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January 1974

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Early Life History and Feeding of Young Mountain White fish

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EARLY LIFE HISTORY AND FEEDING OF

YOUNG MOUNTAIN WHITEFISH

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ABSTRACT

Study of the early life history of the mountain whitefish (*Prosopium williamsoni*) was conducted in the Logan River, and under controlled laboratory conditions in the Utah Water Research Lab and USU Fisheries Laboratory. Culture methods were also developed.

Spawning behavior was observed in the field and in the laboratory. In the Logan River spawning occurs from mid-November to mid-December during the dusk hours.

Hatching success of whitefish eggs was studied in the field by weekly collections from five areas. Total mortality to hatching was 92%. Larval whitefish appeared in quiet areas along the river by early March. Fertilized eggs were incubated in the lab under controlled temperatures of 42, 45, and 48 F (5.6, 7.2, 8.9 C). In the river at ambient temperatures from 1.7 - 6.1 C the eggs began hatching in approximately 79 days and continued for 23 days. At 45 F (7.2 C) they began in 52 days and continued for 23 days, and at 48 F (8.9 C) they began at day 45 and continued for 30 days.

Growth of larval whitefish in two areas of the Logan River showed differences in total length and weight increases. These differences can be partially explained by their temperature experience of accumulated degree-days above 31 F. The water temperatures were consistantly higher in the one area in which the young fish emerged two weeks earlier both sampling years. Length-weight relationships were established. Growth of larval whitefish at three different temperatures (6, 9, 12 C) was examined in the laboratory. Data collected was analyzed by factorial analysis and a simple linear model for predicting growth was developed.

Stomach analysis and field observation show that the larval whitefish begin feeding at 14-15 cm and remain near the bottom. Chironomid larvae were the major food item of age-0 fish ranging from 65.5-90% of total monthly diet. Peak feeding activity occurred in late afternoon and early evening.

Larval whitefish were raised in the lab under various temperature regimes and diets. Starved fry were held at temperatures from 2-14 C at 2 degree intervals. All of the fish held at 8, 10, 12 and 14 C were dead by day 77, 50, 29 and 12 respectively. Between 78 and 92% survived at 2 to 6 C for more than 80 days. Larvae were fed dry trout feed, Oregon Moist Pellet, mosquito larvae and brine shrimp. Total mortality rates varied from 15% for 3 months on brine shrimp to 98% in 1.5 months on Oregon Moist Pellets.

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SECTION I

CONCLUSIONS

1. Male and female whitefish developed tubercles and lateral stripes. Females were discernible from males when nearly ready to deposit their eggs, at this time they became swollen in the anal region.

2. In all cases, spawning occurred between late October and mid-December in lab and Logan River.

3. Spawning was observed during periods of decreasing light intensity at dusk. No spawning was observed after dark.

4. Total egg mortality was found to be 92% over the 106 day incubation period in the Logan River. Hatching extended over approximately 43 days.

5. Differences in total length, weight, and daily instantaneous growth coefficients over time can be explained by temperature experience express as accumulated degree days above 0.5 C.

6. Larval mountain whitefish began feeding at lengths of 14-15 mm before yolk was completely absorbed. Chironomid larvae was the major food item for Age-0 fish (65.5% to 90% of total monthly diet). Mean food size increased with fish size until fish reached 55 mm total length and stabilized near 3 mm for whitefish of 60-112 mm. Peak feeding occurred late afternoon and early evening decreasing after 23:00 hrs. Feeding did not resume until after 8:00 hrs.

7. Unfed whitefish larvae survived up to 63 days at 5.6 C. Survival decreased with increase in temperature.

8. Whitefish larvae survived at higher rates (85%) and grew best on brine-shrimp diets. Dry food diets and Oregon Moist pellets produced lowest survival and growth.

9. Mean monthly growth increments increased with temperature. Time and temperature interaction was significant with the following model predicting growth increments for 1971-72 experiments. $y = 21.55 + .104\, x_1 + .012\, x_1 x_2$ when y = length in mm x_1 = time in days and x_2 = temperature in °C.

SECTION II

RECOMMENDATIONS

This project was limited to field and laboratory study of the spawning behavior, and growth of larval and juvenile mountain whitefish. Culture methods and egg incubation time in the laboratory were described. It was not within the scope of this study to fully determine developmental time and frequency of deformations for whitefish embryos from fertilization to hatch and from hatch to yolk-sac absorption when incubated at different temperatures. It is recommended that such laboratory studies be carried out.

Environmental requirements for the whitefish are poorly known, particularly the effect of temperature change at all life history stages. Since the mountain whitefish inhabits waters potentially and actually receiving thermal effluents it is further recommended that laboratory studies be initiated to determine the upper and lethal threshold temperatures for mountain whitefish embryos, larvae, juveniles and adults.

The effects of prespawning temperature experience on maturation and viability of gametes should be determined as well as growth rates of larval and juvenile mountain whitefish within their range of temperature tolerance.

SECTION III

INTRODUCTION

Information is needed by water-quality control agencies on the long-range effects of sub-lethal concentrations of pollutants on fishes throughout their entire life history. In order to obtain this information under controlled laboratory conditions, fish must be cultured from the time of egg fertilization to sexual maturity and spawning. Little is known about the environmental requirements of many fish species during the early life history stages when larval fish shift from endogenous (yolk) energy reserves to exogenous (food organism) energy sources.

The mountain whitefish (Prosopium williamsoni) is a common river fish in the western United States and is listed by the Duluth Water Quality Laboratory as one of the species on which studies are recommended.

This study began March 28, 1969 and continued through December, 1972. During this time field observations were made in the Logan River on spawning behavior and natural mortality of whitefish eggs. Larvae and adult whitefish were taken as were drift samples of macroinvertebrates. Controlled laboratory experiments investigated development of eggs and growth of young whitefish under different temperature regimes and diets. Field data provided baseline information with which to compare behavior, development, and growth under laboratory conditions.

SECTION IV

STUDY AREA

Logan River

Logan River begins in Franklin County, Idaho, and flows in a southwesternly direction into Cache County, Utah, joining the Bear River west of Logan, Utah. The watershed includes approximately 225 sq. miles (583 sq. kilometers) of mountainous limestone, dolomite, and shale. Advanced weathering of base materials probably accounts for the high alkalinity of the waters. The watershed has an average yearly precipation of about 30 inches (76.2 cm) of which 60 percent is snow. 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 cfs at the mouth of the canyon (first dam), with peak flows in May or June and low flows in February. There are three power and irrigation impoundments on the river upstream from the City of Logan. No upstream fish-passage facilities are in operation. The backwaters of the impoundments have extensive shoals of silt deposits, creating nursery areas for young-of-the-year mountain whitefish, (*Prosopium williamsoni*) brown trout (*Salmo trutta*) and mottled sculpin (*Cotus bairdi*).

Field observations of egg mortality were conducted on five 600 meter sections of the Logan River (Fig. 1). Sections 1-4 were located above the Spring Hollow campground impoundment (third dam). Sections 1 and 2 ran through DeWitt campground in a relatively undisturbed stretch of river with pool and riffle areas. Sections 3 and 4 were in a channelized portion of the river immediately above the third impoundment. Section 5 was located above the first impoundment. This section had also been channelized and was characterized by high gradient and large rock substrate. These areas represented known spawning areas of the mountain whitefish.

Laboratory facilities

Two wet labs were utilized during this study. One was located in the basement of the Natural Resources-Zoology building utilizing dechlorinated tapwater at approximately 11 C. To provide various incubation temperatures water was cooled to 4.5 C in a Min-O-Cool 1/ and then heated with conventional heater-thermoregulators to the desired temperatures.

The other facility was in the Utah Water Research Lab, located along the Logan River. Water supply for this lab was the Logan River which reached minimum temperatures of 1-2 C.

1/ Manufactored by Frigid Units Inc., Toledo, Ohio.

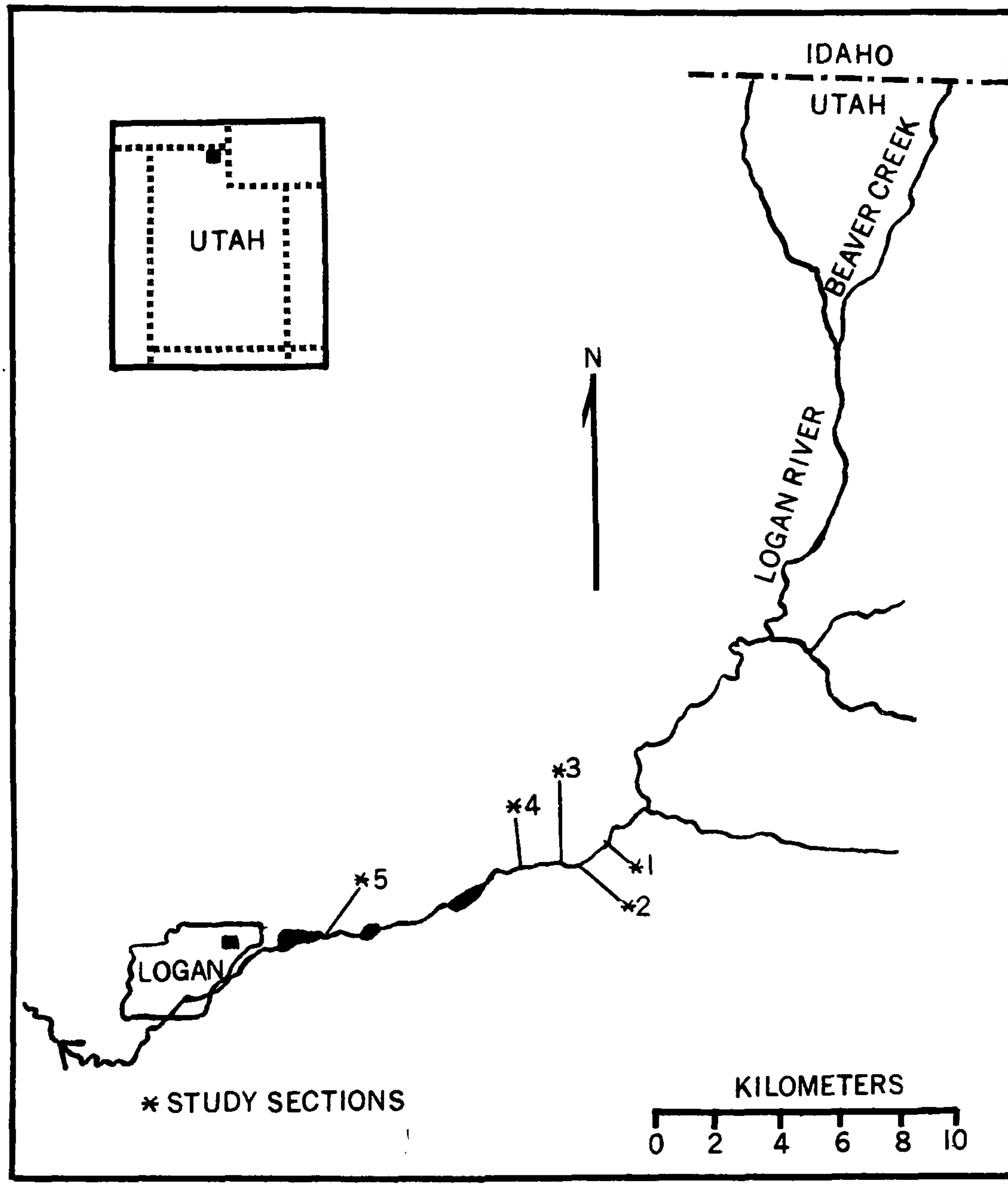

Figure 1. Map of the Logan River, showing study sections, 1969-1972.

SECTION V

OBJECTIVES

The objectives of this study were to:

a) Describe spawning habitat and behavior of mountain whitefish.
b) Describe water temperature regimes and hatching times of mountain whitefish eggs in natural environments.
c) Describe water temperature regimes for growth and development of larval and juvenile mountain whitefish in natural enviromnents.
d) Describe food habits of larval and juvenile mountain whitefish in natural environments.
e) Develop feasible methods to culture mountain whitefish in the laboratory from time of egg-fertilization to end of first 6 months of life.

SECTION VI

SPAWNING BEHAVIOR

Methods

The spawning behavior of the mountain whitefish was studied in the field and in the laboratory. The field studies were conducted from October, 1971 through December, 1971 and the laboratory studies from October through December, 1971 and 1972.

The field studies were conducted in sections 1 and 2. Observations were made by using snorkel, mask, and wet suit. Photographs were taken with a Nikonos underwater camera. Light intensity data was measured with a selenium cell and galvanometer; the readings were taken at or near the water surface and converted to langleys.

Laboratory studies were conducted at the Utah Water Research Laboratory, Logan, Utah. Three living stream aquaria measuring 56 cm wide x 38 cm deep x 147 cm long (inside measurements in the fish holding compartments) were used in 1971. River water was flushed through these tanks at 200 gallons/hour (.0002 m^3/sec.). This flow not only regulated water chemistry, but also kept the temperature regime near that of the river. Lighting was from over-head windows. Although the light intensity was lower indoors, the daily light pattern was essentially the same as outside. Gravel was placed in the aquaria to simulate the river bed substrate. Three sizes of gravel were used; pea gravel, 2-5 cm rock, and 10-15 cm rock. Three patterns of gravel combinations were set up to determine substrate preference (Fig. 2).

Three adult whitefish, 1 female and 2 males, were placed in each tank. The fish were fed aquatic insects collected from the Logan River. The data recorded in 1971 in the laboratory and in the field included time of day spawning occured, description of spawning activities, and light intensity measurements. In the field, notes were recorded after every ten to fifteen minutes of observation with the snorkel gear.

In 1972, field observations were terminated and more intensive laboratory studies were conducted. Three large round tanks were used in addition to the three living stream aquaria. The round tanks were 1.5 m in diameter and 79 cm deep. A glass sided portion of the main flume at the Utah Water Research Laboratory was utilized. This section measured 7.3 m by 2.4 m with a water depth of .9 m . Screens were used at each end of the windowed section to confine the fish.

Two round tanks and two living stream aquaria were provided with two types of gravel for substrate, coarse and fine. One of each type tank was left bare. The round tank allowed unlimited swimming space (in circles) and much greater velocities of water flow. Again, river water was used with lighting from windows at near natural conditions.

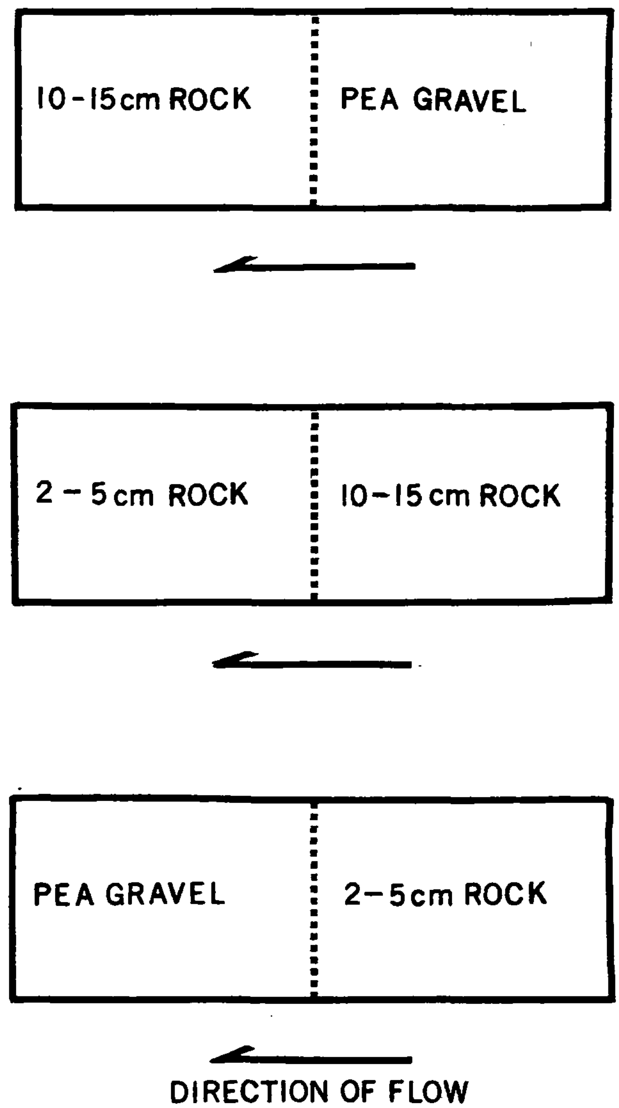

Figure 2. Patterns of gravel substrate in three living stream aquaria, 1971.

The flume was not situated near windows; therefore, a deck of plywood and canvas was fitted to exclude all light from the work area of the laboratory. A curtain was also hung in front of the windows. To simulate natural lighting, a series of flourescent lights, and a series of incandescent lights with timers and automatic dimmers were used. This system was utilized because it eliminated the abrupt change from darkness to light and vice-versa (Drummond and Dawson, 1970). Flourescent lights were placed in three groups to turn on or off at fifteen minute intervals with the incandescent sequence set at twenty minutes. This provided a dawn and dusk sequence of approximately 1 hour.

The substrate used in the flume was 5-10 cm rock. Originally a velocity of 30 cm/sec was planned, but fish drifting downstream had trouble freeing themselves from the screen; therefore a velocity of 14 cm/sec was used. This provided sufficient velocity for orientation, and was slow enough for the fish to maintain position.

Twenty adult whitefish were placed in the flume. There were 5 known males and 5 females in this group. Five adults (3 males and 2 females) were placed in each of the round aquaria and three adults (1 female and 2 males) were placed in the living stream aquaria.

Spawning behavior was observed in the flume through the glass window. Descriptions of the spawning activities were dictated onto a taperecorder. Light intensity and time of day were recorded during all courtship and spawning activities. The day length was altered to determine if light was a major factor in the time of spawning. Both still photographs and 16 mm movies were used for recording the spawning sequence.

The spawning success (or failure) in the round aquaria and the living streams was compared with bottom type and velocity. Percent fertilization of eggs spawned was the criterion of spawning success. The location of the eggs in relation to bottom type was recorded.

Results and Discussion

Secondary Sex Characteristics. As the spawning season approached, the whitefish developed tubercles on their scales and lateral stripes. McAfee (1966) found that neither sex became highly colored but the males developed snouts and prominent body tubercles while females developed only smaller tubercles. In a study on the Bow River, Banff National Park, tubercles were found on the males only (Vladykov, 1970). The presence of stripes on mountain whitefish had not been reported by other authors, however, Normandeau (1969) found that the round whitefish (*Prosopuim cylindraceum*) does develop orange to red coloration on the belly and other areas during breeding.

Fifty-six mountain whitefish were collected from the Logan River and examined in the fall of 1971 for sexual dimorphism. Both males and females had well developed tubercles. Lateral stripes were prominent on fish that were currently spawning. Long snouts were present on a few fish. Females were discernable from males only when they were nearly ready to deposit their eggs; at this time they became swollen in the anal region (Fig. 3). The lateral stripes consisted of a dark back with a light dorsal lateral band, a dark lateral band, and a light ventral side (Fig. 4). The stripes were present only when the fish were ready to spawn and were more prominent in the evening than the morning.

Spawning Periods. The mountain whitefish in the Logan River began courtship activities on October 14, 1971. Spawning was taking place on November 1, and by November 11, had peaked. Some courting, but no complete spawning was observed on December 12. All activity occurred in the evening over rocky areas in the river in pools and/or deep riffles.

The whitefish held in the lab during the fall of 1971 developed at a slower rate than the fish in the wild. Stripes and tubercles were evident on November 1 and spawning did not begin until November 8 and lasted until December 22. The time lag may have been due to the handling and captivity.

During the fall of 1972, the whitefish held in the flume developed tubercles and stripes by November 7 and also began courting on that date. Complete spawning was first observed on November 11. The last complete spawning was observed on December 5, but some courting continued until December 12.

Light Intensity. During 1971 field studies, courting activity began when the light intensity decreased to .023-.009 langleys. Spawning took place as the light further decreased to .003-.0013 langleys. Spawning was observed until intensities of .00026 langleys were reached. Sexual activity may have occurred at lower light levels as it did in the laboratory, but visibility was poor.

The laboratory observations in 1971 revealed similar trends, but were somewhat altered because of overhead lights in the surrounding work area. Spawning in the lab always began after the overhead lights were turned off which would coincide with the start of the evening decrease in light. Courting began at a light level of .00075-.0000023 langleys and spawning occurred at .00045-.0000011 langleys. The lowest light level at which activity was observed was .0000010. Although the light intensities were much lower than field data, the pattern was basically the same.

In the fall of 1972, the light data revealed the same sequence. Courting was first observed as the light decreased from a maximum of .0059 to .0003 langleys. However, courting and spawning usually did not begin until .00094 langleys was reached. Spawning was observed at a light level of .002-.00000038 and occurred until total darkness.

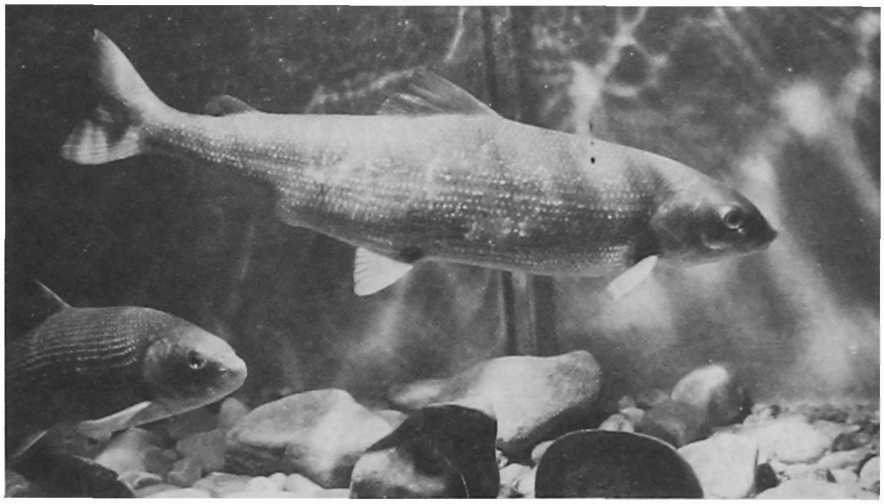

Figure 3. Large female ready to spawn; note swollen anal region. Male with tubercles is seen at lower left.

Figure 4. Fish showing lateral stripes; note center pair exhibiting lateral display.

The time of the onset of dusk was altered to determine if a decrease in light was the triggering machanism for sexual behavior. On November 21, 1972, the lights were left on all night at full intensity (.0059 langleys). There was no sexual activity that night. At 13:45 hrs on the 22nd courting began in full light and continued until 21:37 hrs. Spawning occurred after 30 hours of full light. The lights were left on until the evening of the 24th when the lighting was returned to a normal schedule. No sexual activity occurred during the period from 22:00 hrs on the 22nd till 17:30 hrs on the 24th when the fish began sexual behavior during a standard evening light schedule. This was repeated the morning of December 2 until the evening of December 5 when the fish spawned during a normal evening schedule. On December 4, from 22:35 hrs until 22:47 hrs there were four incomplete courting activities, but the fish did not spawn or start large scale courting until returned to an evening schedule. On November 20, 1972, the evening schedule was conducted at 15:00 hrs instead of 17:00 hrs. The whitefish began courting at 15:00 hrs, 2 hours ahead of the normal schedule.

Spawning Success. Spawning behavior and spawning success were altered depending on the type of aquaria used. Observations during 1971 both in the field and in the lab, indicated that the mountain whitefish needed room to swim about. In the Logan River pairs and groups were seen swimming 15 to 20 feet upstream during courtship. Observations in the living stream aquaria indicated that the spawning sequence was altered. Fish were seen swimming violently against the glass side, and then settling to the bottom. In 1972, three 5 foot diameter circular tanks were used as well as the 24 foot long glass-sided flume. These provided more swimming space.

Spawning success in 1972 was greater in the round aquaria and the flume than in the living stream aquaria (Table 1). Spawning success was measured by the percentage of fertilized eggs.

Table 1. Fertilization percentages in different tanks, velocities, and substrate types, during 1972.

Holding Tank	Velocity	Substrate	% Fertilization
Living Stream	0.0 ft/sec	½ coarse-½ fine	0.0
Living Stream	0.0 ft/sec	½ coarse-½ fine	0.0
Living Stream	0.0 ft/sec	Bare	1.4
Round Tank	0.52 ft/sec	Bare	32.8
Round Tank	0.44 ft/sec	½ coarse-½ fine	1.9
Round Tank	0.49 ft/sec	½ coarse-½ fine	41.4
Flume	0.48 ft/sec	10 cm Rock	23.1

One of the round aquaria produced only 1.9% success. This was due to placing 5 female whitefish and no males in the tank originally. The females deposited their eggs anyway. Later, several males were added and some success was realized, but the spawning season was nearly over. The other two round aquaria produced 32.82% and 41.44% fertilization. The flume had 23.1% success. The spawning success in the living stream aquaria was 1.41% in the bare tank and 0% in the other two. The female in the living stream did not deposit her eggs. All three tanks had both females and males.

The percentage of eggs retrieved from the coarse gravel vs. the fine gravel was also different. In the round aquaria, 66% of the eggs were collected from the coarse gravel of one tank and 85% from another. In the living stream 83% of the eggs were collected from the coarse gravel area. However, the 5-10 cm rock had more space between the rock to catch and hold the eggs. None of the eggs in the living stream aquaria were fertilized indicating the eggs were deposited without sexual interaction of the fish present. During the 1971 observations, fish in two of the three living stream aquaria did spawn successfully, and the eggs appeared evenly distributed although no quantitative measurements were made. This may have been a result of the limited space such that if the eggs were deposited in one area, swimming motions would relocate the eggs.

More research is needed on choice of spawning sites. Most authors agree that the whitefish prefers gravel to rocky areas of rivers. Brown (1952) stated that there was no selection of bottom material, the fish spawned in riffels or next to strong currents. Some lake dwelling populations spawn in lakes and not in the tributaries (McAfee, 1966). This would indicate a substrate preference since silted areas would suffocate eggs. However, the 1972 laboratory experiments indicated little if any substrate preference. More eggs were found in coarse material but agitation by currents and swimming fish would tend to relocate the eggs into the coarser material. The whitefish also spawned successfully in aquaria with bare bottoms. In the Logan River, whitefish have never been observed to spawn in the impoundments, they apparently moved into the river channel orienting to the current. Observations with snorkel gear revealed whitefish in the main channel and brown trout dominating the quiet pockets. Since they spawned at low light levels when visibility was poor, the orientation to the current may have been the greater stimulus over substrate size for choice of spawning sites.

Description of Spawning Act

Brown (1952) gave the most complete report of mountain whitefish spawning. He observed whitefish spawning at night by using a light to observe fish in shallow water. Brown gave the following account: the whitefish would hold their position in the current and come together at intervals until all were in contact. They would then settle to the bottom for 2-4 seconds and then move apart. There were no rapid or violent body motions. In 1972 and 1971, whitefish in the Logan River and in the laboratory displayed a definite but simple courtship, and then swam rigidly upstream for up to twenty feet in groups of 2-7 fish. One fish, presumed to be a male, would approach another fish, there would be a nudge or lateral wavering , and the pair would swim away. Other fish would join them, and the group would settle and emit sex products and then split apart. Eggs were deposited when the fish darted to the bottom and quivered rigidly with fins erected. Sometimes the swimming upstream was very rapid and at other times quite slow. At times the group would immediately swim to the bottom without darting upstream, but during the actual deposition of eggs, the group always moved upstream. Brown (1952) also reported whitefish spawning after dark. In 1971 at DeWitt campground on the Logan River, an attempt was made to observe the fish after dark with a light. The fish were extremely shy of the light and no spawning was observed. Fish in the flume during 1972 spawned at very low light levels but no evidence of spawning in total darkness was found. Since there was not a 24 hour survelence on the tank, they may have spawned at night. This study found the fish spawning during the evening dusk sequence.

SECTION VII

NATURAL EGG MORTALITY

Methods

One square foot (.1 m^2) samples were collected weekly with a Surber sampler from five sections on the Logan River. Each week the samples were collected 3 meters downstream from the previous samples. Four sample sites, A, B, C, and D, were spaced evenly across the river at each station, from south to north, yielding 20 samples per week.

A snorkel, wet suit, and face mask were used to increase sampling efficiency. Sampling began on November 30, 1971 when spawning activity was decreasing. Sampling terminated on April 20, 1972 when no eggs were found.

The method of least squares was used to fit a linear regression line to the data using log transformation of the total number of eggs recovered on each sampling date. By plotting days on the abscissa, the slope of the fitted line was the daily instantaneous mortality rate. This was expanded over the entire incubation period and converted to the total mortality.

Data on the bottom type, water velocity, water temperature, relative position in stream, and stream depth were recorded in conjunction with the egg samples. Comparisons were made among these variables and the number of eggs (eggs/ft. 1m^2). Bottom type was analyzed by grouping the substrate into size groups. Depth, velocity, and bottom type were compared among study sections and positions across the river. Analysis of variance for a completely randomized design was conducted.

Results

Since the number of eggs/ft^2 varied with location, the study sections and the position across the stream were examined for differences. The water depth was greatest in Section 1 and shallowest in Sections 2 and 5. Sections 3 and 4 were median in depth. Sections 2 and 5 were swiftest and sections 4, 3 and 1 were slowest. Bottom type also changed in the different sections. Section 5 had the coarsest substrate and section 4 had the finest with 1, 2, 3 being median. Water velocity tended to be greater in the middle of the stream (Fig. 5). The substrate size did not very with position.

Velocity, section, and position were the most important factors related to the number of eggs recovered (Table 2). Bottom type and depth seemed to have little or no effect. The velocity tended to be highest at midstream, where the concentration of eggs was also greater (Fig. 5 & 6).

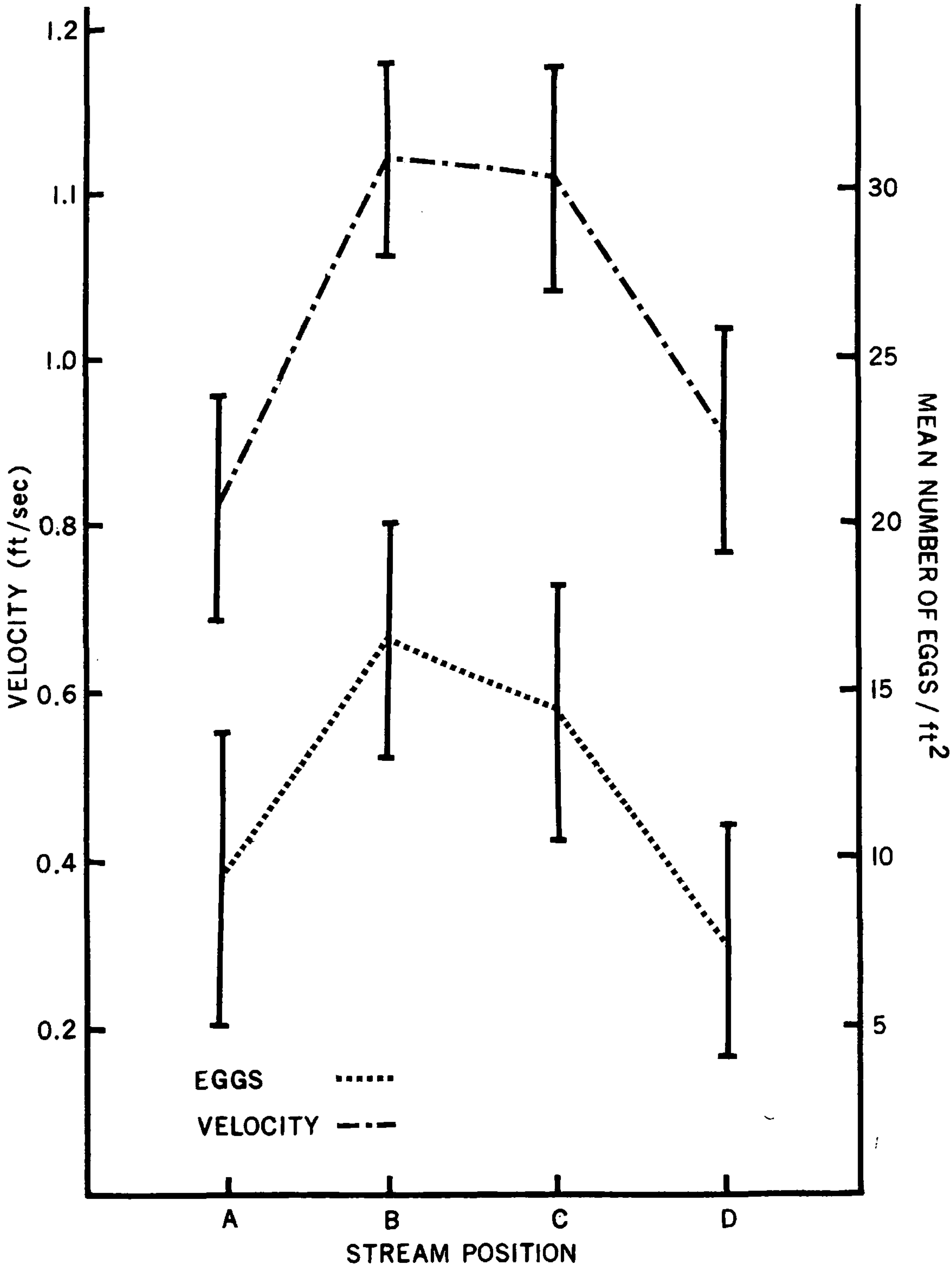

Figure 5. Mean velocities and mean number of eggs recovered from Logan River, 1971 including 95% confidence intervals with respect to stream position.

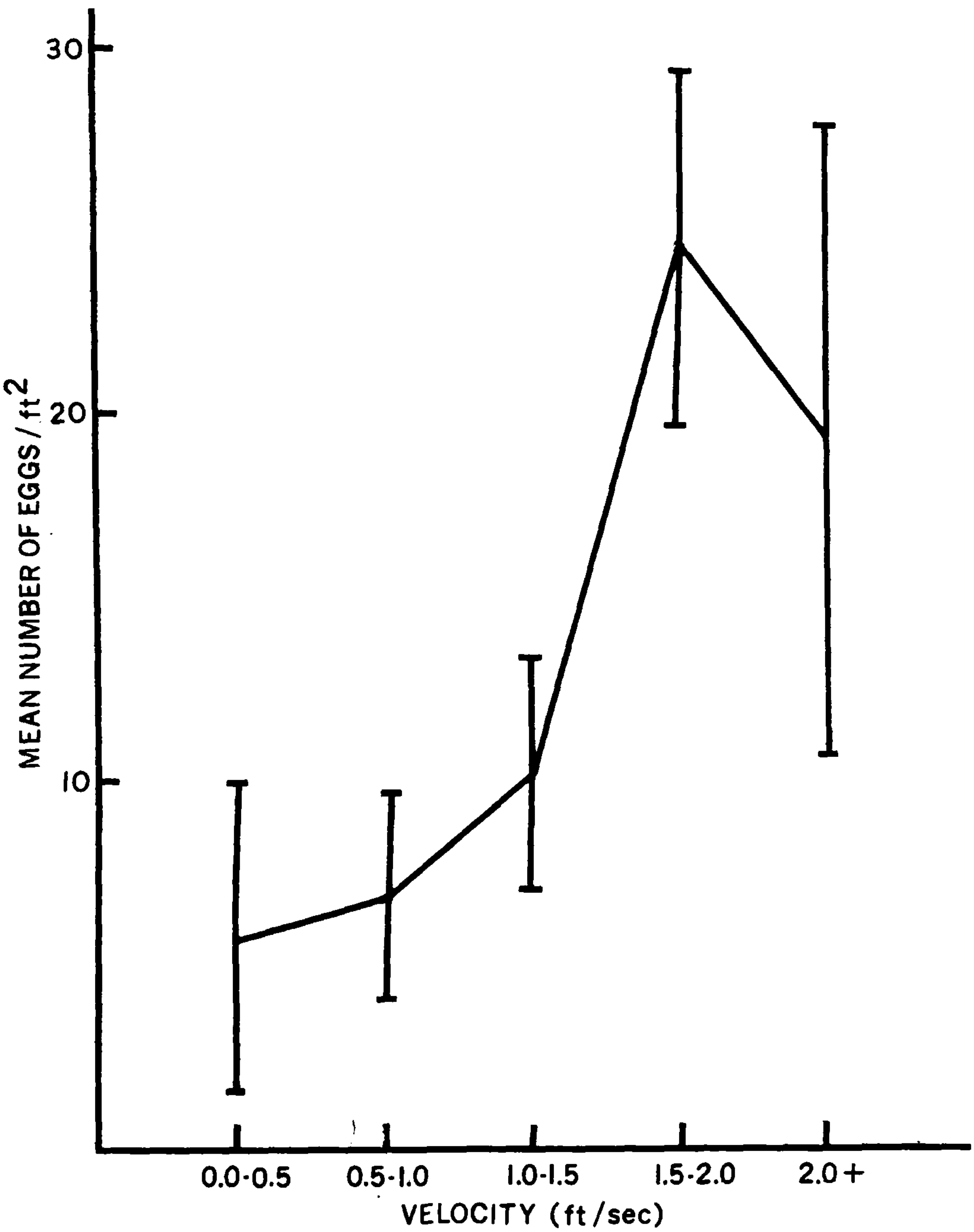

Figure 6. Mean number of eggs recovered and 95% confidence intervals with respect to velocity, Logan River, 1971.

Table 2. Calculated F values for individual comparisons of eggs recovered and physical characteristics of Logan River, 1971.

Comparison	F
$Eggs/ft^2$ vs. section	4.777*
$Eggs/ft^2$ vs. position	3.865*
$Eggs/ft^2$ vs. depth	1.0496
$Eggs/ft^2$ vs. velocity	11.902*
$Eggs/ft^2$ vs. Bottom type	.396
Depth vs. position	1.147
Velocity vs. position	7.674*
Bottom type vs. position	.155
Depth vs. section	32.45*
Velocity vs. section	6.989*
Bottom type vs. section	25.231

* Significance at 0.05 level.

Skindiving observations and electrofishing indicated that mountain whitefish tended to be in the higher velocity pools and channels while trout generally preferred the quieter areas along the banks. Section 4 was the only area that differed significantly in the number of eggs collected. Section 4 had the combination of the lowest velocity and the finest substrate particle size. This may have made it less desirable as a spawning site.

By March 8, 1972, larval whitefish were observed in quiet areas near the river banks. The samples collected on March 22, 1972, contained very few eggs indicating increased hatching activity. Because increased rate of hatching would influence calculated mortality rates, March 15, 1972 was the last sampling date used for mortality estimations (Table 3).

The daily instantaneous mortality rate was -0.024. The total mortality for the estimated 106 day incubation period was 91.88%. By April 20, 1972, no eggs were found in the samples, indicating that the duration of the hatching period was approximately 43 days.

Mortality of the eggs may have been due to incomplete fertilization, predation by insects and fish, and mechanical damage from agitation. Predacious insects of the Tipulidae and Plecoptera were observed in the bottom samples. Brown trout, whitefish, and sculpin, were observed eating eggs during collections. Since no redd is formed, the eggs may be jostled and damaged by the current.

Table 3. Whitefish eggs recovered from Logan River, 1971.

Sampling Date	Total No. Eggs	Mean/ft^2
11-30-71	771	38.55
12-7	596	29.8
12-14	398	19.9
12-21	301	15.05
12-28	273	13.65
1-5-72	194	9.7
1-12	200	10.0
1-20	198	9.9
2-1	129	6.45
2-8	127	6.35
2-15	112	5.6
2-22	92	4.6
2-29	71	3.55
3-7	52	2.60
3-15	48	2.67
3-22	8	.44
3-30	3	.16
4-6	2	.17
4-20	0	0

SECTION VIII

GROWTH AND DEVELOPMENT OF LARVAE AND JUVENILES IN NATURAL ENVIRONMENTS

Methods

Mountain whitefish larvae and fry were collected by dip nets and fingerlings with a direct-current backpack shocker from the backwaters of the First and Third Dams of the Logan River. Collections were made at 10-14 day intervals (except during spring runoff) from March 1970 to September 1970 and again during March 1971. Fish were preserved in 10% formalin. Total and fork lengths were measured to the nearest 0.5 mm. Wet weight was measured to the nearest 0.005 gm. Means and 95% confidence intervals were calculated for each sample and growth curves were fitted by inspection.

Results and Discussion

The mountain whitefish collected from the two backwater areas showed large differences in total length increase (Fig. 7), weight increase (Fig. 8), daily instantaneous growth coefficients (Ricker, 1968) and the pattern of these rates over time (Fig. 9). These differences can be partially explained by the temperature experience expressed as accumulated degree-days above 0.5 C, of the fish from the two areas (Fig. 10). Water temperatures were consistantly higher in First Dam than in Third Dam. The young fish emerged approximately two weeks earlier in First Dam than Third Dam in both years. Fish reached approximately 50 mm total length at the end of 3 months and nearly 100 mm after 6 months growth.

All fish were pooled to establish a length-weight relationship for age 0 mountain whitefish in the river. A scatter diagram of log-weight against log-length indicated three different relationships (Fig. 11). 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 (Table 4). The transition from the initial stanza to the second stanza occurred at a total length of approximately 17 mm. This may reflect the change from endogenous (Yolk) to exogenous nutrition. The transition from the second to third stanza was less certain and appeared to be between 50-60 mm total length. Average condition factors were based on the formula

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

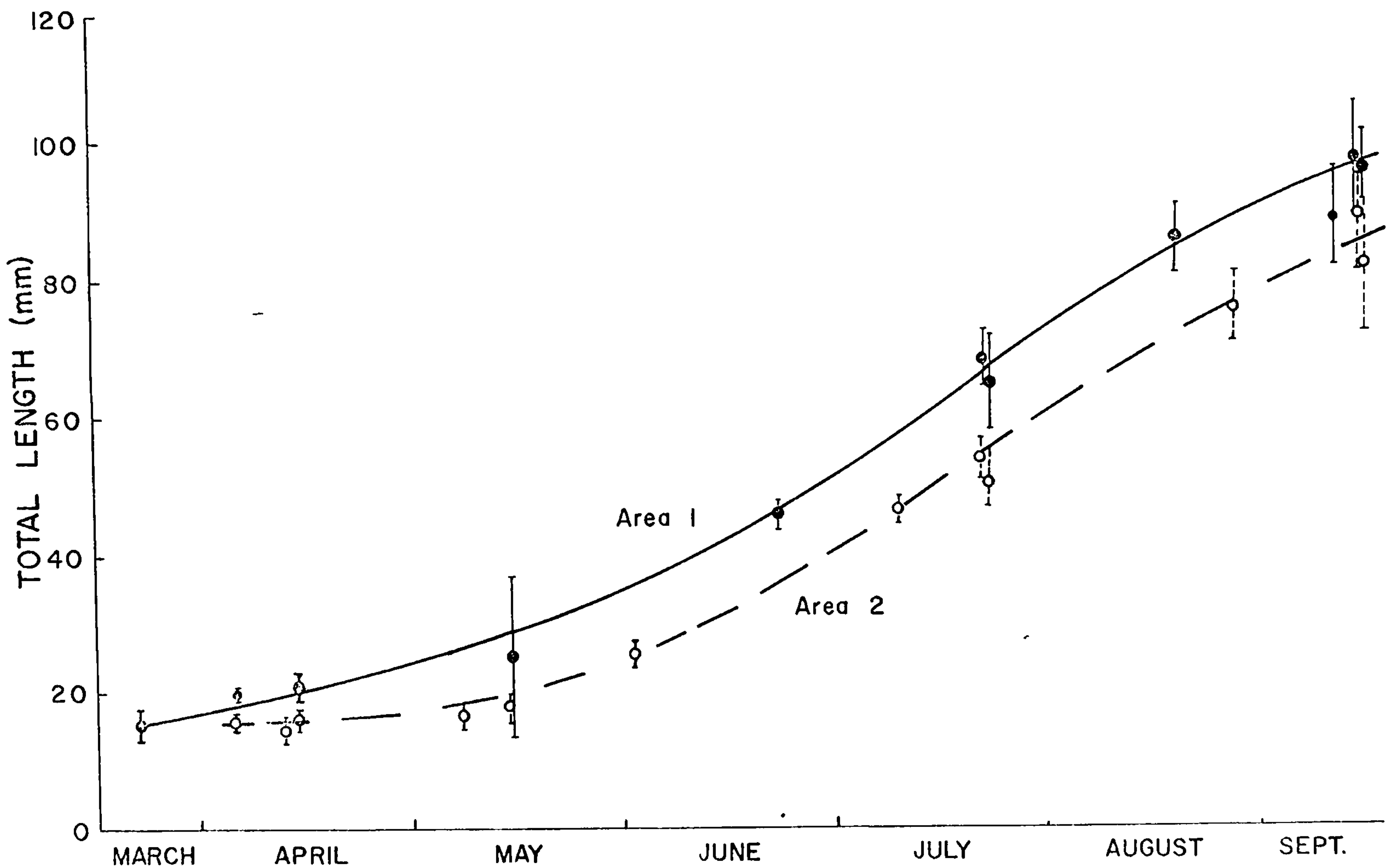

Figure 7. Mean total length (mm) and 95 percent confidence intervals for Age 0 mountain whitefish, First Dam (area 1) and Third Dam (area 2), Logan River, Utah, 1970.

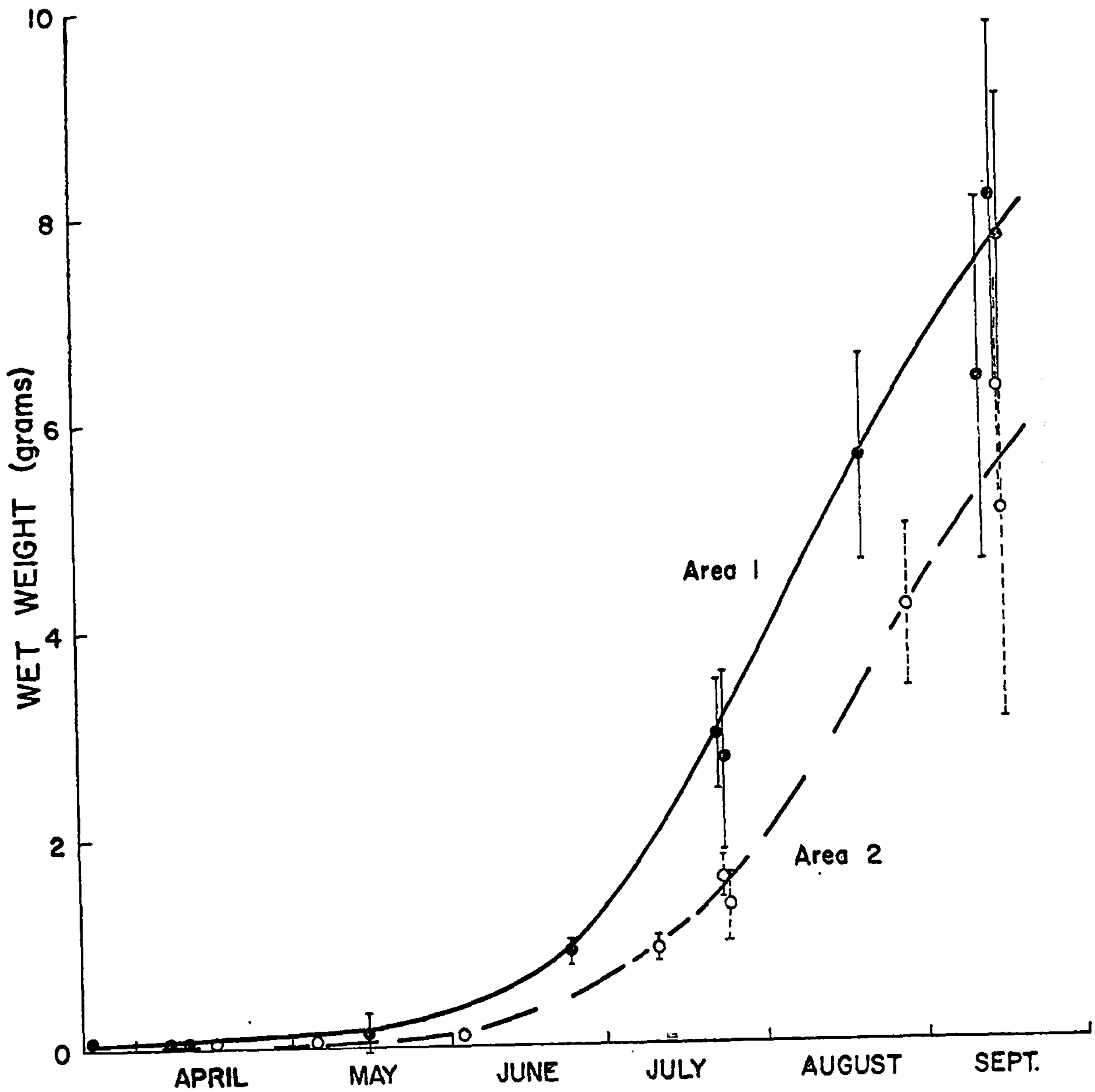

Figure 8. Mean wet weight and 95 percent confidence intervals for Age 0 mountain whitefish, First Dam (area 1) and Third Dam (area 2), Logan River, Utah, 1970.

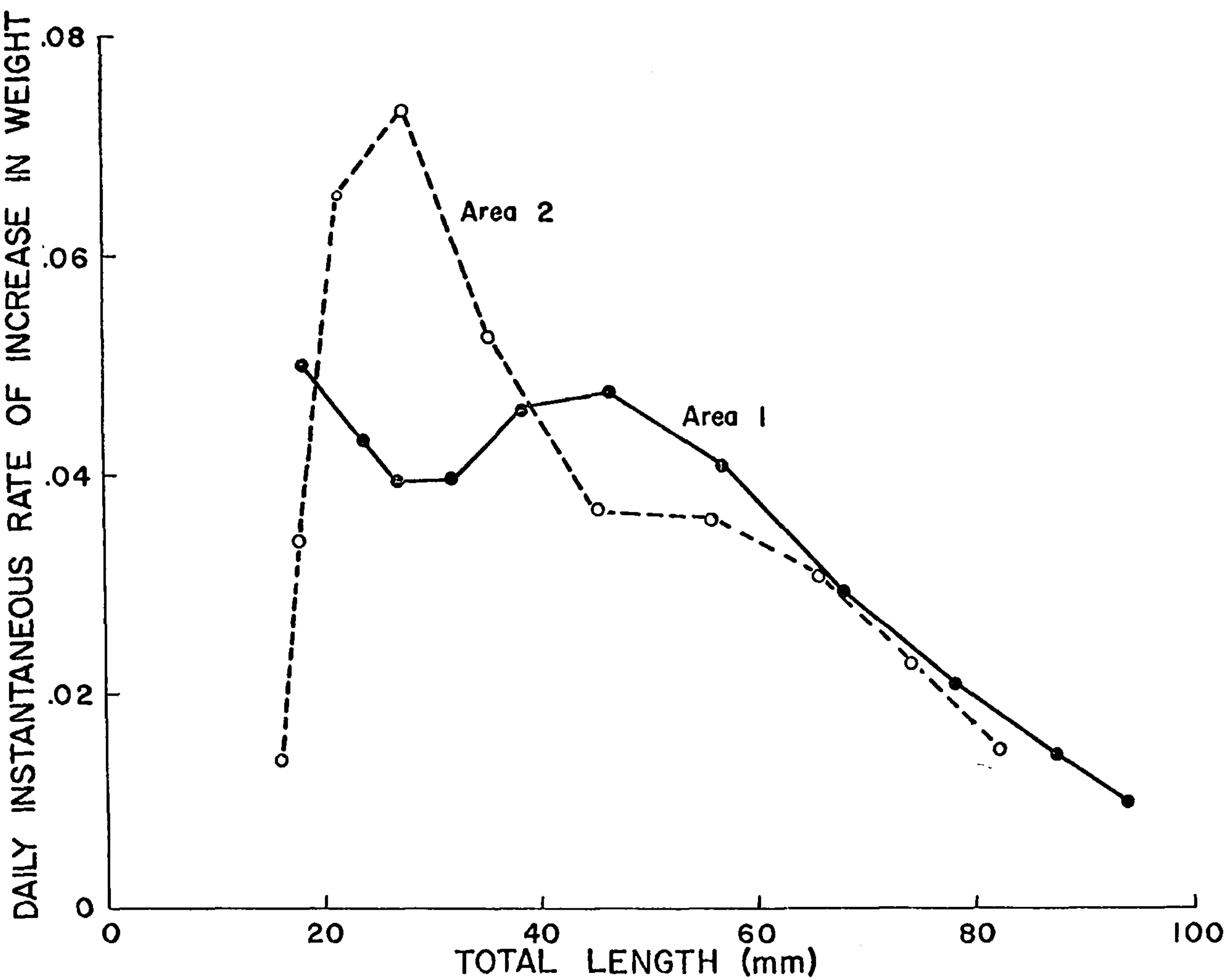

Figure 9. Total length and daily instantaneous rate of increase in weight for Age 0 mountain whitefish, First Dam (area 1) and Third Dam (area 2), Logan River, Utah, 1970.

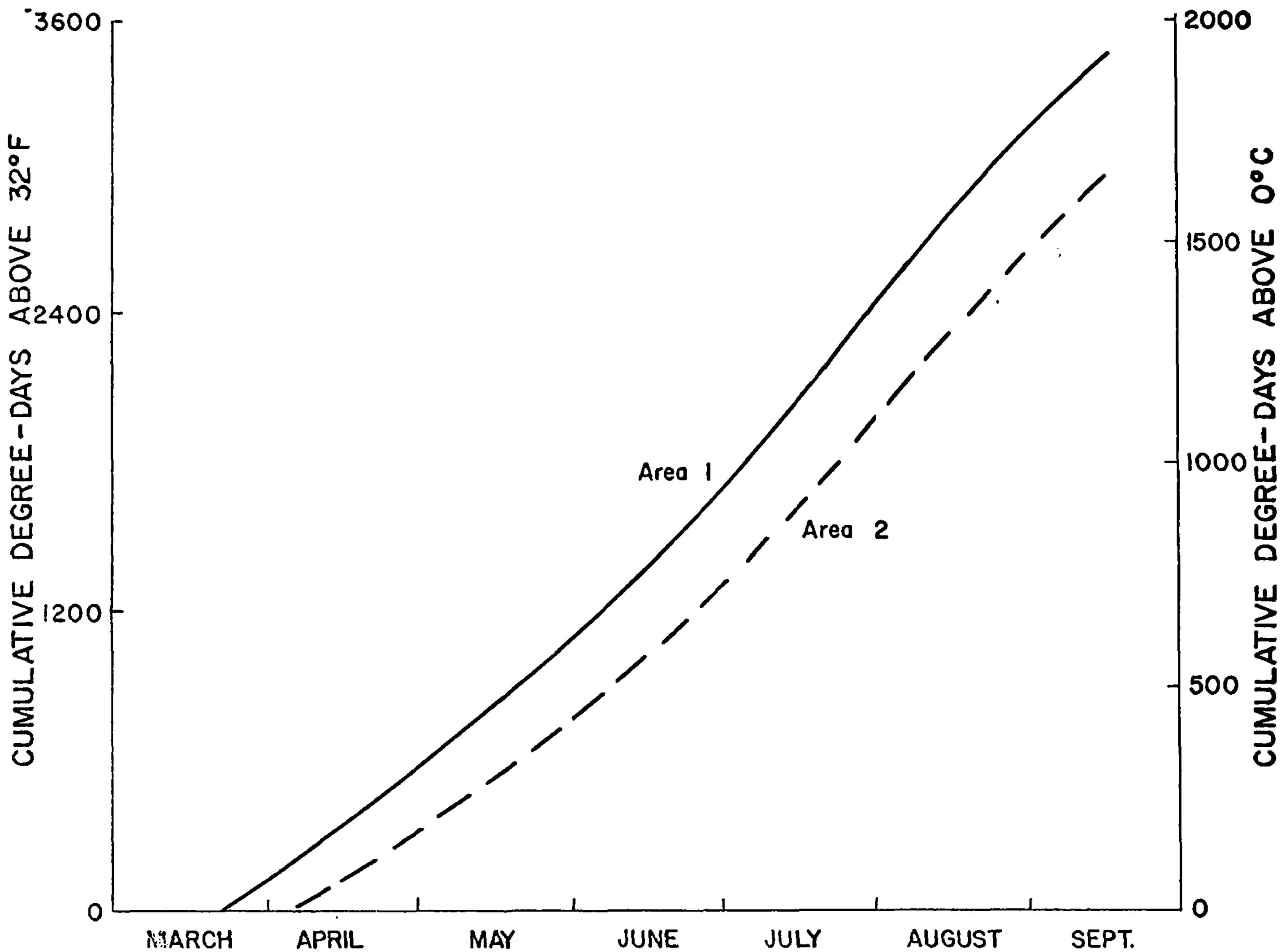

Figure 10. Total temperature experience of Age 0 mountain whitefish, expressed as cumulative degree-days above 32 F and 0 C, First Dam (area 1) and Third Dam (area 2), Logan River, Utah, 1970.

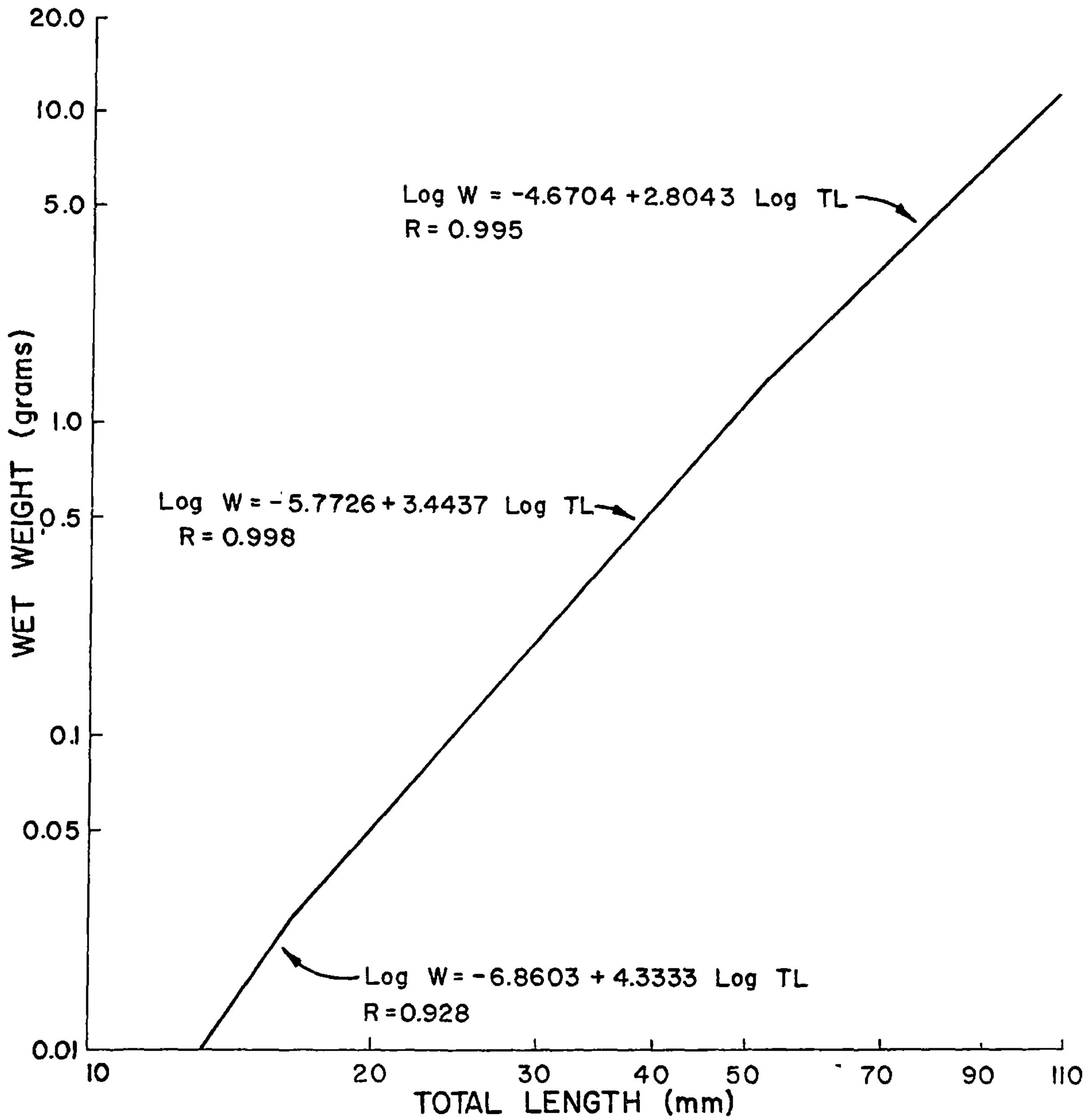

Figure 11. Length-weight relationships of 399 Age 0 mountain whitefish from 12.5 mm to 112 mm total length, Logan River, Utah, 1970-71. Three stanzas are shown with their respective regression equations.

Table 4. 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 @ = -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.

SECTION IX

FOOD HABITS OF LARVAE AND JUVENILES IN NATURAL ENVIRONMENTS

Methods

Stomach contents from 238 fish (12.5 to 112 mm total length) were analyzed for food habits. In larvae and post-larvae, the entire contents of the alimentary canal was examined. In the fingerlings, only the cardiac stomach anterior to the pyloric sphincter was examined. Organisms were sorted taxonomically, counted, and measured to the nearest 0.1 mm. Nineteen drift samples were taken concurrently using a drift sampler of an original design described and pictured by Brown (1972). The drift samples were preserved in 5% formalin and after sorting the organisms were preserved in 70% ethyl alcohol. The stomach contents were compared to the organisms found in the drift in order to get an idea of what the fish were taking compared to what was available.

Results and Discussion

Observations of larval and fingerling mountain whitefish indicated that they remain near the bottom while feeding, moving laterally or vertically only to capture prey. The young fish may occasionally seize food organisms directly from the substrate but usually capture organisms which are drifting in the current. Whitefish larvae began feeding at a total length of 14-15 mm, before complete absorption of the yolk.

Chi-square analysis indicated no difference in food habits of fish from the different collection areas ($P < .01$). Chironomid larvae were the major food item of the Age-0 mountain whitefish ranging from 65.5% to 90% of the total monthly diet in numbers. Chironomid pupae were second in importance (8%) then came Dytiscidae larvae (1.6%), Ephemeroptera nymphs (1.6%) and Simuliidae larvae (1.1%).

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 above 80% (Table 5). Mean food size increased with fish size until the fish reached 55 mm total length then dropped and stabilized near 3 mm for whitefish 60 - 112 mm total length.

Samples collected over 24 hr periods indicated that peak feeding activity occurred in late afternoon and early evening. Numbers of food items in stomachs decreased after 23:00 hrs and the young fish did not resume feeding until after 8:00 hrs. Drift samples taken concurrently indicated no change in available food (Table 6).

Table 5. 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	March'71	April'70	May'70	June'70	July'70	Aug.'70	Sept.'70	TOTALS
Nemata	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)
Misc.	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 6. 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	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)
Misc.	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

SECTION X

WHITEFISH CULTURE

Methods

Egg Incubation. Several adult whitefish were collected with electrofishing gear in November of 1970 and 1971 and sex products collected. The eggs were immediately fertilized using the "dry method" (Lietritz, 1972) and placed in 7 egg hatching jars and 19 screened egg trays in the Utah Water Research Lab and into 16 screened trays in the NR-Z Lab. The eggs were incubated at ambient Logan River temperature and at 45 F (7.2 C) in the UWRL and at 42 F (5.6 C) 45 F (7.2 C) and 48 F (8.9 C) in the NR-Z Lab.

Lighting at the UWRL lab came from windows which kept the eggs and larval whitefish in an ambient lighting pattern. The eggs and fry reared in the NR-Z Lab were lighted by overhead flourescent lights. The day length varied with research activities, but basically followed the standard 8 to 5 workday.

Saprolegnia grew rapidly on the dead eggs in both laboratories and was particularly bothersome on the trays. Eggs incubated in jars were in continuous motion and the fungus growths were restricted to the individual dead eggs. A 10-minute treatment with 20 ppm malachite green proved to be highly effective in controlling the fungus. Dead eggs were removed but not counted.

Survival. Whitefish larvae at birth have developed mouthparts and begin feeding immediately if food is available. In natural environments, however, food may not be present and the larvae must exist on its yolk-energy reserves. In 1970-1971, fry were held at ambient Logan River temperatures (36-45 F), 42, 45, and 48 F until they died of starvation. In 1971-1972, this procedure was repeated at 2,4,5,8,10,12, and 14 C. The later experiment was terminated after 80 days.

Growth. An automatic feeder was developed to provide a continuous supply of live brine shrimp to the whitefish fry and fingerlings. This device was designed to remove the brine shrimp hatched in brine with very little of the brine accompanying them into the fish rearing tanks.

Brine shrimp eggs were hatched in tapered "Halvin" plastic bags hung on a wall hook. Each bag was allowed to incubate at room temperature 48 hrs before being used, thus achieving about a 95% hatch of the eggs. Air was bubbled through the medium during this time. On the third day the intake tygon tubing was inserted down to the base of the tapered bag. This tubing lead through a Buchler Polystaltic Pump and then into the top of the fish tank. The air bubbler line to the brine shrimp was attached to a solenoid valve (ASCO 8320 A 3). Both the peristaltic pump and the solenoid valve were attached to a Tork-8001 timer with a delay-timer switch (Amf Model 533 032 0) between the Tork and the pump (Fig. 12).

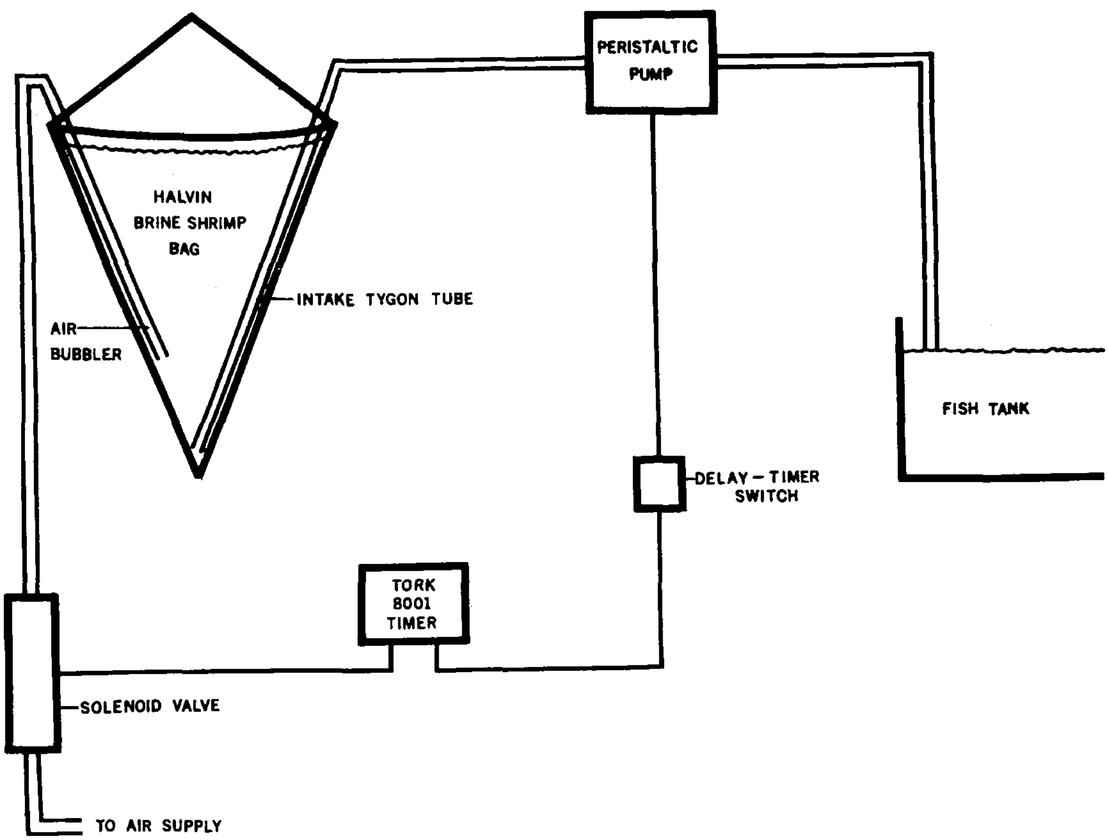

Figure 12. Schematic diagram of automatic brine shrimp feeder.

The timer could be set to feed the fish every forty-five minutes. At this time the solenoid valve was closed thus shutting off the air. The pump did not turn on until eight minutes later giving the brine shrimp a chance to settle and concentrate into the tapered end of the "Halvin" bag.

The pump then switched on for seven minutes and pumped concentrated shrimp from the bag to the fish tank. The pump was turned off and the valve opened for thirty minutes. These time intervals could be adjusted on the timer.

Time needed to maintain this device was about 30 minutes per day. The intake tubes had to be transferred to a new set of Halvin bags and fresh bags of brine shrimp eggs in brine were started. Thus with a minimum of daily work live brine shrimp were supplied to the fish throughout the day.

Brine shrimp are expensive and as the fish grow larger they require a larger size food item. It was desirable to switch the fish to trout pellets by introducing small amounts of dry trout feed into the young whitefish's diet. Gradually the amount of dry food was increased and the amount of brine shrimp was decreased until the fish were entirely on a dry trout food diet.

Diet. After hatching, fry were placed into experimental containers and fed four different diets: newly hatched brine shrimp; dry trout diet of appropriate particle size; mosquito larvae; Oregon Moist Pellet (OMP) trout feed; and a combination of dry food and brine shrimp. Fish were measured and weighed periodically. The experimental containers were suspended in the large min-o-cool units, and water was circulated through each. This facilitated handling the fish and cleaning the containers. As the larval whitefish grew they were placed in min-o-cool tanks or circular tanks. Two replicates of 50 fish each were fed three diets at 48 F for the first 4 months and at 52 F for the last 2 months.

Temperature. In 1970-1971, whitefish larvae were kept at 45 (7.2 C) and 48 F (8.9C) and fed comparable amounts of brine shrimp (4-6 times daily to satiation) for three months. Comparisons were made on the mean monthly increase in total length.

In 1971-1972, the above procedure was repeated for six months at three different temperatures (6, 9, and 12 C). Two replicates were maintained at each temperature, and a sample of five fish was measured monthly and preserved in 10% formalin. Results were analyzed using a mixed effects model of the factorial design (Snedecor & Cochran, 1971). A model was proposed for significant factors using stepwise multiple regression.

Results and Discussion

Egg Incubation. Incubation periods ranged from 45-75 days at 48 F (8.9 C) to 77-98 days at 42 F (5.6 C) in the NR-Z Lab (Table 7). At the lower temperatures in the UWR LAB (Logan River water, 35-43 F), the incubation period was 80-120 days (Fig. 13).

Table 7. Length of incubation period (start to end of hatching), length of hatching period (days), and peak period of hatching (days after fertilization).

Temperature (F)	Incubation Period (Days: Start to Finish)	Length of Hatching Period (Days)	Peak Period (Days after Fertilization)
42[1/] (5.6 C)	77-98	21	83-87
45 (7.2 C)	52-76	24	59-63
48[2/] (8.9 C)	45-75	30	49-55
Logan River (35-43)	80-120	40	---

1/ First 25 days at Logan River temperature (11/17-12/11): Mean = 39 F
2/ First 7 days at Logan River temperature (11/16-11/22): Mean = 39 F

Survival. At 48 F unfed whitefish larvae lived 40 days before death occurred. Fry at 45 F lived for 50 days, and those at 42 F, 63 days (Fig. 14). At ambient Logan River temperatures (36-45 F), fry lived 41 days (Table 8). The shorter life span at the lower Logan River temperatures may have been due to the fish being more active and using more energy in the flow-through containers. Larvae in the NR-Z Lab which were held on shallow screen trays were less active and rested on the screen nearly all of the time, which reduced demands on food energy reserve. Larvae removed and fed brine shrimp after 17, 24, 31 and 38 days of starvation readily took the food items and survived and grew at satisfactory rates.

The survival experiments with unfed fry were repeated in 1972 at 2, 4, 6, 8, 10, 12, and 14 C (Fig. 15). In both tests increase in temperature shortened survival. At 14 C all were dead within 12 days, whereas at 2, 4, or 6 C, 80% or more were alive after 80 days (Table 9).

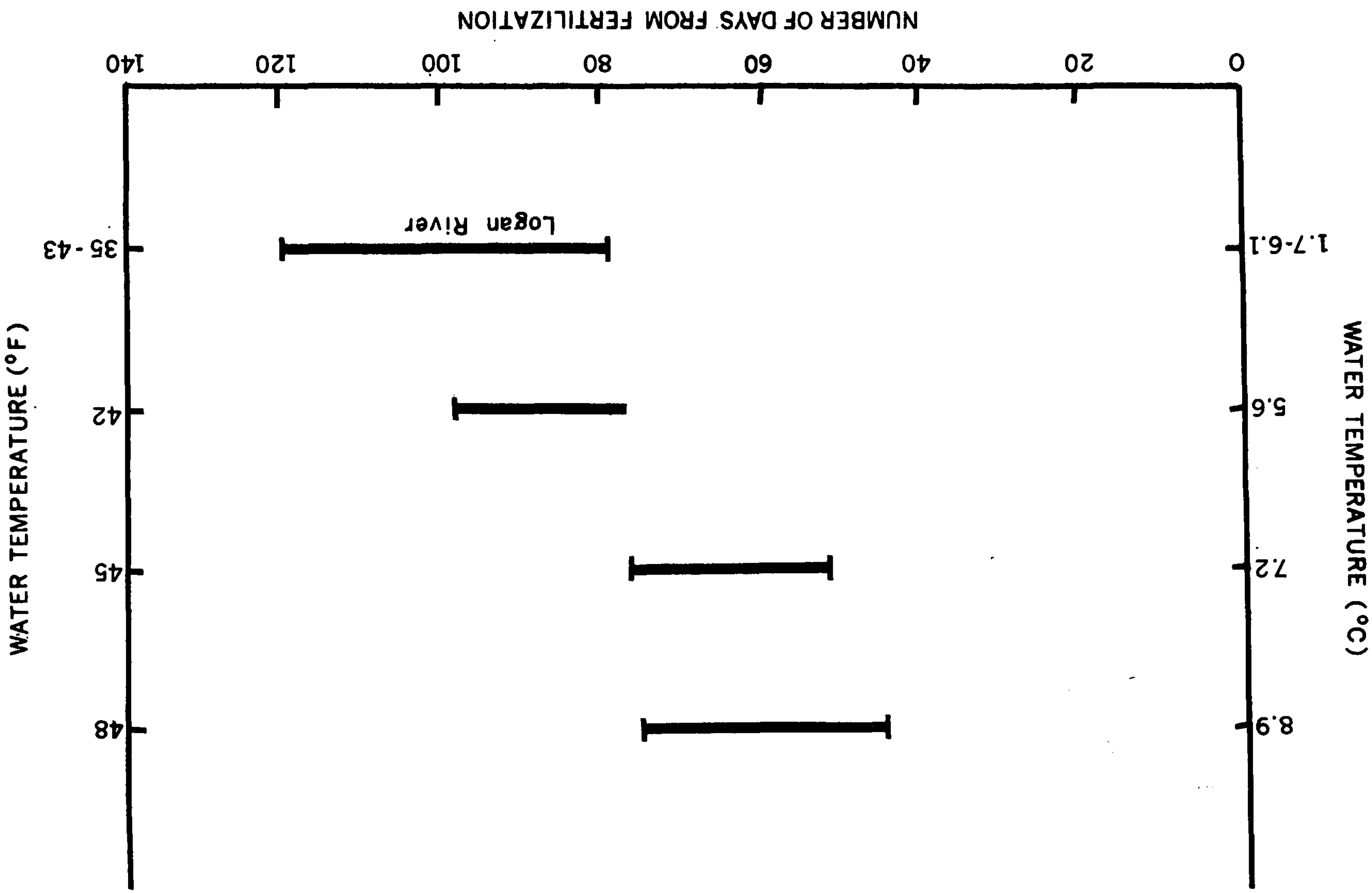

Figure 13. Mountain whitefish egg incubation periods at three controlled temperatures and ambient Logan River temperatures, 1969-1970.

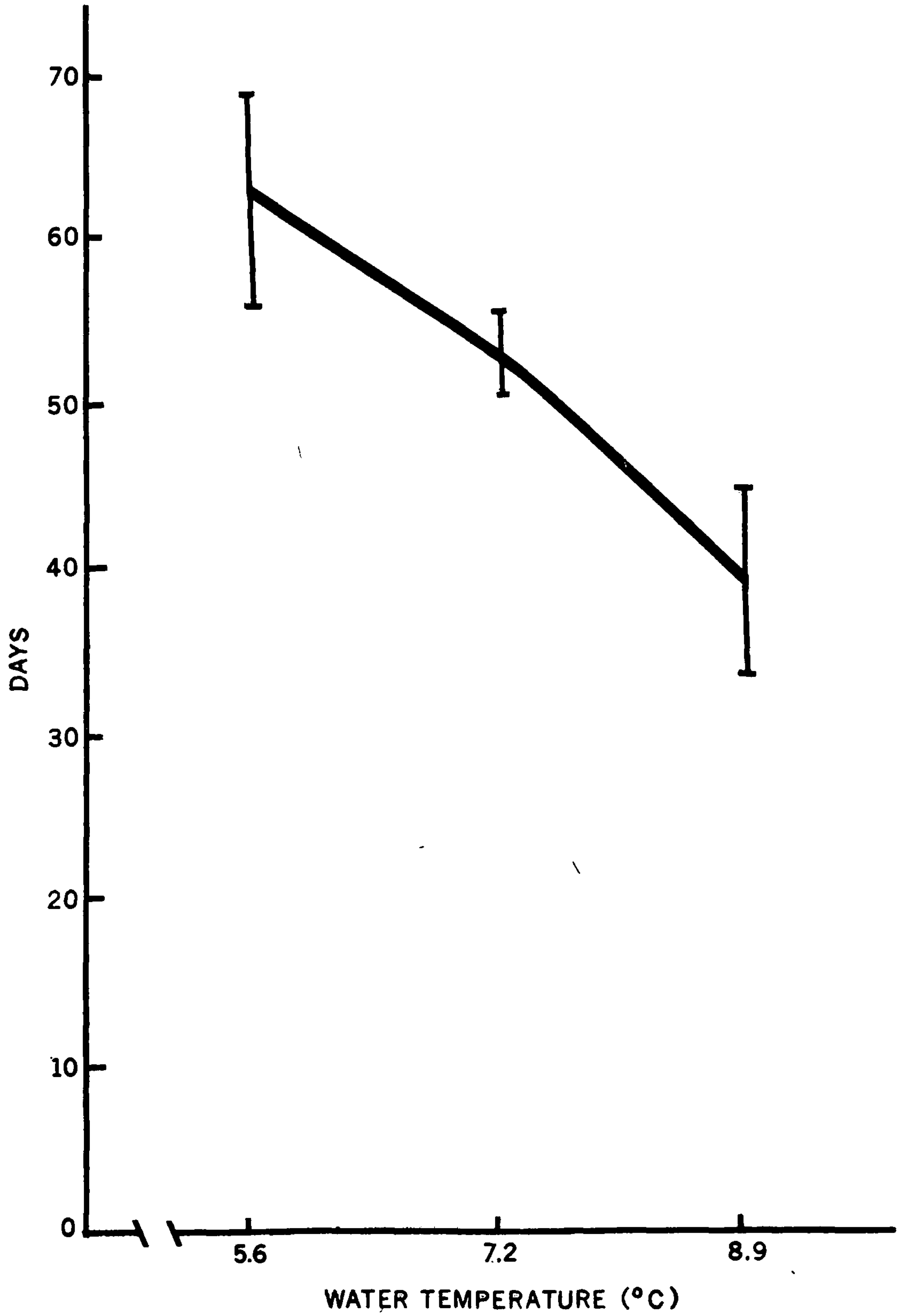

Figure 14. Survival of unfed whitefish larvae at three temperatures (°C), 1970-1971.

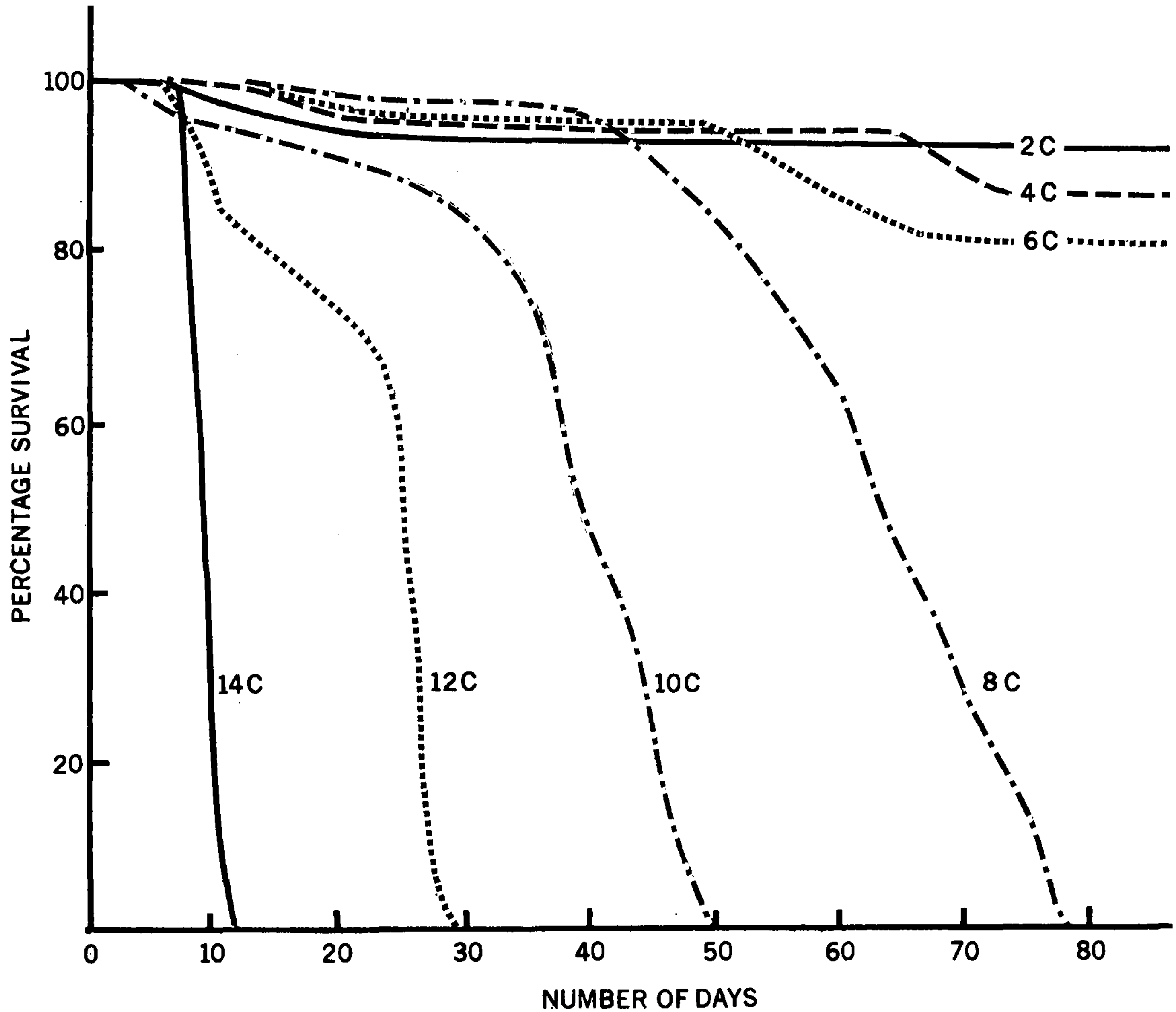

Figure 15. Survival of unfed mountain whitefish larvae at various temperatures, 1971-1972.

Table 8. Survival of unfed mountain whitefish larvae at 42, 45, and 48 F in the NR-Z Lab and at ambient Logan River temperatures in the Water Lab, 1970-1971.

Temperature (F)	No. Replicates[1/]	No. Days Alive Mean	No. Days Alive Range
42 (5.6 C)	3	63	56-68
45 (7.2 C)	4	53	51-56
48 (8.9 C)	3	40	34-45
Logan River (36-45)(2.2-7.2C)	3	41	40-43

1/ 20-170 fry per replicate

Table 9. Survival of unfed mountain whitefish larvae at 2, 4 6, 8, 10, 12, and 14 C, 1971-1972.

Temperature (C)	No. Replicates	No. Days Alive Mean	No. Days Alive Range	% Survival After 80 Days
2	3	80[1]	80	91.7
4	3	80[1]	80	82.0
6	3	80[1]	80	78.0
8	3	75.5	74-77	0.0
10	3	49	48-50	0.0
12	3	28	27-29	0.0
14	3	10.5	10-11	0.0

[1]Experiment Terminated after 80 days.

Mortality. The equation $\text{Log}_e \text{No} - \text{Log}_e N_t = Z_t$ was used to compute daily instantaneous mortality. Highest mortality was observed on the mosquito larvae and OMP. For dry trout diet the total mortality rate was 93% for the first 6 months of life and for OMP it was 98% for 1.5 months. Lowest mortality was in the brine-shrimp-only lots where 3 month mortality rate was 15%. In the combination diet lots, total mortality rate was 44% for the first 6 months of life (Table 10).

Table 10. Mortality of whitefish larvae cultured in the laboratory, 1971.

Diet	Months	Mortality Rates Total (a)	Daily Inst. (Z)
Brine Shrimp	3	15%	0.17%
Mosquito Larvae	3	93%	2.5%
OMP	1.5	98%	8.9%
Dry Trout Diet	5	93%	1.41%
Dry Trout Diet and Brine Shrimp	6	44%	0.83%

Growth-Diet. Larvae on dry trout diet did not grow during the first month, began to grow slowly during the 2nd month (1mm) and the few survivors which were remaining after this time grew at 4 mm/month. All fish on the dry diet were dead by the end of the fifth month. Growth on mosquito larvae was irratic during a 3 month test, being better than that of fry on OMP diet but not as good as those fed brine-shrimp (Fig. 16). In other experiments the OMP and mosquito larvae diet produced similar growth. Both groups were switched to brine shrimp at the end of 3 months. The fry from the mosquito diet did very well and at the end of six months had caught up with the group on brine shrimp diet. The ones fed OMP when switched to brine shrimp grew better but died after 4 months (Fig. 17).

Highest growth rates were observed on the brine shrimp diet and the combination brine shrimp/trout food diet where larvae grew at the rate of 18 mm/month for the first 3 months. During the later 3 months, larvae on brine-shrimp-only grew at approximately 1 mm/month and those on the combination diet did not grow at all.

Growth-Temperature. During the 1970-1971 experiment, larval whitefish raised at 48 F (8.9 C) exhibited a mean monthly growth increment of 12 mm/month for three months. Fish at 45 F (7.2 C), grew at 4.3 mm/month.

Differences in growth as measured by changes in total length also appeared in the 1971-1972 experiment (Table 11). Mean monthly growth increments were 4.95, 5.88 and 7.08 mm/month at 6, 9. and 12 C respectively (Fig. 18). Although the main effect of temperature was not significant ($\alpha = 0.05$), the main effect of time and the interaction of time and temperature were significant at the 0.05 and 0.01 levels (Table 12). The effects of replicates within temperature and the interaction of replicates within temperature and time were also significant ($\alpha = 0.05$).

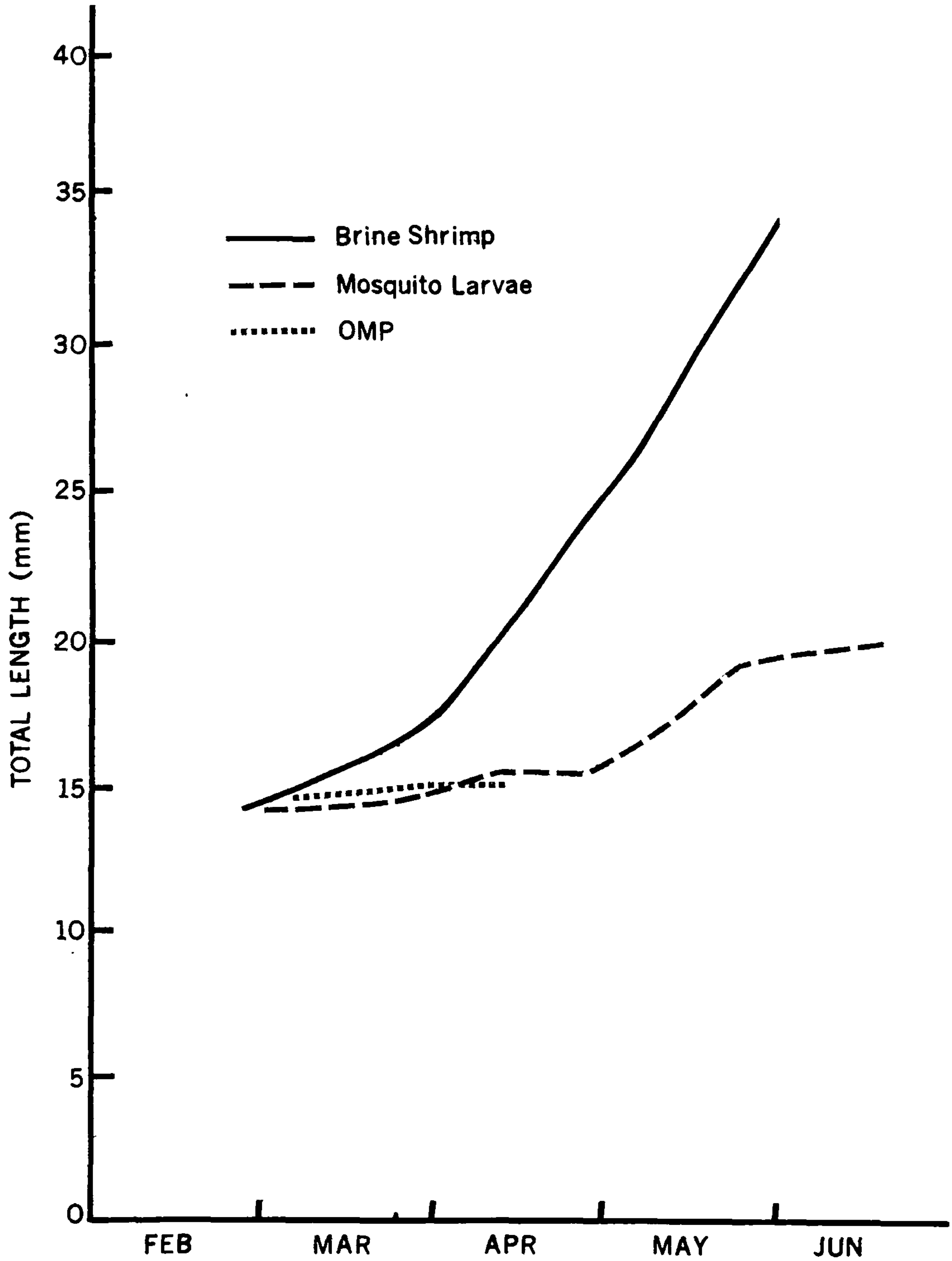

Figure 16. Growth of mountain whitefish larvae fed different diets, 1971.

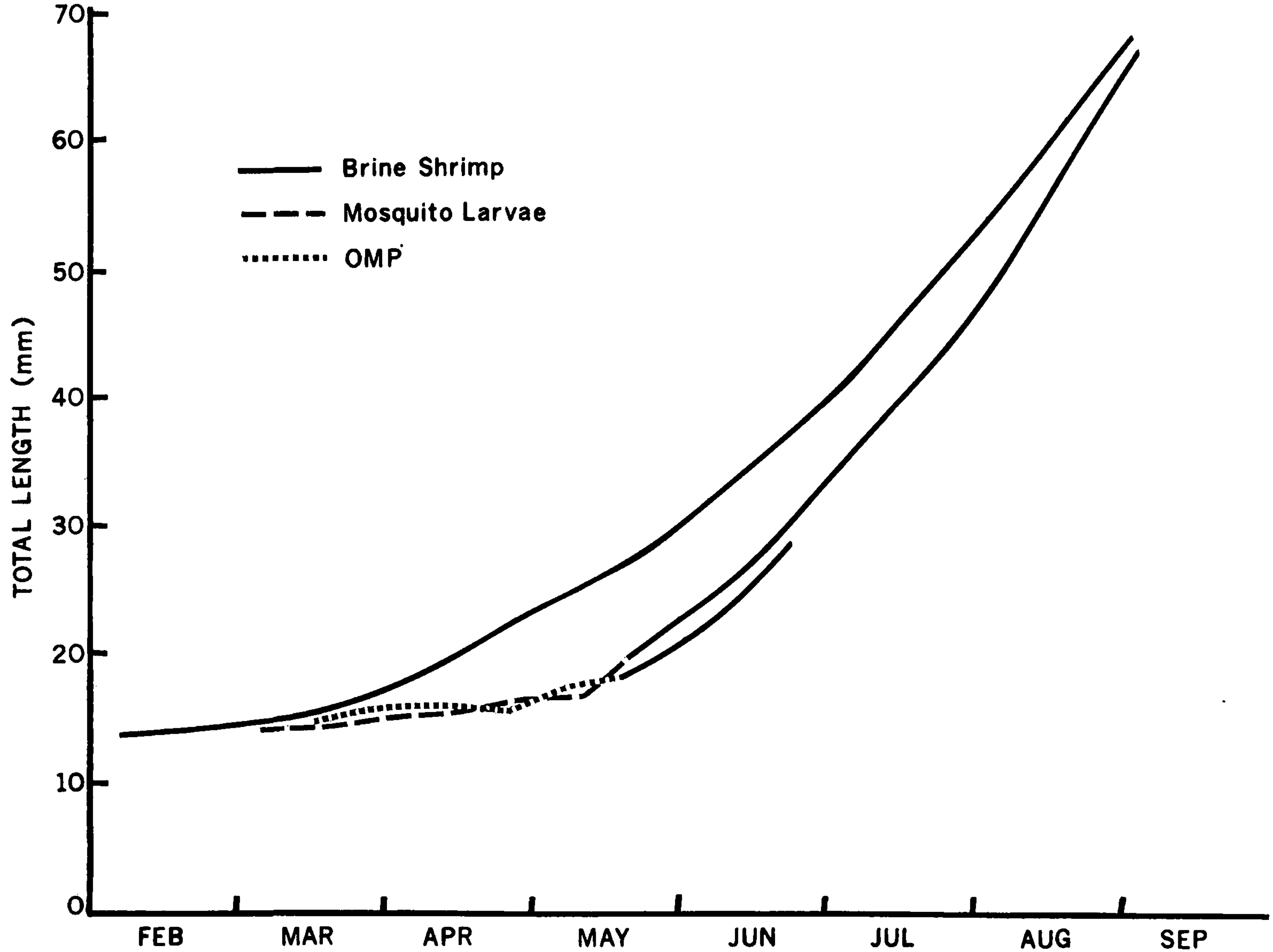

Figure 17. Growth of mountain whitefish larvae fed different diets during six months after hatching, 1971.

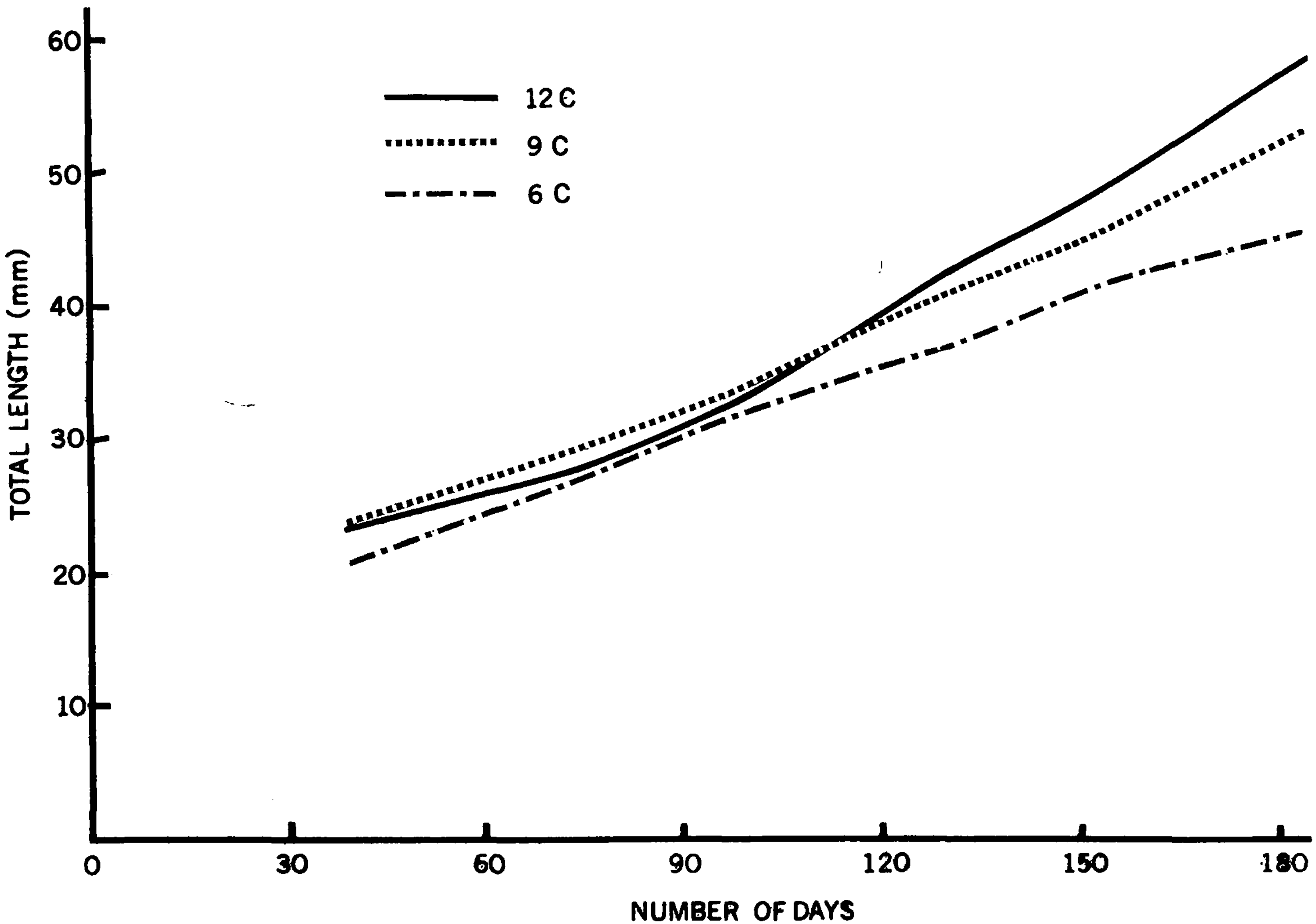

Figure 18. Growth of mountain whitefish larvae at three temperatures (°C), 1972.

The following model was developed with an R^2 value of .90 (Table 13).

$$Y = 21.55 + .104\ X_1 + .012\ X_1X_2$$

where: Y = length in mm

time in days = X_1

temperature = X_2

Table 11. Monthly mean (range) length in mm of larval whitefish at three different temperatures, 1971-1972.

	Temperature (C)		
Month	6	9	12
May	20.8 (19.5-21.5)	23.9 (22.5-25.0)	23.4 (22.5-25.0)
Jun	27.1 (24.5-29.5)	29.3 (28.5-33.0)	28.0 (24.5-31.0)
Jul	32.5 (28.5-35.0)	34.2 (30.5-37.5)	33.1 (30.5-39.0)
Aug	37.3 (34.5-40.5)	41.4 (33.5-46.0)	43.0 (34.0-53.0)
Sep	41.6 (38.0-44.5)	45.5 (41.5-51.0)	48.5 (42.0-49.5)
Oct	45.6 (41.5-51.5)	53.3 (46.5-62.5)	58.8 (48.5-65.5)

Table 12. Abbreviated factorial analysis of factors affecting larval whitefish growth at three different temperatures, 1971-1972.

Source of variation	Degrees of freedom	Mean square
Total	179	123.095
Temperature	2	426.101
Tank/Temperature	3	147.873*
Time in days	5	3793.078**
Temperature X Time in days	10	62.164*
Tank/Temperature X Time in days	14	18.461**
Fish/Temperature X Tank X Time	135	6.612

*Significant at the 0.05 level
**Significant at the 0.01 level

Table 13. Abbreviated regression analysis of factors affecting larval whitefish growth at three different temperatures, 1971-1972.

Source of variation	Degrees of freedom	Mean square
Total	170	111.051
Time in days	1	879.456*
Time in days X Temperature	1	1025.208*
Model	2	8460.671
Error	168	11.650

*Significant at the 0.05 level

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The initiation of the project and collection of data on egg incubation and culture methods was very ably carried out by Dr. Robert H. Kramer former Unit Leader, Utah Cooperative Fishery Unit until his death in December 1972.

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SELECTED WATER RESOURCES ABSTRACTS

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16. Abstract Early life history studies and development of culture methods of the mountain whitefish (Prosopium williamsoni) were conducted in the Logan River, and in the Utah State Research Laboratory and USU Fisheries Laboratory.

Spawning was observed in the laboratory and in the Logan River from mid-November to mid-December during dusk. At ambient river temperature from 1.7-6.1 C eggs began hatching after 79 days and continued for 23 days. Total mortality to hatch of eggs from weekly collections from five areas was 92%. In the laboratory, at 7.2 C eggs began hatching in 52 days and continued for 23 days; at 8.9 C in 45 days and continued for 30 days.

Larval whitefish from two areas showed differences in growth due to temperature experience. Growth was examined in the laboratory at 6, 9, and 12 C. A simple linear model for predicting growth was developed.

Whitefish began feeding when 14-15 cm long, and fed near the bottom mainly on Chironomid larvae.

Larval whitefish were raised at 2-14 C at 2 degree intervals, and were fed dry trout feed, Oregon Moist Pellets, mosquito larvae, and brine shrimp. Starved fish died earlier at higher temperatures; mortality ranged from 15% for 3 months on brine shrimp to 98% in 1.5 months on Oregon Moist Pellets.

17a. Descriptors
*Life history studies, *Spawning, *Water temperature, *Fish behavior *Fish food organisms, Fry, Aquatic habitats, Fish eggs, Thermal pollution, Mortality, Hatching

17b. Identifiers
*Mountain whitefish, *Culture methods, Fish growth, Logan River

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