JENNINGS, TIMOTHY ROBERT

SURVIVAL, GROWTH AND FOOD HABITS OF YOUNG-OF-THE-YEAR ARCTIC GRAYLING STOCKED IN BARREN, SUB-ARCTIC LAKES

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SURVIVAL, GROWTH AND FOOD HABITS OF YOUNG-OF-THE-YEAR ARCTIC GRAYLING STOCKED IN BARREN, SUB-ARCTIC LAKES

A

THESIS

Presented to the Faculty of the University of Alaska

in Partial Fulfillment of the Requirements

for the Degree of

Master of Science

By

Timothy R. Jennings, B.S.

Fairbanks, Alaska

May 1983

SURVIVAL, GROWTH AND FOOD HABITS

OF YOUNG-OF-THE-YEAR ARCTIC GRAYLING

STOCKED IN BARREN, SUB-ARCTIC LAKES

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ABSTRACT

Since 1975 the Alaska Department of Fish and Game has used small, barren lakes near Delta Junction for the rearing of Arctic grayling. Sac-fry are stocked in June, reared for one summer, then recaptured and transplanted in September into the Delta Clearwater River. Survival was examined at various stocking densities (number/hectare) of sac-fry. No correlation existed between stocking density and survival over the range of densities tested (833 to 9,635 sac-fry/hectare). Qualitative evidence suggested that the high rate of mortality within a month after stocking was associated with specific food requirements at time of first feeding, sac-fry mobility and fitness, and predation by invertebrates. Growth rates were almost 2.0 mm/day in June, decreased to 0.5 mm/day by September and averaged over 1.0 mm/day for the entire summer. Larvae ate mainly chironomid pupae; diversity of food items increased with fish size and age.

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ACKNOWLEDGEMENTS

This study resulted from a work-study agreement between the Alaska Cooperative Fishery Research Unit (ACFRU) and the Alaska Department of Fish and Game (ADF&G) Sport Fish Division. I thank my major advisors, Stephen Tack and Dr. Jacqueline LaPerriere, and committee members, Dr. James Reynolds, Robert Armstrong and Richard Peckham for their guidance, encouragement and cooperation. Robert Armstrong also provided invaluable assistance in obtaining obscure literature.

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Nick Hughes, Patricia Anderson, Stephen Tack and Jacqueline LaPerriere of ACFRU assisted with fieldwork. I thank Robert Walker of ACFRU for help with computer analysis and advice. Tass Kelso of the University of Alaska Museum Herbarium identified the aquatic plants. Joyce Beelman of the Alaska Department of Environmental Conservation identified the copepod (<u>Heterocope septentrionalis</u>). And, I thank the U. S. Army, Ft. Greely Range Control for access to the study area.

INTRODUCTION

For many years, Arctic grayling (*Thymallus arcticus*) have been stocked in waters of Alaska to improve sport fishing. The first attempts to enhance grayling sport fishing by stocking occurred in 1952 (Allin 1957). Crescent Lake, Seventeen Mile Lake and Burk Lake, all barren lakes on the Kenai Peninsula, were stocked with juvenile grayling. In each case, grayling were transplanted from native populations. The Crescent Lake grayling transplant of 240 sub-adults was successful in producing a self-perpetuating population that was estimated in 1972 to contain 1,547 adult fish at the conclusion of spawning (Engel 1973). Since 1962, Crescent Lake grayling have served as a donor population for transplants to other Kenai Peninsula lakes (Engel 1970, 1971). Most of these transplants established self-perpetuating populations.

Experimental stocking of hatchery-reared Arctic grayling sac-fry began in 1961 with introductions into three barren lakes near Glennallen (Van Wyhe 1963). Growth rates of young-of-the-year fish stocked in these lakes were extremely high compared to those naturally occurring in streams: in one lake, some grayling attained lengths of over 200 mm in one growing season, about three times that attained by stream-dwelling fish. Results from these first hatchery plants revealed that grayling left to overwinter in the lakes could tolerate winter dissolved oxygen concentrations of less than 1.0 ppm.

Because of the ability of Arctic grayling to survive low dissolved oxygen concentrations, stocking was expanded to include lakes that were marginal or unsuitable for other species (Heckart and Roguski 1966; Williams 1970; Roguski and Tack 1970). In many lakes, sport fisheries developed and provided anglers with additional fishing opportunities.

Survival rates have usually been higher in lakes where predator fishes were absent (Williams 1971). To avoid losses due to predation, grayling have usually been stocked in barren lakes. There are, however, two examples where Arctic grayling survived and successfully competed in the presence of other fishes. Roguski and Tack (1970) found that grayling survived in the presence of lake chub, Couesius plumbeus, and yearling grayling. Van Hulle and Murray (1975) found grayling could survive in the presence of fingerling rainbow trout, Salmo gairdneri, when the trout were stocked one month after the grayling. The month between stockings apparently allowed the grayling time to attain a competitive size.

Stocking Arctic grayling in rivers has had mixed results, depending on the size of fish at time of stocking. The first attempt to stock an Alaskan river with grayling occurred by introducing sac-fry into the Delta Clearwater River (Peckham 1975; Pearse 1976). Pearse concluded that stocking sac-fry into the river was associated with poor survival and should be discontinued.

Survival of stocked Arctic grayling in the Delta Clearwater River has been most successful when sac-fry were first reared in shallow ponds for approximately 3 months. Pond-rearing of grayling was initiated in 1975 and continued through 1978 (Pearse 1976; Peckham 1977, 1978; Peckham and Ridder 1979). During each of these years, summer survival in the ponds ranged from 5 to 34%; over 34,000 grayling juveniles were stocked in the Delta Clearwater River; and most fish were over 100 mm in length at the time of transplanting (Peckham and Ridder 1979). Ridder (1980) found that pond-reared, stocked grayling accounted for 23% of the total harvest of grayling in the Delta Clearwater River in 1979 and 60% of the age-4 grayling in the creel.

The high contribution of pond-reared grayling to the sport fishery of the Delta Clearwater River indicates that short-term rearing prior to stocking was the best method. However, no work had been done to determine the best methods of achieving optimum survival and growth in the rearing ponds. Therefore, in 1980 I began this study to investigate the survival, growth and food habits of young-of-the-year Arctic grayling, stocked as sac-fry, in small, natural ponds. The goal of this study was to determine a stocking density range for grayling sac-fry that optimizes survival and growth of young-of-the-year grayling in rearing ponds. Stocking density is the number of fish stocked per unit of pond surface area, expressed as number/hectare (ha). To achieve the goal, my objectives were to: (1) estimate survival and growth rates; (2) determine the relationship, if any, between survival and stocking density; (3) determine food habits;

and (4) evaluate certain species of invertebrates, occurring naturally in the ponds, as potential predators on young-of-the-year grayling.

Definition of Life Stage Terms

Terms used to distinguish early life stages in fish were taken from Balon (1980) and Morrow (1980). Sac-fry are "young fish just after hatching, with the yolk sac still present." A larva is "an organism from the beginning of exogenous feeding to metamorphosis into juvenile." Juvenile is "a small adult from appearance of all definitive adult structures to the first maturation of gametes." And, young-of-the-year are "young fish in their first year of life; 0+ age group."

In Arctic grayling the sac-fry stage is 4 to 8 days long (length, 10-20 mm) after which grayling begin to feed (Brown and Buck 1939). In interior Alaska, the larval grayling becomes a juvenile at lengths of 40-50 mm (pers. comm. Robert Walker, ACFRU, Fairbanks, Alaska). Complete formation of body scales occurs at 40-50 mm and is the last adult structure to appear.

STUDY AREA

West Pond and Texas 2 Lake are near Delta Junction approximately 160 km (100 mi) southeast of Fairbanks, at longitude 145°53' W and latitude 63°50' N (Figure 1). The two lakes lie between the Delta River and the Richardson Highway 24 km (15 mi) south of Delta Junction on the Ft. Greely military reservation (Figure 2).

Donnelly glaciation correlative to Wisconsinan glaciation, 15,000 to 20,000 years ago, formed West Pond, Texas 2 Lake and other small thaw lakes in the area (Péwé 1975). The surrounding landscape is dominated by Windy Ridge, Donnelly Dome, the Delta River and numerous kettle lakes. Soils in the area are generally well drained; silt, sand and gravel dominate. Areas of permafrost can be found in isolated pockets along the Delta River.

Local vegetation includes black spruce, alder, willow, grasses, sedges, lichens and mosses. Aquatic vegetation found in West Pond include sedges, spike rushes, dwarf buttercup and pond weeds. Sedge species identified were *Carex aquatilis* Wahleb, *Carex rhynchophysa* C.A.Mey. and *Carex oederi* Retz. ssp. *viridula* (Michx.) Hult. Spike rushes found were *Eleocharis palustris* (L.) Roem. and Schult. and *Eleocharis* cf. *acicularis* (L.) Roem. and Schult. The dwarf buttercup identified was *Ranunculus* cf. *pygmaeus* Wahleb. Pond weeds found included *Potamogeton* sp. and *Potamogeton alpinus* Balb.

Selection of rearing ponds was based upon the following criteria: (1) no resident fish; (2) shallow water depth; and (3) gradual sloping

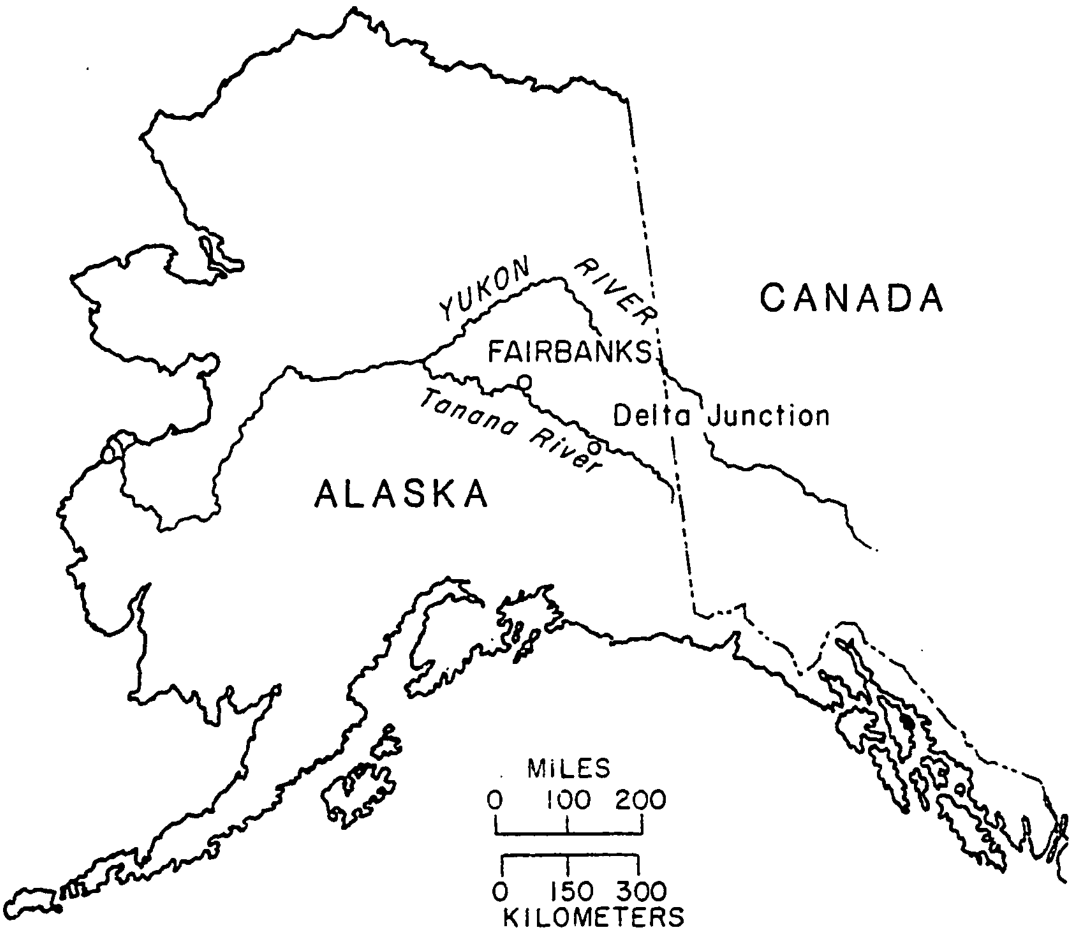

Figure 1. Location of Fairbanks and Delta Junction in Alaska. Study lakes are near Delta Junction.

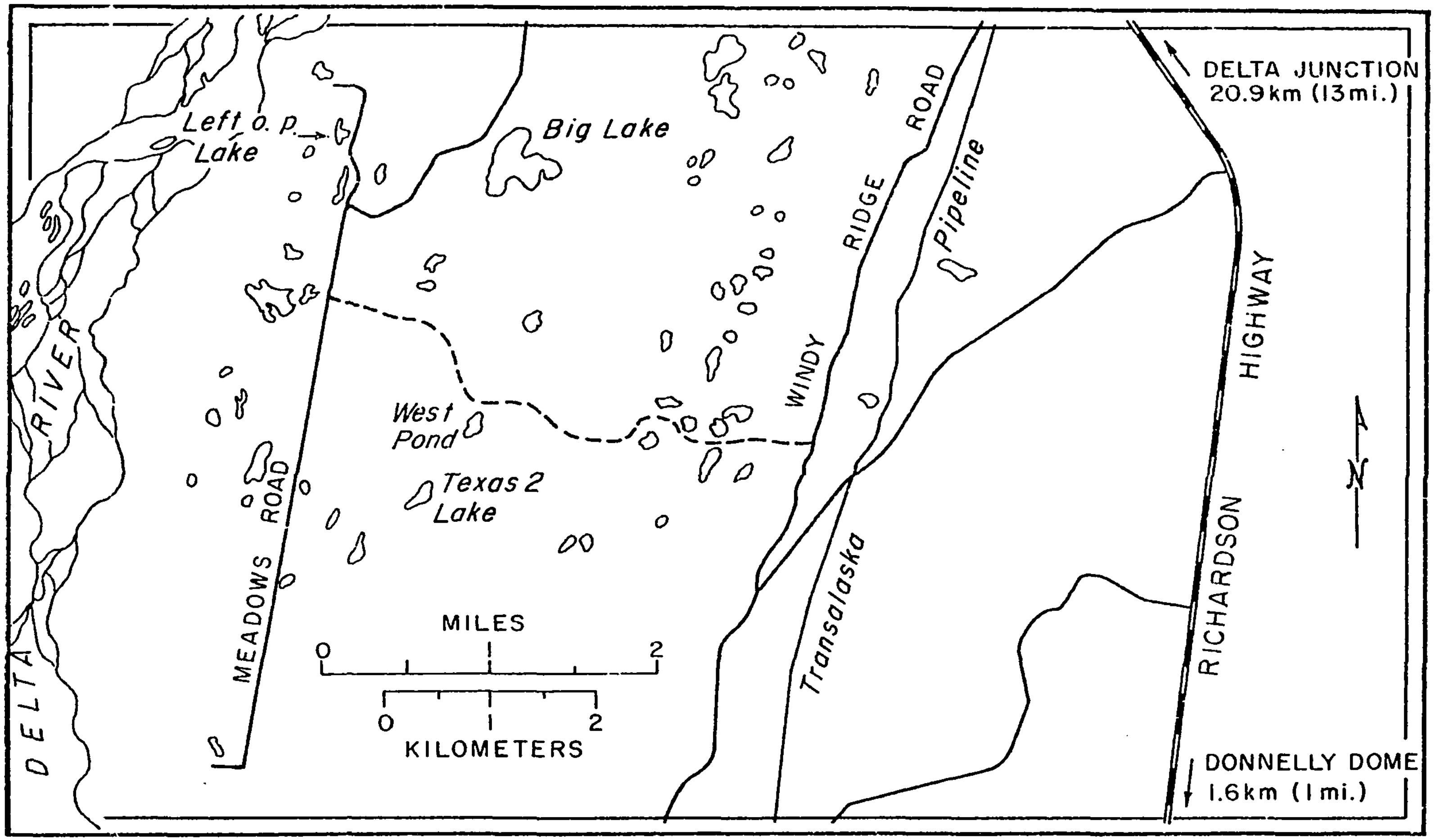

Figure 2. West Pond and Texas 2 Lake are 24 km (15 mi) south of Delta Junction on Ft. Greely Military Reservation and lie between the Delta River and the Richardson Highway near Donnelly Dome. The dashed line represents a road connecting Meadows Road and Windy Ridge Road.

shorelines. The absence of resident fish eliminated competition for food resources and predation between resident fish and newly stocked grayling sac-fry. Shallow water depths, less than 3 m, caused extremely low dissolved oxygen concentrations or anoxia during winter and insured that any stocked grayling eluding capture in the fall would not survive to the following spring. Gradual sloping shorelines were necessary for the effective use of fyke nets and seines.

West Pond and Texas 2 Lake were chosen for stocking because they met the criteria listed above and were similar in many physical and chemical characteristics (Table 1). West Pond has 3.6 ha of surface area; Texas 2 Lake has 4.9 ha. Both lakes are approximately 1.5 m deep. Water temperatures range from near 0 C in winter to 20 C during July. The aforementioned similarities permitted valid comparisons between lakes of the effect of stocking density on survival. West Pond had been used as a rearing pond during 1975-1978; Texas 2 Lake had not been used for rearing before.

Table 1. Physical and chemical characteristics of West Pond and Texas 2. Values are minimum and maximum measurements from June to September during 1980 and 1981.

lake	conductivity micro-mhos/cm	dissolved oxygen mg/l	total alkalinity mg/l as $CaCO_3$	total hardness mg/l as $CaCO_3$	pH
West Pond	95-100	8-10	43-47	51-55	8.0-8.5
Texas 2	90-95	8-10	38-40	47-50	8.0-8.5

METHODS

Stocking

Eggs were taken from Tolsona Lake grayling (Glennallen) in 1980 and Jay Lake grayling (Delta Junction) in 1981. They were incubated at the Ft. Richardson hatchery (Anchorage) in 1980 and Clear hatchery (Clear Air Force Station) in 1981.

Grayling sac-fry were transported from the hatchery one to two days after hatching. Sac-fry were shipped in water-filled plastic bags that were placed in styrofoam or plastic coolers. The coolers were packed with ice at the hatchery to reduce thermal stress. Upon arrival, the plastic bags were submerged in lake water (12 C) until the bag water temperature (5 C) was within 1 C of the lake water. Sac-fry were released into water about 1 m deep and 15 m from shore. At the time of release, the numbers of dead sac-fry were estimated and live sac-fry were observed for signs of stress.

It was hypothesized that stocking density was negatively correlated to survival of stocked grayling sac-fry. In 1980, to test this hypothesis, I stocked West Pond at a low density (4,454 sac-fry or 1,235 sac-fry/ha) and Texas 2 Lake at a relative high density (46,818 sac-fry or 9,635 sac-fry/ha). These two stocking densities represented a low and a medium stocking density in comparison to the stocking densities ranging from 6,945 sac-fry/ha to 16,667 sac-fry/ha used in West Pond and Left O.P. Lake during 1975-1978 by Fish and Game (Peckham and Ridder 1979). In 1981 West Pond was stocked with 3,000 sac-fry (833 sac-fry/ha); Texas 2 Lake was not stocked due to a statewide shortage of grayling eggs.

In 1981 7,000 additional sac-fry were stocked in seven holding pens erected in West Pond. The holding pens were designed to increase sac-fry survival and allow close observation of sac-fry behavior.

The holding pens were constructed with fiberglass window screening (1 mm mesh) and framed with 12.7 mm (0.5 in) PVC pipe. The window screening was sewn into 1 X 1 X 1 m cubes with snaps around the top to allow access into the pens. The PVC pipe was glued together to form a framework for suspending the pens in the water. A wind fence, constructed with spruce stakes and planking, was placed on the prevailing windward side of the pens to provide wind and wave deflection.

Each of the seven holding pens was stocked with 1,000 sac-fry. Fish in three of the holding pens were fed with plankton, mainly Copepoda, collected from West Pond. A Wisconsin net was towed across West Pond to collect the plankton. Approximately 0.05 liters of plankton was introduced three times per day. Fish in the remaining four pens were unfed; food was limited to those items that entered through the mesh of the pens.

Survival

Population estimates with 95% confidence intervals were done twice per season in each lake. The estimates were based upon the Petersen mark and recapture method and the Leslie method (Ricker

1975). Gear used to capture grayling were a bag seine (1.2 by 15 m long, 6.3 mm mesh) and a fyke trap (with a 1.2 by 15 m lead, 9.5 mm mesh). Once captured, fish were marked with upper caudal or adipose fin clips.

Survival estimates were made using the proportion:

S=N(2)/N(1)

where:

S=survival

N(2)=number of fish estimated at time t

N(1)=number of fish stocked

The instantaneous rate of mortality (Z) was estimated by least squares regression of the logarithim base 10 of the number of fish as a function of date (hereafter, all references to log conversions imply base 10; those to ln conversions imply base e). The slope of the regression line (with a sign change) divided by 0.4343 estimated Z (Ricker 1975).

Fyke trap efficiency was estimated by dividing the number of fish captured by the number of fish calculated in the population estimate.

Growth

Ten fish from each lake were sampled biweekly to determine growth rates. Fish were measured in the field to the nearest 1 mm (fork length) and weighed to the nearest 0.1 g.

Growth data were analyzed by the following methods. A weighted linear regression of length as a function of date was computed using

BMDP1R statistical software package (Dixon and Brown 1979). A weighting factor proportional to the inverse of the variance was used because variances between sampling dates were unequal.

Least squares linear regression of log weight as a function of log length was computed. Slopes were compared to the ideal isometric growth coefficient using a paired t-test. Analysis of covariance (ANCOVA) was used to test the equality of slopes.

Production

Production estimates were calculated for each lake using the formula:

$$P=GB$$

where:

P=production

G=instantaneous growth in weight

B=mean biomass

In estimating production, growth was assumed to be exponential. Instantaneous growth in weight was calculated as suggested by Chapman (1978):

$$G=\ln w(2)-\ln w(1)$$

where:

w(1)=mean weight of fish at time t(1)

w(2)=mean weight of fish at time t(2)

The change in biomass was approximated by the formula (Chapman 1978):

$$B=(B(1)+B(2))/2$$

where:

$B(1)$=biomass at time $t(1)$

$B(2)$=biomass at time $t(2)$

Food Habits

Food habits of young-of-the-year grayling were examined biweekly from June 15 to September 30 and expressed as percent composition of food items present in the stomach.

Ten fish from each lake were collected biweekly and preserved in 95% ethanol. Smaller fish (less than 75 mm) were preserved intact, while the larger fish (75 mm to 150 mm) were preserved with abdomens slit.

The points method as described by Hynes (1950) was used to analyze the stomach contents. Stomachs were allotted points on the basis of their fullness and size. Point values for fullness were 0, 1, 2, 4, 8, 16, 20; 0 was given to an empty stomach and 20 to a full stomach. Point values ranging from 1 to 10 were given to stomachs on the basis of stomach size. Small stomachs collected in June were given 1 point while values of 10 were given to stomachs collected in late September. Food items were sorted and identified. Then, the number of points allotted for stomach fullness was divided among the food items present based upon an estimation of volume. Points allotted for stomach size were used as weighting factors to determine the relative importance of food items for the entire summer.

The points method is useful because it (1) is quick and easy; (2) requires no special apparatus; (3) is not influenced by small organisms or by heavy organisms, and does not include large numbers of small and broken organisms; and (4) does not give the false impression of accuracy. However, the points method is subjective and the results cannot be compared with counts of organisms in the habitat.

Because of a lack of information about the food habits of grayling young-of-the-year in published literature, I also examined the stomach contents of 30 grayling from the Chena River near Fairbanks. The grayling were collected and preserved by R. J. Walker, a graduate student with the Alaska Cooperative Fishery Research Unit. A comparison was made between food habits of Chena River grayling larvae and pond-reared grayling larvae.

Predation

Experiments were conducted to determine a list of invertebrate predators on grayling sac-fry. Aquaria (0.3 X 0.27 X 0.5 m) were used at lake side at West Pond during 1981. Fifteen grayling sac-fry and five potential predators of one species were placed into an aquarium for 12 hours. The aquarium was placed in 75-100 mm of lake water to buffer the temperature changes of the aquarium water. A piece of plywood weighted with a rock covered the aquarium. Each experiment was conducted to include some night hours; darkness was short as daylight averaged 19 to 20 hours in mid-June.

Periodic observations were made to witness predation because death from predation could not be distinguished from other causes. At the end of the experiment the number of grayling eaten by a predator species was recorded, along with observations.

RESULTS

Survival

Summer survival for grayling stocked into West Pond and Texas 2 ranged from 0.01 to 0.10 at the time of the final population estimates (Table 2).

Survival of sac-fry stocked in seven holding pens at West Pond during 1981 averaged 0.96 for the first week; survival dropped to an average of 0.04 on day 11 when the use of holding pens was terminated.

The number of fish in West Pond and Texas 2 declined sharply between time of stocking and the first population estimate (Figures 3 and 4). Additional mortality was small during the time period between the first and second estimates of population size.

Estimates of daily instantaneous mortality (Z) were 0.023 (r^2=0.81) in West Pond and 0.047 (r^2=0.93) in Texas 2 during 1980, and 0.025 (r^2=0.66) in West Pond during 1981 (Figure 5).

The hypothesis that survival was negatively correlated to sac-fry stocking density was rejected when examined over the range of densities employed by ADF&G prior to this study and densities used during this study (Figure 6).

Growth

Grayling grew from an average of 10 mm to 135 mm between stocking and removal (Table 3). Total growth for each pond ranged from an average of 112 mm to 125 mm. Grayling stocked in West Pond during

Table 2. Number of sac-fry stocked N(1), final population estimate N(2), 95% confidence interval CI, rate of survival S, number removed N(R), and trap efficiency N(R)/N(2) in Texas 2 and West Pond.

lake/year	N(1)	N(2)	CI	S	N(R)	N(R)/N(2)
Texas 2 1980	46,818	479	456-507	0.01	462	0.96
West Pond 1980	4,454	466	406-537	0.10	453	0.97
West Pond 1981	3,000	116	77-185	0.04	115	0.99

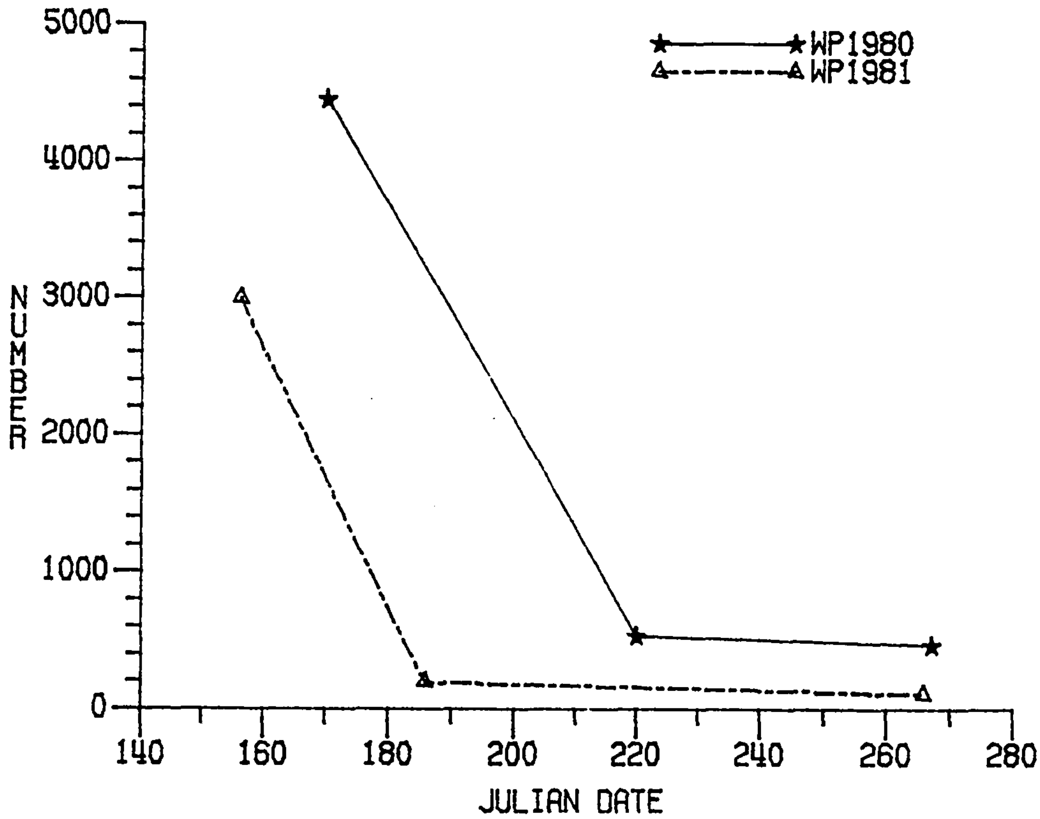

Figure 3. Survivorship curves for young-of-the-year grayling in West Pond during 1980 and 1981 from time of stocking to removal.

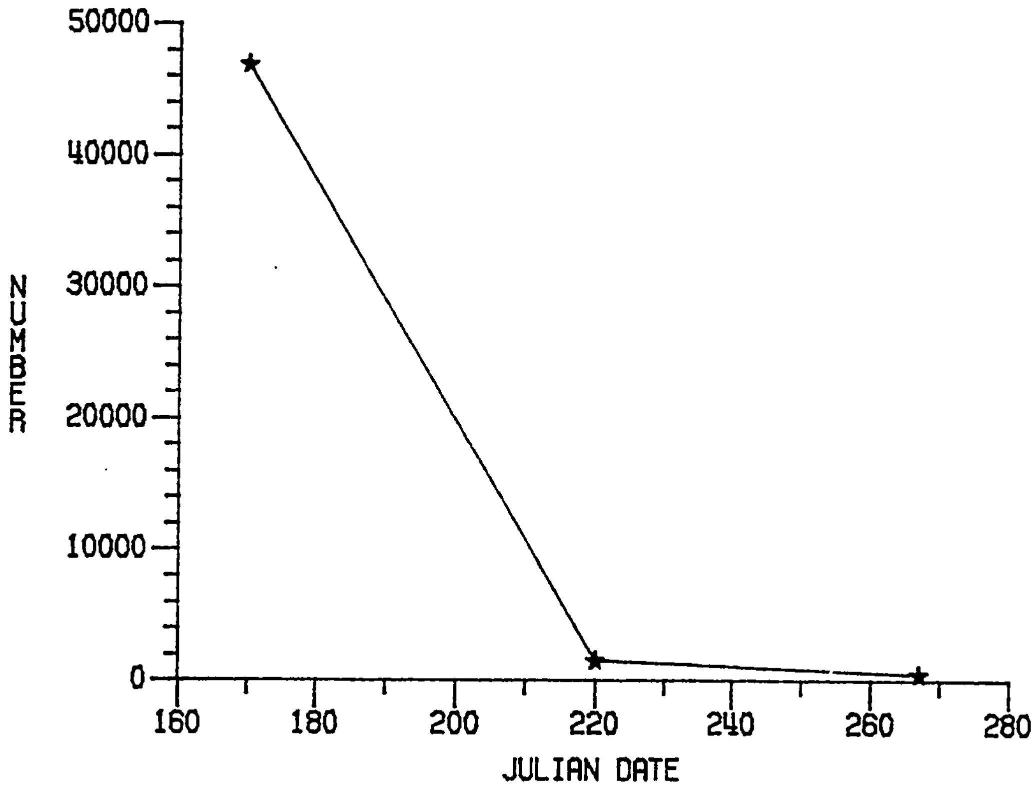

Figure 4. Survivorship curve for young-of-the-year grayling in Texas 2 Lake during 1980 from time of stocking to removal.

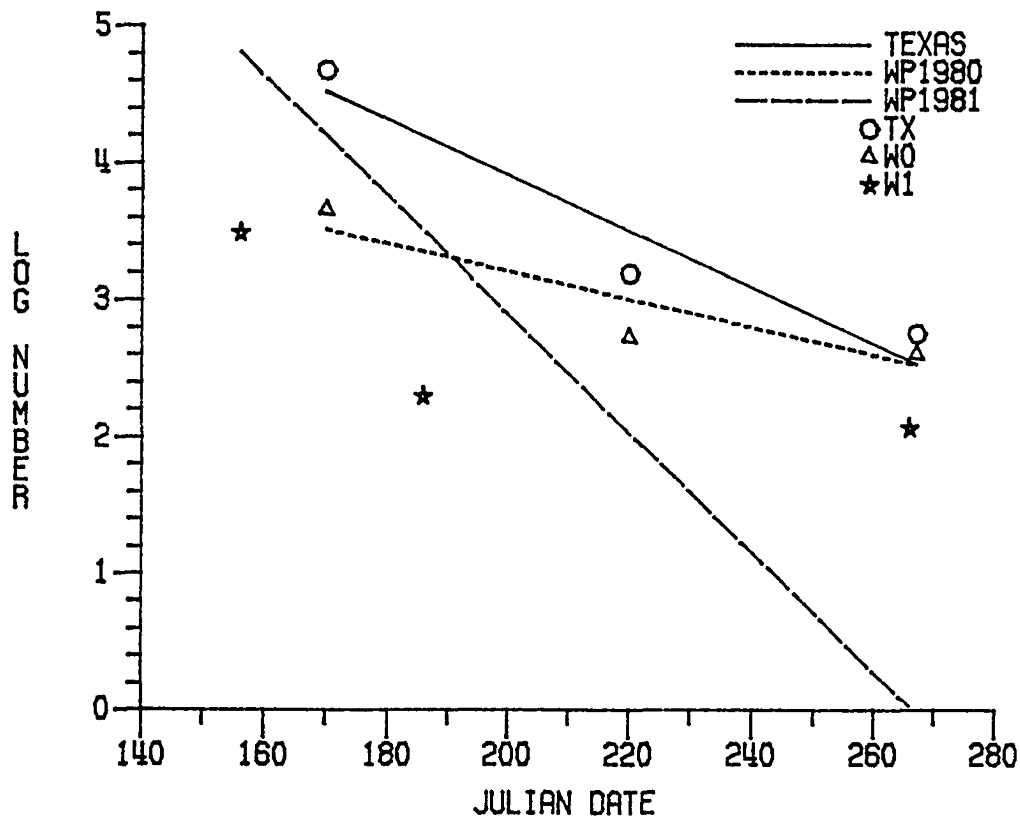

Figure 5. Log number of surviving fish as a function of time for Texas 2 and West Pond during 1980 and 1981.

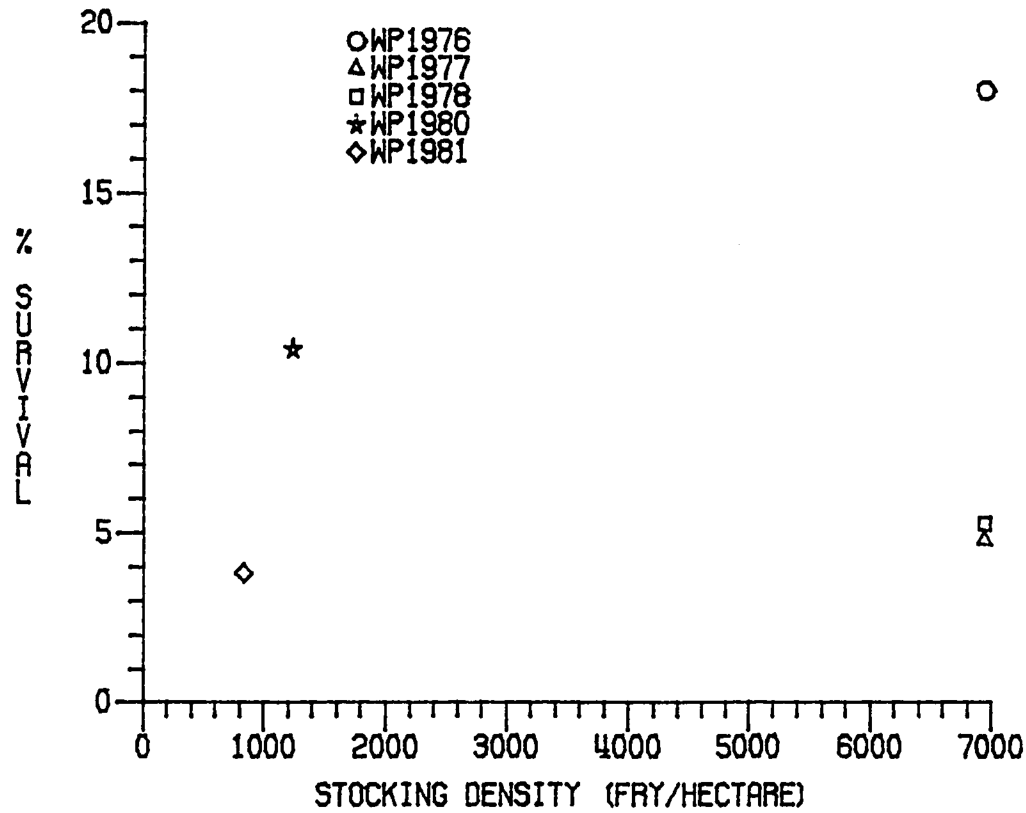

Figure 6. Estimated percent survival of stocked grayling as a function of stocking density in West Pond 1976-1978 and 1980-1981. Estimates for 1976-1978 were obtained from ADF&G data.

Table 3. Average lengths (mm), average weights (g) and associated standard deviations (SD) of grayling stocked in Texas 2 and West Pond.

			Length		Weight	
lake/year	date	n	mean	SD	mean	SD
Texas 2 1980	July 14	10	38.8	3.12	0.6	0.17
	July 26	10	64.0	2.21	2.8	0.28
	Aug. 7	10	79.3	2.41	4.8	0.50
	Aug. 23	10	102.0	3.94	10.8	1.52
	Sept. 24	10	122.6	1.26	16.7	0.81
West Pond 1980	July 14	10	43.7	2.54	0.7	0.17
	July 26	10	66.5	1.58	2.9	0.28
	Aug. 7	10	84.6	4.97	6.3	1.08
	Aug. 23	10	105.7	2.06	11.8	0.81
	Sept. 6	10	120.0	3.09	16.9	1.50
	Sept. 23	10	125.9	6.10	18.4	2.75
West Pond 1981	July 5	10	48.7	2.50	1.1	0.14
	Aug. 2	10	93.4	3.44	9.1	1.13
	Aug. 25	10	119.4	6.48	19.0	3.17
	Sept. 6	10	132.5	4.91	27.2	3.98
	Sept. 22	10	140.4	6.65	29.7	3.91

1981 attained the largest average size of the three different plants.

Grayling grew at the fastest rate in West Pond during 1980. Weighted linear regression of length as a function of time gave an estimate of 1.33 mm/day growth for grayling in West Pond during 1980 ($y=1.33x-212.02$, $r^2=0.97$). During 1981 the estimated rate of growth for West Pond grayling was 1.28 mm/day ($y=1.28x-186.92$, $r^2=0.97$). Texas 2 grayling in 1980 apparently grew at the slowest rate: 1.02 mm/day ($y=1.02x-150.79$, $r^2=0.97$). Growth rates in West Pond during 1980 and 1981 were similar; the difference in elevation of the growth curves was due to different stocking dates (Figure 7).

Significant F-statistics ($P<0.05$) indicated that a second degree polynomial should be considered for the growth data. The polynomial regressions predicted that growth initially was relatively high and during the season slowed until it was almost asymptotic (Figure 8). The West Pond 1980 polynomial regression equation was $y=-0.012x^2+6.78x-820.85$ ($r^2=0.99$), the West Pond 1981 polynomial regression equation was $y=-0.008x^2+4.97x-584.31$ ($r^2=0.99$) and the Texas 2 polynomial regression equation was $y=-0.012x^2+6.58x-799.64$ ($r^2=0.99$).

The polynomial regression predicted that growth rates (mm/day) decreased steadily over the season. A plot of growth rate as a function of time indicated that growth rates for the three plants of grayling were initially 2.0 mm/day and declined to about 0.5 mm/day by late September (Figure 9). Growth rates plotted as a function of fish

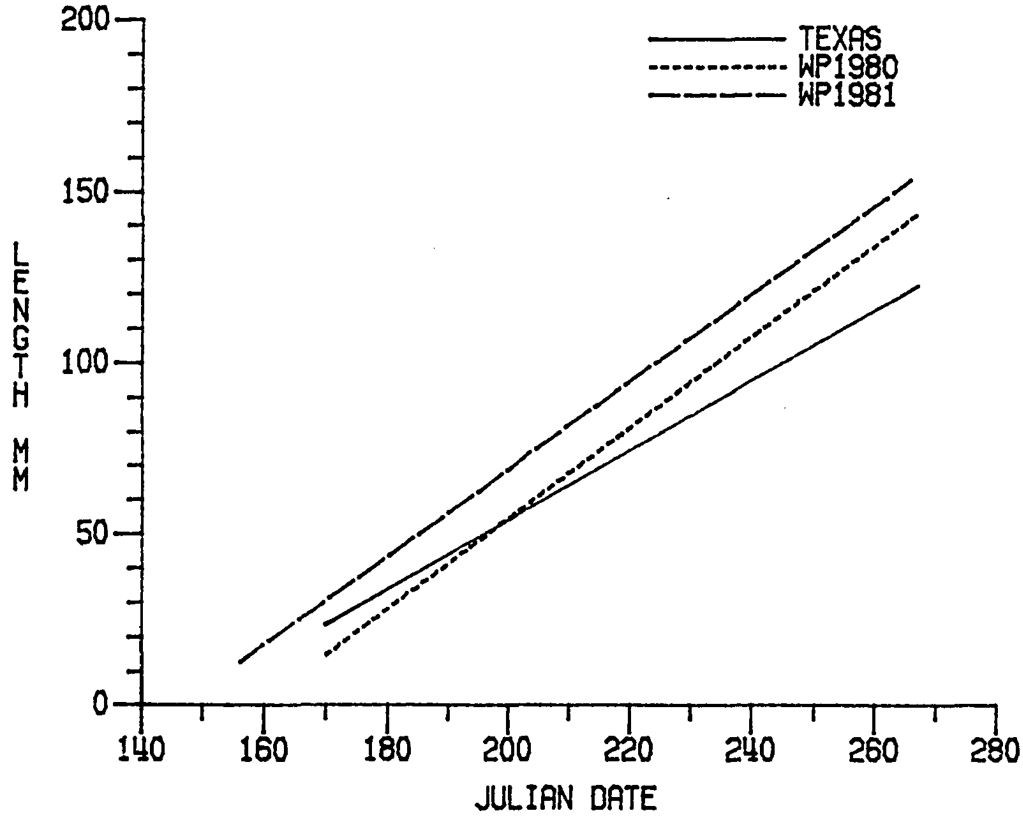

Figure 7. Growth curves fitted by weighted linear regression for Texas 2 1980 and West Pond 1980-1981 grayling.

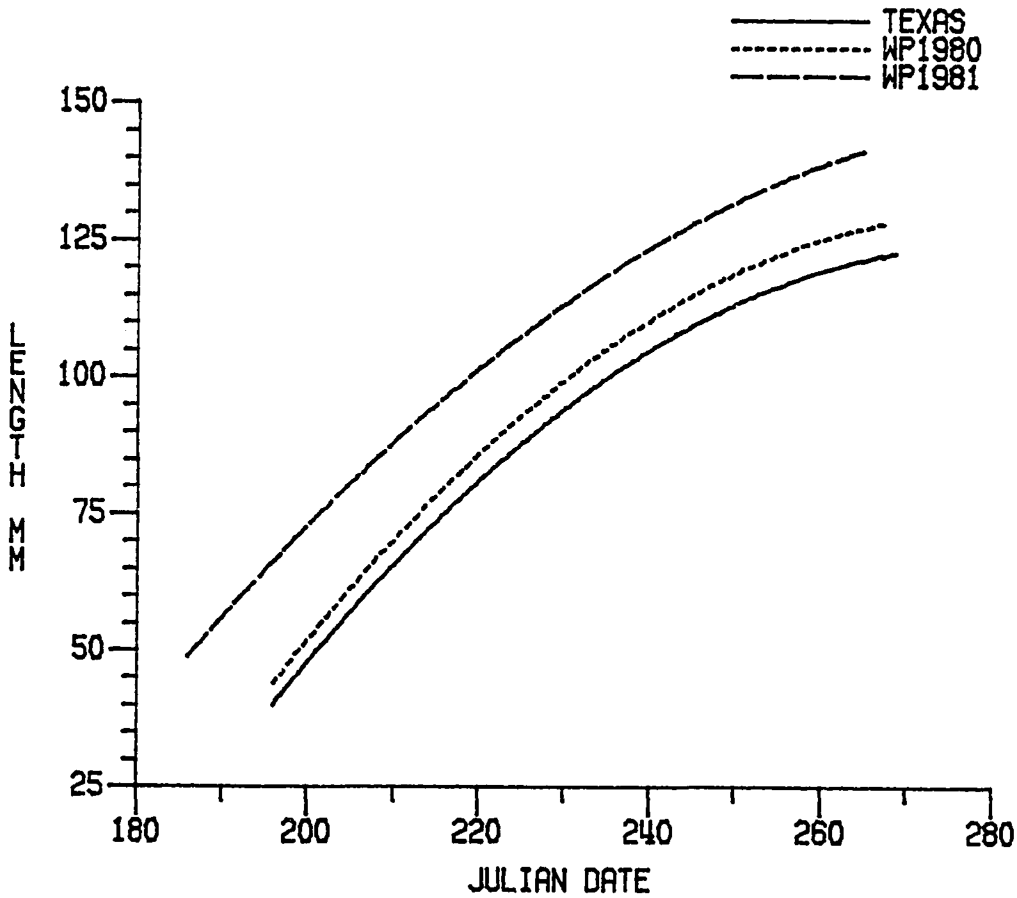

Figure 8. Growth curves fitted by weighted polynomial regression for Texas 2 1980 and West Pond 1980-1981 grayling.

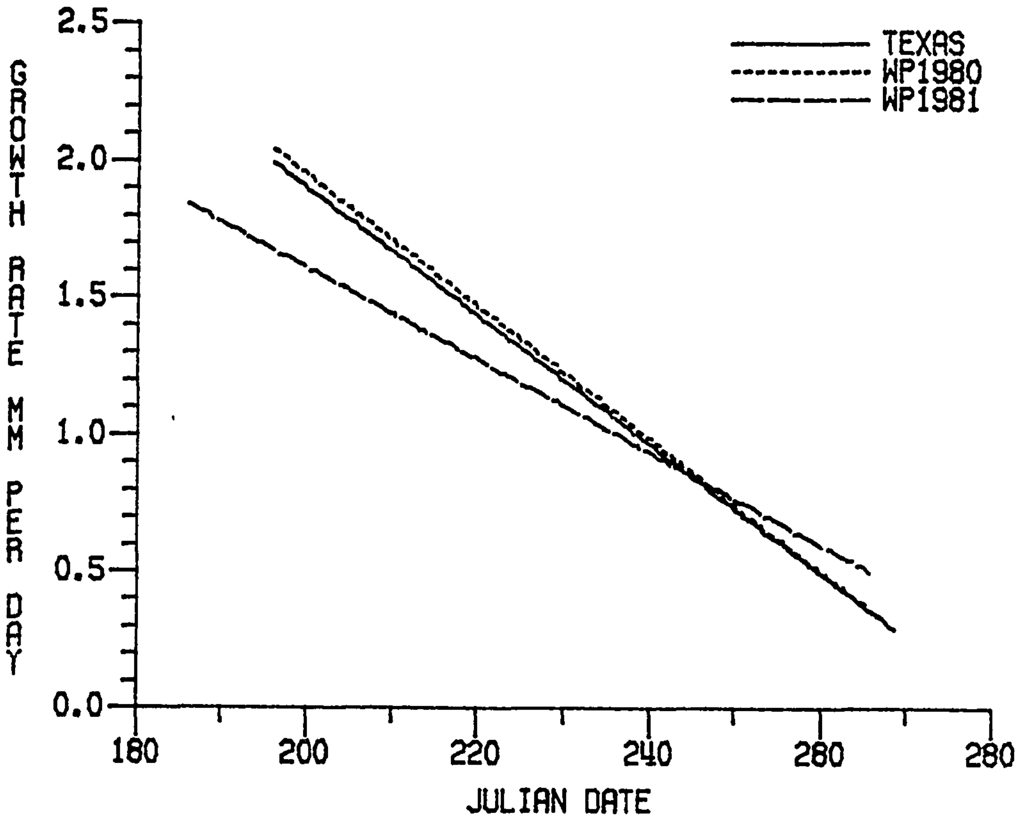

Figure 9. Growth rates as a function of time from the polynomial regression analysis of Texas 2 1980 and West Pond 1980-1981 grayling.

size (length) showed a similar decline. Growth rates were approximately 2.0 mm/day at a length of 40 mm and dropped to 0.5 mm/day between the size range of 120-140 mm (Figure 10).

Weight-length relationships calculated for each of the three plants were found to approach the ideal value of 3.0. The slopes of the regressions of log weight as a function of log length were 3.08 ($y=3.08x-2.17$, $r^2=0.99$) for West Pond 1980 grayling, 3.18 ($y=3.18x-2.33$, $r^2=0.99$) for West Pond 1981 grayling and 2.89 ($y=2.89x-1.81$, $r^2=0.99$) for Texas 2 grayling (Figure 11). Despite the closeness of the values and the apparent identical regression lines, each value was significantly different from the other two (Table 4). The null hypothesis that each weight-length relationship value was equal to the ideal value of 3.0 was tested using a paired sample t-test. In each case the null hypothesis was rejected ($P<0.05$) in favor of the alternate hypothesis that each value was not equal to the ideal isometric value of 3.0.

Production

Total production, production per unit area, and the ratio of production to mean standing crop were highest in Texas 2, 1980 (Table 5). West Pond 1980 produced the greatest biomass that was removed during the fall trapping of the lakes with 8.56 kg of fish removed. In West Pond, 1980 and 1981, over 60% of the total production was trapped and removed during the fall while in Texas 2, 1980, only 21% of the total production was removed. There was a general positive

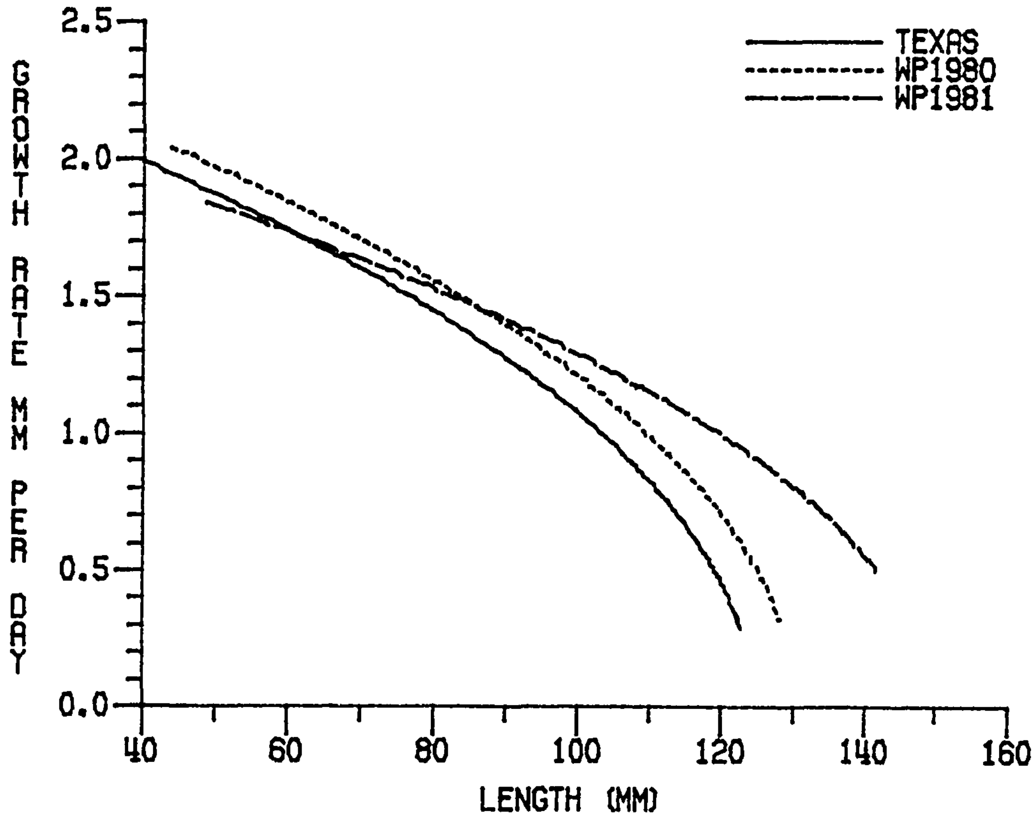

Figure 10. Growth rates as a function of fish length from the polynomial regression analysis of Texas 2 1980 and West Pond 1980-1981 grayling.

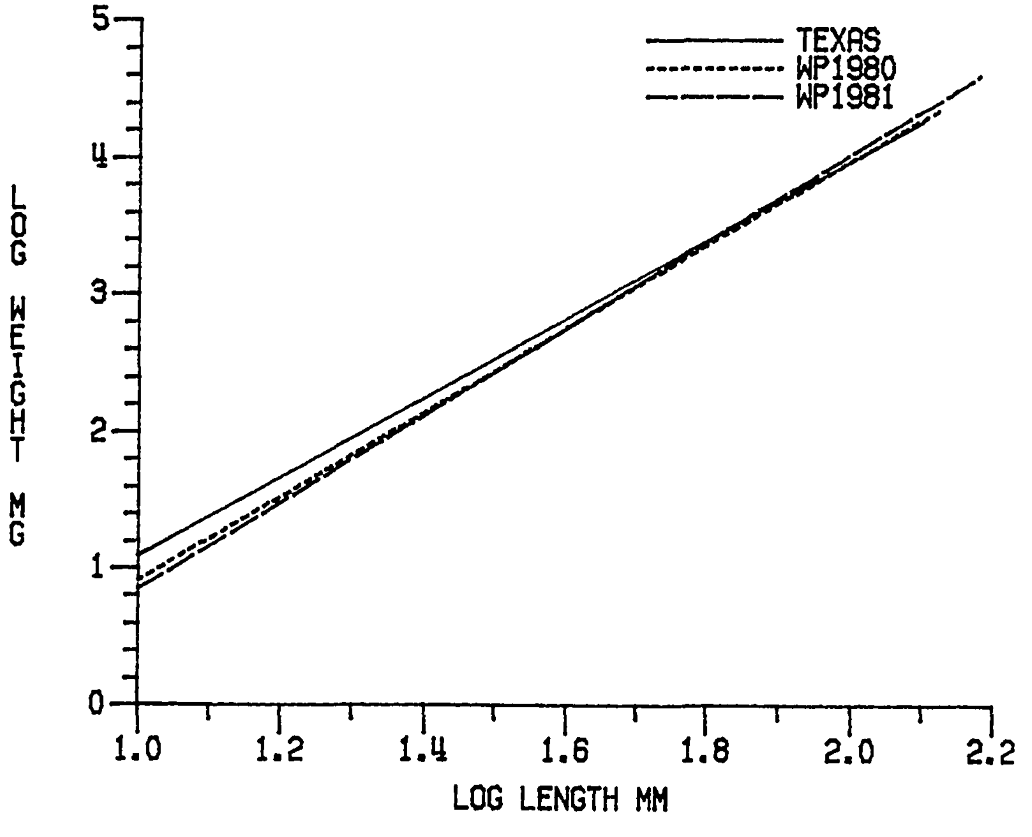

Figure 11. Weight-length relationships for Texas 2 1980 and West Pond 1980-1981 grayling.

Table 4. Multiple range test for weight-length relationship values for Texas 2 and West Pond grayling and associated degrees of freedom (df), number of means in the range of means being tested (p), and q values.

comparison	df	p	Value of q: actual	Value of q: tabular	Conclusion
West Pond 1981 (3.18) vs. Texas 2 1980 (2.89)	96	3	7.16	3.399	≠
West Pond 1981 (3.18) vs. West Pond 1980 (3.08)	106	3	3.77	2.829	≠
Texas 2 1980 (2.89) vs. West Pond 1980 (3.08)	106	2	4.92	2.829	≠

Table 5. Total production (TP), production per unit area (P), production to mean standing crop ratio (P/B), biomass removed (R), biomass removed to production ratio (R/P), and stocking density (sac-fry/hectare) for Texas 2 and West Pond.

lake/year	TP (kg)	P (kg/ha)	P/B	R (kg)	R/P	Stocking Density
Texas 2 1980	37.60	7.74	1.02	8.00	0.21	9,635
West Pond 1980	13.93	3.87	0.53	8.56	0.61	1,235
West Pond 1981	5.27	1.46	0.55	3.44	0.65	833

correlation between stocking density and production.

Food Habits

Chironomid pupae were present in 95% of all grayling stomachs examined within the first month after stocking. Chironomid pupae also totalled 54% by volume of the food items present in stomachs sampled in the first month after stocking in West Pond 1980 and 83% by volume in West Pond 1981 (Figure 12). Chena River grayling larvae also ate mostly chironomid larvae or pupae (Figure 13). The predominance of chironomid pupae rapidly decreased as lake-held grayling reached larger sizes.

Copepods, amphipods, and corixids were the major food items of young-of-the-year grayling when examined over the entire season (Figure 14).

Predation

Five invertebrates (dytiscid beetle larvae, dragonfly larvae, amphipod, dytiscid beetle adult, and leech) and one fish, the slimy sculpin (*Cottus cognatus*), were tested for predatory status upon grayling sac-fry. Dytiscid beetle larvae, dragonfly larvae and leeches were observed consuming grayling sac-fry while the remaining three did not eat any grayling sac-fry during the experiments. Inferences based on these results were difficult to make because of the artificial setting of the aquaria. For example, slimy sculpin were observed "hiding" in the corners of the aquarium with only rare move-

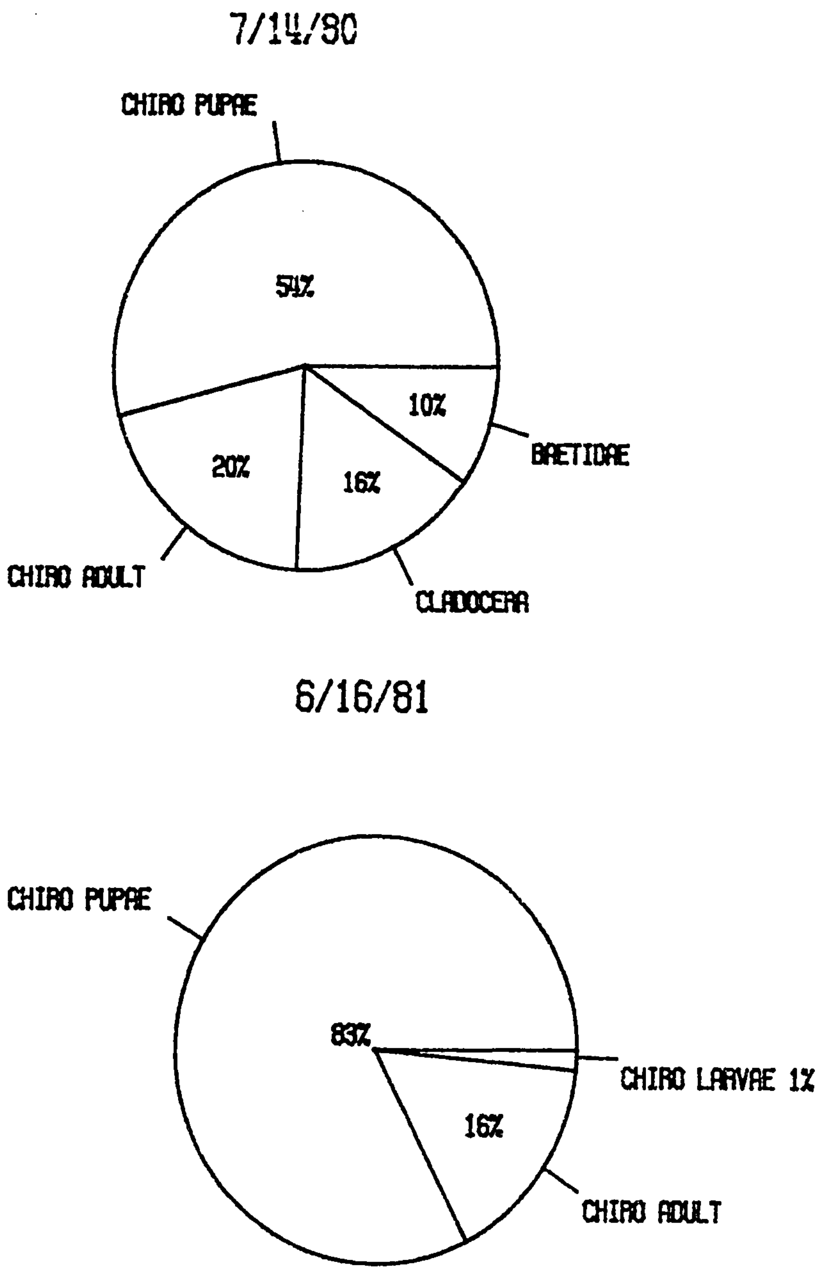

Figure 12. Food items, by volume, of 10 grayling larvae (mean length=43.7 mm, range 40-48) in West Pond 1980 and 10 grayling larvae (mean length=14.7 mm, range 12-18) in West Pond 1981.

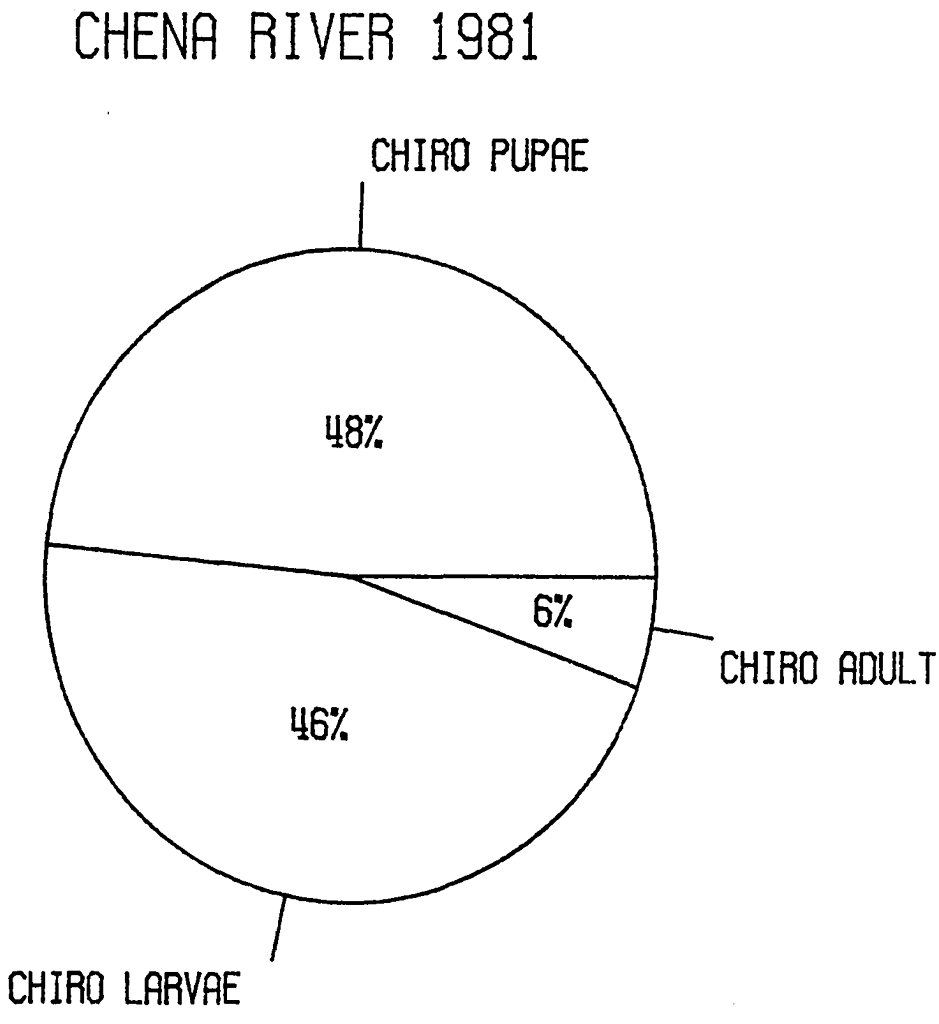

Figure 13. Food items, by volume, of 30 grayling larvae (mean length=14.0 mm, range 11-16) in the Chena River.

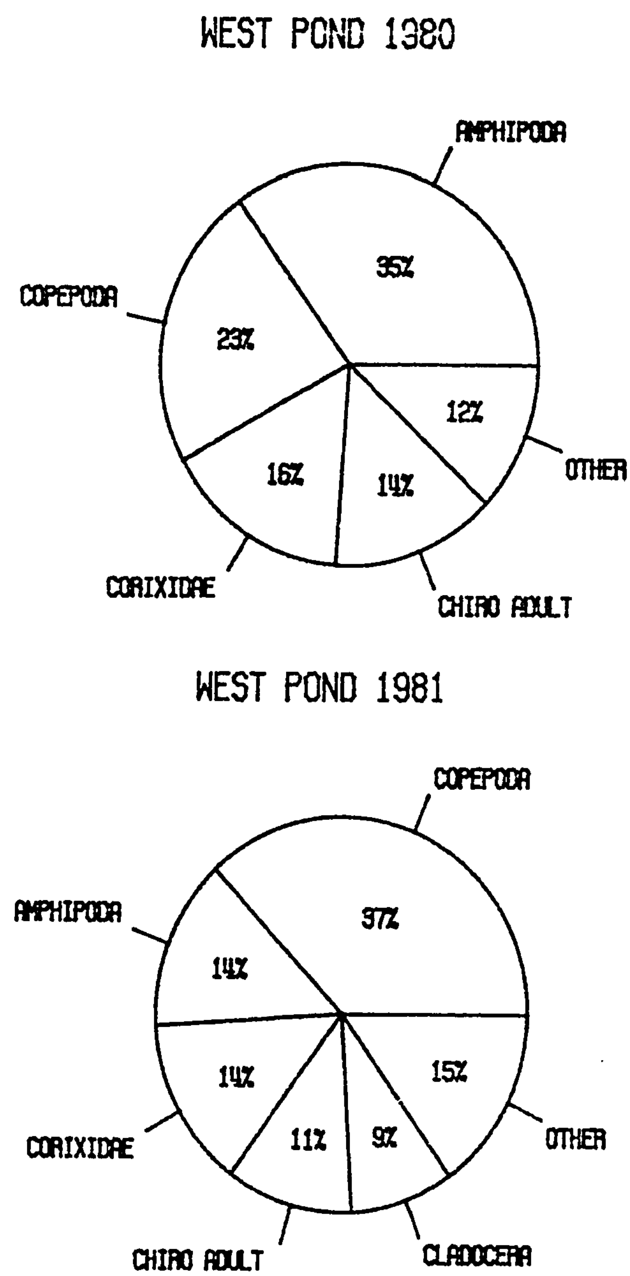

Figure 14. Food items, by volume, of young-of-the-year grayling (length range 12-151 mm) in West Pond, June-September 1980 and 1981.

ment, and then only to another corner.

Dytiscid beetle larvae were observed to "hang" suspended in the water column with their pincer-like mandibles opened wide. When the unwary sac-fry swam into range, a larva would clamp its mandibles around its prey, piercing the abdomen. After sucking the body fluids out, the dytiscid larvae opened their mandibles and dropped the dead grayling. Based upon general observations, dytiscid larvae were the most efficient predators on grayling sac-fry of those tested.

Leeches were observed consuming grayling only when sac-fry were immobile and laying on the bottom. Actively swimming sac-fry apparently avoided leech predation.

DISCUSSION

Survival

One important finding of this study is the lack of correlation between stocking density and survival of Arctic grayling sac-fry, at least for the range of stocking densities tested. This was due to the high mortality of sac-fry soon after stocking. Factors other than stocking density, such as fry mobility and fitness, predation by invertebrates, and first feeding may be more important in determining sac-fry survival.

Arctic grayling sac-fry and larvae are weak swimmers for the first 2-3 weeks after hatching and usually spend 3-4 days in the gravels of the spawning bed before swimming up into the water column (Kratt and Smith 1977). The lack of a sub-gravel stage for hatchery-reared, stocked grayling is a possible source of stress as stocking occurs within 1-2 days after hatching. Susceptibility to wave-action disturbances and predation by invertebrates is likely increased.

Most of the mortality of stocked Arctic grayling occurred within the first month after stocking. The first estimate of mortality at 30 days was the earliest possible because of the necessity of being able to mark fish with a recognizable fin clip. Fish smaller than 35-50 mm could not be handled and marked because of their size. If smaller fish could be marked, I believe the results would show that most of the mortality occurred within two weeks after stocking. This is the period when grayling are in the larval stage and have not yet metamorphosed into juveniles. They still possess temporary embryonic structures and are weak swimmers. This time frame has been termed a "critical period" and has been the subject of research in both marine and freshwater fish larvae (Baum 1978).

The high mortality of Arctic grayling sac-fry in the holding pen enclosures in West Pond during 1981 was likely due to lack of food. Grayling usually begin to take food within 4 days after hatching and by the eighth day all fish are feeding (Brown and Buck 1939). This fact in conjunction with my observation that fish in the holding pens had no distinguishable food in their gut suggests strongly that the high and sudden mortality was a result of malnutrition. The holding pens likely acted as a barrier to preferred prey items.

The attempt to concentrate a food source inside the holding pens by introducing zooplankton failed because uncaged Arctic grayling larvae fed on chironomid pupae, not copepods. Schmidt and O'Brien (1982) found Arctic grayling 30-200 mm would pursue and capture all of the zooplankton common in the Toolik Lake area (200 km south of Prudhoe Bay, Alaska) with two exceptions. The copepod _Diaptomus pribilofensis_ was never attacked nor eaten by any grayling. This copepod was the appropriate size and pigmented a bright red. The other exception, a large copepod _Heterocope septentrionalis_, although attacked, evaded capture. Successful evasion by the zooplankton was dependent upon grayling size and water temperature. _Heterocope septentrionalis_ was the zooplankton introduced into the holding pens in my study. Schmidt and O'Brien found that capture success ranged between 20-50 percent for grayling 30 mm and increased as fish size increased to 85 mm. I believe that this trend holds for grayling under 30 mm and that the capture success falls to zero for grayling 10-20 mm.

Summer survival of Arctic grayling stocked into West Pond and Texas 2 during 1980-1981 was lower than the survival range of 20-34 percent in Left O.P. Lake during 1975-1978 (Peckham and Ridder 1979). Left O.P. Lake was not used in this study because falling water levels had reduced its size to approximately 0.8 ha. The higher survival in Left O.P. Lake is probably a result of two factors. Left O.P. Lake has a rich organic layer that covers over 75 percent of the lake bottom. This condition provides some of the basis for higher productivity relative to West Pond where less than 25 percent of the lake bottom is covered with an organic layer. The second factor is that Left O.P. Lake lies in a protected basin with a tree covered ridge surrounding it. This ridge provides protection from the strong southerly winds and probably decreases sac-fry mortality due to wave action.

Hatchery Rearing

The high mortality rates of Arctic grayling stocked as sac-fry brings up the question--why stock them at this stage? One reason for stocking grayling as sac-fry is the lack of space in the State of Alaska hatcheries for rearing grayling to juveniles. This space problem stems from the high priority given to the Pacific salmon and rainbow trout.

Another reason for stocking Arctic grayling as sac-fry is cost. Rearing is expensive in terms of man power, feed, and hatchery facilities. Currently there is one hatchery in the state at Clear Air Force Station that incubates grayling eggs. However, the hatchery is severely limited in rearing capabilities due to the lack of raceway and rearing pond facilities. It would be expensive to add these facilities.

The main reason for stocking sac-fry is limited experience and knowledge in grayling culture techniques. The high priority of Pacific salmon and rainbow trout aquaculture in Alaska has slowed the development of aquaculture techniques in other species--including Arctic grayling. It has only been in the past few years that fish culturists in Alaska have recognized the growing need for hatchery-produced grayling.

In 1981 approximately 18,000 Arctic grayling were held at the Clear Hatchery for feeding and rearing experiments (pers. comm. Irv Brock, Clear Hatchery, Clear, Alaska). During the first week after hatching, survival was over 90 percent; heavy mortality ensued on day 8 and continued until day 14. At this time only 10 percent of the original number of sac-fry had survived. After hatching, sac-fry were inactive and remained on the bottom of the trough. Feeding proved unsuccessful as the fish would not move off the bottom and swim up into the water column. Heavy mortality, within ten days after hatching, also occurred in earlier attempts to feed and rear grayling (pers. comm. Charles Harris, Ft. Richardson Hatchery, Anchorage, Alaska).

The difficulties of feeding Arctic grayling under artificial conditions have been noted by Henshall (1898, 1900, 1907), Leach (1923), and Lord (1932). The best feeding success with grayling has occurred with beef liver (Henshall 1907, Laird 1928, and Lord 1932), beef heart (Fuqua 1939), or live plankton (Tugarina and Ryzhova 1969). Fuqua (1939) found that grayling could be successfully reared solely on beef heart up to one month after stocking. Tugarina and Ryzhova (1969) successfully reared the Baikal grayling (Thymallus arcticus baicalensis) under artificial conditions by feeding the newly hatched fish cladocerans and rotifers.

Fuqua (1939) also found that temperature affected the feeding success and subsequent survival of Arctic grayling larvae. Larvae held at 10 C were found to suffer twice the mortality of fry held in water at 13 C.

Rearing of the European grayling (Thymallus thymallus) and whitefish (Coregonidae) present difficulties like those encountered in rearing the Arctic grayling. Janković (1964) reported the sensivitity of the European grayling in terms of their food requirements. Rearing of the European grayling in ponds or feeding larvae live plankton in hatcheries are methods practiced in Sweden (pers. comm. Hugo Bjuhr, Norsjo Fish Hatchery, Norsjo, Sweden) and Yugoslavia (Jankovic 1964). Survival in some Swedish ponds ranges between 60 and 70 percent while in others the survival is very poor.

European grayling are reared in northern Sweden in temporary ponds that are created by diverting waters from a nearby stream (pers. comm. Bo-Goran Persson, University of Umea, Sweden). European grayling are planted in the temporary ponds as sac-fry and are reared to the juvenile stage. In the fall, fish are trapped near the outlet of the pond and transported to stocking sites. This is almost identical to the current method of pond-rearing Arctic grayling in Alaska--with the use of temporary ponds created by stream diversions being the major difference.

Penáz (1975), in a review of the early development of the European grayling, gives a detailed account of artificial culture techniques. He notes that European grayling can be reared on live plankton, mixed spleen, blood or commercial dry feeds of suitable granulation.

Fluchter (1980) concludes that two reasons account for the high mortality of whitefish (Coregonidae) larvae in the natural environment. Whitefish require specific food items at the larval stage of development and suffer high mortalities due to short-term lack of food. Raisanen and Behmer (1982) were successful in rearing the lake whitefish on a live zooplankton diet, but found that insufficient densities of zooplankton could lead to mortality from a gas bubble problem. High fish density was thought to prevent a normal prey capture response. Einsele (1965) found that stocking whitefish as larvae produced very few adults and survival to adult never exceeded 0.01 percent. However, survival to adult was 10-25 percent or greater when juveniles were stocked.

Survival of Arctic grayling in rearing ponds would likely increase if they were first reared for a short time in the hatchery. Limited hatchery facilities and rearing techniques currently makes this possibility doubtful. Expanded facilities and the knowledge of rearing techniques of the European grayling and whitefish combined with further experimentation with Arctic grayling rearing techniques may someday make rearing grayling in hatcheries feasible.

In the interim other alternatives can be tried in an effort to increase sac-fry survival and make it more predictable. The use of holding pen enclosures for a few days after stocking is one alternative. Holding pens and a wind fence would give the grayling sac-fry protection from wave-action disturbances and predation. And, if fish were released in 4-5 days after stocking, food availability inside the enclosures would not become a factor as it did at West Pond in 1981. Another alternative is lake fertilization. If lake fertilization would significantly increase chironomid production it may increase the success of first feeding for grayling fry and their subsequent survival.

Growth

Growth of young-of-the-year Arctic grayling stocked in 1980 and 1981 was slightly higher than the growth of grayling stocked in rearing ponds during 1975-1978. Peckham and Ridder (1979) found that Left O.P. grayling in 1978 had the best growth of the 1975-1978 plants and averaged 18.0 g at the time of removal. This compares with an average weight of 16.7 g for grayling in Texas 2 Lake 1980, 18.4 g for grayling in West Pond 1980, and 29.7 g for grayling in West Pond 1981.

The average size of Arctic grayling at time of removal in West Pond in 1981 was higher than any previous rearing pond plant. This resulted from a longer growing season: grayling were stocked about 2 weeks earlier than normal.

The growth of Arctic grayling in the rearing ponds is significantly greater than stream-reared grayling. At the end of their first growing season, stream-reared grayling in the Delta area average between 80-90 mm (Tack 1974) while the average size of pond-reared grayling is greater than 100 mm (Ridder 1980). Because of these growth differences, scale characteristics can be used to distinguish the origin of a fish in a river that contains both stream-reared and pond-reared grayling. Peckham and Ridder (1979) used the number of circuli before the first annulus to distinguish pond-reared grayling from stream-reared grayling in the Delta Clearwater River. Pond-reared grayling had a mean of 12.9 circuli before the first annulus with a range from 10 to 16. Stream-reared grayling had counts ranging from 5 to 12 with a mean of 8.5. The probability of separation was not calculated; overlap was assumed to be minimal.

Arctic grayling stocked in rearing ponds during 1980-1981 gained between 1.0-1.3 mm/day when estimated by a linear regression model. This is close to the 1.0 mm/day rate of growth reported by Tugarina and Ryzhova (1969) for the Baikal grayling reared under "optimal" hatchery conditions.

The age of the young-of-the-year Arctic grayling and water temperatures combined to produce the declining growth rates that were predicted by the polynomial regression analysis. It has been found that the respiratory rate of young-of-the-year grayling decreases with age and with falling water temperature (Tugarina and Ryzhova 1969). As young-of-the-year grayling get older their intrinsic rate of growth decreases. Falling water temperatures in late August and September resulted in a further decrease in the respiratory rate and slowed the growth rate of pond reared grayling even more. The polynomial regression analysis predicts the growth curve more accurately and can be explained by plausible biological observations. Walker (1983) found a similiar decline in growth rates of young-of-the-year grayling in the Chena River.

Growth rates and weight-length relationships of the pond-reared grayling varied from one pond to another and from one year to the next. These differences may be due to rather subtle changes in environmental conditions.

Production

Production estimates for Texas 2 1980 and West Pond 1980-1981 Arctic grayling were much lower than the range of 25-50 kg/ha attained in Swedish temporary ponds for European grayling (pers. comm. Bo-Goran Persson, University of Umea, Sweden). It is possible that the higher productivity is a result of diverting water into the temporary ponds from a nearby stream. This method gives the temporary pond the benefit of both pond and stream primary and secondary production.

Production estimates in this study are a function of growth, number of fish stocked, and the subsequent survival of the stocked fish. The rate of survival after stocking is the main source of error in the production estimates because survival was calculated only twice during the season. Other values were a result of interpolation. Interpolating survival between stocking and the first population estimate produced the largest error because survival was assumed to be exponential. In reality the change in survival was probably knife-edged with a dramatic decrease occurring immediately after yolk-sac absorption; if this is so, the estimates of production are too high.

Food Habits

The most significant finding with regards to the food habits of young-of-the-year Arctic grayling is the importance of chironomid pupae in their diet at time of first feeding. The importance of chironomid pupae was surprising. It was expected that in lake habitats copepods and cladocera would be the preferred prey items of grayling larvae. However, copepods and cladocera were first observed in stomach samples one month after stocking.

The predominance of chironomid pupae is in agreement with the findings of Elliott (1982). He found that young-of-the-year Arctic grayling in the Atigun River, in northern Alaska, fed mainly on chironomid larvae and pupae. No other published literature was found that mentioned the food habits of young-of-the-year Arctic grayling in the natural environment.

The diversity of food items in the stomachs of young-of-the-year Arctic grayling increased with age and size. Elliott (1982) also observed this in young-of-the-year grayling in the Atigun River. The increase in diversity of food with age and size supports the contention that Arctic grayling larvae have specific food requirements necessary for survival.

Predation

Three invertebrates--dytiscid beetle larvae, dragonfly larvae and leeches--preyed upon Arctic grayling sac-fry in aquaria. The actual impact that these predators have on survival of sac-fry in the ponds is not known. Most of the predation by these invertebrates probably occurs within the first 3-4 days after stocking. During this time period grayling were observed laying on the bottom of the holding pen enclosures. This behavior would make sac-fry very susceptible to predation.

It is very likely that the slimy sculpin (Cottus cognatus) is a predator on grayling sac-fry. If sculpin were held in aquaria for a week or two to "acclimatize", the results of the experiment would probably change.

The possibility of predation by invertebrates would be greatly reduced if grayling were stocked at a larger size. Until this can be done, holding pen enclosures could be effectively used for 4-5 days to reduce the predation on newly stocked sac-fry. Fish are actively swimming by this time and could possibly evade capture more readily.

SUMMARY

1. During early summer, the Alaska Department of Fish and Game (ADF&G) stocks Arctic grayling sac-fry into small sub-arctic lakes which are barren of other fish, but contain ample food for young grayling. After a summer of exceptional growth, the survivors are recaptured and stocked in the Delta Clearwater River where they contribute significantly to angler harvest. This study was initiated in 1980 to examine the summer survival, growth, and food habits of young-of-the-year Arctic grayling stocked in these rearing ponds.

2. The effect of stocking density (grayling sac-fry per hectare) on survival was examined over a density range of 833 to 9,635 sac-fry/ha. No correlation was found between stocking density and survival over the range of densities tested.

3. Sac-fry in holding pens died off catastrophically in 7 to 11 days after stocking. Food introduced in the enclosures was mainly the copepod (_Heterocope septentrionalis_), which can evade grayling capture. Uncaged grayling larvae (of same age) in the rearing pond ate mainly chironomid pupae. This suggests that fish in the enclosures died because of the lack of preferred prey items.

4. Most of the mortality of stocked grayling occurred within the first month after stocking. Specific food requirements (chironomid pupae) for initial feeding, fry mobility and fitness, and predation by

invertebrates may have contributed to this mortality.

5. Young-of-the-year grayling grew at the rate of almost 2.0 mm/day in June, at 0.5 mm/day in September, and averaged approximately 1.0 mm/day for the entire summer. The decrease in growth rates can be attributed to slower intrinsic rates of growth as the fish grew older and to decreasing water temperatures in August and September.

6. Pond-reared grayling grew larger than stream-reared grayling. This growth difference, as expressed in scale development, has been successfully used by ADF&G to seperate pond-reared grayling from stream-reared grayling in rivers where the two coexist.

7. Weight-length relationships of young-of-the-year grayling were found to approach the ideal isometric growth value of 3.0. However, weight-length relationships for fish stocked in different ponds and in different years were significantly different ($P<0.05$) from each other and the ideal value.

8. Production in the rearing ponds ranged from 1.5 kg/ha to 7.7 kg/ha and was much lower than production of summer-reared European grayling in Swedish temporary ponds (25-50 kg/ha) created by stream diversion.

9. The diversity of food items in the stomachs of young-of-the-year grayling increased with fish size and age. The summer food habits of pond-reared grayling were similar to young-of-the-year grayling in the Chena and Atigun Rivers, Alaska.

10. Copepods, amphipods and corixids were the main food items found in stomachs of young-of-the-year grayling when examined over the entire rearing pond season, June-September. Chironomid pupae (important in first feeding) were a small percentage of the total volume.

11. Three invertebrates--dytiscid beetle larvae, dragonfly larvae, and leeches--were found to eat grayling sac-fry and larvae in aquaria. The slimy sculpin (Cottus cognatus) may be a predator upon grayling young-of-the-year. However, in experiments conducted in aquaria for short periods no grayling were eaten by sculpin.

12. Rearing grayling in hatcheries or in holding pens for 4-5 days after hatching prior to release into rearing ponds may increase survival.

13. Techniques used to rear the European grayling and whitefish under artificial conditions may have application in rearing the Arctic grayling in hatcheries.

14. Lake fertilization may increase the survival of stocked grayling sac-fry if (1) chironomid production were increased as a result of the fertilization; and (2) successful first feeding by grayling increased as a result of increased chironomid production.

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