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

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Abstract.—Fish populations were sampled at Walker Lake within the Gates of the Arctic National Park and Preserve during the spring and summer of 1987 and 1988. Creel surveys were conducted to determine sport 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, determine relative abundance in different habitat types, 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 lake throughout the summer.

Harvests were within the levels considered sustainable for arctic and subarctic lakes. Summer creel surveys took place from June to September of 1987 and 1988. In 1989, the operator of the Walker Lake fishing lodge kept records of catch and harvest by lodge-based anglers. Over the three years, creel survey information was collected from 342 anglers. Sport fishing catch per unit effort increased steadily, while annual effort and harvest declined between 1987 and 1989. Estimated yields ranged from 0.005 to 0.007 kg/hectare for lake trout and from 0.005 to 0.009 kg/hectare for Arctic char.

A Schnabel multiple census was used to estimate population sizes for lake trout and Arctic char. The population estimate for lake trout ($\geq$ 312 mm in fork length) was $\hat{N} = 1{,}695$ fish (95% confidence interval, 1,166 - 2,871), based on a total of 335 fish captured (151 marked, 21 recaptured). The population estimate for Arctic char ($\geq$298 mm in fork length) was $\hat{N} = 2{,}543$ fish (95% confidence interval, 1,263 - 5,565), based on 218 fish captured (118 marked, six recaptured). Analysis of relative abundance by habitat type indicated an increase in lake trout abundance near stream mouths and a decrease in Arctic char abundance over cobble/boulder substrates from early to late season.

Lake trout averaged 551 mm in the 1987 gill net catch and 493 mm in 1988; and Arctic char averaged 557 mm in 1987 and 502 mm in 1988. Size differences between years corresponded to the smaller mesh size gill nets employed in 1988. Weight-length regression coefficients were within the range of values reported for these species in Alaska and Canada, and indicate healthy growth.

A sample of lake trout ranged in age from 5 to 26 years with mean lengths from 203 to 805 mm; and Arctic char ranged from 3 to 15 years with mean lengths from 320 to 600 mm. Growth rates of lake trout after age 5 appeared to be greater than other northern and central

Alaska populations. Arctic char growth rates appeared to be greater than several other populations in northern Alaska.

Analysis of stomach contents showed that lake trout were primarily piscivorous and Arctic char primarily nonpiscivorous. Round whitefish was the most important food item by weight in the lake trout diet. For Arctic char, snails were the most important food item by weight.

Of the 51 lake trout analyzed for fecundity and maturity, nine fish were considered to be ripening for spawning in the year of capture. Ripening females had fecundities (3,089 - 4,067 ova) within the range documented for other populations in northern Alaska. A sample of 16 Arctic char included one ripening male and no ripening females.

Harvest levels were low relative to population size, 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 0.07 kg/hectare for lake trout and 0.16 kg/hectare for Arctic char. Management options are discussed.

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Introduction

Gates of the Arctic National Park and Preserve (GAAR), located in the central part 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 typically 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, exploitation levels, and 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 cultural subsistence needs of rural residents and to provide sport fishing opportunities.

Walker Lake, in the south central region of GAAR (Figure 1), provides an important sport fishery for lake trout, Arctic char, and Arctic grayling. A fishing guide service based at the Walker Lake lodge operated through 1989. There are three private dwellings on the lake, a house and two cabins. Visitors to Walker Lake include groups of fishers, hikers, kayakers, and rafters transported by private aircraft or by guiding and charter services from Bettles and Fairbanks. Access is primarily by float plane, and occurs from June through September. Sporadic fishing through the ice may occur during early spring, and in some years fishing effort increases in May when there is a band of open water around the edge of the lake (Bruce Collins, National Park Service, Anchorage, personal communication).

Prior to this study, few data on Walker Lake fish populations had been collected. A cursory survey of the lake was made in 1967 by Roguski and Spetz (1968). After 42 hours of gill net effort they captured 13 lake trout, two Arctic char, and two Arctic grayling. One lake trout weighed 8.8 kg and was 13 years old. Round whitefish *Prosopium cylindraceum*, slimy sculpin *Cottus cognatus*, and least cisco *Coregonus sardinella* have also been captured (Ken Alt, Alaska Department of Fish and Game, Fairbanks, personal communication).

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.

This is the final report for this study and summarizes 1987 and 1988 field activities, and includes 1989 catch and harvest data provided by the Walker Lake lodge. The overall study

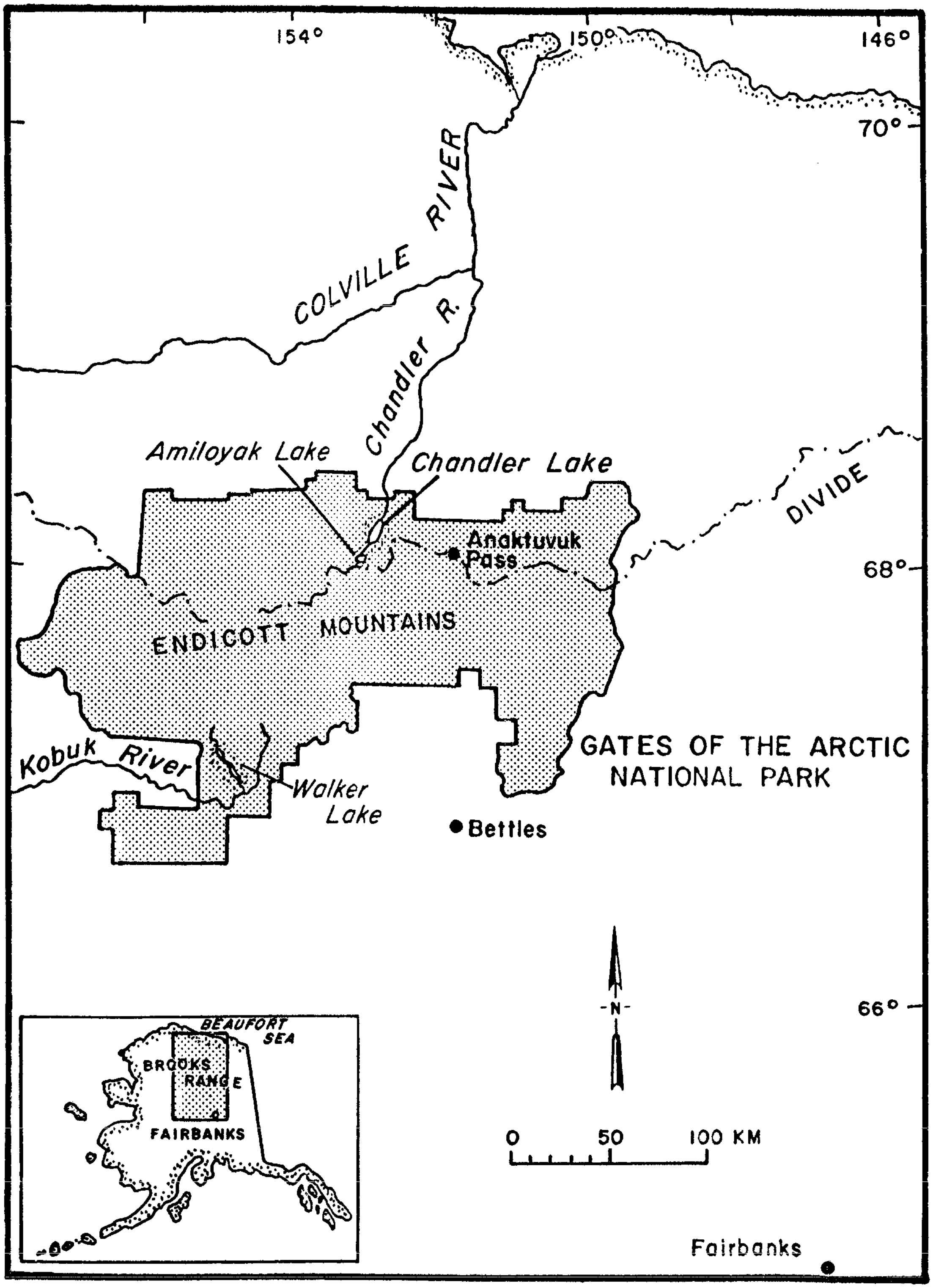

FIGURE 1.—Location of Walker Lake within Gates of the Arctic National Park and Preserve.

objective was to provide baseline information on lake fish populations and their exploitation in lakes within GAAR. In addition to Walker Lake, fish population and exploitation data were collected on the Chandler lake system in northern GAAR (Figure 1) and are summarized in a separate report (Troyer and Johnson 1994). Specific study objectives for Walker Lake were to:

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

Study Area

Walker Lake is a single lake system at 67° 15' N latitude and 206 m above mean sea level, with a surface area of 3,800 hectares and a maximum depth of 122 m (Figure 2). Taiga forest surrounds the lake and the climate is similar to interior Alaska with generally clear skies and calm winds. The south side of the Brooks Range below 762 m elevation is classified as subarctic (National Park Service 1986). Precipitation ranges from 30 to 48 cm of rain and 152 to 203 cm of snow, annually. Average July minimum and maximum temperatures are 6 and 21°C. Average January minimum and maximum temperatures are -34 and -17°C.

The lake's main inlet is Kaluluktok Creek, a drainage of the Endicott Mountains. The outlet creek flows south to join the Kobuk River. Nine smaller creeks drain into Walker Lake. The north section of the lake is predominately characterized by several streams and steep shorelines dropping to depths greater than 100 m (Figure 2). The middle section has four islands and three shoal areas, two distinct basins, and a maximum depth of 58 m. The southern section of the lake contains a submerged plateau that extends from the west and drops off into the lake's deepest basin (122 m).

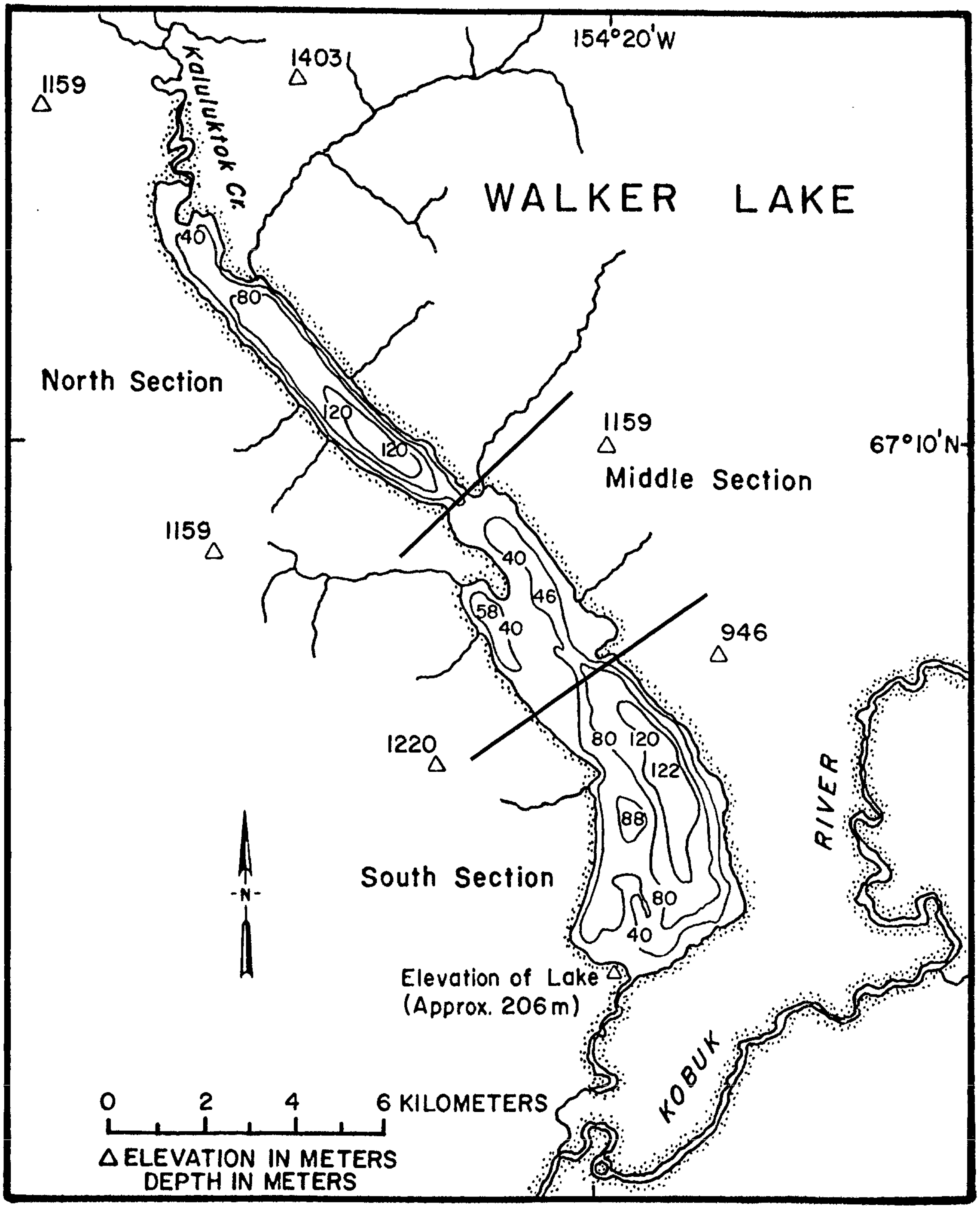

FIGURE 2.—Bathymetric map of Walker Lake (adapted from Reanier and Anderson 1986).

Methods

Creel Survey

Creel surveys were conducted in 1987 and 1988. The 1987 survey was conducted over a 94 day period (June 15 - September 16), and the 1988 survey over a 104 day period (June 6 - September 17). Because of the low level of fishing activity it was not practical to make periodic estimates of total fishing effort; instead, we attempted to interview every angler. Many anglers were interviewed more than once to obtain complete trip information. Data recorded from interviews included: date, hours fished, target species, angler type (boat or shore; lodge-based or independent), catch, and harvest. Fork length and weight were recorded opportunistically.

From angler interviews during the months of June, July, August, and September we estimated total catch and harvest, total angler-hours, and catch and harvest by species per angler-hour. Estimates do not include any expansion for anglers not interviewed or for the incomplete portion of some trips, as both factors appeared to be minor contributors to total catch and harvest and neither could be accurately assessed.

Catches per angler-hour (CPUE) for lake trout, Arctic char, and Arctic grayling, were calculated for the jth month using the formula:

$$(1) \qquad CPUE_j = \frac{\sum_{i=1}^{n} C_{ij}}{\sum_{i=1}^{n} h_{ij}} ,$$

where C_{ij} was total recorded catch, by species, on the ith day of the jth month, h_{ij} was total recorded angler-hours on the ith day of the jth month, and n was total number of days when fishing took place in the jth month (Cochran 1977).

The estimate of CPUE sample variance was calculated using the formula:

$$(2) \qquad v(CPUE_j) = \frac{\sum_{i=1}^{n} (cpue_i - CPUE_j)^2}{n-1} ,$$

where $cpue_i$ was catch per angler-hour on the ith day of the jth month (Cochran 1977). Variabilities in monthly CPUEs were reported as coefficients of variation (CV%) to show the relative dispersion of values about the mean:

(3) $$CV\%(CPUE_j) = \frac{\sqrt{v(CPUE_j)}}{CPUE_j} \times 100\% .$$

Estimates of harvest per angler-hour (HPUE) were calculated by substituting H (harvest) for C in equation 1. Variances and coefficients of variation for HPUE were calculated by substituting harvest for catch values in equations 2 and 3.

The hypotheses that CPUE and HPUE from incomplete angler trips are unbiased estimators of CPUE and HPUE from completed angler trips was tested by species for significance using Mann-Whitney U tests[1] ($P = 0.05$). If results were not significant, data from incomplete and completed angler trips were pooled for calculating CPUE and HPUE; if results were significant, only data from complete trips were used. Total harvest for the year was tallied and reported by species in number of fish and weight per unit lake surface area. For the latter calculation, mean weight of fish caught was assumed to equal the mean weight of fish harvested.

Statistical comparisons were made to determine the distribution of fishing effort. Differences in daily fishing effort between weekends and weekdays and between boat and shore anglers were tested with Mann-Whitney U tests ($P = 0.05$).

In 1989, the lodge operator kept records of catch and harvest from lodge-based anglers over the 79 day period of guiding service (June 21 - September 7). Total catch and harvest in 1989 were estimated by dividing 1989 lodge-based catch and harvest by the mean percentages of total catch and harvest attributed to lodge-based anglers in 1987 and 1988. Catch rates by species were compared among years for lodge-based anglers with Kruskal-Wallis tests and nonparametric Tukey multiple comparisons ($P = 0.05$).

Shoreline Sampling Gear and Stratification

In 1987, sampling was conducted June 17 - September 16. 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 in an attempt to intercept fish moving between deep and shallow water.

Net sites were selected subjectively to try to maximize catch: the sites found to be most productive were fished repeatedly. Ten sites were fished in the northern half of the lake and 34 sites were fished in the southern half. Gill nets were fished from 30 minutes to 8 hours and were monitored continuously to reduce mortalities. An important constraint of the study design was the requirement that total mortalities not exceed 100 lake trout or Arctic char over the duration of the project. Because sampling was non-random, 1987 data were not used for

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

estimating absolute[1] and relative abundance but were included with 1988 data for determining condition, age, growth, food habits, fecundity, and maturity.

In 1988, sampling was divided into two, three-week intensive sampling periods: early (June 13 - July 4), and late (August 24 - September 15). A different size of experimental gill net was used in 1988 in an effort to reduce mortalities of lake trout and Arctic char. Monofilament gill nets (45.7 m x 4.9 m with 15 m panels of 1.3, 1.9, and 2.5 cm bar meshes, and 45.7 m x 4.9 m with 3.8 cm bar mesh) were used. These "tooth nets" snag larger fish by their teeth instead of actually gilling the fish (Williams 1966).

At each sample site, the nets were fished in tandem beginning at or near the shoreline and extending offshore perpendicular to the bottom contour. Nets were anchored with three 8 kg weights, one at either end and one in the middle where the nets were joined. The smaller mesh net was fished in the littoral zone (depths less than 14 m) and the larger mesh net was fished in the pelagic zone (depths 14 m and greater). The distinction between zones was based on the mean Secchi disk transparency from weekly readings made during summer 1987.

A stratified random sampling scheme was used in 1988. The lake was stratified into three sections: north, middle, and south. The lake was further stratified by shoreline type, substrate type, and depth zone (Table 1). Shoreline types were divided into six strata: sraight, where there is no abrupt change in shoreline form; peninsulas, areas of increased shoreline development; stream mouths, where permanent streams enter the lake; islands, where islands or shoals occur; inlet stream, where Kaluluktok Creek enters the lake; and the unnamed outlet stream which connects Walker Lake to the Kobuk River.

Substrates were mapped between June 7 and 10, 1988. Substrate types included sand/pebble/gravel (SPG), cobble/boulder (CB), and mixed SPG+CB (MIX) and were determined by consensus of visual observations by three independent observers. A lead ball, 64 mm in diameter, was used as a standard to differentiate substrate types. SPG substrate areas were defined as having at least 50% bottom material less than 64 mm in diameter; CB substrate areas had at least 50% bottom material greater than or equal to 64 mm in diameter; and MIX substrate was where no clear distinction could be made between the two (Orth 1983). Two depth zones were sampled: littoral and pelagic.

Sample sites were allocated to each lake section in proportion to length of shoreline in the section (Appendix 1). Sampling was further apportioned by percent of each shoreline/substrate type within a section (Appendix 2). Once the number of sites for each shoreline/substrate type was determined for each lake section, actual sampling sites were selected using a table of random numbers and a numbered grid of the lake. A total of 34 sites were sampled: 13 in the north, 11 in the middle, and 10 in the south sections (Figure 3). We fished four sites per day so that each site was sampled twice during each three-week period: once during the daytime (net set before 1700 hrs) and once in the evening (net set after 1700 hrs). Nets were set for 4 hours and checked at 20 minute intervals to minimize mortalities. The following data were recorded for each fish captured: species, sample site, net of capture (littoral or pelagic), and capture depth (upper or lower half of the net).

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[1] In 1987, lake trout and Arctic char less than 450 mm were tagged with gray Floy anchor tags, and fish 450 mm or larger received yellow spaghetti tags. Preliminary population estimates were made in 1987; however, the estimates were considered to be biased by non-random sampling.

TABLE 1.—Stratification criteria and sampling strata for Walker Lake.

Criterion	Strata
Lake section	North, middle, south
Shoreline type	Straight, peninsulas, islands, inlet stream, outlet stream, stream mouths (tributaries)
Substrate type	Sand/pebble/gravel (SPG), cobble/boulder (CB), mixed SPG+CB (MIX)
Depth zone	Littoral (less than 14m), pelagic (14m and greater)

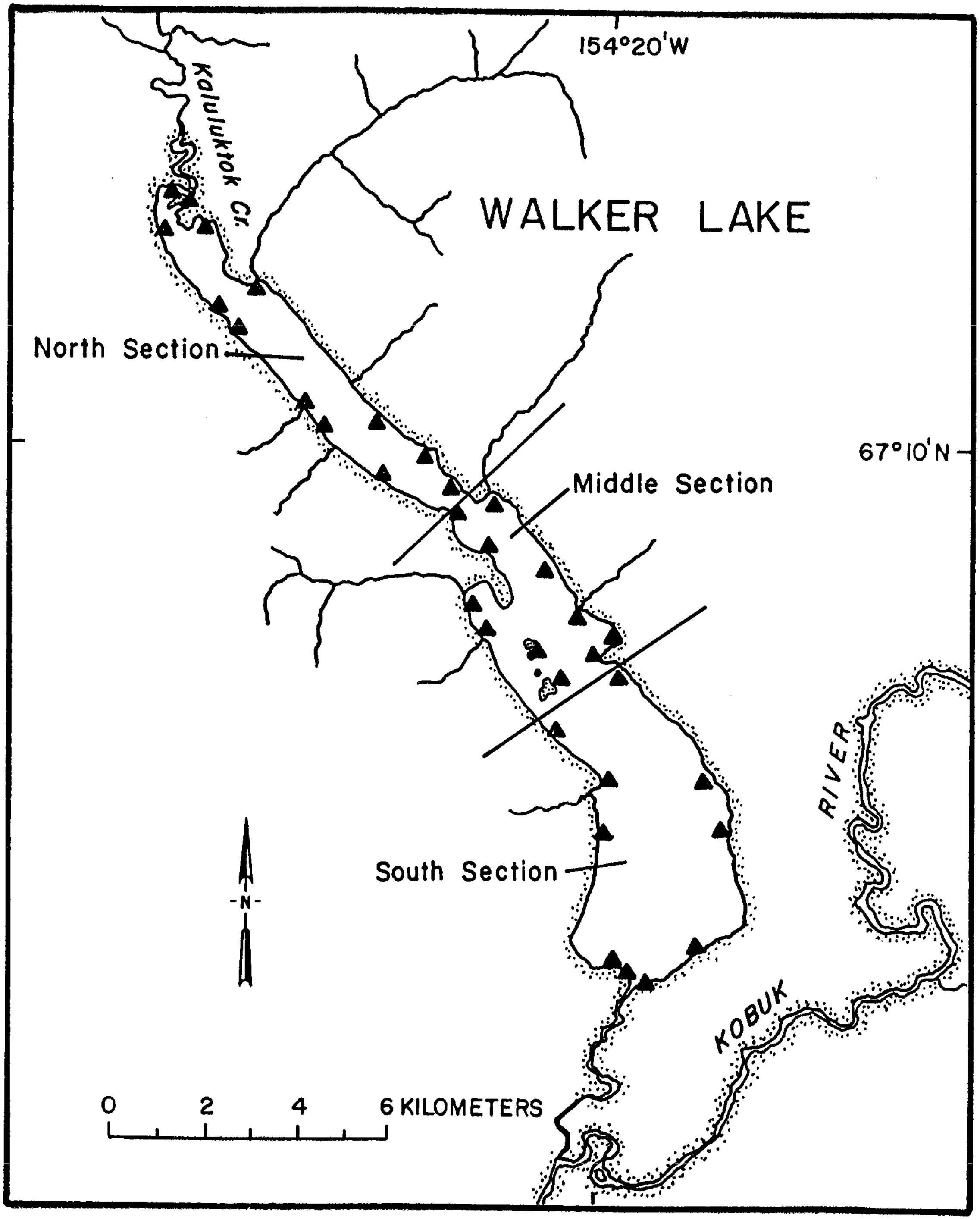

FIGURE 3.—Shoreline gill net sampling sites for Walker Lake, 1988.

Relative Abundance

Relative abundance of lake trout and Arctic char was estimated from shoreline sampling in 1988. Relative abundance was expressed as catch per sample site per hour (KPUE). KPUE was calculated for each stratum during each sampling period using the formula:

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

where, K_j was the catch by species per site from the jth sample, h_j was the number of hours fished per site during the jth sample and n was the number of samples in the stratum. Hypotheses that KPUEs are equal among sections, shorelines, substrates, and times of day were tested within sampling periods using Kruskal-Wallis tests and nonparametric Tukey multiple comparisons ($P = 0.05$). The hypothesis that early season KPUE is equal to late season KPUE was tested for each stratum using a Wilcoxon paired-sample test ($P = 0.05$).

Absolute Abundance

Fish captured during the early intensive sampling period in 1988 were tagged with numbered Floy anchor tags. No tagging occurred during the late intensive sampling period. The number of fish caught, number of marked fish at large, and number of recaptures were recorded daily during both sampling periods. Fish tagged in 1988 received an adipose fin clip to monitor tag loss. All fish captured were examined for adipose clips.

Several tagged and stomach pumped (described below under *Food Habits*) lake trout and Arctic char were retained from 21 to 48 hours in a 1.5 m x 0.75 m hoop net to assess short term tag loss and handling mortality. This was considered a maximum estimate of short term handling mortality because all fish retained for observation were both tagged and stomach pumped, whereas most fish tagged in this study were not subjected to the additional stress of stomach pumping.

Population estimates for the catchable populations[1] 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 using the formula:

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

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[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. We estimated standing crop (absolute abundance or weight of catchable sized fish per unit area) based on the Schnabel population estimate and on the mean weight of fish in the 1988 shoreline gill net catch.

Offshore Sampling and Beach Seining

Sampling was conducted in midsummer between July 6 and August 26, 1988 and focused on identifying juvenile fish (< 200 mm fork length) rearing areas and determining relative abundance. Monofilament gill nets (45.7 m x 4.9 m with 15 m panels of 1.3, 1.9, and 2.5 cm bar meshes) were fished at offshore sites. Lake sections were sampled in proportion to the pelagic area of each section as a percentage of total lake area (Appendix 1): north (24%), middle (16%) and south (45%). Using a table of random numbers and a numbered grid of the lake we selected six sampling sites in the north, four in the middle, and twelve in the south sections (Figure 4). One net was anchored on the bottom and the other set concurrently at mid-depth in the water column. Nets were initially set for one hour to evaluate sampling mortalities. After all sites had been sampled once, with one lake trout mortality, nets were set for twenty-four hours at each site. Therefore, each site received a total of twenty-five hours of effort per net.

Beach seines were used between July 12 and August 26, 1988. Two types of beach seine (10.0 m x 1.5 m with 0.6 cm bar mesh; and 45.7 m x 3.1 m, with 0.6 cm bar mesh) were used for sampling shallow reaches of the lake and stream mouths (Figure 4). Seining sites included shoals along the lake shore and stream mouth deltas with moderate to low gradients. Few shoreline sites were suitable for seining due to the prevalence of steep gradients. Seining was limited to smooth substrate types (SPG) due to the inefficiency of seining over coarse substrates (CB). Because the amounts of shoreline with SPG substrate were approximately equal in each lake section, three sites were randomly selected per section (nine total shore sites). Each lake section had three stream mouths suitable for seining (nine total stream sites).

The 18 seining sites were sampled three times each over the six week period. Each sample consisted of two hauls with the small seine and one haul with the large seine. The small seine was walked parallel to shore for about 10 m. The large seine was set by boat in a semi-circle with one end stationary on shore. Number caught by species and location of capture were recorded for all seine hauls. Because of the taxonomic difficulty in separating lake trout and Arctic char less than 100 mm in fork length, these fish were grouped together as *Salvelinus* spp. In each seine haul, all fish were measured for samples of 20 fish or fewer (by species); otherwise, 10 of the largest and 10 of the smallest fish (estimated visually) of a species were measured to estimate size range.

Length, Weight, and Condition

In 1987 and 1988, fork lengths (mm) and wet weights (g) were recorded from all lake trout and Arctic char caught in gill nets. Fork lengths were measured to the nearest millimeter. To test for differences in mean length of the shoreline gill net catch between years, *t* tests

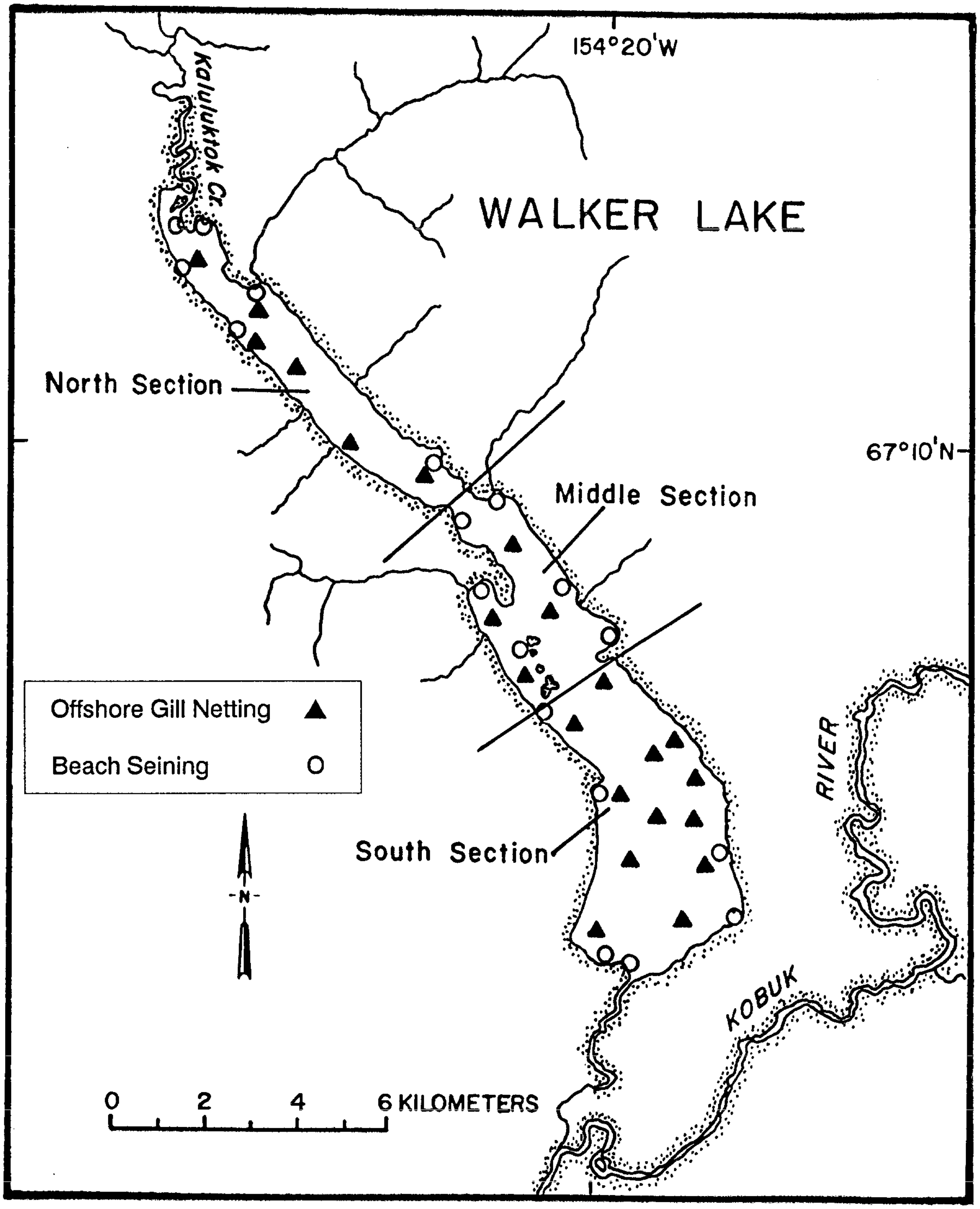

FIGURE 4.—Offshore gill net and beach seine sampling sites for Walker Lake, 1988.

were used (Zar 1984). Weights of fish were determined with Pesola spring scales to different levels of precision depending on fish size. Fish weights less than 500 g were measured to the nearest 5 g; weights from 500 g to 1 kg were measured to the nearest 10 g; weights between 1 and 2 kg were measured to the nearest 25 g; and weights of 2 kg and greater were measured to the nearest 50 g.

Fish used for weight-length relations included those caught in shoreline and offshore gill nets and the sample of sport angler catch which was weighed and measured. Weight-length relations for lake trout and Arctic char were described using 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 regressions and intercepts were estimated using geometric mean regression techniques (Ricker 1975). Analysis of covariance comparisons of slopes and intercepts were used to determine if 1987 and 1988 data could be pooled ($P = 0.05$).

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 populations from Chandler and Amiloyak lakes (Troyer and Johnson 1994). Weight-length regression lines were compared with either (1) a multiple regression model with dummy variables (test for coincidence; $P = 0.05$) if sample variances were not significantly different or (2) *t* tests of slopes and intercepts ($P = 0.016$) if variances differed significantly (Kleinbaum and Kupper 1978). Differences among variances were determined with Levene's test ($P = 0.05$; Snedecor and Cochran 1980).

Relative condition factors (Kn) for lake trout and Arctic char were calculated with the equation (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 1 (approximately the midpoint of ice-free season) and fish caught after August 1.

Age and Growth

Otoliths were obtained from net mortalities, fish sacrificed, and some fish caught by anglers in 1987 and 1988. 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 using 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 age 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 fish sacrificed. 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, or genus in the case of *Salvelinus* spp. less than 100 mm in length. Data are presented as frequency of occurrence and percent by wet weight (Bowen 1983).

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 and 1988 sampling were used to calculate a gonadosomatic index (GSI) where gonad weight is expressed as a percentage of total body weight. 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).

Physical and Chemical Sampling

Surface readings of alkalinity, hardness, pH, conductivity, dissolved oxygen, water temperature, and Secchi transparency were recorded in 1988 during the months of June, July, August, and September at offshore gill net sites (Figure 4). 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. Surface dissolved oxygen concentration was measured in the north, middle, and south sections; dissolved oxygen samples at a depth of 110 m in the north and south sections were collected with a Kemmerer sampler according to Standard Methods for the Examination of Water and Wastewater (American Public Health Association 1985). A Secchi disk was used to determine the depth of transmitted light. Conductivity was measured using a Hach® Model 17250 mini-conductivity meter. Spatial and temporal differences in surface readings were tested with Kruskal-Wallis tests and nonparametric Tukey multiple comparisons ($P < 0.05$).

Results

Creel Survey

During the 1987 summer creel survey, 186 anglers were interviewed over a 94 day period. Anglers were present on 45% of the days, fishing a total of 852 hours. Total angler-hours were highest in August (617), followed by September (118), July (97), and June (20). Total recorded angler catch in 1987 was 339 fish, including 47 lake trout, 30 Arctic char, and 262 Arctic grayling (Table 2). Total reported angler harvest was 22 lake trout, 20 Arctic char and 32 Arctic grayling. Catch to harvest ratios were 2:1 for lake trout, 1.5:1 for Arctic char, and 8:1 for Arctic grayling.

Eighty-seven percent of the anglers were interviewed after completed fishing trips. Complete and incomplete trips were pooled for calculating CPUE and HPUE, because catch and harvest rates by species did not differ significantly between complete and incomplete trips ($0.22 < P < 0.73$). Catch per angler-hour was highest in June for Arctic char (0.15) and July for lake trout (0.23) and Arctic grayling (0.73; Table 3). Catch rates were lowest in August for both lake trout (0.03) and Arctic char (0.02). There was no reported catch of Arctic grayling in June or September. Both CPUE and HPUE were highly variable, with coefficients of variation exceeding 100% for all months and all three species.

During the 1988 summer creel survey, 117 anglers were interviewed over a 104 day period. Anglers were present on 34% of the days, fishing a total of 406 hours. Total angler-hours were highest in July (206), followed by August (72), September (66), and June (62). Total reported angler catch in 1988 was 738 fish, including 63 lake trout, 104 Arctic char, and 571 Arctic grayling (Table 2). Total reported angler harvest was 16 lake trout, 10 Arctic char, and 24 Arctic grayling. Catch to harvest ratios were 4:1 for lake trout, 10.5:1 for Arctic char, and 24:1 for Arctic grayling.

Eighty-two percent of the anglers were interviewed after completed fishing trips. Complete and incomplete trips were pooled for calculating CPUE and HPUE ($0.23 < P < 0.69$). Catch of lake trout per angler-hour was highest in June (0.37) and lowest in July and August (0.11; Table 3). Arctic char CPUE was highest in September (0.71) and lowest in July (0.03). Arctic grayling CPUE was highest in July (2.38) and lowest in June (0.10).

A sample of lake trout caught by anglers in 1987 and 1988 (N = 95) averaged 474 mm (312 - 800 mm) and 1.20 kg (0.32 - 4.70 kg); a sample of Arctic char (N = 77) averaged 500 mm (259 - 724 mm) and 1.79 kg (0.19 - 3.75 kg). Assuming the mean weight of fish caught equalled the mean weight of fish harvested, the 1987 reported harvest equaled 0.007 kg/hectare for lake trout and 0.009 kg/hectare for Arctic char. The 1988 reported harvest equalled 0.005 kg/hectare for lake trout and 0.005 kg/hectare for Arctic char. In 1987 and 1988 combined, only 10% of the anglers harvested one or more lake trout, and only 2% harvested two or more. For Arctic char, 7% of the anglers harvested one or more fish, and 1% harvested two or more.

Forty-three percent of the anglers interviewed in 1987 and 1988 indicated they were fishing for more than one species. Most anglers (57%) were seeking only one species: lake trout were most frequently targeted (19% of all anglers interviewed), followed by Arctic grayling (15%), Arctic char (12%), northern pike (10%), and burbot (1%). Lodge-based anglers expended most of the fishing effort (70%) and accounted for most of the lake trout catch (59%), Arctic char catch (79%), and Arctic grayling catch (61%). There was no significant

TABLE 2.—Reported catch and harvest by month in 1987 and 1988 creel surveys of Walker Lake.

Month	Number of anglers	Angler-hours	Lake Trout		Arctic char		Arctic grayling	
			Catch	Harvest	Catch	Harvest	Catch	Harvest
				1987				
June	5	20	2	0	3	0	0	0
July	41	97	22	6	4	4	71	14
August	115	617	16	9	13	6	191	18
September	25	118	7	7	10	10	0	0
Total	186	852	47	22	30	20	262	32
				1988				
June	15	62	23	3	18	2	6	0
July	52	206	22	9	6	2	490	15
August	28	72	8	4	33	3	65	9
September	22	66	10	0	47	3	10	0
Total	117	406	63	16	104	10	571	24

TABLE 3.—Catch per angler-hour (CPUE), harvest per angler-hour (HPUE), and their coefficients of variation (CV%) for lake trout, Arctic char, and Arctic grayling at Walker Lake during the months of June, July, August, and September, 1987 and 1988. Standard errors are in parentheses.

	Lake trout				Arctic char				Arctic grayling			
Date	CPUE	CV%	HPUE	CV%	CPUE	CV%	HPUE	CV%	CPUE	CV%	HPUE	CV%
1987												
Jun 15 - 30	0.10 (0.09)	120.2	0	---	0.15 (0.13)	120.2	0	---	0	---	0	---
Jul 1 - 31	0.23 (0.08)	132.6	0.06 (0.02)	142.5	0.04 (0.03)	299.5	0.04 (0.03)	299.5	0.73 (0.29)	146.7	0.14 (0.06)	157.3
Aug 1 - 31	0.03 (0.02)	289.8	0.01 (0.02)	495.2	0.02 (0.02)	292.4	0.01 (0.01)	499.3	0.31 (0.21)	276.9	0.03 (0.02)	234.8
Sep 1 - 16	0.06 (0.11)	572.4	0.06 (0.11)	572.4	0.08 (0.34)	1219.4	0.08 (0.34)	1219.4	0	---	0	---
1988												
Jun 6 - 30	0.37 (0.10)	60.8	0.05 (0.02)	94.1	0.29 (0.09)	67.4	0.03 (0.05)	348.7	0.10 (0.21)	477.3	0	---
Jul 1 - 31	0.11 (0.13)	473.4	0.04 (0.13)	1195.6	0.03 (0.01)	128.2	0.01 (0.01)	298.8	2.38 (0.60)	100.9	0.07 (0.04)	192.7
Aug 1 - 31	0.11 (0.12)	274.9	0.06 (0.05)	229.5	0.46 (0.31)	181.1	0.04 (0.05)	302.8	0.90 (0.73)	213.5	0.13 (0.06)	117.8
Sep 1 - 16	0.15 (0.03)	54.0	0	---	0.71 (0.25)	92.9	0.05 (0.02)	118.3	0.15 (0.24)	420.3	0	---

difference ($P > 0.05$) in fishing effort between weekends and weekdays. Fishing effort differed significantly between boat and shore anglers ($P < 0.005$), with boat anglers comprising 79% of the fishing effort.

In 1989, the lodge reported 39 lodge-based anglers fishing 228 angler-hours during the period June 21 - September 7 (Table 4). Since lodge-based fishers comprised 70% of 1987-88 effort, we estimate a total effort of 326 angler-hours in 1989. Total estimated catch for 1989 was 86 lake trout, 96 Arctic char and 154 Arctic grayling. Estimated CPUEs for the season were 0.26 lake trout, 0.29 Arctic char, and 0.47 Arctic grayling per angler-hour. An estimated 23 lake trout, 14 Arctic char and 0 Arctic grayling were harvested. Catch to harvest ratios were 3.5:1 for lake trout and 7:1 for Arctic char. Estimated total yields were 0.007 kg/hectare for lake trout and 0.007 kg/hectare for Arctic char.

The CPUE estimates for Arctic char and lake trout show a trend of steadily increasing angler success from 1987 to 1989 (Figure 5). For both lake trout and Arctic char, CPUE differed significantly between 1987 and subsequent years ($P < 0.02$), whereas 1988 and 1989 did not differ significantly ($P > 0.10$). The increase in angler effectiveness after 1987 was balanced by a decrease in the percentage of fish harvested (Figure 6).

Relative Abundance

In 1988, 34 shoreline sites were sampled a total of 544 hours. Experimental gill net catches used for relative abundance[1] totalled 323 lake trout and 200 Arctic char. Early and late season KPUEs did not differ significantly for most sampling strata, with the exception of stream mouths for lake trout ($P < 0.05$; greater KPUE in late season; Table 5) and cobble/boulder substrates for Arctic char ($P < 0.01$; greater KPUE in early season; Table 6). Comparing sampling strata within seasons, stream mouths differed significantly from all other shoreline types in lake trout KPUE during late season ($P < 0.01$; Table 7). Cobble/boulder substrates differed significantly from sand/pebble/gravel substrates in Arctic char KPUE during late season ($P < 0.05$; Table 8).

Sixty percent of the lake trout and 60% of the Arctic char were captured in the littoral gill nets. Ninety-five percent of the lake trout and 81% of the Arctic char were captured in the lower 2.5 m of the nets. Catches of other species in 1988 were 236 Arctic grayling and 590 round whitefish during the early season and 590 Arctic grayling and 342 round whitefish during the late season. In addition to these species, one chum salmon *Onchorynchus keta* (735 mm fork length) was caught in 1987 where Kaluluktok Creek empties into Walker Lake.

Absolute Abundance

The Schnabel population estimate for lake trout ($\geq$ 312 mm) was 1,695 fish (95% confidence interval, 1,166 - 2,871), based on a total of 335 fish captured (151 marked, 21 recaptured). Estimates of lake trout standing crop were 0.45 fish/hectare and 0.65 kg/hectare. The Schnabel population estimate for Arctic char ($\geq$ 298 mm) was 2,543 fish (95% confidence interval, 1,263 - 5,565), based on a total of 218 fish captured (118 marked,

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[1] Two sites were fished in the early sampling period but not in the late sampling period, and thus were not included in the relative abundance analysis.

TABLE 4.—Estimates of total catch and harvest from Walker Lake, 1989. Estimates were obtained by dividing 1989 lodge based catch and harvest by the average percentage contributed by lodge based anglers to total catch and harvest in 1987 and 1988.

Source	Number of anglers	Angler-hours	Lake trout		Arctic char		Arctic grayling	
			Catch	Harvest	Catch	Harvest	Catch	Harvest
Lodge-based	39	228	51	9	76	10	94	0
Percent contribution (%)[a]	62	70	59	39	79	73	61	46
Total 63	326	86	23	96	14	154	0	

[a] Average percentage lodge-based contribution in 1987 and 1988.

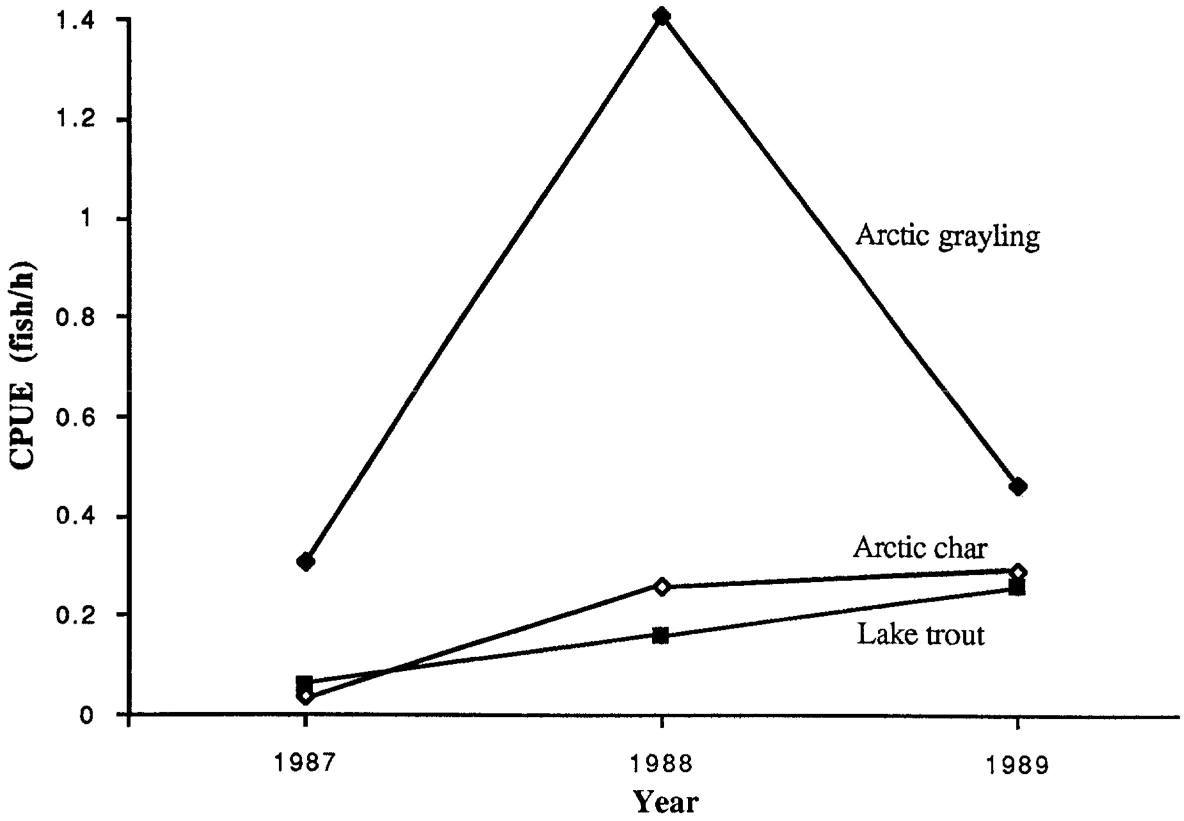

FIGURE 5.—Trends in CPUE estimates for lake trout, Arctic char, and Arctic grayling from creel surveys of Walker Lake, 1987 - 1989.

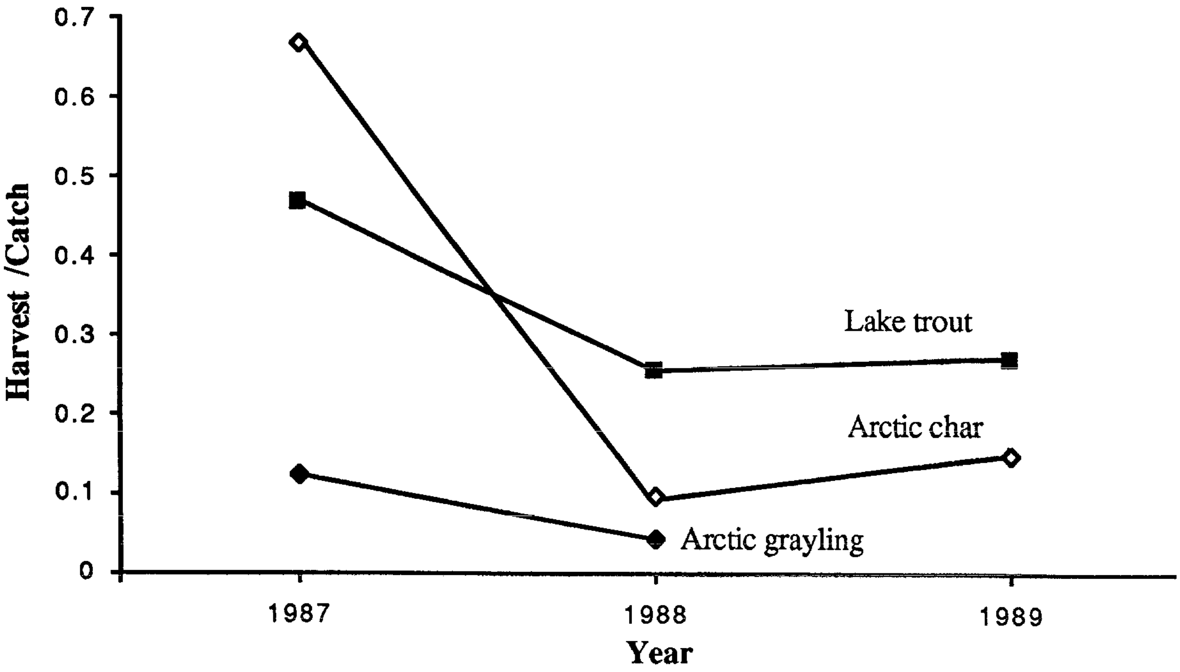

FIGURE 6.—Trends in the proportion of fish harvested for lake trout, Arctic char, and Arctic grayling from creel surveys of Walker Lake, 1987 -1989.

TABLE 5.—Gill net catch of lake trout per hour (KPUE) compared between early and late seasons within strata at Walker Lake, 1988. Significant differences ($P < 0.05$) between early and late season samples are denoted by asterisks.

Stratification criterion and strata	Number of sites	Effort per sampling period (h)	Number captured		KPUE	
			Early	Late	Early	Late
Sampling period	34	272	179	144	0.66	0.53
Time of day						
day	34	136	98	73	0.72	0.54
evening	34	136	81	71	0.60	0.52
Section						
north	13	104	77	54	0.74	0.52
middle	11	88	57	61	0.65	0.69
south	10	80	45	29	0.56	0.36
Substrate						
sand/pebble/gravel	22	176	121	93	0.69	0.53
cobble/boulder	5	40	25	16	0.63	0.40
mix	7	56	33	35	0.59	0.63
Shoreline						
straight	12	96	74	49	0.77	0.51
peninsula	10	80	47	38	0.59	0.48
island	2	16	13	4	0.81	0.25
stream mouth	6	48	30	49	0.63*	1.02*
inlet	2	16	13	2	0.81	0.13
outlet	2	16	2	2	0.13	0.13

TABLE 6.—Gill net catch of Arctic char per hour (KPUE) compared between early and late seasons within strata at Walker Lake, 1988. Significant differences ($P < 0.05$) between early and late season samples are denoted by asterisks.

Stratification criterion and strata	Number of sites	Effort per sampling period (h)	Number captured		KPUE	
			Early	Late	Early	Late
Sampling period	34	272	117	83	0.43	0.31
Time of day						
day	34	136	63	42	0.46	0.31
evening	34	136	54	41	0.40	0.30
Section						
north	13	104	31	26	0.30	0.25
middle	11	88	33	40	0.38	0.45
south	10	80	53	17	0.66	0.21
Substrate						
sand/pebble/gravel	22	176	88	67	0.50	0.38
cobble/boulder	5	40	16	1	0.40*	0.03*
mix	7	56	13	15	0.23	0.27
Shoreline						
straight	12	96	32	21	0.33	0.22
peninsula	10	80	41	14	0.51	0.18
island	2	16	11	1	0.69	0.06
stream mouth	6	48	14	39	0.29	0.81
inlet	2	16	4	3	0.25	0.19
outlet	2	16	15	5	0.94	0.31

TABLE 7.—Gill net catch of lake trout per hour (KPUE) at Walker Lake in 1988 compared between strata within seasons for four different stratification criteria: time of day, lake section, substrate type, and shoreline type. KPUEs along a row without a letter in common are significantly different ($P < 0.05$).

Season | Stratification criterion

Time of day

Season	Daytime KPUE	Evening KPUE
Early	0.72z	0.60z
Late	0.54z	0.52z

Lake section

Season	North KPUE	Middle KPUE	South KPUE
Early	0.74z	0.65z	0.56z
Late	0.52z	0.69z	0.36z

Substrate

Season	Sand/pebble/gravel KPUE	Cobble/boulder KPUE	Mixed KPUE
Early	0.69z	0.63z	0.59z
Late	0.53z	0.40z	0.63z

Shoreline

Season	Straight KPUE	Peninsula KPUE	Island KPUE	Stream mouth KPUE	Inlet KPUE	Outlet KPUE
Early	0.77z	0.59z	0.81z	0.63z	0.81z	0.13z
Late	0.51z	0.48z	0.25z	1.02y	0.13z	0.13z

TABLE 8.—Gill net catch of Arctic char per hour (KPUE) at Walker Lake in 1988 compared between strata within seasons for four different stratification criteria: time of day, lake section, substrate type, and shoreline type. KPUEs along a row without a letter in common are significantly different ($P < 0.05$).

Season | Stratification criterion

Time of day

Season	Daytime KPUE	Evening KPUE
Early	0.46z	0.40z
Late	0.31z	0.30z

Lake section

Season	North KPUE	Middle KPUE	South KPUE
Early	0.30z	0.38z	0.66z
Late	0.25z	0.45z	0.21z

Substrate

Season	Sand/pebble/gravel KPUE	Cobble/boulder KPUE	Mixed KPUE
Early	0.50z	0.40z	0.23z
Late	0.38z	0.03y	0.27zy

Shoreline

Season	Straight KPUE	Peninsula KPUE	Island KPUE	Stream mouth KPUE	Inlet KPUE	Outlet KPUE
Early	0.33z	0.51z	0.69z	0.29z	0.25z	0.94z
Late	0.22z	0.18z	0.06z	0.81z	0.19z	0.31z

six recaptured). Standing crop of Arctic char was estimated at 0.67 fish/hectare and 1.14 kg/hectare.

Twenty-one lake trout (13.9% of the total tagged) and 13 Arctic char (11.0% of the total tagged) were held an average of 26 hours each to monitor tag loss and handling mortality. No fish lost tags and no mortality occurred. Two of the 21 lake trout recaptured were missing tags but had adipose fin clips, indicating a 9.5% tag loss. However, tag loss was measurable because of the adipose clips, and therefore did not bias the population estimate. No Arctic char recaptured were missing tags.

Offshore Sampling and Beach Seining

Midsummer deep water gill netting captured 27 fish during 550 hours of effort. No juvenile lake trout or Arctic char less than 200 mm in length were captured. One large lake trout (667 mm), twelve smaller lake trout (203 - 323 mm), one Arctic char (202 mm) and 13 least cisco (130 - 296 mm) were captured. One of the smaller lake trout (309 mm) was caught in a mid-water set, and the others were caught in bottom sets.

Least cisco (35 - 103 mm) was the most numerous species caught in 162 beach seine hauls, followed by slimy sculpin (17 - 64 mm), round whitefish (57 - 191 mm), and *Salvelinus* spp. (30 - 66 mm; Table 9). More least cisco and round whitefish were caught at shore sampling sites, even though equal seining effort was given to stream mouth sampling sites. All other species were caught in greater numbers at stream mouth sampling sites. Catches of other species included 26 Arctic grayling (89 - 470 mm), 27 northern pike (108 - 155 mm), and five burbot (25 - 100 mm).

Eighty percent of the 104 juvenile lake trout and Arctic char *Salvelinus* spp. were captured at stream mouth seining sites. A sample of 24 juvenile *Salvelinus* spp. was sent to the Larval Fish Laboratory at Colorado State University for identification. They concluded that no clear distinction could be made between juvenile lake trout and Arctic char, but that the fish examined were, as a group, more like Arctic char than lake trout (D.E. Snyder, Larval Fish Laboratory, Colorado State University, personal communication).

Length, Weight, and Condition

Lake trout caught by gill nets in 1987 had a mean length of 551 mm and ranged from 235 mm to 924 mm (Table 10). Smaller mesh gill nets were used in 1988, and the shoreline gill net catch in 1988 had a smaller mean length (493 mm) and more limited size range (326 - 850 mm); the 1987 and 1988 means were significantly different ($P < 0.01$). Length frequency distributions for lake trout caught in 1987 and 1988 are similar for fish less than 600 mm, but relatively few fish 600 mm or longer were caught in 1988 (Figure 7).

For Arctic char, mean lengths also differed significantly between years ($P < 0.01$), with smaller fish caught in 1988 (502 mm, compared to 557 mm in 1987; Table 10). Arctic char greater than 550 mm were well represented in both year's catches, whereas fish less than 550 mm were more numerous in the 1988 catch (Figure 8).

Weight-length relationships were not significantly different between years for lake trout ($P > 0.15$) and Arctic char ($P > 0.25$), and therefore, data were pooled by species (Figures 9 and 10). Lake trout and Arctic char exhibited allometric growth ($P < 0.001$) with slopes

TABLE 9.—Beach seine catch from Walker Lake by species, lake section, and seining stratum, July - August, 1988.

		Species						
Lake section	Seining stratum	*Salvelinus* species	Round whitefish	Least cisco	Arctic grayling	Slimy sculpin	Burbot	Northern pike
North	Shore	3	520	224	3	606	0	2
	Stream	30	499	1,400	9	305	2	25
Middle	Shore	1	170	4,459	5	313	0	0
	Stream	33	248	2,329	6	708	1	0
South	Shore	17	93	946	0	498	1	0
	Stream	20	17	221	3	1,106	1	0
Total	Shore	21	783	5,629	8	1,417	1	2
	Stream	83	764	3,950	18	2,164	4	25

TABLE 10.—Length and weight statistics of lake trout and Arctic char caught by experimental gill nets in Walker Lake, 1987 and 1988.

		Length (mm)			Weight (kg)		
Year	N	Mean	SD	Range	Mean	SD	Range
				Lake trout			
1987[a]	271	551	116	235 - 924	2.08	1.60	0.13 - 8.50
1988[b]	335	493	95	326 - 850	1.45	1.06	0.37 - 7.75
				Arctic char			
1987[a]	71	557	75	320 - 670	2.37	0.90	0.37 - 4.20
1988[b]	218	502	87	267 - 678	1.70	0.91	0.20 - 4.40

[a] Experimental gill net 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, fished singly or in tandem with another net of the same type.

[b] Experimental gill net 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.

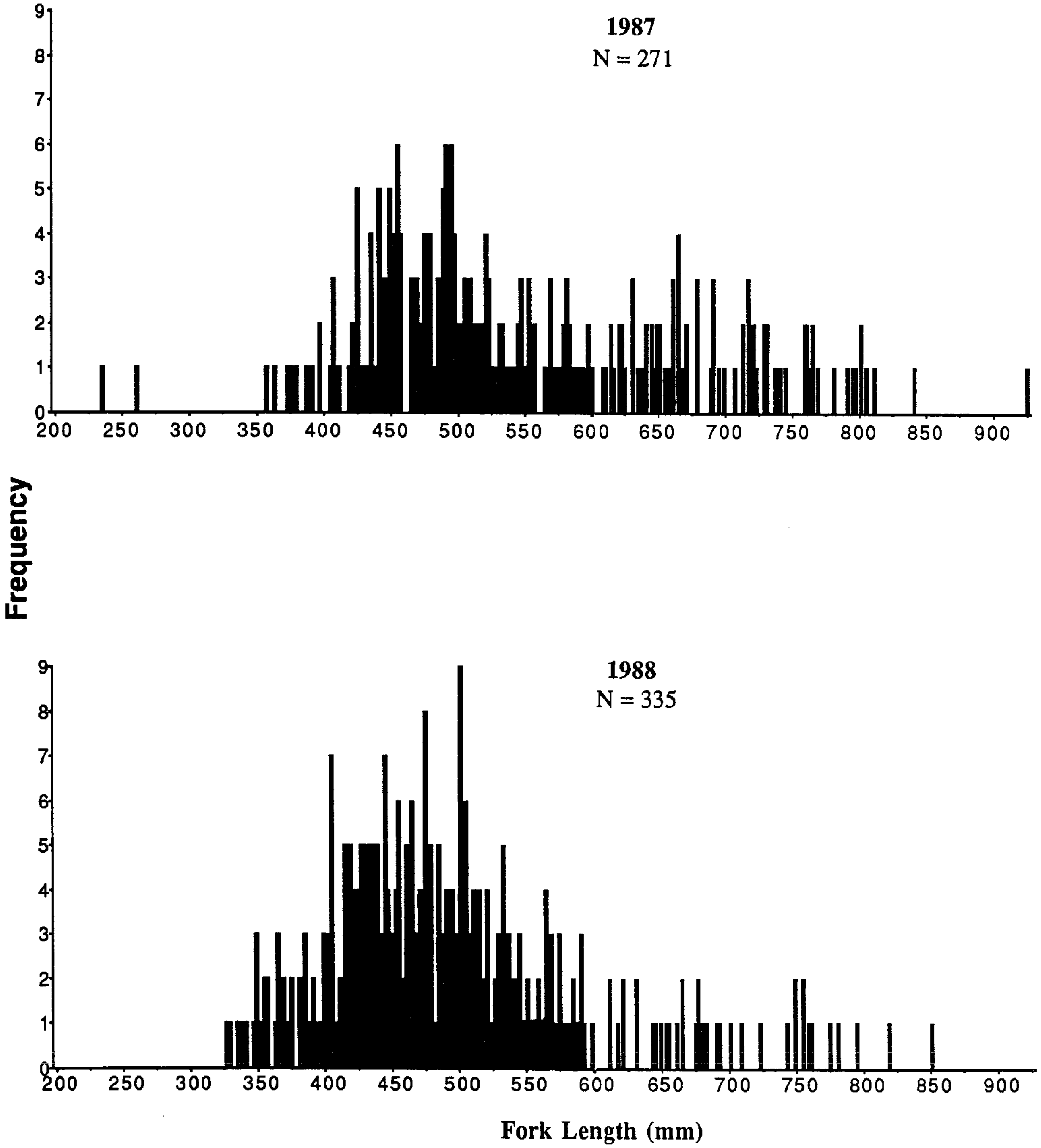

FIGURE 7.—Length frequency of lake trout from shoreline sampling with experimental gill nets in Walker Lake, 1987 and 1988. Gill nets had 1.3, 1.9, 2.5, 3.8, 5.1, and 6.3 cm bar meshes in 1987, and 1.3, 1.9, 2.5, and 3.8 cm bar meshes in 1988.

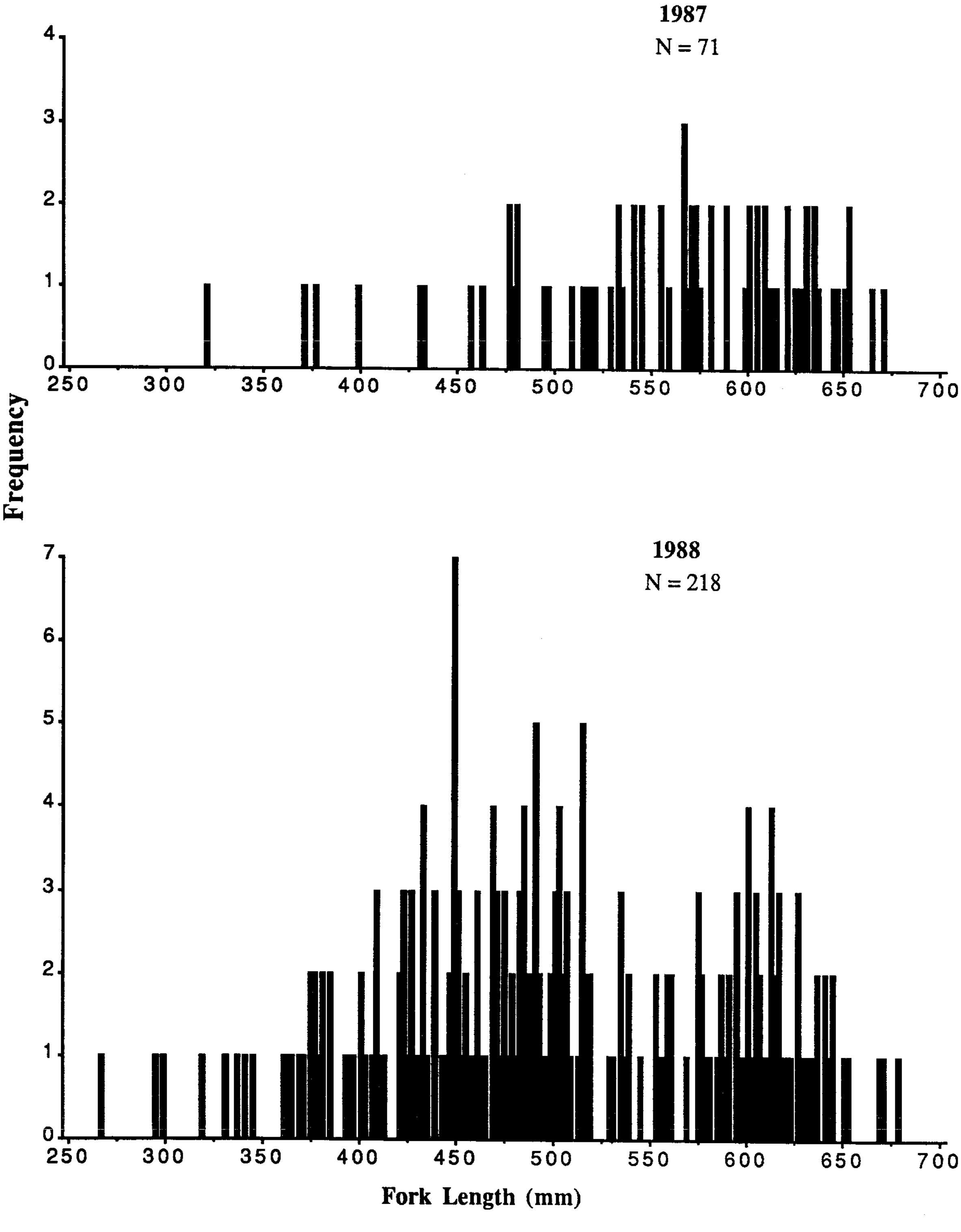

FIGURE 8.—Length frequency of Arctic char from shoreline sampling with experimental gill nets in Walker Lake, 1987 and 1988. Gill nets had 1.3, 1.9, 2.5, 3.8, 5.1, and 6.3 cm bar meshes in 1987, and 1.3, 1.9, 2.5, and 3.8 cm bar meshes in 1988.

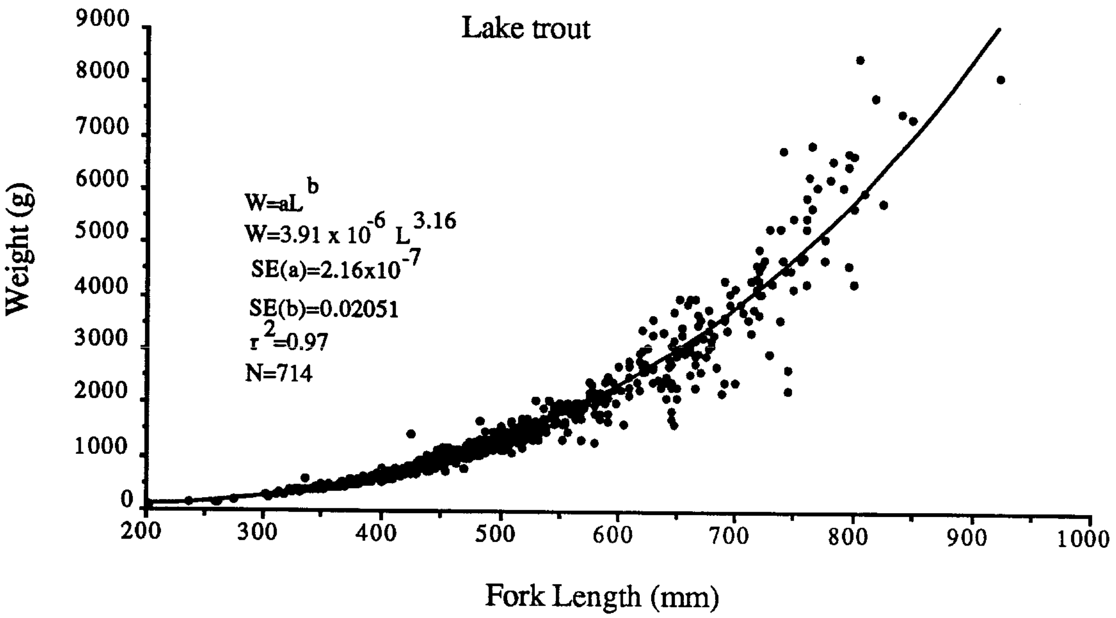

FIGURE 9.—Weight-length relations for lake trout collected from Walker Lake during 1987 and 1988.

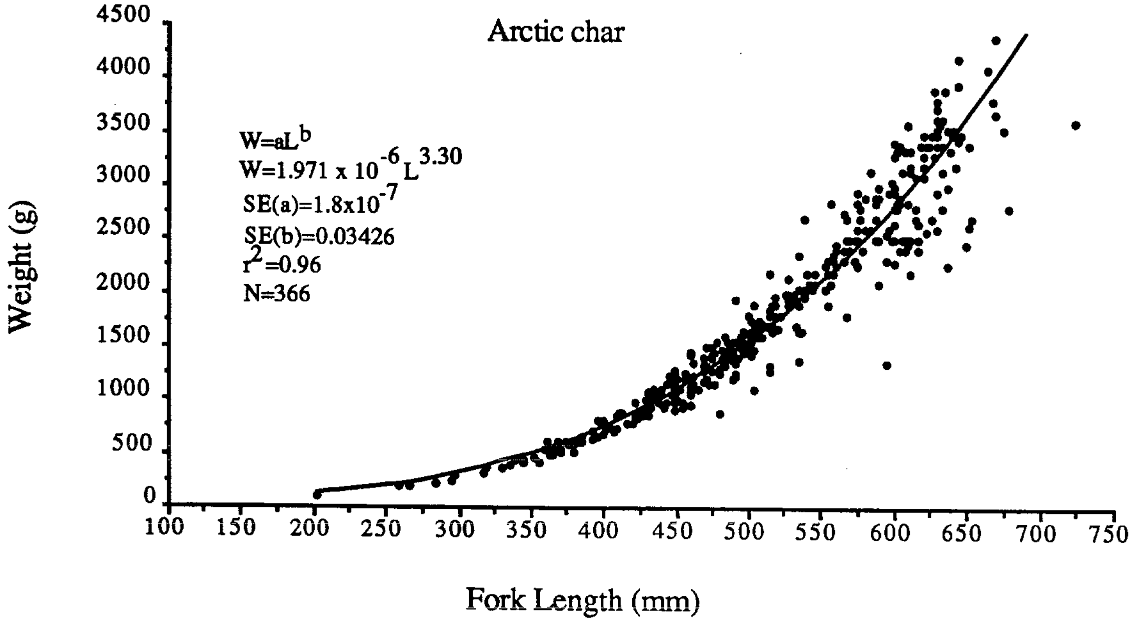

FIGURE 10.—Weight-length relations for Arctic char collected from Walker Lake during 1987 and 1988.

(b) of 3.16 and 3.30, respectively. Coefficients of determination (r^2) equalled 0.97 for lake trout and 0.96 for Arctic char. The scatter of points about the regression line increased markedly for lake trout greater than 600 mm and Arctic char greater than 500 mm.

Comparing the lake trout weight-length relation to populations in the northern Brooks Range (Figure 11), Walker Lake differed significantly from Chandler Lake ($P < 0.005$), but did not differ significantly from Amiloyak Lake ($P > 0.30$). Weight-length relations for Arctic char did not differ significantly among Walker, Chandler, and Amiloyak lakes ($P > 0.05$; Figure 12).

Relative condition factors (Kn) for lake trout and Arctic char from Walker Lake differed significantly between sampling seasons (1987 and 1988 data pooled; $P < 0.05$). Mean Kn increased by 0.03 for lake trout and 0.08 for Arctic char from the early to late season (Table 11).

Age and Growth

Age determinations were made on 98 lake trout and 35 Arctic char, these are the only mortalities associated with the study. Lake trout ranged from 5 to 26 years with corresponding mean lengths of 203 to 805 mm (Table 12); and Arctic char ranged from 3 to 15 years with corresponding mean lengths of 320 to 600 mm (Table 13). Asymptotic lengths from the von Bertalanffy growth equations were 1,025 mm for lake trout (Figure 13) and 748 mm for Arctic char (Figure 14); these values were slightly greater than the largest fork lengths recorded in this study, 924 mm for lake trout and 678 mm for Arctic char.

Food Habits

Stomach samples were collected from 137 lake trout, with 126 (92%) containing food items. Of the 70 Arctic char stomachs examined, 58 (83%) contained food. Fish were the most important food item by weight in the lake trout diet, followed by insects and snails (Table 14; Figure 15). Round whitefish was the most important prey species by weight, comprising 72.8% of the total diet. For Arctic char, insects and snails were the most frequently occurring food items, and snails were the most important by weight (Table 15; Figure 16). Fish were found in only 5.2% of non-empty stomachs and comprised < 0.1% of the total weight in the Arctic char diet (Table 15).

Fecundity and Maturity

Gonadosomatic indices (GSI) calculated for lake trout and Arctic char caught in 1987 and 1988 indicated most were not going to spawn that fall. A sample of 51 lake trout (30 females, 21 males) included three ripening females and six ripening males, based on GSI criteria (Table 16). A sample of 16 Arctic char (nine males, seven females) included one ripening male and no ripening females.

The highest GSI values were from lake trout collected in June and July (Appendices 3 and 5); GSI values were relatively low in the limited sample of Arctic char, which was collected in August and September (Appendices 4 and 6). No lake trout or Arctic char collected in September were classified as ripening. Ripening female lake trout were 18 to 25 years old,

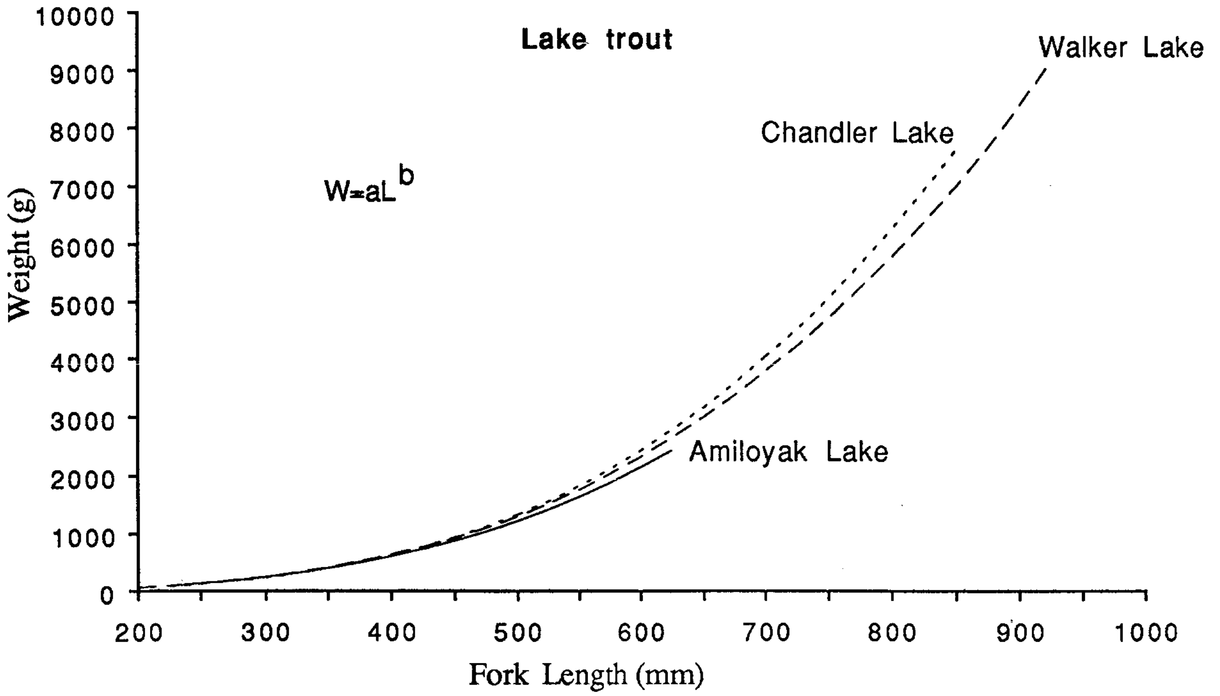

FIGURE 11.–Comparison of predicted weights (from the weight-length relations) of lake trout from Walker Lake to predicted weights of lake trout from Chandler and Amiloyak lakes (Troyer and Johnson 1994).

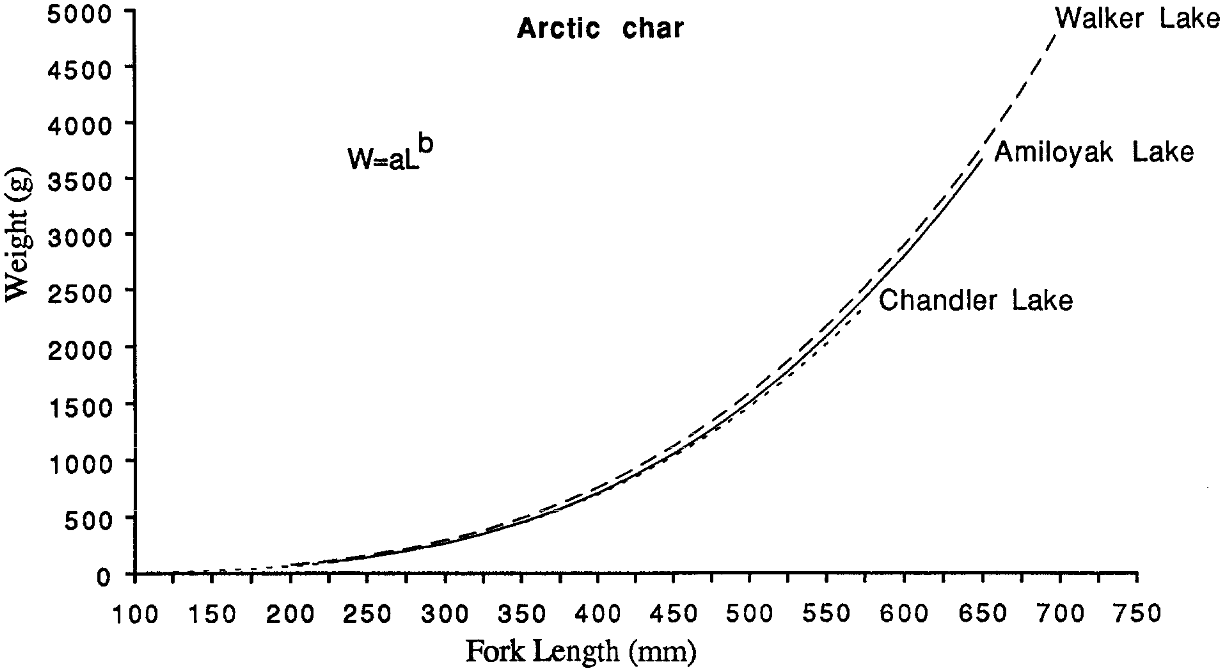

FIGURE 12.—Comparison of predicted weights (from the weight-length relations) of Arctic char from Walker Lake to predicted weights of Arctic char from Chandler and Amiloyak lakes (Troyer and Johnson 1994).

TABLE 11.—Relative condition factor (Kn) statistics for lake trout and Arctic char from Walker Lake during early and late season in 1987 and 1988. Significant differences ($P < 0.05$) between early and late season are denoted by asterisks.

Relative condition factor and statistics	Early[a]	Late[b]
	Lake trout	
Mean	0.986*	1.013*
N	462	252
SE	0.006	0.007
Kn range	0.574-1.864	0.485-1.384
Length range	203-850	234-924
	Arctic char	
Mean	0.934*	1.017*
N	176	190
SE	0.008	0.008
Kn range	0.483-1.184	0.651-1.332
Length range	202-678	267-724

[a] June 8 - August 1
[b] August 2 - September 16

TABLE 12.—Ages and lengths of lake trout in Walker Lake, 1987 and 1988.

		Fork length (mm)		
Age	N	Mean	SD	Range
5	1	203	---	---
8	1	235	---	---
9	4	282	41	235 - 322
10	4	346	39	302 - 390
11	7	405	64	301 - 453
12	10	406	78	274 - 540
13	9	446	63	317 - 565
14	20	471	76	259 - 657
15	11	492	67	440 - 668
16	12	521	79	405 - 724
17	3	598	65	529 - 657
18	3	712	45	665 - 755
19	4	691	78	608 - 795
21	4	665	28	633 - 690
22	2	572	11	564 - 580
23	2	677	39	649 - 704
26	1	805	---	---
Total	98	486	128	203 - 805

TABLE 13.—Ages and lengths of Arctic char in Walker Lake, 1987 and 1988.

		Fork length (mm)		
Age	N	Mean	SD	Range
3	1	320	---	---
4	5	308	73	202 - 374
5	3	388	81	295 - 438
6	3	372	41	330 - 412
7	4	476	44	430 - 518
8	4	477	14	462 - 495
9	2	500	21	485 - 515
10	1	545	---	---
11	2	426	25	408 - 443
12	6	586	42	525 - 630
13	2	609	51	573 - 630
14	1	566	---	---
15	1	600	---	---
Total	35	464	110	202 - 630

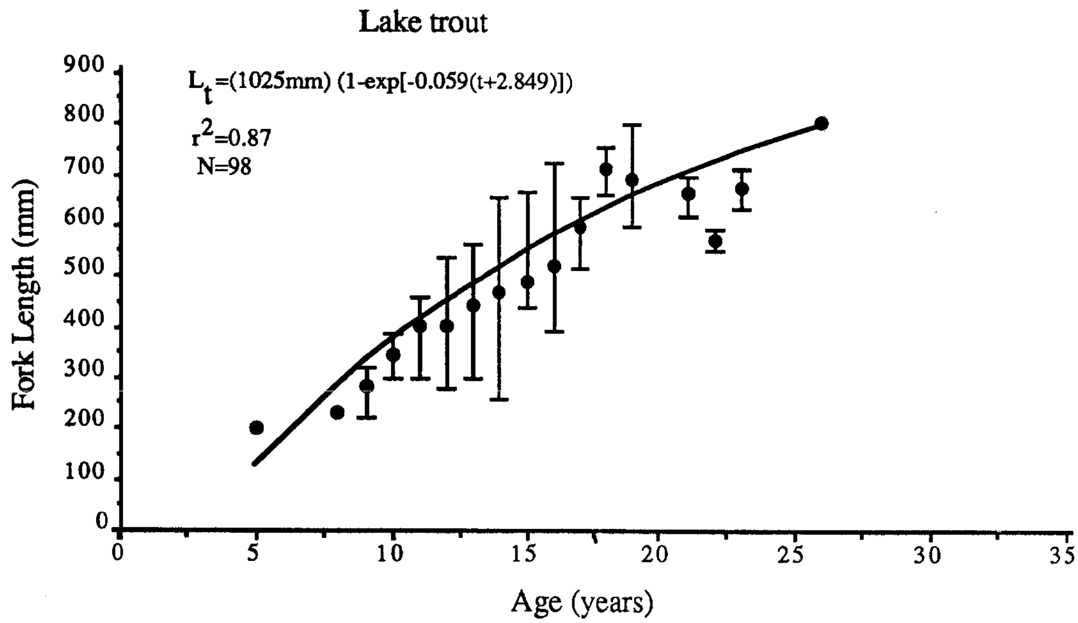

FIGURE 13.—Von Bertalanffy growth equations and mean lengths at age for lake trout from Walker Lake. Vertical lines represent the range of lengths at a given age.

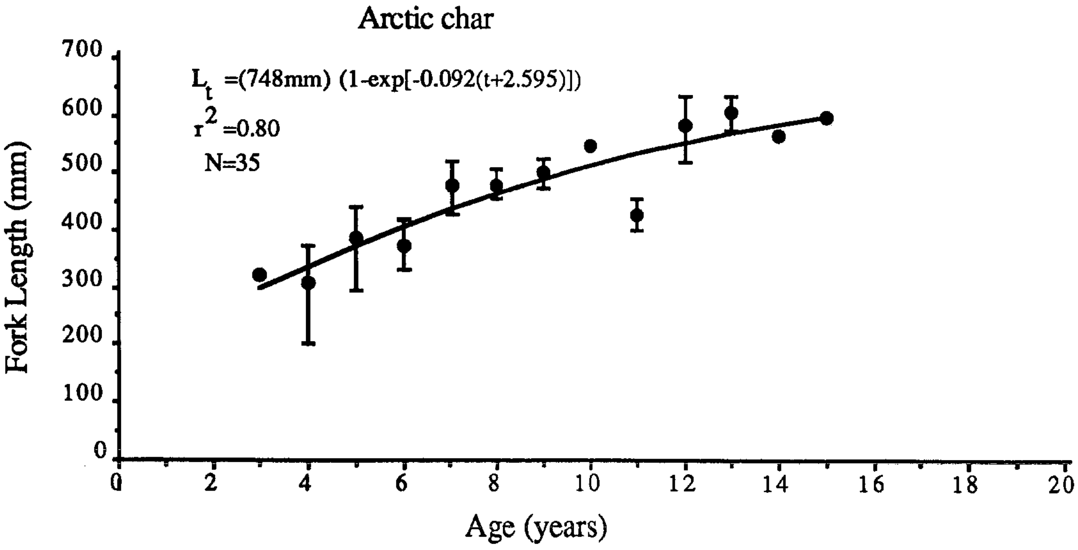

FIGURE 14.—Von Bertalanffy growth equations and mean lengths at age for Arctic char from Walker Lake. Vertical lines represent the range of lengths at a given age.

TABLE 14.—Frequency of occurrence and percent weight of food items in stomachs of lake trout (203 - 805 mm) collected from Walker Lake in 1987 and 1988. N = 126 (nonempty stomachs).

Food item	Frequency of occurrence (%)	Percent weight
MOLLUSCA		
Gastropoda	39.6	7.3
Pelecypoda	6.3	<0.1
ANNELIDA		
Clitellata (leech)	2.4	<0.1
CRUSTACEA		
Copepoda	0.8	<0.1
INSECTA		
Ephemeroptera (adult)	3.2	<0.1
Hemiptera (adult)	4.0	<0.1
Plecoptera (larvae)	0.8	<0.1
Trichoptera (larvae)	23.8	4.7
Hymenoptera (adult)	7.9	2.0
Coleoptera (adult)	9.5	3.5
Diptera (adult)	4.8	4.6
Chironomidae pupae	46.8	17.0
Chironomidae larvae	1.6	<0.1
Culicidae (larvae)	0.8	<0.1
Unidentified Insecta	16.7	3.4
OSTEICHTHYES		
Salmonidae		
Least cisco	4.0	0.8
Round whitefish	4.8	72.8
Thymallidae		
Arctic grayling	0.8	<0.1
Cottidae		
Slimy sculpin	19.0	3.5
Unidentified parts	27.8	2.1
RODENTIA	7.1	0.7
DETRITUS	38.9	1.2

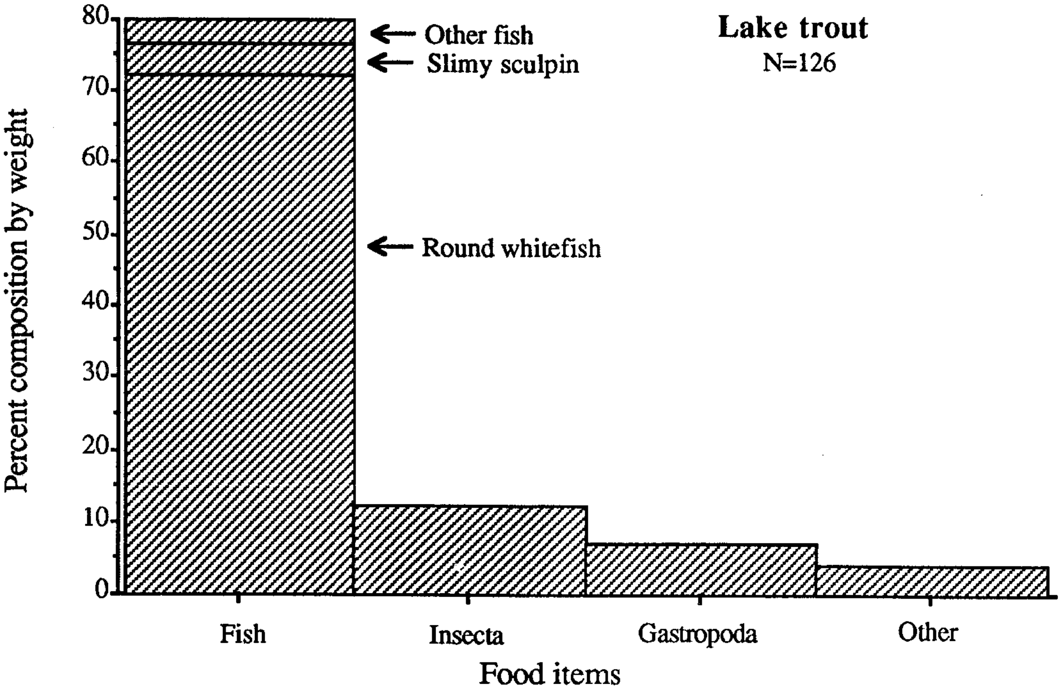

FIGURE 15.—Percent composition by weight of the diet of lake trout (203 - 805 mm) from Walker Lake. Data were pooled from the summers of 1987 and 1988. Other includes Rodentia, Crustacea, Annelida, and detritus.

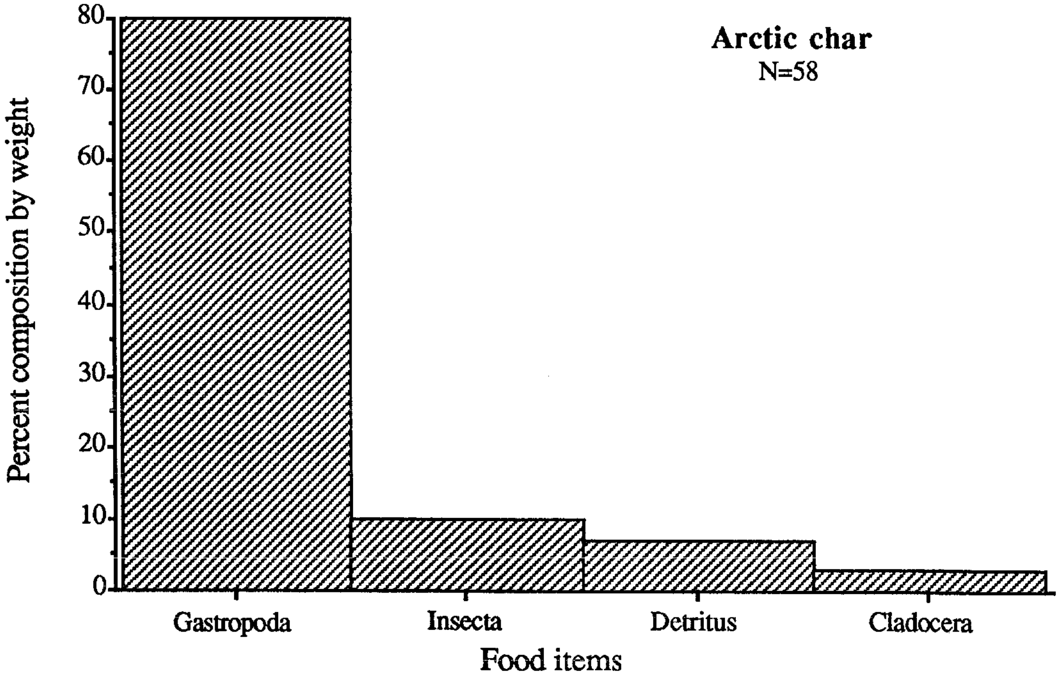

FIGURE 16.—Percent composition by weight of the diet of Arctic char (202 - 678 mm) from Walker Lake. Data were pooled from the summers of 1987 and 1988.

TABLE 15.—Frequency of occurrence and percent weight of food items in stomachs of Arctic char (202 - 678 mm) collected from Walker Lake in 1987 and 1988. N = 58 (nonempty stomachs).

Food item	Frequency of occurrence (%)	Percent weight
MOLLUSCA		
Gastropoda	72.4	79.8
Pelecypoda	3.4	<0.1
CRUSTACEA		
Cladocera	20.7	3.1
ARACHNIDA	1.7	<0.1
INSECTA		
Ephemeroptera (adult)	74.1	9.8
Hemiptera (adult)	1.7	<0.1
Trichoptera (larvae)	3.4	0.1
Hymenoptera (adult)	20.7	1.3
Diptera (adult)	1.7	<0.1
Chironomidae	55.2	4.1
pupae	46.6	4.1
larvae	19.0	<0.1
Unidentified Insecta	20.7	3.5
OSTEICHTHYES		
Unidentified parts	5.2	<0.1
DETRITUS	41.4	7.3

TABLE 16.—Gonadosomatic indices (GSI), lengths, and ages of ripening and non-ripening lake trout and Arctic char collected from Walker Lake, 1987 and 1988.

		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	27	0.87	0.47	0.30 - 2.80	520	94	425 - 755	16	3	11 - 25
Ripening females	3	7.93	4.07	4.70 - 12.50	721	72	651 - 795	21	4	18 - 25
Non-ripening males	15	0.29	0.20	0.10 - 0.80	546	88	435 - 690	16	4	12 - 26
Ripening males	6	3.52	2.35	1.10 - 7.70	551	81	452 - 687	17	4	11 - 23
Arctic char										
Non-ripening females	7	0.57	0.30	0.16 - 0.87	405	67	295 - 475	6	1	5 - 8
Ripening females	--	---	---	---	---	---	---	---	---	---
Non-ripening males	8	0.07	0.03	0.03 - 0.13	485	93	336 - 645	9	3	4 - 13
Ripening males	1	2.34	---	---	600	---	---	15	---	---

651 to 795 mm in length, and had fecundities ranging from 3,089 to 4,067 ova. Ova diameters from ripening fish ranged from 3.0 to 5.0 mm.

Physical and Chemical Sampling

Surface water temperature was not significantly different between sections except during the month of June ($P < 0.05$), when mean temperature was 2.0 - 3.5 °C colder in the south section (Table 17). Surface readings of dissolved oxygen were at or near saturation levels throughout the summer and did not differ significantly between lake sections in any sampling month ($P > 0.05$). Secchi transparency ranged from 10.0 m to 18.5 m and was greatest in the south section; south and north section means differed significantly in August and September ($P < 0.05$). Temperatures at 110 m depth ranged from 4.2°C in June to 4.0°C in July, August, and September.

Water temperatures in July and August were 1.5 - 7.5 °C higher than either June or September temperatures; significant temporal differences were detected for both the north and south sections (Table 18). Surface dissolved oxygen levels were generally higher during months with cooler water temperatures (June and September) than in mid summer. Dissolved oxygen at 110 m depth ranged from 5.7 mg/l (44% of saturation; Hammer 1977) in June to 8.0 mg/l (61% of saturation) in July; measurements in August (7.2 mg/l; 55% of saturation) and September (7.7 mg/l; 59% of saturation) were similar to July. Water clarity increased during the summer, with mean Secchi transparencies differing significantly between June and August in each lake section ($P < 0.001$; Table 18).

Alkalinity showed slight spatial and temporal fluctuations, with highest values in the south section and gradual increases from early to late summer. Total hardness was higher during the cooler months, June and September (70 - 72 mg/l), than during July and August (56 - 74 mg/l; Table 18). Conductivity and pH showed little variation throughout the sampling period. Conductivity ranged from 130 to 150 uS/cm; and pH was slightly alkaline, ranging from 7.3 to 7.6.

TABLE 17.—Mean surface measurements of water temperature, dissolved oxygen, Secchi transparency, pH, alkalinity, total hardness, and conductivity compared between lake sections within months for offshore sampling sites in Walker Lake, 1988. For each month, means along a row without a letter in common are significantly different ($P < 0.05$). Sample sizes (N) are in parentheses.

Parameter	June			July			August			September		
	North	Middle	South	North	Middle	South	North	Middle	South	North	Middle	South
Water temperature °C	12.0z (21)	10.5z (21)	8.5y (21)	16.0z (18)	16.0z (18)	16.0z (18)	13.0z (30)	13.0z (30)	12.0z (30)	10.0z (16)	10.0z (16)	10.5z (16)
Dissolved O_2 (mg/l)	11.0z (21)	11.0z (21)	12.0z (21)	10.0z (18)	10.0z (18)	10.0z (18)	10.0z (30)	10.5z (30)	11.0z (30)	11.0z (16)	11.0z (16)	11.0z (16)
Secchi transparency (m)	10.0z (21)	11.0z (21)	13.0z (21)	12.0z (18)	15.5z (18)	16.0z (18)	15.5z (30)	17.0z (30)	18.0y (30)	15.0y (16)	17.5zy (16)	18.5z (16)
pH	7.3 (1)	7.4 (2)	7.4 (1)	7.5 (1)	7.6 (2)	7.6 (1)	7.5 (1)	7.5 (2)	7.5 (1)	7.5 (1)	7.4 (2)	7.4 (1)
Alkalinity (mg/l)	53 (1)	55 (2)	56 (2)	59 (1)	57 (2)	63 (1)	63 (1)	67 (2)	66 (1)	63 (1)	63 (2)	68 (1)
Total hardness (mg/l)	72 (1)	71 (2)	72 (1)	64 (1)	64 (2)	74 (1)	66 (1)	56 (2)	64 (1)	70 (1)	72 (2)	72 (1)
Conductivity (uS/cm)	130 (1)	140 (2)	150 (1)	140 (1)	140 (2)	140 (1)	140 (1)	140 (2)	150 (1)	140 (1)	140 (2)	140 (2)

TABLE 18.—Mean surface measurements of water temperature, dissolved oxygen, Secchi transparency, pH, alkalinity, total hardness, and conductivity compared between months within lake sections for offshore sampling sites in Walker Lake, 1988. For each lake section, means along a row without a letter in common are significantly different ($P < 0.05$). Sample sizes (N) are in parentheses.

	Lake Section											
	North				Middle				South			
Parameter	June	July	Aug.	Sept.	June	July	Aug.	Sept.	June	July	Aug.	Sept.
Water temperature °C	12.0z (21)	16.0x (18)	13.0z (30)	10.0y (16)	10.5z (21)	16.0z (18)	13.0z (30)	10.0z (16)	8.5z (21)	16.0x (18)	12.0y (30)	10.5z (16)
Dissolved O_2 (mg/l)	11.0z (21)	10.0z (18)	10.0z (30)	11.0z (16)	11.0z (21)	10.0x (18)	10.5y (30)	11.0z (16)	12.0z (21)	10.0x (18)	11.0zy (30)	11.0zy (16)
Secchi transparency (m)	10.0y (21)	12.0yz (18)	15.5z (30)	15.0z (16)	11.0y (21)	15.5z (18)	17.0z (30)	17.5z (16)	13.0x (21)	16.0y (18)	18.0yz (30)	18.5z (16)
pH	7.3 (1)	7.5 (1)	7.5 (1)	7.5 (1)	7.4 (2)	7.6 (2)	7.5 (2)	7.4 (2)	7.4 (1)	7.6 (1)	7.5 (1)	7.4 (1)
Alkalinity (mg/l)	53 (1)	59 (1)	63 (1)	63 (1)	55 (2)	57 (2)	67 (2)	63 (2)	56 (1)	63 (1)	66 (1)	68 (1)
Total hardness (mg/l)	72 (1)	64 (1)	66 (1)	70 (1)	71 (2)	64 (2)	56 (2)	72 (2)	72 (1)	74 (1)	64 (1)	72 (1)
Conductivity (uS/cm)	130 (1)	140 (1)	140 (1)	140 (1)	140 (2)	140 (2)	140 (2)	140 (2)	150 (1)	140 (1)	150 (1)	140 (1)

Discussion

Exploitation

Current annual yields of lake trout (0.005 - 0.007 kg/hectare) at Walker Lake are well within the levels 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. Potential yield may be lower than 0.2 kg/hectare for Walker Lake, because lake trout exhibit the slow growth typical of northern populations (Power 1978; Martin and Olver 1980) and have a particularly low standing crop (see discussion under *Absolute Abundance*, below).

A general estimate of the potential lake trout yield from Walker Lake may be obtained by comparison to two lakes of comparable size[1] which have been exploited more heavily than Walker 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 Alaska Department of Fish and Game 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 rate (Healey 1978) so that lengths at age would approximate those of Paxson Lake (see discussion under *Age and Growth*, below), Walker Lake might sustain a maximum annual harvest of about 10% of the standing crop (0.65 kg/hectare), or 0.07 kg/hectare. The Service suggests that annual harvest should not exceed 0.07 kg/hectare, which is a total of 266 kg or 222 lake trout of the average size (1.20 kg) caught in 1987 and 1988.

Current annual harvests of Arctic char (0.005 - 0.009 kg/hectare) are well within the levels 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 Walker Lake Arctic char; however, Keyhole Lake and Walker Lake populations appear to be similar in age composition, and thus turnover time for the harvestable stock (Johnson 1980). Using projected maximum sustainable yield for Keyhole Lake as a guideline, potential yield at Walker Lake may be about 14% of the standing crop (1.14 kg/hectare), or 0.16 kg/hectare. The Service suggests that annual harvest should not exceed 0.16 kg/hectare, which is a total of 608 kg or 340 Arctic char of the average size (1.79 kg) caught in 1987 and 1988.

Relative to the 0.07 and 0.16 kg/hectare suggested maximum yields, errors in our estimates of total harvest are negligible. Anglers were interviewed during the summer fishery, but missed interviews could have occurred before our arrival and after our departure from the

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[1] Surface areas are 3,800 hectares for Walker Lake, 1,575 hectares for Paxson Lake, and 5,860 hectares for Lake Opeongo.

lake. In addition, an unknown fraction of angler effort may have been unaccounted for due to missed interviews during the summer and incomplete angler trips (15% of anglers interviewed had not completed their trips). Mean weight of fish caught was assumed to equal mean weight of fish harvested, but anglers probably tended to harvest larger fish. Although our estimates of harvest may be conservative, actual lake trout harvest would have to be 10 - 14 times greater than the documented 1987 - 1988 harvests to reach the estimated maximum level; Arctic char harvests would have to be 18 - 32 times greater.

From 1987 to 1988 there was a noticeable increase in catch to harvest ratios for lake trout and Arctic char, because anglers were keeping fewer of the fish they caught. This practice probably was due in part to the lodge operator encouraging catch and release fishing, and to our field crew answering anglers' questions about the study and increasing their awareness of the finite size of the fish populations.

The creel survey in 1989 was a first attempt to estimate yield solely upon catch and harvest data supplied by the lodge. This method held potential as a means of long term monitoring of the sport fishery. However, in March of 1990 the lodge was purchased by the National Park Service. This acquisition alters the characteristics of the fishery but should not change management recommendations or the potential for using guides as a means of gathering harvest information. The Service suggests that all sport fish guiding operations be required to provide catch and harvest information as a condition of their special use permit. This information could be combined with intensive surveys to document unguided catch and harvest. Surveys of guided and unguided anglers will be most useful if done on a yearly basis, given the variability between years in angler effort, catch, and catch to harvest ratios documented in this study.

Relative Abundance

Comparisons of early to late season KPUE indicated an increase in lake trout abundance at shorelines with stream mouths and a decrease in Arctic char abundance over cobble/boulder substrates. The increase in abundance of lake trout at stream mouths may be in response to cooling water temperatures in late August and September, and is probably more directly related to feeding than to spawning. Prey species such as round whitefish and least cisco are known to spawn in September in nearshore areas with sand/gravel substrate (Morrow 1980), and may gather near stream mouths, attracting lake trout to these areas. Stream mouths would not likely be used by lake trout for spawning because the substrate is relatively fine, with silt deposition near shore, and lake trout generally spawn in cobble/boulder areas cleaned by wave action (Martin and Olver 1980). In contrast, Arctic char almost invariably spawn on gravel substrates (Johnson 1980), and this may explain the higher KPUE at sand/pebble/gravel sites than at cobble/boulder sites during late season. The Service suggests relative abundance indices presented in this study be used as a baseline for time period and substrate specific fish abundance.

The capture of one adult male chum salmon in a shoreline gill net set near Kaluluktok Creek (main inlet to Walker Lake) was the first documentation of this species in Walker Lake. Chum salmon are not known to spawn in the inlet or outlet streams of Walker Lake, nor in the Kobuk River above the confluence of the Walker Lake outlet (Alaska Department of Fish and Game 1992).

Absolute Abundance

The standing crop of 0.45 lake trout/hectare[1] in Walker Lake is generally low compared to populations in other lakes. For lakes in the continental U.S. and Canada of comparable size to Walker Lake (1468 - 5860 hectares), standing crops of lake trout range from 0.76 to 10.74 fish/hectare. For Paxson Lake in south central Alaska, Burr (1990) reported 3.1 lake trout/hectare; and for Chandler Lake in northern Alaska, Troyer and Johnson (1994) reported 1.1 lake trout/hectare. Both Paxson and Chandler lakes are less than half the size of Walker Lake, and in general, higher lake trout production per unit area is expected in smaller lakes (Olver et al. 1991). Low density of lake trout and apparently low density of Arctic char (0.67 fish/hectare[1]) in Walker Lake is probably due in part to naturally low productivity. Jones *et al.* (1990) found that primary productivity, measured in Chlorophyll-*a* concentration, was low ($\bar{x}$ = 0.60 μg/L) in Walker Lake. 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 1988 length frequency distributions (500 mm for lake trout and 448 mm for Arctic char) 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[2].

Two other possible sources of bias are tag loss and handling mortality, which were not factored into the population estimates. Not accounting for loss of marked fish from the population causes an overestimate of population size. However, tag loss can be discounted because fish were also marked with an adipose fin clip and all fish were examined for this second mark. Also, there was no evidence of short term handling mortality, and efforts were made to minimize long term handling mortality by releasing only those fish which appeared to be in good condition.

Offshore Sampling and Beach Seining

The low catch rates of lake trout and arctic char in deep water gill net sets indicated low densities of these species in offshore areas. The deep water habitat apparently is utilized by smaller lake trout (12 of 13 fish were 203 - 323 mm) than commonly found in nearshore areas, as only two fish less than 325 mm were caught in all 1987 and 1988 shoreline gill net

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[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.

[1] Estimates of Arctic char abundance in lakes of comparable size to Walker Lake are not available.

[2] 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.

sets. Other studies have shown that young lake trout generally occupy deeper water (Martin 1952; Johnson 1972; Evans *et al.* 1991) and are less migratory than adults (Smith and Van Oosten 1940; Eschmeyer *et al.* 1953).

The absence of smaller lake trout (< 200 mm) from both shoreline and offshore samples may be due to the ineffectiveness of our gill nets on smaller fish. Lake trout less than 200 mm are most commonly found in depths of 12 - 122 m (Royce 1951; Martin 1952; Jude *et al.* 1981); however, extended residence of juveniles in nearshore shallows has been documented in Lake Superior (Peck 1982), Great Bear Lake (Miller and Kennedy 1948), and Paxson, Summit, and Sevenmile lakes in Alaska (John Burr, Alaska Department of Fish and Game, Fairbanks, personal communication).

Juvenile *Salvelinus* spp. (30 - 66 mm) caught by beach seines along shore in Walker Lake were probably young of the year (Martin and Olver 1980; Johnson 1980). Most or all of these fish may have been Arctic char, as suggested by laboratory analysis and the apparent preference for stream habitat which is typical of juvenile Arctic char in northern latitude lakes (Johnson 1976).

Length, Weight, and Condition

The scarcity of larger lake trout (> 600 mm) in the 1988 catch may be due to the use of smaller mesh sizes than in 1987. Bias in the 1987 sampling may be another factor contributing to the difference in length frequencies between years for both lake trout and Arctic char: selection of gill net sites was not random in 1987 and there may have been a tendency to revisit sites which seemed to have the most and biggest fish. This was certainly true for Arctic char, because a known holding area for large Arctic char, where the inlet stream enters the lake, was targeted frequently in 1987 whereas sampling was random in 1988.

Weight-length regression coefficients for lake trout and Arctic char are within the range of values reported for these species in Alaska and Canada, and indicate healthy growth. Lake trout exhibited allometric growth with slopes (*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 also exhibited allometric growth with slopes within the range of values documented by Hunter (1970) and McCart (1980) for Alaskan and Canadian north slope lake resident Arctic char.

Relative condition factors (Kn) for lake trout and Arctic char increased from early to late summer, probably reflecting a steady weight gain through the summer after the seven months of ice cover and relatively limited food supply. 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

Walker Lake lake trout and Arctic char appear to grow at expected rates for high latitude populations. Growth rates (increase in length per year on the von Bertalanffy curve) of lake trout after age 5 in Walker Lake were greater than subarctic populations in Paxson and Summit lakes (Burr 1987, 1988); however, shorter fork length at age 5 indicates relatively slow growth in Walker Lake prior to age 5 (Figure 17). Perhaps at about age 5

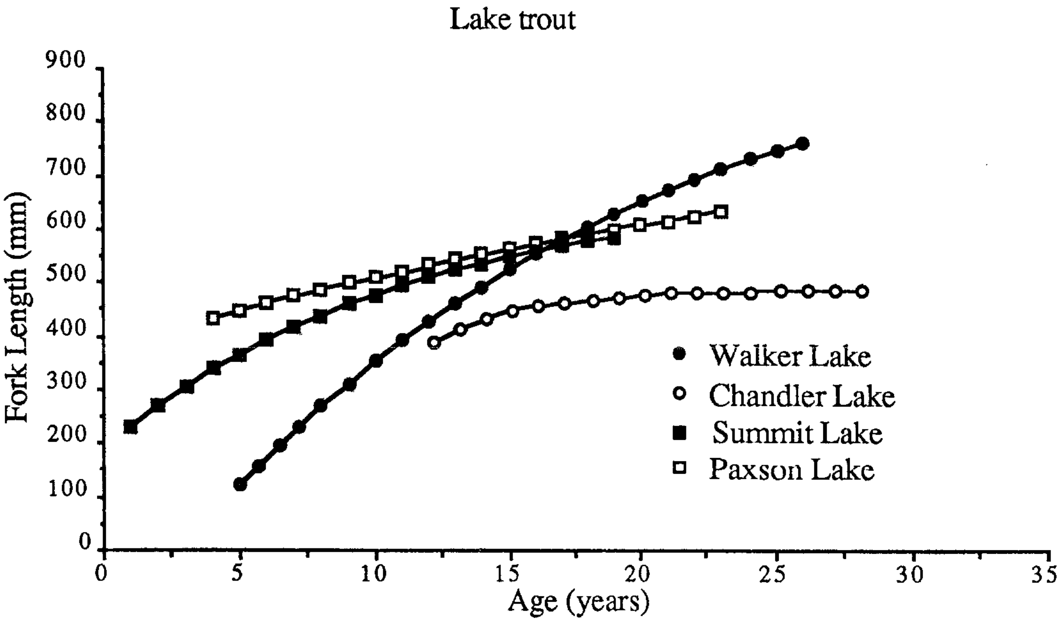

FIGURE 17.—Von Bertalanffy growth curves for lake trout from Walker Lake and other Alaskan lakes (Burr 1987, 1988; Troyer and Johnson 1994).

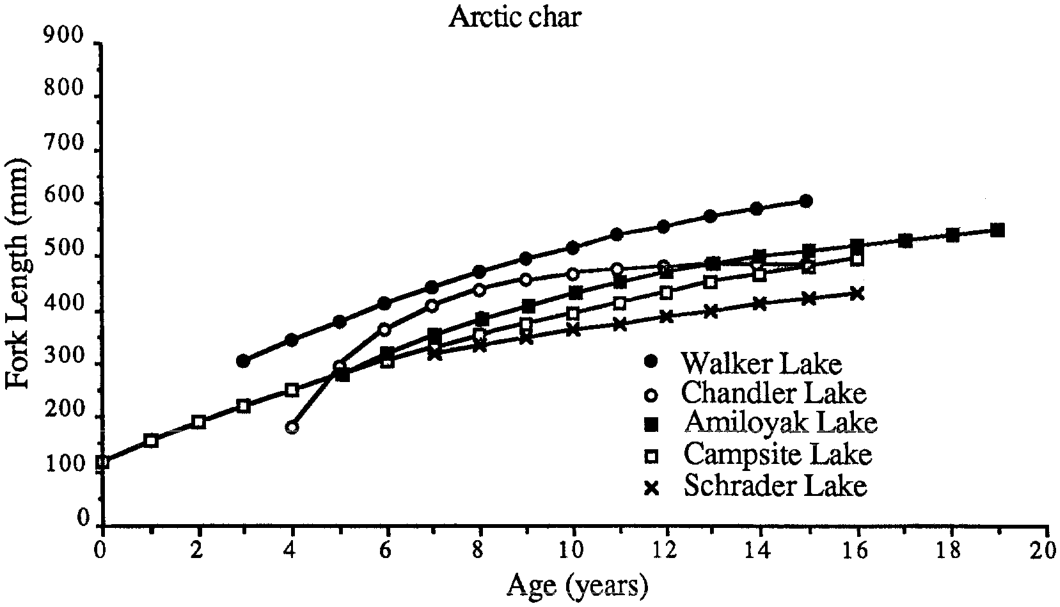

FIGURE 18.—Von Bertalanffy growth curves for Arctic char from Walker Lake and other Alaskan lakes (McCart 1980; Troyer and Johnson 1994).

(approximately 200 mm fork length) Walker Lake lake trout are beginning the transition from an invertebrate diet to a diet primarily of fish. This change in diet would reduce competition with Arctic char. Walker Lake lake trout do not achieve sizes comparable to Paxson and Summit Lake fish until about age 16 (mean lengths 572 - 598 mm). The apparently slow growth of older lake trout in Summit and Paxson lakes may well be caused by sampling bias (few large fish are sacrificed for aging) and by sport fishing harvest of larger fish, which decreases the L_∞ parameter and flattens the growth curve (John Burr, Alaska Department of Fish and Game, Fairbanks, personal communication).

Length at age 12 was about the same in Walker and Chandler lakes, but lake trout older than age 12 grew consistently faster at Walker Lake (Figure 17). This difference in growth rate may reflect differences in availability and type of larger prey species: round whitefish comprised 73% of the lake trout diet in Walker Lake, whereas Arctic grayling were 67% of the diet in Chandler Lake and none of the stomachs examined (N = 68) contained round whitefish (Troyer and Johnson 1994).

Relatively fast growth of older lake trout documented in this study may be an artifact of small sample sizes of fish older than 16 years: there may have been an absence of older slower growing fish in our sample. Alternatively, the rapid growth may be real and attributable to the combination of a good forage base and limited population size of lake trout. Population size may be limited by natural suppression of recruitment, such as cannibalism or displacement of juveniles into shallows where they are easily preyed upon by birds (Johnson 1976), and also by fishing pressure (Healey 1978). Low levels of fishing pressure were found in this study, but levels may have been higher in prior years.

Arctic char lengths at age and growth rates exceed those of several other northern Alaska populations (Figure 18). Compared to those populations, Walker Lake Arctic char have greater length at all ages sampled. Walker Lake is farther south than the other lakes in Figure 18 and its Arctic char apparently benefit from a longer growing season (Walker Lake is ice free for about 5 months, versus about 3.5 months for Chandler Lake) as well as an ample forage base of invertebrates. 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 sample of Arctic char (N = 35).

Food Habits

Lake trout were primarily piscivorous and Arctic char primarily 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 benefit both species and has probably improved the quality of the sport fishery.

Fecundity and Maturity

Lake trout fecundity found in this study (3000 - 4000 ova) is within the range of other northern Alaska populations. In lakes north of the Brooks Range, fecundities ranging from 274 to 13,000 ova have been recorded (McCart *et al.* 1972; Craig and Wells 1975). For Arctic char, 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, 18% of the lake trout and six percent of the Arctic char examined would spawn in the year of capture. The small sample of Arctic char (N = 16) probably was not adequate to reflect the actual percentage 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 mature 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, and the likelihood of spawning, are highly subjective (Healey 1978; Martin and Olver 1980). Intermittent spawning and a lack of representation of the younger age 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 ranging from four to five years. Assuming Walker Lake 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

Physical and chemical properties of Walker Lake suggest it is similar to other high latitude lakes supporting lake trout and Arctic char populations (Wong and Whillans 1973; Johnson 1975; Pearse 1978; Martin and Olver 1980). Surface dissolved oxygen was inversely related to water temperature and was at or near saturation throughout the summer. Walker Lake is slightly alkaline (pH ranging from 7.3 to 7.6), most likely because of limestone deposits in the basin (Jones *et al.* 1990). Water clarity was highest at the south end of the lake throughout the summer, possibly because prevailing winds were from the south, keeping more sediments suspended at the north end. The clarity gradient may also be linked to algal concentration: Jones *et al.* (1990) recorded higher average Chlorophyll-*a* in the north basin than in the south; they suggested this was due to nutrient loading from the major tributaries entering at the north end of the lake.

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 (Alaska Sport Fishing Regulations Summary, Alaska Department of Fish and Game, 1994).

Annual yield estimates and harvest recommendations are summarized in Table 19. 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. Although fishing effort at Walker Lake exhibited a steady decline from 1987 to 1989, decreasing from 852 to 326 angler-hours, state-wide effort levels have an average increase of 5% per year between 1977 and 1992 (Mills 1993). Current regulations could prove inadequate in preserving a sustainable yield if 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 regulating the length of the sport fishing season, as both lake trout and Arctic char are particularly vulnerable to sport fishing when they frequent the shallows, from approximately late May to mid June and mid September to mid October.

Continual monitoring of sport angling pressure will be necessary to ensure that Walker Lake fish stocks remain healthy. Baseline data from this study will provide a means for assessing future changes in the lake trout and Arctic char populations and fishing effort, catch, and harvest. We suggest that the National Park Service develop a monitoring program whereby fishing pressure could be monitored seasonally. A minimal program should require catch and harvest information from fishing guides and include periodic overflights to determine general trends in fishing effort. If use appears to be increasing, we recommend a comprehensive harvest survey designed to interview all anglers during the fishing season. This would require a constant presence at the lake by creel clerks. Because many anglers seem willing to practice catch and release fishing, we further recommend that the National Park Service develop a fishing brochure emphasizing the low density, high quality fishery in Walker Lake and the benefits of catch and release fishing.

TABLE 19.—Summary of estimates for standing crop and current annual yield of Lake trout and Arctic char in Walker Lake with recommended maximum harvest levels. Assumptions for the calculation of estimates, including average fish size, are provided in the text.

			Recommended maximum annual harvest	
Species	Standing crop (kg/ha)	Current yield (kg/ha)	kg/ha	Number of average-size fish
Lake trout	0.65	0.005-0.007	0.07	222
Arctic char	1.14	0.005-0.009	0.16	340

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APPENDIX 1.–Physical descriptions of the three lake section strata at Walker Lake.

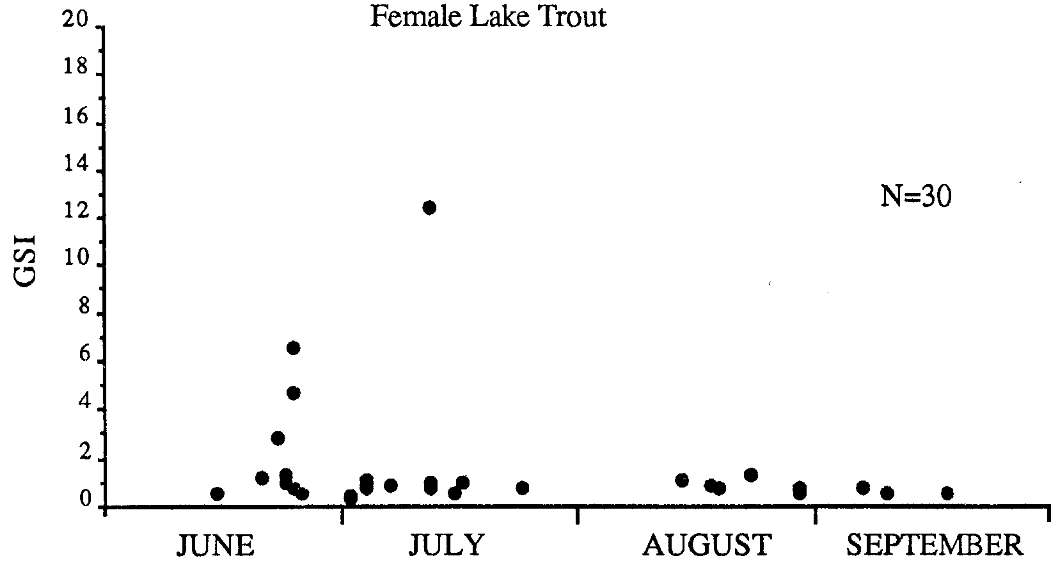
Physical Characteristic	Lake section North	 Middle	 South	Total
Surface area (ha)	1064	874	1862	3800
Percent of total lake surface area	28	23	49	100
Shoreline				
length (km)	23	19	18	60
Percent of total shoreline	38	32	30	100
Depth zone				
Littoral area (ha)	160	253	168	581
Littoral area (%)	4	7	4	15
Pelagic area (ha)	904	621	1694	3219
Pelagic area (%)	24	16	45	85
Predominant substrate				
Type	SPG[a]	SPG	SPG	
Percent	77%	77%	66%	
Maximum depth (m)	120	58	122	

[a] Sand/Pebble/Gravel substrate. See substrate type characteristics Appendix 2.

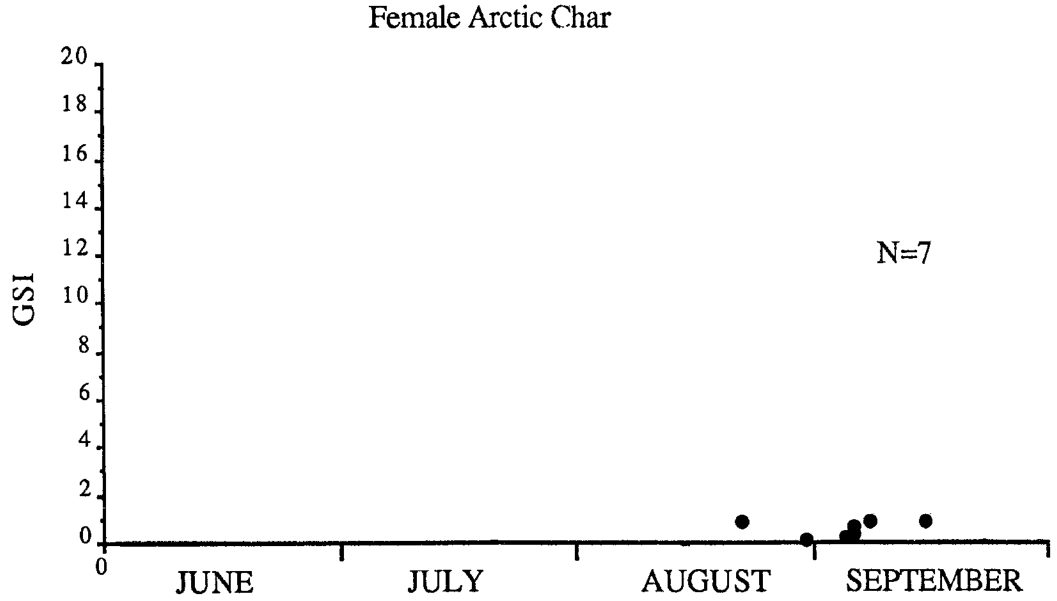
APPENDIX 2.—Walker Lake shoreline sampling site allocation by strata. The weighted number of sites was in proportion to shoreline length of each feature/substrate type as a percentage of total shoreline length. "Rounding" of the number of sites was done so that all feature/subtrate types had a maximum of two sampling sites per lake section and a mimimum of two sampling sites among all sections.

					Lake Section					
					North		Middle		South	
Shoreline type	Substrate type	Percent shoreline length			Number of sites		Number of sites		Number of sites	
		North	Middle	South	Weighted	Rounded	Weighted	Rounded	Weighted	Rounded
Straight	SPG[a]	22.8	25.7	37.5	3.0	2	2.8	2	3.8	2
	CB	15.0	4.7	0	2.0	2	0.5	1	0	0
	MIX	0	5.5	26.6	0	0	0.6	1	2.7	2
Peninsula	SPG	28.7	22.0	20.3	3.7	2	2.4	2	2.0	2
	CB	3.0	0	0	0.4	2	0	0	0	0
	MIX	0	0	10.9	0	0	0	0	1.1	2
Stream mouth	SPG	22.1	16.5	0	2.9	2	1.8	2	0	0
	MIX	4.8	12.8	0	0.6	1	1.4	1	0	0
Island	SPG	0	12.8	0	0	0	1.4	2	0	0
Inlet stream	SPG	3.6	0	0	0.5	2	0	0	0	0
Outlet stream	SPG	0	0	4.7	0	0	0	0	0.5	2
Total		100	100	100		13		11		10

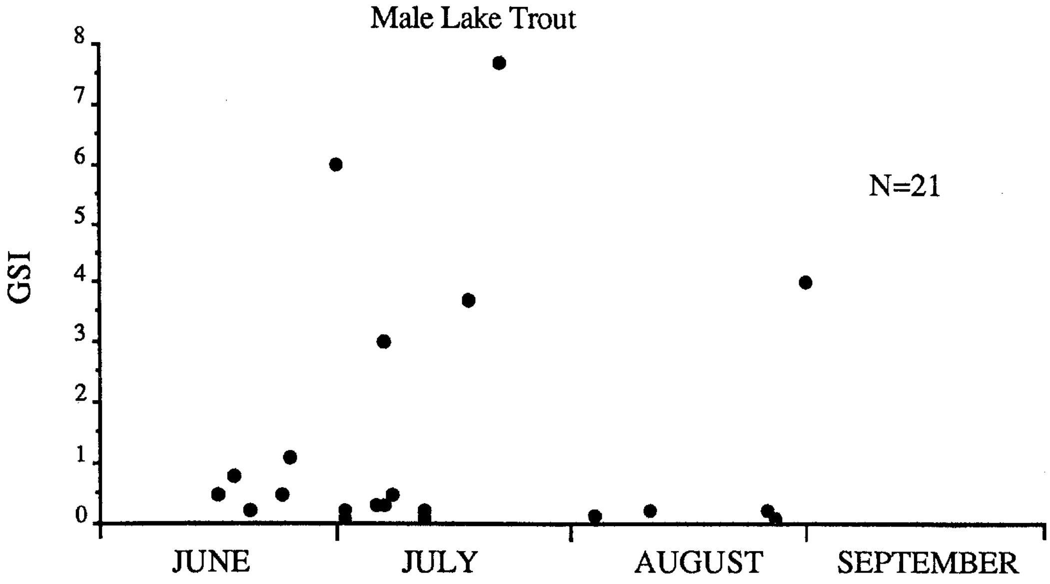
[a] SPG = sand/pebble/gravel; CB = cobble/boulder; MIX = substrate intermediate between the other two types.



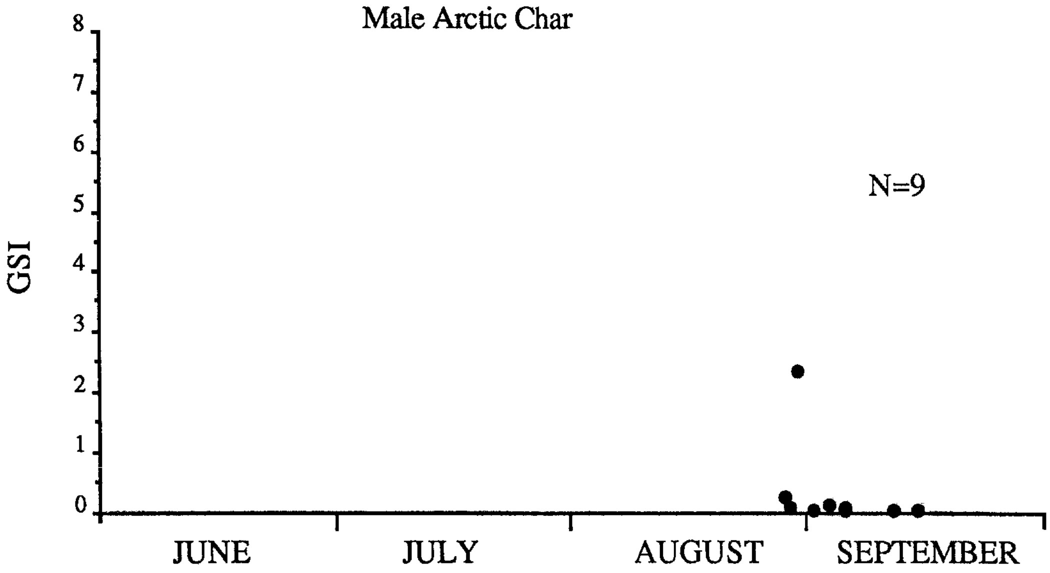
APPENDIX 3.—Gonadosomatic indices (GSI) for female lake trout from Walker Lake for the months of June through September, 1987 and 1988.



APPENDIX 4.—Gonadosomatic indices (GSI) for female Arctic char from Walker Lake for the months of June through September, 1987 and 1988.



APPENDIX 5.—Gonadosomatic indices (GSI) for male lake trout from Walker Lake for the months of June through September, 1987 and 1988.



APPENDIX 6.—Gonadosomatic indices (GSI) for male Arctic char from Walker Lake for the months of June through September, 1987 and 1988.