 mm were collected. The largest chub collected measured 396 mm (station 5) and 386 mm (station 3). Optimum habitat for small- to medium-sized chub appeared to be vegetative snags in areas with some current. The chub in this size range were most frequently collected from this type of habitat, especially at station 4, where vegetative snags dominate throughout. Larger chub were collected primarily from deep pool areas. Deep pools (usually formed by boulders) are most abundant at stations 1, 2, 3 and 5. Few large chub were collected from stations 4 and 6 due to the lack of deep pools.

Since information pertaining to growth rates and reproduction of the Virgin chub is generally lacking, it is difficult to assess spawning success. Deacon (1985) did not document successful reproduction at any location in the Virgin River during 1984. However, he did state that the species reproduced successfully throughout the river in 1983. If young-of-the-year chub are less than 50 mm by November, then no evidence of spawning was observed during this study.

Schumann (1978) considered Virgin chub under 100 mm (TL) to be young-of-the-year fish. Since 1983 was reported to be a good year for chub reproduction, and the 101-150 size range was most dominant, I would tentatively label those chub in this size range (and possibly some of those in the 151-200mm range) as being in their second year of life. Based upon this, and the information presented by Schumann (1978), I have tentatively labeled those chub less than 100 mm (during November and December) as young-of-the-year fish.

Table 21 presents the percentage of the total catch consisting of young-of-the-year chub during November and December. Due to age class uncertainty and the few numbers of chub that were collected from some of the stations, this data is preliminary. Spawning success of chub does follow the same trend as that of the woundfin. Spawning was most successful at stations 2, 3 and 4. Station 4 appears to contain the most optimum habitat for spawning and the rearing of young chub. However, since habitat for larger chub is more available at station 3, the fish could have spawned there and the young, drifted downstream to station 4.

Obviously, more information pertaining to the Virgin chub is required in order to identify the habitat requirements for reproduction and determine age classes. Hopefully, this information will be provided by this study, by the Woundfin Recovery Team and any other studies that might be conducted during the next few years.

Exotic Species

At least thirteen different non-native fish species have been reported from the Virgin River system. During 1984 six different exotic fish species were collected from the Virgin River in Utah (Tables 1 through 6). No exotic species were collected at the LaVerkin Creek station. These fish were most abundant below the Washington Fields diversion, the most modified section of the river.

A total of fourteen largemouth bass (Micropterus salmoides) were collected at stations 1 through 6. No specimens over 70mm in length (TL) were collected and the bass were found only during the July and August sampling periods. Although bass are found in reservoirs and ponds within the Virgin River system, it is doubtful that they can survive year 'round in the Virgin River in Utah under present conditions. Cross (1975) collected bass from Santa Clara Creek above Gunlock Reservoir and in the Bloomington area from the Virgin River. Since Cross made his collections, bass have been stocked in ponds along the Virgin River. I have captured bass in La Verkin Creek (1982) during the summer, which had escaped from adjacent ponds.

Three adult black bullhead catfish, Ictalurus melas, (from stations 5 and 6) and one adult channel catfish, Ictalurus punctatus, (from station 5) were collected. It does not appear that the catfish are any more abundant now than when Cross (1975) made his collections. It is not likely that they will become more abundant in the Virgin River (Utah) under present conditions. Their preferred habitat (pools, slow current, cover, etc.) is most nearly met during the summer below Washington Fields diversion.

Thirteen mosquitofish (Gambusia affinis) were collected from station 5. Cross (1975) collected this fish from several areas below the Washington Fields diversion. Even though this species occurs in several ponds along the Virgin River, it does not appear to have increased in abundance during the past ten years. They are found in quiet backwater areas and will probably not increase in abundance in the Virgin River under present conditions.

One cutthroat trout (Salmo clarki) was collected at station 3. This appears to be the first report of any trout collected this far downstream in the Virgin River. It was probably washed downstream from one of the tributary streams where naturally reproducing populations occur. Trout are not able to persist this far downstream in the Virgin River due to high summer temperatures.

A total of fourteen red shiners (Notropis lutrensis) were collected at station 5 and one from station 6. Sampling by the Woundfin Recovery Team and this study during 1984 documented the first collections of red shiners from the Virgin River in Utah. The ability for this species to withstand high temperatures, high turbidities and low flows accounts for its success in certain areas of the Virgin River (Cross 1975). At Mesquite and Riverside, Nevada, the red shiner has increased in abundance over the past ten or fifteen years to a point where it clearly dominates (during lower flow years) the samples from these areas. The red shiner and woundfin occur sympatrically in the Virgin River and probably competitively interact. Usually where one is abundant, the other is reduced in number (Williams 1977). The red shiner presents a serious threat to the woundfin, especially in habitats that have been modified, and should be monitored.

Future reports will analyze the change in abundance anticipated by these exotic species under various flow regimes.

Of interest is the collection of three spiny softshell turtles (*Trionyx spiniferus*) during October, 1984 at station 4. All were less than 60mm (from snout to rear) and were collected along a mud bank with a seine. There are reports of large turtles being collected from the Virgin River in Utah; however, no other turtles were seen or collected during this study.

Parasitism

The copepod _Lernaea_ and an unidentified leech were found on 50 to 85% of the woundfin and chub collected at station 6. About 15% of the woundfin and chub at station 5 contained these parasites. Only about 1 to 2% of the fish from the other stations exhibited parasitism. Rarely were parasites found on fish other than woundfin or chub. These external parasites were found primarily at the base of the dorsal fin; occasionally they were found on the pectoral, pelvic, anal and caudal fins or on the side of the body.

The incidence of parasitism appeared to decrease as water temperatures decreased and flows increased. Fish collected from pools (during low flows) under crowding conditions seemed to produce the highest incidence of parasites. Cross (1975) reported _Lernaea_ from fish collected in Arizona and from areas outside of the woundfin and chub range in Utah. These were found primarily on desert suckers. During September, 1983, Randy Radant (UDWR), Mike Coffeen (UDWR) and myself found _Lernaea_ at the base of the dorsal fin on 10% of the chub collected below the Santa Clara Creek confluence. No _Lernaea_ were found at other locations during the sampling trip.

At this time it is unknown why the parasites are so dominant at station 6 and why they are found only on the chub and woundfin (with a few minor exceptions). One possibility is the sewage treatment outflow which enters Santa Clara Creek near its confluence with the Virgin River. It is possible that something besides the sewage treatment outflow may be causing the problem. Low flows, which produce crowding and stress, could be a factor, but flows are lower and crowding is more prevelant at station 5, yet the incidence of parasitism is lower. Other potential sources include Gunlock Reservoir on Santa Clara Creek, irrigation return flow at Ft. Pierce Wash or seepage in the Bloomington area. This situation will be monitored during the course of this study.

Habitat Model

For a detailed discussion on the habitat model (rationale, development, methods, etc.) the reader should refer to the study plan outline distributed in April, 1984. Following is a discussion on the progress of this model during 1984.

The intent of the habitat sampling effort is to provide an acceptably calibrated Instream Flow Group - 4 (IFG-4) data set from each of the study stations for three flows (high, medium and low). In addition to this quantitative sampling effort, additional transects at each station are being collected for key microhabitats. Standard IFG-4 single transect data was collected from each station for the low flow period during August, 1984. Habitat data for the high and medium flow will be collected during 1985. By nature of the data entry process and analysis, these data will be reduced as a set after the final transects have been collected.

Model development has progressed according to first principals with establishment of a fisheries data entry and retrival system. The system is designed to reproduce the field sampling forms and to provide a wide latitude of user options on selected statistics. These include sort routines and user specified format output files. These latter files can be used to access a variety of computer statistical packages and plotting routines. The key elements for the evaluation of the relative suitability of specific habitat cells is complete and methods of integrating habitat availability for serial time dependent trends in the decision analysis are being explored. Operational limits for the boundaries of each decision are being examined.

It is anticipated that a draft model formulation in terms of parameters, their limits and the evaluation criterion, will be available for review at the annual meeting with the USFWS and UDWR.

Water Quality

Water quality parameters do not vary significantly from station to station; however they can vary significantly from one day to the next as a result of the variability of flows exhibited by the Virgin River. Localized areas of differing water quality exists (tributaries, springs and irrigation return flows) but they do not have a significant impact on the Virgin River because of the mixing that takes place in a relatively short distance upon entrance to the river.

The Pa Tempe Hot Springs does have a significant effect upon the water quality of the Virgin River for at least two miles downstream. The effect is even more dramatic during low flow conditions when the springs may comprise the majority of the flow in the river down to the Ash and La Verkin Creek confluence. Essentially Pa Tempe Hot Springs increases the salinity, conductivity and temperature of the river while decreasing the dissolved oxygen. As a result, no fish are found in the immediate vicinity of the springs and the springs prevents the upstream movement of woundfin and chub.

Williams (1977) measured selected water quality parameters at the springs and compared them with measurements made above the Ash and La Verkin Creek confluence at the power plant (approximately one and one-half miles downstream). These measurements were made in September and October, 1976, during low flow conditions. The following mean values were recorded at the springs: conductivity - 17,225 (umhs/cm); oxygen - 0.9 (ppm); temperature - 39.7°C; pH - 6.8; and salinity - 7.4 (ppt). The following mean values were recorded at the power plant: conductivity - 2250 (umhs/cm); oxygen - 8.4 (ppm); temperature - 18.5°C; pH - 7.0; and salinity - 0.8 (ppt). Values for the springs appear to be constant throughout the year.

Mean values for conductivity measurements taken between Sept. and Dec., 1984 showed a slight increase in a downstream direction. This is probably attributed to soil-leaching flows which enter the river from irrigation return flows and during runoff. The lowest conductivity measurements were recorded from LaVerkin Creek (mean of 1,500 umhs/cm). The highest readings were 2,200 (umhs/cm), recorded at stations 5 and 6. The irrigation return flow at station 5 had readings of 2,200 (umhs/cm).

Because the Virgin River transports large quantities of silt and clay-sized particles in suspension and sand-sized sediment as bedload, it is usually very turbid. The turbidity increases dramatically during the spring runoff and during periods of thunderstorm activity. No significant difference was noted in turbidity values between stations during the monthly sampling (although La Verkin Creek measurements were always low). Values did differ, however, from month to month. The values ranged from 35 (ftu) to 450 (ftu). The irrigation return flow at station 5 varied from 75 (ftu) to 430 (ftu).

The pH values varied from 7.5 to 8.8 with an overall average of 8.0 during monthly measurements. There was a slight trend for pH to increase in a downstream direction. This was probably due to irrigation return flows which tended to have a slightly higher pH.

Water temperatures varied considerably between July and December, 1984. The lowest water temperature at which fish were collected was 4°C (air was 2°C) during December and the highest was 33°C (air was 39°C) during July. All six native fish species were collected at these temperature extremes. Usually water temperatures varied less than 10°C throughout the day while air temperatures varied by as much as 20°C. Although the sampling stations are located a considerable distance apart, there was little variation in water temperatures between stations during the monthly sampling period.

I am in the process of placing a thermograph (continuous recording for six months) in the river. Difficulties have been encountered in finding a suitable location where the thermograph will not be buried under several feet of sediment, left exposed out of the water or vandalized. Once the thermograph is in place, I intended to monitor diurnal and seasonal fluctuations in temperature.

During 1985 I intend to add the following water quality measurements at each station: dissolved oxygen, total nitrogen and total reactive phosphorus.

Literature Cited

Adams, F. 1903. Agriculture under irrigation in the basin of Virgin River. In: Report of irrigation investigations in Utah. Office of Exp. Stat., U.S.D.A. Bul. No. 124. 330 pp.

Bolton, H.E. 1950. Pageant in the wilderness, the story of the Escalante Expedition to the Interior Basin, 1776. Utah Hist. Quart. 18: 1-265.

Cope, E.D. and H.C. Yarrow. 1875. Report upon the collections of fishes made in portions of Nevada, Utah, California, Colorado, New Mexico and Arizona, during the years 1871, 1872, 1873 and 1874. Rept. Geog. Geol., Expl. and Surv. W. 100th Merid. (Wheeler Survey), 5: 635-703.

Crampton, C.G. 1972. Land of living rock. Alfred A. Knopf Co., New York.

Cross, J.N. 1975. Ecological distribution of the fishes of the Virgin River (Utah, Arizona, Nevada). M.S. Thesis, Univ. Nevada, Las Vegas. 187 pp.

Deacon, J.E. 1983. Annual report of monitoring activities by the Woundfin Recovery Team during 1982 and 1983. Environ. Consl., Inc., Las Vegas, Nevada.

_________. 1985. Fish population monitoring activities by the Woundfin Recovery Team in the Virgin River, Utah, Arizona, Nevada, on April 18 and October 5, 1984. Environ. Consl., Inc., Las Vegas, Nevada.

_________ and T.M. Baugh. 1984. Fish population monitoring activities by the Woundfin Recovery Team, Virgin River, Utah, Arizona, Nevada, April 18, 1984. Environ. Consl., Inc., Las Vegas, Nevada.

_________ and T.B. Hardy. 1982. Streamflow requirements of woundfin (*Plagopterus argentissimus*): Cyprinidae in the Virgin River, Utah, Arizona, Nevada. Festschrift for Walter W. Dalquest. Dept. Bio., Midwestern St. Univ. pp 45-56.

_________ and W.L. Minckley. 1973. A review of information on the woundfin, *Plagoterus argentissimus* (Pisces; Cyprinidae). Progress Rept. to U.S. Bur. Sport. Fish. Wild., Salt Lake City, Ut. 38 pp.

Glancy, P.A. and A.S. Van Denburgh. 1969. Water resource appraisal of the lower Virgin River valley area, Nevada, Arizona, and Utah. U.S.G.S., Wat. Res. Recon. Ser. Rept. 51.

Greger, P. and J.E. Deacon. 1982. Some observations of woundfin spawning and growth in an outdoor experimental stream. Great Basin Nat. 42(4) 549-552.

Hinton, W.H. 1961. Soil and water conservation in Washington County. M.S. Thesis. Univ. Utah, Salt Lake City. 105 pp.

Holden, P.B. and C.B. Stalnaker. 1970. Systematic studies of the cyprinid genus *Gila*, in the upper Colorado River basin. Copeia 1970(3): 409-420.

La Rivers, I. 1962. Fishes and fisheries of Nevada. Nevada State Print. Off., Carson City.

Larson, K.A. 1961. "I was called to Dixie." The Virgin River basin: unique experiences in Mormon pioneering. The Deseret News Press. 681 pp.

Lockhart, J.N. 1979. Ecology of the woundfin minnow, Plagoterus argentissimus. M.S. Thesis, Univ. Nevada, Las Vegas. 187 pp.

Miller, R.R. 1946. Gila cypha, a remarkable new species of cyprinid fish from the Colorado River in Grand Canyon, Arizona. J. Wash. Acad. Sci. 36(12): 409-415.

Minckley, W.L. 1973. Fishes of Arizona. Arizona Game and Fish Dept. 293 pp.

Morgan, D.L. 1953. Jedediah Smith and the opening of the West. Univ. Nebraska Press, Lincoln.

Peters, E.J. 1970. Changes with growth in selected body proportions of the woundfin (Plagopterus argentissimus: Cyprinidae). M.S. Thesis, Brigham Young Univ., Provo, Utah. 25 pp.

Schumann, P.B. 1978. Responses to temperature and dissolved oxygen in the roundtail chub, Gila robusta. M.S. Thesis, Univ. Nevada, Las Vegas. 79 pp.

Steward, J.H. 1938. Basin - Plateau aboriginal sociopolitical groups. U.S. Govt. Print. Off., Wash. D.C.

Williams, J.E. 1977. Adoptive responses of woundfin, Plagoterus argentissimus, and the red shiner, Notropis lutrensis, to a salt spring and their probable effects on competition. M.S. Thesis, Univ. Nevada, Las Vegas 91 pp.

Woodbury, A.M. 1950. A history of southern Utah and its national parks. Utah St. Hist. Soc. 12(3-4): 107-224.

U.S. Fish and Wildlife Service. 1984. Recovery Plan for the woundfin (Plagopterus argentissimus). Albuquerque, New Mexico.

APPENDIX A

(Figures 1-7)

Figure 1. Map of the study area with the locations of the sampling stations, major diversions and gauging stations.

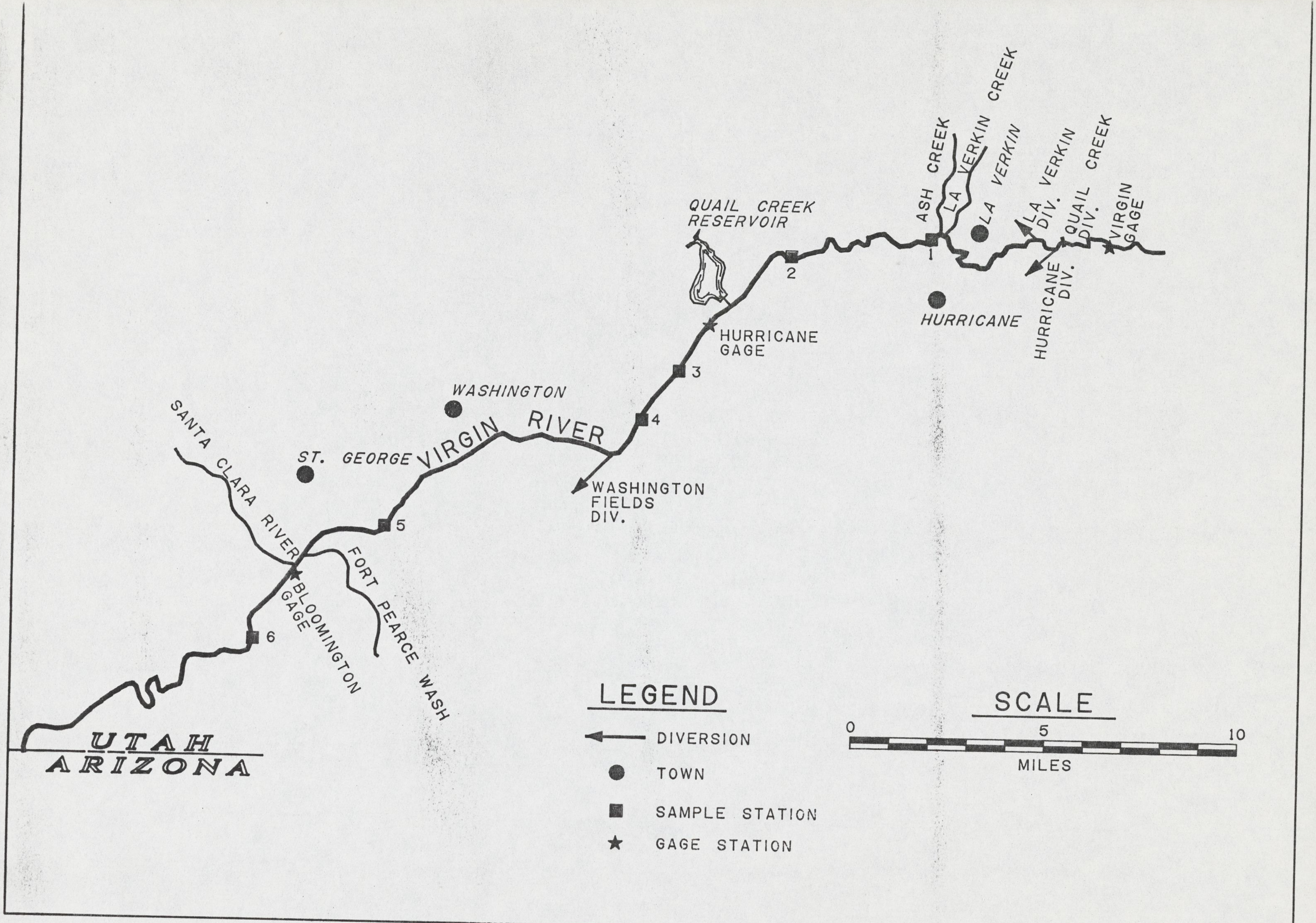

QUAIL CREEK RESERVOIR
ASH CREEK
LA VERKIN CREEK
LA VERKIN
LA VERKIN DIV.
QUAIL CREEK DIV.
VIRGIN GAGE
1
2
HURRICANE
HURRICANE DIV.
HURRICANE GAGE
3
4
WASHINGTON
VIRGIN RIVER
ST. GEORGE
WASHINGTON FIELDS DIV.
SANTA CLARA RIVER
5
FORT PEARCE WASH
BLOOMINGTON GAGE
6
UTAH
ARIZONA
LEGEND
DIVERSION
TOWN
SAMPLE STATION
GAGE STATION
SCALE
0
5
10
MILES

Figure 2. Mean monthly discharge of the Virgin River at the Hurricane (1967-1984) and Bloomington (1977-1983) gauges. Jan. is number 1 and Dec. is number 12.

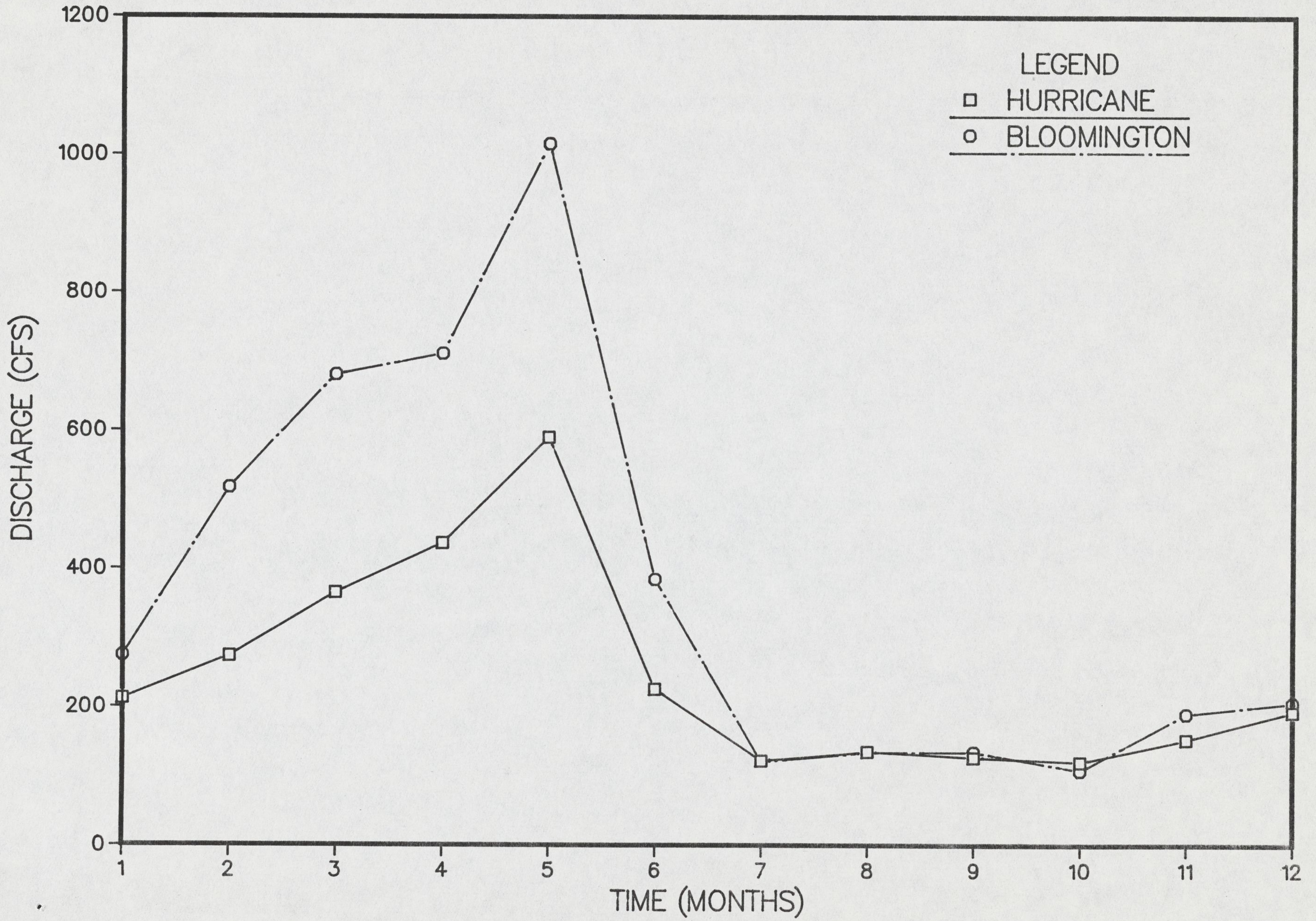


Figure 3. Mean monthly discharge of the Virgin River at the Hurricane gauge from March, 1967 through September, 1984. Longer lines represent January.

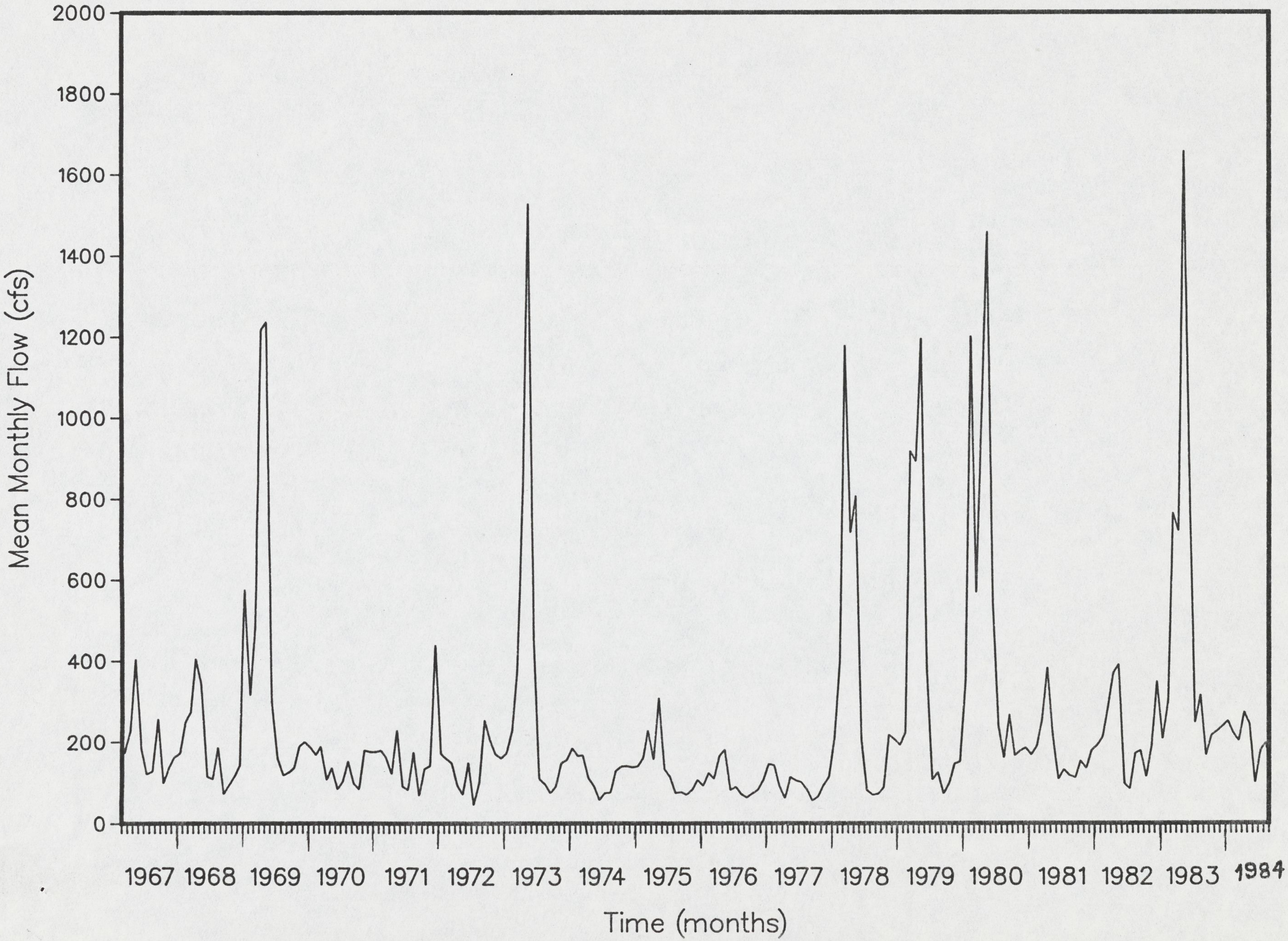


Figure 4. Mean monthly discharge of the Virgin River at the Bloomington gauge from October, 1977 through September, 1983.

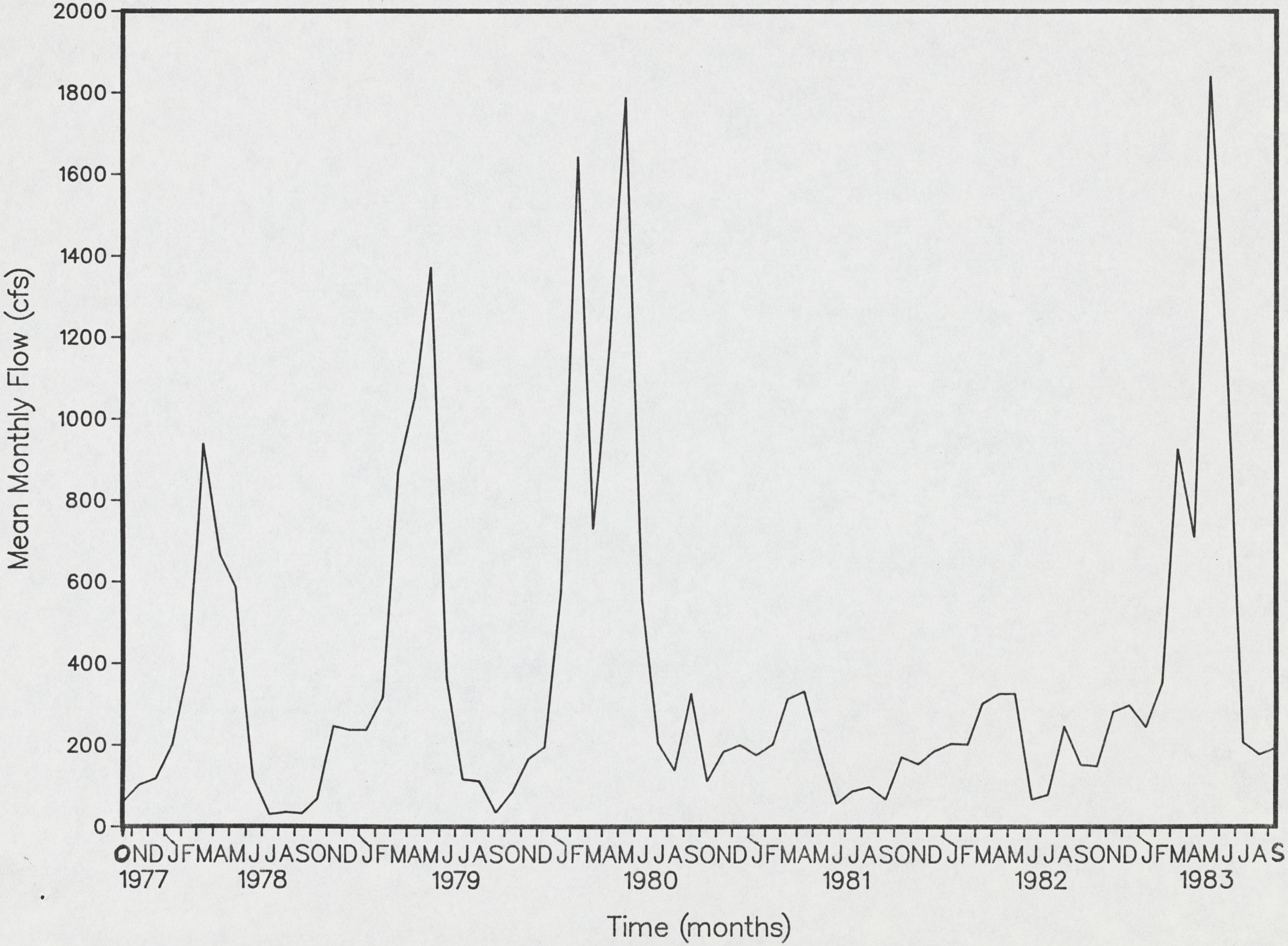


Figure 5. Density of all fish collected at each sampling station. Station 1 is on the left and 6 is on the right. Seines were used during July, Aug., Oct. and Dec., electroshocking in Nov., and seining and electroshocking in Sept.

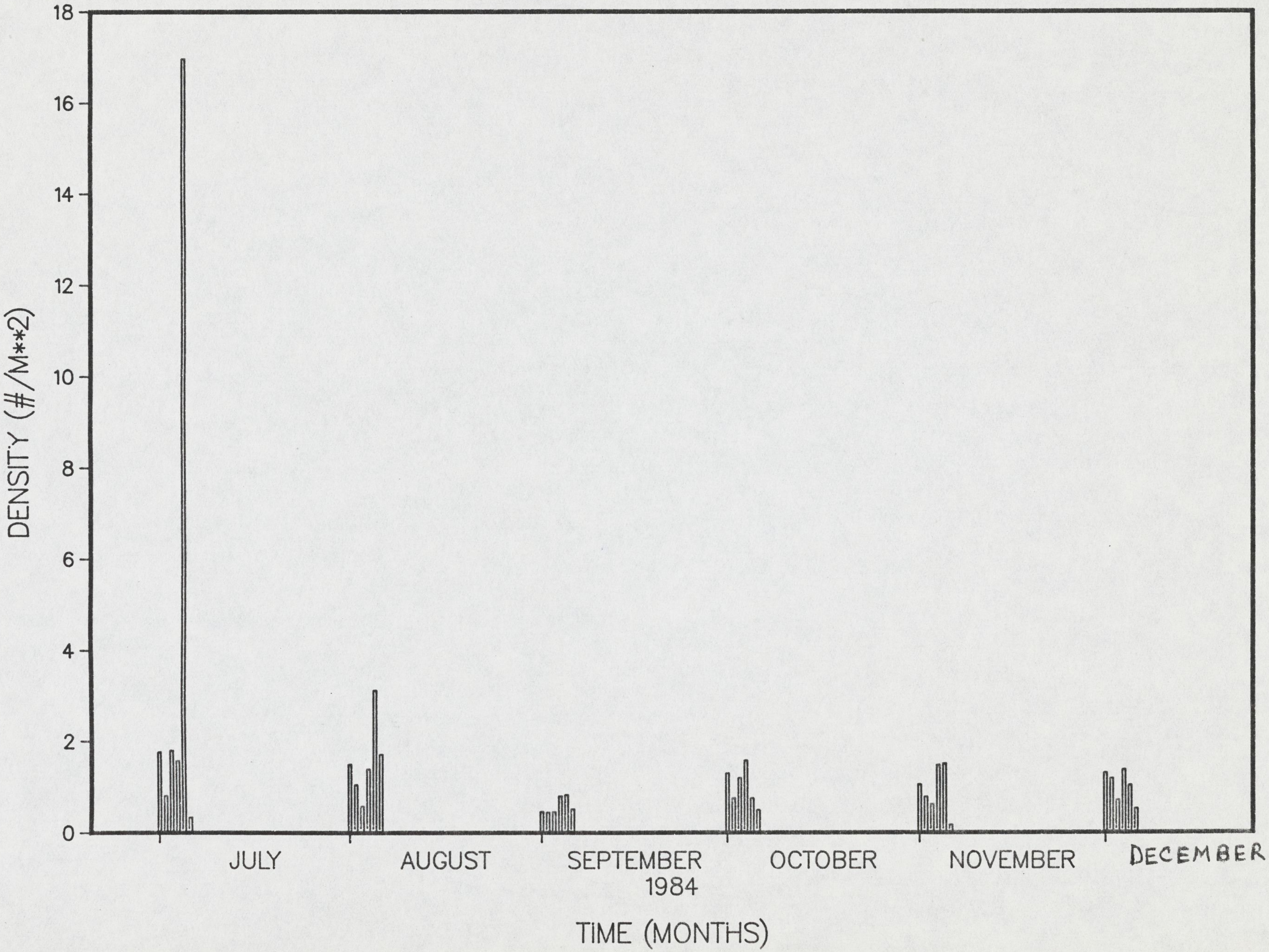


Figure 6. Density of woundfin populations at each sampling station. Station 1 is on the left and 6 is on the right. Seines were used during July, Aug., Oct. and Dec., electroshocking in Nov. and seining and electroshocking in Sept.

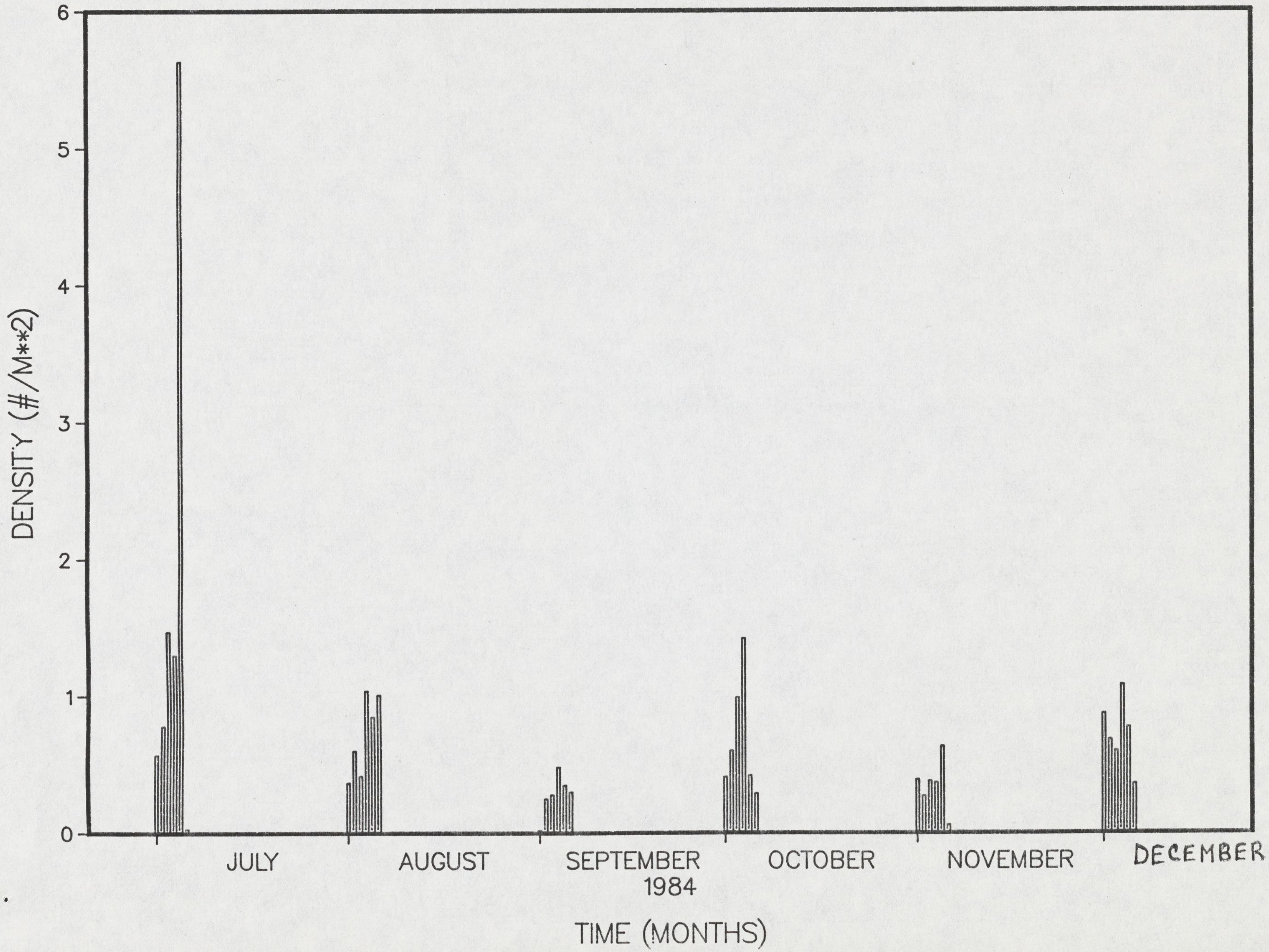
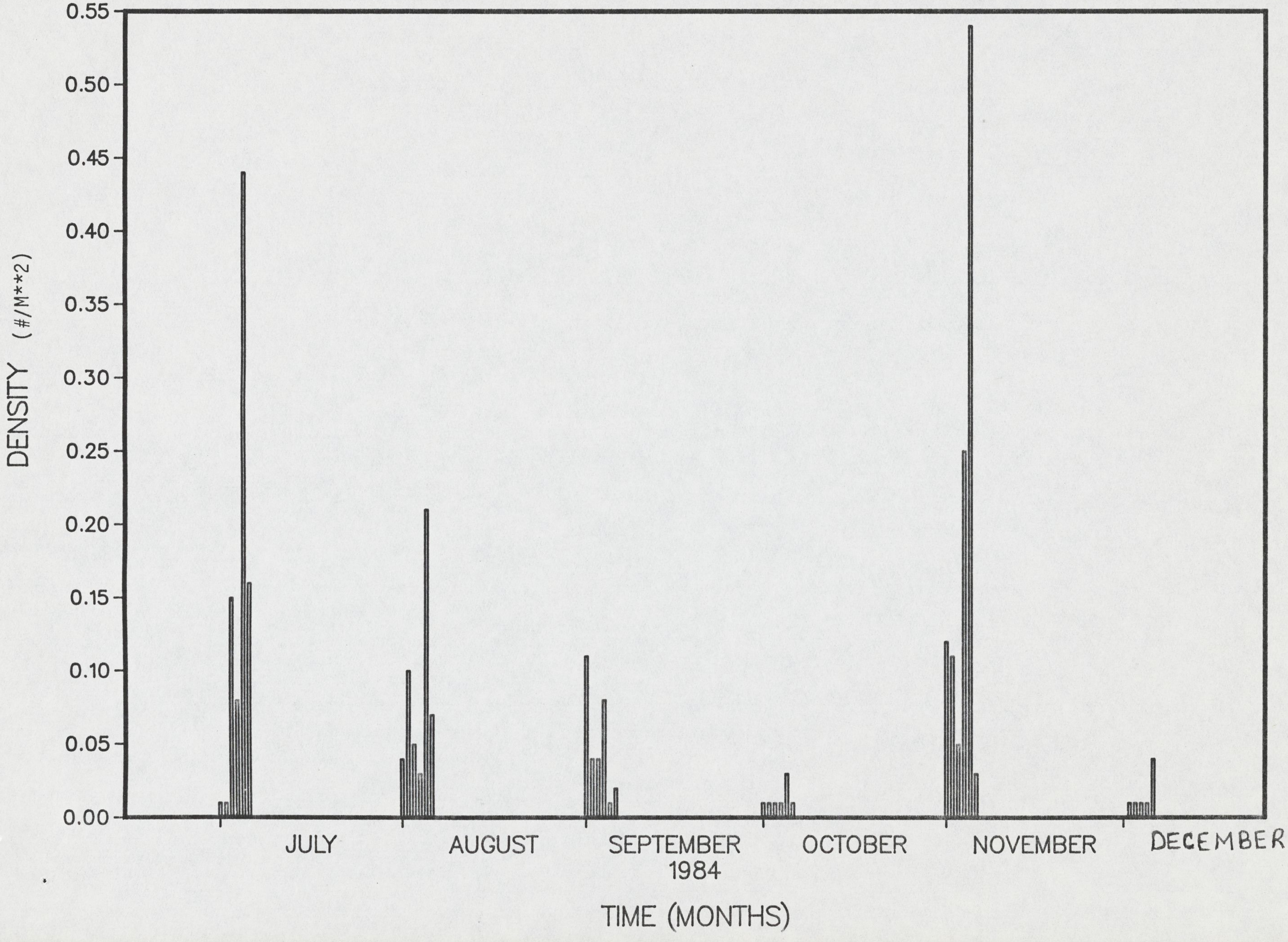


Figure 7. Density of Virgin chub populations at each sampling station. Station 1 is on the left and 6 is on the right. Seines were used during July, Aug., Oct. and Dec., electroshocking in Nov. and seining and electroshocking in Sept.



APPENDIX B

(Tables 1-21)

Table 1. Total number of species collected during July, 1984 (seining only).

Species	Station 1	2	3	4	5	6	Total
woundfin	61	127	206	218	1183	3	1798
speckeled dace	14	3	2	16	392	4	431
flannel sucker	41	9	9	6	349	2	416
desert sucker	3	1	4	9	1571	11	1599
spine dace	79	0	9	1	0	0	89
chub	1	1	19	14	105	13	153
lg. mouth bass	2	1	1	1	7	0	12
Totals	201	142	250	265	3607	33	4498

Table 2. Total number of species collected during Aug., 1984 (seining only).

Species	Station 1	2	3	4	5	6	Total
woundfin	89	132	78	170	175	172	816
speckeled dace	100	13	11	63	53	24	264
flannel sucker	39	29	8	2	77	9	164
desert sucker	30	18	3	1	268	74	394
spine dace	71	31	0	0	0	0	102
chub	9	22	10	5	42	8	96
lg. mouth bass	0	0	0	1	1	0	2
black bullhead catfish	0	0	0	0	0	1	1
Totals	338	245	110	242	616	288	1839

Table 3. Total number of species collected during Sept., 1984 (seining and electrofishing).

Species	Station 1	2	3	4	5	6	Total
woundfin	9	133	158	186	219	81	786
speckeled dace	12	19	42	53	108	14	248
flannel sucker	115	77	14	20	32	3	261
desert sucker	103	60	30	17	35	38	283
spine dace	22	2	0	0	0	0	24
chub	84	28	26	28	5	5	174
channel catfish	0	0	0	0	1	0	1
red shiner	0	0	0	0	2	0	2
Totals	345	317	270	304	402	141	1779

Table 4. Total number of species collected during Oct., 1984 (seining only).

Species	Station								
	La Verkin	1	2	3	4	5	6	State Line	Total
woundfin	27	199	343	534	788	267	145	47	2350
speckel dace	39	40	25	43	30	119	19	5	320
flannel sucker	27	69	29	25	21	24	5	3	203
desert sucker	5	62	25	44	30	66	70	8	310
spine dace	29	252	3	0	0	0	0	0	284
chub	0	7	5	3	1	20	3	3	42
red shiner	0	0	0	0	0	6	1	2	9
gambusia	0	0	0	0	0	11	0	0	11
Totals	127	629	430	649	870	513	243	68	3529

Table 5. Total number of species collected during Nov., 1984 (electrofishing only).

Species	Station 1	2	3	4	5	6	Total
woundfin	168	115	142	168	339	37	969
speckeled dace	30	54	19	116	68	11	298
flannel sucker	87	86	30	163	88	7	461
desert sucker	34	19	28	130	105	19	335
spine dace	66	5	0	3	0	0	74
chub	46	44	22	120	421	20	673
red shiner	0	0	0	0	1	0	1
black bullhead catfish	0	0	0	0	1	0	1
cutthroat trout	0	0	1	0	0	0	1
Totals	431	323	242	700	1023	94	2813

Table 6. Total number of species collected during Dec., 1984 (seining only).

Species	Station							
	1	2	3	4	5	6	La Verkin	Total
woundfin	510	408	335	590	473	192	31	2539
speckel dace	25	60	36	72	65	22	29	309
flannel sucker	56	65	8	18	20	13	64	244
desert sucker	61	170	21	68	59	28	60	467
spine dace	108	4	0	0	0	0	141	253
chub	0	4	1	4	9	23	1	42
red shiner	0	0	0	0	5	0	0	5
gambusia	0	0	0	0	2	0	0	2
black bullhead catfish	0	0	0	0	0	1	0	1
Totals	760	711	401	752	633	279	326	3862

Table 8. woundfin size ranges (mm) for Aug., 1984 (seining only).

Size Range	Station 1	2	3	4	5	6	Total
∠30	0	0	6	3	0	0	9
30 - 40	0	11	27	6	0	1	45
41 - 50	1	5	0	2	0	0	8
51 - 60	12	34	14	94	13	4	171
61 - 70	55	59	20	59	103	87	383
71 - 80	18	18	6	6	55	77	180
81+	3	5	5	0	4	3	20
Total	89	132	78	170	175	172	816

Table 7. woundfin size ranges (mm) for July, 1984 (seining only).

Size Range	Station 1	2	3	4	5	6	Total
∠30	0	0	0	0	0	0	0
30 - 40	0	0	4	2	0	0	6
41 - 50	0	3	5	18	0	0	26
51 - 60	1	74	125	125	32	0	356
61 - 70	27	38	66	55	72	1	259
71 - 80	29	11	7	14	12	3	76
81+	10	0	1	4	4	0	19
Total	67	126	208	218	120*	3	742

* 1183 woundfin were collected, but only 120 were measured.

Table 10. woundfin size ranges (mm) for Oct., 1984 (seining only).

Size Range	Station 1	2	3	4	5	6	La Verkin	State Line	Total
<30	0	0	0	0	0	0	0	0	0
30 - 40	0	6	83	82	0	0	0	0	171
41 - 50	2	64	86	88	3	13	0	0	256
51 - 60	4	18	97	262	16	6	0	4	407
61 - 70	79	141	197	286	183	51	7	14	958
71 - 80	94	88	42	47	58	68	14	28	439
81+	20	26	29	23	7	7	6	1	119
Total	199	343	534	788	267	145	27	47	2350

Table 9. woundfin size ranges (mm) for Sept., 1984 (seining and electrofishing).

Size Range	Station 1	2	3	4	5	6	Total
<30	0	0	0	0	0	0	0
30 - 40	0	12	14	37	1	0	64
41 - 50	0	32	6	17	1	3	59
51 - 60	0	3	21	61	19	0	104
61 - 70	4	59	71	58	123	30	345
71 - 80	1	20	31	9	67	46	174
81+	4	7	15	4	8	2	40
Total	9	133	158	186	219	81	786

Table 12. woundfin size ranges (mm) for Dec., 1984 (seining only).

Size Range	Station 1	2	3	4	5	6	La Verkin	Total
≤30	0	0	0	0	0	0	0	0
30 - 40	1	14	58	80	2	0	0	155
41 - 50	14	92	62	55	2	0	0	255
51 - 60	21	41	55	192	25	5	0	339
61 - 70	278	155	112	201	282	58	5	1091
71 - 80	154	88	30	39	154	116	15	596
81+	42	18	18	23	8	13	11	133
Total	510	408	335	590	473	192	31	2539

Table 11. woundfin size ranges (mm) for Nov., 1984 (electrofishing only).

Size Range	Station 1	2	3	4	5	6	Total
≤30	0	0	0	0	0	0	0
30 - 40	0	0	7	1	0	0	8
41 - 50	1	11	4	8	1	0	25
51 - 60	1	13	17	59	12	0	102
61 - 70	60	51	70	77	158	7	423
71 - 80	79	37	30	18	149	25	338
81+	27	3	14	5	19	5	73
Total	168	115	142	168	339	37	969

Table 13. mean monthly spring flows (cfs) at the Hurricane gage for the period of record (1967-1984).

Water Year	April	May	June	Average
1967	227	405	183	152
1968	406	344	115	288
1969	1,218	1,236	300	918
1970	109	138	90	112
1971	123	230	92	148
1972	94	72	150	105
1973	814	1,527	461	934
1974	112	93	59	88
1975	158	309	133	200
1976	167	182	63	137
1977	63	115	106	95
1978	717	807	206	577
1979	893	1,195	383	824
1980	1,018	1,458	550	1,009
1981	383	219	110	237
1982	370	391	98	286
1983	721	1,657	869	1,082
1984	274	244	101	206

Table 14. Percent of total catch consisting of Y-O-Y woundfin (<51mm) during Oct. and Dec., 1984 (seining only).

Station	Oct.	Dec.
La Verkin Creek	0%	0%
1	1%	3%
2	21%	26%
3	32%	36%
4	21%	23%
5	1%	1%
6	9%	0%

Table 16. chub size ranges (mm) for Aug., 1984 (seining only).

Size Range	Station 1	2	3	4	5	6	Total
<50	0	0	0	0	0	0	0
50 - 100	0	5	0	3	5	0	13
101 - 150	1	9	2	1	35	2	50
151 - 200	0	5	1	1	0	4	11
201 - 250	6	3	4	0	2	2	17
251 - 300	1	0	2	0	0	0	3
301 - 350	1	0	0	0	0	0	1
351+	0	0	1	0	0	0	1
Total	9	22	10	5	42	8	96

Table 15. chub size ranges (mm) for July, 1984 (seining only).

Size Range	Station 1	2	3	4	5	6	Total
<50	0	0	0	0	0	0	0
50 - 100	0	1	6	12	0	0	19
101 - 150	1	0	10	1	13	11	36
151 - 200	0	0	2	0	18	2	22
201 - 250	0	0	1	1	17	0	19
251 - 300	0	0	0	0	2	0	2
301 - 350	0	0	0	0	0	0	0
351+	0	0	0	0	0	0	0
Total	1	1	19	14	50*	13	98

* collected 105 chub, but only measured 50.

Table 18. chub size ranges (mm) for Oct., 1984 (seining only).

Size Range	Station						
	1	2	3	4	5	6	Total
< 50	0	0	0	0	0	0	0
50 - 100	0	4	1	1	1	0	7
101 - 150	2	14	0	2	4	5	27
151 - 200	1	0	0	0	0	2	3
201 - 250	0	0	0	0	0	0	0
251 - 300	0	2	0	0	0	0	2
301 - 350	0	0	0	0	0	0	0
350+	0	0	0	0	0	0	0
Total	3	20	1	3	5	7	39

Table 17. chub size ranges (mm) for Sept., 1984 (electrofishing and seining).

Size Range	Station						
	1	2	3	4	5	6	Total
< 50	0	0	0	0	0	0	0
50 - 100	2	2	4	11	0	3	22
101 - 150	15	15	11	12	1	2	56
151 - 200	17	2	3	2	1	0	25
201 - 250	31	4	5	2	1	0	43
251 - 300	10	4	2	1	1	0	18
301 - 350	8	1	0	0	0	0	9
351+	1	0	1	0	1	0	3
Total	84	28	26	28	5	5	176

Table 20. chub size ranges (mm) for Dec., 1984 (seining only).

Size Range	Station 1	2	3	4	5	6	La Verkin	Total
< 50	0	0	0	0	0	0	0	0
50 - 100	0	1	1	4	0	1	1	8
101 - 150	0	3	0	0	6	21	0	30
151 - 200	0	0	0	0	2	1	0	3
201 - 250	0	0	0	0	1	0	0	1
251 - 300	0	0	0	0	0	0	0	0
301 - 350	0	0	0	0	0	0	0	0
351+	0	0	0	0	0	0	0	0
Total	0	4	1	4	9	23	1	42

Table 19. chub size ranges (mm) for Nov., 1984 (electrofishing only).

Size Range	Station 1	2	3	4	5	6	Total
< 50	0	0	0	0	0	0	0
50 - 100	1	13	6	49	13	3	85
101 - 150	22	30	8	46	249	15	370
151 - 200	3	0	1	4	88	2	98
201 - 250	7	0	4	15	62	0	88
251 - 300	10	1	2	6	9	0	28
301 - 350	3	0	1	0	0	0	4
351+	0	0	0	0	0	0	0
Total	46	44	22	120	421	20	673

Table 21. Percent of total catch consisting of Y-0-Y Virgin chub (<101 mm) during November and December, 1984.

Station	Nov.[a]	Dec.[b]
La Verkin Creek	*	0%
1	2%	0%
2	30%	25%
3	27%	100%
4	41%	100%
5	3%	0%
6	15%	4%

a - collections by electrofishing

b - collections by seining

* - did not sample

To Bob Behnke

Reprint from the *Proceedings of the Utah Academy of Sciences, Arts, and Letters*, vol. 51, part 2. 1974

THREATENED FISHES OF UTAH

Paul Holden—Chairman[1]

William White, Gary Somerville,
Donald Duff, Robert Gervais, and Steve Gloss

Introduction

The following report catalogs those species and populations of fish that are endangered or threatened in Utah. Definitions of endangered and threatened species follow the Endangered Species Act of 1973, P. L. 93-205. An endangered species is "any species (or subspecies) which is in danger of extinction throughout all or a significant portion of its range." Threatened species are defined as "any species (or subspecies) which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." These definitions require knowledge of natural ranges and population abundance and indicate that significant reductions in range and/or abundance should be determined for placement in either category. A third term, indeterminate status, will be used where knowledge is lacking for placement into one of the other categories but the species is thought to be rare.

These definitions apply to river systems, not political boundaries, for fish. Therefore, we need to differentiate between endangered species and endangered populations which are rare only in a particular area (Utah) and not throughout most of their natural range.

Each species will be discussed in five categories:

1. *Description.* A general description of the species and characteristics separating it from similar and/or often confused species.
2. *Documentation.* This section will examine the decrease in range and/or abundance that has initiated the rare classification. It will give original range and abundance or the most complete knowledge of such available. Present natural populations will be documented, with emphasis on those in Utah. Areas most important for reproduction will be mentioned, if known.

---

1. Utah Fishes Committee, Bonneville Chapter, American Fisheries Society, 2586 Country Oaks Drive, Layton, Utah 84041.

3. *Factors Influencing Decline.* Reported important factors influencing the decline of separate species or species inhabiting similar environments will be presented.
4. *Recent Studies.* Current or recently completed research will be noted.
5. *Recommendations.* General recommendations for chapter support of paths of future research will be made. It is understood that the life histories of many rare fishes have not been elucidated to any great extent. We generally recommend, however, that support for rare fishes be used for population status research first and for life history studies secondarily.

Cutthroat Trout

It must be emphasized that population trends are paramount in separating cutthroat subspecies; thus individual specimens may not be distinguishable. Identification of possible "pure" populations is definitely difficult for persons unfamiliar with cutthroat subspecies. Dr. Robert Behnke, Colorado State University, is available for classification of cutthroat populations and currently is the authority for identification of specimens.

Salmo clarki pleuriticus—Colorado Cutthroat Trout

Status: Endangered subspecies
Description: There are virtually no published descriptions of the Colorado cutthroat trout. Behnke (1973) gives the following characters: "Spots, large and pronounced, concentrated mainly posteriorly; scales in lateral series (counted two rows above lateral line) 175-200+; scales above lateral line 38-48; vertebrae 61-63; pyloric caeca, mean values typically 30-40; gillrakers, 18-22; basibranchial teeth present, typically 1-15. Coloration may be gaudy, particularly on males in breeding season, red-crimson and orange and yellow colors emphasized. In some specimens, whole ventral region may be crimson."
Documentation: Original range of the Colorado cutthroat trout was the upper Colorado River basin of Wyoming, Colorado, Utah, and New Mexico. In Utah the Uinta Mountains and plateaus draining into the Green River as far south as the Dirty Devil River contained this subspecies (Behnke, 1973). Presently in Utah it is known only in the Little West Fork of the Blacks Fork River, Summit County. It is also found in three Wyoming and three Colorado streams, all small headwaters.

Salmo clarki utah–Utah Cutthroat Trout

Status: Endangered subspecies
Description: Utah cutthroat were originally described from Utah Lake by Suckley (1874) as a large-scaled, silvery fish with small, irregular spots. These characters may have been greatly influenced by the lacustrine conditions. Behnke (1973) characterizes Utah cutthroat trout as follows: "... scale counts (36-42 above lateral line and 145-180 in the lateral series ...) and the vertebral counts (typical modal values of 62-63 ...)." No other descriptions of Utah cutthroat are known. Lemon-yellow cutthroat slash marks appear to be a distinguishing character of freshly caught specimens. Biochemical analysis of genetic characteristics of Utah cutthroat (Utah State University) shows distinct differences from Yellowstone cutthroat trout or rainbow trout influenced populations.
Documentation: Utah cutthroat were found throughout the Bonneville basin of Utah, Wyoming, Idaho, and Nevada. An exception is Snake Valley of Utah and Nevada, which appears to have a distinct subspecies. Known populations in Utah are from Water Canyon and a small tributary of Reservoir Canyon, Washington County; an isolated tributary of Little Cottonwood Creek near Salt Lake City; and Birch Creek near Beaver. Another population is found in Thomas Fork of Bear River, Lincoln County, Wyoming.

Salmo clarki subsp.–Snake Valley or Mt. Wheeler Cutthroat Trout

Status: Endangered subspecies
Description: The Snake Valley cutthroat was recently determined to be a separate subspecies. Therefore, little is known of this form and descriptions are lacking. Behnke (1973) analyzed the available specimens and described it thusly: chunky, long head and dorsal fin, 15-50 basibranchial teeth ($\overline{X}$ = 25-28), gillrakers 19-23 and lateral line scales 145-180 but usually 145-150. Since the range of this form is within the Bonneville basin, it may be confused with the Utah cutthroat. Spots are more evenly distributed over body, more basibranchial teeth, more gillrakers (18-21 in Utah cutthroat) and fewer lateral line scales (145-180 for Utah cutthroat) in Snake Valley cutthroat.
Documentation: Apparently this fish was originally found only in the Trout Creek drainage of Snake Valley, Utah, and Nevada. In the late 1800s fish from Trout Creek were stocked into troutless, small, internally drained basins in Nevada (Behnke, 1973). It is from one of these, Pine Creek, White Pine County, Nevada, that this trout was first identified. Later investigations found it in isolated tributaries of Trout Creek in

Nevada. A recently identified population exists in the headwaters of Trout Creek on the east slope of the Deep Creek Range in Utah.

Factors Influencing Decline

Hybridization with introduced cutthroat strains (Yellowstone usually) and rainbow trout is the major decimating factor in the loss of all cutthroat subspecies. Water manipulation may be a second factor often integrally tied with the first.

Recent Studies

Dr. Robert Behnke is continuing long-term studies of cutthroat trout morphology at Colorado State University. Dr. Clair Stalnaker and Gerald Klar (Utah State University) are presently studying biochemical genetic characteristics of cutthroat trout populations. Wernsman (1973) summarized knowledge of the Colorado cutthroat. The U.S. Forest Service has recently installed a fish barrier on the Little West Fork, Blacks Fork River, to stop upstream movement of other fishes from Meeks Cabin Reservoir. The Bureau of Land Management is currently studying Green River tributaries in Desolation Canyon for presence of Colorado cutthroats. Present populations of the Snake Valley cutthroat in Nevada are being protected by the U.S. Forest Service, Bureau of Land Management, and Nevada Fish and Game Department. Frank Dodge (Nevada Fish and Game, Ely) has done much of the field work on this rare form.

Recommendations

A thorough search should be undertaken of all possible sites where the three subspecies may be located. This is especially important on the south slope of the Uinta Range, as oil shale and other developments may soon eliminate the Colorado form before populations are identified. Complete protection to ensure continued vitality of this subspecies in the Little West Fork is recommended. Streams that will support pure populations should be enumerated and protected from modification, with the anticipation of future transplants from available populations should investigations of range and abundance so indicate.

Colorado River Fishes

Ptychocheilus lucius–Colorado Squawfish

Status: Endangered species

Description: The Colorado squawfish is a large silvery fish that once attained sizes of 80-100 pounds and 5-6 feet TL. Body is pike-like with long head and jaws, upper jaw reaching to near posterior margin of eye in adults. Lateral line scales 80-95, 9 dorsal and anal rays, pharyngeal teeth 2, 5-4, 2. Light green or gray on back, silver laterally and white on belly. No distinguishing sexual coloration, breeding tubercles cover body on both sexes although finer on females. Often confused with round-tailed chub, *Gila robusta;* however, adults can be separated by shorter jaw length of chub, seldom reaching beyond middle of eye (Figure 1). Chubs are usually darker dorsally, have orange or red coloration on breeding males, and are more robust. Postlarvae of both species have a caudal spot, but that of the squawfish is large and centered and that of the chub is below center and small. The caudal spot is retained by juvenile squawfish but lost in juvenile chub.

Documentation: The Colorado squawfish originally occupied the entire large river habitat of the Colorado River system. This included the states of Wyoming, Colorado, Utah, New Mexico, Arizona, Nevada, and Califor-

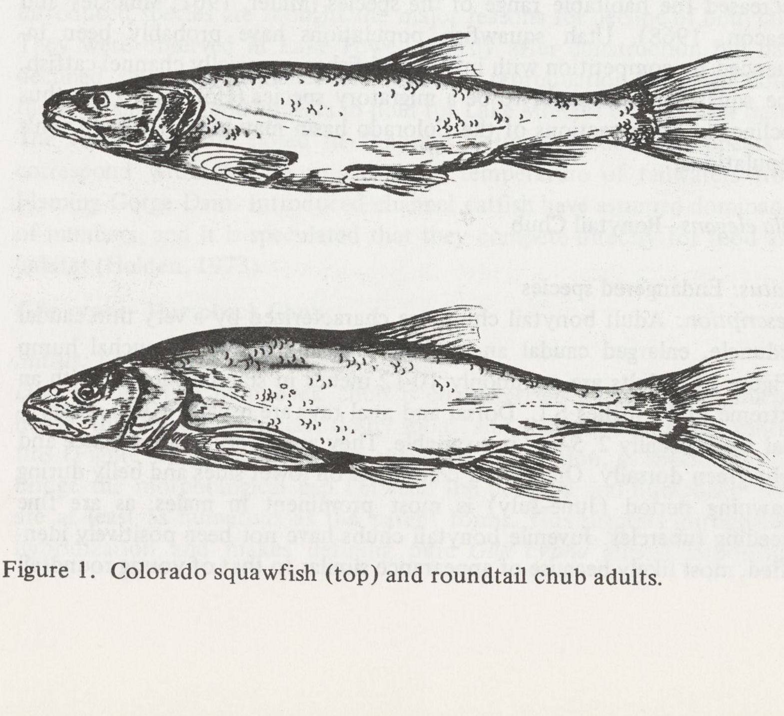


Figure 1. Colorado squawfish (top) and roundtail chub adults.

nia (Jordan, 1891; Jordan and Evermann, 1896). Apparently quite common, this fish was used as food by Indians and early settlers. It was frequently caught by hook and line until the 1930s. This fish is presently extinct, or nearly so, below the Grand Canyon (Minckley and Deacon, 1968) and in Wyoming (Baxter and Simon, 1970). Populations in the upper basin appear much lower than earlier in the 20th century, and spawning populations are known from only a few sites (Holden, 1973). Presently Colorado squawfish are found in all the major channels of the Green and Colorado Rivers in Utah except the area below Flaming Gorge Dam to the Colorado state line. Areas of most consistent reproduction are on the Green River below Ouray, Utah, to its mouth, including Desolation Canyon and the Canyonlands National Park area. Little recent reproduction has been noted above Ouray or in the Colorado River within Utah (Holden, 1973). Populations of squawfish are also known from Colorado in the Green and Yampa Rivers of Dinosaur National Monument and the Colorado and Gunnison Rivers near Grand Junction, Colorado. Unfortunately, reproduction in these areas appears poor (Holden, 1973). Utah is presently the stronghold of this species.

Factors Influencing Decline: Major reasons for decline of Colorado squawfish are reservoir construction, water diversion, and competition from introduced species. This river species apparently cannot adapt to large reservoirs (Minckley and Deacon, 1968; Holden, 1973). Also, loss of habitat through water diversion, as in the Gila drainage of Arizona, has decreased the habitable range of the species (Miller, 1961; Minckley and Deacon, 1968). Utah squawfish populations have probably been influenced by competition with introduced fishes, especially channel catfish. The squawfish is thought to be a migratory species (Holden, 1973); thus declines in other sections of the Colorado basin may have affected Utah's populations.

Gila elegans—Bonytail Chub

Status: Endangered species

Description: Adult bonytail chubs are characterized by a very thin caudal peduncle, enlarged caudal and paired fins, and a smooth nuchal hump (Figure 2). Adults are commonly 10-12 inches in standard length with an extreme of 18 inches S.L. Dorsal and anal rays are usually 10-10, pharyngeal teeth usually 2, 5-4, 2 but variable. They are silvery in appearance and light green dorsally. Orange-red coloration on lower sides and belly during spawning period (June-July) is most prominent in males, as are fine breeding tubercles. Juvenile bonytail chubs have not been positively identified, most likely because of appearance similar to that of young roundtail chubs. Adults of these two chubs are often confused. Characters separating specimens over 7-8 inches S.L. are: dorsal and anal fin ray counts–roundtail 9-9, bonytail 10-10; least depth of caudal peduncle–roundtail 0.051-0.081 of the S.L., bonytail 0.035-0.049 of the S.L.; head depth–roundtail 0.086-0.123 of the S.L., bonytail 0.059-0.088 of the S.L. (Holden and Stalnaker, 1970). Juveniles should be readily distinguished by fin ray counts, but postlarvae probably appear identical.

Documentation: The original range of the bonytail chub was the large river environment of the Colorado River basin from Wyoming and Colorado to Mexico (Jordan, 1891; Jordan and Evermann, 1896). They were readily caught by early settlers and feeding on the surface was noted by early river explorers (Kolb and Kolb, 1914). The bonytail is nearly extinct in the lower Colorado basin (Minckley and Deacon, 1968), with a few large individuals still found in Lake Mohave. According to Vanicek, Kramer, and Franklin (1970) bonytails were common in the Green River of Dinosaur National Monument, Utah and Colorado, in 1964-66. Holden (1973) found bonytails to be very rare in Dinosaur National Monument and the remainder of the upper Colorado basin, including Grand Canyon. No recent confirmed reports of reproduction are known. Present populations of bonytails are known only from the Green River of Utah and the Green and Yampa Rivers of Colorado. Holden (1973) considered this to be the most endangered species in the Colorado River basin.

Factors Influencing Decline: Similar to other endemic Colorado River basin fishes, dam construction, water diversion, and competition with introduced species are thought the major reasons for decline of bonytails. They were observed in Lake Powell shortly after construction but have declined since. No evidence of successful reproduction has been noted there. A similar trend appears to hold for Lake Mohave of the lower basin. The recent decrease noted in Dinosaur National Monument appears to correspond with changes in flow and temperature of tailwaters from Flaming Gorge Dam. Introduced channel catfish have assumed dominance of numbers, and it is speculated that they compete directly for food and habitat (Holden, 1973).

Gila cypha–Humpback Chub

Status: Endangered species

Description: The humpback chub is characterized by an abrupt nuchal hump, thin caudal peduncle, fleshy snout, and enlarged caudal and ventral fins (Figure 2). Its validity as a species is in question, as specimens that bridge the morphological gap between the bonytail and humpback chub are at least as numerous as the parent forms. This suggests introgressive hybridization and makes defining pure *Gila cypha* almost impossible.

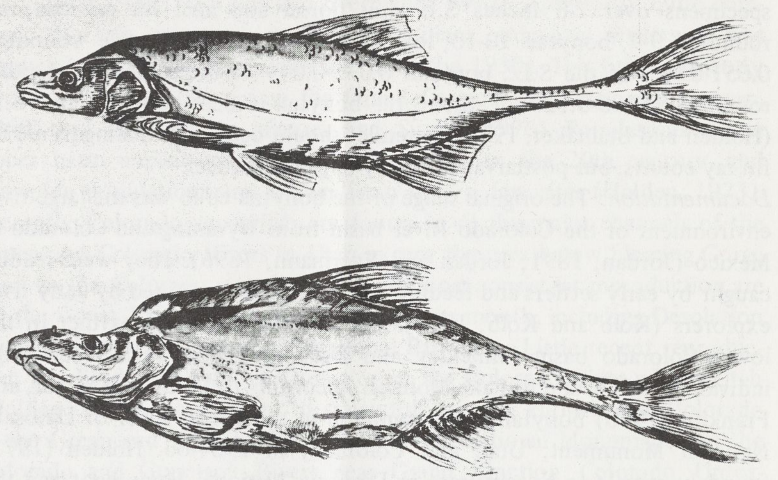


Figure 2. Bonytail chub (top) and humpback chub adults.

Holden and Stalnaker (1970) suggest the humpback might be best considered a subspecies of the bonytail. The term humpback chub will be used here to refer to those humped *Gila* not bonytails. Characters separating these two groups are: caudal peduncle deeper in humpback than bonytail (0.049-0.057 of S.L. to 0.035-0.049 of S.L. respectively); overhanging fleshy snout in humpbacks, not in bonytails; humpbacks have a more abrupt nuchal hump with a crease separating head and trunk; dorsal fin rays usually 9 or 10 in humpbacks and 10 in bonytails. Holden (1973) reports collecting juvenile chubs that appear to be humpbacks. They were distinguished from other chubs by a nuchal hump.

Documentation: Endemic to the Colorado River basin, the humpback chub appears restricted to the swift water canyons. It was first reported in the 1940s from Grand Canyon (Miller, 1946). Since that time it has rarely been found and never in great numbers. Miller (1955) reported remains of this fish from Indian ruins in the lower Colorado basin, indicating some degree of abundance in prehistoric times. The humpback chub has not been collected in recent times below the Grand Canyon. It was considered rare in the upper basin by Holden (1973). In Utah, humpback chubs are found in the Green River in Desolation Canyon and in Lake Powell, where they are declining. They are also found in the Green and Yampa Rivers of Colorado in Dinosaur National Monument and in the Grand Canyon area of Arizona. Reproduction appears likely for this form in Desolation Canyon (Holden, 1973).

Factors Influencing Decline: Since no "before" data are available, it is questionable whether humpback chubs have actually declined in abundance. It appears likely that this form was a phenotype near extinction when discovered. The apparent introgressive hybridization with bonytails may be a sign of this extinction process. If so, alteration of the Colorado River by man may have hastened the demise of this phenotype through loss of habitat and competition with introduced species.

Xyrauchen texanus–Humpback or Razorback Sucker

Status: Endangered species

Description: Adult humpback suckers are readily distinguished by the prominent bony keel behind a flat head (Figure 3). The keel becomes obvious in 8-10-inch fish. Juveniles have seldom been identified. They may appear much like juvenile flannelmouth, except lateral line scales are fewer (68-87 to 90-116) (Sigler and Miller, 1963). Postlarvae are distinguished from flannelmouth and bluehead suckers by large black spots on the dorsal surface (Winn and Miller, 1954). Adults exhibit orange, yellow, and violet lateral coloration during spawning season (Spring). Large breeding tubercles appear on the anal and caudal fins of adult males. Most adults are 12-18 inches and 3-5 pounds. The humpback and flannelmouth sucker hybrid is common but easily distinguished by a poorly developed keel and intermediate scale counts (Hubbs and Miller, 1953).

Documentation: Humpback suckers originally were found in major channels and tributaries throughout the Colorado River basin (Jordan, 1891; Jordan and Evermann, 1896). They were used as food by Indians and settlers, even sold commercially at one time. They are nearly extinct in the free-flowing sections of the lower Colorado basin (Minckley and Deacon, 1968). Fairly large numbers of adults are found in Lake Mohave

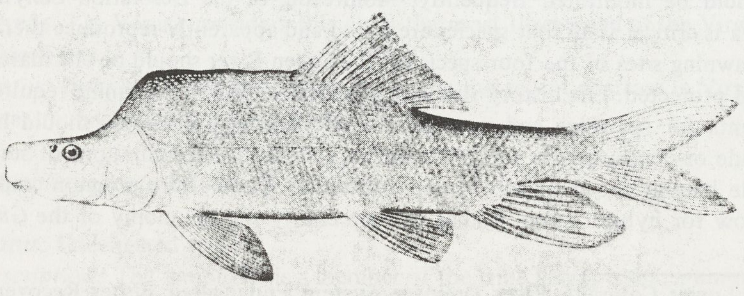


Figure 3. Humpback sucker adult.

and other lower basin reservoirs. Spawning has been observed, but no juveniles have been found. Upper basin populations appear much lower than in the late 1800s, and no large reservoir populations have been noted. Holden (1973) found only 53 humpback suckers in four summers of collecting in the upper basin and listed them as rare. In Utah they are found in the Green and Colorado Rivers, and a few have been reported from Lake Powell.

Factors Influencing Decline: Similar to other large river fishes of the Colorado basin, habitat destruction through dam construction, water diversion, and competition with introduced species are considered major decimating factors for humpback suckers. This species has not fared well during the 20th century while man has been altering its habitat.

Recent Studies

Holden (1973) documented the abundance and distribution of the Colorado squawfish, bonytail chub, humpback chub, and humpback sucker in the Upper Colorado basin. Adults of these species are currently being sought to obtain brood stocks for artificial propagation and eventual restocking of suitable habitats in the lower basin.[2] Squawfish and humpback suckers are presently being held in the Willow Beach National Fish Hatchery. At this date over 3,500 juvenile humpback suckers and 6,000-7,000 squawfish have been hatched from these fish. Utah State University has initiated a radio telemetry study of humpback suckers and squawfish in Dinosaur National Monument. The Lower Colorado River Drainage Recovery Team is funding a life history study of humpback suckers in Lake Mohave.

Recommendations

Utah populations of the four endangered Colorado River system species should be monitored frequently. Monitoring of the Desolation Canyon area is critical as all four species are found and apparently reproduce there. Spawning sites of the four species in the Green River should be elucidated and protected. Life history studies are recommended to determine requirements for spawning and juvenile survival. Recovery attempts should be made or continued for the four species, as should determinations of suitable habitat for artificially reared individuals. The culture program could allow for hybridization studies to help clarify the taxonomy of the *Gila*

---

2. Lower Colorado River Drainage System Endangered Fishes Recovery Team, Gail Kobetich, Fish and Wildlife Service, Parker, Arizona, Chairman.

group. Any further alteration of the Colorado River System should be discouraged.

Virgin River Fishes

Gila robusta seminuda–Virgin River Chub

Status: Endangered subspecies
Description: Taxonomy of the Virgin River chub is uncertain, as its association with the Pahranagat roundtail (*G.r. jordani*) and roundtail chub (*G.r. robusta*) is unclear. This discussion is limited to the roundtail of the Virgin River, *G.r. seminuda.* Descriptions of this form are lacking; Holden and Stalnaker (1970) examined six specimens and Miller (1946) examined the five type specimens. Major differences between *G.r. seminuda* and *G.r. robusta* were dorsal fin rays 9-10 (9.3) and 9 respectively, gillrakers 24-31 (27.7) and 20-28 (24) respectively, and vertebrae 40-42 (40.7) and 41-44 (42.2) respectively. The original description of *seminuda* stressed an absence of scales on ventral and dorsal areas. This character was found to be variable in *Gila robusta* throughout the Colorado basin (Holden and Stalnaker, 1970). The Virgin River chub is very silvery, as are other Virgin River fish.
Documentation: Original range of the Virgin River chub was the Virgin River up to La Verkin Spring near Hurricane, Utah. Much of the lower Virgin River is now flooded by Lake Mead. The chub was very abundant in the Utah section of the river in the late 1960s. Recent studies by Cross and Deacon (1973) did not find this form above the mouth of Beaver Dam Wash, Arizona, or in Utah except at La Verkin Spring. They found it to be more common below Beaver Dam Wash in Arizona and Nevada. It is based on this recent and apparently drastic reduction in the Utah and part of the Arizona population and the loss of habitat due to Lake Mead that the endangered status is believed warranted. Dr. James Deacon (University of Nevada, Las Vegas) considers this chub the most threatened of the Virgin River fishes.
Factors Influencing Decline: Factors causing the recent decrease in Virgin River chub populations are unknown.

Plagopterus argentissimus–Woundfin

Status: Endangered species
Description: The woundfin is a member of the tribe Plagopterini, a unique group of minnows endemic to the Lower Colorado River basin. This tribe is characterized by spines in the dorsal and pelvic fins. The woundfin is

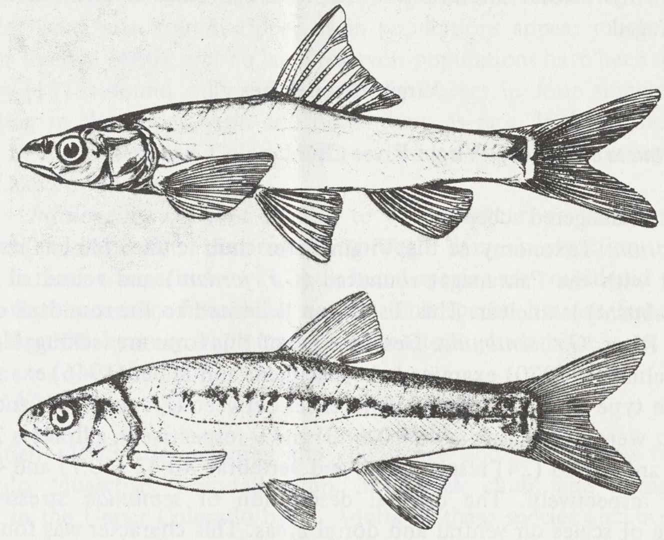


Figure 4. Woundfin (top) and Virgin River spinedace adults.

very silvery, with little other color present. The body is very streamlined, with a flat head, large subterminal mouth, barbels, and enlarged fins typical of swiftwater fishes (Figure 4). The body is essentially scaleless, spines are developed on pectoral fins, and size seldom exceeds 4 inches. Dorsal rays 8-9 (10), anal rays 9-11, pharyngeal teeth in two rows and variable from 1, 5-4, 2 (Deacon and Minckley, 1973).

Documentation: The original range of the woundfin was the Gila River system from Tempe, Arizona, to its mouth at Yuma, the main Colorado River from Yuma to the mouth of the Virgin River and up the Virgin in Nevada, Arizona, and Utah to La Verkin Spring near Hurricane, Utah (Gilbert and Scolfield, 1898; Deacon and Minckley, 1973). Apparently it was not common in tributaries of the Virgin. It is presently found only in the Virgin River below La Verkin Spring, with the exception of one specimen from the Moapa River, Nevada (formerly a tributary of the Virgin River), taken in the late 1960s (Deacon and Minckley, 1973). The woundfin has been transplanted in several locations but is established only in Sycamore Creek, Arizona (tributary of Gila River). They were reported introduced into the Paria River, Utah and Arizona, but were not found in the spring of 1974 (Gail Kobetich, Fish and Wildlife Service, Parker, Arizona). The woundfin occupies the main channel of the swift, highly turbid, and extremely warm (90 F summer temperature) sections of the Virgin River with sandy, constantly shifting bottoms.

Factors Influencing Decline: Loss of habitat in the Gila River system through irrigation demands and in the main Colorado River and lower Virgin by reservoir construction appear to be major decimating factors for woundfin. Virgin River populations remain strong, although recent construction of Interstate Highway 15 through Virgin River Canyon (Arizona) may have a negative effect on populations there.

Lepidomeda mollispinis mollispinis—Virgin River Spinedace

Status: Threatened species

Description: A member of the cyprinid tribe Plagopterini, the Virgin River spinedace has two weakly developed dorsal spines, is very silvery, and usually has random dark speckles over its body (Figure 4). Dorsal fin rays usually 9, anal fin rays 8-10 (9), lateral line scales 77-91, and pharyngeal teeth 2, 5-4, 2. Small amounts of reddish-orange or pink are found at the axils of the paired fins and the base of the anal fin. It is distinguished from the woundfin (*Plagopterus argentissimus*) by a lack of barbels and evident scales.

Documentation: Endemic to the Virgin River system of Utah, Arizona, and Nevada, the Virgin River spinedace is a tributary form associated with cool, clear water. In Utah it is found in the Santa Clara River system, Leeds Creek, Ash Creek, and North Fork of Virgin River. It is found in the main Virgin River only near the mouth of one of the above tributaries and usually at low periods of flow and turbidity (Cross and Deacon, 1973). It is also found in Beaver Dam Creek, Arizona. It was reported from the Paria River of Utah (Utah Division of Wildlife Resources), but 1974 sampling in Arizona failed to recover the species. Spinedace were abundant in the Santa Clara River system until just recently. Introduced redside shiner (*Richardsonius balteatus*) populations have increased there, and a marked decrease in spinedace was noticed in 1972 and 1973 (Behnke, 1973). Also, largemouth bass (*Micropterus salmoides*) introduced into Gunlock Reservoir on the Santa Clara have moved upstream and spinedace populations have dropped markedly (Cross and Deacon, 1973). This very sharp population decline in the spinedace's best habitat has promoted the threatened status.

Factors Influencing Decline: Introduction of redside shiner and largemouth bass into spinedace habitat appear to be the primary decimating factors.

Recent Studies

Inventory studies of all rare Virgin River fishes are currently under way by the University of Nevada, Las Vegas, including a life history study of the Virgin River chub. A Woundfin Recovery Team has been established to monitor woundfin abundance and expand reintroduction activities. The Bureau of Land Management is conducting aquatic habitat surveys to determine woundfin habitat status.

Recommendations

It is recommended that studies of the range, abundance, and habitat for these fishes be continued on the Virgin River system to guard against further reductions. Reasons for the recent decline in Virgin River chub need to be determined. The spread of introduced species in the Virgin River should be halted. The feasibility of rehabilitation programs to free the streams of introduced species and placement of a suitable barrier should be considered. Utah woundfin populations have shown no appreciable decrease in historical times. The major reason for this has been little alteration of the harsh Virgin River environment, favorable only to the highly specialized native fishes. Any alteration of the near natural stream system could be very detrimental to these fish in Nevada and Arizona as well as Utah. Proposals for dam construction and blockage of the highly saline La Verkin Spring are presently being considered. Either could be extremely dangerous to the remaining native fish populations. Any alteration of the small, and hence easily modified, Virgin River and tributaries should be discouraged. Reintroduction of all species into other suitable habitat, once such habitat is determined, remains a prime consideration.

Bonneville Basin Fishes

Iotichthys phlegethontis–Least Chub

Status: Endangered species

Description: The least chub is a small cyprinid seldom exceeding 2½ inches in length (Figure 5). Lateral line scales are 34-38, pharyngeal teeth 2, 5-4 2, dorsal fin rays 8 or 9, and anal fin rays 8. Males are olive green dorsally and steel blue laterally, with a golden band on the lower sides. The fins are often a lemon-amber. Females and young have dull green backs and silvery sides (Sigler and Miller, 1963). Least chubs superficially resemble small Utah chubs but can be distinguished by a lower lateral line scale number (45-65 in Utah chub) and a dorsal origin behind the insertion of the pelvic fins (Utah chub dorsal origin directly over insertion of pelvics) (Sigler and Miller, 1963).

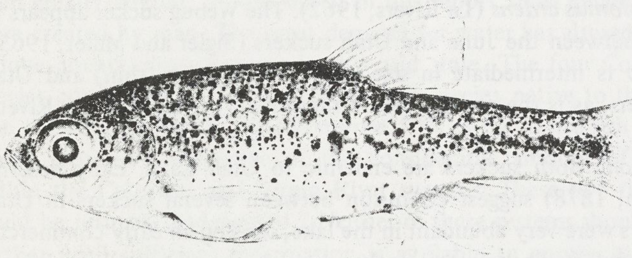


Figure 5. Least chub adult.

Documentation: The least chub is endemic to the Bonneville basin of Utah. It was originally common in most lowland streams, springs, and ponds (Jordan, 1891; Sigler and Miller, 1963). A decrease in range and abundance was noted in the 1940s and 1950s by R. R. Miller and C. L. Hubbs. More recent investigations have found the least chub in only a few springs in Snake Valley of extreme western Utah (Utah Division of Wildlife, Bureau of Land Management). Present data suggest that this species is very rare, although no thorough study of range and abundance has been completed.
Factors Influencing Decline: The major reason for decline of least chub populations appears to be loss of habitat through water diversion. A case in point is the type locality in the Beaver River, which is presently dry much of the year. Many of the small streams emanating from the Wasatch Range are diverted or polluted once they reach the valley.
Recent Studies: The Utah Division of Wildlife Resources and the Bureau of Land Management are currently examining range and occurrence of the species in the Snake Valley area.
Recommendations: It is recommended that a study be made into the statewide distribution of this species. Protection of the Snake Valley populations should be adequate to preserve the species.

Chasmistes liorus–June Sucker; *Catostomus fecundus*–Webug Sucker

Status: Indeterminate
Description: The confusion surrounding these sucker species seriously hampers accurate description. The genus *Chasmistes* is characterized by a large, flat head and a distinctive terminal mouth. The very unsuckerlike mouth has a thin upper lip and a folded lower lip. The upper lip is con-

cealed by an overhanging snout. Few papillae are present on the upper lip and not arranged in rows as in other sympatric suckers, such as the Utah sucker, *Catostomus ardens* (La Rivers, 1962). The Webug sucker appears to be a hybrid between the June and Utah suckers (Sigler and Miller, 1963). Its upper lip is intermediate in size between the June (thin) and Utah (thick) suckers, as is the amount and arrangement of papillae (La Rivers, 1962).

Documentation: Both suckers are endemic to Utah Lake. Early descriptions (Jordan, 1878) suggest confusion between several suckers in Utah Lake. Suckers were very abundant in the lake, causing an early commercial fisherman to call it the "greatest sucker pond in the universe" (La Rivers, 1962). Tanner (1936) considered the June sucker extinct; he also considered the Utah sucker and Webug suckers (*Catostomus fecundus*) to be the same species as the June sucker. Specimens of *Chasmistes*-like fish are still collected in Utah Lake. R. R. Miller (University of Michigan) considers these recent specimens as hybrids of Utah and June suckers. He says they do not appear similar to early *Chasmistes* from the lake and suggest that this hybrid population may be a self-sustaining, i.e., a reproducing population. Whether or not this recent hybrid resembles the original Webug sucker is unknown.

Factors Influencing Decline: The taxonomic confusion concerning these species leaves little room for conclusions of any kind. Apparently Tanner's (1936) hypothesis of extinction for the June sucker was based on the severe drought of the early 1930s. Winter kill in 1934-35 killed most of the fish remaining in Utah Lake. Hybridization due to low population levels may have occurred after 1935, creating present conditions.

Recent Studies: We are aware of no recent studies on Utah Lake suckers.

Recommendations: A thorough taxonomic study of Utah Lake suckers, especially the *Chasmistes*-like specimens, is needed to clarify the present confusion. Once this is done, a more realistic assessment of June sucker and Webug sucker population status can be made.

Discussion

All of the rare fishes listed in this report are adapted to specific environments. Many are endemic to a small geographic area or to a distinct portion of a larger drainage system. Because they are highly specialized, they are less flexible and do not easily adapt to new conditions. Alterations of their environment cause population declines, sometimes to the point of extinction. Generalist species, especially introduced forms, often become abundant in disturbed environments where specialist species are declining, creating added competition to the further detriment of the highly specialized fishes.

The 13 fishes listed in this report constitute approximately 40% of the native fishes of Utah. This indicates that Utah's aquatic environments have been greatly altered. As was noted in this report, most decimating factors were created by man. The great demand for water has altered most of the unique aquatic environments in this arid state. The four Colorado basin species constitute 57% of the large river species native to that drainage. The three Virgin River fishes comprise 50% of the native fish fauna there. These values are indicative of the considerable amount of disturbance within the Colorado and Virgin River systems. These two river environs could be termed "endangered." Neither of these systems should be altered further until sufficient information is available to ensure survival of the native fishes.

The status of the fishes in the Bonneville basin is poorly understood. This basin has also suffered major alterations in its aquatic environments. Studies are needed to determine what factors may cause other native fishes to become threatened or endangered. Monitoring of these populations should be considered, especially for species restricted to small areas, such as Bear Lake.

It is further recommended that investigative efforts on the most critical species be supported first. Those projects with highest priority are: (1) least chub–continue studies of distribution and abundance; (2) bonytail chub–clarification of population status, especially reproduction; (3) Virgin River chub–ascertain cause of recent population decline; (4) June and Webug suckers–taxonomic analysis of Utah Lake suckers. Other studies recommended in the species accounts should receive support after the top priority studies are underway.

It should be stressed that many of Utah's aquatic environments are being seriously threatened by human exploitation. It is intended that this report provide information for natural resource agencies in Utah, as well as other interested groups and individuals. Hopefully, it will foster more concern for the unique aquatic environments in Utah and for the unique fishes living there.

Table 1 compares the status of Utah's endangered fishes as determined in this report with other natural resource agencies or organizations.

Acknowledgments

We would like to thank W. F. Sigler and R. R. Miller for permission to use drawings of fish from their book, Fishes of Utah. Also, Debbie Ruggiero must be thanked for her drawings of Colorado squawfish, roundtail chub, humpback chub, and bonytail chub. The report was funded by the Ecology Center, Utah State University, and the Bonneville Chapter.

Table 1

Status of rare fishes in Utah as determined in this report and by other natural resource agencies or organizations

	This Report	Utah Div. Wildl. Resources	U.S. Dept. Interior	Amer. Fisheries Society	U.S. Dept. Agri. (Forest Service)
Colorado cutthroat trout	Endangered				
Utah cutthroat trout	Endangered				
Snake Valley cutthroat trout	Endangered				
Colorado squawfish	Endangered	Endangered and protected	Endangered	Rare and endangered	Endangered
Bonytail chub	Endangered	Depleted and protected		Depleted	
Humpback chub	Endangered	Endangered and protected	Endangered	Rare and endangered	Endangered
Virgin River chub	Endangered				
Least chub	Endangered	Rare and protected		Rare	
Woundfin	Endangered	Endangered and protected	Endangered	Rare and endangered	
Virgin River spinedace	Threatened	Rare and protected			
Humpback sucker	Endangered	Rare and protected		Rare	
June and Webug suckers	Indeterminate				

Bibliography

Baxter, G. T., and J. R. Simon. 1970. Wyoming fishes (Revised). Wyoming Game and Fish Department, Bulletin No. 4.

Behnke, R. 1973. Rare and endangered fish reports. Prepared for Region 2, U.S. Bureau of Sport Fisheries and Wildlife, Albuquerque, Mimeographed.

Cross, J., and J. E. Deacon. 1973. Ecological distribution of the fishes of the Virgin River system, pp. 30-47. *In* J. E. Deacon (ed), Population dispersion and community structure of fishes of the Virgin River system. Progress report to U.S. Bureau of Sport Fisheries and Wildlife, Salt Lake City. Mimeographed.

Deacon, J. E., and W. L. Minckley. 1973. A review of information on the woundfin *Plagopterus argentissimus.* Cope (Pisces, Cyprinidae) pp. 3-28. *In* J. E. Deacon (ed), Population dispersion and community structure of fishes of the Virgin River system. Progress report to U.S. Bureau of Sport Fisheries and Wildlife, Salt Lake City. Mimeographed.

Gilberg, C. H., and N. B. Scofield. 1898. Notes on a collection of fishes from the Colorado Basin in Arizona. Proc. U.S. Natl. Mus. 20:487-99.

Holden, P. B. 1973. Distribution, abundance and life history of the fishes of the upper Colorado River basin. Ph.D. dissertation. Utah State University.

_______________ and C. B. Stalnaker. 1970. Systematic studies of the cyprinid genus *Gila* in the upper Colorado River basin. Copeia 1970 (3):409-20.

Hubbs, C. L., and R. R. Miller. 1953. Hybridization in nature between the fish genera *Catostomus* and *Xyrauchen.* Papers Mich. Acad. Science, Arts and Letters 38 (1952):207-33.

Jordan, D. S. 1878. A catalogue of the fishes of the freshwaters of North America, pp. 405-42. *In* F. V. Hayden (ed.), Geological and geographical surveys of the territories. Bull. Haydens Geol. Surv. Terr. 4 (2).

_______________. 1891. Report of explorations in Colorado and Utah during the summer of 1889 with an account of the fishes found in each of the river basins examined. U. S. Fish. Comm. Bull. 9 (1889):1-40.

_______________ and B. W. Evermann. 1896. The fishes of North and Middle America. U. S. Natl. Mus. Bull. 47 (1):1-1240.

Kolb, Ellsworth, and Emory Kolb. 1914. Experiences in Grand Canyon. National Geographic 26(2):99-184.

La Rivers, I. 1962. Fishes and fisheries of Nevada. Nevada State Fish and Game Comm.

Miller, R. R. 1946. *Gila cypha,* a remarkable new species of cyprinid fish from the Colorado River in Grand Canyon, Arizona. Jour. Wash. Acad. of Science 36 (12):409-13.

____________. 1955. Fish remains from archaeological sites in the lower Colorado River basin, Arizona. Papers Mich. Acad. Science, Arts and Letters 40 (1954): 125-36.

____________. 1961. Man and the changing fish fauna of the American Southwest. Papers Mich. Acad. of Science, Arts and Letters 46 (1960):365-404.

____________. 1972. Threatened freshwater fishes of the United States. Trans. Amer. Fish. Soc. 101(2):239-52.

Minckley, W. L., and J. E. Deacon. 1968. Southwestern fishes and the enigma of "endangered species." Science 159(3822):1424-32.

Sigler, W. F., and R. R. Miller. 1963. Fishes of Utah. Utah State Department of Fish and Game.

Suckley, G. 1874. Monograph of the genus *Salmo.* Report of U.S. Comm. Fish for 1872-73, App. B:91-160.

Tanner, V. M. 1936. A study of the fishes of Utah. Utah Acad. Sciences, Arts, and Letters 13:155-84.

Vanicek, C. D., R. H. Kramer, and D. R. Franklin. 1970. Distribution of Green River fishes in Utah and Colorado following closure of Flaming Gorge Dam. Southwestern Naturalist 14(3):297-315.

Wernsman, G. 1973. Native trouts of Colorado. M.S. thesis, Colorado State University.

Winn, H. E., and R. R. Miller. 1954. Native postlarval fishes of the lower Colorado River basin, with a key to their identification. Calif. Fish and Game 40:273-85.

Printed at Brigham Young University Press
1975 .2M 11782

SUMMARY

Uintah Basin Ponds sampled 10/26/72

Pond		Donaldson	Jones Hole
Molnar's - temp. 10°C	Length	21.2 (16.9 - 24.6)	23.4 (19.4 - 26.9)
D.O. 8.3 ppm -	Weight	99.2 (51.0 - 154.0)	142.6 (75.0 - 213.0)
Simmons -	Length	17.9 (11.4 - 21.6)	20.7 (14.9 - 26.4)
temp. 9.5°C - D.O. 8.4ppm	Weight	57.9 (14.0 - 104.5)	94.0 (57.0 - 196.5)

The fish eggs from Jones Hole came from the Caribou Trout Ranch at Soda Springs, Idaho. They were listed at 3" and weighed 91 fish per pound.

The water quality of Jones Hole is ph. 8.1, dissolved solids 170 mg/l, Ca Co_3 165 mg/l, HCO_3 199 mg/l, Ca 41 mg/l, sodium as Na 3.0 mg/l, nitrate as No_3 2.5 mg/l.

The water temperature is 52° year around.

Farrell Simmons' Pond 10/26/72

temp. 9.5°C
D.O. 8.4 ppm

Donaldson

L	W
20.6	87.5
11.4	14.0
17.1	46.4
18.0	50.4
18.4	58.0
19.1	66.0
19.5	68.4
17.8	51.0
17.8	49.0
16.1	38.4
16.2	36.7
17.5	54.2
17.4	48.0
21.0	92.0
17.9	52.1
17.9	56.0
17.4	50.0
17.2	47.0
19.2	65.5
18.7	68.2
18.3	55.0
20.5	92.5
16.2	40.3
18.0	53.5
19.5	72.5
18.2	61.0
17.0	52.0
17.0	46.2
21.6	104.5
19.8	81.0
20.0	85.0
18.0	58.5
18.1	55.8
16.2	45.5
13.5	24.0
628.1	2026.1
$\bar{x}$ 17.9	57.9
range 11.4-21.6	14.0-104.5

Jones Hole

L	W
19.9	86.0
19.0	68.4
20.2	85.5
19.4	67.0
20.5	87.0
16.9	50.4
21.6	100.7
22.7	117.2
25.1	174.3
21.3	100.0
21.9	105.2
21.6	104.0
21.4	98.5
21.1	90.5
20.9	89.5
19.0	79.0
19.4	74.2
19.5	78.5
23.4	131.2
24.0	144.0
20.0	95.0
18.9	66.8
21.0	84.0
19.7	75.0
26.4	196.5
22.0	110.0
14.9	86.0
20.2	80.4
20.2	81.2
22.8	130.0
20.7	91.5
20.3	85.0
21.1	92.5
20.7	88.5
19.0	70.5
16.8	57.0
20.6	58.0
764.1	3479.0
$\bar{x}$ 20.7	94.0
range 14.9-26.4	57.0-196.5

Steve Molnar's Pond 10/26/72

temp 10°C

8.3ppm D.O.

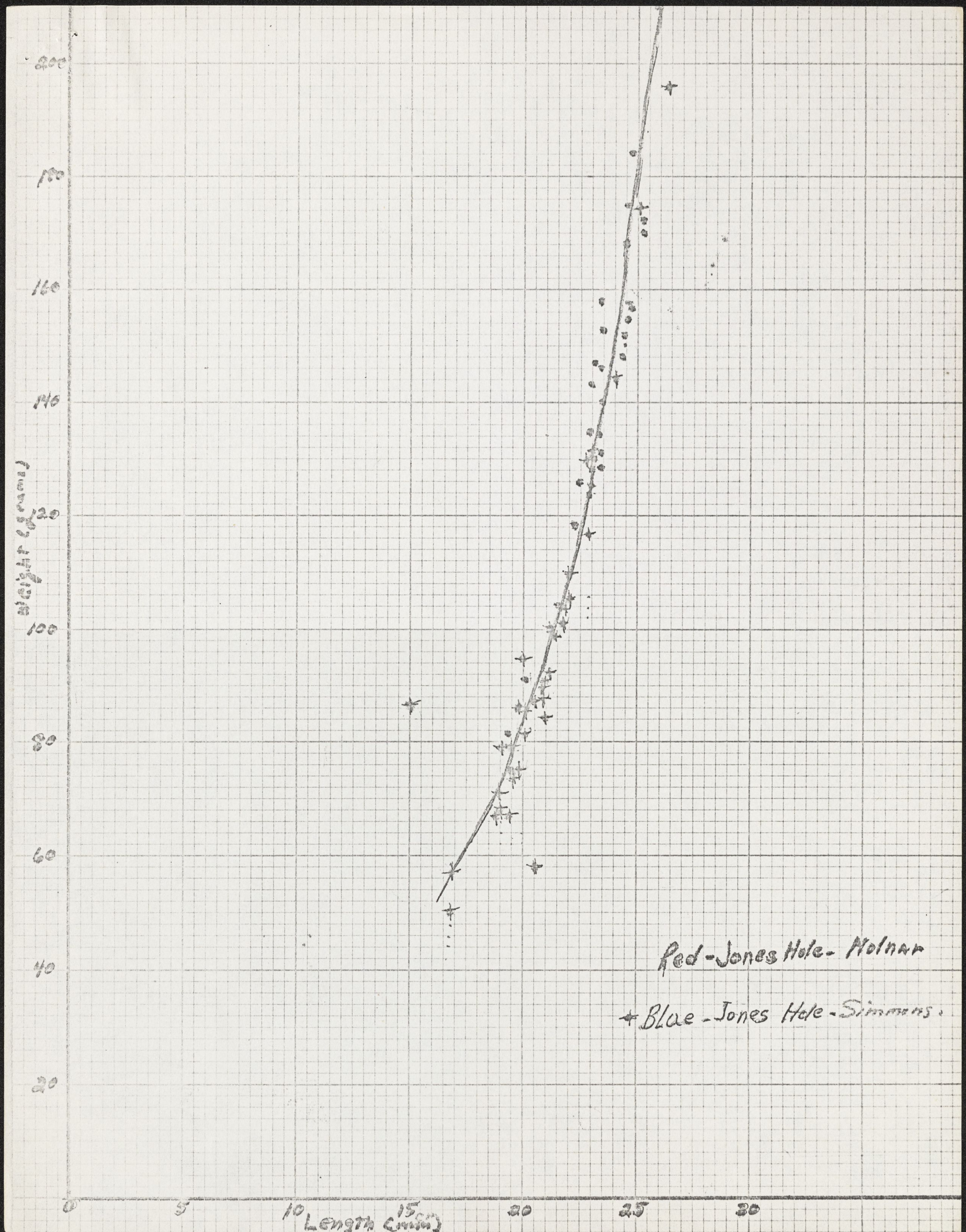
Donaldson

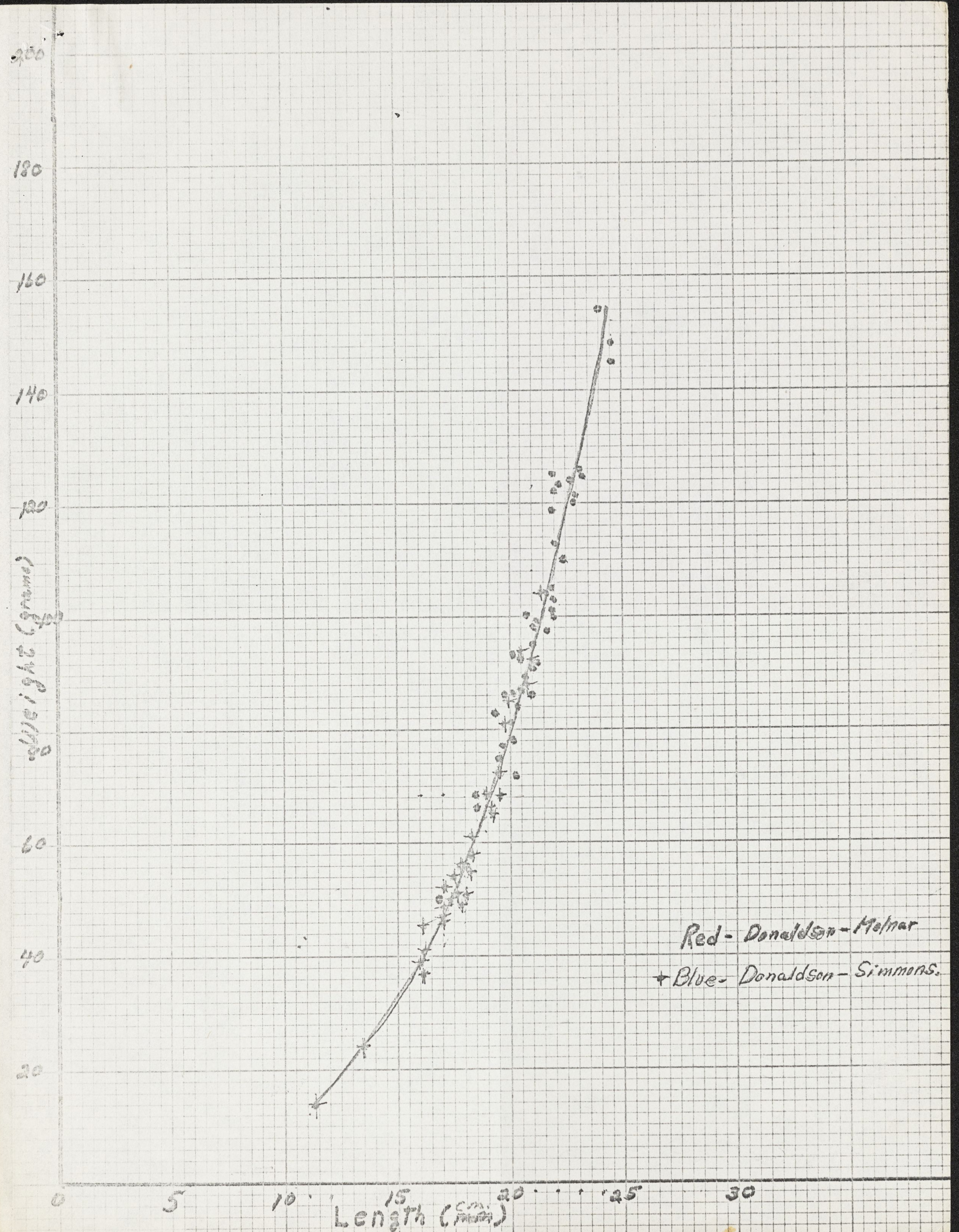
L	W
21.0	91.5
20.6	87.0
19.6	75.2
19.8	86.0
21.6	104.0
22.9	120.0
21.1	98.0
20.5	92.4
18.4	68.4
19.3	83.0
20.2	74.5
21.7	101.5
23.2	126.3
21.8	102.5
20.2	78.0
21.3	99.3
22.0	100.0
21.6	97.4
20.2	86.3
19.6	77.0
24.6	145.0
21.7	118.5
22.9	121.2
23.2	124.5
21.9	104.6
22.0	113.0
24.5	148.0
22.1	122.0
21.1	86.7
20.7	89.0
20.0	80.5
16.9	51.0
20.4	84.0
22.5	110.8
22.7	124.0
22.6	123.5
24.0	154.0
21.8	125.0
21.0	95.0
20.8	100.0
21.3	91.0
21.0	86.0
18.5	66.0
20.2	93.5
18.2	56.2
953.3	4461.3
$\bar{x}$ 21.2	99.2

range - 16.9-24.6, 51.0-154.0
About 100 fish caught that were not measured.

Jones Hole

L	W
24.6	175.0
23.5	140.0
23.2	130.0
24.4	152.2
23.4	130.8
23.2	143.4
25.8	210.3
24.6	148.0
20.1	91.7
24.8	184.0
24.7	157.3
23.4	157.5
23.4	146.0
25.3	172.0
21.5	104.0
24.4	158.5
23.2	146.5
26.9	213.0
24.6	155.0
22.4	118.0
23.3	128.2
22.7	135.0
22.9	124.0
23.0	125.3
22.4	126.2
19.4	81.7
25.4	172.0
23.3	134.7
23.0	128.0
23.1	137.0
23.4	153.0
24.6	168.0
23.3	128.5
19.5	75.0
796.7	4849.8
$\bar{x}$ 23.4	142.6
range - 19.4-26.9	75-213.0


Weight (grams)
Length (mm)
Red - Jones Hole - Molnar
+ Blue - Jones Hole - Simmons.


200
180
160
140
120
100
80
60
40
20
Weight (grams)
0
5
10
15
20
25
30
Length (cm)
Red- Donaldson-Molnar
+ Blue- Donaldson-Simmons.

5/30/73

Summary

Pond	Donaldson		Jones Hole	
Molnar's Pond	Ave.	Range	Ave.	Range
Length (cm)	24.1	17.7 - 27.2	28.6	23.8 - 32.7
Wt. (g)	140.3	50 - 225	281.7	160 - 450
Pop. est.	N = 390 ± 149 (241 - 539)			
Simmons Pond				
Length	22.4	19.0 - 25.2	24.3	21.9 - 28.4
Wt.	99.8	75 - 140	139.2	105 - 230
Pop. est.	N = 64 ± 31 (33 - 95)			

Molnar's Pond 5/30/73

1st haul 141 fish
2nd haul 90 fish
(has removed approx. 70 by fishing)

Donaldson (clipped)

L (total-cm.)	W (grams)
25.1	125
24.0	130
23.0	135
26.7	150
26.2	185
24.6	115
24.1	110
24.6	125
25.2	185
25.4	140
25.3	165
25.0	165
26.6	205
27.0	185
17.9	50
26.1	160
22.6	130
22.0	145
23.3	105
24.0	155
22.5	100
23.7	145
24.6	175
22.9	125
25.1	140
25.2	160
25.4	135
25.2	180
26.0	185
21.0	75
25.2	135
26.5	210
25.8	150
24.1	170
25.6	160
23.7	110
25.0	135
22.6	195
17.7	70
20.2	65
24.4	130
25.1	155

Jones Hole

L (total-cm.)	W (grams)
30.5	340
28.3	225
31.5	360
26.6	215
29.3	290
26.5	215
23.8	160
29.2	350
28.7	325
29.1	330
28.9	260
31.2	300
27.5	230
26.2	180
28.4	270
27.9	240
28.0	240
28.3	285
30.5	360
30.3	350
29.9	345
27.1	235
27.0	235
27.6	250
30.3	360
31.6	355
32.7	450
30.0	305
27.8	270
27.5	205
25.9	200
27.8	245
24.3	185
27.7	265
29.2	340
30.1	375
28.0	275
29.2	300
29.5	300
26.6	210
27.5	255
31.1	345
1199.1	11830

Donaldson (clipped)

L (total-cm.)	W (grams)
23.9	130
25.5	155
23.8	110
22.5	135
24.6	155
26.6	190
27.2	225
24.0	115
25.2	170
18.4	65
24.6	130
24.0	160
25.2	110
23.7	100
25.1	140
19.8	80
1400.3	8140

$\bar{x}$ = 24.1 $\bar{x}$ = 140.3

range -17.7-27.2 50-225

Jones Hole

$\bar{x}$ = 28.6 $\bar{x}$ = 282

range - 23.8-32.7 160-450

Simmons' Pond 5/30/72

temp. $60^{o}F$.
time 10:30 a.m.
1st haul 31 fish
2nd haul 16 fish

Donaldson (clipped)

L (total-cm.)	W (grams)
24.2	100
19.6	85
23.7	115
22.5	80
22.0	110
19.0	75
22.9	85
23.8	105
21.5	75
22.7	110
21.8	115
25.2	140
21.9	105
22.5	100
24.0	95
21.7	85
22.0	110
20.1	85
20.7	80
23.9	115
23.7	105
23.7	115
22.5	100
21.9	95
22.1	90
23.0	100
23.6	125
22.1	95
628.3	2795

$\bar{x} = 22.4$ $\bar{x} = 100$

range - 19.0-25.2 75-140

Jones Hole

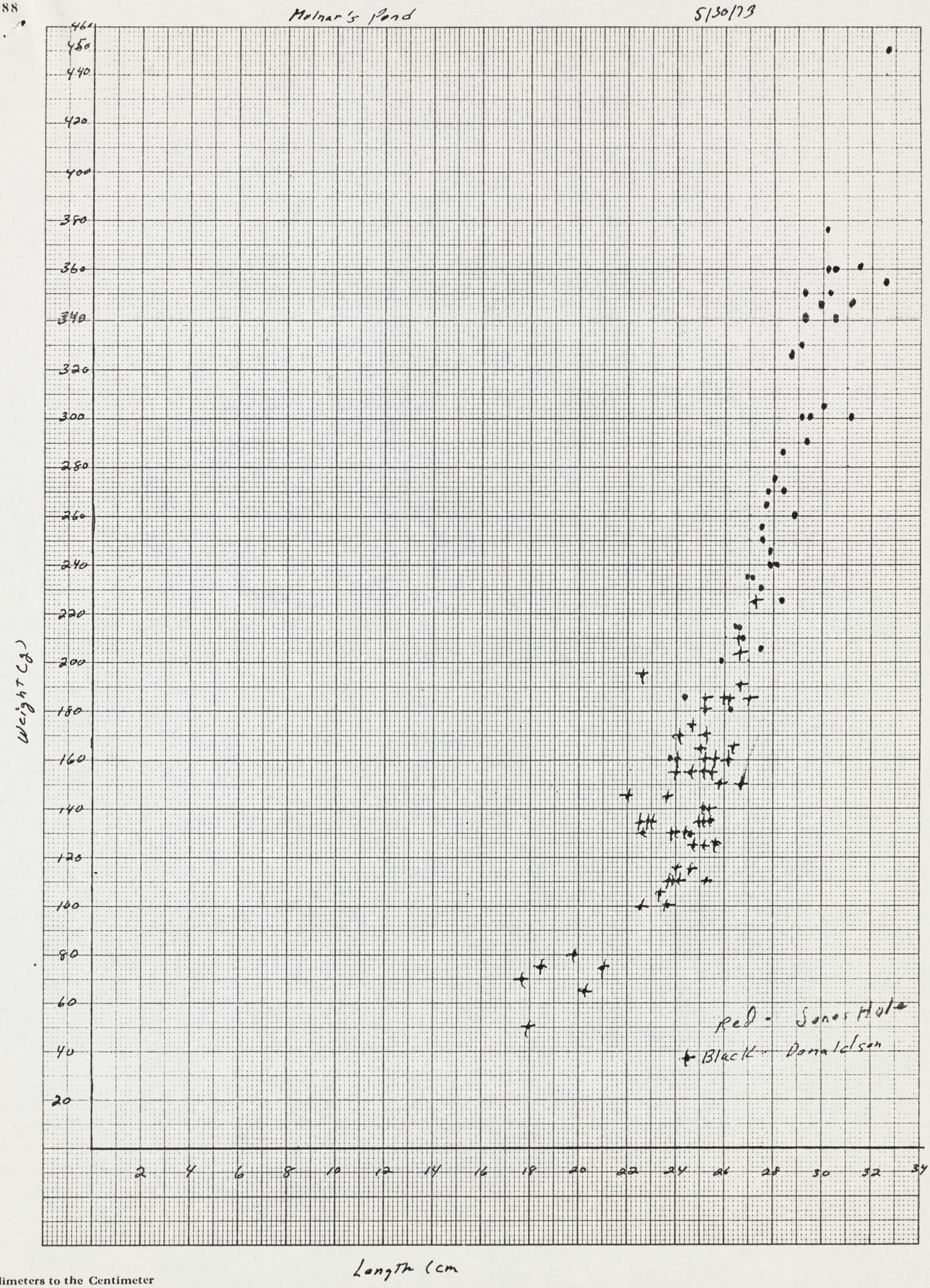
L (total-cm.)	W (grams)
25.8	170
28.4*	105*
25.5	140
24.3	135
21.9	110
26.7	180
24.6	145
27.6	230
23.5	130
24.6	155
23.2	120
22.4	110
24.7	150
22.6	135
22.7	115
24.6	140
23.1	115
23.0	125
23.0	135
433.8	2540

$\bar{x} = 24.1$ $\bar{x} = 141$

range 21.9-27.6 110-230

* This fish either weighed or measured incorrectly--not included in totals, means, or ranges.

12-188


Molnar's Pond
5/30/73
Weight (g)
460
450
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
Red - Jones Hole
Black - Donaldson
Length (cm

Simmons Pond 5/30/73