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OF THE BUREAU OF SPORT FISHERIES AND WILDLIFE

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5. Ecology of Gila Trout in Main Diamond Creek in New Mexico

By Danny M. Regan
Colorado Cooperative Fishery Unit

Washington January 1966

UNITED STATES DEPARTMENT OF THE INTERIOR
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CONTENTS

ECOLOGY OF GILA TROUT IN MAIN DIAMOND CREEK IN NEW MEXICO

By Danny M. Regan, Fishery Biologist
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ABSTRACT.--Data on Gila trout (Salmo gilae) ecology were collected from a 2 1/2-mile section of Main Diamond Creek in New Mexico, in the upper range of the Transition Zone (approximately 8,000 feet). Between June 7 and November 1, 1962, stream flow ranged from 175 to 423 gallons a minute; water temperature was 43° to 60° F. Chemical characteristics were comparable to those of other tributaries in the same altitude range. Total fish population in Main Diamond Creek was estimated at 4,300, representing age groups I through VI. The Gila trout is the only fish in the upper part of Main Diamond Creek. Growth rate for this species was much slower than for three other trout species in the Gila River drainage. There was a steady decline in condition factor from June to November 1962. Analysis of bottom fauna and stomach samples showed little variation between utilization and occurrence. Trichoptera, Ephemeroptera, Diptera, and Coleoptera were the most important food items. A high incidence of scale regeneration and subsequent variability resulted in inadequate body-scale relations. Meristic and morphometric characters for 25 Gila trout were approximately the same as those for paratypes collected 25 years ago.

The range of the Gila trout (Salmo gilae Miller, 1950) has shrunk in recent years. Overfishing, change in climate, introduction of exotics, and overgrazing have been postulated as reasons, but little is known about the ecology of the species.

The Gila trout was described from specimens obtained at Main Diamond Creek in New Mexico, July 18, 1939. Outstanding characteristics are the extremely fine and profuse spotting on the dorsal and caudal fins--spotting that is generally restricted dorsally to the lateral line--and the unusually large and well-spotted adipose fin.

A pure strain of Gila trout inhabits three headwater streams of the Gila River in New Mexico. Two factors contributing to survival of this species are natural stream barriers and the conservation policy of the New Mexico Department of Game and Fish in not stocking exotic species in certain streams.

Past attempts to propagate this species artificially were unsuccessful, but with improved hatchery techniques, propagation should now be possible. The New Mexico Department of Game and Fish is attempting to rear the species at the Glenwood Hatchery, Glenwood, N. Mex. If successful, the department plans to rehabilitate former habitat and reestablish the species.

Main Diamond Creek (T.11S., R.10W.) is in the northwest part of Sierra County. The study area covers a 2 1/2-mile section upstream from the James Brothers Cabin. Average stream width is approximately 7 feet, and average depth is approximately 4 inches. Stream improvement structures, installed in

This paper is based on a thesis submitted to the Graduate Faculty, Colorado State University, Fort Collins, Colo., in partial fulfillment of the requirements for the degree of Master of Science.

1931, have created small pools where fish congregate.

The object of this study was to obtain information that will provide a base for future management and preservation of Gila trout as a potential sport fishery resource and as a unique fish species. For this, it was necessary to determine the ecological status of Gila trout in Main Diamond Creek. This investigation therefore sought the following information: (1) Estimated population, age composition, growth characteristics, reproductive potential, and effect of fishing. (2) Physical, chemical, and biological characters of the stream.

I am indebted to Dr. Robert E. Vincent, Dr. Howard A. Tanner, Dr. Elmer Remmenga, and Dr. Harold W. Steinhoff for their guidance and assistance in the organization and presentation of this study. Ladd Gordon and Roy E. Barker of the New Mexico Department of Game and Fish made the collection of field data possible. Wade Halvorson, Jr., assisted in programing the computer that expedited data evaluation.

METHODS AND EQUIPMENT

Because the only available data on Gila trout are taxonomic, the field collections included information on many aspects of the ecology of this species in Main Diamond Creek. Field studies were conducted during the years 1962 and 1963.

FIELD PROCEDURES

One of the primary considerations in field work was the collection of Gila trout for scale samples, lengths, weights, stomachs, and other data. Limnological observations included data on dissolved oxygen, alkalinity, free carbon dioxide, pH, temperature, and volume of flow.

A 115/230-volt alternating-current electric generator was used to collect fish. Eight 200-foot sections of stream were established for sampling. Blocking seines of 1/4-inch mesh were placed across the upper and lower ends of a section during electrofishing. Captured fish were placed in live boxes until necessary data could be recorded.

A concern in this study was to keep handling mortality at a minimum. One pass with electrofishing gear should give an adequate estimate of total population without excessive mortality. To determine whether this was so, stations 1 and 2 were electrofished three times. At station 1, 95 percent of the fish were captured the first time, 5 percent the second time, and none the third time. At station 2, 96 percent were captured the first time and 2 percent each of the other two times.

Scale samples were taken immediately dorsal to the lateral line, at the level of the anterior insertion of the dorsal fin. Scales were placed in standard scale envelopes on which the species, sample number, station number, total length in millimeters, weight in grams, and date of capture were recorded.

Chemical analysis included dissolved oxygen by the Alsterberg (Azide) modification of the Winkler method (Lagler, 1956); phenolphthalein and methyl orange alkalinity by titration with standard sodium hydroxide; and pH determined colorimetrically with a Hellige comparator. Water temperature readings were taken with a pocket thermometer. The float method was used to obtain estimated volume of flow.

Stomachs were removed from fish that were killed accidentally when Main Diamond Creek was electrofished during June, August, and November, 1962. The part of the digestive tract between the esophagus and the pyloric valve was removed, labeled, and preserved in 10-percent formalin.

Bottom samples were obtained with a Surber square-foot bottom sampler. The contents of each sample were labeled and preserved in 10-percent formalin.

LABORATORY PROCEDURES

In the laboratory, age of scales was determined and an attempt was made to establish the body-scale relation. Length-weight relation and coefficient of condition were computed. Aquatic invertebrates found in stomachs and square-foot bottom samples were classified and enumerated. Morphometric and meristic characters were established for the study population of Gila trout.

Scale samples were examined until a nonregenerated scale was found to make a wet mount. A 35-mm. camera, adapted to a binocular microscope, was used to photograph each scale on fine-grain film. Negatives were numbered, and 3 1/2- by 4 1/2-inch glossy prints were made. The magnification factor was determined by photographing a hemacytometer counting chamber. A calculated magnification factor of 46 diameters was used on all scales.

Age of each fish was determined by a modification of procedures set forth by Rounsefell and Everhart (1953) and Carlander (1956). Each scale photograph was read at least twice. When there was disagreement, a third reading was made. Agreement of any two readings was considered substantiation of that age; if there was no agreement between the three readings, that fish was eliminated from the study.

Each age-group was designated by a Roman numeral that indicates the number of winters the fish has lived. Since all collections were made after the time of annulus formation and hatching, the number also indicates the year of life for each fish.

One of the first requirements for back-calculation of fish length from measurement of the distance between annuli is an understanding of the relation between growth of the fish and growth of the scale. Values for fish lengths and scale lengths can be considered random samples from the general population; therefore, it is both possible and meaningful to manipulate the regression so that the desired regression can be determined directly (Winsor, 1946). Because predictions were to be made from the scale length, it was considered the independent variable.

Scale-length measurements were made from the scale photographs by a ruler graduated in millimeters. Distance was measured from the center of the scale focus to each annulus and to the scale margin along the most anterior median radius of the scale that best exhibited the final assessed age of each fish. Measurements were read to the nearest millimeter and were recorded on the back of each photograph.

The regression formula $L = a + bS$ was used to assess the rectilinear relation between body length and scale length (Whitney and Carlander, 1956; Snedecor, 1956).

Curvilinear relations were determined for age groups I and II, age groups III and above, and the total sample of usable scales. These relations were determined by the formulas $\log L = a' + b'S$ and $\log L = a' + b \log S$ (Steel and Torrie, 1960).

All computations were made on a desk calculator and later checked on computer programed to supply necessary information on curvilinear relations and to run an analysis of covariance.

Length-weight relations were computed for each of the three collections made in 1962 and for the combined samples. The relation is satisfactorily described by the formula $W = a L^n$ where W is the weight, L is the length, and a and n are empirically determined constants. In determining the above relation, measurements were expressed as total length in millimeters and weight in grams. Measurements were transformed into logarithms to facilitate the use of the following length-weight computational formula from Lagler (1956): $\log W = \log a + n \log L$

The coefficient K(TL) was used to obtain a mathematical measurement of the condition or relative robustness of Gila trout. Because shape and specific gravity were assumed constant, the K(TL) of each fish varied with the cube of its length and was computed from the following formula:

$$K(TL) = \frac{W\ 10^5}{L^3}$$

where W = weight in grams and L = total length in millimeters. Nomograph charts (Carlander, 1953) were used in the computation of K(TL) for individual Gila trout.

Total volume of each stomach content and square-foot bottom sample was measured by displacement. Importance of each invertebrate order was evaluated by number of organisms and by volume found in each stomach and square-foot bottom sample.

TAXONOMY

A dial-reading caliper was used to measure morphometric characters. All measurements were made in a straight line, from point to point, rather than around the curve. When the body or part measured had been curled, bloated, or otherwise distorted on death or preservation, the part was gently forced into as nearly the normal appearance as possible before being measured. All measurements were made to the nearest tenth of a millimeter.

Lateral-line scale counts were made by counting the total number of scales two rows above the lateral line, starting with the scale that touched the pectoral arch and ending at the caudal base. Remaining meristic and morphometric characters were evaluated in accordance with Hubbs and Lagler (1958).

Because the fish were of unequal length, it was necessary to convert all morphometric readings to comparable data. This was done by dividing the measurements by the standard length in millimeters. The results are expressed in thousandths of the standard length.

DISTRIBUTION

The distribution of a given organism must change or the organism must adapt as new environmental conditions arise. Before man became dominant, changes were slow and the biotic community was frequently able to make the necessary adjustments. Man-caused changes have been drastic and rapid. Modification of existing environments and introduction of exotics have encouraged replacement of native forms through competition, predation, and hybridization. Numerous species and subspecies have become extinct, others are endangered.

The Gila trout is an endangered species. Once important in the Gila River system, changes in stream ecology and introduction of exotics have resulted in a range contraction to three headwater streams.

FORMER DISTRIBUTION

This species was widely distributed in the Gila River system as late as 1915. In 1896, Gila trout ranged down the Gila River to the town of Cliff, N. Mex. At one time, population levels were so high in Gilita and Willow creeks that it was possible to catch members of the species at the rate of about one a minute. These fish usually weighed from one-half to 1 pound and averaged about 12 inches in length (Miller, 1950). Other streams that once contained sizable populations of Gila trout were Black Canyon Creek, Mogollon Creek, Diamond Creek, South Diamond Creek, and Whitewater Creek (fig. 1).

A species inhabiting suitable tributaries of Salt River and the headwaters of Little Colorado River was tentatively referred to as Salmo gilae (Miller, 1961). This group was found in Oak Creek as far downstream as Sedona, Ariz. Early residents reported these fish so plentiful in the White Mountain streams that an inexperienced angler could catch 100 in a few hours or 200 in a full afternoon.

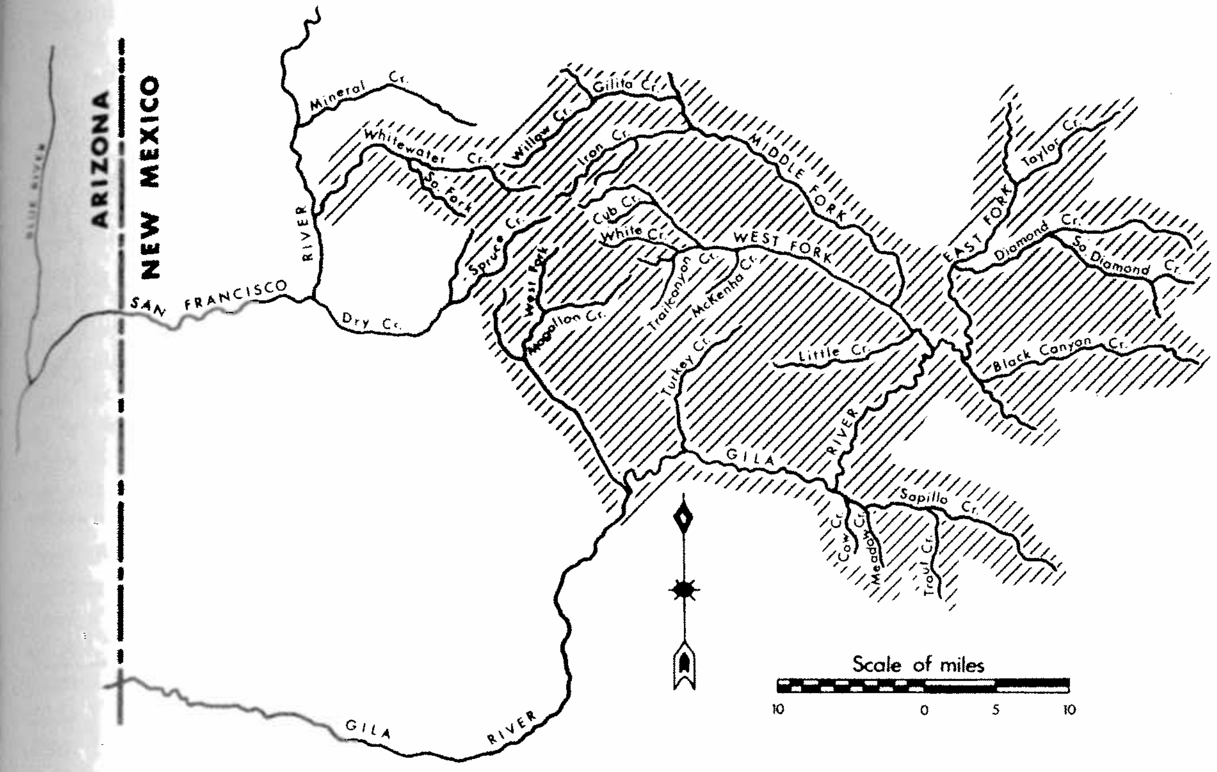

Figure 1.--Former distribution of Gila trout in New Mexico.

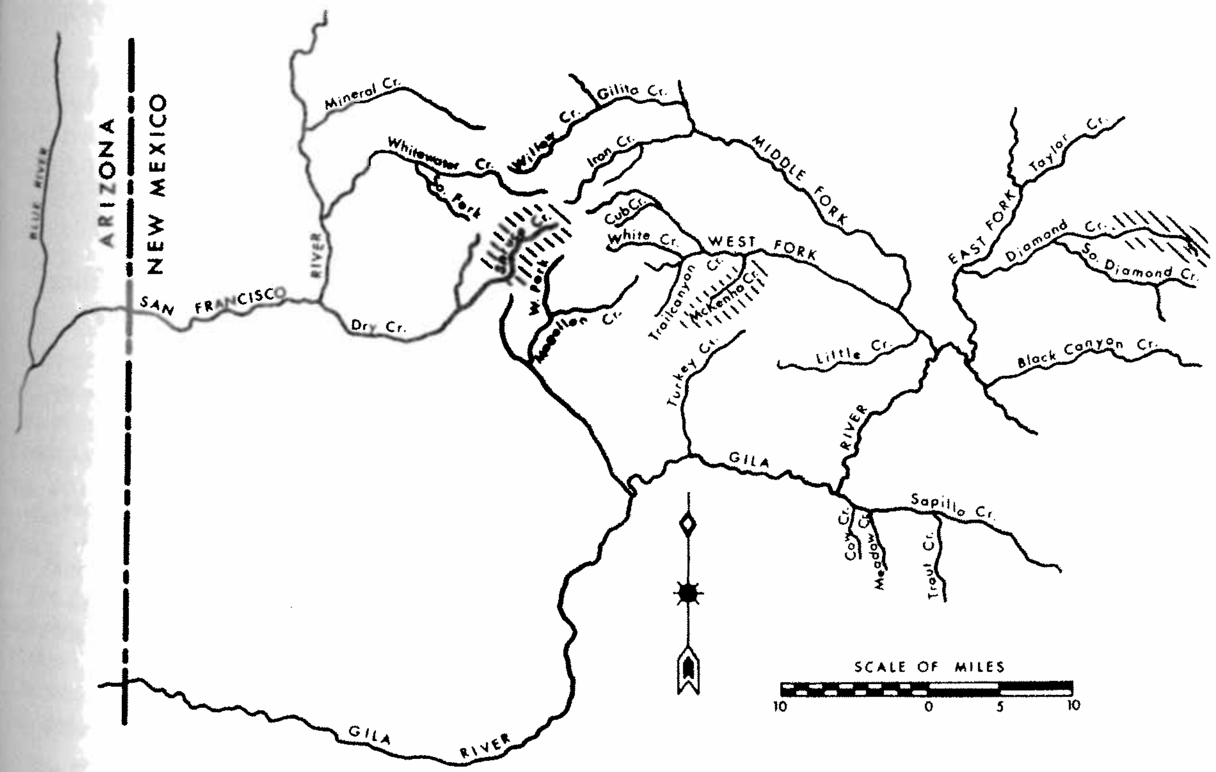

Figure 2.--Present distribution of Gila trout in New Mexico.

PRESENT DISTRIBUTION

The present distribution of Gila trout is limited to three small headwater streams. Streams in which Gila trout are presently found have been isolated from the main stream by barriers, and man's influence has been minimized by isolation. Exotic fishes have not been introduced above the barriers.

Recent investigations resulted in the conclusion that a pure strain of Gila trout can still be found in Diamond Creek, McKenna Creek, and Spruce Creek (fig. 2). Mixed populations of rainbow trout, cutthroat trout, and Gila trout were found in the following waters: West Fork of the Gila River, Langstroth Creek, Willow Creek, Cub Creek, and Iron Creek.

A pure strain of Gila trout could be found in the upper headwaters of Eagle Creek, Greenlee County, Ariz. (Mulch and Gamble, 1954). A hybrid between Gila trout and rainbow trout can be found in Black River, White River, and White Mountain streams in Arizona.

LOCATION AND DESCRIPTION

The Gila River originates in the mountains of southwestern New Mexico and southeastern Arizona. The basin encompasses a total drainage area of approximately 59,000 square miles, approximately one-fourth of the total drainage area of the Colorado River basin.

The study area encompasses a 2 1/2-mile section of Main Diamond Creek (fig. 3). Acess to the study area is good during much of the year.

PHYSICAL CHARACTERS

Main Diamond Creek is formed by permanent springs and seasonal runoff. It originates at an elevation of approximately 8,500 feet, near Diamond Peak in the Black Range, and descends to approximately 5,900 feet at its confluence with the East Fork of the Gila River. Main Diamond Creek flows through various types of country, from the rough terrain of high mountains covered with Douglas-fir (Pseudotsuga menziesii), Engelmann spruce (Picea engelmannii), and trembling aspen (Populus tremuloides) to the lower elevations where pinyon pine (Pinus edulis), juniper (Juniperus sp.), and ponderosa pine (Pinus ponderosa) are the dominant vegetation.

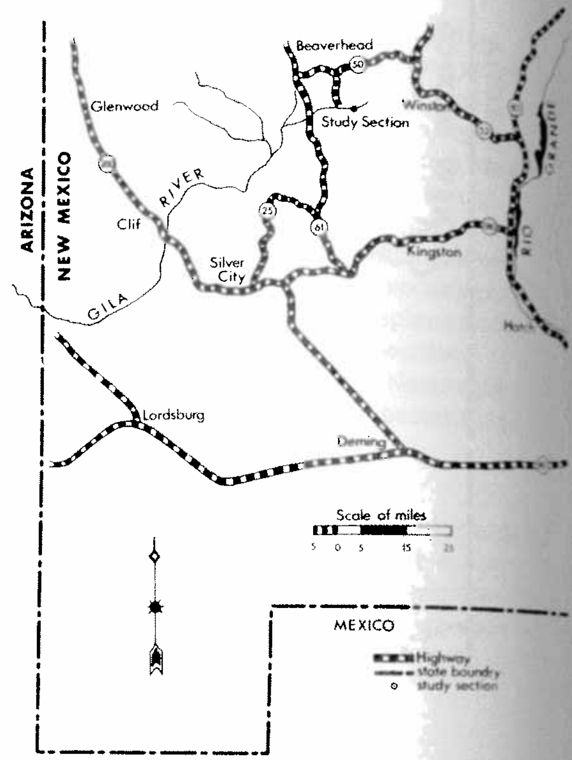

Figure 3.--Location and accessibility of study section of Main Diamond Creek.

The stream goes underground approximately half a mile below the study area. There is no surface flow, except occasional runoff, for approximately 12 miles. This has prevented the upstream migration of fish fauna now present in lower Main Diamond Creek and in East Fork of the Gila River. Stream flow above the study area is intermittent. Volume of flow decreased from 225 gallons a minute in June to 175 gallons a minute in August.

The highest volume of flow, 423 gallons a minute, was recorded October 30, 1962. During periods of low flow, the fish congregate in pools created by stream improvement structures (fig. 4).

Shortly after installation of stream improvement structures, the New Mexico Department of Game and Fish closed the stream to fishing. At the same time the Forest Service reduced grazing allotments on the watershed and fenced portions of the bottom land to prevent grazing. As a result, the watershed is in good condition, and the stream bank vegetation is quite dense (fig. 5).

Combined climatological data from Kingston, Mimbres, Winston, and Fort Bayard weather stations show that from 1869 to 1932 the average annual precipitation was 16.94 inches, while from 1932 to 1956 it was 15.36 inches (Reynolds, 1956b). The 1956 precipitation total of 5.27 inches for Winston was the lowest recorded since 1921, while a precipitation total of 11.17 inches for Fort Bayard in 1905 was the highest since 1896.

The mean annual temperature at Fort Bayard over a 95-year period was 55.1° F., while over a 7-year period at Winston it was 52.0° F. (Reynolds, 1956a). Extreme temperatures of record at Fort Bayard were 105° F. and -6° F., and at Winston, 102° F. and -5° F.

The greater part of the Black Range is one of irregular ridges, plateaus, and valleys and does not conform to the basic idea of simple parallel ranges. It presents a complicated history of intrusions, faulting, lava flows, and various erosion cycles typical of the Datil Lava Field (Chambers, 1960).

The Canadian Zone covers the peaks and ridges above 8,500 feet on the northern slopes and 9,500 feet on southern slopes. The vegetation is characterized by spruce, fir, and aspen.

The study section is in the upper range of the Transition Zone. This zone spreads over plateau tops and middle slopes from approximately 6,500 to 8,500 feet on northern exposures and 8,000 to 9,500 feet on southern exposures. Vegetation is delineated by a ponderosa pine overstory interspersed with Gamble oak (Quercus gambelii), silverleaf oak (Quercus hypoleucoides), snowberry (Symphoricarpos sp.), and locust (Robinia neomexicana).

The Upper Sonoran Zone includes lower parts of the plateau from about 5,000 feet on northern slopes to 7,500 feet on southern slopes. One-seeded juniper (Juniperus monosperma), alligator juniper (Juniperus depeana), pinyon pine (Pinus edulis), gray oak (Quercus grisea), wavyleaf oak (Quercus undulata), mountain mahogany (Cercocarpus sp.), silktassel (Garrya wrightii), skunkbush (Rhus trilobata), walnut (Juglans major), and manzanita (Arctostaphylos sp.) compose the overstory.

CHEMICAL CHARACTERS

Data on the chemical characteristics of Main Diamond Creek were collected between June 7 and October 30, 1962 (table 1). The water temperature ranged from a high of 60° F. in June to a low of 43° F. in October. Dissolved oxygen ranged from 6.6 to 8.8 p.p.m., alkalinity 26 to 31 p.p.m., and total hardness remained constant at 34 p.p.m. No trace of CO_2 or phth was found.

BIOLOGICAL CHARACTERS

The Gila trout is the only fish in the upper section of Main Diamond Creek. Below the natural stream barrier the fish fauna includes rainbow trout, white sucker (Catostomus commersoni), Gila sucker (Pantosteus clarki), longfin dace (Agosia chrysogaster), and speckled dace (Rhinichthys osculus).

Quality of the aquatic invertebrate population was evaluated by square-foot bottom samples taken above and below the

Figure 4.--One of the numerous pools created by stream improvement structures in Main Diamond Creek.

Figure 5.--Dense growth of vegetation along the bank of Main Diamond Creek.

Table 1.--Chemical features of Main Diamond Creek, June 7 through November 1, 1962

Item	Station 1	Station 8	Station 1	Station 8	Station 1	Station 8
Date..............	6/7/62	6/11/62	8/14/62	8/16/62	10/30/62	11/1/62
Time..............	1:35 p.m.	1:15 p.m.	12:50 p.m.	11 a.m.	11 a.m.	12:45 p.m.
Air temperature....	79° F.	82° F.	66° F.	65° F.	45° F.	47° F.
Water temperature..	54° F.	60° F.	54° F.	60° F.	43° F.	43° F.
O_2 (p.p.m.).......	6.6	6.8	7.0	6.5	8.2	8.8
M. O. alk. (p.p.m.)	30.0	31.0	27.0	30.0	28.0	26.0
pH...............	7.0	7.0	7.0	7.5	7.0	7.0

center stake at each of the eight sampling stations. Collections were obtained June 7 through June 11, 1962, and August 14 through August 16, 1962.

Trichoptera and Ephemeroptera were the two most abundant orders in both the June and August collections (fig. 6). Ephemeroptera represented approximately 55 percent of the total number and 25 percent of the total volume, while Trichoptera contributed approximately 18 percent of the total number and 55 percent of the total volume.

Total volume of the June collections ranged between 0.1 and 2.3 cc., while the August collections varied from 0.4 to 5.2 cc. Using the standards of richness proposed by Lagler (1956), both collections would be considered average since the volume was between 1 and 2 cc. and the number of organisms was greater than 50.

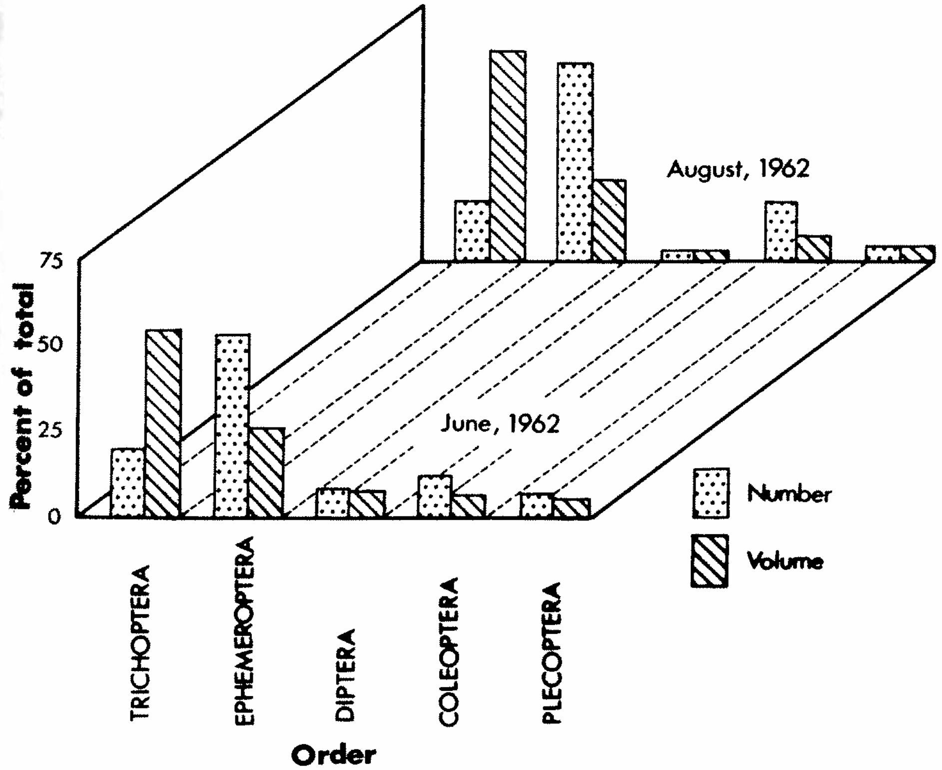

Figure 6.--Occurrence of aquatic invertebrates in square-foot bottom samples from Main Diamond Creek.

PRESENTATION OF DATA

Total population of Gila trout was estimated at 4,300 fish longer than 50 mm. in total length. This estimate is based on fish captured in 1,600 feet of Main Diamond Creek, June 7 through June 11, 1962. Young of the year were not included, as sampling techniques prevented a reliable estimation.

AGE AND GROWTH

An analysis of covariance was conducted on length-weight measurements of 50 male and 48 female Gila trout. Computed F values showed no difference at the 95 percent confidence level, in regression coefficients or in adjusted treatment means. This test was considered sufficient justification for combining male and female Gila trout data for further analysis.

During the period June 7 through November 1, 1962, 525 scale samples were taken. Usable scales were found in 337, or 64 percent of the total collection. On some fish, as many as 100 scales were examined without finding a scale that was not regenerated.

There were only slight differences in length-frequency distributions for the total sample of 525 fish and for the 337 fish from which usable scales were obtained (fig. 7). Largest deviation was in the 110-119mm. size group, where the usable scale sample was 4 percent below the total sample.

Of scale readings, 86 percent were verified by second reading, while 14 percent required a third reading. Agreements between second and third readings and between first and third readings were 45 and 35 percent. Eight were rejected for lack of agreement. Age groups I through VI are represented in the 1962 collections from Main Diamond Creek.

Two methods for validating annuli as year marks (Hill, 1941) were fulfilled in this study. Average length of fish increased consistently with age (table 2), and there was close agreement between the modes of length-frequency distributions and modal length of age groups based on scale readings (fig. 8). Gila trout scales showed no accessory growth checks that resemble annuli.

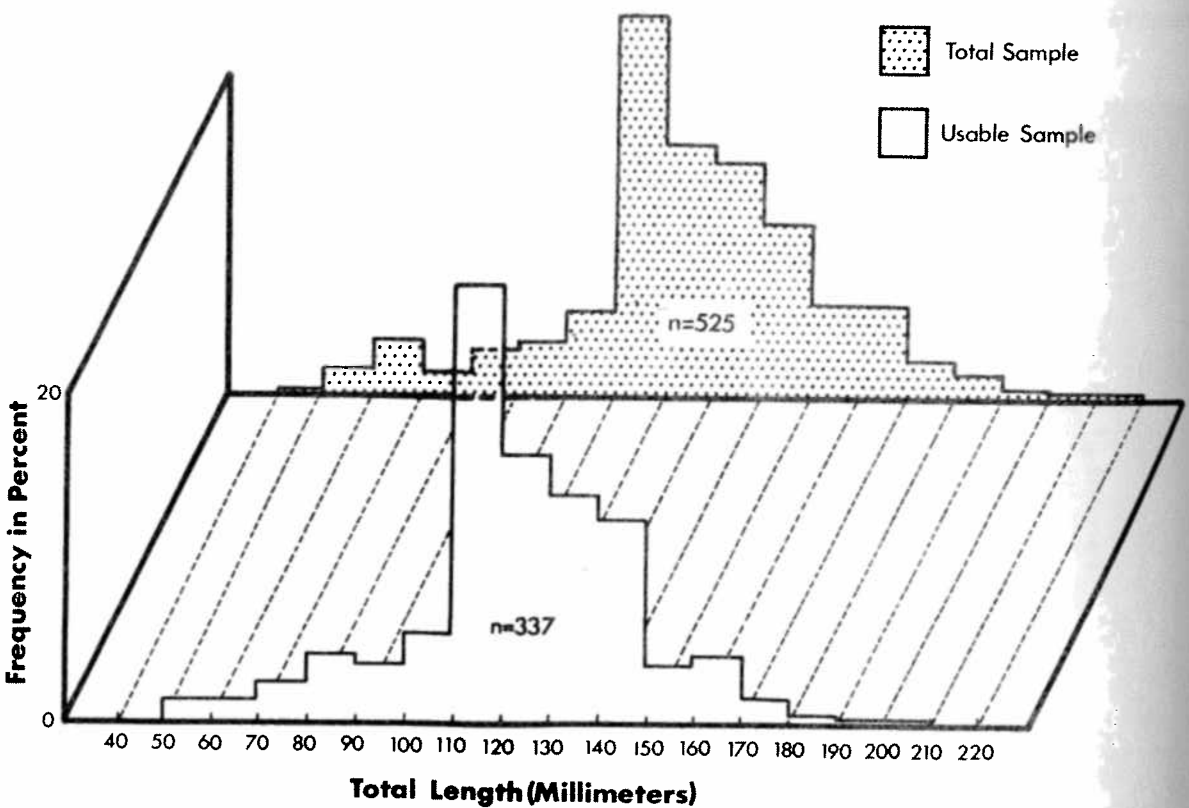

Figure 7.--Comparison of percentage length-frequency between total and usable scale samples.

Table 2.--Distribution, by length group and by age group, of Gila trout from Main Diamond Creek, June 7 through November 1, 1962

Length Group	Number in age group-- I	II	III	IV	V	VI
50-59 mm........	5	--	--	--	--	--
60-69 mm........	5	--	--	--	--	--
70-79 mm........	8	--	--	--	--	--
80-89 mm........	14	--	--	--	--	--
90-99 mm........	12	2	--	--	--	--
100-109 mm......	2	17	--	--	--	--
110-119 mm......	--	90	--	--	--	--
120-129 mm......	--	43	13	--	--	--
130-139 mm......	--	7	43	--	--	--
140-149 mm......	--	--	29	10	--	--
150-159 mm......	--	--	2	11	--	--
160-169 mm......	--	--	--	7	7	--
170-179 mm......	--	--	--	--	5	--
180-189 mm......	--	--	--	--	1	2
190-199 mm......	--	--	--	--	--	1
200-209 mm......	--	--	--	--	--	1
All sizes.....	46	159	87	28	13	4

The mathematical relation between length (L) and weight (W) was computed from the general equation $W = aL^n$ where a and n are determined empirically.

The following equations were developed from collections made June 7 through 11, August 14 through 16, and October 30 through November 1, and from the combined sample for 1962.

Collection 1, $\log W = -5.23358 + 3.13113 \log L$

Collection 2, $\log W = -5.26827 + 3.13267 \log L$

Collection 3, $\log W = -5.34047 + 3.14994 \log L$

Combined sample, $\log W = -5.27816 + 3.14009 \log L$

Use of individual lines would not improve agreement between observed and calculated data to an extent to warrant their use instead of the combined line shown in figure 9. A computed correlation coefficient of 0.98

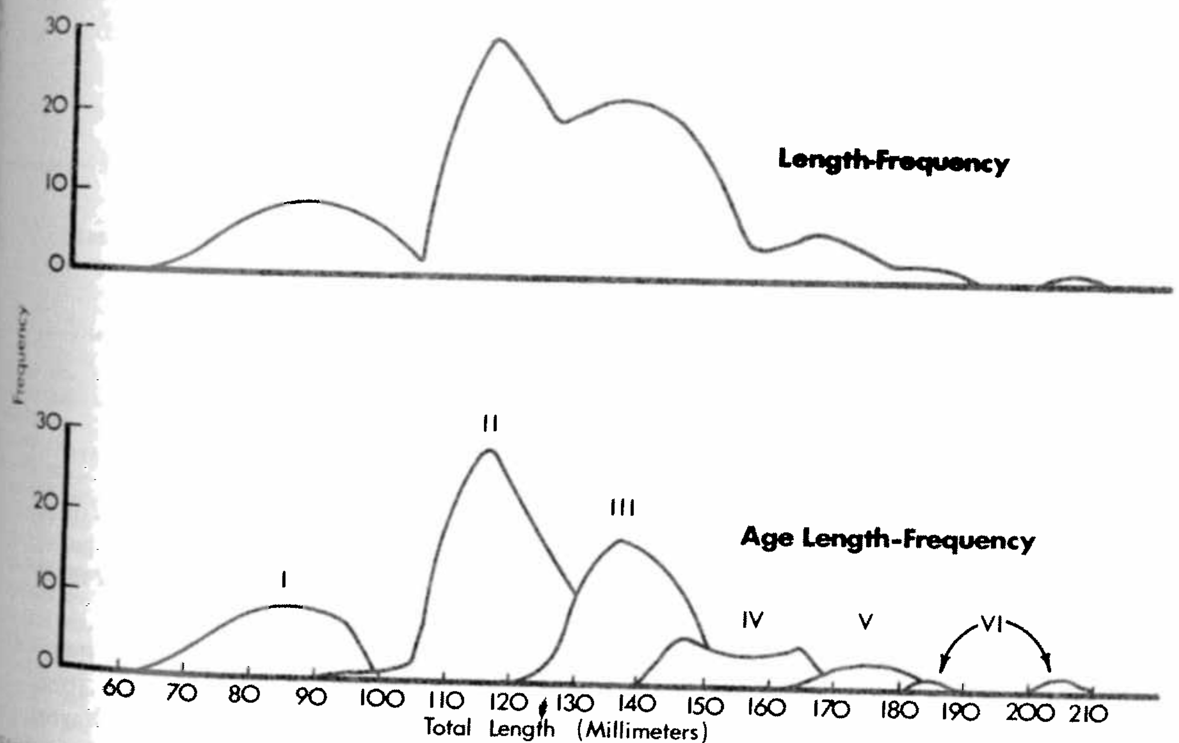

Figure 8.--Length-frequency and age-length-frequency distributions of 131 Gila trout from Main Diamond Creek, August 14 through 16, 1962.

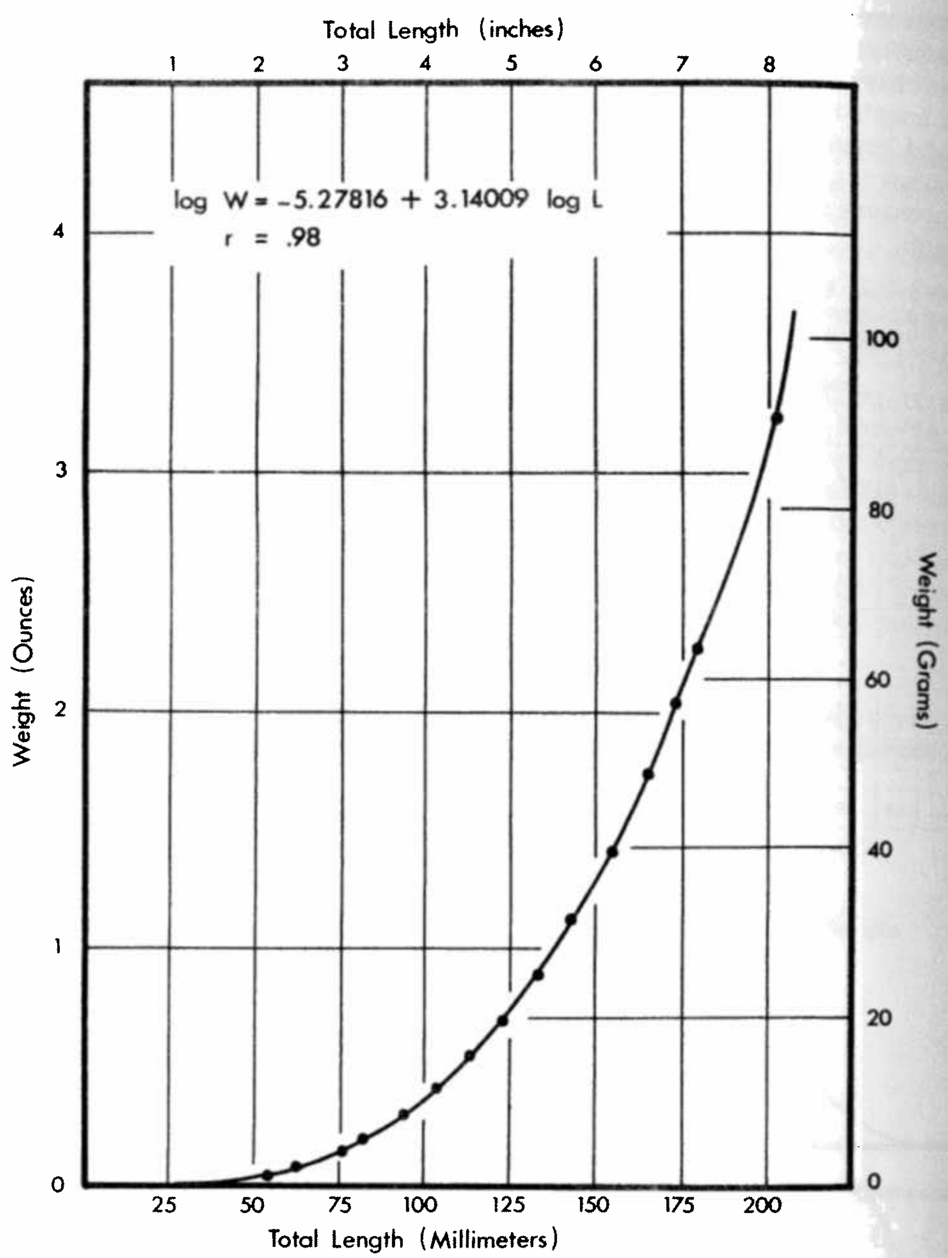

Figure 9.--Calculated length-weight relation for combined collection of Gila trout from Main Diamond Creek, 1962. Dots represent empirical means.

and agreement between empirical and calculated weight are further justifications for using the combined line.

Condition factors were computed for each of the three 1962 Gila trout collections. In evaluating these different coefficients, increases were interperted as denoting better condition. The average K(TL) values for various age groups of Gila trout showed an increase with age (fig. 10) and a general trend for increase with mean length (table 3).

The body-scale relation for most fish populations, after first annulus formation, is rectilinear (Carlander, 1956). Different types of relation have been used to describe the body-scale data for various

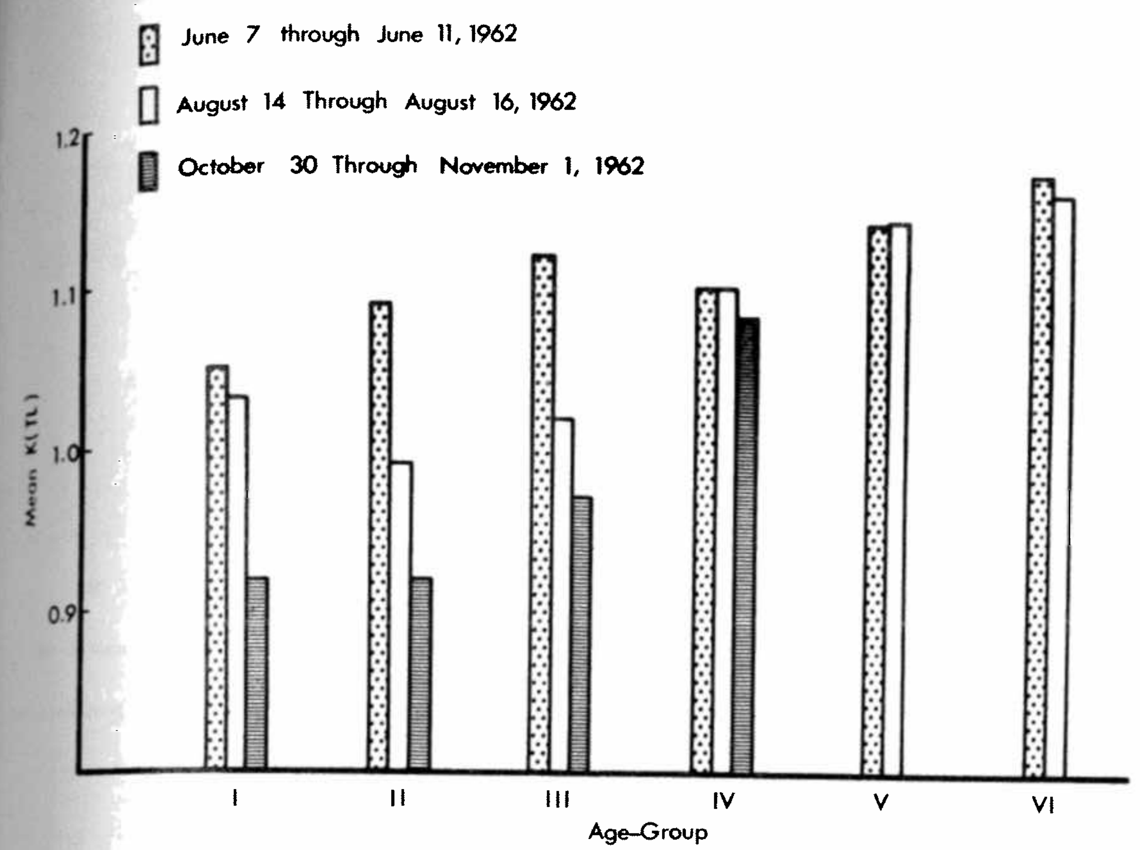

Figure 10.--Mean variation in coefficient of condition with age of 337 Gila trout from Main Diamond Creek, June 7 through November 1, 1962.

Table 3.--Mean variation in coefficient of condition with length of 337 Gila trout from Main Diamond Creek, June 7 through November 1, 1962

Size group	Collection 1 (June 7-11, 1962)			Collection 2 (Aug. 14-16, 1962)			Collection 3 (Oct. 30-Nov. 1, 1962)		
	Number of fish	Mean length (mm)	Mean K(TL)	Number of fish	Mean length (mm)	Mean K(TL)	Number of fish	Mean length (mm)	Mean K(TL)
50-59 mm........	4	55.8	0.97	--	--	--	1	52.0	0.71
60-69 mm........	4	63.2	1.08	1	65.0	1.32	--	--	--
70-79 mm........	--	--	--	6	76.2	1.09	2	75.5	1.04
80-89 mm........	1	82.0	1.27	9	83.8	0.91	4	85.5	0.88
90-99 mm........	1	98.0	0.96	8	95.2	1.11	5	92.2	0.94
100-109 mm......	16	105.5	1.10	2	105.5	1.01	1	100.0	0.90
110-119 mm......	46	114.0	1.09	29	114.8	0.97	15	114.1	0.93
120-129 mm......	19	123.0	1.11	19	124.0	1.02	18	123.7	0.91
130-139 mm......	16	133.9	1.14	22	134.0	1.00	12	133.4	0.94
140-149 mm......	13	144.1	1.09	19	143.0	1.07	7	144.4	1.01
150-159 mm......	8	155.1	1.10	4	154.8	1.10	1	150.0	1.01
160-169 mm......	6	166.3	1.13	6	163.3	1.11	2	165.5	1.08
170-179 mm......	2	173.5	1.17	3	173.7	1.14	--	--	--
180-189 mm......	1	180.0	1.23	2	180.0	1.15	--	--	--
190-199 mm......	1	197.0	1.11	--	--	--	--	--	--
200-209 mm......	--	--	--	1	201.0	1.16	--	--	--

Salmonidae. For example: lake trout (Salvelinus namaycush), sigmoid over a range of 6 to 26 inches (Webster et al., 1960); brown trout (Salmo trutta), curvilinear over a range of 51 to 384 millimeters (Sigler, 1952); and cutthroat trout (Salmo clarki), curvilinear over a range of 44 to 255 millimeters (Fleener, 1952).

Scale samples from 361 Gila trout, obtained at Main Diamond Creek between June 7, 1962, and June 23, 1963, were used in the analysis of body-scale relations.

The relation between scale length and body length was evaluated by assuming both rectilinear and curvilinear characteristics (table 4). Linearity accounted for 64 to 79 percent of the regression variance (correlation coefficient squared). This was not considered adequate correlation for back-calculation. A complete evaluation of these relations will be published separately.

Table 4.--Body-scale relations for 361 Gila trout from Main Diamond Creek, June 7, 1962, through June 23, 1963

Relation	Age groups	Correlation coefficient
L = a + b S.......	I-VI	0.89
log L = a'+ b' S......	I-VI	.85
log L = a'+ b' S......	I-II	.80
log L = a'+ b' S......	III-VI	.83
log L = a'+ b log S....	I-VI	.82
log L = a'+ b log S....	I-II	.81
log L = a'+ b log S....	III-VI	.84

Growth analysis was limited to a comparison of actual rate for the three collections (fig. 11) and a comparison of the seasonal pattern for age groups collected during the period June 7 through November 1, 1962 (figs. 12 and 13). This limitation was imposed because inadequate

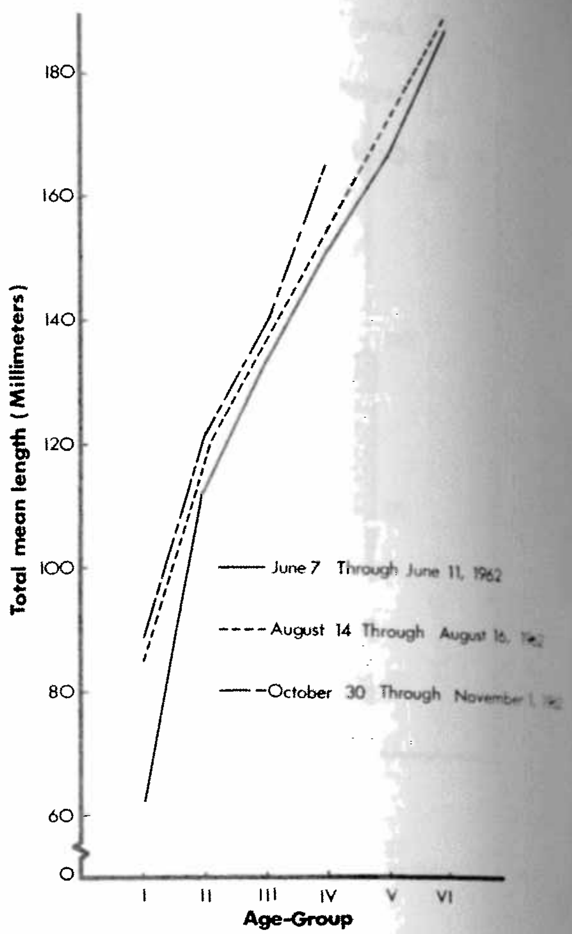

Figure 11.--Actual rate of growth for 337 Gila trout from Main Diamond Creek.

correlation between body length and scale length precluded back-calculation of length at the time of annulus formation.

Increases in mean total length were as follows: age group I, 23 mm.; age group II, 7 mm.; age group III, 5 mm. The November collection included two age group IV fish and no age group V or VI. Increase in length for these age groups was limited to the interval between June 7 and August 16, 1962. Increases were as follows: age group IV, 4 mm.; age group V, 6 mm.; and age group VI, 2mm.

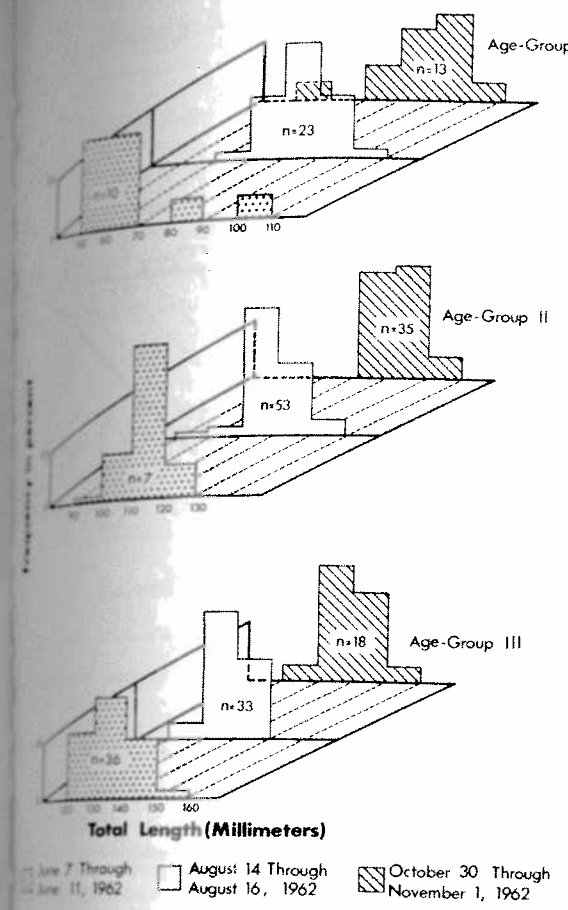

Figure 12.--Seasonal percentage length-frequency distributions for age groups I, II, and III of Gila trout from Main Diamond Creek.

FECUNDITY

Estimated fecundity of Gila trout was determined from two specimens obtained at Main Diamond Creek and 13 specimens held at the Glenwood Hatchery. Total length ranged from 185 to 270 mm. Ovum counts on the two fish from Main Diamond Creek were 196 and 96. Counts on the hatchery fish, based on the total number of eggs, averaged [illegible] eggs per female.

FOOD HABITS

Feeding habits of Gila trout were evaluated from 63 stomachs collected during the follow-

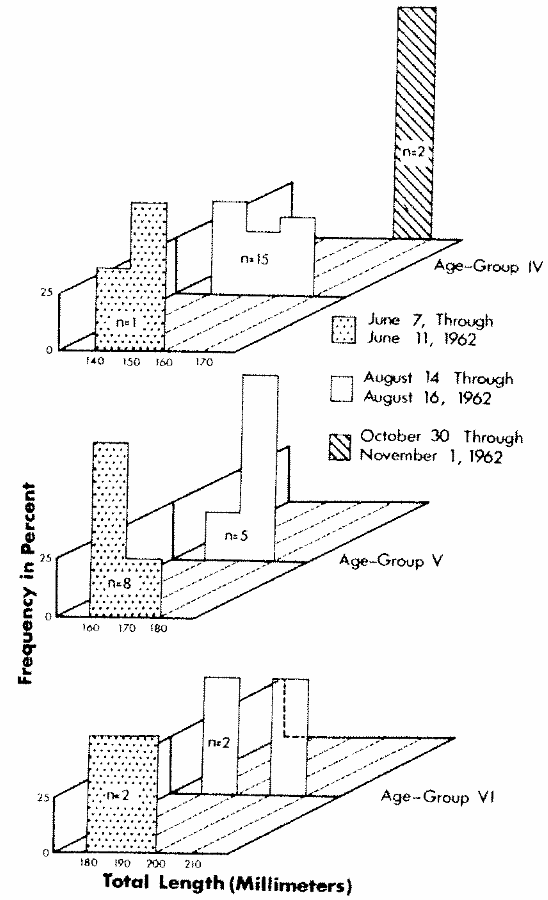

Figure 13.--Seasonal percenrage length-frequency distributions for age groups IV, V, and VI of Gila trout from Main Diamond Creek.

ing periods: 20 in June, 20 in August, and 13 in October and November, 1962. Stomachs were obtained from fish that had a total length of 47 to 168 mm. There was little change in food habits with increased size over the ranges sampled, but there was some seasonal variation in food habits (fig. 14).

The most important food item in the June collection was adult Diptera. They contributed 37 percent of the total number, 28 percent of the total volume, and were represented in 80 percent of the observed stomachs. The next most important group was Trichoptera which represented 19 percent of the total number, 15 percent of the total volume, and

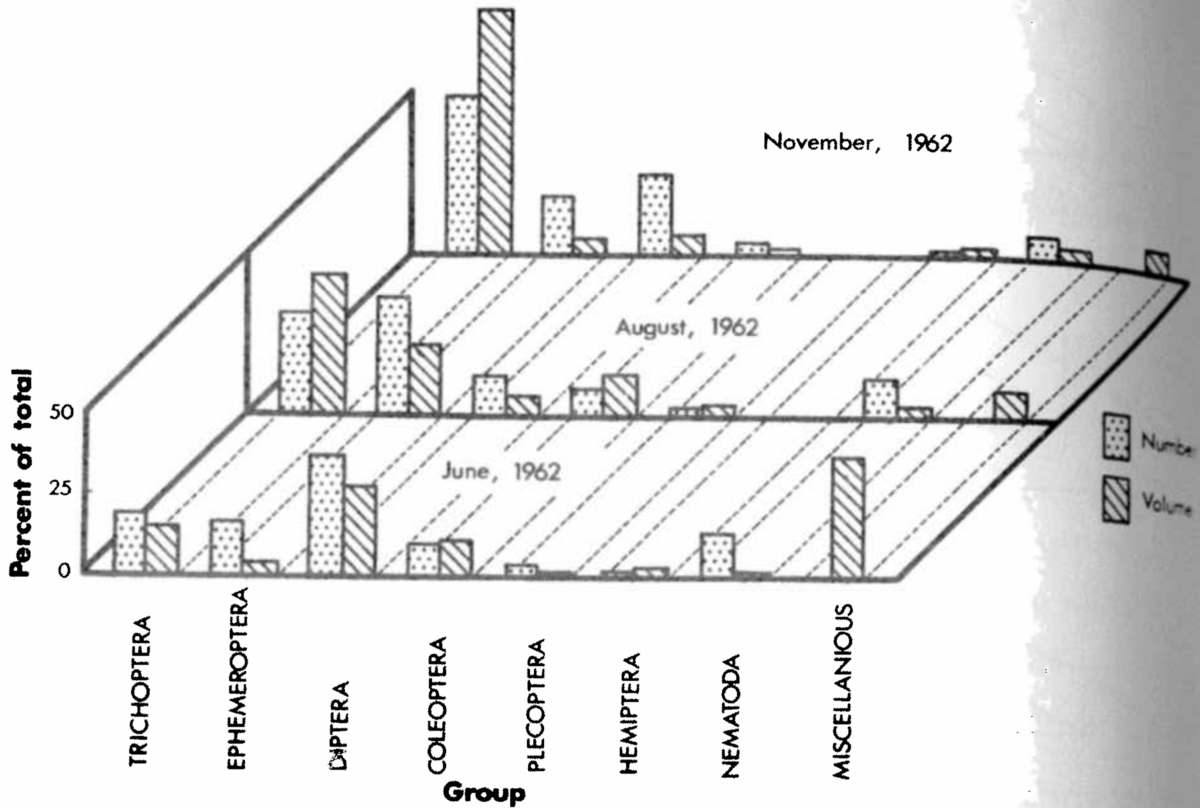

Figure 14.--Occurrence of food items in stomachs of Gila trout from Main Diamond Creek.

had a 88 percent frequency of occurrence. In addition to the above two orders, Coleoptera, Ephemeroptera, Plecoptera, Hemiptera, and Nematoda made minor contributions to the total number and volume.

Total number and volume of Diptera in the August collection dropped to 12 percent and 6 percent respectively, and they appeared in only 40 percent of the stomachs. The two major food groups at this time were Trichoptera, which contributed 31 percent of the total number and 47 percent of the total volume, and Ephemeroptera, 35 percent of the total number and 22 percent of the total volume. The frequency of occurrence for Trichoptera and Ephemeroptera was 88 percent and 92 percent respectively.

Trichoptera was the most important food item in the 13 stomachs obtained October 30 through November 2, 1962. It represented 48 percent of the total number, 76 percent of the total volume, and were found in 92 percent of the stomachs.

TAXONOMY

Counts and measurements were made on 25 specimens of Gila trout obtained from Main Diamond Creek. These fish were 98 mm. to 157 mm. in total length with a mean of 116 mm. Analysis is limited to six meristic and 15 morphometric characters. In a comparison of 17 different collections of *Salmo*, Needham and Gard (1959) concluded that 10 of these characters demonstrated differences without overlap except range, and five showed only overlap of standard deviations.

Morphological characters of Gila trout, obtained from Main Diamond Creek July 18, 1939, were evaluated by Miller (1950) and by Needham and Gard (1959). Meristic and morphometric characters examined in this study compare favorably with those made by other authorities (tables 5 and 6).

Table 5.--Comparison of meristic characters of Gila trout from Main Diamond Creek

Character	Miller (1950)		Needham and Gard (1959)		Present	
	Range	Number	Range	Number	Range	Number
Scales two rows above lateral line..........	133-151 (141.2)	25	138-158 (146.0)	17	130-159 (143)	25
Scales above lateral line................	24-29	16	28-35 (31.8)	17	25-33 (29)	25
Scales below lateral line................	23-27	16	22-29 (25.1)	17	23-28 (26)	25
Branchiostegal rays.....	9-11 (10.2)	25	10-11 (10.6)	25	10-11 (10.6)	25
Pelvic rays.............	9-10 (9.6)	34	9-10 (9.8)	25	9-10 (9.8)	25
Pyloric caeca..........	31-42	20			28-38 (32)	25

Table 6.--Comparison of morphometric characters of Gila trout from Main Diamond Creek
[Expressed as thousandths of the standard length]

Character	Miller (1950)		Needham and Gard (1959)		Present	
	Range	Number	Range	Number	Range	Number
Standard length in mm...	72-126 (104)	6	70-127 (92)	17	98-157 (116)	25
Body depth.............	256-284 (271)	6	239-267 (254)	17	231-292 (256)	25
Body width.............	127-153 (141)	6	128-152 (138)	17	129-176 (147)	25
Head length............	296-320 (306)	6	291-315 (302)	16	273-319 (294)	25
Head width.............	124-153 (142)	6	133-158 (146)	17	135-163 (149)	25
Head depth.............	178-203 (192)	6	193-212 (201)	17	168-199 (188)	25
Orbit width............	67-75 (70)	6	63-71 (67)	17	63-87 (77)	25
Snout length...........	66-77 (71)	6	62-70 (66)	17	68-85 (74)	25
Upper jaw, length.......	162-175 (169)	6	148-172 (161)	17	144-184 (157)	25
Dorsal origin to tip of snout............	523-542 (534)	6	507-537 (522)	17	505-547 (530)	25
Pelvic origin to tip of snout............	556-570 (565)	6	543-569 (557)	17	545-605 (573)	25
Dorsal fin, basal length	138-148 (142)	6	135-153 (143)	17	137-165 (148)	25
Dorsal fin, depressed length...............	237-253 (243)	6	233-256 (246)	17	227-262 (241)	25
Pectoral fin, length....	187-211 (197)	6	189-207 (197)	17	159-198 (182)	25
Pelvic fin, length......	151-164 (161)	6	145-164 (155)	17	123-154 (140)	25
Adipose fin, depressed length...............	118-125 (122)	6	98-117 (108)	17	104-129 (114)	25

DISCUSSION

Primary causes of decline of Gila trout in Gila River drainage are the introduction of exotics and changing climate. In compiling data on historical stocking, Huntington (1955) recorded the following introductions since 1901: cutthroat trout, rainbow trout, brook trout (*Salvelinus fontinalis*), brown trout, channel catfish (*Ictalurus punctatus*), bullhead (*Ictalurus* sp.), bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), and smallmouth bass (*Micropterus dolomieui*). Water in sections of the river, which historically contained sizable populations of Gila trout, has warmed to where it now is more suitable for warm-water species.

Under the classification of streams suggested by Kuehne (1962), Main Diamond Creek would be designated an order 1 stream. It is 20 miles in length; 12 are dry except during high runoff. Three characters distinguish the stream from many other small tributaries in southwestern New Mexico: it is isolated by a barrier that prevents invasion by downstream fish fauna; no exotics have been introduced; and the study section has a higher pool-riffle ratio than most comparable streams. The study section would receive a rating of S_1-T_1-F_2

(Lagler, 1956). The part of Main Diamond Creek above the study section, where the Gila trout population is negligible, has a poor pool-riffle ratio, S_3-T_3-F_3.

The population of Gila trout in Main Diamond Creek was estimated at approximately 4,300 fish, excluding young of the year. Low reproductive rate (less than 200 eggs per female) and limited summer flow are believed to limit population size.

Angling has been at a minimum since the stream was closed in 1933. The effect of opening the stream to angling was evaluated by subjecting the population to controlled fishing. Two anglers, using barbless flies, caught 130 fish in 5 hours. Gila trout are susceptible to angling because they have little fear of man and because they are concentrated in pools.

There is no chemical differences of the water that would contribute to species survival in Main Diamond Creek. Measurements of dissolved oxygen, alkalinity, carbon dioxide, pH, total hardness, and water temperature were comparable to those of other tributaries in the same altitude range.

The limited number of square-foot bottom samples showed little variation in composition of insect orders during the months of June and August 1962. Stomach samples collected during these months show a close agreement between occurrence and utilization. The major disagreement was the high percentage of Diptera in the June collection. These were mostly adults that did not appear in the corresponding bottom samples. A comparison between the bottom fauna of Main Diamond Creek and a composite sample from other tributary streams resulted in approximately the same average number per square-foot sample (table 7). Greater numbers of Trichoptera and Diptera were found in the composite stream, while more Ephemeroptera and Coleoptera were found in the study section.

Total volume per stomach sample declined as summer progressed. This could have resulted from increased competition for food during periods of decreased flow. Trichoptera, Ephemeroptera, Diptera, and Coleoptera were the four most important food items in the Gila trout diet. An examination of other species in the Gila River drainage showed the following orders to be most important: rainbow trout--Trichoptera and Coleoptera; brown trout--Diptera, Trichoptera, Plecoptera, and Coleoptera; brook trout--Diptera, Trichoptera, and Coleoptera (Huntington, 1955). In view of the parallel feeding habits of these species, there may be strong interspecific competition for food.

The greatest difficulty in determining age composition from the scales of Main Diamond Creek Gila trout was obtaining nonregenerated scales. The high incidence of regenerated scales is throught to be caused by abrasion during periods of low flow and restricted habitat.

None of the body-scale relations evaluated in this study demonstrated adequate agreement between empirical and calculated data to warrant back-calculation of body length.

Table 7.--Average number and frequency of occurrence of bottom fauna in the Gila River drainage

Order	Average number per square foot		Frequency of occurrence	
	Drainage[1]	Study section	Drainage[1]	Study section
Trichoptera.........	40.9	12.4	100	91
Ephemeroptera.......	27.5	44.0	96	97
Diptera.............	11.1	4.0	91	81
Coleoptera..........	4.9	10.7	87	81
Plecoptera..........	1.3	4.2	55	75

[1] Average of 24 square-foot bottom samples taken from streams in the Gila River drainage (Huntington, 1955).

The primary cause for this deviation was scale variability. This could have been caused by the large number of scales taken from each fish. Variation in the body-scale relation of scales taken from different parts of the body has been demonstrated by Carlander (1950) and Phillips (1948). Reiger (1962) removed approximately 10 scales from a key area to establish a usable body-scale relation of bluegill (Lepomis macrochirus).

Age groups I through VI were represented in the 1962 collections. Growth of Gila trout is slower than growth of other trouts in the Gila River drainage (fig. 15). The controlling factor governing growth rate of Gila trout is believed to be environmental and not characteristic of the species. After a short period of acclimatization, Gila trout moved from Main Diamond Creek to a hatchery had approximately the same growth rate as rainbow trout.

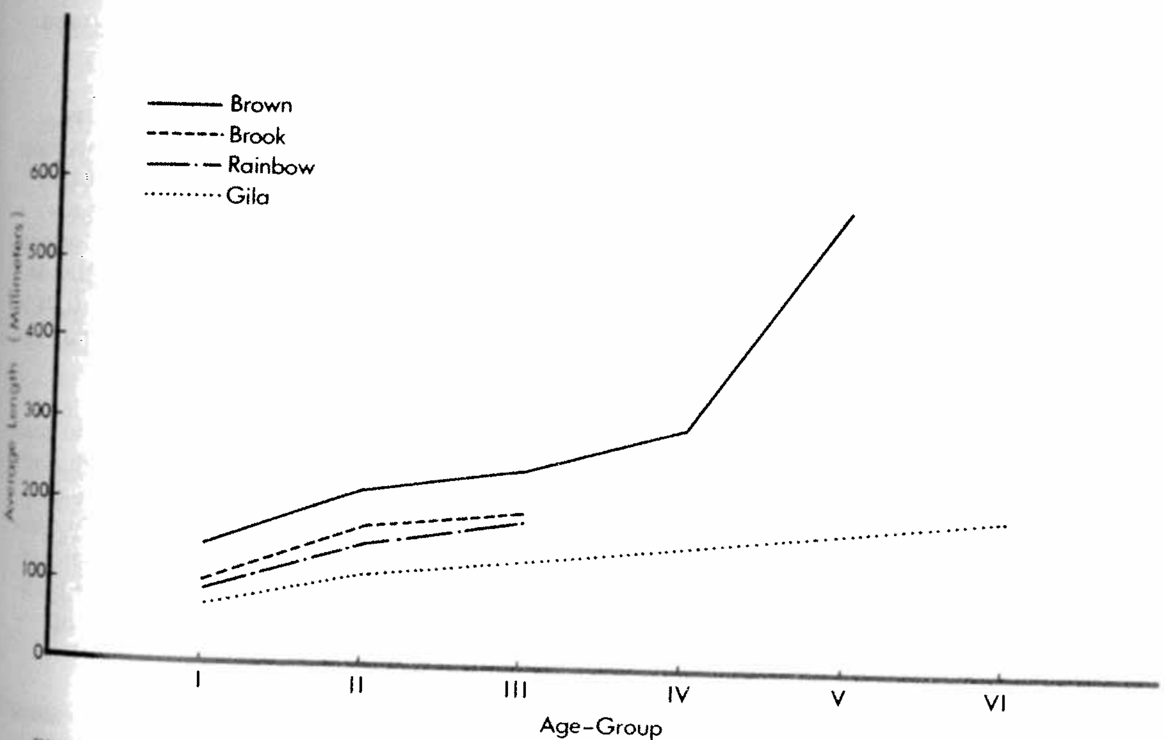

Figure 15.--Comparison of age composition and length data for trouts found in the Gila River drainage.

Meristic and morphometric characters of Gila trout examined in this study were approximately the same as those for specimens obtained in 1939. The following diagnostic characters (Miller, 1950) proved valid to distinguish the population in Main Diamond Creek from closely related trouts:

"An outstanding characteristic of this species is the extremely fine and profuse spotting on the dorsal and caudal fins. The body spots are mostly restricted to the region above the lateral line, and the adipose fin is unusually large and well spotted. In life, the body is deep golden yellow, with a yellowish "cutthroat" mark. The head is long and conical, and the maxillary is long, extending far behind the eye. The moderate-sized scales number 133 to 151 along the side just above the lateral line. Pyloric caeca usually number 31 to 36. There are no hyoid teeth."

In addition to these characteristics, the Gila trout has morphological resemblances to both the rainbow trout and the cutthroat trout (Miller, 1950; Needham and Gard, 1959). These resemblances and the capacity to cross freely suggests the possibility of hybridization between ancestral parents.

Further substantiating evidence for this theory is the low reproductive potential of

Gila trout. Past studies with intergrades or hybrids have often shown a lowered fecundity (Hubbs, 1961). Ovum counts on Gila trout from Main Diamond Creek averaged fewer than 200 eggs per female. The fecundity of the Arizona native trout, tentatively classified as Salmo gilae, is 200 to 600 eggs (Mulch and Gamble, 1954). Fecundity of rainbow and cutthroat trouts of comparable lengths average respectively, 2,400 and 1,577 eggs per female (Rounsefell, 1957).

The status of survival of Gila trout in New Mexico is at best precarious. The Main Diamond Creek population exhibits the following characteristics: (1) ability to survive in a marginal habitat; (2) low reproductive rate; (3) slower growth rate than other trouts in the Gila River drainage; (4) feeding habits similar to those of other trouts in the Gila River drainage; (5) high incidence of scale regeneration and variability resulting in inadequate body-scale relations; and (6) summer decline in the condition factor.

SUMMARY

The Gila trout (Salmo gilae) was once widely distributed in headwaters of the Gila River in New Mexico. Introduction of exotics and changing climate have resulted in marked decline of the species. At the present time, pure strains have been found in only three isolated tributary streams. One of these, Main Diamond Creek, was selected for this study. It is in the Black Range of the Gila National Forest and has an altitude of 5,900 to 8,500 feet.

Study objectives were to obtain information that would provide a base for management and preservation of Gila trout as a potential sport fishery resource and as a unique species. Information on the ecological status of Gila trout and its taxonomic relationship with closely related trouts was of primary concern in reaching these objectives.

The study area is a 2 1/2-mile section of Main Diamond Creek. Parts of the stream are dry above and below this section. Data on physical, chemical, and biological characters were obtained during 1962 and 1963.

There were no chemical differences that would contribute to species survival in Main Diamond Creek. Measurements of dissolved oxygen, alkalinity, carbon dioxide, pH, total hardness, and water temperature were comparable to those of other tributaries in the same altitude range.

The population of Gila trout in Main Diamond Creek was estimated at approximately 4,300 fish over 50 mm. in total length. Nonregenerated scales were found in 337 of the 525 scale samples collected between June 7 and November 2, 1962. These scales were from fish that had a total length range of 50 to 201 mm. and represented age groups I through VI.

Gila trout in Main Diamond Creek exhibited a much slower growth rate than three other trout species found in the Gila River drainage. Seasonal reductions in flow restricted fish to pools and intensified competition for food and space. A steady decline in condition factor, from 1.10 in June to 0.94 in November, is a further indication of this competition.

The relation between body length and scale length was evaluated by assuming both rectilinear and curvilinear relations. None of seven relations evaluated in this study demonstrated sufficient agreement between empirical and calculated data to warrant back-calculation of body length at the time of annulus formation.

A qualitative analysis of the bottom fauna of Main Diamond Creek compared favorably with analyses other tributary streams. There was little variation in composition of insect orders during the sampling period. Stomach samples showed close agreement between utilization and occurrence. Trichoptera, Ephemeroptera, Diptera, and Coleoptera were the most important food items in both bottom and stomach samples.

Meristic and morphometric characters of 25 Gila trout examined in this study were

approximately the same as those of paratypes collected 25 years ago. A very large adipose fin, diagnostic spotting, and life colors are characteristic of the species. Taxonomic resemblances between Gila trout and cutthroat trout were the cutthroat mark, long upper jaw, long conical head, pointed snout, and few pyloric caeca. General body shape, lack of hyoid teeth, pale borders of anal, pelvic, and dorsal fins, and scale counts are similar to those of the rainbow trout.

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