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SURVEY OF LAKE TROUT AND ARCTIC CHAR IN THE CHANDLER LAKE SYSTEM, GATES OF THE ARCTIC NATIONAL PARK AND PRESERVE, 1987 AND 1989

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Survey of Lake Trout and Arctic Char in the Chandler Lake System, Gates of the Arctic National Park and Preserve, 1987 and 1989.

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Abstract.—Fish populations were sampled at the Chandler lake system within the Gates of the Arctic National Park and Preserve during the summer of 1987 and the spring and summer of 1989. Creel surveys were conducted to determine sport and subsistence fishing effort, catch, and harvest levels of lake trout *Salvelinus namaycush* and Arctic char *S. alpinus*. Gill nets were deployed in nearshore areas to mark and recapture fish for population estimates and assessment of fish movement, determine relative abundance, and obtain biological samples for determining age, growth, weight-length, fecundity, maturity, and food habits. Data were also collected on physical and chemical properties of the lakes during the summer. Six lakes were sampled, but only two of these, Chandler Lake and Amiloyak Lake, were sampled intensively over several weeks during the summer.

Harvests were within the levels considered sustainable for arctic and subarctic lakes. Sport anglers interviewed (N=20) harvested 10 lake trout and 18 Arctic grayling *Thymallus arcticus* from the lake system during a summer creel survey in 1987. No sport fishing activity was observed during eight overflights in the summer of 1989. Subsistence anglers harvested an estimated 57 lake trout (0.03 kg/hectare) and 66 Arctic char (0.03 kg/hectare) during the ice fishery at Chandler Lake from March to April 1989.

A Schnabel multiple census was used to estimate population sizes for lake trout and Arctic char. The population estimate for lake trout ($\geq$234 mm in fork length) in Chandler Lake was $\hat{N}$ = 1,737 fish (95% confidence interval, 1,090 - 3,524), based on 243 fish captured (200 marked, 13 recaptured). Captures of Arctic char at Chandler Lake were less frequent and no population estimate could be made (97 captured, 72 marked, 0 recaptured). The population estimate for Arctic char ($\geq$ 225 mm in fork length) in Amiloyak Lake was $\hat{N}$ = 2,030 fish (95% confidence interval, 1,295 - 3,352), based on a total of 317 fish captured (228 marked, 17 recaptured). Lake trout in Amiloyak Lake were rare and their numbers too small for a reliable population estimate to be made (39 fish marked, one recaptured).

We documented within season movement of lake trout from Little Chandler Lake to Chandler Lake (3 fish), and between season movement of Arctic char in both directions between Chandler and Amiloyak lakes (1 fish in each direction). Movement of fish between lakes may require that the system be managed as a whole rather than by individual lakes.

Relative abundance of Arctic char differed significantly between the northern and southern halves of Amiloyak Lake. Greater abundance in the southern half of the lake may be linked to the presence of a large group of Arctic char observed holding near the inlet creek during August.

Chandler Lake lake trout averaged 462 mm and 1.25 kg; Arctic char averaged 398 mm and 0.84 kg. Compared to Chandler Lake fish, lake trout in Amiloyak Lake were

significantly smaller (424 mm and 0.76 kg), and Arctic char significantly larger (496 mm and 1.55 kg). Chandler Lake is larger and deeper than Amiloyak Lake and may have more favorable habitat for lake trout. The larger size of Arctic char in Amiloyak Lake may be attributable to favorable habitat and/or immigration of spawning fish from other lakes in the system.

Weight-length regression coefficients for lake trout and Arctic char from Chandler and Amiloyak Lakes are within the range of values reported for these species in Alaska and Canada, and indicate healthy growth. For both lake trout and Arctic char, no differences in relative condition (Kn) were found between lakes or between early and late summer samples.

Lake trout sampled for age and growth ranged from 12 to 28 years with mean lengths from 390 to 478 mm, having generally slower growth rates than populations from lower latitudes in Alaska. Arctic char from Amiloyak Lake ranged from 5 to 19 years with mean lengths from 334 to 535 mm and growth rates similar to other northern Alaska populations. Arctic char from Chandler Lake appear to have fast growth between ages 4 and 8 and rapid decline in growth rate at later ages, in contrast to relatively constant growth rates at Amiloyak Lake. This difference may be linked to size and age structure differences between the lakes, with young Arctic char (< age 8) benefitting from reduced competition with older, larger Arctic char in Chandler Lake.

Analysis of stomach contents from Chandler Lake showed that lake trout were primarily piscivorous and Arctic char nonpiscivorous. Arctic grayling was the most important food item by weight in the lake trout diet, followed by snails and insects. Cladocera, insects and snails were the most frequently occurring food items in the Arctic char diet.

Fecundities of ripening female Arctic char (3,200 - 4000 ova) were within the range of values documented for populations in northern Canada and Alaska. Based on gonadosomatic index criteria, we estimated that 11% of the lake trout (N = 27) and 35% of the Arctic char (N = 20) examined would have spawned in the year of capture.

Harvest levels were low relative to population sizes, and there was no evidence of over-exploitation. The U. S. Fish and Wildlife Service recommends a continuing effort be made to monitor harvest and to establish yield levels that do not exceed 0.14 kg/hectare for lake trout and 0.22 kg/hectare for Arctic char at Chandler Lake, and 0.22 kg/hectare for lake trout and 1.88 kg/hectare for Arctic char at Amiloyak Lake. Management options are discussed.

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Introduction

Gates of the Arctic National Park and Preserve (GAAR), located in the central region of the Brooks Range (Figure 1), contains a number of deep, high latitude lakes that support sport and subsistence fishing activities. Research results from high latitude lakes show that these waters exhibit low productivity (Wohlschlag 1953; Kennedy 1954; Thomasson 1956; Brewer 1958; Wong and Whillans 1973; Schindler *et al.* 1974; Welch 1974, 1985; Johnson 1975; Welch and Bergmann 1985a, 1985b; Bergmann and Welch 1985) and slow growth rates for fish (Hunter 1970; Holeton 1973; Johnson 1976, 1983; Healey 1978; Pearse 1978; Langeland 1986; Fraser and Power 1989). As a consequence, the quality of these fisheries is prone to decline from even limited fishing pressure (Hunter 1970; Martin and Olver 1980; Langeland 1986; McDonald and Hershey 1989).

The Alaska National Interest Lands Conservation Act (ANILCA) of 1980 mandates the maintenance of natural and healthy fish populations within the park and preserve. Few baseline data are currently available on fish populations, current exploitation levels, and the physical and chemical properties of park and preserve lakes. Such information is needed by land and natural resource managers to properly manage fish populations, their habitats, and their use.

The two lake species of greatest concern for harvest management within GAAR are lake trout *Salvelinus namaycush* and Arctic char *S. alpinus*, although Arctic grayling *Thymallus arcticus* are also harvested. Other species occasionally harvested are northern pike *Esox lucius* and burbot *Lota lota*. Lake trout and Arctic char are prominent attractions for park visitors and subsistence users and are harvested from deep lakes within the region. Sport fishing lodges, air taxi operators, and guide services depend economically upon lake fisheries. Maintenance of natural and healthy fish populations is necessary to support subsistence needs of rural residents and to provide sport fishing opportunities.

The Chandler lake system, in the north central region of GAAR (Figures 1 and 2), provides an important subsistence fishery for both lake trout and Arctic char. The primary subsistence users of the Chandler lake system are from the town of Anaktuvuk Pass. Anaktuvuk Pass has 54 households and a population of 246 (ADCRA 1990). Travel distances are about 50 km to Chandler Lake and 63 km to Amiloyak Lake. Subsistence fishermen travel to the lakes by snowmobile, ATV, and in some cases airplane[1]. Sporadic use of the lake system by subsistence fishermen from the towns of Nuiqsut (population 316; about 230 km from Chandler Lake by snowmobile) and Barrow (population 3,379; about 370 km from Chandler Lake by airplane) has been reported (John Peterson, National Park Service, Anaktuvuk Pass, personal communication).

The Alaska Department of Fish and Game (Department) has made numerous surveys of the Chandler lake system (Kogl 1971; Furniss 1974; Department, Sportfish Division, Fairbanks, Alaska, unpublished data 1977, 1984; Bendock 1979; Bendock and Burr 1986). In those surveys, lake trout, Arctic char, Arctic grayling, round whitefish *Prosopium cylindraceum* and slimy sculpin *Cottus cognatus* were captured. The lakes were described as having cobble/gravel bottoms that are potential spawning habitat for lake trout and Arctic char. Chandler Lake included some of North America's oldest known lake trout (>42 years) and Arctic char (>16 years; Furniss 1974). Previous investigators did not capture burbot *Lota*

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[1]Aircraft access for subsistence fishing is not allowed in GAAR, which includes the southern half of Chandler Lake and all of Amiloyak Lake (ANILCA 1980). The northern half of Chandler Lake is part of a Nunamiut Corporation inholding and is subject to state subsistence regulations, which do not restrict means of access.

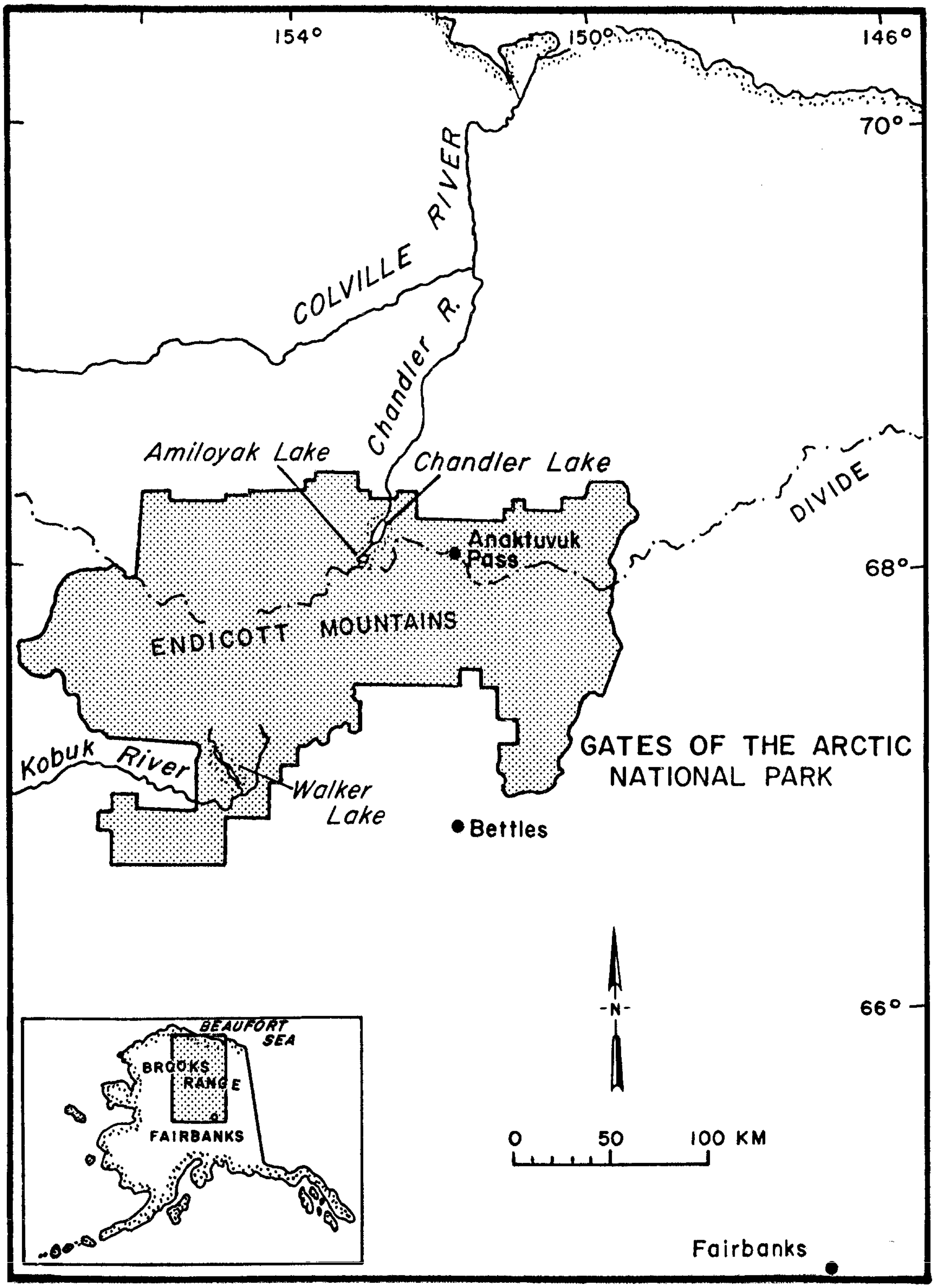

FIGURE 1.—Locations of Chandler and Amiloyak lakes within Gates of the Arctic National Park and Preserve.

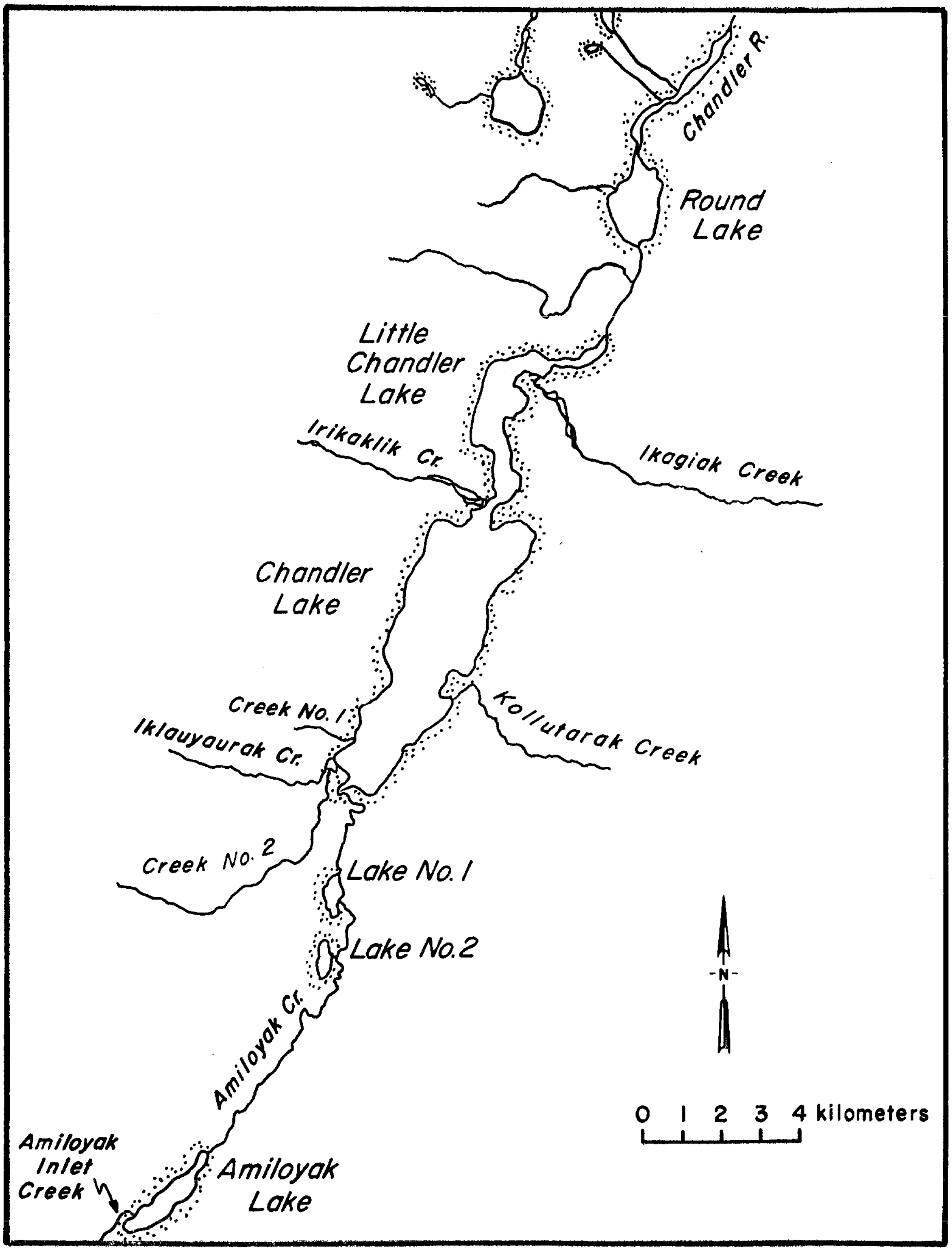

FIGURE 2.—Lakes, rivers, and creeks of the Chandler lake system.

lota, but local residents have reported their occurrence. Ciscos *Coregonus* spp. have not been documented in the system.

The sympatric relation of lake trout with Arctic char is considered unusual (Johnson 1980). Fraser and Power (1989) documented some of the effects of sympatry on Arctic char, including lower yields and survival rates, a nonpiscivorous diet, and faster growth rates. Ciscos are generally present when lake trout and Arctic char are found together (Johnson 1980), but their absence is not unusual for lakes on the north side of the Brooks Range (McPhail and Lindsey 1970; Kogl 1971; Furniss 1974; Bendock 1979).

This is the final report for this study and summarizes 1987 and 1989 field activities. The overall study objective was to provide baseline information on lake fish populations and their exploitation in lakes within GAAR. In addition to sampling in the Chandler lake system, fish population and exploitation data were collected from Walker Lake in southern GAAR (Figure 1); these data are summarized in a separate report (Johnson and Troyer 1994). Specific study objectives for the Chandler lake system were to:

1) Estimate harvest from the summer sport fisheries.
2) Estimate harvest from the spring ice fishery.
3) Estimate the absolute and relative abundance of catchable size lake trout and Arctic char.
4) Document movement of lake trout and Arctic char.
5) Document length, weight, and condition of lake trout and Arctic char.
6) Document age and growth, food habits, fecundity and maturity of lake trout and Arctic char.
7) Document the physical and chemical characteristics of Chandler and Amiloyak lakes.
8) Provide management and study recommendations.

Study Area

The Chandler lake system is located at approximately 68° 15' N and 890 m above sea level. The system contains six lakes: Round, Little Chandler, Chandler, and Amiloyak lakes, and unnamed lakes 1 and 2 (Figure 2). Arctic tundra borders this system and the summer weather is generally cloudy and windy (National Park Service 1986). The warmest month is July with temperature ranges of 7 to 18°C. February is the coldest month with average temperatures ranging from -21 to -23°C. Precipitation ranges from 13 to 25 cm per year. Ice conditions at the lakes vary from year to year, with breakup usually occurring in mid to late June and full freeze in early to mid October (Grant Spearman, Museum Curator, Anaktuvuk Pass).

The system has two major interconnecting waterways, the Chandler River and Amiloyak Creek (unofficial name). All water flows north from Amiloyak Lake, through other lakes in the system, and then into the Colville River. Amiloyak Lake is 970 m in elevation with a surface area of 100 hectares and a maximum depth of 10 m (Figure 3). Numerous small creeks drain into the lake with flows ranging from 0.04 to 0.27 m^3/s. The outlet into Amiloyak Creek has a summer flow of approximately 0.59 m^3/s (Bendock and Burr 1986). Unnamed lake 2 is 8 km downstream from Amiloyak Lake and has a surface area of 24 hectares. Unnamed lake 1 is 2 km farther downstream and has a surface area of 40 hectares.

Chandler Lake is 888 m in elevation with a surface area of 1,300 hectares and a maximum depth of 22 m (Figure 4). Six major inlet creeks flow into Chandler Lake: Irikaklik, Iklauyaurak, Kollutarak, unnamed creeks 1 and 2, and Amiloyak Creek (Figure 2). Chandler Lake is connected at the north end to Little Chandler Lake (317 hectares) by a 200 m long, 70 m wide section of shallows. Round Lake (170 hectares) is 4 km downriver from Little Chandler Lake and is 12 m lower in elevation.

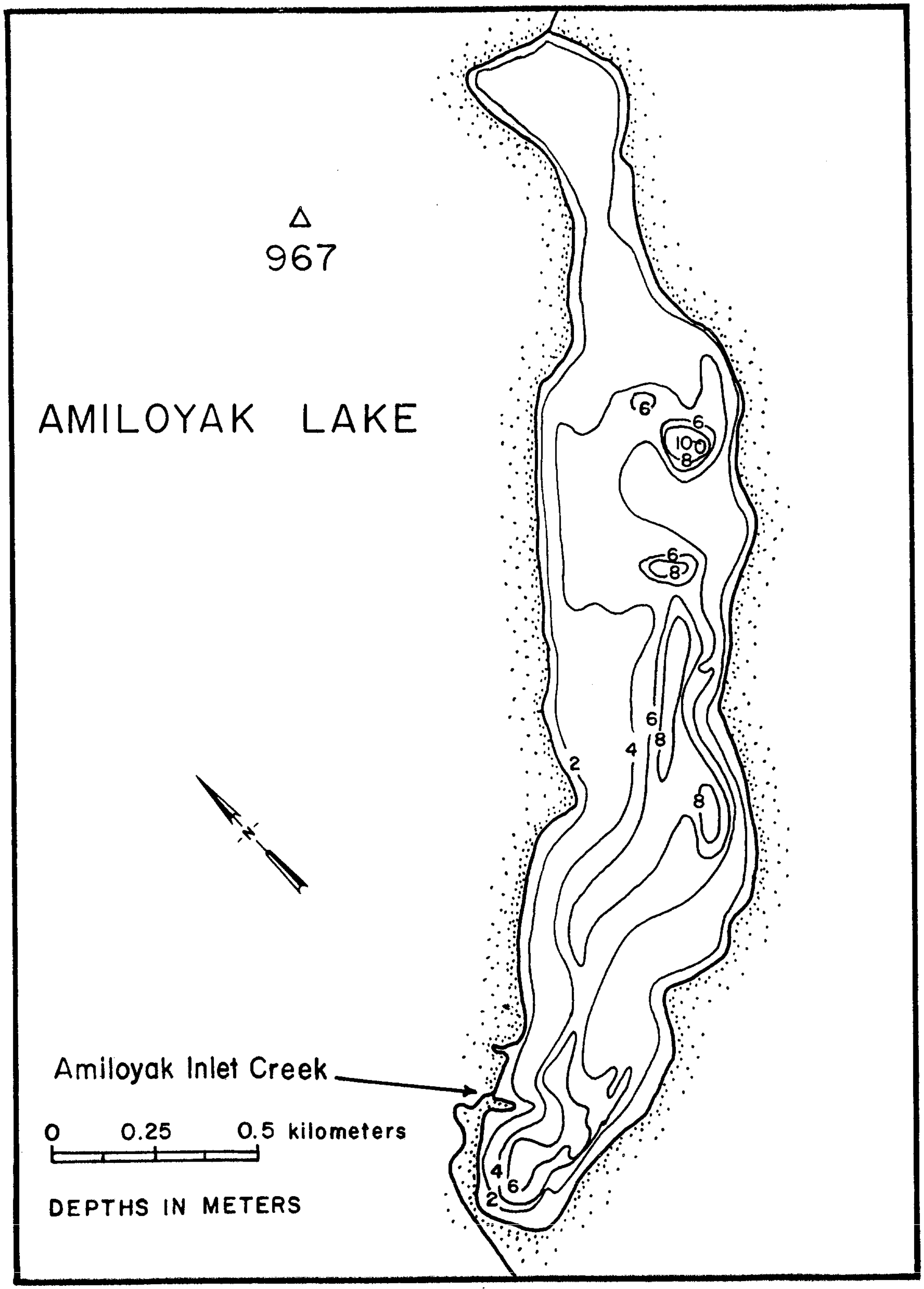

FIGURE 3.—Bathymetric map of Amiloyak Lake (Reanier and Anderson 1986).

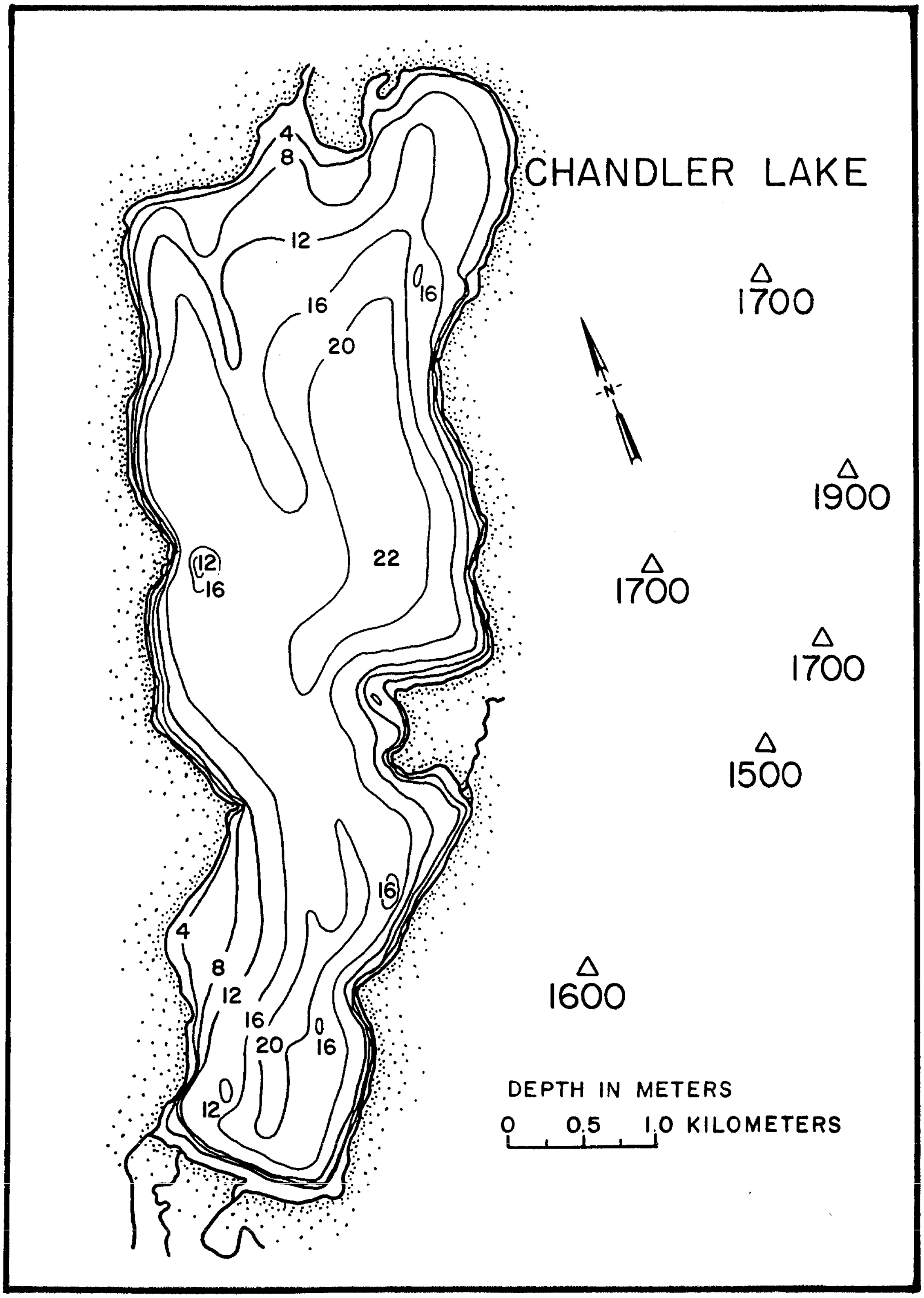

FIGURE 4.—Bathymetric map of Chandler Lake (Reanier and Anderson 1986).

Methods

Creel Survey

A creel survey was conducted in the spring of 1989. Seven one-day trips were made to the lakes by snowmobile between March 20 and April 16. An attempt was made to interview every angler. Data recorded from interviews included hours fished, target species, catch, and harvest. Length and weight measurements were recorded opportunistically.

In addition to interviews at the lakes, 18 households (from a total of 54) in Anaktuvuk Pass were visited and household members were interviewed between March 16 and April 11. Households were chosen arbitrarily at first, but later, as knowledge was gained of who the fishers were in town, interviews were directed at those households most likely to have fishers. Households members were asked if they fished, and if so, when and where they fished. They were also asked to rate changes in the fishery over time as: better, worse, same, or no opinion.

From interviews at the lakes and in Anaktuvuk Pass we estimated total catch (C) by species for the spring ice fishing season with the formula:

$$C = CPUE \times A \times D,$$

where, CPUE was mean catch per angler-hour, A was mean number of hours fished per angler per day on days when fishing took place, and D was the number of angler-days of fishing. CPUE and A were determined from observations and interviews at the lakes. Total number of angler-days (D) was estimated from interviews at the lakes and in Anaktuvuk Pass with the formula:

$$D = D_L + D_H ,$$

where, D_L was the number of angler-days determined from interviews at the lakes and D_H was angler-days recorded from household interviews that had not been documented at the lakes.

All interviews at the lakes were conducted prior to completion of the fishing trip; therefore, total angler-hours and mean angler hours per day were determined from anglers' estimated times of trip completion. Total harvest by species for the spring ice fishing season (H) was calculated by substituting HPUE for CPUE. Yield was calculated by multiplying total harvest by mean weight of the sample of fish harvested; the result was reported in weight per unit lake surface area.

Summer creel surveys were conducted during 1987 and 1989. The 1987 survey, conducted by field crews at the lakes, attempted to interview every angler from July 14 through September 13. Catch, harvest, effort, and target species were recorded from each angler; yield was calculated from the observed harvest. The 1989 survey consisted of eight overflights of the lake system between July 1 and August 20. Overflights took place on weekends, weather permitting.

Sampling Gear and Sites

In 1987, all six lakes in the system were sampled with monofilament gill nets. Two types of gill net sets were employed: one experimental gill net (45.7 m x 2.4 m with six 7.6 m panels of 1.3, 1.9, 2.5, 3.8, 5.1, and 6.3 cm bar meshes), and two of these nets attached in tandem. Nets were usually set perpendicular to shore with one end secured to shore and the other end anchored with a 3 kg weight. Nets were sometimes set parallel to shore (both ends anchored) along shoals to intercept fish moving between deep and shallow water.

In 1987, net sites were selected subjectively in an attempt to maximize catch: effort was concentrated in areas where catch rates seemed to be highest. Gill nets were monitored continuously to reduce mortalities. An important constraint of the study design was the requirement that total mortality not exceed 100 lake trout and 100 Arctic char over the duration of the project. This constraint was satisfied, with known net and angling mortalities totaling less than 30 fish of each species in each of Chandler and Amiloyak lakes.

Sampling was dispersed throughout the system in 1987, and effort was not equally distributed among lakes. Round and Little Chandler lakes and unnamed lakes 1 and 2 received relatively limited sampling. Six gill net sites were fished at Round Lake for 0.5 to 2 h each (Figure 5). Nine gill net sites were fished at Little Chandler Lake for 1 to 4 h each (Figure 5). Thirteen sites were fished at lake 1 and 7 sites at lake 2 for 0.5 h each (Figure 6).

Chandler and Amiloyak lakes were sampled more intensively than the other four lakes. Sampling at Chandler Lake was divided into two time periods, July 19 to August 14 (27 days), and August 15 to September 9 (26 days). Eighteen gill net sites were fished in the northern half of the lake and 40 sites were fished in the southern half for 0.5 to 8 h each (Figure 7). Areas adjacent to gill net sites were angled while nets were fishing. Amiloyak Lake was sampled from July 31 to August 20 with gill nets, rod and reel, and seines (45.7 m x 3.1 m, with 0.6 cm bar mesh). Gill nets were fished at sixteen sites, including four sites near the inlet, for 0.5 to 2 h each (Figure 8). All seining (8 hauls) and most of the angling effort (30 h) occurred in the inlet area.

In 1989, Amiloyak Lake was re-sampled, primarily to distribute effort throughout more of the lake for estimating lake trout and Arctic char population sizes. Sample dates were from July 27 to August 10. Multifilament gill nets (45.7 m x 2.4 m of 2.5 cm bar mesh) were set singly or in tandem. These "tooth nets" were intended to reduce mortalities by snagging larger fish by their teeth instead of gilling them (Williams 1966). Nets were set perpendicular to shore for 4 hour periods and were checked every hour. Gill net sites along the shoreline were selected randomly using a numbered grid of the lake. Fifty-five sites were fished, 28 in the northern half of the lake and 27 in the southern half (Figure 9). Areas adjacent to five gill net sites were angled for a total of 10 h of effort.

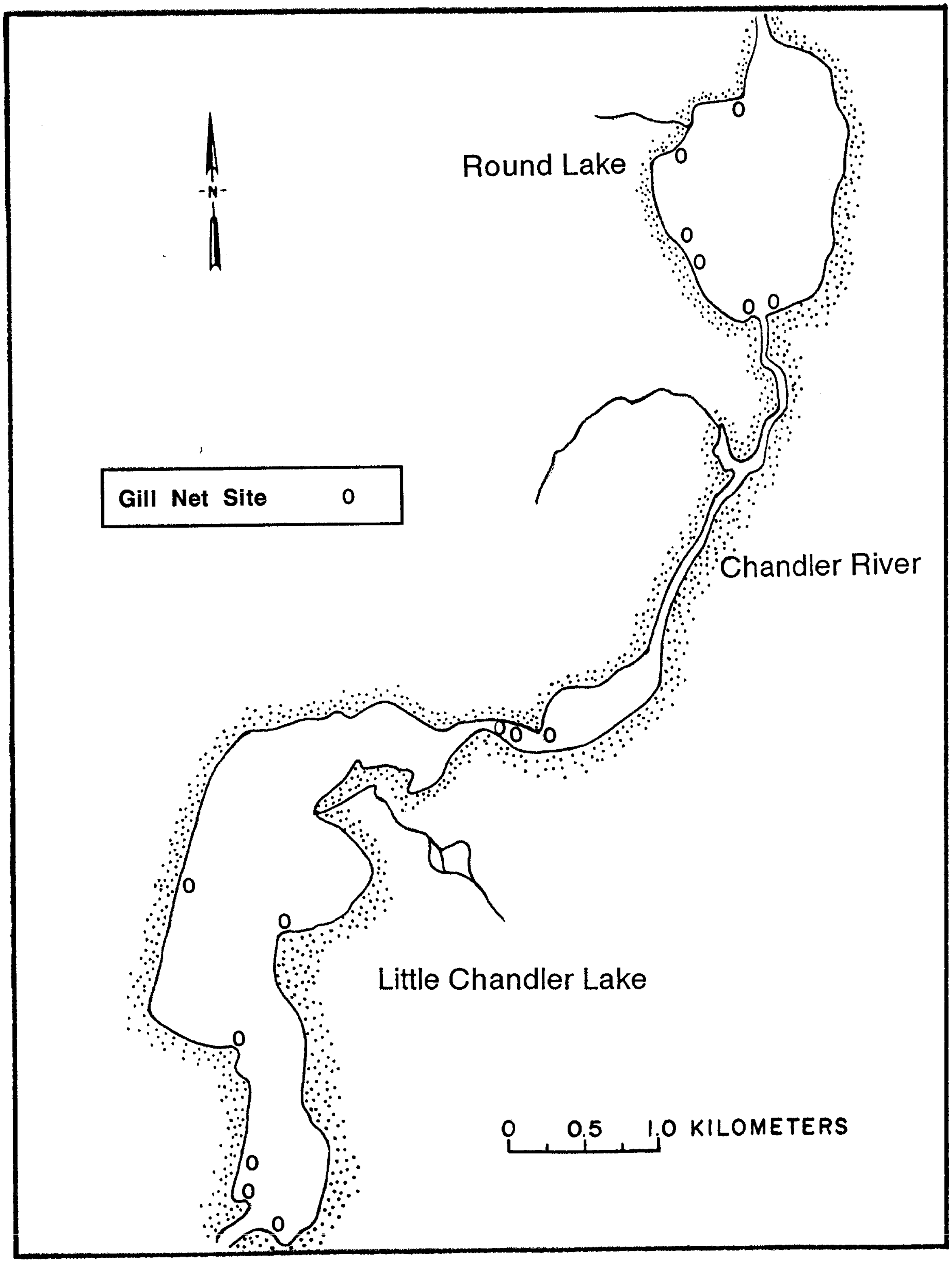

FIGURE 5.—Gill net sample sites for Little Chandler and Round lakes, 1987.

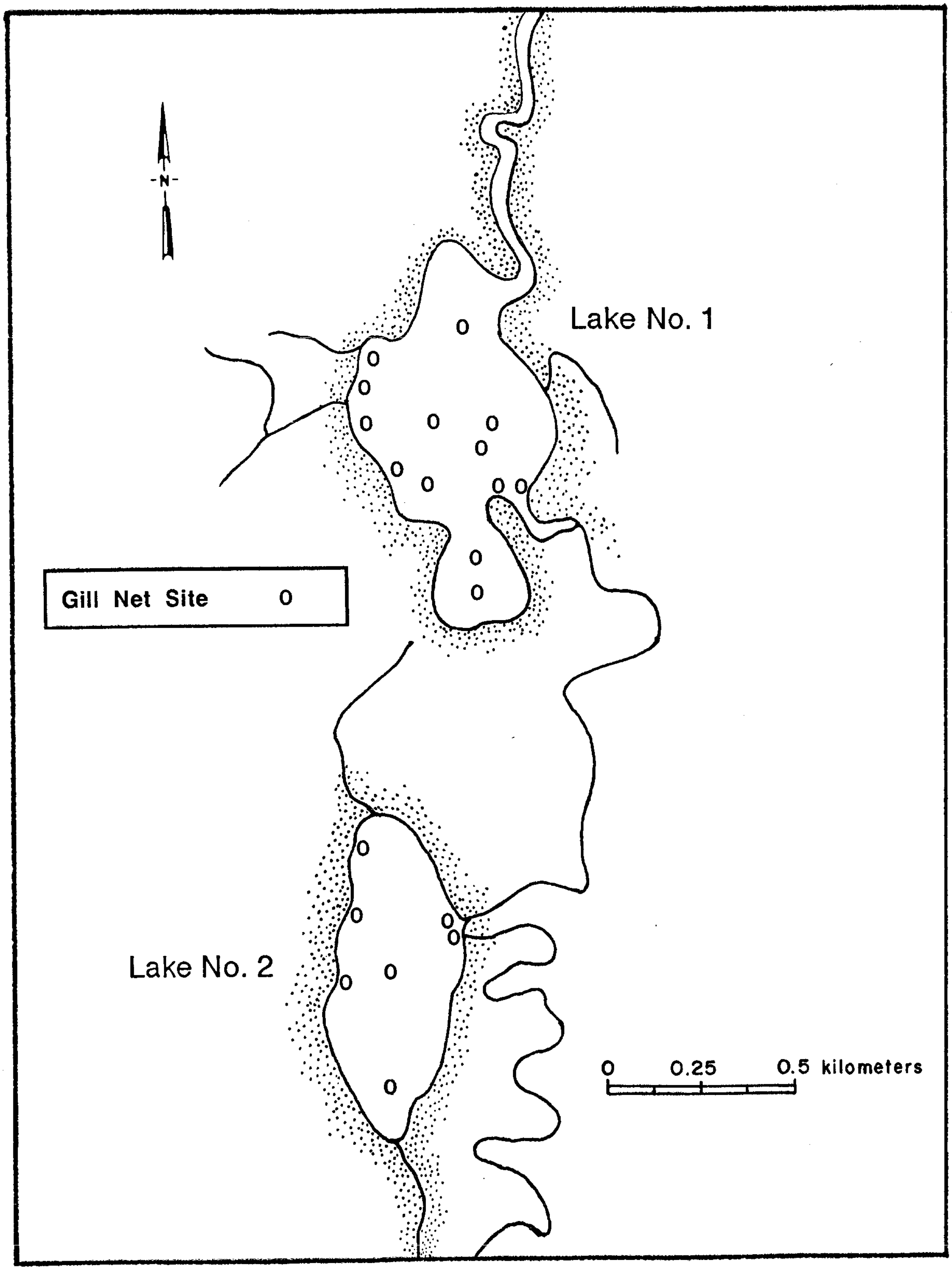

FIGURE 6.—Gill net sample sites for unnamed lakes 1 and 2, 1987.

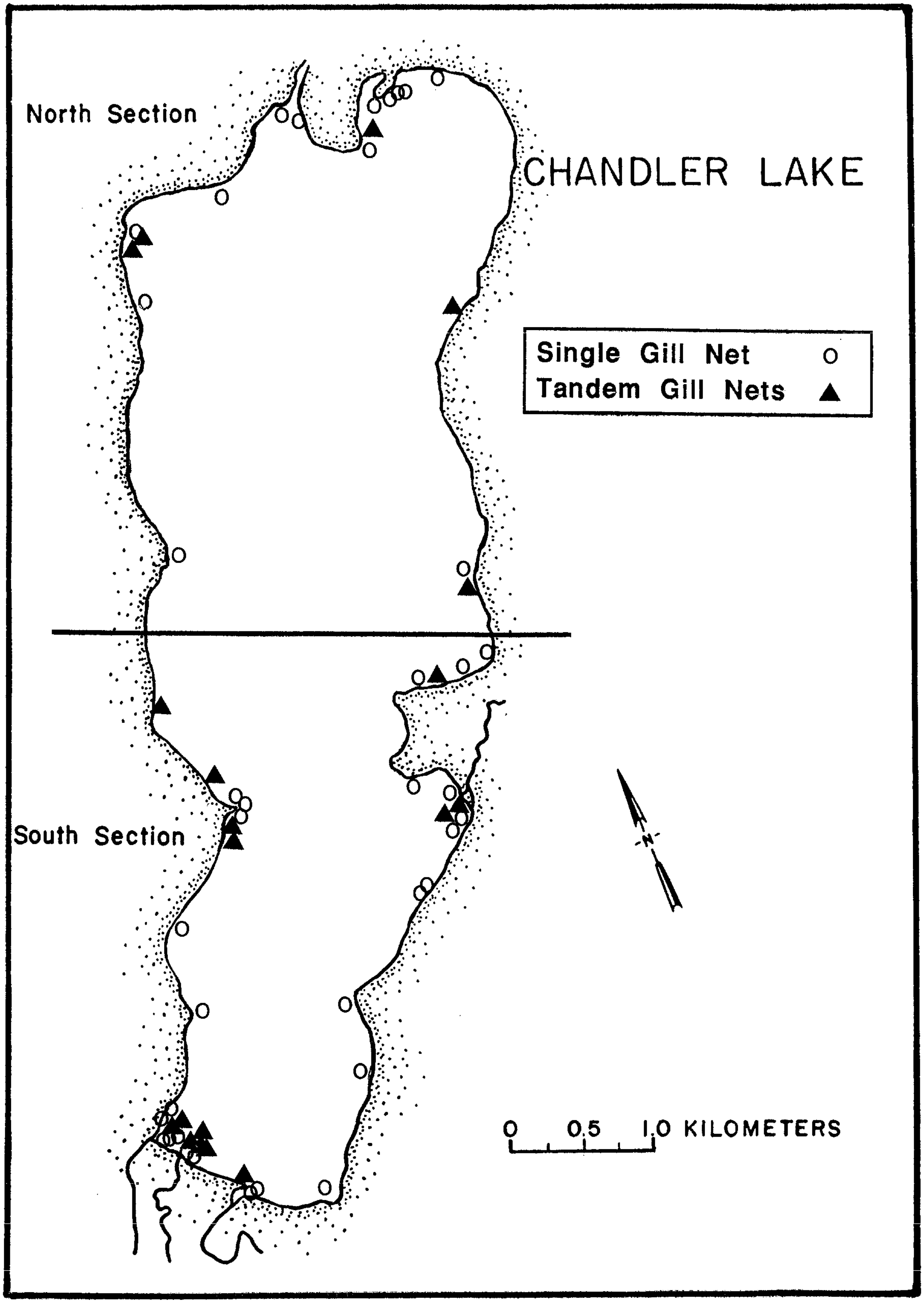

FIGURE 7.—Single and tandem gill net sample sites for Chandler Lake, 1987.

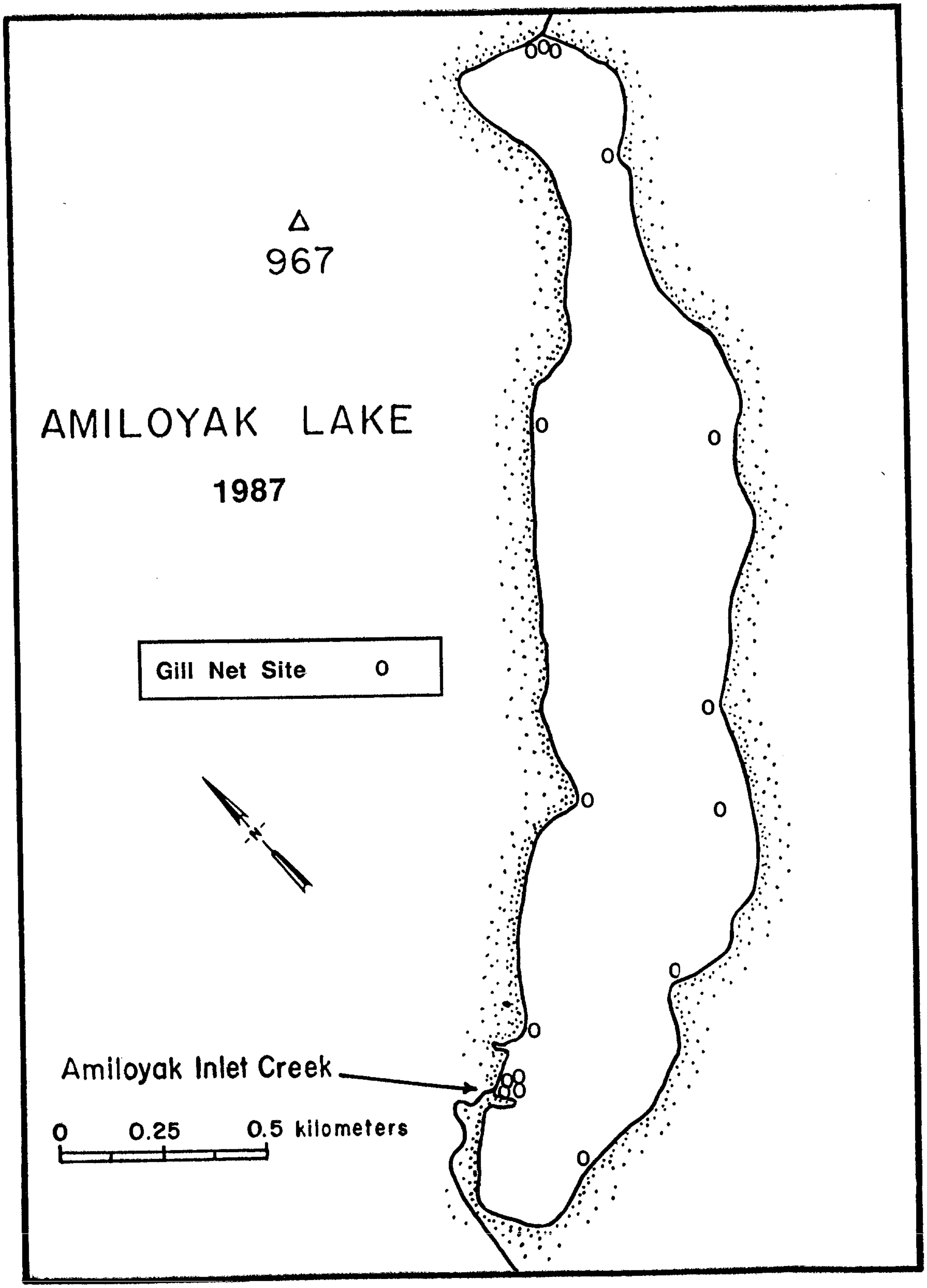

FIGURE 8.—Gill net sample sites for Amiloyak Lake, 1987.

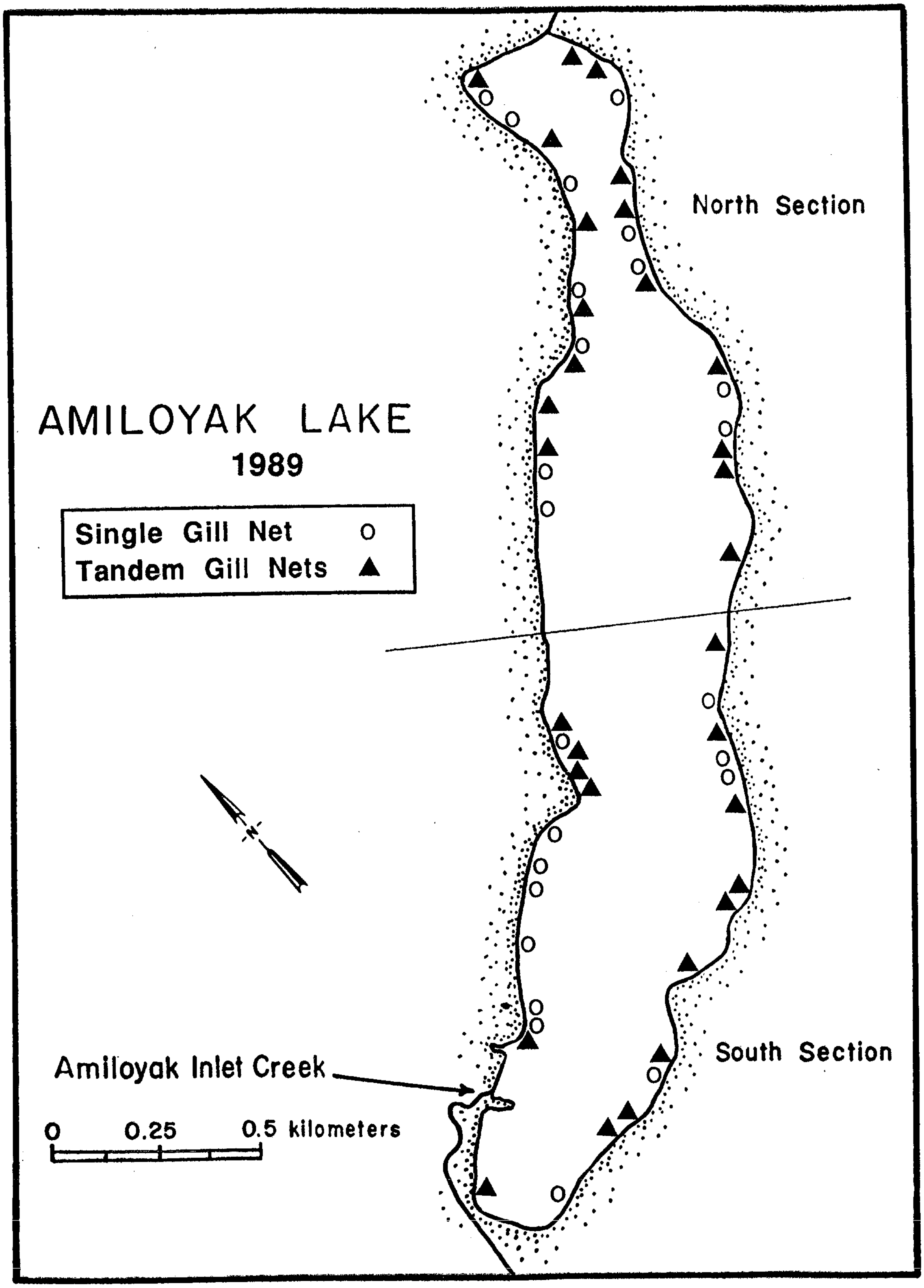

FIGURE 9.–Single and tandem gill net sample sites for Amiloyak Lake, 1989.

Relative Abundance

Relative abundance was estimated from gill net catches at Chandler Lake in 1987 and at Amiloyak Lake in 1989. Some net sets in 1987 were baited with salmon eggs and thus were not included in the relative abundance estimates. Gill net catch per hour for each stratum (KPUE) was calculated for adult (≥ 200 mm) lake trout and Arctic char using the equation:

$$KPUE = \frac{\sum_{j=1}^{n} K_j}{\sum_{j=1}^{n} h_j} ,$$

where, K_j was the catch by species per net from the jth sample, h_j was the number of hours fished per net during the jth sample and n was the number of samples per stratum. The strata were lake sections (north and south) and time periods (early and late summer). Mann-Whitney U tests[1] ($P = 0.05$) were used to test for differences in KPUE between lake sections and between time periods (Systat 1988).

Mean KPUE values were calculated by lake from unbaited gill net catches in 1987 at Little Chandler, Round, and Amiloyak lakes and unnamed lakes 1 and 2. The sampling effort in these lakes was insufficient for spacial and temporal comparisons of KPUE to be made.

Absolute Abundance

In 1987, lake trout and Arctic char less than 450 mm were tagged with gray Floy anchor tags, lake trout 450 mm or larger received yellow spaghetti tags, and Arctic char 450 mm or larger received either tag. In 1989, lake trout and Arctic char were marked in Amiloyak Lake using a hole punch in the lower lobe of the caudal fin. All fish marked in 1987 and 1989 received an adipose fin clip to monitor tag loss. An effort was made to minimize handling mortality by releasing only those fish which appeared to be in good condition. Handling mortality was assessed at Amiloyak Lake in 1989 by tethering lake trout and Arctic char on lines from 12 to 21 hours.

Population estimates for the catchable[1] populations of lake trout and Arctic char were calculated using a Schnabel multiple census technique with the Chapman modification (Ricker 1975). The Schnabel multiple census estimate of population size (N) was calculated with the formula:

$$N = \left(\frac{\sum (C_t M_t)}{R+1}\right) - 1 ,$$

[1]All statistical tests in this report were conducted with Systat software (Systat 1988).

[1]Minimum catchable size determined by smallest fish caught.

where, C_t was the total sample taken on day t, M_t was the total number of marked fish at large at the beginning of day t and R was the total number of recaptures during the experiment. R was treated as a Poisson variable for calculating 95% confidence intervals (Ricker 1975). Absolute abundance estimates were also reported as standing crop (number or weight of fish per unit lake surface area), based on mean weight by species in the gill net catches.

Population estimates were made by lake unless evidence of movement between lakes was found within a sampling season, in which case interconnected lakes were treated as a single body of water. For Amiloyak Lake, the tag and recapture data from random sampling in 1989 were used instead of the non-random sample in 1987.

Fish Movement

During gill netting at Amiloyak Lake in 1989, recaptures of lake trout and Arctic char tagged by the Department and by the U.S. Fish and Wildlife Service (Service) were used to document movement between lakes and estimate growth. Two hundred and twenty nine Arctic char were tagged by the Department in Amiloyak Lake in 1985; 296 Arctic char (222 in Amiloyak Lake) and 254 lake trout were tagged by the Service throughout the Chandler lake system in 1987.

Length, Weight, and Condition

Fork length (mm) and wet weight (g) were recorded from all lake trout and Arctic char captured. Fork length was measured to the nearest millimeter. Weights of fish were determined with Pesola® spring scales to different levels of precision depending on fish size. Fish weights between 0 and 500 g were measured to the nearest 5 g; weights between 500 g and 1 kg were measured to the nearest 10 g; weights between 1 and 2 kg were measured to the nearest 25 g; and weights greater than 2 kg were measured to the nearest 50 g.

Differences in mean lengths caught by different gear types were tested within lakes using Kruskall-Wallis tests and nonparametric Tukey multiple comparisons ($P = 0.05$) of samples with at least 30 fish per gear type. Length data which could be pooled among gear types for samples of more than 30 fish were also pooled for lakes where smaller samples were collected with the same gear types. Length data were then compared between lakes (for samples sizes > 30) with Kruskall-Wallis tests and nonparametric Tukey multiple comparisons ($P = 0.05$).

Weight-length relations for lake trout and Arctic char were described with the growth model:

$$W = aL^b ,$$

where, a and b are constants derived from regressing the logarithms (base 10) of wet weight (W) and fork length (L). Functional regression slopes and intercepts were estimated using geometric mean regression techniques (Ricker 1975). Analysis of covariance procedures (see below) were used to test for pooling 1987 and 1989 data from Amiloyak Lake, and pooling 1987 data from Chandler and Little Chandler lakes ($P = 0.05$).

Types of growth (isometric versus allometric) were determined with *t* tests of the hypothesis that $b = 3$, the slope for a population with isometric growth. Weight-length relations from this study were compared to lake trout and Arctic char populations from Walker Lake (Johnson and Troyer 1994). Analysis of covariance procedures for comparing weight-length regression lines were as follows: if sample variances were not significantly different between lakes, regression line coincidence was tested with a multiple regression model with dummy variables ($P = 0.05$); and if variances differed significantly, slopes and intercepts were compared with analysis of variance ($P = 0.05$; Kleinbaum and Kupper 1978). Differences among variances were determined with Levene's test ($P = 0.05$; Snedecor and Cochran 1980).

Relative condition was used to detect temporal changes in weight-length relations from Chandler Lake. Samples from other lakes were either too small or taken over too short a time-period to be analyzed for temporal changes. Relative condition factors (Kn) for lake trout and Arctic char from early and late sampling periods were calculated as follows (Anderson and Gutreuter 1983):

$$Kn = \frac{W}{aL^b} .$$

Mann-Whitney U tests ($P = 0.05$) were used to compare condition factors of fish caught on or before August 15 (approximately the midpoint of the ice-free season) and fish caught after August 15. Mann-Whitney U tests ($P = 0.05$) were also used to detect spatial differences in relative condition between early season samples from Chandler and Amiloyak lakes.

Age and Growth

Otoliths were obtained from net and angling mortalities, fish sacrificed, and sport-caught fish. Because otoliths were taken from all available mortalities, the age and growth sample was not necessarily representative of length frequency in the gill net catch. Sagittal otoliths from Arctic char and lake trout were aged by surface readings (Jearld 1983) and the break and burn method (Barber and McFarlane 1987). Otoliths were aged using indirect light at low magnification through dissecting microscopes. Ages were assigned based on two independent readings. A third reading was made of samples for which assigned ages disagreed and a final age was determined based on majority agreement.

Growth curves were fitted to mean lengths at age with the von Bertalanffy equation:

$$l_t = L_\infty\left(1-e^{-K(t-t_0)}\right),$$

where l_t is the length of a fish at time t, L_∞ is the asymptotic fork length, K is the Brody growth coefficient and t_0 is the hypothetical age the fish would have been at zero fork length if it had always grown in the manner described by the equation (Ricker 1975).

Food Habits

Stomach contents were collected from all lake trout and some of the Arctic char sacrificed in 1987 sampling at Chandler Lake. In addition, stomach contents were taken from some live fish with stomach pumps of the type described by Seaburg (1957) and Giles (1980). Food items were identified to order, except for fish, which were identified to species. Data are summarized as frequency of occurrence and percent by wet weight (Bowen 1983). Because few Arctic char stomachs were collected (N=13), percent by weight was not calculated.

Fecundity and Maturity

Estimates of fecundity for lake trout and Arctic char were determined by gravimetric enumeration (Snyder 1983). Body and gonad weights from fish sacrificed during 1987 sampling were used to calculate a gonadosomatic index (GSI) where gonad weight is expressed as a percentage of total body weight (Snyder 1983). Separate GSI values were calculated for male and female lake trout and Arctic char. Individual fish were assessed as non-ripening or ripening (would have spawned in year of capture) based on GSI information from other studies. Lake trout were considered to be in a ripening phase when GSI values were greater than 3.5% for females and 1.0% for males (Martin and Olver 1980). Arctic char were considered to be in a ripening phase when GSI values were greater than 2.5% for females and 2.0% for males (Hunter 1970). Ova diameters were measured by placing randomly selected ova on a 10 cm egg board and determining average diameter (Snyder 1983). Data were summarized for the Chandler lake system as a whole due to small sample sizes (< 10 fish of each sex) from individual lakes.

Physical and Chemical Sampling

Surface readings of water temperature, dissolved oxygen, and Secchi transparency were recorded at Chandler Lake in 1987 during the months of July, August, and September at areas corresponding to the deepest parts of the north and south sections. Additional surface measurements made at those sites in July and August included alkalinity, hardness, pH, and conductivity. Round, Little Chandler, and Amiloyak lakes were each sampled during August, 1987 at a site estimated to be in the center of the lake. Alkalinity, total hardness, and pH were measured using a Hach® Model FF-1 water chemistry kit. Dissolved oxygen and water temperature were determined using a Yellow Springs Instrument® Model 54A oxygen-temperature meter. A Secchi disk was used to determine the depth of transmitted light. Conductivity was measured using a Hach® Model 17250 mini-conductivity meter.

Results

Creel Survey

Anglers from Anaktuvuk Pass were present at Chandler Lake during four of the seven one-day surveys made between March 20 and April 16, 1989. Estimated total effort was 206 angler-hours for 25 angler-days of fishing (Table 1), an average of 8.3 hours per angler per day. Anglers had caught 26 lake trout and 30 Arctic char at the time of interview. All fish caught were harvested.

An additional nine angler-days of effort were discovered in household interviews. Including the additional angler-days, total effort was estimated at 281 hours. At the catch rates of 0.202 fish/h and 0.234 fish/h from interviews at the lakes (Table 1), estimates of total catch were 57 lake trout and 66 Arctic char. No Arctic grayling were reported in the catch. Mean weight and length of lake trout harvested was 874 g and 481 mm, and for Arctic char 767 g and 451 mm. Estimated yield of lake trout was 0.03 kg/hectare and for Arctic char 0.03 kg/hectare considering Chandler and Little Chandler lakes as one body of water (see *Fish Movement*, below).

All fishing (observed and reported) occurred at Chandler Lake between March 3 and April 15 and was presumed to be subsistence harvest. No fishers were observed at other lakes in the system. During this 44-day period, anglers were present on 25% of the days. Eighty-eight percent of the fishing effort took place on weekends. All anglers interviewed indicated Arctic char as a target species. Seventy-two percent of the households contacted said they have fished at Chandler Lake during the spring ice fishery, and 33% said they have ice fished during the fall (October through early November).

Fourteen households responded to questions regarding changes in the quality of the fishery over time. Seven percent thought the fishery had improved, 29% thought the fishery had declined, 29% thought the fishery was the same, and 35% had no opinion. A good day's catch was considered to range from two to 20 fish.

Overflights of the lake system were made on July 1, 8, 22, 29 and August 5, 12, 19, and 20 in 1989. No anglers were observed.

Anglers were present at the Chandler lake system on 8% of the days during the 1987 summer creel survey. Twelve unguided recreational anglers fished 71 angler-hours catching seven lake trout and 17 Arctic grayling at Chandler Lake; and eight unguided anglers fished 60 angler-hours catching three lake trout and one Arctic grayling at Round Lake. All anglers at Chandler Lake were from Fairbanks, whereas the one group of anglers at Round Lake was from Anaktuvuk Pass. All lake trout and all but two Arctic grayling caught were harvested. Summer yield of lake trout from Chandler Lake (including Little Chandler Lake) was 0.004 kg/hectare, and 0.02 kg/hectare from Round Lake assuming an average fish weight[1] of

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[1]Average lake trout weight in the 1989 spring ice fishing survey. Weights not taken in 1987 summer survey.

TABLE 1.—Summary of creel survey data collected during the subsistence ice fishery at Chandler Lake, 1989.

Date	Number of anglers	Angler-hours at time of interview	Estimated total angler-hours	Lake trout		Arctic char	
				Observed Catch	CPUE (fish/h)	Observed Catch	CPUE (fish/h)
3/20	0	---	---	---	---	---	---
3/25	0	---	---	---	---	---	---
4/8	2	18.6	18.6	0	0	0	0
4/9	10	46.5	79.4	12	0.258	18	0.387
4/10	2	13.4	24.0	3	0.224	7	0.522
4/15	11	49.9	84.4	11	0.220	5	0.100
4/16	0	---	---	---	---	---	---
Total	25	128.4	206.4	26	0.202	30	0.234

874 g. All anglers were interviewed after completed fishing trips, had fished from shore, and indicated lake trout and Arctic grayling as target species.

Relative Abundance

Chandler Lake was sampled at 58 sites for a total of 89 hours with unbaited gill nets in 1987. Ninety lake trout and 51 Arctic char were captured. Significant differences in KPUE between lake sections or sampling seasons were not detected ($P > 0.05$) for lake trout (Table 2) or Arctic char (Table 3). Catches of other species in Chandler Lake were 39 Arctic grayling and 117 round whitefish.

Amiloyak Lake was sampled at 55 sites for a total of 217 hours with unbaited gill nets in 1989. Thirty-eight lake trout and 279 Arctic char were captured. Significant differences in KPUE between lake sections were not detected ($P > 0.05$) for lake trout in Amiloyak Lake (Table 2). Tandem gill net KPUE of Arctic char differed significantly ($P < 0.05$) between the north and south sections of Amiloyak Lake, with KPUE almost three times higher in the south section (Table 3). Catches of other species in Amiloyak Lake were 115 Arctic grayling and 388 round whitefish.

Gill net sampling in 1987 of Little Chandler, Round, and Amiloyak lakes, and lakes 1 and 2 was relatively limited, with 6 - 16 sites and 4.5 - 12.6 hours of effort per lake (Table 4). Lake trout KPUE was highest in Little Chandler Lake (2.17 fish/h) and lowest in Amiloyak Lake (0.55 fish/h). Arctic char KPUE was highest in Amiloyak Lake (5.94 fish/h) and lowest in Round Lake and Lake 2 (0 fish/h). Variability among sites was high with KPUE standard deviations exceeding the means for most lakes.

Seining and angling at Amiloyak Lake in 1987 targeted a large group of Arctic char seen holding in the inlet area during August. The catch rate of Arctic char in eight seine hauls was 11.2 fish/haul. The catch rate in 30 h of angling effort at the inlet was 2.7 fish/angler-hour.

Absolute Abundance

The Schnabel population estimate for lake trout (≥ 234 mm) in Chandler and Little Chandler lakes was 1,737 fish (95% confidence interval, 1,090 - 3,524), based on a total of 243 fish captured (200 marked, 13 recaptured). Chandler and Little Chandler were considered one body of water for the population estimate because we documented within season movement of lake trout between the lakes. The standing crop of lake trout was estimated at 1.07 fish/hectare or 1.41 kg/hectare. Arctic char captures in Chandler and Little Chandler lakes were less frequent and no population estimate could be made (97 captured, 72 tagged, 0 recaptured).

The Schnabel population estimate for Arctic char (≥ 225 mm) in Amiloyak Lake was 2,030 fish (95% confidence interval, 1,295 - 3,352), based on a total of 317 fish captured (228 marked, 17 recaptured). The standing crop of Arctic char was estimated at 20.30 fish/hectare or 31.47 kg/hectare. Few lake trout were captured and their numbers were too small for a reliable population estimate to be made (39 fish tagged, one recaptured). Population estimates were not possible for lake trout and Arctic char in other lakes in the system because few fish were tagged and none were recaptured.

TABLE 2.—Gill net catch per hour (KPUE) for lake trout during early (July 19 - August 15) and late (August 16 - September 9) season sampling at Chandler and Amiloyak lakes, 1987 and 1989. Significant differences were not detected ($P > 0.05$) between seasons or sections within each gear type.

Section	Number of sites		Effort (h)		Number captured		KPUE	
	Early	Late	Early	Late	Early	Late	Early	Late
				Chandler Lake 1987[a]				
Combined	21	18	27.14	27.95	18	22	0.66	0.79
North	6	7	10.25	4.25	9	8	0.88	1.88
South	15	11	16.98	23.71	9	14	0.53	0.59
				Chandler Lake 1987[b]				
Combined	5	14	12.00	21.95	22	28	1.83	1.28
North	2	3	9.00	4.08	15	7	1.67	1.72
South	3	11	3.00	17.87	7	21	2.33	1.18
				Amiloyak Lake 1989[c]				
Combined	24	---	96.25	----	12	---	0.12	----
North	12	---	47.75	----	6	---	0.13	----
South	12	---	48.50	----	6	---	0.12	----
				Amiloyak Lake 1989[d]				
Combined	31	---	124.32	----	26	---	0.21	----
North	16	---	64.07	----	17	---	0.27	----
South	15	---	60.25	----	9	---	0.15	----

[a]One 45.7 m experimental gill net.
[b]Two 45.7 m experimental gill nets used in tandem.
[c]One 45.7 m multifilament gill net.
[d]Two 45.7 m multifilament gill nets used in tandem.

TABLE 3.—Gill net catch per hour (KPUE) for Arctic char during early (July 19 - August 15) and late (August 16 - September 9) season sampling at Chandler and Amiloyak lakes, 1987 and 1989. Asterisks indicate significant differences ($P < 0.05$) between seasons or sections within each gear type.

Section	Number of sites		Effort (h)		Number captured		KPUE	
	Early	Late	Early	Late	Early	Late	Early	Late
Chandler Lake 1987[a]								
Combined	21	18	27.14	27.96	5	13	0.18	0.46
North	6	7	10.25	4.25	1	0	0.10	0
South	15	11	16.89	23.71	4	13	0.24	0.55
Chandler Lake 1987[b]								
Combined	5	14	12.00	21.95	16	17	1.33	0.77
North	2	3	9.00	4.08	0	0	0	0
South	3	11	3.00	17.87	16	17	5.33	0.95
Amiloyak Lake 1989[c]								
Combined	24	---	96.25	----	69	---	0.72	----
North	12	---	47.75	----	18	---	0.38	----
South	12	---	48.50	----	51	---	1.05	----
Amiloyak Lake 1989[d]								
Combined	31	---	124.32	----	210	---	1.69	----
North	16	---	64.07	----	58	---	0.91*	----
South	15	---	60.25	----	152	---	2.52*	----

[a]One 45.7 m experimental gill net.
[b]Two 45.7 m experimental gill nets used in tandem.
[c]One 45.7 m multifilament gill net.
[d]Two 45.7 m multifilament gill nets used in tandem.

TABLE 4.—Gill net catch per hour (KPUE) for lake trout and Arctic char from 1987 sampling of Little Chandler, Round, and Amiloyak lakes, and unnamed lakes 1 and 2.

			Lake trout			Arctic char		
				KPUE (fish/h)			KPUE (fish/h)	
Lake	Number of sites	Effort (h)	Catch	Mean	SD	Catch	Mean	SD
Little Chandler	9	12.00	26	2.17	3.34	1	0.08	0.84
Round	6	11.74	18	1.53	1.24	0	0	---
#1	13	7.00	9	1.29	1.59	2	0.29	0.78
#2	7	4.50	8	1.78	1.42	0	0	---
Amiloyak	16	12.63	7	0.55	0.80	75	5.94	11.98

Five lake trout (13% of the total catch) and 16 Arctic char (5% of the total catch) caught in Amiloyak Lake were held an average of 20 hours each to assess handling mortality. One lake trout and one Arctic char died, for handling mortality rates of 20% and 6%, respectively. None of the lake trout or Arctic char recaptured were missing tags or caudal hole punch marks.

Fish Movement

Nine of the 13 lake trout recaptured in Chandler and Little Chandler lakes in 1987 were recaptured in the same area where they were tagged (Appendix 1). Three fish moved from the south end of Little Chandler Lake into the north end of Chandler Lake. One fish moved about 0.5 km east along the north shore of Chandler Lake.

Sampling of Amiloyak Lake in 1987 was concentrated mainly near the inlet; 18 of the 23 Arctic char recaptured were caught in the inlet area, where they had been tagged (Appendix 2). Four fish were recaptured within 1 km of the inlet tagging site. One fish was recaptured at the inlet after having been tagged at the outlet.

Movement of Arctic char between Chandler and Amiloyak lakes was not found within season but did occur between years. One Arctic char, tagged during the summer of 1987 at the south end of Chandler Lake, was recaptured in Amiloyak Lake in 1989. This fish traveled 13 km up Amiloyak Creek against a gradient of 2 m/km. Another Arctic char, tagged in 1987 along the west shoreline of Amiloyak Lake was recaptured in Chandler Lake by a subsistence fisherman in April, 1992 (Patty Rost, National Park Service, Fairbanks, personal communication).

Length, Weight, and Condition

Fish length did not differ significantly between angling and gill net catches ($P > 0.5$) for the three samples of sufficient size to be tested (Chandler Lake lake trout and 1987 and 1989 samples of Amiloyak Lake Arctic char). The mean length of Arctic char caught in seines differed significantly ($P < 0.05$) from catches by other gear types used at Amiloyak Lake in 1987. Seine data were therefore grouped separately and angling and gill net data were pooled within each lake for summarizing length and weight (Table 5). Pooled gill net and angling catches of Arctic char from Amiloyak Lake did not differ significantly in length between 1987 and 1989 ($P > 0.5$); however, greater mean length was found in the seine catch, which differed significantly from both 1987 and 1989 pooled gill net/angling samples ($P < 0.05$).

Lake trout from Chandler and Little Chandler lakes differed significantly in length ($P < 0.001$), with greater mean size found at Little Chandler Lake (Table 5, Figure 10). The 1989 Amiloyak Lake sample averaged 424 mm, which differed significantly from mean lengths of 462 mm and 510 mm at Chandler and Little Chandler lakes ($P < 0.001$), respectively. Arctic char mean length was smallest at Chandler Lake (398 mm) and differed significantly from the three samples from Amiloyak Lake (Table 5, Figure 11).

Weight-length relationships for lake trout did not differ significantly between Chandler and Little Chandler lakes ($P > 0.4$); therefore, the data were pooled. Data were also pooled for Arctic char although small sample size at Little Chandler Lake (one fish) precluded a statistical analysis for pooling. Weight-length data from the 1987 and 1989 samples from Amiloyak Lake could not be pooled for Arctic char ($P < 0.001$), and therefore were also not pooled for lake trout (small sample size precluded testing). Arctic char had generally less weight at a given length in the 1987 sample (Figure 12), most of which was collected from

TABLE 5.—Length and weight statistics of lake trout and Arctic char caught in the Chandler lake system, 1987 and 1989. For each species, fork length means without a letter in common (for sample sizes > 30) are significantly different ($P < 0.05$).

Lake	N	Length (mm)			Weight (kg)		
		Mean	SD	Range	Mean	SD	Range
Lake trout							
Chandler	189	462 x	102	234 - 865	1.25	1.36	0.12 - 8.50
Little Chandler	40	510 y	79	398 - 754	1.60	1.00	0.63 - 5.30
Round	25	491	114	354 - 880	1.44	1.49	0.43 - 7.75
#1	10	464	49	397 - 549	0.98	0.29	0.57 - 1.50
#2	10	408	35	360 - 476	0.67	0.17	0.46 - 1.00
Amiloyak[a]	17	428	52	365 - 593	0.79	0.26	0.44 - 1.55
Amiloyak[b]	0	---	--	---	---	---	---
Amiloyak[c]	39	424 z	44	348 - 601	0.76	0.27	0.40 - 2.00
Arctic char							
Chandler	96	398 x	103	158 - 557	0.84	0.50	0.05 - 1.85
Little Chandler	1	452	---	---	1.05	---	---
Round	2	404	115	322 - 485	0.90	0.80	0.33 - 1.47
#1	2	522	39	494 - 549	1.56	0.37	1.30 - 1.83
#2	0	---	--	---	---	---	---
Amiloyak[a]	164	497 y	50	293 - 615	1.44	0.38	0.28 - 2.90
Amiloyak[b]	81	514 z	46	382 - 587	1.55	0.36	0.55 - 2.10
Amiloyak[c]	300	496 y	63	225 - 635	1.55	0.50	0.11 - 3.15

[a]1987 pooled sample from angling and experimental gill nets (45.7 m x 2.4 m with equal panels of 1.3, 1.9, 2.5, 3.8, 5.1, and 6.3 cm bar mesh).
[b]1987 sample from seines (45.7 m x 3.1 m with 0.6 cm bar mesh).
[c]1989 pooled sample from angling and experimental gill nets (45.7 m x 2.4 m with equal panels of 1.3, 1.9, and 2.5 cm bar mesh, fished in tandem with gill net 45.7 m x 2.4 m with 3.8 cm bar mesh).

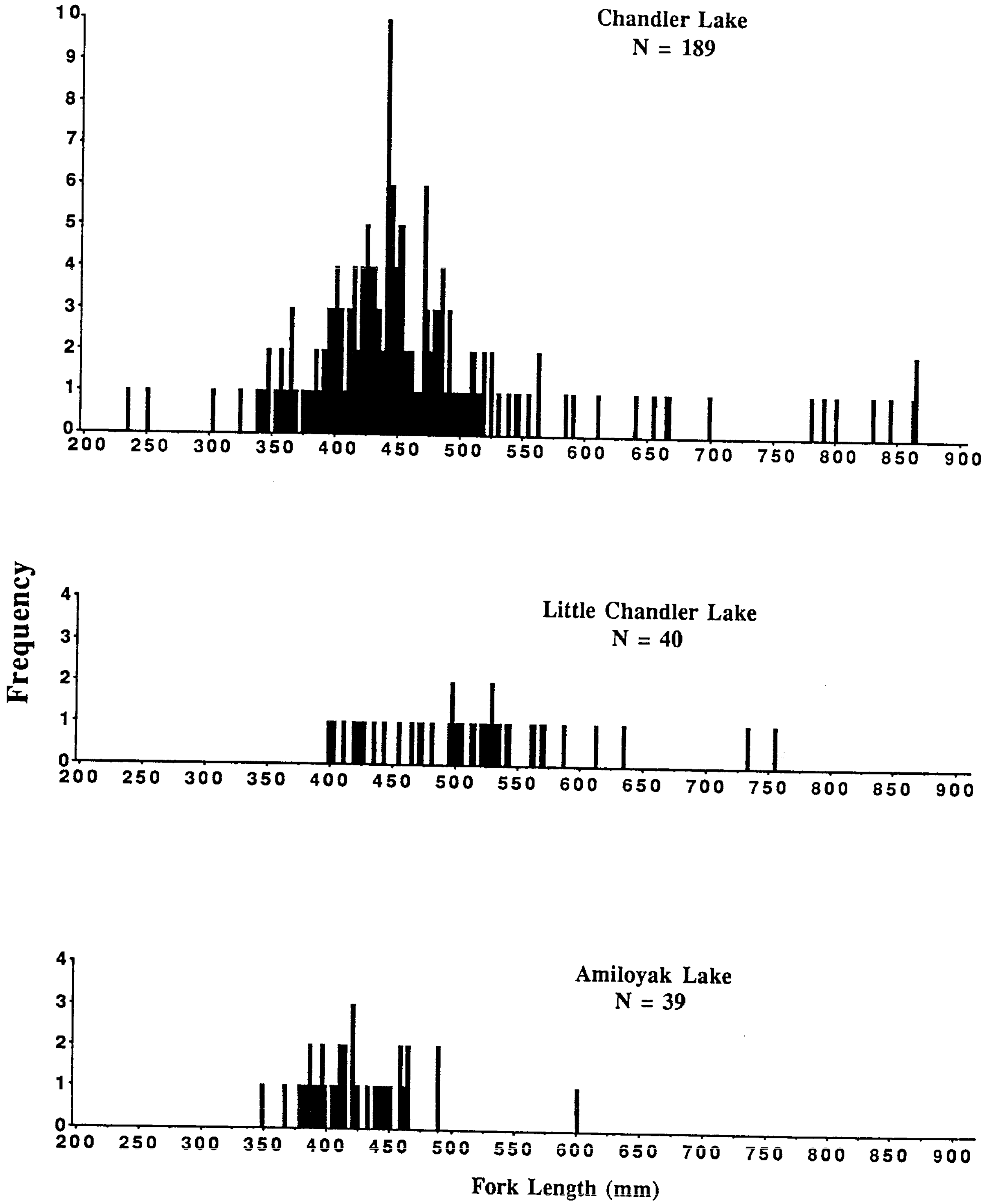

FIGURE 10.—Length frequency of lake trout from angling and experimental gill net catches (pooled data) at Chandler and Little Chandler lakes in 1987 and Amiloyak Lake in 1989.

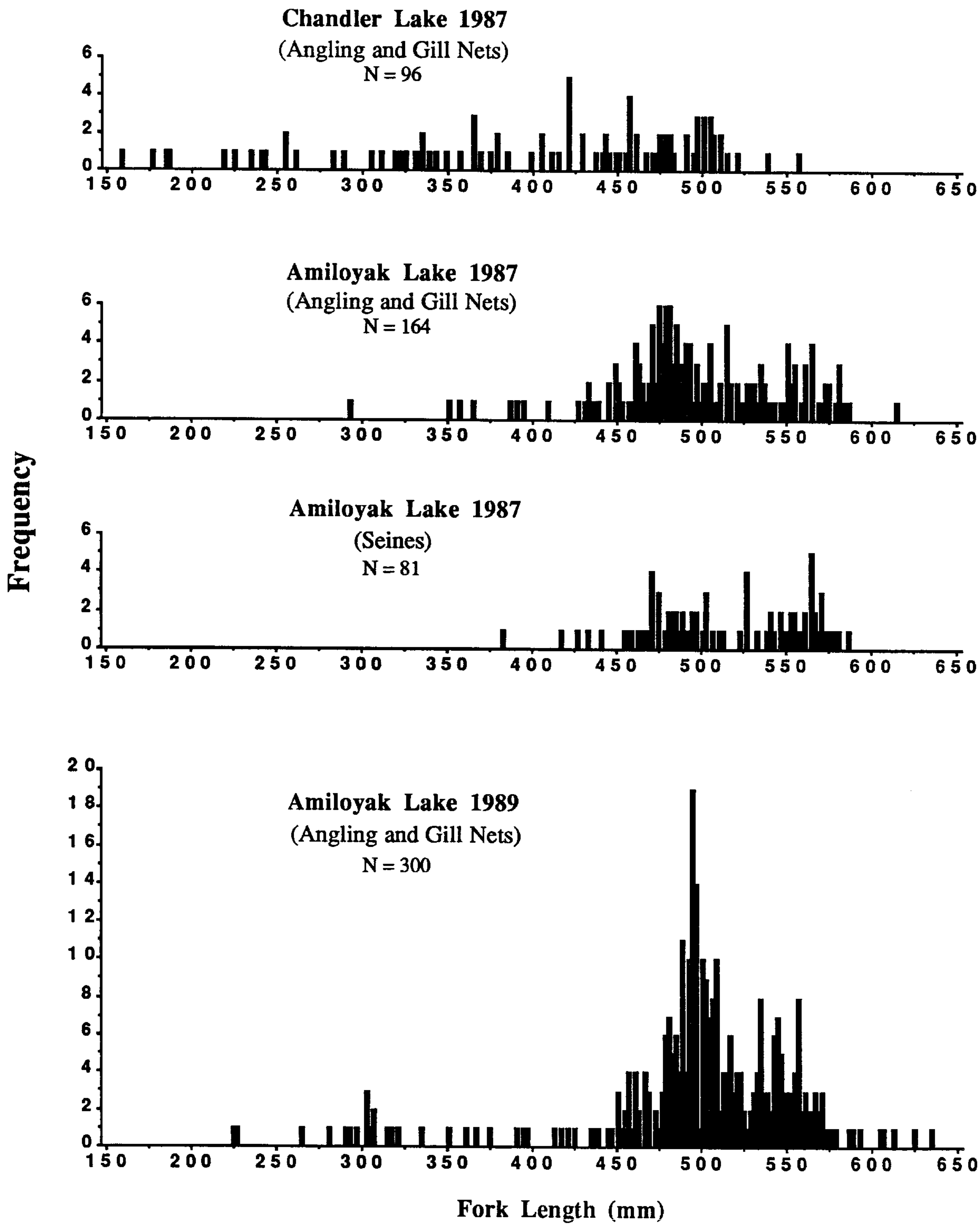

FIGURE 11.—Length frequency of Arctic char caught in different gear types at Chandler Lake in 1987 and Amiloyak Lake in 1987 and 1989.

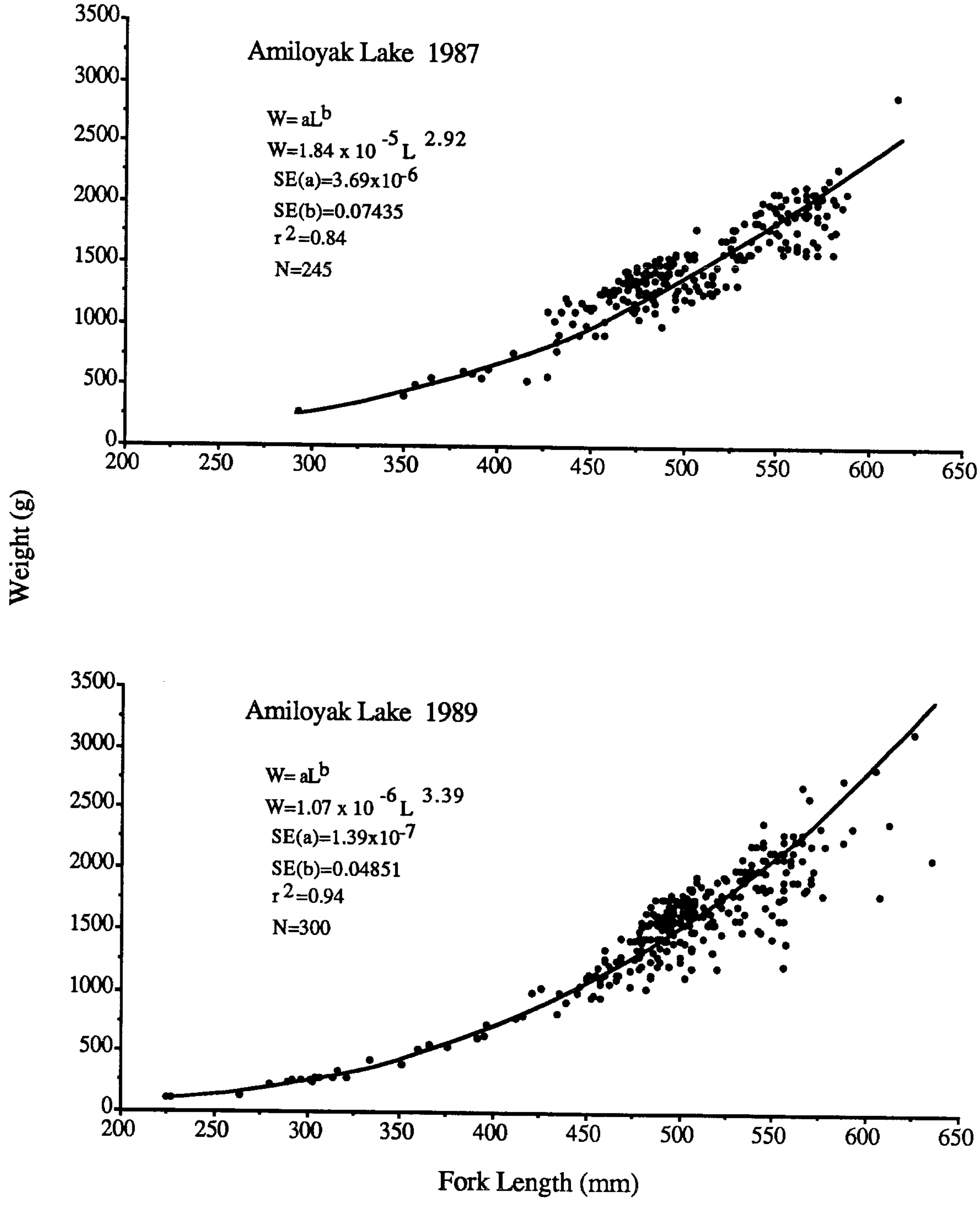

FIGURE 12.—Weight-length relations for Arctic char collected from Amiloyak Lake during 1987 and 1989.

near the inlet. The 1989 sample was random and was therefore selected in favor of the 1987 sample for comparing Amiloyak Lake to other lakes.

Lake trout and Arctic char exhibited allometric growth at Chandler Lake (b = 3.28 and 3.33), as did Arctic char at Amiloyak Lake (b = 3.39; $P < 0.05$; Figures 12,13, and 14). Allometric growth was not indicated for lake trout at Amiloyak Lake (b = 3.06; $P > 0.50$), probably because of the limited range of lengths in this small sample (N = 39). Coefficients of determination (r^2) for the fitted regression lines ranged from 0.91 to 0.99.

Weight-length relations for lake trout did not differ significantly between Chandler and Amiloyak lakes ($P > 0.05$). Comparing the lake trout weight-length relations to a population in the southern Brooks Range (Figure 15), Chandler Lake differed significantly from Walker Lake ($P < 0.005$), but Amiloyak Lake did not differ significantly from Walker Lake ($P > 0.30$). Weight-length relations for Arctic char did not differ significantly between Walker, Chandler, and Amiloyak lakes ($P > 0.05$; Figure 16).

Relative condition factors did not differ significantly between early and late season for lake trout ($P > 0.50$) or Arctic char ($P > 0.05$) from Chandler Lake (Table 6). Spatial differences in relative condition factor were not detected between early season samples from Chandler and Amiloyak lakes ($P > 0.30$ for lake trout; $P > 0.50$ for Arctic char).

Three juvenile Arctic char (159 - 184 mm) were caught in Chandler Lake using gill nets. One was caught at the mouth of Iklauyaurak Creek and two at the mouth of Kollutarak Creek.

Five Arctic char tagged in 1985 and 11 tagged in 1987 were recaptured in Amiloyak Lake in 1989 (Table 7). Recaptured fish ranged from 446 to 625 mm in length. Arctic char lengths increased an average of 4.2 mm per year (negative values not included; Table 7). Five of the eleven fish tagged in 1987 and recaptured in 1989 had lost weight over the two year period. Average weight loss was 90 g per year, and average weight gain was 87 g per year.

Age and Growth

Ages were determined for 23 lake trout and 29 Arctic char from Chandler Lake (including Little Chandler Lake) and 27 Arctic char from Amiloyak Lake. Lake trout from Chandler Lake ranged from 12 to 28 years with corresponding mean lengths of 390 to 478 mm; Table 8). Arctic char ranged from 4 to 15 years (mean lengths from 190 to 475 mm) in the Chandler Lake sample, and from 5 to 19 years (mean lengths from 334 to 535 mm) in the Amiloyak Lake sample (Tables 9 and 10).

Lake trout from Chandler Lake exhibited slow growth, averaging about 6 mm per year between ages 12 and 28 (Figure 17). The asymptotic length from the von Bertalanffy curve (489 mm) is substantially smaller than the largest fork length recorded in the full sample of lake trout from Chandler Lake (865 mm). Arctic char from Chandler Lake exhibited faster growth up to approximately age 8 and a smaller asymptotic length than the Amiloyak Lake population (Figure 18). Asymptotic lengths for Arctic char from Chandler (490 mm) and Amiloyak (597 mm) lakes are smaller than the largest sizes sampled (557 and 635 mm respectively).

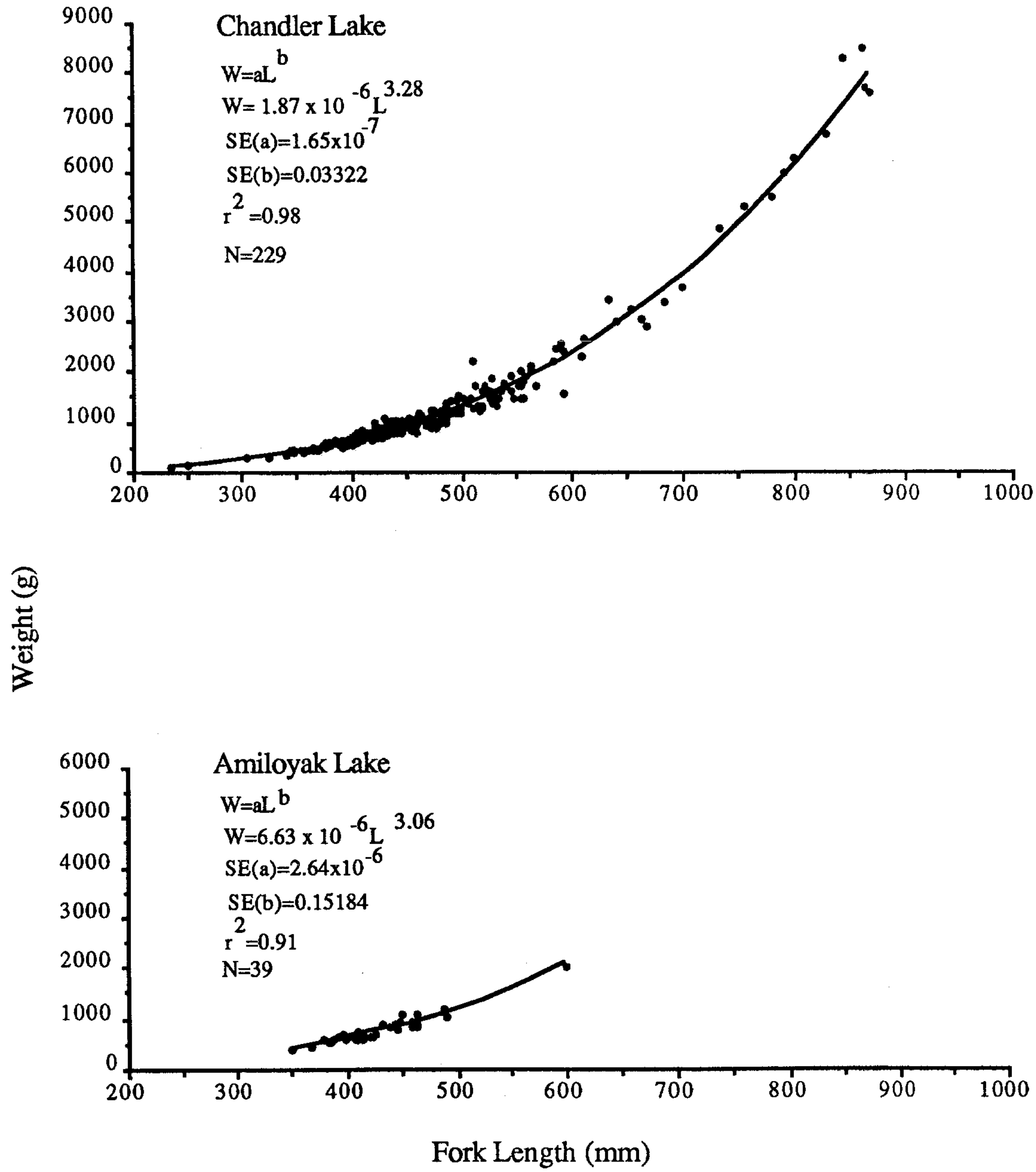

FIGURE 13.—Weight-length relations for lake trout collected from Chandler Lake (including Little Chandler Lake) in 1987 and Amiloyak Lake in 1989.

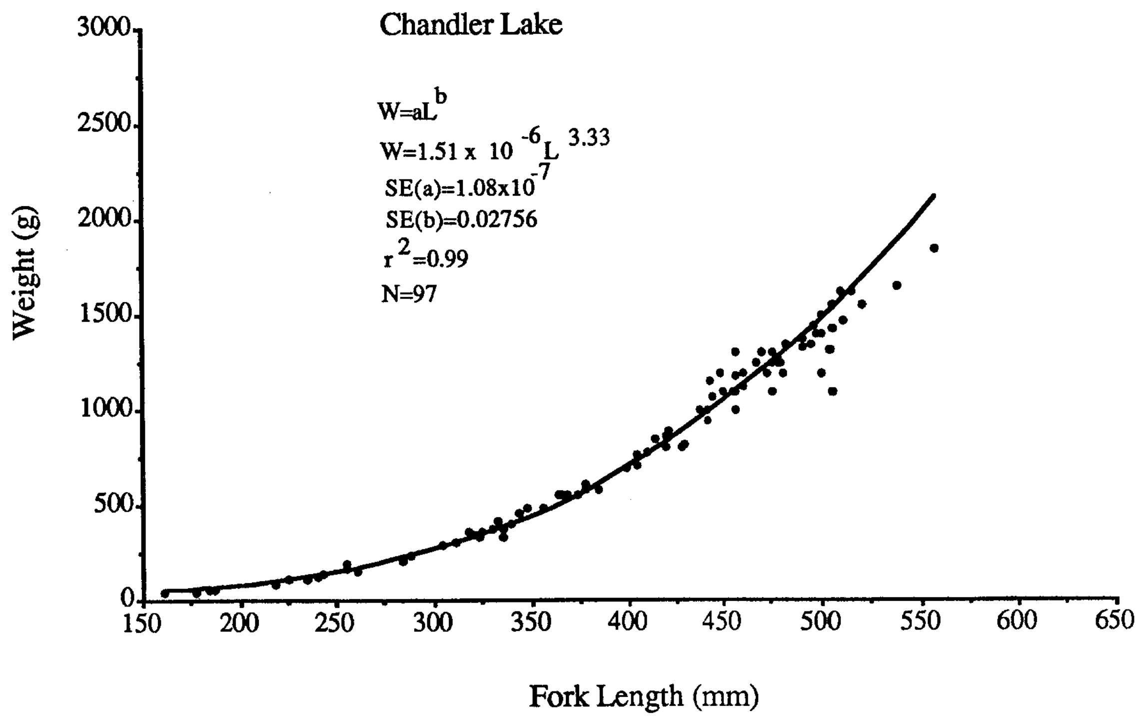

FIGURE 14.—Weight-length relations for Arctic char collected from Chandler Lake in 1987.

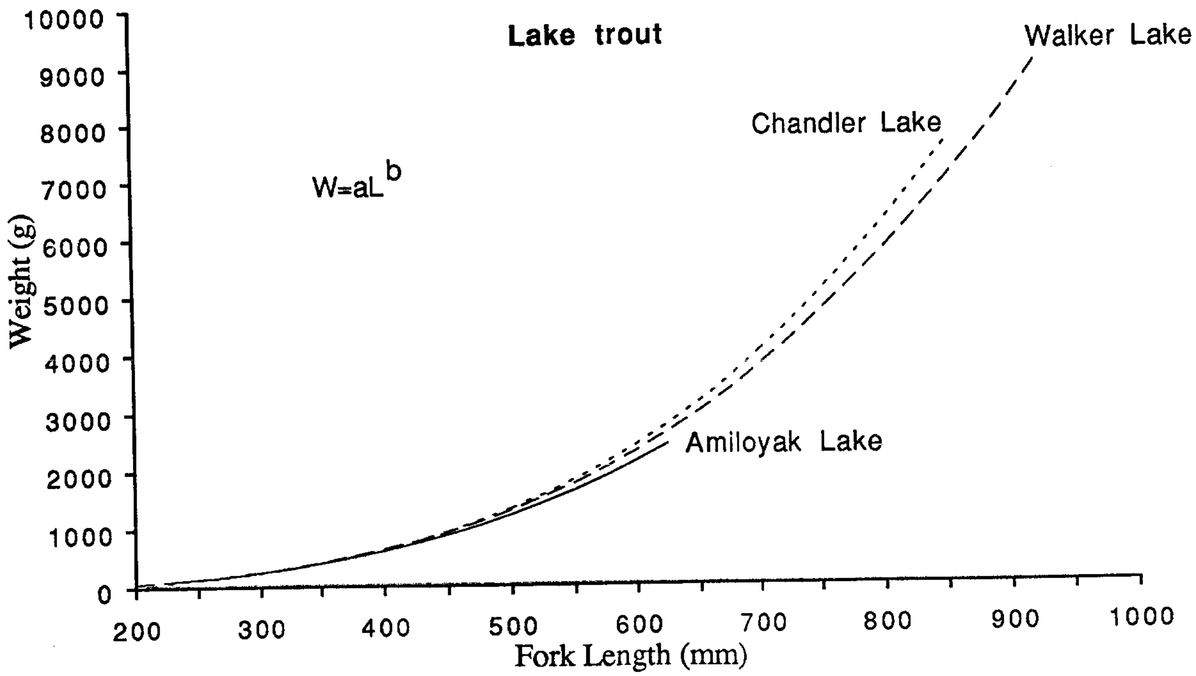

FIGURE 15.—Comparison of predicted weights (from the weight-length relations) of lake trout from Chandler and Amiloyak lakes to predicted weights of lake trout from Walker Lake (Johnson and Troyer 1994).

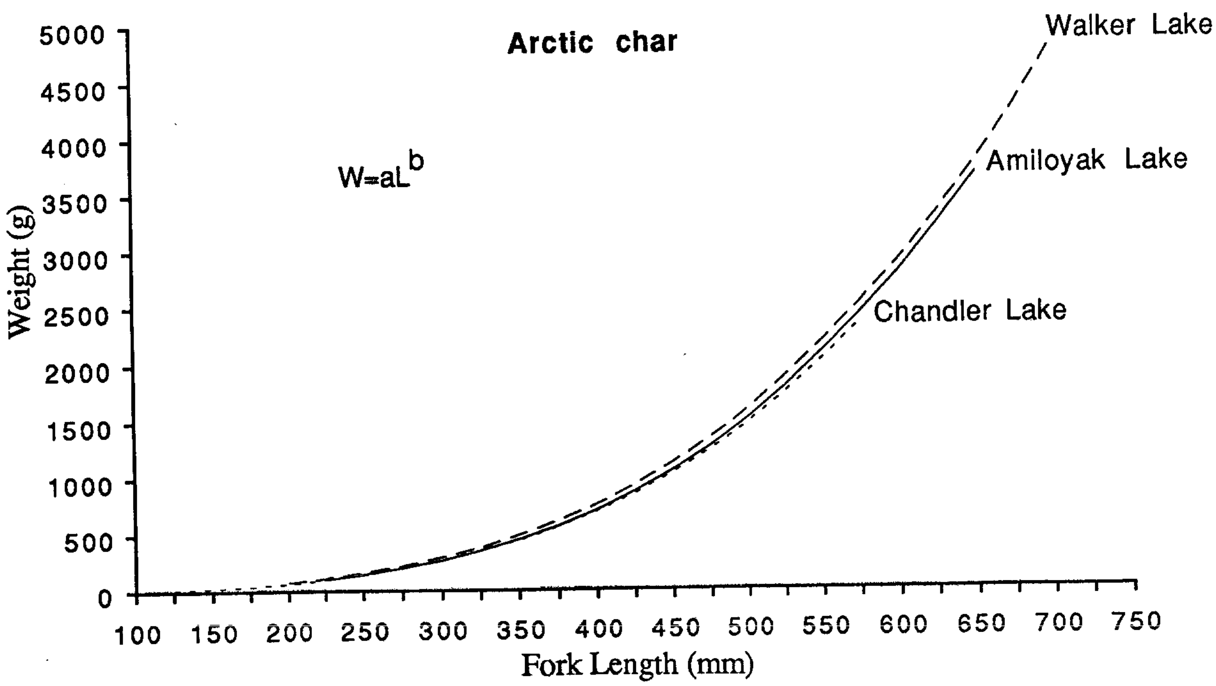

FIGURE 16.—Comparison of predicted weights (from the weight-length relations) of Arctic char from Chandler and Amiloyak lakes to predicted weights of Arctic char from Walker Lake (Johnson and Troyer 1994).

TABLE 6.—Relative condition factor (Kn) statistics for lake trout and Arctic char from Amiloyak Lake and Chandler Lake during early and late sampling periods. Significant differences in relative condition were not detected ($P > 0.05$) between early and late periods nor between lakes.

Relative condition factor and statistics	Chandler Lake		
	Early[a]	Late[b]	Amiloyak Lake[c]
	Lake trout		
Mean	1.015	1.006	0.995
N	150	79	39
SE	0.008	0.012	0.015
Kn range	0.812-1.246	0.777-1.540	0.860-1.235
Length range	234-865	250-863	348-601
	Arctic char		
Mean	0.999	1.039	1.015
N	55	42	300
SE	0.012	0.019	0.008
Kn range	0.719-1.192	0.816-1.575	0.101-1.276
Length range	187-615	120-587	225-635

[a]July 19 - August 15, 1987
[b]August 16 - September 9, 1987
[c]July 27 - August 10, 1989

TABLE 7.—Growth in length and weight of Arctic char tagged in the Chandler lake system in 1985 and 1987 and recaptured in Amiloyak Lake during the summer of 1989.

Year	Agency	Tagging lake	Initial length (mm)	Recapture length (mm)	Change per year (mm)	Initial weight (g)	Recapture weight (g)	Change per year (g)
1985	ADF&G	Amiloyak	479	516	+9.3		1,575	
1985	ADF&G	Amiloyak	495	500	+1.3		1,520	
1985	ADF&G	Amiloyak	585	583	-0.5		1,850	
1985	ADF&G	Amiloyak	472	496	+6.0		1,525	
1985	ADF&G	Amiloyak	588	550	-9.5		1,450	
1987	USFWS	Amiloyak	502	505	+1.5	1,600	1,600	0
1987	USFWS	Amiloyak	437	446	+4.5	1,225	1,050	-87.5
1987	USFWS	Amiloyak	552	556	+2.0	2,000	1,900	-50.0
1987	USFWS	Amiloyak	554	556	+1.0	2,050	1,775	-137.5
1987	USFWS	Amiloyak	578	586	+4.0	2,200	1,950	-125.0
1987	USFWS	Amiloyak	615	625	+5.0	2,900	3,150	+125.0
1987	USFWS	Chandler	467	495	+14.0	1,250	1,625	+187.5
1987	USFWS	Amiloyak	541	542	+0.5	1,950	1,850	-50.0
1987	USFWS	Amiloyak	484	489	+2.5	1,175	1,375	+100.0
1987	USFWS	Amiloyak	505	501	-2.0	1,390	1,425	+17.5
1987	USFWS	Amiloyak	507	514	+3.5	1,790	1,800	+5.0

TABLE 8.—Length at age statistics of lake trout collected from Chandler Lake in 1987.

Age	N	Fork Length (mm)		
		Mean	SD	Range
12	5	390	29	364 - 432
13	3	422	3	420 - 425
14	3	417	45	365 - 446
15	3	431	25	403 - 450
16	2	509	54	471 - 547
17	1	421	--	---
18	1	498	--	---
23	1	440	--	---
24	2	506	51	470 - 542
26	1	484	--	---
28	1	478	--	---
Total	23	439	50	364 - 547

TABLE 9.—Length at age statistics of Arctic char collected from Chandler Lake in 1987.

Age	N	Fork Length (mm)		
		Mean	SD	Range
5	8	284	65	218 - 385
6	4	297	100	187 - 420
7	2	471	20	457 - 485
8	5	434	79	335 - 511
9	2	480	32	457 - 502
10	2	471	37	444 - 497
11	1	502	--	---
12	1	420	--	---
14	1	510	--	---
15	1	475	--	---
Total	29	371	116	120 - 511

TABLE 10.—Length at age statistics of Arctic char collected from Amiloyak Lake in 1989.

Age	N	Fork Length (mm)		
		Mean	SD	Range
5	1	334	--	---
6	2	262	50	227 - 297
7	1	360	--	---
8	1	264	--	---
9	2	464	6	460 - 468
10	3	454	63	382 - 492
11	1	450	--	---
12	2	493	22	477 - 508
13	4	509	11	493 - 520
14	4	493	9	485 - 504
15	4	498	50	446 - 565
16	1	502	--	---
19	1	535	--	---
Total	27	453	85	227 - 565

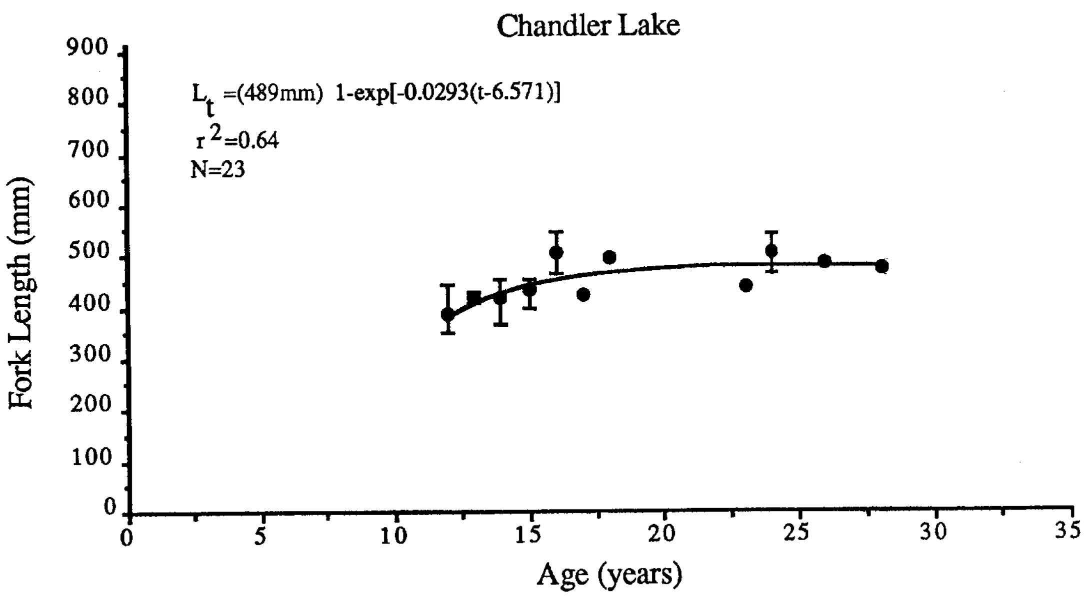

FIGURE 17.—Von Bertalanffy growth equation and mean lengths at age for lake trout from Chandler Lake, 1987. Vertical lines represent the range of lengths at a given age.

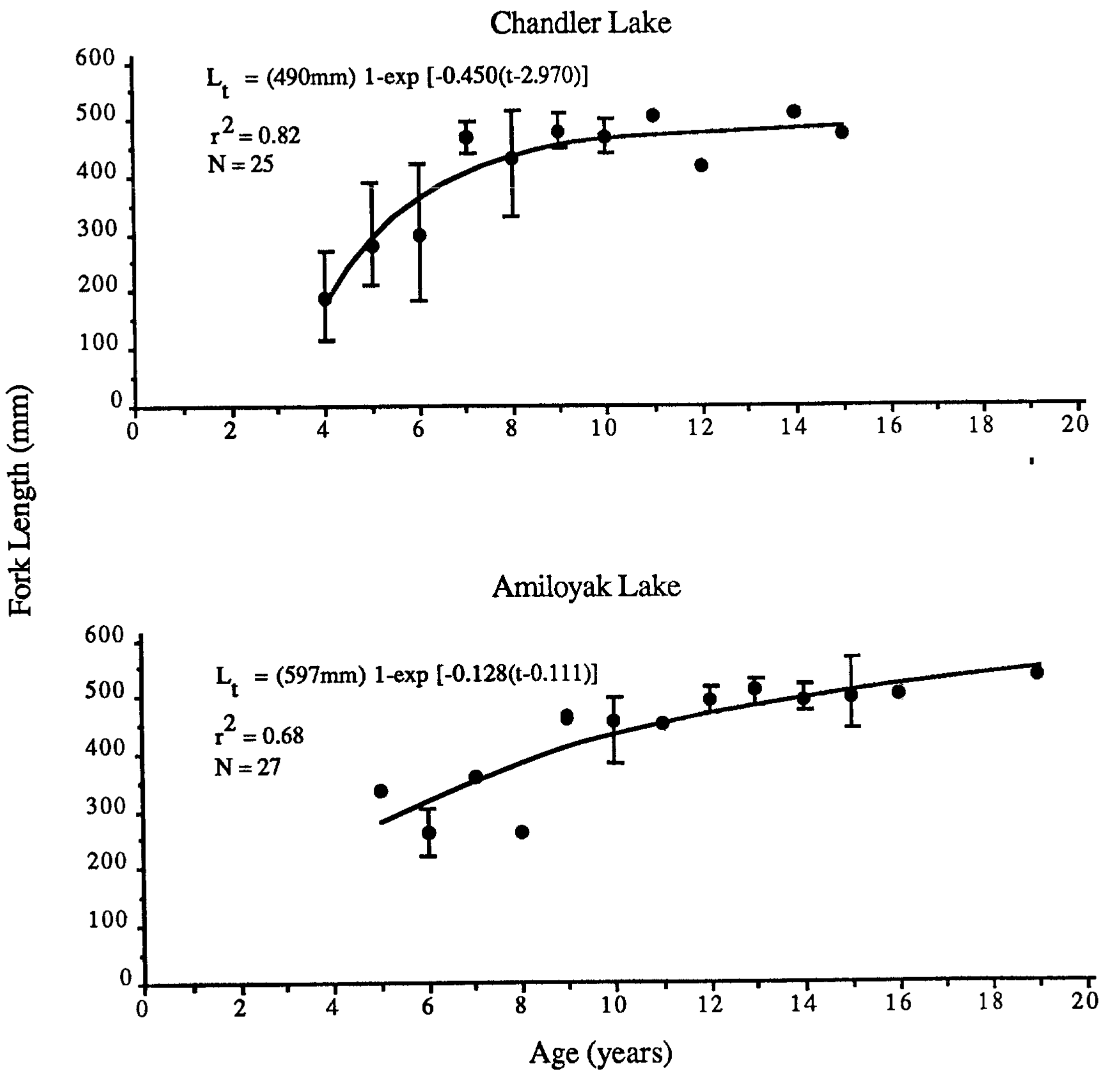

FIGURE 18.—Von Bertalanffy growth equations and mean lengths at age for Arctic char collected from Chandler Lake in 1987 and Amiloyak Lake in 1989. Vertical lines represent the range of lengths at a given age.

Food Habits

Stomach contents were collected from 68 lake trout from Chandler Lake (including Little Chandler Lake), with 58 (85%) containing food items. Of 14 Arctic char stomachs sampled, 13 (93%) contained food. Fish were the most important food item by weight in the lake trout diet, followed by snails and insects (Table 11; Figure 19). Arctic grayling was the most important prey species by weight, comprising 70.9% of the total diet. For Arctic char, Cladocera, insects and snails were the most frequently occurring food items (Table 12). No fish were found in Arctic char stomachs.

Fecundity and Maturity

Gonadosomatic indices (GSI) calculated for lake trout and Arctic char from the Chandler lake system indicated most were not going to spawn that fall. A sample of 27 lake trout (12 females, 15 males) included three ripening males and no ripening females (Table 13; Appendices 3 - 6). Ripening males ranged from 13 to 23 years old and 403 to 440 mm in length. Ripening male lake trout were from Chandler Lake, as was the majority of the sample (12 of 15 fish). Two ripening males were collected in August and one in September (Appendix 5).

A sample of 20 Arctic char (11 females, 9 males) included seven ripening females and no ripening males. Ripening female Arctic char were 8 to 11 years old, 456 to 529 mm in length, and had fecundities ranging from 3,251 to 3,990 ova. Ova diameters from ripening females ranged from 1.62 to 4.75 mm. The ripening female Arctic char were collected from Amiloyak Lake and the non-ripening female Arctic char from Chandler Lake. All ripening females were collected in August; however, few fish from July and September were analyzed (Appendix 4).

Physical and Chemical Sampling

Monthly mean surface water temperatures at Chandler Lake ranged from 4.1 to 10.9°C during the summer, with September being the coldest month (Table 14). Mean surface readings of dissolved oxygen ranged from 9.9 to 11 mg/l, with low and high extremes occurring in August in the south and north sections of the lake. Transparency gradually increased from 2.5 to 4.4 m over the course of the summer.

Single samples from Little Chandler and Round lakes were comparable to August samples at Chandler Lake in dissolved oxygen, alkalinity, pH, and conductivity, whereas temperature and transparency were higher and total hardness lower than at Chandler Lake (Table 14). Water temperature from the single sample at Amiloyak Lake was higher, dissolved oxygen lower, and Secchi transparency lower than at Chandler Lake in August. Alkalinity, hardness, and conductivity in Amiloyak Lake were about half the values measured in Chandler Lake.

TABLE 11.—Frequency of occurrence and percent weight of food items in stomachs of lake trout (339 - 865 mm) collected from Chandler Lake in 1987. N = 58 (nonempty stomachs).

Food item	Frequency of occurrence (%)	Percent weight
MOLLUSCA		
Gastropoda	22.4	2.1
Pelecypoda	3.4	<0.1
ANNELIDA		
Clitellata (leech)	5.2	0.6
CRUSTACEA		
Copepoda	13.8	1.2
Cladocera	1.7	<0.1
INSECTA		
Hemiptera (adult)	1.7	<0.1
Plecoptera (larvae)	1.7	<0.1
Trichoptera (larvae)	3.4	<0.1
Hymenoptera (adult)	1.7	<0.1
Diptera		
Chironomidae pupae	31.0	0.4
Chironomidae larvae	8.6	<0.1
Culicidae larvae	1.7	1.2
Unidentified Insecta	10.3	<0.1
OSTEICHTHYES		
Salmonidae		
Arctic char	1.7	4.4
Thymallidae		
Arctic grayling	10.3	70.9
Cottidae		
Slimy sculpin	25.9	12.2
Unidentified parts	36.2	6.6
RODENTIA	6.9	1.4
DETRITUS	41.4	0.7

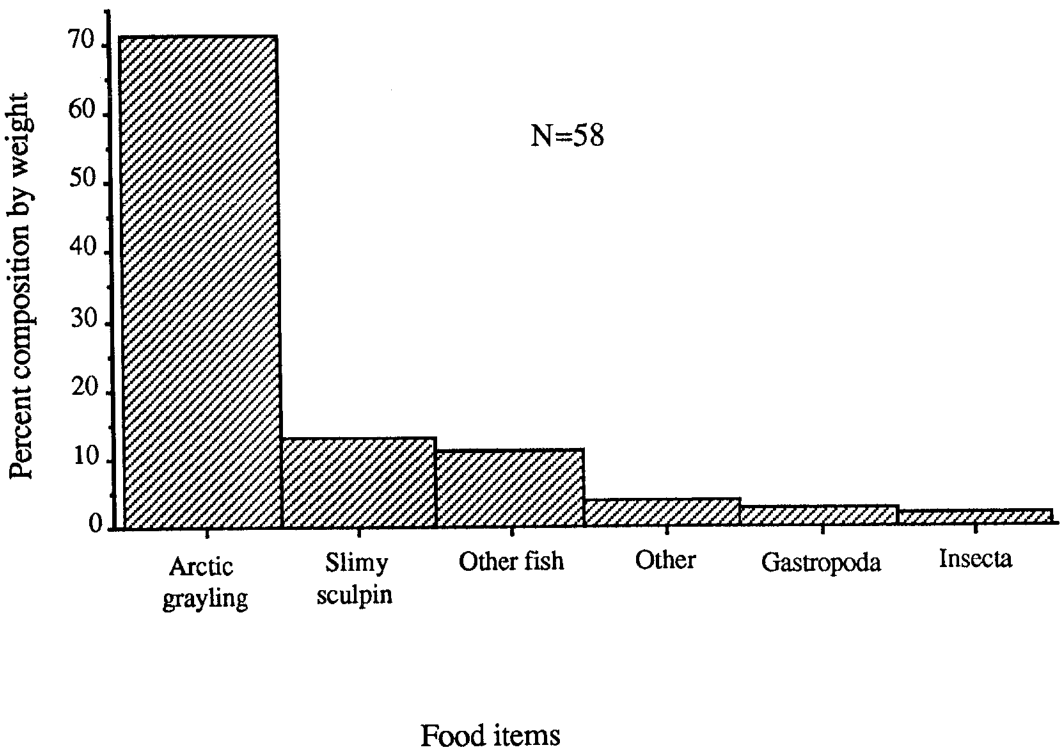

FIGURE 19.—Percent composition by weight of the diet of lake trout (339 - 865 mm fork length) from Chandler Lake, 1987. Other includes Rodentia, Copepoda, Annelida, and detritus.

TABLE 12.—Frequency of occurrence of food items in stomachs of Arctic char (210 - 546 mm) collected from Chandler Lake in 1987. N = 13 (nonempty stomachs).

Food item	Frequency of occurrence (%)
MOLLUSCA	
Gastropoda	23.1
CRUSTACEA	
Cladocera	61.5
INSECTA	
Ephemeroptera (adult)	30.8
Diptera (adult)	7.7
Chironomidae (pupae)	23.1

TABLE 13.—Gonadosomatic indices (GSI), lengths, and ages of ripening and non-ripening lake trout and Arctic char collected from the Chandler lake system, 1987.

		GSI (% of body weight)			Length (mm)			Age		
State of maturation	N	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Lake trout										
Non-ripening females	12	0.76	0.40	0.29 - 1.39	492	78	410 - 684	17	3	13 - 24
Ripening females	0	---	---	---	---	---	---	---	---	---
Non-ripening males	12	0.09	0.06	0.03 - 0.20	440	57	368 - 558	18	8	12 - 34
Ripening males	3	1.67	0.56	1.09 - 2.22	421	19	403 - 440	17	5	13 - 23
Arctic char										
Non-ripening females	4	0.77	0.38	0.22 - 1.10	421	65	324 - 457	8	2	6 - 10
Ripening females	7	13.57	3.29	9.45 - 17.71	492	27	456 - 529	10	1	8 - 11
Non-ripening males	9	0.25	0.40	0.03 - 1.14	479	67	322 - 546	10	3	7 - 15
Ripening males	0	---	---	---	---	---	---	---	---	---

TABLE 14.—Mean surface measurements of water temperature, dissolved oxygen, Secchi transparency, alkalinity, total hardness, pH, and conductivity above the deepest sections of Chandler, Little Chandler, Round, and Amiloyak lakes, summer 1987. Sample sizes (N) are in parentheses.

	Chandler Lake						Little Chandler Lake	Round Lake	Amiloyak Lake
	July		August		September				
Parameter	North	South	North	South	North	South	August	August	August
Water temp. °C	10.9 (2)	9.3 (2)	9.2 (3)	9.0 (3)	4.1 (1)	---	10.5 (1)	10.2 (1)	9.5 (1)
Dissolved O_2	10.8 (2)	10.9 (2)	11.0 (3)	9.9 (3)	10.8 (1)	---	10.2 (1)	10.2 (1)	9.2 (1)
Secchi transparency (m)	---	2.5 (1)	3.2 (2)	---	4.4 (2)	---	3.6 (1)	3.8 (1)	2.6 (1)
Alkalinity (mg/l)	---	21 (1)	21 (2)	---	---	---	20 (1)	22 (1)	11 (1)
Total hardness (mg/l)	---	41 (1)	31 (2)	---	---	---	22 (1)	23 (1)	15 (1)
pH	---	7.1 (1)	7.1 (2)	---	---	---	7.1 (1)	7.2 (1)	7.0 (1)
Conductivity (*u*S/cm)	---	60 (1)	68 (2)	---	---	---	67 (1)	68 (1)	33 (1)

Discussion

Exploitation

Lake trout.—The annual yield of lake trout (0.03 kg/hectare) at Chandler Lake (including Little Chandler Lake) is well within the level considered sustainable for arctic and subarctic lakes. Based on comprehensive analyses of exploited lake trout populations in Canada, Healey (1978) suggested that 0.2 kg/hectare may be a maximum sustainable yield for lake trout populations with slow growth and low standing crop of mature fish.

A general estimate of the potential lake trout yield from Chandler Lake may be obtained by comparison to two lakes of comparable size[1] which have been exploited more heavily than Chandler Lake. Lake Opeongo in Ontario was being overharvested at 0.6 - 0.7 kg/hectare (Fry 1939), but subsequently sustained long term harvests of 0.33 kg/hectare (Martin and Fry 1973), amounting to 17% of the standing crop of catchable sized lake trout (1.9 kg/hectare; Hackney 1973). For Paxson Lake in central Alaska, the Department has developed a maximum harvest guideline of 0.5 kg/hectare, which is 10% of the standing crop of fish ≥ 362 mm (5.0/kg hectare; Burr 1992). Assuming that an increase in harvest level would cause a compensatory increase in growth (Healey 1978) so that growth rates would approximate those of Paxson Lake, Chandler Lake might sustain a maximum annual harvest of about 10% of the standing crop (1.41 kg/hectare), or 0.14 kg/hectare.

No fishing at Amiloyak Lake was documented. This lake is probably less exploited than Chandler Lake because of its greater distance from Anaktuvuk Pass. No population estimate was made of the lake trout in Amiloyak Lake, but catch rates in unbaited gill nets (0.17 fish/h) indicate that lake trout are much less abundant than Arctic char (1.27 fish/h). Extrapolating a rough population estimate from these relative abundance figures and the estimate of 20.3 Arctic char/hectare, Amiloyak lake may contain about 2.8 lake trout/hectare, or 2.2 kg/hectare. Maximum sustainable harvest might be about 10% of the standing crop, or 0.22 kg/hectare.

The Service suggests that annual harvest of lake trout should not exceed 0.14 kg/hectare at Chandler Lake, which is a total of 226 kg or 260 lake trout of the average size (0.87 kg) caught in the 1989 spring ice fishery. Until better information is obtained for Amiloyak Lake, annual harvest should not exceed 0.22 kg/hectare, which is a total of 22 kg or 25 lake trout.

Arctic char.—Annual harvest of Arctic char (0.03 kg/hectare) at Chandler Lake (including Little Chandler Lake) is well within the level considered sustainable for arctic and subarctic lakes. Few data exist on the harvest of lake populations of Arctic char. However, two studies of unexploited populations in northern Canada determined potential yield based on estimates of growth, mortality, and standing crop. For Char Lake on Cornwallis Island, yearly production was estimated at 0.55 kg/hectare, which was 6% of the standing crop (9.23 kg/hectare; Johnson 1980). For Keyhole Lake on Victoria Island, Hunter (1970) estimated a maximum sustainable yield of 6 kg/hectare, which was 14% of the standing crop (43.5 kg/hectare). Both populations have slower growth rates than Chandler Lake Arctic char; however, Keyhole Lake and Chandler Lake populations appear to be similar in age composition, and thus turnover time for the harvestable stock (Johnson 1980).

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[1]Surface areas are 1,617 hectares for Chandler and Little Chandler lakes, 1,575 hectares for Paxson Lake, and 5,860 hectares for Lake Opeongo.

Using projected maximum sustainable yield for Keyhole Lake as a guideline, potential yield at Chandler Lake may be about 14% of the standing crop. No population estimate was made of the Arctic char in Chandler Lake, but catch rates in unbaited gill nets (1.01 fish/h) indicate that they are at least as abundant as lake trout (0.57 fish/h). Extrapolating a rough population estimate from these relative abundance figures and the estimate of 1.07 lake trout/hectare, Chandler lake may contain about 1.9 Arctic char/hectare, or 1.6 kg/hectare. Estimated maximum sustainable yield would be 14% of the standing crop, or 0.22 kg/hectare.

No harvest of Arctic char was documented in Amiloyak Lake itself, but at least one fish from Amiloyak Lake was later caught in Chandler Lake. However, without knowing the extent of Arctic char movement between lakes, sustainable yield was determined for Amiloyak Lake as a separate water body with a high density of Arctic char (20.3 fish/hectare). Age structure from Amiloyak Lake is more similar to Char Lake than to Keyhole Lake populations (Johnson 1980, Hunter 1970), so maximum sustainable yield was calculated as 6% of standing crop (31.47 kg/hectare), or 1.88 kg/hectare.

The Service suggests that annual harvest of Arctic char should not exceed 1.88 kg/hectare at Amiloyak Lake, which is a total of 188 kg or 245 Arctic char of the average size (0.77 kg) caught in the 1989 spring ice fishery at Chandler Lake. Until better information is obtained for Chandler Lake, annual harvest should not exceed 0.22 kg/hectare, which is a total of 356 kg or 464 Arctic char.

Our estimates of exploitation are probably conservative. Harvest of fish during the fall ice fishery at Chandler Lake was not estimated, and yet fall fishing was reported in 33% of the household interviews in Anaktuvuk Pass. In addition, we may not have interviewed all the fishers in Anaktuvuk Pass, and more spring fishing may have occurred after our departure (April 15). Missed interviews probably occurred during the 1987 summer creel survey, especially on lakes other than Chandler Lake, where the field crew was stationed. Although our estimates of harvest may be conservative, actual lake trout harvest from Chandler Lake would have to be 4 - 5 times greater than the documented 1989 harvest to reach the estimated maximum level; Arctic char harvests would have to be 7 - 8 times greater.

Relative Abundance

The spacial and temporal variables we measured generally did not indicate trends in abundance between sampling periods or lake sections. However, Arctic char KPUE was almost three times higher in the south section of Amiloyak Lake than in the north section, probably because fishing effort in the south section was concentrated near the inlet, where a large group of Arctic char was holding. The Service suggests relative abundance indices from this study be used as a baseline for determining future trends in interannual abundance.

Absolute Abundance

The standing crop of 1.07 lake trout/hectare[1] in Chandler Lake is within the range documented for other lakes of comparable size. For lakes in the continental U.S. and Canada ranging from 1,468 to 2,964 hectares, standing crops of lake trout range from 0.76 to 10.74 fish/hectare (Martin and Olver 1980). For Paxson Lake in southcentral Alaska, Burr (1990) reported 3.1 lake trout/hectare; and for Walker Lake, Johnson and Troyer (1994) reported

[1]Standing crop is discussed here in terms of fish/hectare for comparison to other populations, most of which have been documented in fish/hectare, rather than kg/hectare.

0.45 lake trout/hectare. For Arctic char, the apparently high density found in Amiloyak Lake (20.3 fish/hectare) is not unusual for small Arctic lakes: standing crop in Keyhole Lake (49 hectares) was estimated at 163 fish/hectare (Hunter 1970). The standing crop values documented in this study may be used as baseline information for future assessment of the effects of exploitation.

There are at least three potential sources of bias in the estimates of absolute abundance. First, fish smaller than the modal sizes in the length frequency distributions (442 mm for lake trout from Chandler Lake, and 492 mm for Arctic char from Amiloyak Lake) may not have been fully vulnerable to the sampling gear, and therefore would not have been captured in proportion to their actual abundance. This type of net selectivity would tend to cause an underestimate of population size (Ricker 1975). However, the observed length frequency distributions are not necessarily indicative of net selectivity. Johnson (1976) argued that the bell or dome shaped length frequency distributions common in sampling northern populations of lake trout and Arctic char may be caused by a feedback mechanism restricting recruitment and dampening fluctuations in year-class strength, but allowing an increase in growth rate for the few individuals recruited[1].

Another possible source of bias was the lack of randomness in sampling Chandler and Little Chandler lakes. At both lakes there was a tendency to revisit areas which seemed to have the most fish. The most likely effect of this non-random sampling would be to increase the probability of recapturing tagged fish (9 of 13 lake trout recaptured in Chandler Lake were found in the same area where they were tagged), and thus underestimate population size.

The third possible source of bias was not factoring tag loss and handling mortality into the population estimates. Not accounting for loss of marked fish from the population causes an overestimate of population size. There was no evidence of tag loss, but we found handling mortality rates of 6% and 20% in small samples of tethered Arctic char and lake trout. Actual handling mortality may have been lower than our estimates, because tethering itself probably added to fish stress and mortality.

Fish Movement

Movement of Arctic char between lakes was documented with the recapture of one fish in Amiloyak Lake that was tagged in Chandler Lake 2 years earlier, and another fish in Chandler Lake that was tagged in Amiloyak Lake 5 years earlier. Given the potential for movement between lakes, it may be necessary to manage both lake trout and Arctic char for the lake system as a whole rather than by individual lakes, particularly if harvests approach maximum sustainable yield levels. Future recaptures of tagged fish by subsistence and sport fishermen should be recorded to help determine the extent of fish movement between lakes.

The large group of Arctic char holding near the inlet creek mouth in Amiloyak Lake in August, 1987 was also observed in a previous study. Bendock and Burr (1986) noted that Arctic char assemble during the summer in Amiloyak Lake at the inlet creek; during this time they were extremely vulnerable to exploitation by anglers. It was suggested that these fish

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[1]Johnson draws a parallel to a climax forest in which young trees are suppressed by exclusion of light caused by the canopy of older trees, and when a break in the canopy occurs, young trees (recruits) quickly fill the available space.

leave the inlet creek in early September to spawn along the shoreline (Bendock and Burr 1986). If harvests increased substantially, a closure of the inlet creek area could be implemented to decrease catch and harvest.

Length, Weight, and Condition

The few lake trout caught in Amiloyak Lake in 1989 had smaller mean length than Chandler lake fish, possibly because of the smaller mesh used in Amiloyak lake in 1989. However, relatively small fish were also caught in Amiloyak lake in 1987 when the larger mesh was used. Also, the change in mesh size between 1987 and 1989 apparently had no effect on the length of Arctic char captured. Smaller mean length of lake trout in Amiloyak Lake may be due to less optimal habitat for foraging, lack of deep water refuge areas, a slightly shorter growing season than at Chandler Lake, and/or competition with Arctic char for invertebrate food items.

Mean length of lake trout differed significantly between Chandler and Little Chandler lakes. However, sampling coverage of Little Chandler Lake was limited, and most of the fish were caught from one area (the narrows near the north end). This could be a feeding or spawning area occupied by fish of larger than average size for the lake as a whole.

Arctic char averaged about 100 mm smaller in Chandler Lake than in each sample from Amiloyak Lake. The vast size difference could be due to competition with or displacement to suboptimal habitats by lake trout in Chandler Lake. However, these interspecific effects should be reflected in slower growth rates of char in Chandler Lake, and they are not (see *Age and Growth* discussion, below). The age structure is skewed toward older fish at Amiloyak Lake, which may be due to less fishing pressure than at Chandler Lake, spawning migration from Chandler Lake to Amiloyak Lake, or a combination of the two factors. It seems unlikely that fishing pressure alone could account for the absence of fish larger than 556 mm in the entire Chandler Lake sample, when at least 10% of each sample from Amiloyak Lake was larger than 556 mm.

Mean length of Arctic char differed significantly between seine and gill/angling catches from Amiloyak Lake perhaps because seines were used only at the inlet creek mouth. These fish may have been mostly mature pre-spawners, and thus of larger than average size for the lake.

Weight-length regression coefficients for lake trout and Arctic char from Chandler and Amiloyak Lakes are within the range of values reported for these species in Alaska and Canada, and indicate healthy growth. Lake trout growth equations had regression coefficients b within the range of values documented by McCart et al. (1972) and Craig and Wells (1975) for Alaskan and Canadian north slope populations. Arctic char exhibited allometric growth with regression coefficients b within the range of values documented by Hunter (1970) and McCart (1980) for Alaskan and Canadian north slope lake resident Arctic char. Furniss (1974) recorded a regression coefficient for Chandler Lake of 2.65 which is 0.68 less than our calculated b value. This difference may be due to the limited sample ($N = 34$) and length range (372 - 590 mm) used by Furniss.

The significant difference in Arctic char weight-length relations between 1987 (mainly from inlet area) and 1989 (random) samples from Amiloyak Lake may reflect environmental or food availability differences between years, or may indicate poorer condition for fish assembled in the inlet creek area than those in the rest of the lake. Sampling was initiated at about the same time in both years (late July), but extended 10 days later in 1987 (August 20). The 1987 sample may have included a higher percentage of post-spawning fish due to the later timing or the location of the sample. Alternatively, the group of Arctic char holding near the inlet might have included fish that had completed a spawning migration, taxing their fat reserves.

For Chandler Lake lake trout and Arctic char, no differences in fish condition between early and late season were demonstrated. The expected weight gain over the course of the summer might have been balanced by a post-spawning decrease in condition in the late sample. The Service recommends that weight-length regression coefficients and relative condition factors presented in this study be used as a baseline for fish condition.

Age and Growth

The lake trout from Chandler Lake (including Little Chandler Lake) show slower growth rates than populations from lower latitudes in Alaska. Growth rate (absolute increase in length per year on the von Bertalanffy curve) of lake trout between ages 12 and 17 in Chandler Lake was similar to subarctic populations in Paxson and Summit lakes of the Tanana River drainage of Alaska (Burr 1987, 1988); however, shorter fork lengths at age indicate relatively slow growth in Chandler Lake prior to age 12, and growth is again relatively slow after age 17 (Figure 20). Length at age 12 was about the same in Chandler and Walker lakes, but older lake trout (>12 years) grew consistently faster in Walker Lake.

The leveling-off of the Chandler Lake growth curve after age 17 is probably influenced by the lack of large fish (> 550 mm) sacrificed for ageing. The largest fish aged was 547 mm, whereas 13% of lake trout sampled from Chandler Lake were larger than 547 mm. The lack of larger fish in our age sample would decrease the L_{∞} parameter and hence, the growth rate. Alternatively, the leveling-off may simply represent the growth constraints at high latitude.

Growth rates for Arctic char from Amiloyak lake were similar to other Alaskan populations, with mean lengths intermediate between Walker Lake and north slope populations from Campsite and Schrader lakes (Figure 21). Chandler Lake and Amiloyak Lake von Bertalanffy curves differ from each other in that growth appears to be faster at Chandler Lake until age 8, after which growth rates decrease markedly, in contrast to the relatively constant growth rates at Amiloyak Lake. The samples also differ from each other in age structure, with a mean age of 7 and 45% of the fish age 8 or older for Chandler Lake, versus a mean age of 12 and 85% of the fish age 8 or older for Amiloyak Lake. This difference does not appear to be an artifact of the small sample sizes used in the age and growth analysis, because the entire gill net/angling sample from Chandler Lake contained few large fish.

Extreme variability in lengths at age is common for slow growing arctic species (McCart et al. 1972; Johnson 1983; Burr 1987) and may cause inaccuracy in growth curves generated from small samples, such as our samples of Arctic char (N = 29 for Chandler Lake, N = 27 for Amiloyak). However, if the relatively fast growth of Arctic char up to age 8 in Chandler Lake does occur, it may be a response to reduced competition with larger, older fish.

At Amiloyak Lake we documented a mean growth rate of 4.2 mm per year from recaptured Arctic char tagged in previous studies; however, this data should be regarded with some caution. The negative and extreme growth rates recorded are probably due to errors in measurements taken from live unanesthetized fish. The hypothesized spawning periodicity of

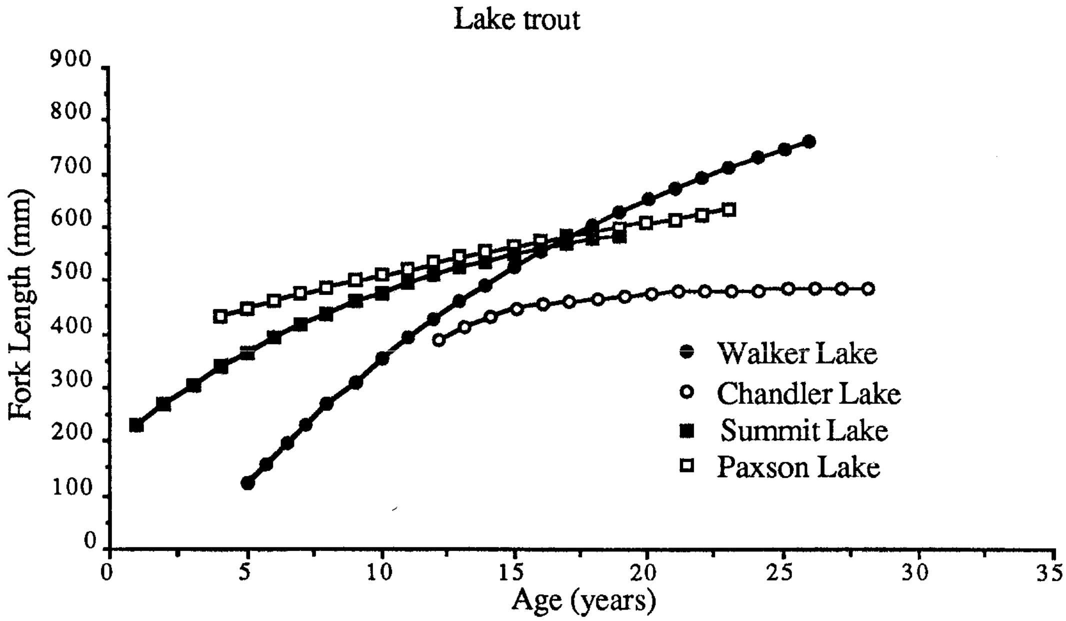

FIGURE 20.—Von Bertalanffy growth curves for lake trout from Chandler Lake and other Alaskan lakes (Burr 1987, 1988; Johnson and Troyer 1994).

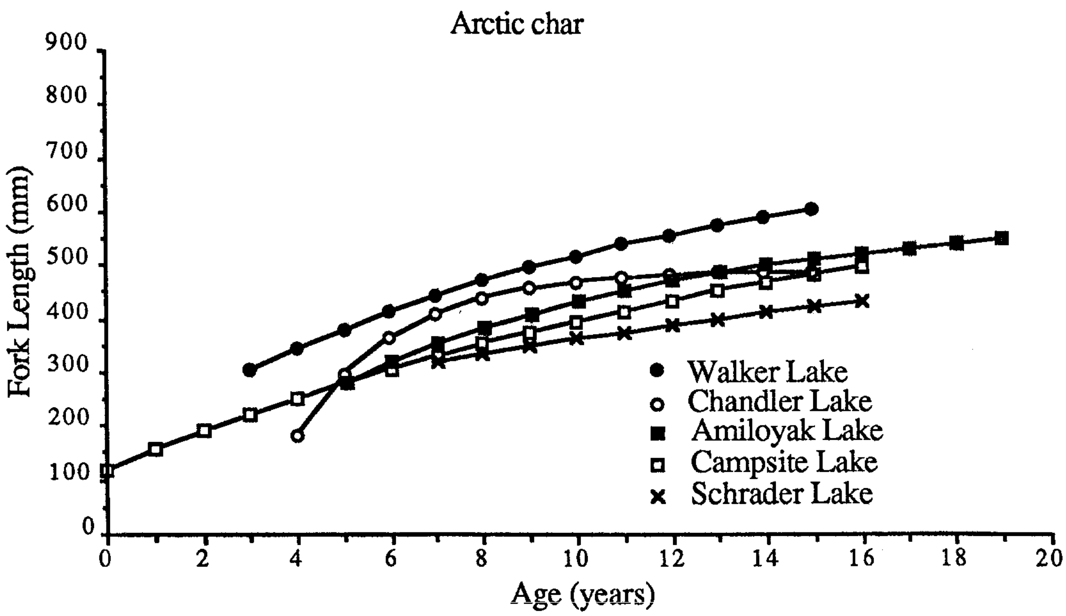

FIGURE 21.—Von Bertalanffy growth curves for Arctic char from Chandler, Amiloyak, and other Alaskan lakes (McCart 1980; Troyer and Johnson 1994).

lake resident Arctic char in the Brooks Range (McCart 1980) would, in part, explain the observed fluctuations in weight, which ranged from 13% loss to 30% gain over two years. The highest gonadosomatic index found in the sample of seven ripening fish from Amiloyak Lake was 17.7%. Gonadosomatic indices are not available for other resident Arctic char populations; however, anadromous populations on the Arctic coast average 17.8% with an extreme of 25.8% (Craig 1977).

Food Habits

Lake trout from Chandler Lake were primarily piscivorous and Arctic char nonpiscivorous. Piscivorous lake trout populations have higher growth rates than nonpiscivorous populations (Martin and Olver 1980). It has been suggested that lake trout, as top predators, control stunting in Arctic char populations, and that Arctic char sympatric with lake trout tend to be nonpiscivorous (Fraser and Power 1989). This sympatric relation may have benefitted both species and has probably improved the quality of the sport and subsistence fisheries.

Fecundity and Maturity

Arctic char fecundities found in this study (3,200 - 4000 ova) are similar to the values reported for Amiloyak Lake by Bendock and Burr (1986), who documented a range of 2,012 to 3,790 ova (465 - 520 mm; N=12); and for populations in northern Canada and the north slope of the Brooks Range (Johnson 1980; McCart 1980). For lake trout, the absence of ripening females in our sample precluded assessment of fecundity.

Intermittent spawning is a common characteristic of high latitude populations of lake trout and Arctic char (Johnson 1980; Power 1978; Martin and Olver 1980). Based on our GSI criteria, 11% of the lake trout and 35% of the Arctic char examined would spawn in the year of capture. The small samples of lake trout (N = 27) and Arctic char (N = 20) are probably not adequate to reflect the actual percentages of fish likely to spawn. Female lake trout from Great Bear Lake in northern Canada were found to spawn every third year (Miller and Kennedy 1948), and in Great Slave Lake every other year (Kennedy 1954). Fry (1949) documented a lake trout population in Lake Opeongo, Ontario, Canada (which is south of 60°N) where some fish failed to spawn after reaching maturity. McCart (1980) documented intermittent spawning of lake resident Arctic char populations in Campsite Lake and Big Lake located on the north slope of the Brooks Range, Alaska.

Criteria for evaluation of maturity, or the likelihood of spawning, are highly subjective (Healey 1978; Martin and Olver 1980). Intermittent spawning and the lack of representation of the younger ages classes in our sample precluded a means of predicting age of maturity. Burr (1987, 1988) estimated AM_{99} (the age when 99% of the population is mature) for lake trout from Paxson Lake at 8.7 years for females and 7.5 years for males; and lake trout from Summit Lake at 7.7 years for females and 8.6 years for males. McCart (1980) estimated AM_{99} for north slope lake resident Arctic char as four to five years. Assuming Chandler lake system fish are similar to these other populations in age at maturity, all of the lake trout and almost all of the Arctic char in our GSI analysis were mature.

Physical and Chemical Characteristics

Observations of physical and chemical properties of the study lakes suggest they are similar to other high latitude lakes supporting lake trout and Arctic char populations at high latitudes (Wong and Whillans 1973; Johnson 1975; Pearse 1978; Martin and Olver 1980). Amiloyak Lake is less alkaline than the other lakes in the system, but no other major differences among lakes were apparent in our limited sampling.

Management and Harvest Recommendations

Current sport fishing regulations for lake trout are four per day, four in possession, no size limit; and for Arctic char, 10 per day, 10 in possession, no size limit. The season is open the entire year and multiple hooks with a gap between point and shank greater than one-half inch may be used for both species (1994 Alaska Sport Fishing Regulations Summary, Arctic-Yukon-Kuskokwim Region, Alaska Department of Fish and Game). Subsistence fishing regulations have few restrictions: there is no harvest limit, and handlines, fishing rods[1], and various types of nets are allowed (1993-1994 Arctic-Yukon-Kuskokwim Region Commercial and Subsistence Fishing Regulations, Alaska Department of Fish and Game).

Annual yield estimates and harvest recommendations are summarized in Table 15. The assumptions leading to these estimates are discussed above under *Exploitation*. Lake trout and Arctic char are being harvested well below maximum sustainable yield levels and fish stocks appear to be healthy. However, subsistence fishing effort may increase with increased availability of snowmobiles and ATVs, and sport angling effort probably will increase steadily as it has state-wide. State-wide sport angling effort levels have shown an average increase of 5% per year between 1977 and 1992 (Mills 1993). Current regulations could prove inadequate in providing a sustainable yield if sport or subsistence harvest increased substantially. With increased harvest, a combination of bag limit reductions and size restrictions could be used to manage for long-term sustainable populations. Size restrictions could be based on biological characteristics, such as length at maturity. Harvest management could also include area and season closures, since both lake trout and Arctic char are particularly vulnerable to sport fishing when they frequent the shallows from late June to mid July and mid September to early October.

Continual monitoring of fishing pressure will be necessary to ensure that fish stocks remain healthy in the Chandler lake system. Baseline data from this study will provide a means for assessing future changes in the lake trout and Arctic char populations and fishing effort. We suggest that the National Park Service develop a monitoring program whereby fishing pressure could be monitored seasonally. A minimal program should include weekend overflights of the lake system during March, April, and May and periodic summer overflights to determine general trends in fishing effort, particularly increased use of Amiloyak Lake.

The suggestion that Arctic char migrate from Chandler Lake to Amiloyak Lake to spawn remains unproven, but fish movement between these lakes does occur and Amiloyak Lake does support a relatively dense population of large Arctic char. These Arctic char may include spawning fish from other lakes in the system, and their vulnerability to summer angling may eventually require frequent surveys of fishing activity at this lake.

If use of the lake system appears to be increasing, we recommend a comprehensive harvest survey designed to interview all anglers during the fishing seasons. This would require interviewing subsistence fishers at the lakes and in Anaktuvuk Pass during the spring and fall, and a constant presence at the lakes by creel clerks during the summer.

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[1]Subsistence fishing with the line attached to a rod or pole is allowed only when fishing through the ice.

TABLE 15.—Summary of estimates for standing crop and current annual yield of lake trout and Arctic char in Chandler Lake and Amiloyak Lake, plus recommended maximum harvest levels. Assumptions for the calculation of estimates, including average fish size for each lake, are provided in text.

			Recommended maximum annual harvest	
	Standing crop (kg/ha)	Current yield (kg/ha)	kg/ha	Number of average-size fish
		Chandler Lake		
Lake trout	1.41	0.03	0.14	260
Arctic char	1.60	0.03	0.22	464
		Amiloyak Lake		
Lake trout	2.20	no data	0.22	25
Arctic char	31.47	no data	1.88	245

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References

Anderson, R. O., and S. J. Gutreuter. 1983. Length, Weight, and Associated Structural Indices. Pages 283-300 *in* L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

ADCRA (Alaska Department of Community and Regional Affairs). 1990. Municipal population report. Alaska Department of Community and Regional Affairs Northern Regional Offices, Fairbanks, Alaska.

Barber, W. E., and G. A. McFarlane. 1987. Evaluation of three techniques to age Arctic char from Alaskan and Canadian waters. Transactions of the American Fisheries Society 116(6):874-881.

Bendock, T. N. 1979. Inventory and cataloging of Arctic area waters. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Project F-9-11, Volume 20, Juneau, Alaska.

Bendock, T. N., and J. M. Burr. 1986. Arctic area trout studies. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Project F-9-18, Volume 27, Juneau, Alaska.

Bergmann, M. A., and H. E. Welch. 1985. Spring meltwater mixing in small Arctic lakes. Canadian Journal of Fisheries and Aquatic Sciences 42:1789-1793.

Bowen, S. H. 1983. Quantitative description of the diet. Pages 325-336 *in* L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Brewer, M. C. 1958. The thermal regime of an Arctic lake. Transactions of the American Geophysical Union 39(2):278-284.

Burr, J. M. 1987. Synopsis and bibliography of lake trout *Salvelinus namaycush* in Alaska. Alaska Department of Fish and Game, Fishery Manuscript Number 5, Juneau, Alaska.

Burr, J. M. 1988. Stock assessment and biological characteristics of lake trout populations in Interior Alaska, 1987. Alaska Department of Fish and Game, Fishery Data Series Number 66, Juneau, Alaska.

Burr, J. M. 1990. Stock assessment and biological characteristics of lake trout populations in Interior Alaska, 1989. Alaska Department of Fish and Game, Fishery Data Series Number 90-33, Juneau, Alaska.

Burr, J. M. 1992. A summary of abundance and density estimates for selected lake trout populations in the Alaska Range and an examination of trends in yield. Alaska Department of Fish and Game, Fishery Manuscript Number 92-1, Anchorage, Alaska.

Craig, P. C. 1977. Ecological studies of anadromous and resident populations of Arctic char in the Canning River drainage and adjacent coastal waters of the Beaufort Sea, Alaska. Canadian Arctic Gas Study, Limited/Alaska Arctic Gas Study Company. Biological Report Series 41, Calgary, Alberta.

Craig, P. C., and J. Wells. 1975. Fisheries investigations in the Chandalar River region, Northeast Alaska. Canadian Arctic Gas Study, Limited/Alaska Arctic Gas Study Company. Biological Report Series 34, Calgary, Alberta.

Fraser, N. C., and G. Power. 1989. Influences of lake trout on lake-resident Arctic char in Northern Quebec, Canada. Transactions of the American Fisheries Society 118(1):36-45.

Fry, F. E. J. 1939. A comparative study of lake trout fisheries in Algonquin Park, Ontario. University of Toronto Studies, Biological Series 46, Publication of Ontario Fisheries Research Laboratory 58:1-69.

Fry. F. E. J. 1949. Statistics of a lake trout fishery. Biometrics 5(1):27-67.

Furniss, R. A. 1974. Inventory and cataloging of Arctic area waters. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Project F-9-6, Volume 15, Juneau, Alaska.

Giles, N. 1980. A stomach sampler for use on live fish. Journal of Fishery Biology 16:441-444.

Hackney, P. A. 1973. Ecology of the burbot (*Lota lota*) with special reference to its role in the Lake Opeongo fish community. Ph.D. Thesis. University of Toronto, Toronto, Ontario.

Healey, M. C. 1978. The dynamics of exploited lake trout populations and implications for management. Journal of Wildlife Management 42(2):307-328.

Holeton, G. F. 1973. Respiration of Arctic char *Salvelinus alpinus* from a high Arctic lake. Journal of the Fisheries Research Board of Canada 30(6):717-723.

Hunter, J. G. 1970. Production of Arctic char *Salvelinus alpinus* Linneaus in a small Arctic lake. Fisheries Research Board of Canada Technical Report Number 231.

Jearld, A. 1983. Age determination. Pages 301-324 *in* L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Johnson, L. 1975. Physical and chemical characteristics of Great Bear Lake, Northwest Territories. Journal of the Fisheries Research Board of Canada 32:1971-1987.

Johnson, L. 1976. Ecology of Arctic populations of lake trout *Salvelinus namaycush*, lake whitefish *Coregonus clupeaformis*, Arctic char *S. alpinus*, and associated species in unexploited lakes of the Canadian Northwest Territories. Journal of the Fisheries Research Board of Canada 33:2459-2488.

Johnson, L. 1980. The Arctic charr, *Salvelinus alpinus*. Pages 15-98 *in* E. K. Balon, editor. Charrs, Salmonid Fishes of the Genus *Salvelinus*. Dr. W. Junk Publishers, The Hague, Netherlands.

Johnson, L. 1983. Homeostatic characteristics of single species fish stocks in Arctic lakes. Journal of the Fisheries Research Board of Canada 33:2459-2488.

Johnson, R. R., and K. D. Troyer. 1994. Survey of lake trout and Arctic char in Walker Lake, Gates of the Arctic National Park and Preserve, 1987 - 1989. U.S. Fish and Wildlife Service, Fairbanks Fishery Resource Office, Alaska Fisheries Technical Report Number 25, Fairbanks, Alaska.

Kennedy, W. A. 1954. Growth, maturity and mortality in the relatively unexploited lake trout, *Cristivomer namaycush*, of Great Slave Lake. Journal of the Fisheries Research Board of Canada 11(6):827-852.

Kleinbaum, D. G., and L. L. Kupper. 1978. Applied regression analysis and other multivariable methods. Duxbury Press, Belmont, California.

Kogl, D. R. 1971. Monitoring and evaluation of Arctic waters with emphasis on the North Slope drainages: Colville River study. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Project F-9-3, Volume 12, Juneau, Alaska.

Langeland, A. 1986. Heavy exploitation of dense resident populations of Arctic char in a mountain lake in Central Norway. North American Journal of Fisheries Management 6(4):519-525.

Martin, N. V., and F. E. J. Fry. 1973. Lake Opeongo. The ecology of the fish community and of man's effects on it. Great Lakes Fisheries Commission Technical Report 24:1-34.

Martin, N. V., and C. H. Olver. 1980. The lake charr, *Salvelinus namaycush*. Pages 205-280 in E. K. Balon, editor. Charrs, Salmonid Fishes of the Genus *Salvelinus*. Dr. W. Junk Publishers, The Hague, Netherlands.

McCart, P. J., P. C. Craig, and H. Bain. 1972. Report on fisheries investigations in the Sagavanirktok River and neighboring drainages. Alyeska Pipeline Service Company, Anchorage, Alaska.

McCart, P. J. 1980. A review of the systematics and ecology of Arctic char *Salvelinus alpinus* in the Western Arctic. Canada Department of Fisheries and Oceans, Canadian Technical Report of Fisheries and Aquatic Sciences Number 935, Winnipeg, Manitoba.

McDonald, M. E., and A. E. Hershey. 1989. Size structure of a lake trout *Salvelinus namaycush* population in an Arctic lake: influence of angling and implications for fish community structure. Canadian Journal of Fisheries and Aquatic Sciences. 46:2153-2156.

McPhail, J. D., and C. C. Lindsey. 1970. Freshwater Fishes of Northwestern Canada and Alaska. Fisheries Research Board of Canada, Bulletin 173, Ottawa.

Miller, R. B., and W. A. Kennedy. 1948. Observations on the lake trout of Great Bear Lake. Journal of the Fisheries Research Board of Canada 74:176-189.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries in 1990. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage, Alaska.

National Park Service. 1986. Gates of the Arctic, general management plan, land protection plan, wilderness suitability review. Gates of the Arctic National Park and Preserve, Fairbanks, Alaska.

Pearse, G. 1978. Inventory and cataloging Interior waters with emphasis on upper Yukon and haul road. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Project F-9-10, Volume 20, Juneau, Alaska.

Power, G. 1978. Fish population structure in Arctic lakes. Journal of the Fisheries Research Board of Canada 35:53-59.

Reanier, W. E., and P. M. Anderson. 1986. A bathymetric study of nine lakes in the south-central Brooks Range: A report to the National Park Service. College of Forestry, University of Washington, Seattle, Washington.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin Number 191, Ottawa.

Schindler, D. W., H. E. Welch, J. Kalff, G. J. Brunskill, and N. Kritsch. 1974. Physical and chemical limnology of char lakes, Cornwallis Island, 75^{o} North Latitude. Journal of the Fisheries Research Board of Canada 31:585-607.

Seaburg, K. G. 1957. A stomach sampler for live fish. The Progressive Fish Culturist 19:137-139.

Snedecor, G. W., and W. G. Cochran. 1980. Statistical methods. Iowa State University Press , Ames, Iowa.

Snyder, D. E. 1983. Fish eggs and larvae. Pages 165-198 *in* L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Systat. 1988. Systat: The system for statistics, version 4.1. Systat Inc., Evanston, Illinois.

Thomasson, K. 1956. Reflections on Arctic and alpine lakes. OIKOS 7(1).

Welch, H. E. 1974. Metabolic rates of Arctic lakes. Limnology and Oceanography 19:65-73.

Welch, H. E. 1985. Introduction to limnological research at Seqvaqjuac, Northern Hudson Bay, Canada. Canadian Journal of Fisheries and Aquatic Sciences 42(3):494-505.

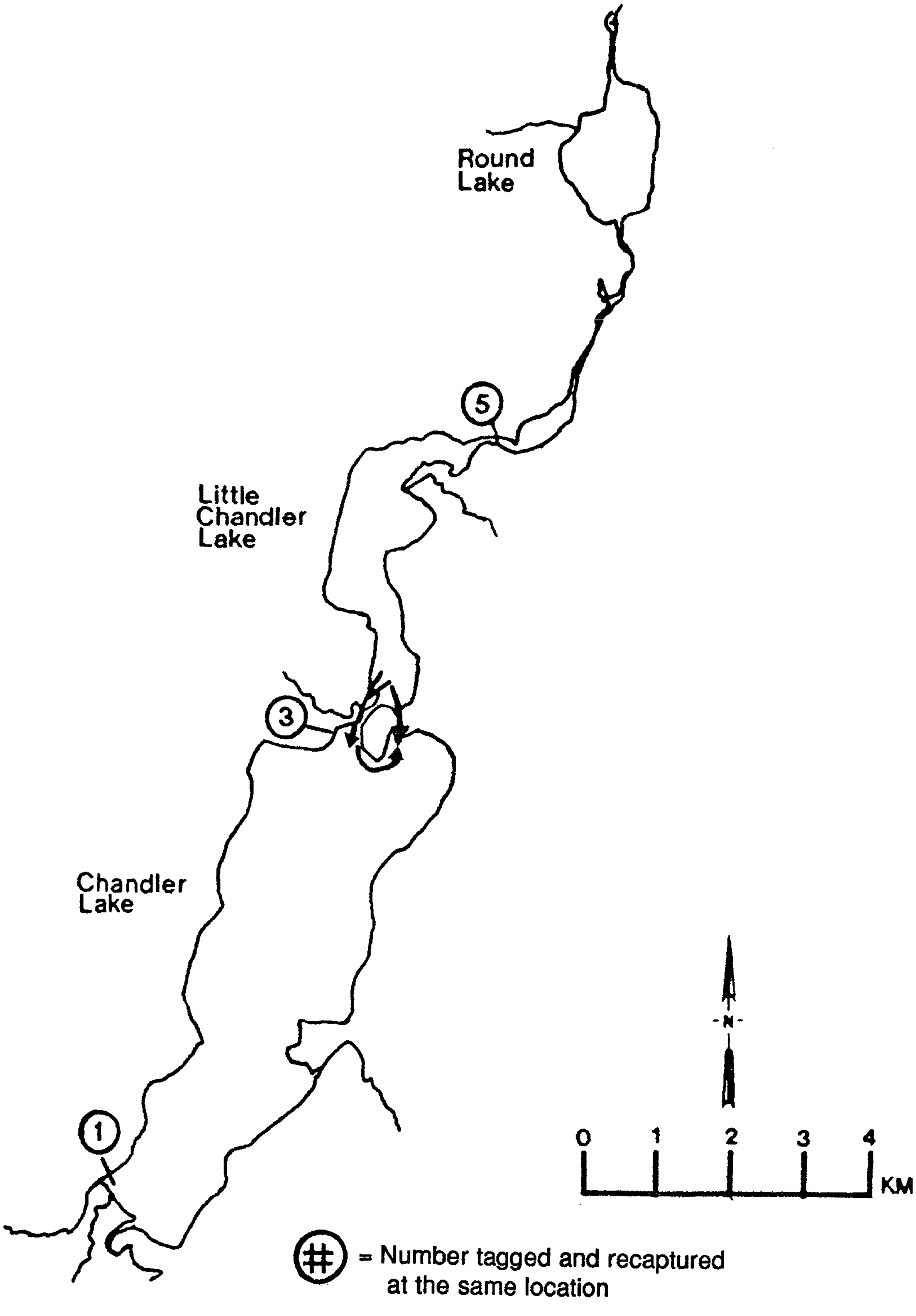
Welch, H. E., and M. A. Bergmann. 1985a. Water circulation in small Arctic lakes in winter. Canadian Journal of Fisheries and Aquatic Sciences 42(3):506-520.

Welch, H. E., and M. A. Bergmann. 1985b. Winter respiration of lakes at Saqvaqjuac, N.W.T. Canadian Journal of Fisheries and Aquatic Sciences 42(3):521-528.

Williams, F. T. 1966. Inventory and cataloging of sport fish and sport fish waters of the Copper River and Prince William Sound drainages, and the upper Susitna River. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Project F-5-R-7, Volume 7, Juneau, Alaska.

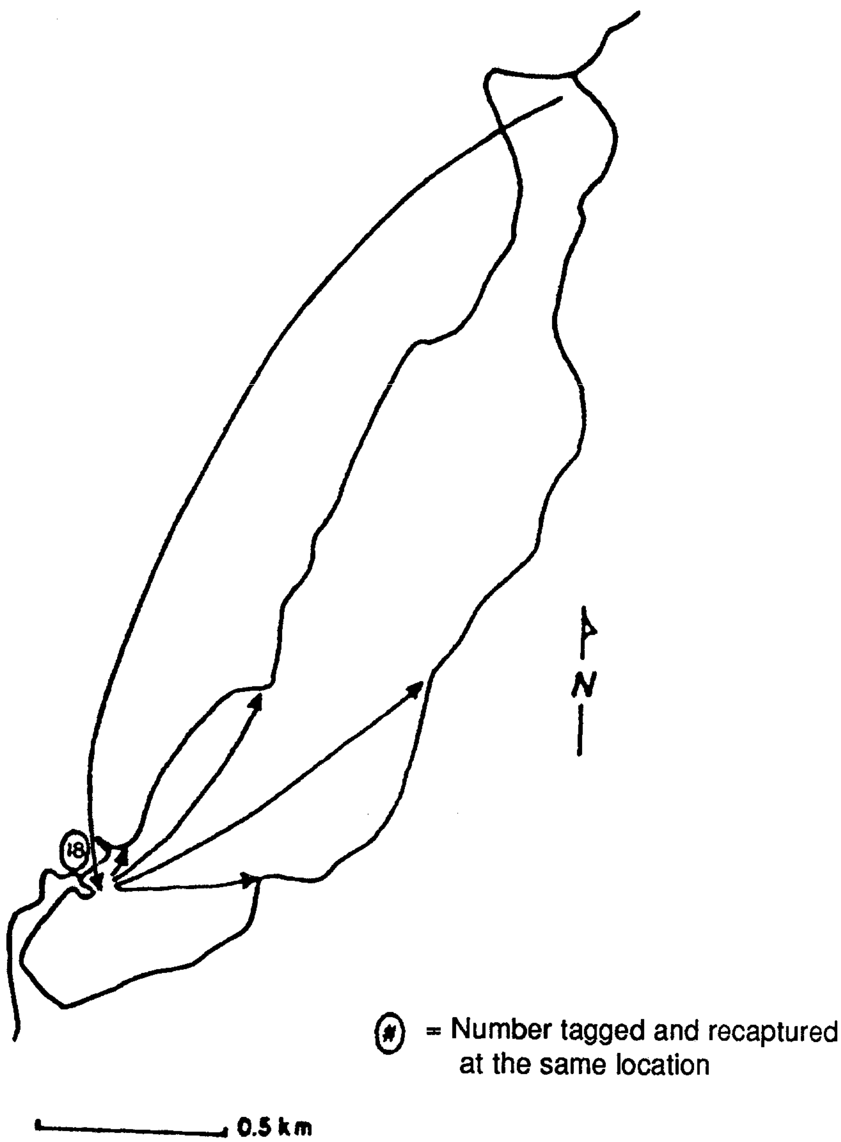
Wohlschlag, D. E. 1953. Some characteristics of the fish populations in an Arctic Alaskan lake. Pages 19-29 *in* I. L. Wiggins, editor. Current Biological Research in the Alaskan Arctic, University Series in the Biological Sciences. Stanford University Publications Volume 11, Stanford, CA.

Wong, B, and T. Whillans. 1973. Limnological and biological survey of Hottah Lake, Northwest Territories. Technical Report Fishes and Marine Service. Technical Report Series Number CEN T-73-6, Government of the Northwest Territories, Canada.

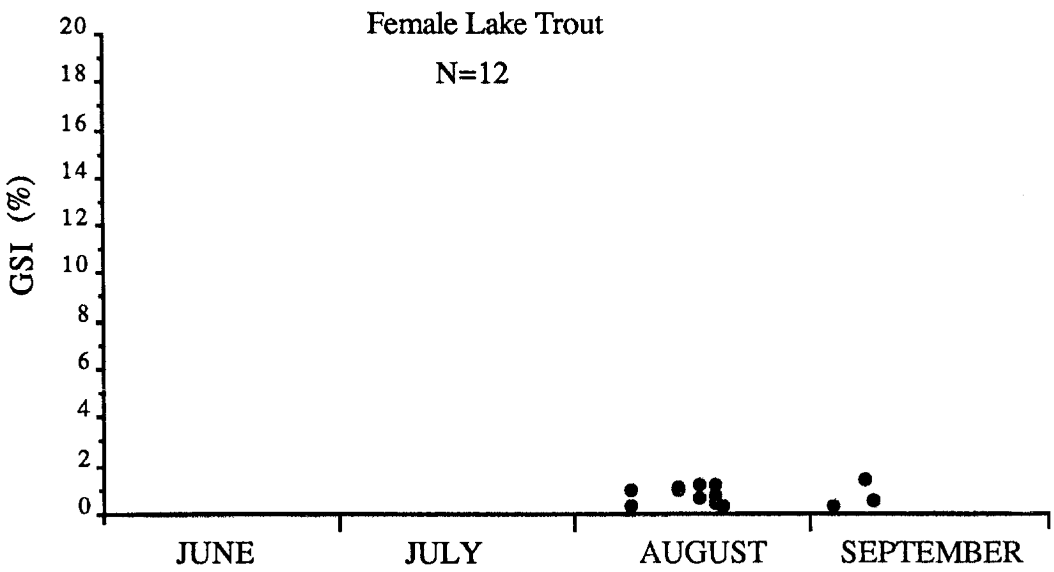


Appendix 1.—Movements of lake trout in the Chandler Lake system, summer 1987.

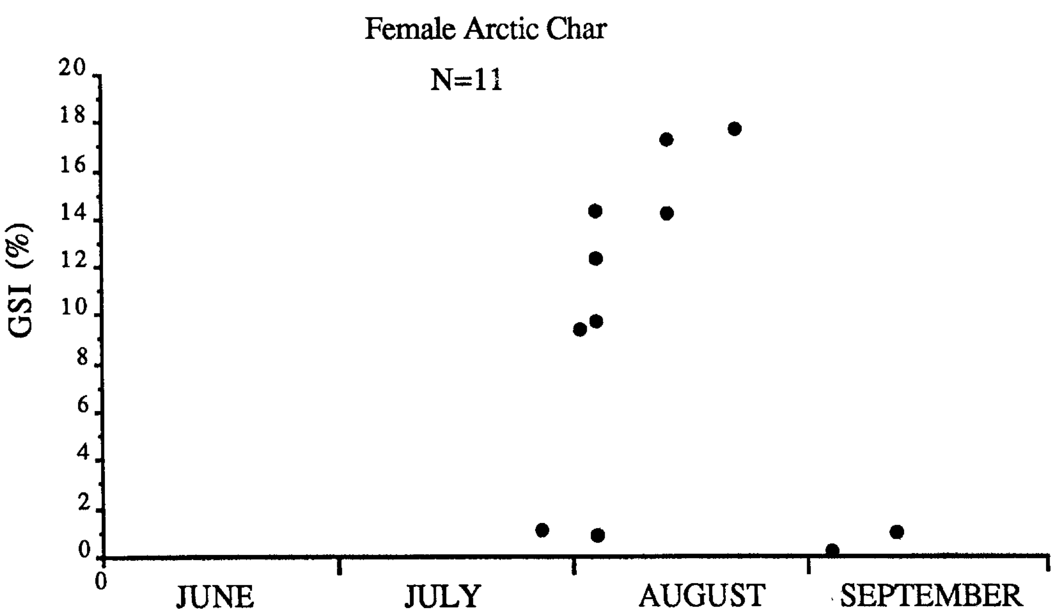
AMILOYAK LAKE



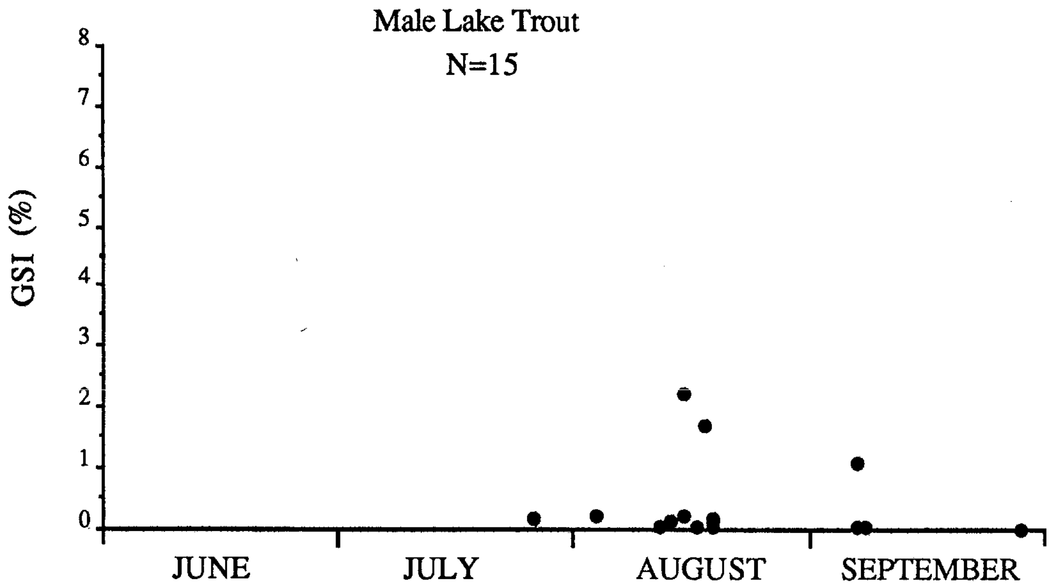
Appendix 2.—Movements of Arctic char in Amiloyak Lake, summer 1987.



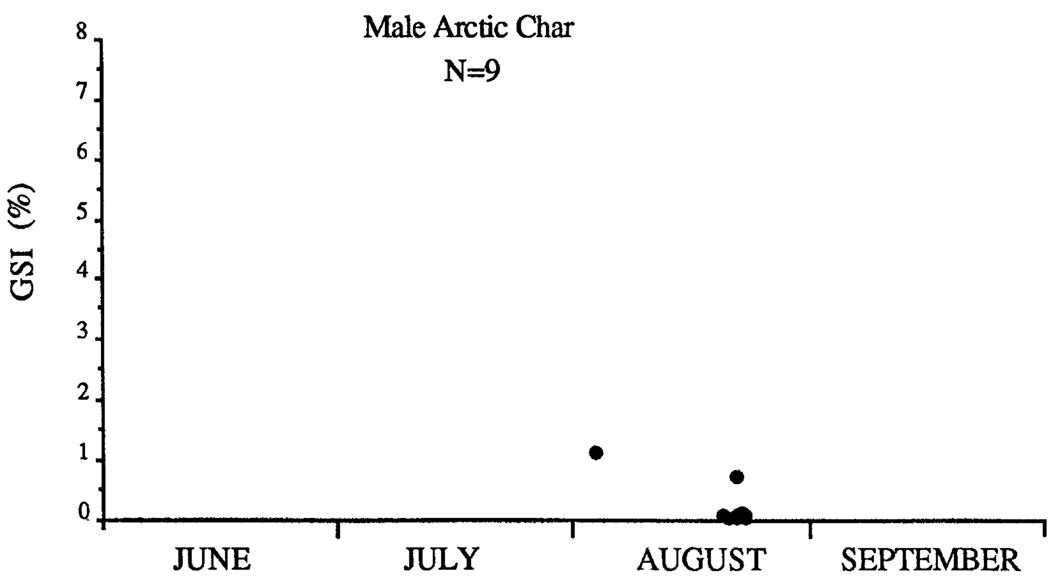
APPENDIX 3.—Gonadosomatic indices (GSI) for female lake trout from the Chandler lake system, 1987.



APPENDIX 4.—Gonadosomatic indices (GSI) for female Arctic char from the Chandler lake system, 1987.



APPENDIX 5.—Gonadosomatic indices (GSI) for male lake trout from the Chandler lake system, 1987.



APPENDIX 6.—Gonadosomatic indices (GSI) for male Arctic char from the Chandler lake system, 1987.