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Early Life History of the Mountain Whitefish Prosopium williamsoni (Girard) in the Logan River, Utah

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EARLY LIFE HISTORY OF THE MOUNTAIN WHITEFISH

PROSOPIUM WILLIAMSONI (GIRARD)

IN THE LOGAN RIVER, UTAH

by

Lawrence Guy Brown

A thesis submitted in partial fulfillment
of the requirements for the degree

of

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Lawrence Guy Brown

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in the Logan River, Utah

by

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Utah State University, 1972

Major Professor: Dr. Robert H. Kramer
Department: Wildlife Resources

Growth and food habits of 399 Age 0 mountain whitefish from the Logan River, Utah, were studied between March, 1970, and April, 1971. At the end of their first six months of life, whitefish were 86-96 mm total length and weighed 6-8 grams (wet). Total temperature experience was 2,950-3,430 degree-days above 32^{o} F. The length-weight relationship for Age 0 mountain whitefish was best described by three stanzas with slopes of 4.3333 for fish 12.5-17.0 mm total length, 3.4437 for fish 17.0-55.0 mm total length, and 2.8043 for fish 50.0-112.0 mm total length. Scalation commenced at 30-35 mm total length and was complete at 40-50 mm total length. Feeding began before yolk-sac absorption was complete and 85 percent of the total diet in numbers was chironomid larvae. Age 0 mountain whitefish in the Logan River fed during daylight and evening hours, and selected chironomid larvae and other food organisms 2-4 mm long.

(47 pages)

INTRODUCTION

This study was an integral part of a project being conducted by the Utah Cooperative Fishery Unit, Dr. Robert H. Kramer, Unit Leader, to develop methods for the culture of mountain whitefish (Prosopium williamsoni) from the time of egg deposition to the end of the first six months of life. This information is needed by water-control agencies in their efforts to determine long-range effects of sub-lethal pollutants on selected fishes throughout their entire life history.

The mountain whitefish is widespread throughout western Canada and the United States. Lindsey (1956) listed the Liard, Nass, Peace, Skeena, Fraser, Okanogan, and Columbia river systems of British Canada as containing the mountain whitefish. In Alberta, they are present in the Peace, Athabaska, South and North Saskatchewan, and Milk river systems (McHugh, 1941). In the United States, mountain whitefish are found in most river systems of the Pacific slope, from Washington south to the Lahontan Basin of Nevada, and the west slope of the Rocky Mountains in Utah, Colorado, and Wyoming. They are also present in the Missouri river headwaters of Wyoming and Montana (Beckman, 1952; Simon, 1946).

Considerable variation in growth rates has been found over a large portion of the whitefish's natural range. Calculated lengths at the end of the third year of life range from 6.4 inches (163 mm) in Pyramid Lake, Nevada, to 11.7 inches

(297 mm) in Okanogan Lake, B. C. (Sigler, 1951). The growth rates are about equal for both sexes (Beckman, 1952; Hagen, 1970).

Mountain whitefish in Montana mature in their third and occasionally their second year. Spawning occurs from October to early November at temperatures of 42° F (5.6° C) or lower. Spawning takes place in stream riffles over gravel, but nest construction has not been observed (Brown, 1952). Hagen (1970) reported that mountain whitefish in Phelps Lake, Wyoming, preferred to spawn in the lake proper, rather than ascend available streams. Fecundity has been reported from 4,401 to 6,885 eggs per pound (9,704 to 15,181 eggs per kilogram) of fish (Brown, 1952; Simon, 1946). Embryonic development from fertilization to hatching takes 36 days at 52° F (11.1° C) (Brown, 1952).

The mountain whitefish is a bottom-feeding fish subsisting mainly on aquatic insects and a greater variety of organisms is eaten by river-dwelling forms than by lake-dwelling fish (McHugh, 1940). In the Gallatin River, Montana, caddisflies predominated in the autumn diet, midges in winter, stoneflies and caddisflies in spring, and stoneflies in summer (Laakso, 1951). In Lakelse Lake, B.C., immature insects (mainly Ephemeroptera) made up 60 percent of the food by volume (Godfrey, 1955). Sigler (1951) found that mountain whitefish from 7.4 to 18.7 inches (187 to 475 mm) from the Logan River, Utah, ate primarily Trichoptera, Diptera, Ephemeroptera, and Plecoptera. The most important dipterans were Chironomidae and Simuliidae. Hagen (1970) reported that the most common planktonic organisms in whitefish stomachs from Phelps Lake, Wyoming, were *Daphnia longispina* var., *Diaptomous shoshoni*, and *Nothalca* sp.

Objectives

Because little is known about the environmental requirements of young mountain whitefish, the primary objectives of this study were:

1. To describe the growth and development of larval and juvenile mountain whitefish through their first six months of life in the Logan River, Utah.
2. To describe the food habits of these Age 0 whitefish, particularly in relation to the organisms present in the nursery areas.

STUDY AREA

Logan River heads in Franklin County, southern Idaho, and flows southwesterly into Cache County, Utah, joining the Bear River a few miles west of the city of Logan. The watershed covers approximately 225 square miles (583 square kilometers) of mountainous limestone, dolomite, and shale. Advanced weathering of base materials probably accounts for the alkalinity of the waters of this region. The watershed has an average yearly precipitation of about 30 inches (76.2 cm) inches, of which 60 percent is snow (Sigler, 1951).

The major water source for the river is springs. River temperature seldom exceeds 60° F (15.6° C) during the summer. Dissolved oxygen is usually at or near saturation throughout the canyon. Sigler (1951) reported an average discharge of 247 cubic feet per second (cfs) at the junction of the Cache National Forest and Cache Valley, with highest flow in May or June and the lowest in February.

In addition to mountain whitefish, other native fishes in the Logan River include cutthroat trout (*Salmo clarki*), mottled sculpin (*Cottus bairdi*), and rarely, redside shiner (*Richardsonius balteatus*). Introduced fishes are brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*), and rainbow trout (*Salmo gairdneri*). Since the introduction of the rainbow, a hybrid rainbow x cutthroat has appeared (Sigler, 1951).

There are three power and irrigation impoundments on the river upstream from the city of Logan (Figure 1). No upstream fish-passage facilities are in operation at any of these dams. The backwaters of the impoundments have extensive shoals of silt deposits, creating nursery areas for young-of-the-year mountain whitefish, brown trout and mottled sculpin.

Three main study areas were chosen (Figure 1). Area 1 was on the west shore of First Dam backwaters in an eddy near where the main stream flowed into the impoundment. The current was slow, which provided a relatively stable nursery habitat for young whitefish. Area 2 was similar in all respects, but was located in the backwaters of Third Dam, five miles upstream. Area 3 (about 1/4 mile upstream from area 2) was a known mountain whitefish spawning site, with a moderate to rapid current and a fine to medium gravel substrate. Sampling at area 3 was discontinued in June when the young fish were no longer available, probably having moved downstream into the Third Dam impoundment. Young fish were abundant in areas 1 and 2 throughout the study period.

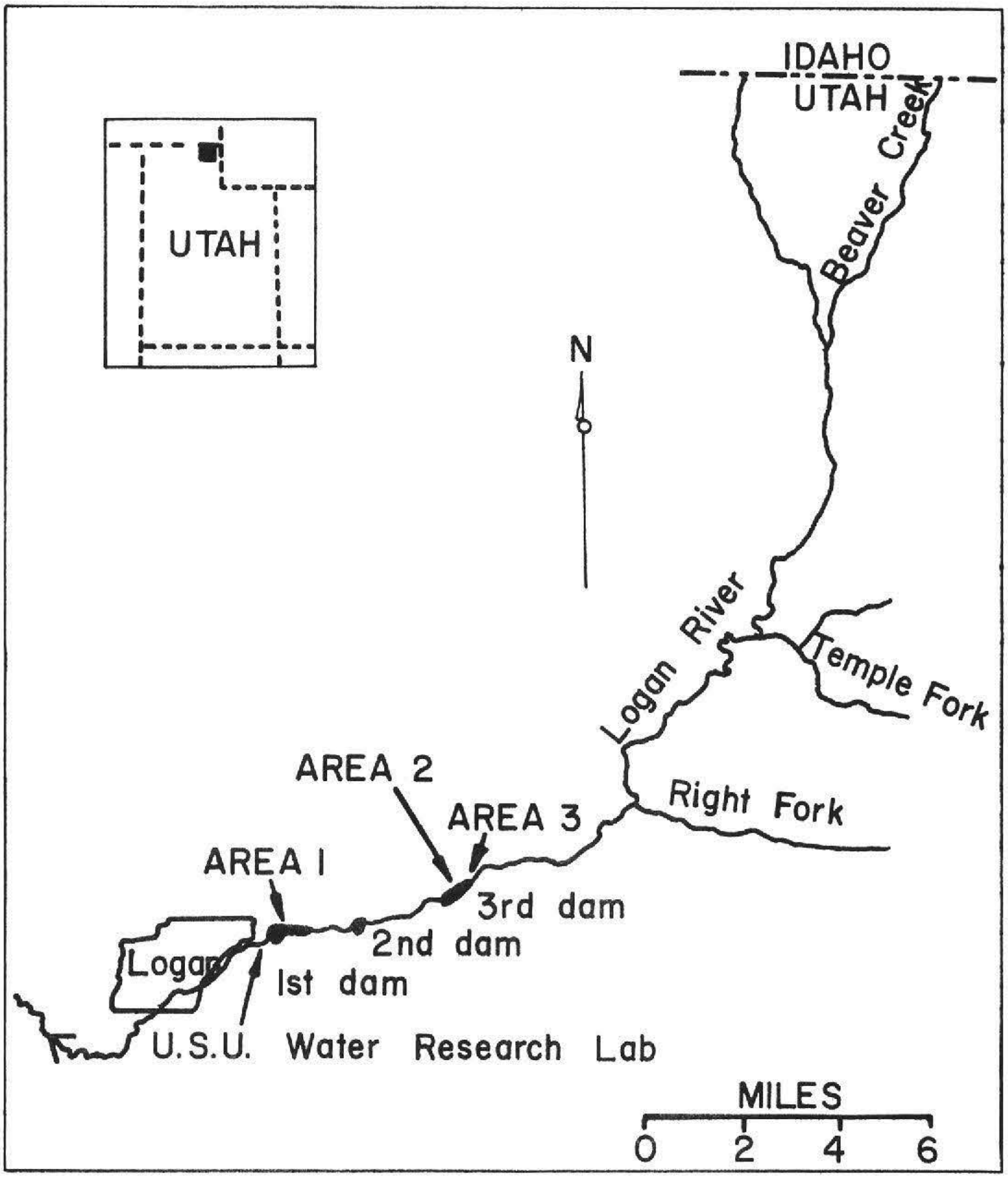

Figure 1. Map of the Logan River, showing study areas, 1970-71.

METHODS AND MATERIALS

Water temperatures were recorded at two permanent stations on the Logan River. A Ryan continuous recording thermometer (Model D-30) was placed in the river at area 3. River temperatures were also recorded at the Utah State University Water Research Laboratory, immediately downstream from First Dam, with a Foxboro 30-day continuous recorder. Temperatures were taken with a hand thermometer on each sampling trip to correlate microhabitat temperatures with those in the main stream flow.

Mountain whitefish larvae and fry were collected with dip nets and fingerlings with a direct-current back pack shocker. Collections were made at 10- to 14-day intervals (except during spring runoff) from March 23, 1970, to September 15, 1970, and again during March, 1971. Fish were preserved in 10 percent formalin. A total of 399 Age 0 mountain whitefish was collected from the three study areas.

Stomach contents from 238 fish (12.5 to 112.0 mm total length) were analyzed for food habits. Nineteen drift samples were taken concurrently with those fish analyzed for food habits. Drift samples were preserved in 5 percent formalin and after sorting, all organisms were preserved in 70 percent ethyl alcohol.

The drift sampler was an original design and was constructed by the Technical Services Department at Utah State University. It was designed to capture only those organisms which were drifting in the immediate vicinity of the young mountain whitefish, as the young fish preferred limited home areas with a silty substrate and very little current, usually in back eddies near shore. The mouth of the drift sampler was 6 inches square (0.25 square foot opening). The sampler was 9 1/2 inches long (without plankton net), constructed of stainless steel, screened, and adapted at the rear to fit a 5-inch-diameter Clarke-Bumpus type collar for attaching plankton nets. It was designed to sit on the bottom and capture organisms rolling along the substrate in addition to those organisms drifting freely. When fully assembled, the sampler has a long avenue of escape for water entering the opening, thus minimizing back pressure and turbulence at the mouth (Figure 2).

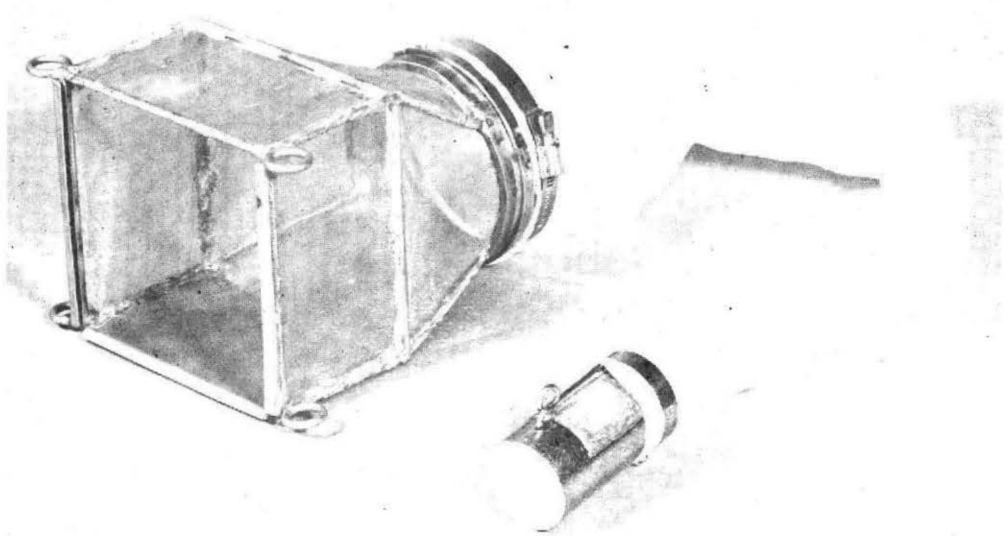

Figure 2. Drift sampler used concurrently with collections of Age 0 mountain whitefish, Logan River, Utah, 1970-71.

RESULTS AND DISCUSSION

Water Temperature and Stream Flow

Temperature of the Logan River at the Water Research Laboratory during 1970-71 varied from a high of 59° F (15° C) in July and August to a low of 34.2° F (1.2° C) in January (Figure 3). There was little difference in the main stream temperature between area 3 and the Water Laboratory except during midsummer. From the last week of July through mid-August, river temperatures at the Water Laboratory were as much as 2.8° F (1.6° C) warmer than at area 3, probably due to a cumulative effect of solar insolation in the three impoundments.

Temperatures in the impoundments varied about the main river temperature, being as much as 5.8° F (3.2° C) higher at area 1 on July 22 and 7.2° F (4.0° C) lower at area 2 on September 15. This fluctuation was apparently dependent on immediate weather conditions and time of day.

A near normal "water year" was reported for 1970-71. Maximum daily flow occurred in June (1,210 cfs; 34.3 cubic meters per second) and minimum in December (85 cfs; 2.4 cubic meters per second). The overall mean flow was 246 cfs (6.97 cubic meters per second) (United States Geological Survey, unpublished report, 1971).

Growth

Total and fork lengths were measured to the nearest 0.5 millimeter. Wet weight was measured to the nearest 0.005 gram. Means and 95 percent

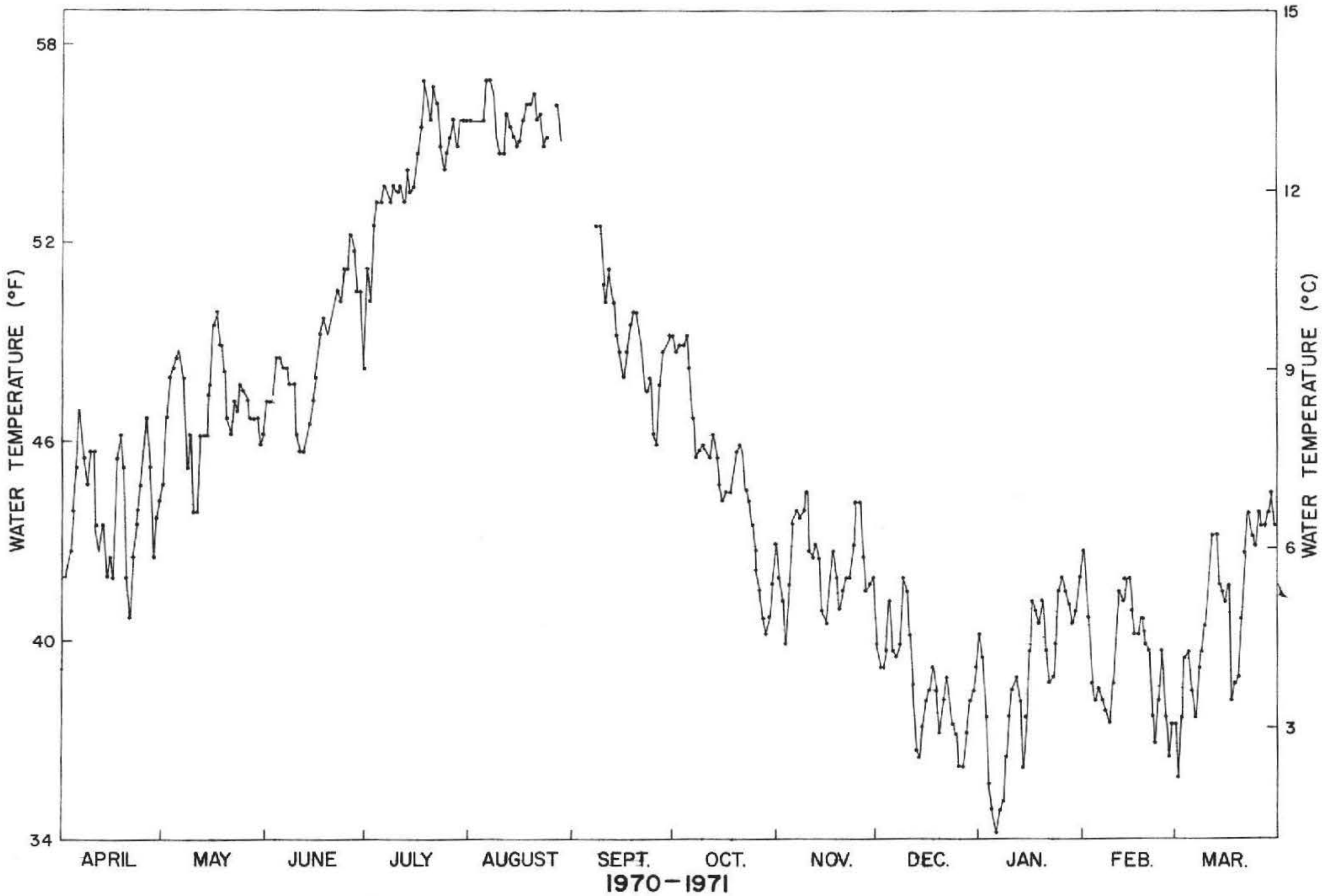

Figure 3. Temperature of the main flow of Logan River at the Utah State University Water Research Laboratory, 1970-71.

confidence intervals on the means were calculated for each collection, and growth curves were fitted by inspection.

Growth in length and weight

The smallest mountain whitefish collected at each study area were approximately 12.5 mm total length. After six months of growth, mean total length of whitefish in area 1 was 96.5 mm and 86.5 mm in area 2 (Figure 4). The difference in weight was even more pronounced, where after six months in area 1, mean wet weight was nearly 8 grams and in area 2, only 6 grams (Figure 5).

The young fish in the two study areas also exhibited large differences in both the daily instantaneous growth coefficients (Ricker, 1968), and the pattern of these rates over time (Figure 6). For area 1 fish, the growth coefficient began relatively high (0.050), fluctuated between 0.040 and 0.050 until stabilizing at 50 to 55 mm total length. The fish from area 2 displayed a different pattern: the growth coefficient rose steeply from 0.015 to 0.070 as the fish grew from 15 to 25 mm total length, then dropped rapidly, stabilizing when the fish reached 55-60 mm. The growth coefficients for both groups displayed a similar rate of decrease after the fish reached 50-60 mm total length (Figure 6).

Growth and temperature

Total temperature experience, expressed as cumulative degree-days above 32° F, was calculated for fish from the two study areas. Accumulation began with the date of first collection in each area (Figure 7). The shoal areas

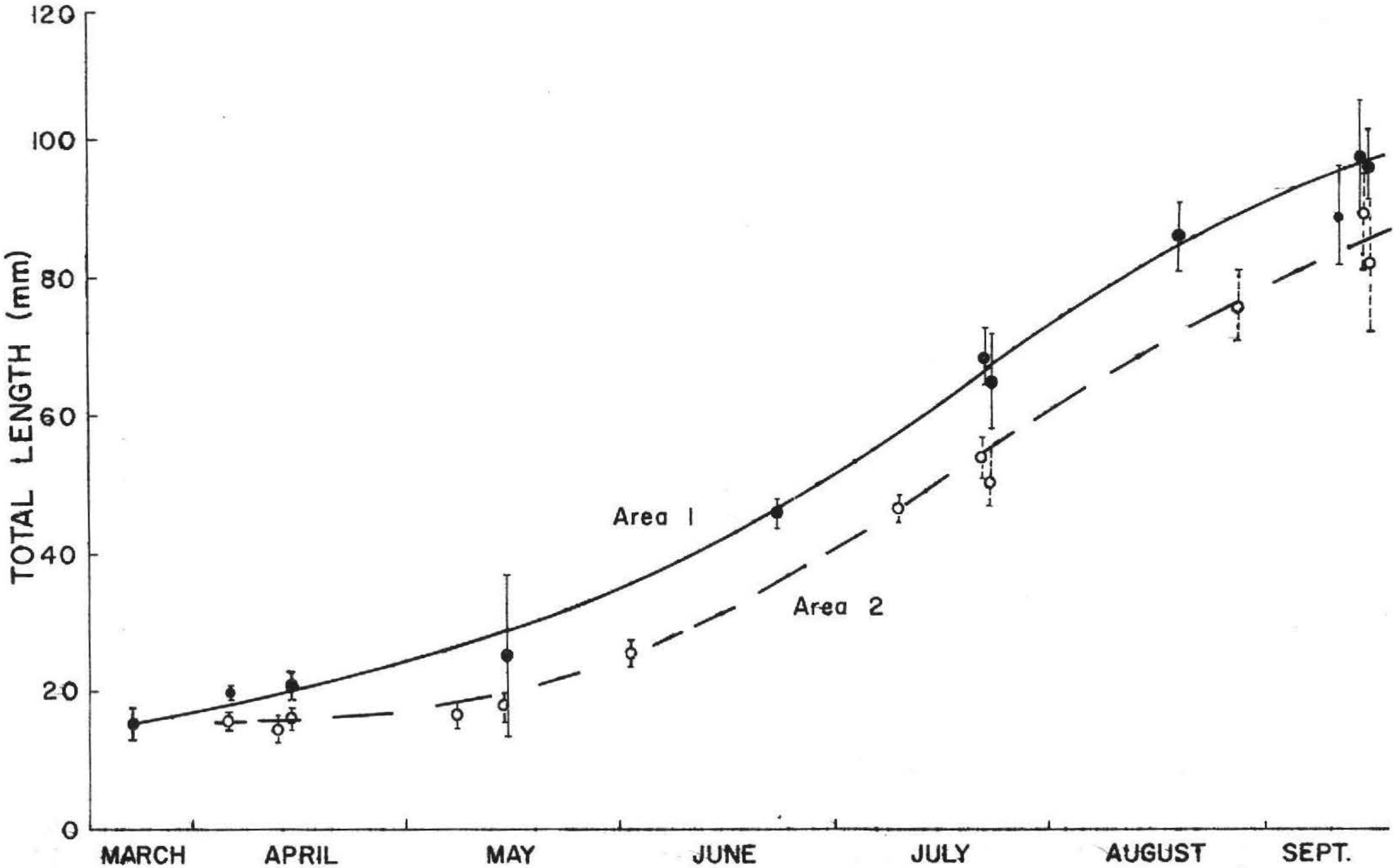

Figure 4. Mean total length (mm) and 95 percent confidence intervals for Age 0 mountain whitefish, areas 1 and 2, Logan River, Utah, 1970.

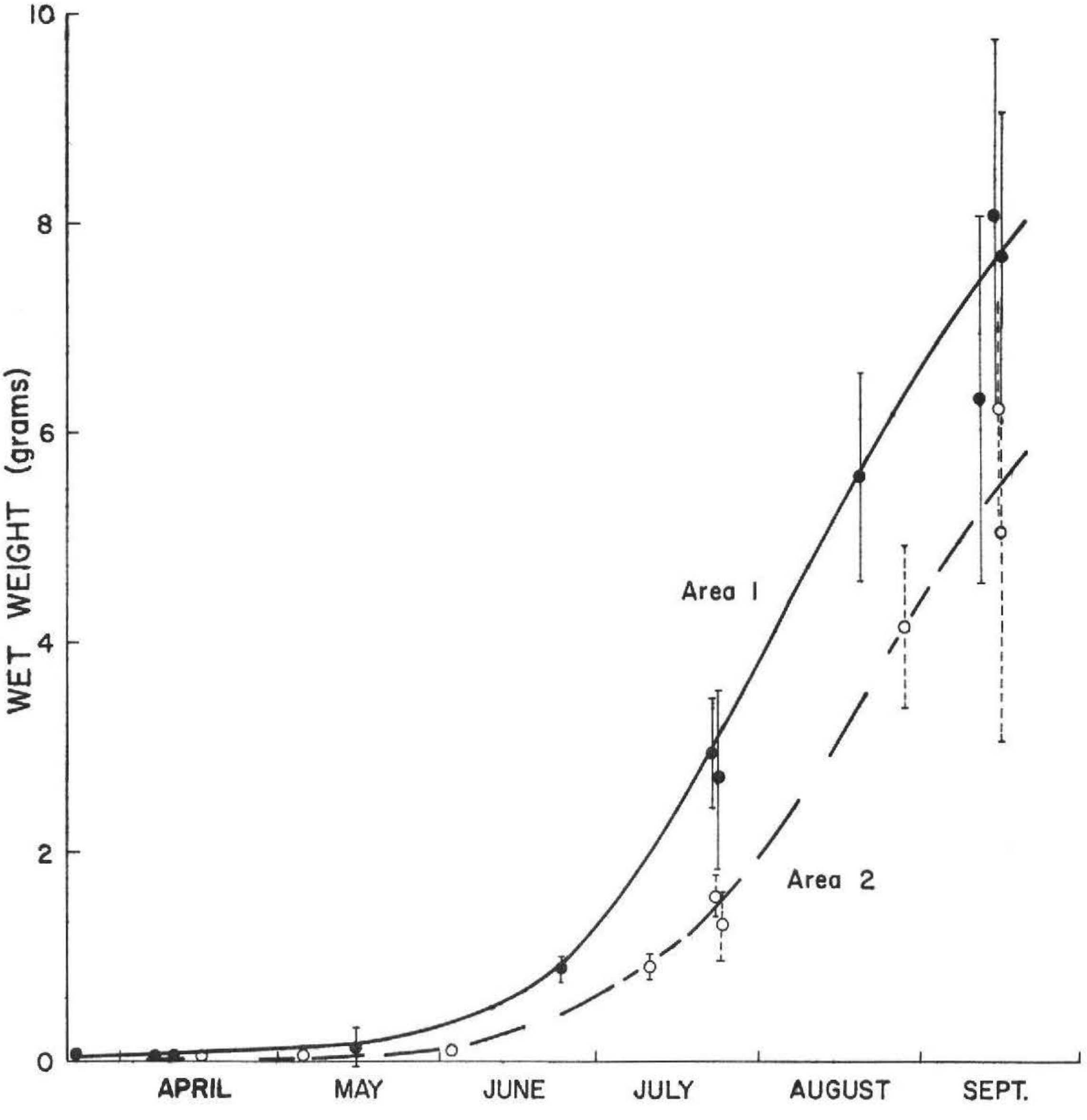

Figure 5. Mean wet weight and 95 percent confidence intervals for Age 0 mountain whitefish, areas 1 and 2, Logan River, Utah, 1970.

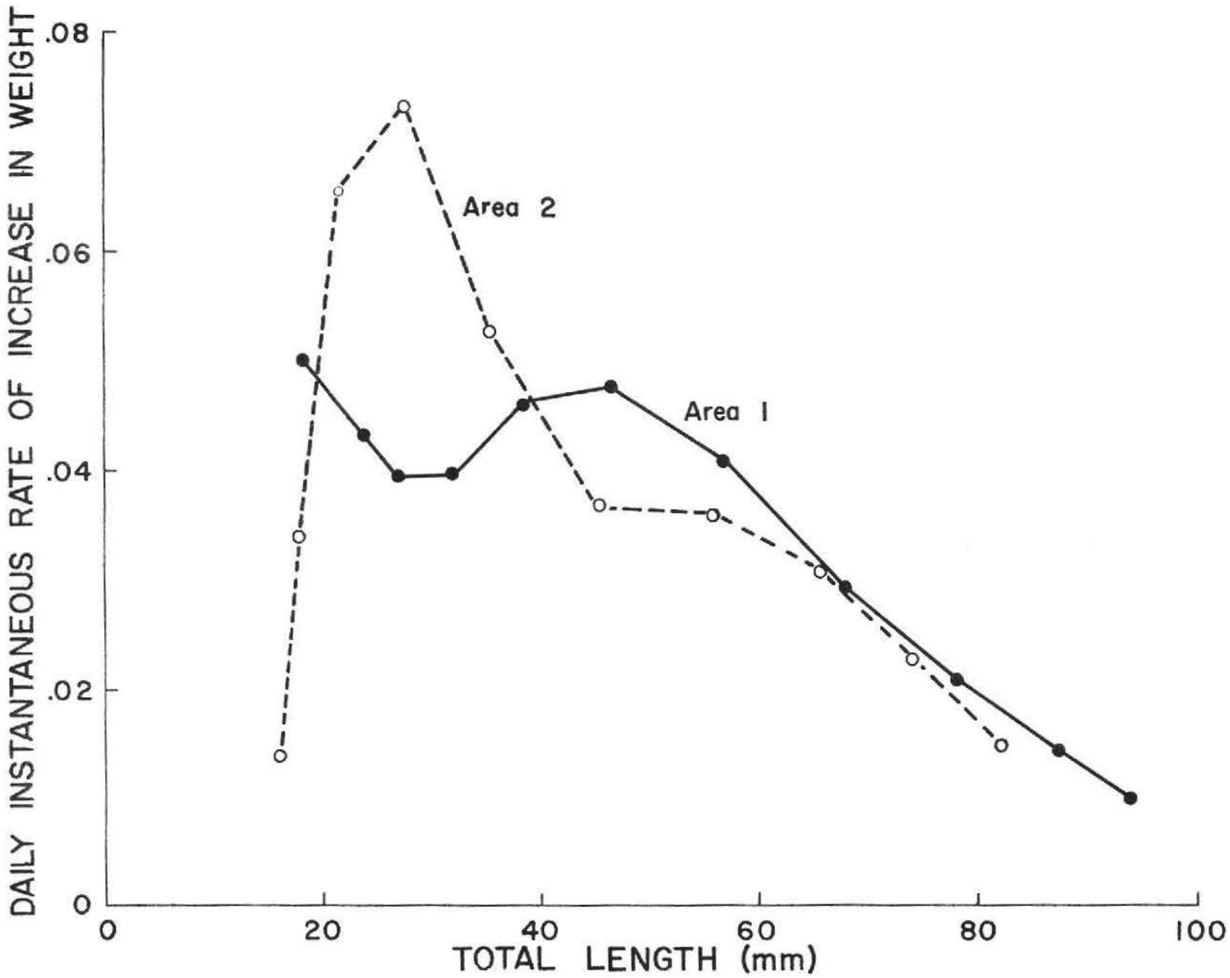

Figure 6. Total length and daily instantaneous rate of increase in weight for Age 0 mountain whitefish, areas 1 and 2, Logan River, Utah, 1970.

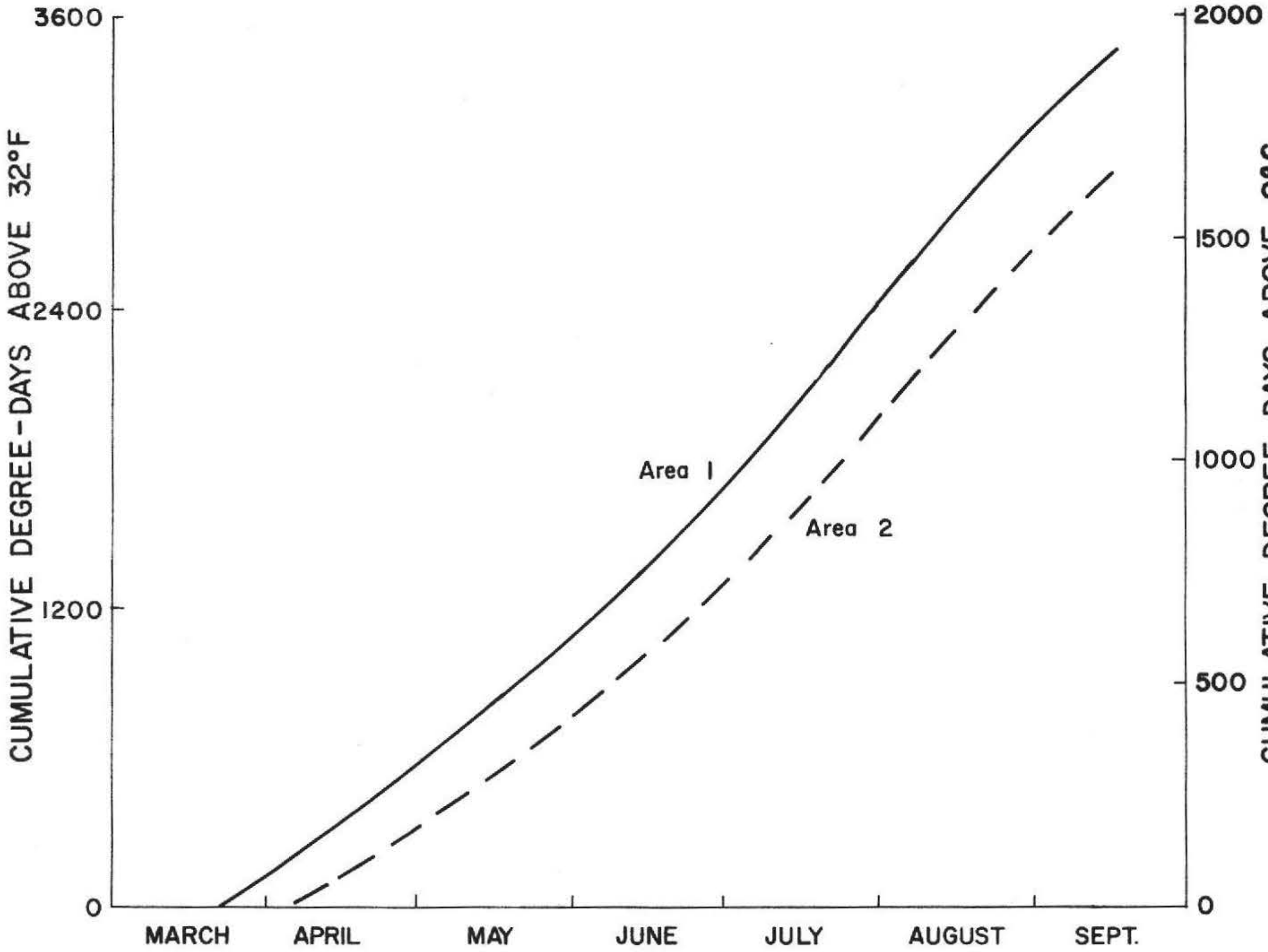

Figure 7. Total temperature experience of Age 0 mountain whitefish, expressed as cumulative degree-days above 32° F and 0 °C, areas 1 and 2, Logan River, Utah, 1970.

at area 1 were much more extensive than at area 2, allowing a greater influx of insolation, and water temperatures were consistently higher in area 1 than in area 2 (from 1 to 10^{o} F higher). On September 15, the total accumulated temperature experience for area 1 fish was 3,430 degree-days above 32^{o} F (1,906 degree-days above 0^{o} C), while for area 2 fish the total was only 2,950 degree-days above 32^{o} F (1,639 degree-days above 0^{o} C). The difference in temperature experience may have been partially responsible for the greater size of the young mountain whitefish in area 1.

Growth and emergence

The greater size of Age 0 mountain whitefish in area 1 at the end of the growing season may also be a function of earlier emergence. The young fish were available to my sampling methods approximately two weeks earlier in area 1 than area 2 in 1970. This difference was found again in 1971, when on February 14, six to eight newly hatched fry were observed at area 1, while there were no fry at areas 2 or 3 until March 13. Observations during the spawning season (November and December) indicated a later and more prolonged spawning period at area 3 than in the spawning riffles above area 1.

Length-Weight Relationship

All fish were pooled to establish a length-weight relationship for Age 0 mountain whitefish in the Logan River. A scatter diagram of log-weight against log-length indicated three different relationships (Table 1). Linear regressions were fitted by the method of least squares. The slope of the first was 4.3333, the second 3.4437, and the third 2.8043.

The transition from the initial stanza to the second stanza occurred at a total length of approximately 17 millimeters. This inflection may reflect the transition from endogenous to exogenous nutrition, since the largest larva examined with noticeable yolk reserves was 15.5 mm in total length.

The transition from the second to the third stanza was less apparent, but appeared to be between 50 and 60 mm total length. This size was also where the decrease in growth coefficients stabilized. The best fit (based on correlation coefficients) of the second and third stanzas was obtained by overlapping data for fish of 50 to 55 mm total length (Table 1 and Figure 8).

Average condition factors (Table 1) were based on the formula

$$K_{(TL)} = \frac{\text{Weight (grams)}}{\text{Total Length (mm)}^3} \times 10^5$$

The $K_{(TL)}$ is an average of individual K's calculated for each fish in a length-weight stanza and is representative of the general robustness of the young whitefish within that stanza. The gradation of $K_{(TL)}$ from 0.503 in the initial stanza to 0.917 in the third stanza indicates that allometric growth occurred during the six months of the study.

Table 1. Length-weight relationships for three total length ranges of Age 0 mountain whitefish, Logan River, Utah, 1970-71

Total-length range and length-weight regressions [1]	Correlation coefficient (R)	Standard error of the mean ($S_{\bar{x}}$)	Regression mean square error	Average condition factor (K_{TL})
from hatching to onset of active feeding (approximately 12.5-17.0 mm total length)				
Log W = -6.7603 + 4.3333 Log TL	0.928	0.0052	0.0022	0.503
from 17.0 to approximately 55.0 mm total length				
Log W = -5.7726 + 3.4437 Log TL	0.998	0.0131	0.0012	0.758
from approximately 50.0 to 112.0 mm total length (end of study period) [2]				
Log W = -4.6704 + 2.8043 Log TL	0.995	0.0067	0.0006	0.917

[1] Where W = wet weight in grams, TL = total length in millimeters.

[2] A slight (5 mm) overlap of data was used to calculate the second and third stanzas.

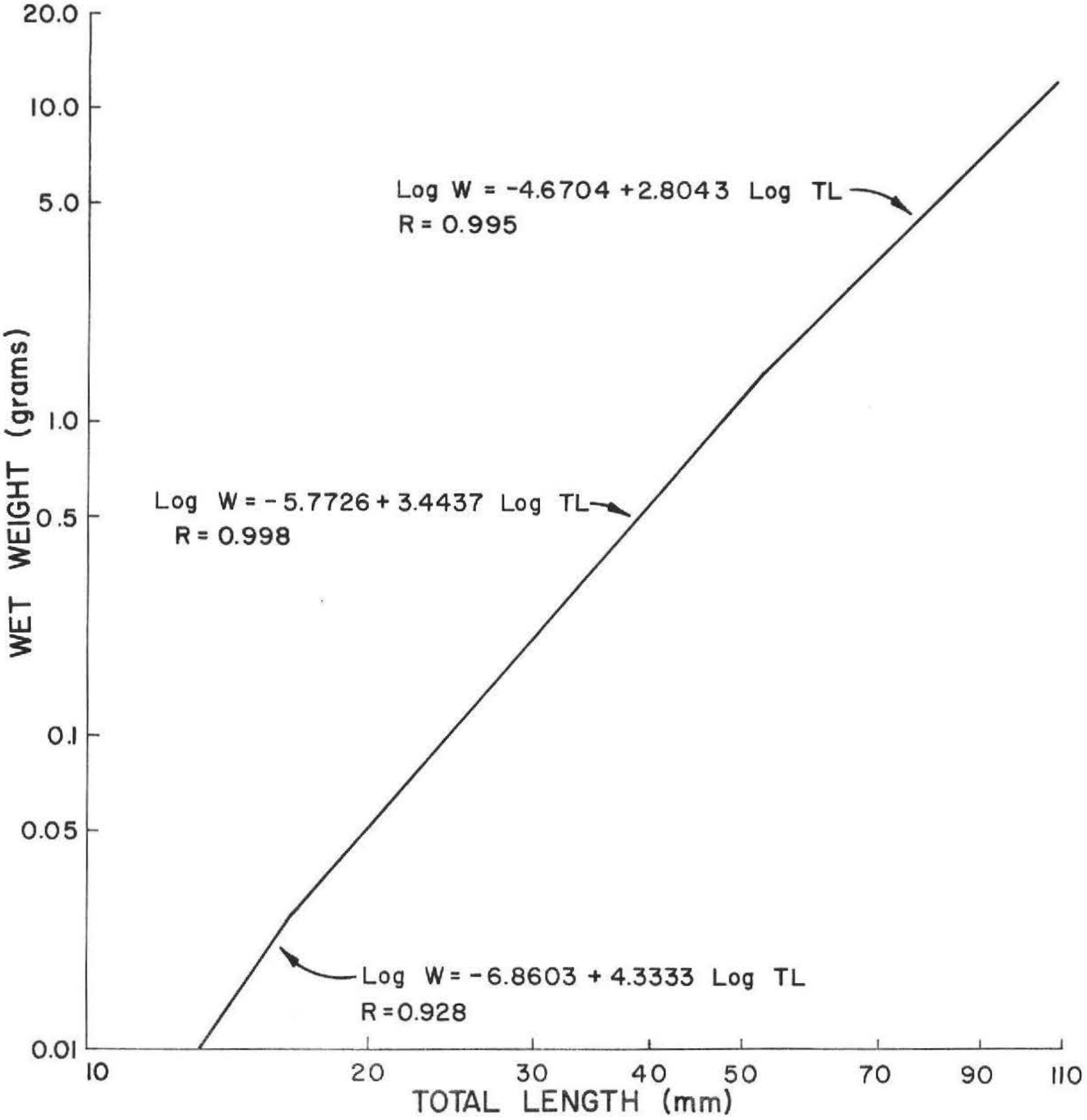

Figure 8. Length-weight relationships of 399 Age 0 mountain whitefish from 12.5 mm to 112 mm total length, Logan River, Utah, 1970-71. Three stanzas are shown with their respective regression equations.

Total Length/Fork Length Ratio

Ratios of total length to fork length were calculated for fish grouped by 5 or 10 mm total-length intervals, and plotted against total length (Figure 9). Data for fish over 200 mm total length were obtained from 34 adult mountain whitefish collected about 150 yards (137 meters) upstream from area 1 in December, 1970. TL/FL ratios were near 1.030 for the smallest fish, increased to 1.084 for 115 mm fish and decreased to 1.060 for 420 mm fish. The relationship between total length and TL/FL ratio was not constant. The curve (fitted by inspection) for Age 0 mountain whitefish was asymptotic near a ratio of 1.084, agreeing with Hagen's (1956) value for mountain whitefish in Phelps Lake, Wyoming, but when data from additional fish (adults) were added, the relationship dropped toward the ratio reported by Sigler (1951) for Logan River whitefish from 58 to 413 mm standard length.

Scale Formation

Scalation began between 30 and 35 mm total length. The first scale platelets were located in the two lateral rows, above and below the lateral line and directly below the dorsal fin. Full scalation was completed between 40 and 50 mm total length. These findings agree with those of Hagen (1956) for mountain whitefish in Phelps Lake, Wyoming.

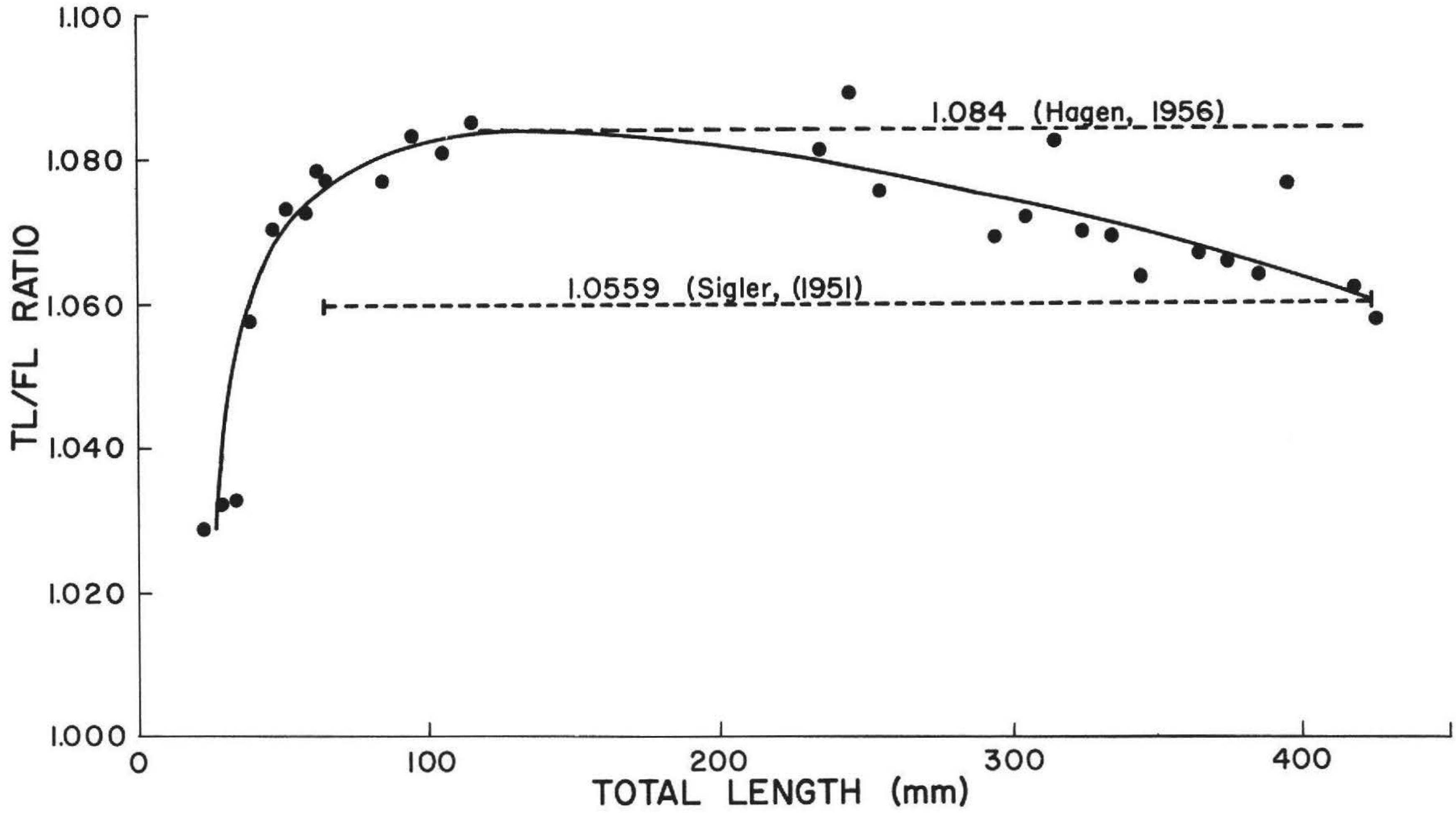

Figure 9. Scatter diagram of TL/FL ratios for 5 and 10 mm size intervals of 433 mountain whitefish, Logan River, Utah, 1970 and 1971, published TL/FL ratios shown for comparison. The curve was fitted by inspection.

Food Habits

Observations of larval and fingerling mountain whitefish indicated that they remain near the bottom while feeding, repeatedly moving either laterally or vertically to capture prey. The young fish were observed in the act of seizing food items directly from the substrate on several occasions, but appeared usually to capture food which was drifting freely in the current. Whitefish larvae began feeding at a total length of 14 to 15 millimeters before complete absorption of the yolk sac.

Mountain whitefish collected concurrently with drift samples were analyzed for food habits, for I assumed that available food was either drifting freely or tumbling along the substrate. In larvae and post-larvae, the alimentary canal is a straight tube and the entire gut contents were examined. In fingerlings, the gut is convoluted and only the cardiac stomach anterior to the pyloric sphincter was examined. Organisms were sorted into various taxonomic groups and counted. Length of organism was measured to the nearest 0.1 millimeter with an ocular micrometer.

Chi-square analysis indicated no difference in food habits between areas ($P < .01$), so all stomach contents data were combined (Table 2). Samples of drift organisms were analyzed the same as the stomach samples after initial sorting (Table 3).

Chironomid larvae were the major food item of age 0 mountain whitefish, ranging from 65.5 percent to 90.0 percent of the total monthly diet in numbers. Chironomid pupae were second in importance (8 percent of the overall

Table 2. Number of organisms and their percentages of the monthly total (in parentheses) from 238 Age 0 mountain whitefish taken concurrently with drift samples, Logan River, Utah, 1970-71

Item	Month and year							
	March '71	April '70	May '70	June '70	July '70	Aug. '70	Sept. '70	TOTALS
Nematа	0	0	0	0	0	1(tr)[1]	1(tr)	2(tr)
Oligochaeta	0	0	0	0	0	0	3(tr)	3(tr)
Cladocera	0	0	0	0	0	1(tr)	0	1(tr)
Ostracoda	0	0	0	0	0	0	4(tr)	4(tr)
Copepoda	6(6.0)	0	0	1(0.5)	0	2(tr)	1(tr)	10(0.1)
Ephemeroptera	3(3.0)	0	2(2.3)	29(15.6)	6(4.3)	136(6.2)	89(1.5)	265(3.0)
Plecoptera	0	0	0	0	0	3(0.1)	3(tr)	6(tr)
Hemiptera								
Corixidae	0	0	0	0	0	0	1(tr)	1(tr)
Coleoptera								
Dytiscidae	0	0	0	0	0	8(0.4)	131(2.2)	139(1.6)
Trichoptera	0	0	0	3(1.6)	0	24(1.1)	14(0.2)	41(0.5)
Diptera								
Chironomidae								
larvae	90(90.0)	61(87.1)	78(90.7)	122(65.6)	99(71.7)	1806(82.4)	5183(87.3)	7439(85.4)
pupae	0	4(5.7)	0	15(8.1)	24(17.4)	179(8.2)	471(7.9)	693(8.0)
Simuliidae	1(1.0)	5(7.1)	6(7.0)	15(8.1)	9(6.5)	31(1.4)	29(0.5)	96(1.1)
Miscellaneous	0	0	0	0	0	0	5(tr)	5(tr)
Acari	0	0	0	0	0	1(tr)	1(tr)	2(tr)
Miscellaneous	0	0	0	1(0.5)	0	1(tr)	1(tr)	3(tr)
TOTAL NUMBERS	100	70	86	186	138	2193	5937	8710
Number of fish	59	11	14	26	62	22	44	238

[1](tr) = less than 0.1.

Table 3. Number of organisms and their percentages of the monthly totals (in parentheses) from 19 drift samples taken concurrently with Age 0 mountain whitefish collections, Logan River, Utah, 1970-71

Item	Month and year							
	March '71	April '70	May '70	June '70	July '70	Aug. '70	Sept. '70	TOTALS
Nemata	0	0	1(1.6)	3(9.4)	1(14.3)	4(1.6)	4(1.4)	13(1.5)
Oligochaeta	7(3.3)	1(2.6)	17(26.6)	4(12.5)	0	12(7.5)	21(7.5)	62(7.0)
Cladocera	0	0	0	0	0	2(0.8)	4(1.4)	6(0.7)
Ostracoda	37(17.3)	0	0	0	0	0	0	37(4.2)
Copepoda	49(22.9)	0	0	6(18.8)	1(14.3)	2(0.8)	55(19.6)	113(12.8)
Ephemeroptera	14(6.5)	1(2.6)	2(3.1)	3(9.4)	0	27(10.8)	17(6.1)	64(7.2)
Plecoptera	5(2.3)	0	0	0	0	1(0.4)	2(0.7)	8(0.9)
Hemiptera								
Corixidae	0	0	0	0	1(14.3)	0	3(1.1)	4(0.5)
Coleoptera								
Dytiscidae	2(0.9)	0	0	0	1(14.3)	2(0.8)	5(1.8)	10(1.1)
Misc.	0	0	0	2(6.2)	0	2(0.8)	1(0.4)	5(0.6)
Trichoptera	0	0	0	2(6.2)	0	3(1.2)	6(2.1)	11(1.2)
Diptera								
Chironomidae								
larvae	67(31.3)	25(64.1)	39(60.9)	8(25.0)	3(42.8)	156(62.7)	123(43.9)	421(47.6)
pupae	7(3.3)	0	1(1.6)	0	0	12(4.8)	10(3.6)	30(3.4)
adults	16(7.5)	0	0	0	0	0	0	16(1.8)
Simuliidae	6(2.8)	12(30.8)	4(6.2)	2(6.2)	0	17(6.8)	2(0.7)	43(4.9)
Miscellaneous	1(0.5)	0	0	2(6.2)	0	3(1.2)	5(1.8)	11(1.2)
Acari	2(0.9)	0	0	0	0	4(1.6)	19(6.8)	25(2.8)
Miscellaneous	1(0.5)	0	0	0	0	2(0.8)	3(1.1)	6(0.7)
TOTAL NUMBERS	214	39	64	32	7	249	280	885
Number of samples	7	1	1	2	1	2	5	19

total). Other food items of notable importance were Dytiscidae larvae (1.6 percent), Ephemeroptera nymphs (1.6 percent), and Simuliidae larvae (1.1 percent) (Table 2).

Changes with fish size

As the young whitefish increased in size, their feeding habits became more diverse, although the percentage composition in numbers of chironomid larvae in the diet remained high (82 to 87 percent). Various other food items were consumed near the end of summer (Table 2), but few occurred in more than trace amounts (0.1 percent). The organisms contributing most significantly to the diet in numbers (besides chironomidae) were Ephemeroptera (1.5 - 6.2 percent), Dytiscidae (0.4 - 2.2 percent), Trichoptera (0.2 - 1.1 percent), and Simuliidae (0.5 - 1.4 percent).

Mean food size and 95 percent confidence intervals on the means were calculated for whitefish grouped into 10 mm total length intervals (Figure 10). Mean food size increased with fish size until the fish reached 55 mm total length, but then dropped and stabilized near 3 mm for whitefish 60 to 112 mm total length.

Diurnal feeding patterns

Two separate samples, each covering a full day, were taken to describe diurnal feeding patterns based on mean number of organisms in the stomachs (Figure 11). The results indicated that peak feeding activity occurred in late

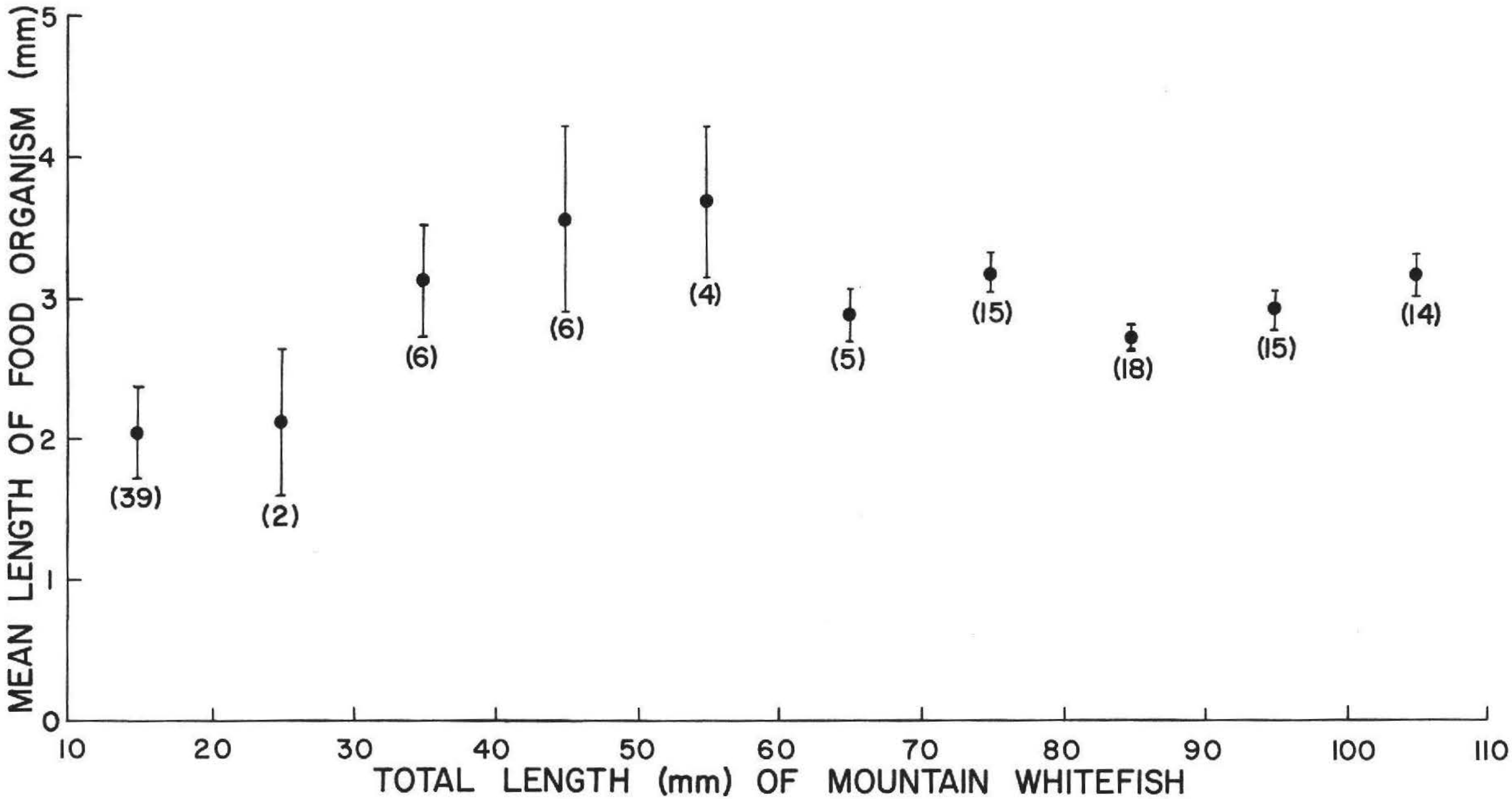

Figure 10. Mean length (mm) with 95 percent confidence intervals, of food organisms from stomachs of 123 Age 0 mountain whitefish, compared to total length of the whitefish, Logan River, Utah, 1970-71. Numbers in parentheses indicate number of fish in each 10 mm length interval.

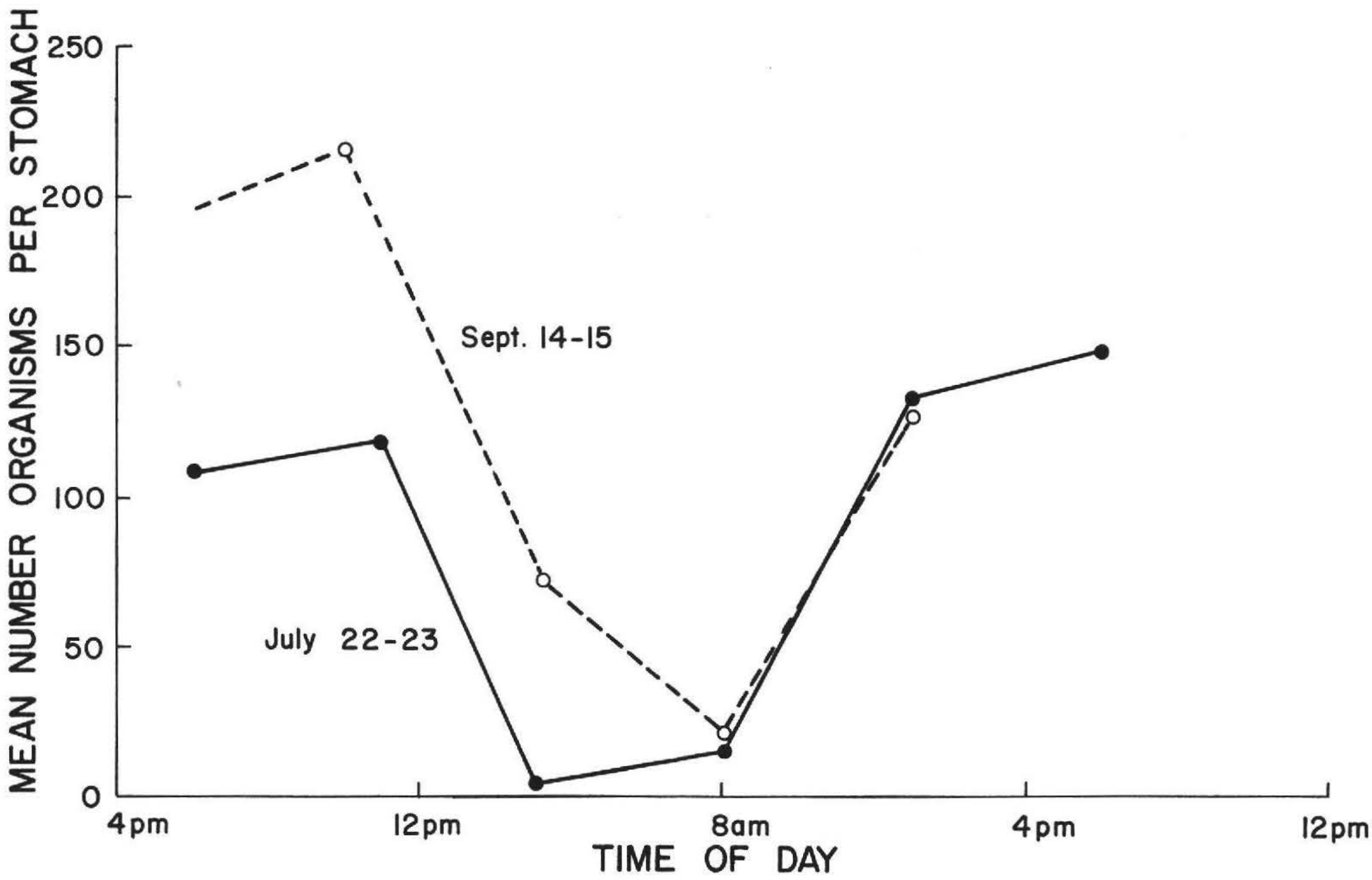

Figure 11. Mean number of organisms per stomach of Age 0 mountain whitefish at 4 to 5 hour intervals during two 24-hour periods, area 1, Logan River, Utah, 1970.

afternoon and evening. Numbers of food items in stomachs decreased after 11:00 p.m. and the young fish did not resume feeding until after 8:00 a.m. the next morning. Drift samples were taken concurrently with fish samples on September 14 at 12:30 p.m. and 10:00 p.m. and on September 15 at 3:00 a.m. The rate of occurrence for drifting organisms was approximately the same at all three sampling times, 0.03 organisms per cubic foot per minute (1.06 organisms per cubic meter per minute), indicating no change in available food. Sigler (1951) reported that adult Logan River whitefish fed permarily at night or twilight.

Electivity

The tabulated results from stomach content and drift samples form a basis for examining food selectivity, or preference, exhibited by young-of-the-year mountain whitefish. The relationship between whitefish diet and availability of food organisms was expressed by Ivlev's (1961) equation:

$$E = \frac{s - d}{s + d}$$

where E = electivity index; s = the percentage composition of an organism in the stomachs; and d = the percentage composition of the same organism in the corresponding drift samples.

Positive selection for an organism is expressed by a positive "E" value (between 0 and +1), and negative selection is expressed by a negative "E" value (between 0 and -1). An "E" value of zero indicates no selection, the relative proportion of an organism in the stomachs equaling the proportion in the drift. Statistical significance of electivity values is difficult to assess and electivity is most useful as an indicator of trends rather than providing absolute values for statistical comparisons.

Electivity values were calculated for taxonomic groups of organisms (Table 4) and for organisms grouped into 1 mm length intervals (Table 5). Electivity values approaching +1.0 or -1.0 should be viewed with caution as they are probably an artifact of inadequate numbers in that particular category, resulting in very small percentages of the total.

Chironomid larvae were consistently selected for, and monthly electivity values ranged from +.14 to +.48, with an overall electivity value for chironomid larvae of +.28. The only other organisms yielding positive overall electivity values were chironomid pupae (+.40) and dytiscid larvae (+.19).

Electivity for size changed sporadically early in the year, but stabilized at about the 2 to 5 mm range in July, August, and September. Greatest selection was for organisms between 2.0 and 3.9 mm length (Table 5).

Electivity appears to be a useful tool for analyzing relative food habits and trends. Some problems were encountered in the interpretation of "E" values on a monthly basis because of relatively small numbers of organisms in either the stomachs or the corresponding drift samples. Future investigators wishing to use these indices should make certain that adequate samples are obtained. The overall "E" values obtained in this study show clear indication of

Table 4. Selection for type of drift organism by Age 0 mountain whitefish in the Logan River, 1970-71. Percentage composition of food organisms in stomach samples is compared with percentage composition in drift samples, expressed as Ivlev's Electivity Value (0, no selection; +1, selection for; -1, selection against)

Item	Month and year							
	March '71	April '70	May '70	June '70	July '70	Aug. '70	Sept. '70	Overall
Nemata	---	---	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
Oligochaeta	-1.00	-1.00	-1.00	-1.00	---	-1.00	-1.00	-1.00
Cladocera	---	---	---	---	---	-1.00	-1.00	-1.00
Ostracoda	-1.00	---	---	---	---	---	+1.00	-1.00
Copepoda	- .58	---	---	- .95	-1.00	- .99	- .99	-1.00
Ephemeroptera	- .37	-1.00	- .15	+ .25	+1.00	- .27	- .61	- .41
Plecoptera	-1.00	---	---	---	---	- .99	-1.00	-1.00
Hemiptera								
Corixidae	---	---	---	---	-1.00	---	-1.00	-1.00
Coleoptera								
Dytiscidae	-1.00	---	---	---	-1.00	- .33	+ .10	+ .19
Miscellaneous	---	---	---	-1.00	--	-1.00	-1.00	-1.00
Trichoptera	---	---	---	- .59	---	- .04	- .83	- .41
Diptera								
Chironomidae								
larvae	+ .48	+ .15	+ .20	+ .45	+ .25	+ .14	+ .33	+ .28
pupae	-1.00	+1.00	-1.00	+1.00	+1.00	+ .26	+ .37	+ .40
adults	-1.00	---	---	---	---	---	---	-1.00
Simuliidae	- .47	- .63	+ .06	+ .13	+1.00	- .66	- .17	- .63
Miscellaneous	-1.00	---	---	-1.00	---	-1.00	-1.00	-1.00
Acari	-1.00	---	---	---	---	-1.00	-1.00	-1.00
Miscellaneous	-1.00	---	---	+1.00	---	-1.00	-1.00	-1.00

Table 5. Selection for size of drift organism by Age 0 mountain whitefish in the Logan River, 1970-71. Percentage composition of food organisms (1 mm size intervals) in stomach samples is compared with drift samples, expressed as Ivlev's Electivity Values (0, no selection; +1, selection for; -1, selection against)

Length of food organism in mm	Month and year							
	March '71	April '70	May '70	June '70	July '70	Aug. '70	Sept. '70	Overall
0-0.9	- .44	---	0	---	- .91	- .70	- .95	- .89
1-1.9	+ .30	+ .26	+ .10	0	---	- .51	- .35	- .35
2-2.9	---	- .32	- .03	+ .16	+ .11	+ .19	+ .25	+ .24
3-3.9	+ .13	- .32	+ .33	0	+ .06	+ .31	+ .30	+ .23
4-4.9	- .01	+ .02	---	- .25	- .36	+ .19	+ .13	+ .09
5-5.9	+ .24	---	---	+ .09	- .55	- .19	+ .17	- .03
6-6.9	---	---	---	+ .09	---	- .33	- .12	- .07
7-7.9	---	---	---	+ .09	---	- .33	- .33	- .17
8-8.9	---	---	---	---	---	---	---	0
9-9.9	---	---	---	---	---	- .33	---	0

food selectivity by Age 0 mountain whitefish for specific organisms (chironomids) and for food items 2.0 to 3.9 mm long.

SUMMARY

A total of 399 young-of-the-year mountain whitefish was examined from three areas of the Logan River, Utah, from March 1970 through March 1971.

A difference in growth patterns was exhibited by whitefish from the two main areas. Whitefish in area 1 emerged about 2 weeks earlier, experienced higher water temperatures, and grew more rapidly than those from area 2. Average weight at the end of six months of growth was 8 grams for area 1 fish and 6 grams for area 2 fish. Total temperature experience from date of first collection was 3,430 degree-days above 32^{o} F for area 1 and 2,950 for area 2.

The length-weight relationship for young-of-the-year mountain whitefish was best described by three stanzas; the initial stanza (Log W = -6.8603 + 4.3333 Log TL) from hatching (approximately 12.5 mm) to 17.0 mm; the second stanza (Log W = -5.7726 + 3.4437 Log TL) from 17.0 mm to approximately 55.0 mm; and the third stanza (Log W = -4.6704 + 2.8043 Log TL) from approximately 50.0 mm to 112.0 mm total length. Average condition factors for each stanza were 0.503, 0.758, and 0.917, respectively, indicating an allometric growth pattern.

Total-length/fork-length ratios appeared asymptotic at 1.084 for the Age 0 mountain whitefish, but decreased for adult whitefish greater than 200 mm total length.

Scale formation commenced at 30 to 35 mm total length and was completed between 40 and 50 mm total length.

Mountain whitefish larvae began feeding before complete absorption of the yolk sac. Larvae and fingerlings fed primarily near the bottom. On the average, their diet consisted of 85.4 percent chironomid larvae, 8.0 percent chironomid pupae, 3.0 percent mayfly nymphs, 1.6 percent dytiscid larvae, 1.1 percent simuliid larvae, and 0.5 percent trichopteran larvae. Various other food items were present only in trace amounts (0.1 percent or less). Peak feeding activity occurred during the afternoon and early evening.

Young whitefish exhibited selective feeding behavior. Chironomid larvae were the only organism consistently selected for ("E" values from +.14 to +.48). The mean food size found in whitefish stomachs increased at first, but then dropped and stabilized near 3 mm for fish of 60 to 112 mm total length. Fish of all sizes selected organisms between 2.0 and 3.9 mm long (electivity values of +.24 and +.23).

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APPENDIXES

Table 6. Number and percentage (in parentheses) of drift organisms captured concurrently with Age 0 mountain whitefish collections, areas 1 and 2, Logan River, Utah, 1970-71

Size interval (mm)	Month and year							
	March '71	April '70	May '70	June '70	July '70	Aug. '70	Sept. '70	Overall
0-0.9	55(25.7)	1(2.6)	4(6.2)	---	1(0.7)	13(5.2)	43(15.4)	117(13.2)
1-1.9	64(29.9)	17(43.6)	33(51.6)	6(18.8)	---	96(38.6)	92(32.9)	308(38.4)
2-2.9	32(15.0)	12(30.8)	17(26.6)	7(21.9)	2(28.6)	81(32.5)	68(24.3)	219(24.7)
3-3.9	33(15.4)	5(12.8)	2(3.1)	8(25.0)	2(28.6)	43(17.3)	43(15.4)	136(15.4)
4-4.9	11(5.1)	2(5.1)	4(6.2)	6(18.8)	1(14.3)	7(2.8)	20(7.1)	51(5.8)
5-5.9	13(6.1)	---	1(1.6)	1(3.1)	1(14.3)	4(1.6)	8(2.9)	28(3.2)
6-6.9	4(1.9)	2(5.1)	---	2(6.2)	---	2(0.2)	4(1.4)	14(1.6)
7-7.9	1(0.5)	---	---	1(3.1)	---	1(0.4)	1(0.4)	6(0.7)
8-8.9	---	---	1(1.6)	1(3.1)	---	---	---	2(0.2)
9-9.9	1(0.5)	---	---	---	---	1(0.4)	---	2(0.2)
10-10.9	---	---	1(1.6)	---	---	---	---	1(0.1)
11-11.9	---	---	1(1.6)	---	---	---	---	1(0.1)
TOTAL NUMBER	214	39	64	32	7	249	280	885
Number of samples	7	1	1	2	1	2	5	19

Table 7. Number and percentage (in parentheses) of organisms found in the stomachs of Age 0 mountain whitefish collected concurrently with drift samples, Logan River, Utah, 1970-71

Size interval (mm)	Month and year							
	March '71	April '70	May '70	June '70	July '70	Aug. '70	Sept. '70	Overall
0-0.9	2(10.0)	---	1(6.2)	---	1(0.7)	4(0.9)	2(0.4)	10(0.8)
1-1.9	11(55.0)	14(73.7)	10(62.5)	15(18.8)	24(16.2)	58(17.6)	84(15.8)	216(16.9)
2-2.9	---	3(15.8)	4(25.0)	24(30.0)	53(35.8)	219(47.4)	214(40.2)	517(40.5)
3-3.9	4(20.0)	1(5.3)	1(6.2)	20(25.0)	48(32.4)	152(32.9)	151(28.3)	377(24.5)
4-4.9	1(5.0)	1(5.3)	---	9(11.2)	10(6.8)	19(4.1)	49(9.2)	89(7.0)
5-5.9	2(10.0)	---	---	3(3.8)	6(4.1)	5(1.1)	22(4.1)	38(3.0)
6-6.9	---	---	---	6(7.5)	4(2.7)	2(0.4)	6(1.1)	18(1.4)
7-7.9	---	---	---	3(3.8)	2(1.4)	1(0.2)	1(0.2)	7(0.5)
8-8.9	---	---	---	---	---	---	3(0.6)	3(0.2)
9-9.9	---	---	---	---	---	1(0.2)	1(0.2)	2(0.2)
10-10.9	---	---	---	---	---	---	---	---
11-11.9	---	---	---	---	---	1(0.2)	---	1(0.1)
TOTAL NUMBER	20	19	16	80	148	462	533	1278
Number of fish	59	11	14	26	62	22	44	238

VITA

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