Fish Population Characteristics of Arctic National Wildlife Refuge Coastal Waters, Summer 1988

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Key Words: Fish, distribution, relative abundance, age, condition factor, movements, Beaufort Sea, Arctic National Wildlife Refuge

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Abstract

Fishes inhabiting Beaufort Sea coastal waters within and near the Arctic National Wildlife Refuge, Alaska were sampled at eight fyke net and six gill net stations during the summer 1988 open-water season (approximately mid-July through mid-September). Specific study areas included Camden Bay, the Kaktovik and Jago lagoons area, and Pokok Bay. Concurrent physical habitat measurements in each study area included water temperature and salinity, current direction and velocity, and wind direction and velocity. Eighteen fish species were collected by fyke net, the six most abundant being Arctic cod *(Boreogadus saida)* Arctic cisco *(Coregonus autumnalis)*, fourhorn sculpin *(Myoxocephalus quadricornis)*, Arctic char *(Salvelinus alpinus)*, ninespine stickleback *(Pungitius pungitius)*, and Arctic flounder *(Liopsetta glacialis)*. The only species collected by gill net were Arctic cisco, Arctic char, and least cisco *(Coregonus sardinella)*.

Species composition and relative abundance were generally consistent with findings of previous studies in Beaufort Sea coastal waters, though capelin *(Mallotus villosus)*, which were very abundant in the Camden Bay study area in 1987 were captured in much lower numbers in 1988. Ninespine stickleback were relatively more abundant than reported in prior studies. Arctic cod were more abundant in Camden Bay and small (<200 mm) Arctic cisco were more abundant in Pokok Bay than in the other two study areas. Arctic char, fourhorn sculpin and Arctic flounder were more abundant in southwestern Kaktovik Lagoon than in the other areas sampled.

Gill net sampling in Camden Bay indicated that Arctic cisco and least cisco were more abundant closer to shore than farther offshore; there was no difference in Arctic char abundance with distance from shore. Arctic char, Arctic cisco and least cisco were all more abundant in the upper 2.4 meters of the water column than in deeper waters of Camden Bay.

Mark-recapture data conform with current ideas concerning movements of Arctic cisco in Beaufort Sea coastal waters, with substantial (>40 km) movements documented for three individuals of this species. Movements of 7 and 8 km were documented for two fourhorn sculpin; one of these individuals moved between two lagoons.

Length frequency data are presented for Arctic cisco, Arctic char, least cisco, Arctic cod, fourhorn sculpin, and Arctic flounder. Arctic char larger than 300 mm fork length were generally absent from coastal waters after the end of August, though smaller fish remained through the end of the sampling period. Intermediate size groups of Arctic and least cisco were absent from catches in all study areas despite pronounced frequency modes for both smaller and larger size groups.

Weight-length relationships for Arctic char, Arctic cisco, least cisco, Arctic cod, Arctic flounder and fourhorn sculpin were within the ranges reported for these species in previous studies in Beaufort Sea coastal waters. Condition coefficients for immature and mature Arctic char and immature fourhorn sculpin increased significantly between the first and second halves of the summer sampling period. Arctic char ranged in age from 1 to 15 years, though most were age 6 or less. Length ranges within each age class were wide, with considerable overlap between age classes.

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Introduction

Increasing attention has focused on the possibility of commercial quantities of oil and gas lying beneath the coastal plain of the Arctic National Wildlife Refuge (Figure 1) since discovery of the Prudhoe Bay oilfield in 1968. A report to the U.S. Congress (Clough et al. 1987) indicated a 19% chance of finding recoverable oil and gas and described a scenario of how those resources might be produced from the area and transported to refining facilities. Oil and gas leasing on the refuge is currently prohibited by Section 1003 of the Alaska National Interest Lands Conservation Act. Legislation to allow leasing on the coastal plain is currently being considered by the U.S. Congress. Should further exploration and eventual production of oil and gas be permitted on the coastal plain, development of coastal support facilities such as ports will likely occur.

In addition to possible oil production on the coastal plain, a number of oil leases have been sold in federal and state waters offshore of the refuge since the early 1980's. Exploratory wells have been drilled in some of these areas. Continued exploration in the offshore waters is likely, with possible development of production facilities.

Anadromous and marine fish species utilize lagoons and other nearshore Beaufort Sea brackish coastal habitats for feeding during summer (Craig 1984). These areas are important because they are relatively warmer than offshore Beaufort Sea waters and have a high food organism concentration. Such conditions facilitate the accumulation of fat reserves in fish for overwintering and sexual maturation. The nearshore brackish band also appears to serve as an important migratory pathway for several anadromous species (Craig 1984). The physical habitat factors that appear to be most important to fishes in these nearshore waters are salinity and temperature. These habitat factors are in turn determined by nearshore ocean currents which appear to be wind driven (Sharma 1979).

Coastal oil or gas and port site development, including causeways and seawater intakes, may affect fish that utilize Beaufort Sea coastal waters. A series of such causeways and/or water intakes may reduce habitat quality for some fish species utilizing coastal areas (Craig 1984). Fish may also be affected by inadvertent oil and other hazardous materials spills.

Reliable baseline data are necessary for detecting possible effects of oil and gas development on fish populations and habitat. Such data are also necessary to understanding fish population dynamics and habitat requirements in Beaufort Sea coastal waters. An understanding of these features is essential to intelligently manage and mitigate oil and gas activities.

Fish studies in Arctic Refuge coastal waters began in the summer of 1970 with a gill net study that spanned the entire refuge coastal area (Roguski and Komarek 1971). Refuge coastal waters, including Kaktovik Lagoon, were sampled in the 1970's by Ward and Craig (1974) and Griffiths et al. (1977) to gather baseline data for a proposed gas pipeline across the refuge. Beaufort and Angun lagoons were studied in 1982 by Griffiths (1983) as part of a biological characterization of eastern Beaufort Sea lagoons. Craig (1983) sampled Kaktovik Lagoon during the summer of 1983 to monitor effects of gravel dredging on the east shore of Barter Island. Kaktovik Lagoon was also sampled by fyke net in 1985 as part of a study of the Kaktovik subsistence fishery (Nelson et al. 1986). The U.S. Fish and Wildlife Service began sampling refuge coastal waters with a fyke net survey of Beaufort Lagoon during the summers of 1984 and 1985 (West and Wiswar 1985; Wiswar and West 1987). This work continued with similar surveys of Oruktalik Lagoon in 1986 (Wiswar et al. *In Preparation*) and western Camden Bay in 1987 (Wiswar and Fruge *In Preparation*).

Although the above studies resulted in a substantial amount of fisheries data from refuge coastal waters, none of these studies provided site-specific data on fish usage of the areas identified as possible port sites by Clough et al. (1987), nor did any of these studies address annual variability in fish abundance, which can be substantial

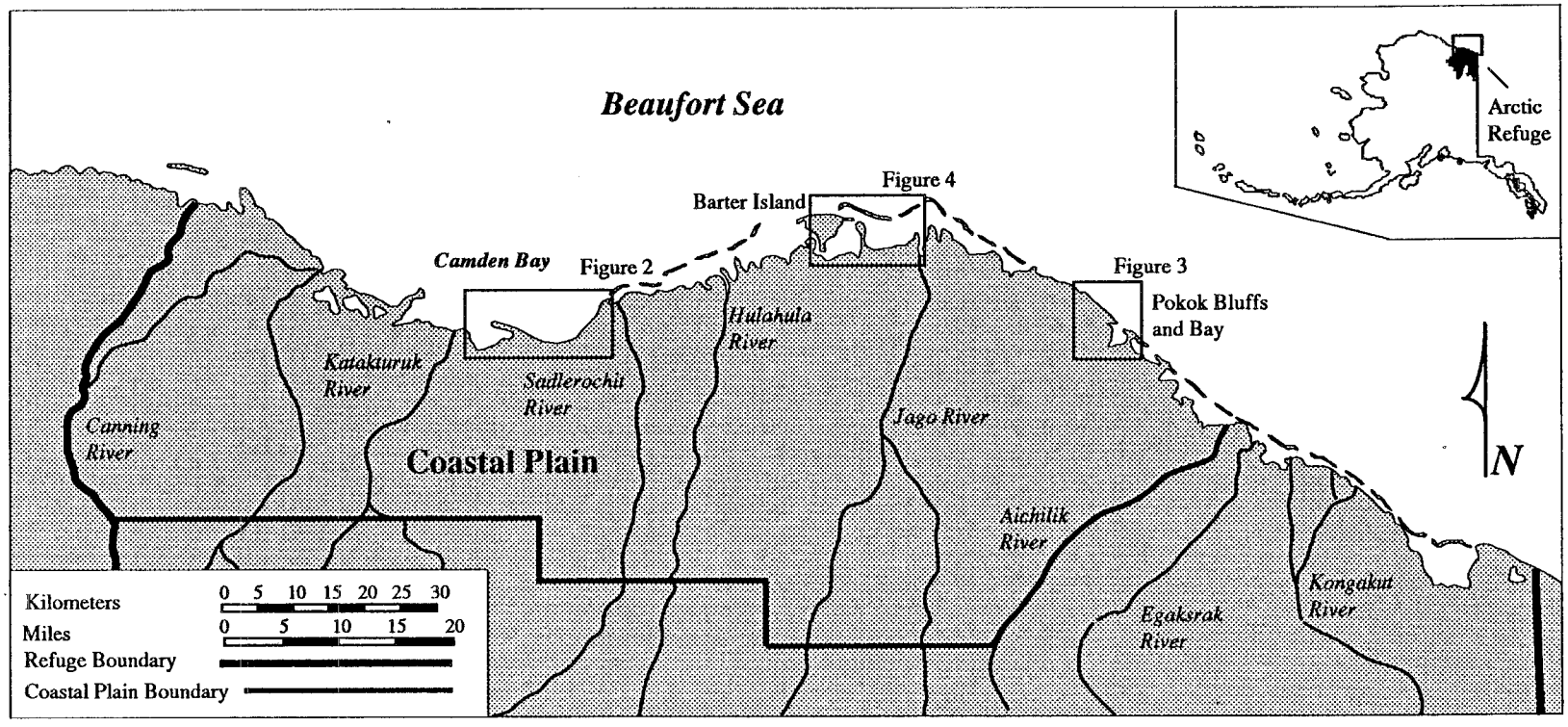

FIGURE 1.—Beaufort Sea coast and coastal plain of the Arctic National Wildlife Refuge and study areas sampled for fish and physical hydrographic characteristics during mid-July through mid-September 1988.

in coastal Beaufort Sea waters. To improve the existing baseline database on coastal fish populations and habitats, the U.S. Fish and Wildlife Service began a 5-year study in 1988. First year sampling focused on three study areas. Two of these, Camden Bay and the Pokok Bluffs/Bay area, are possible port sites. A third study area was comprised of Kaktovik and Jago lagoons. Specific objectives in all three study areas were as follows:

1. Determine relative abundance, distribution and movements of anadromous and marine fish species.

2. Determine length frequency, age structure, weight-length relationships and condition factors for Arctic cisco *(Coregonus autumnalis)*, least cisco *(Coregonus sardinella)*, Arctic char *(Salvelinus alpinus)*, Arctic cod *(Boreogadus saida)*, fourhorn sculpin *(Myoxocephalus quadricornis)* and Arctic flounder *(Liopsetta glacialis)*.

3. Determine spacial and temporal hydrographic characteristics (current, temperature and salinity) and the relationships of these characteristics to meteorological parameters (wind direction and velocity).

4. Determine the relationships between fish distribution and abundance and hydrographic characteristics.

This report summarizes fisheries data from 1988 sampling activities; data on hydrographic characteristics will be presented in a future report. More comprehensive data analyses will be discussed in a final report.

Study Area

Three areas of the Arctic Refuge coast were sampled for fish and hydrographic characteristics: Camden Bay; Pokok Bay and Bluffs; and Kaktovik and Jago lagoons (Figures 1-4). The westernmost sampling area, Camden Bay (Figure 2), is centered approximately 43 km southwest of the village of Kaktovik. Camden Bay is a broad open-water zone along the Arctic Refuge coast extending between the Canning River delta (Figure 1) and Anderson Point (Figure 2). Collinson Point, a gravel/sand spit extending into Camden Bay, partially encloses an embayment known as Simpson Cove where maximum depth is approximately 3.4 m (Nautical Chart 16044, U.S. Department of Commerce) (Figure 5) .

Camden Bay east of Collinson Point consists of a broad arcuate bight extending southeastward and then curving northeastward toward Anderson Point. This bight area was identified by Clough et al. (1987) as a possible port site should oil and gas development occur. Depth in this part of Camden Bay drops off quickly, reaching depths of around 6 m within about 0.5 km of the shore (Nautical Chart 16044, U.S. Department of Commerce) (Figure 5). The bottom gradient is less steep farther out, reaching a depth of about 9 m approximately 5 km from shore (Nautical Chart 16044, U.S. Department of Commerce). Most of the Camden Bay shoreline is sand/gravel beach at the base of tundra bluffs, mostly 1-2 m high, though in some areas these bluffs may be as high as 3-5 m.

The major stream drainages discharging into Camden Bay are the Katakturuk River, Marsh Creek and Carter Creek. Several unnamed smaller streams also drain into the bay. Other major rivers nearby include the Canning River to the west and the Sadlerochit River to the east.

The Pokok Bay and Bluffs study area (Figure 3) is centered approximately 43 km southeast of Kaktovik. Though called a bay, Pokok Bay is more properly described as a lagoon. It is small relative to most lagoon systems on the Arctic Refuge coast. It has a single narrow opening to the Beaufort Sea and was classified by Hachmeister and Vinelli (1984) as a pulsing lagoon since it exhibits pulsing effects in water level due to tidal pumping. Hachmeister and Vinelli (1984) also described the physical parameters and hydrography of Pokok Bay. Maximum depth is approximately 4 m (Figure 6) (Nautical Chart 16042, U.S. Department of Commerce). The major tributary to the lagoon is the Kimikpaurauk River, a tundra stream. Most of the lagoon's shoreline is physically similar to that described for Camden Bay, being sand/gravel beach below tundra bluffs.

The Pokok Bluffs portion of the Pokok Bay and Bluffs study area consists of those Beaufort Sea waters adjacent to an area of relatively high elevation along the coast approximately 6 km northeast of Pokok Bay (Figure 3). The Pokok Bluffs area was the other site identified by Clough et al. (1987) as a possible port site. The steepest bottom gradient found in refuge coastal waters occurs offshore of the Pokok Bluffs area, reaching depths of 10 m within 1 km of shore (Nautical Chart 16042, U.S. Department of Commerce) (Figure 6).

Kaktovik and Jago lagoons are located immediately east of Barter Island (Figure 4). Barter Island forms the western and northern shores of Kaktovik Lagoon. Jago Lagoon is east of Kaktovik Lagoon and divided from it by a low sand/gravel spit between the mainland and an island (locally known as Manning Point or Drum Island). The spit is sometimes inundated during periods of high water making the two lagoons contiguous. Jago Lagoon is separated from the Beaufort Sea by a barrier island. The Jago River delta forms the eastern shore of Jago Lagoon.

These two lagoons fit the description of limited exchange lagoons given by Hachmeister and Vinelli (1984). Kaktovik Lagoon has two channels leading to outside waters. One is known as Nelsaluk Pass which connects Kaktovik and Jago lagoons. Another shallow channel at the southwest end Kaktovik Lagoon opens to waters west of Barter Island. No streams of any consequence empty into Kaktovik Lagoon. Jago Lagoon has two entrances to the Beaufort Sea. One is in the western part of the lagoon between Barter Island and Bernard Spit. The other, known as Jago Entrance, is a much broader opening to the Beaufort Sea near the Jago Delta between Bernard Spit and Jago Spit. Jago Lagoon is also connected to another lagoon to the east by a shallow expanse of water between the Jago Delta and Jago Spit. Other than the Jago River, there are no prominent streams draining into Jago Lagoon.

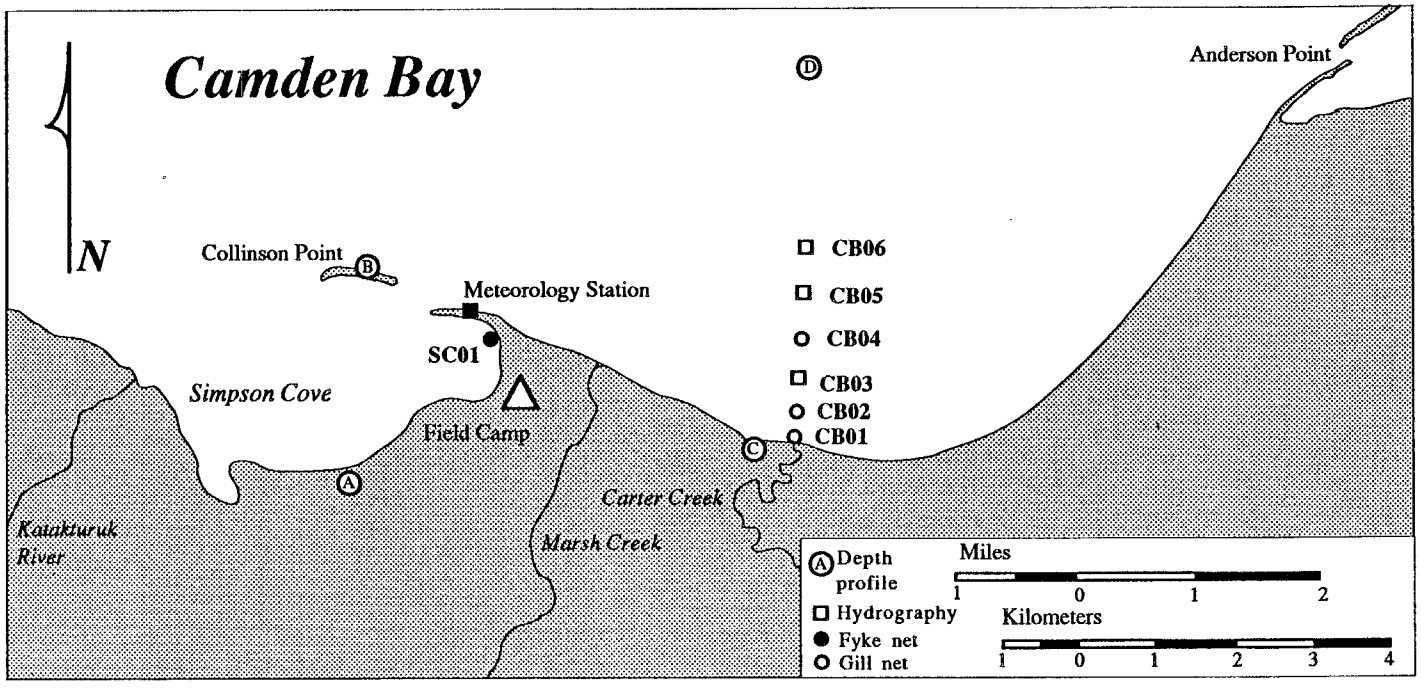

FIGURE 2.—Sampling stations in the Camden Bay study area on Arctic National Wildlife Refuge during mid-July through mid-September 1988 (circled letters indicate the ends of depth profiles depicted in Figure 5).

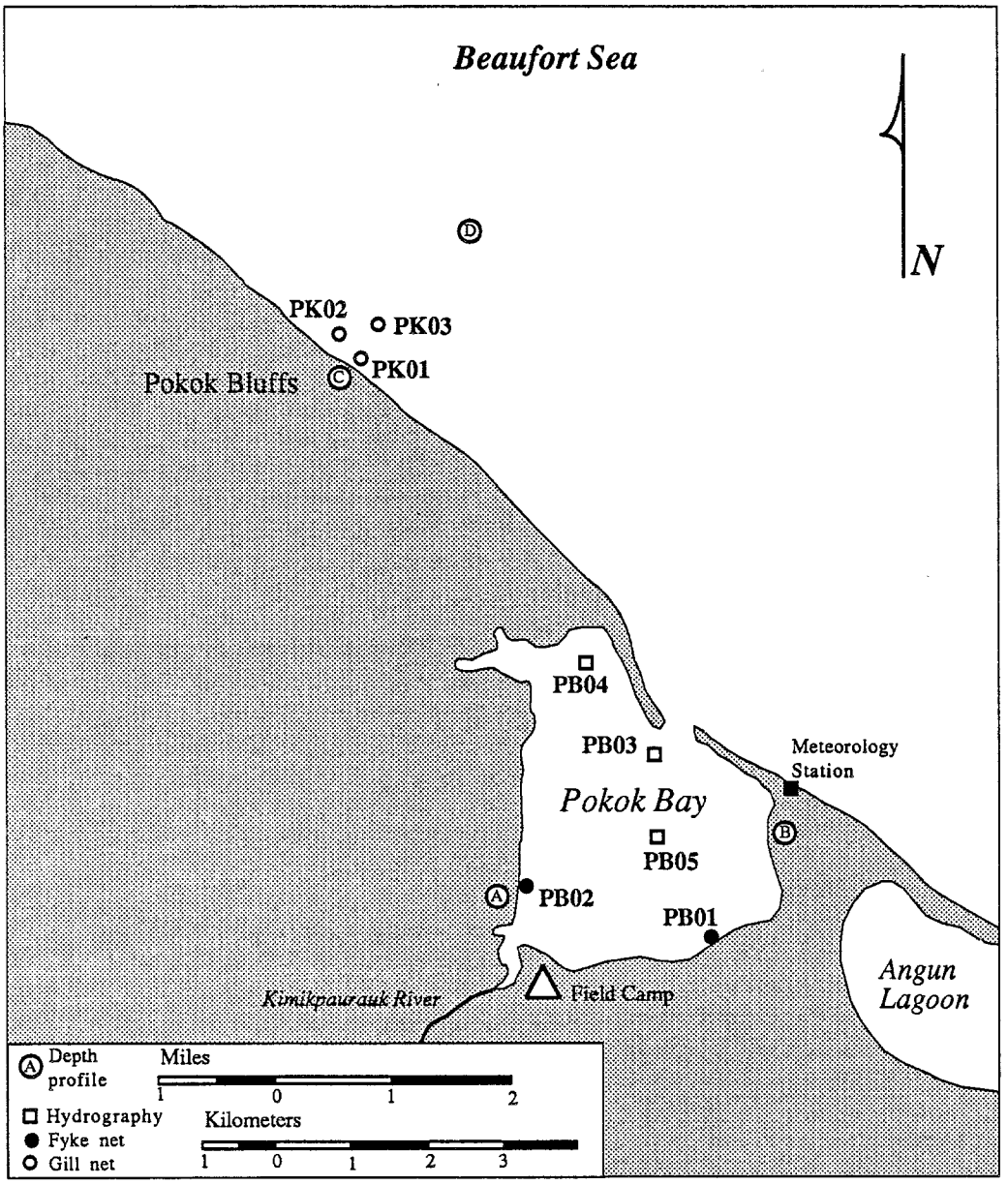

FIGURE 3.—Sampling stations in the Pokok Bay and Bluffs study area on the Arctic National Wildlife Refuge during mid-July through mid-September 1988 (circled letters indicate the ends of depth profiles depicted in Figure 6).

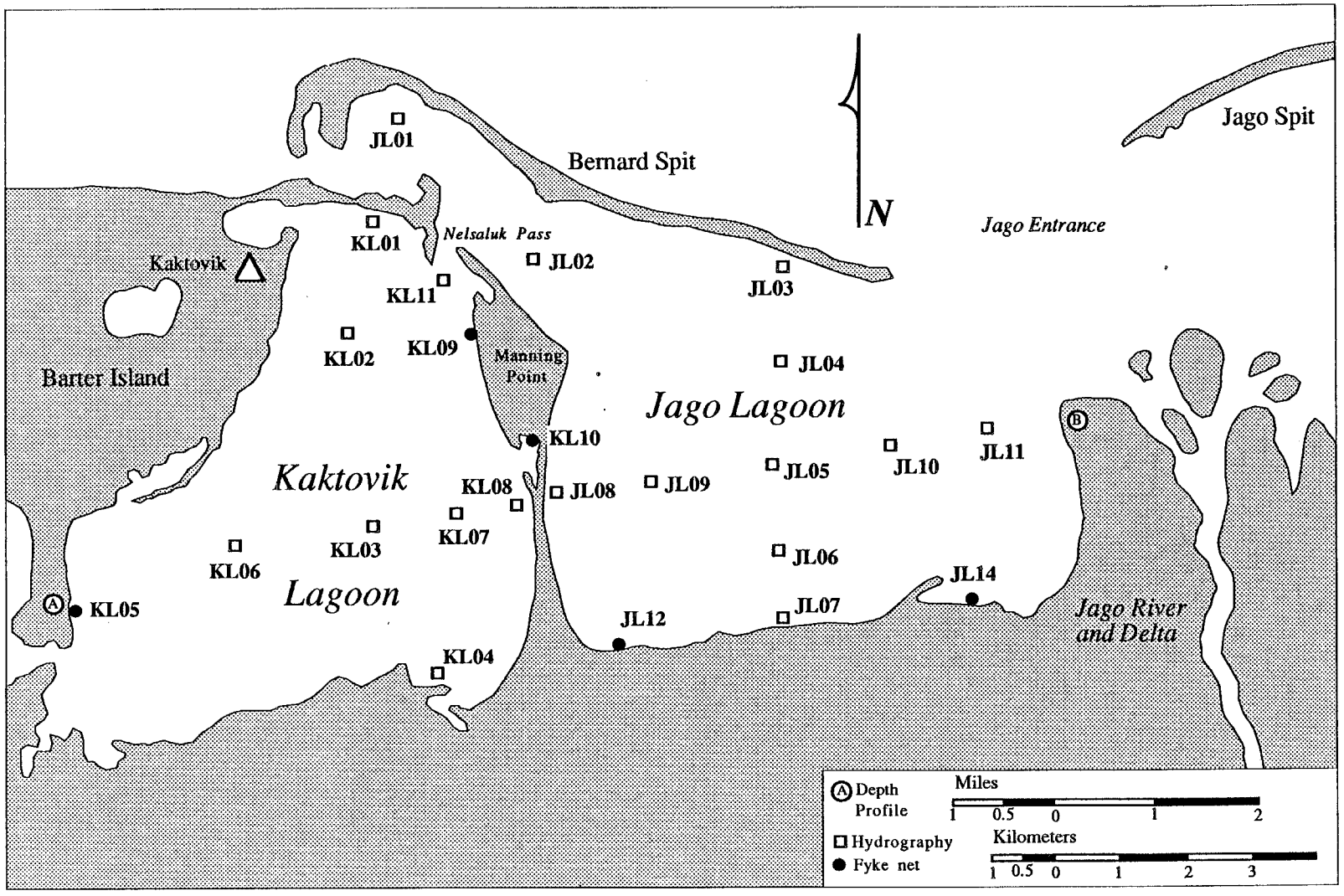

FIGURE 4.—Sampling stations in the Kaktovik and Jago lagoons area on the Arctic National Wildlife Refuge during mid-July through mid-September 1988 (circled letters indicate the ends of depth profiles depicted in Figure 7).

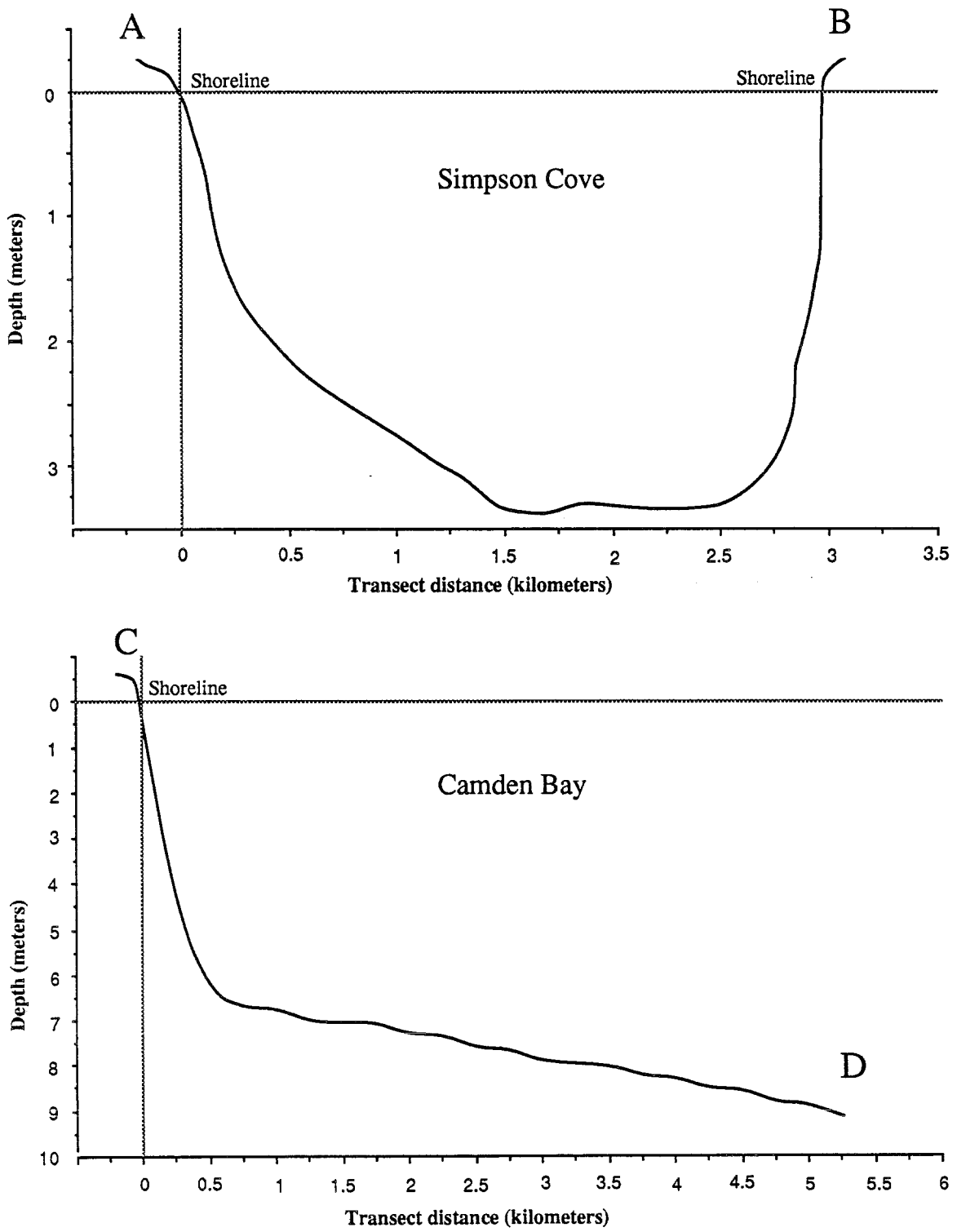

FIGURE 5.—Depth profiles across Camden Bay (letters at the end of each profile correspond to points identified in Figure 2).

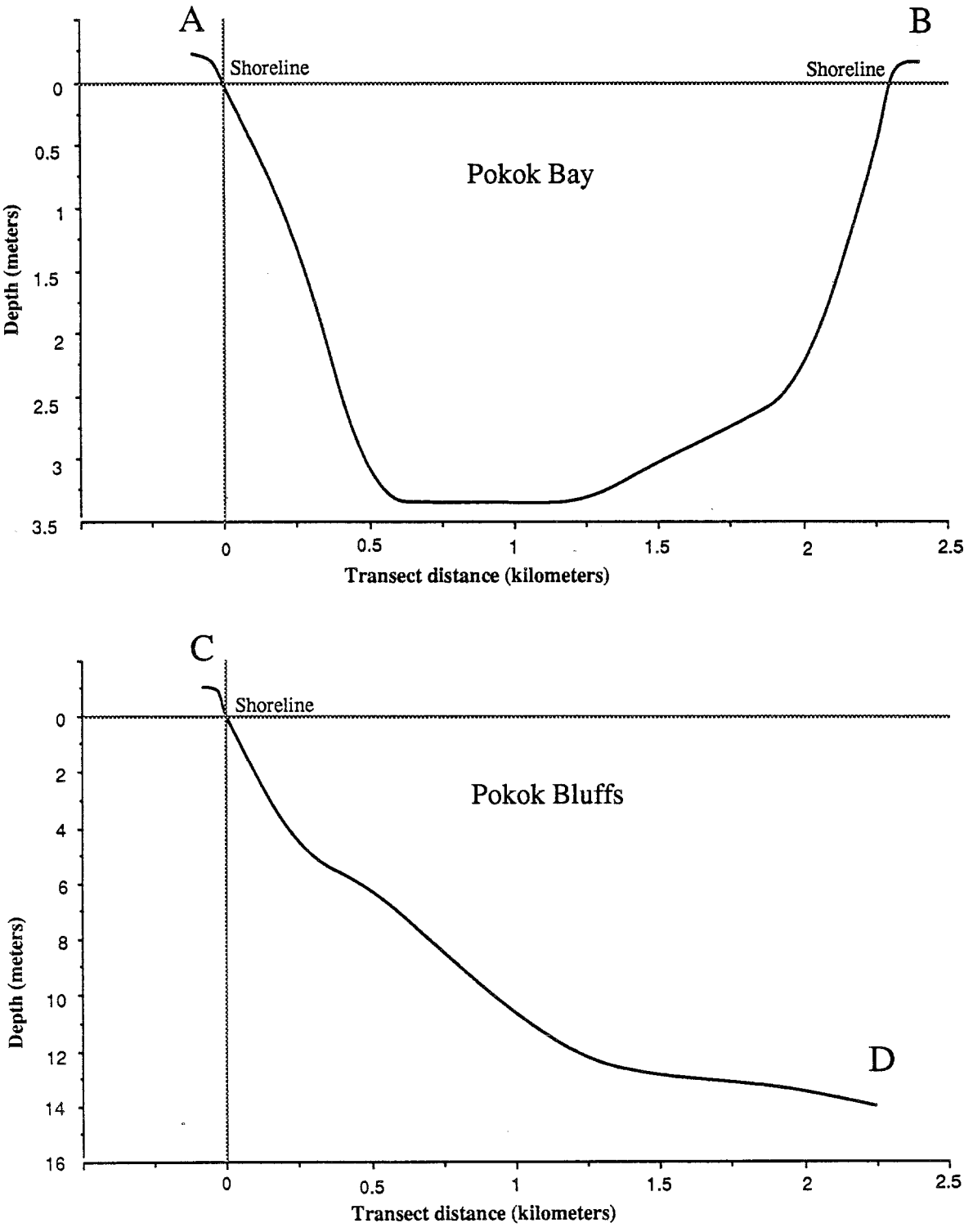

FIGURE 6.—Depth profiles across Pokok Bay and Pokok Bluffs offshore area (letters at the end of each profile correspond to points identified in Figure 3).

Maximum water depth in Kaktovik and Jago lagoons is approximately 4 m (Nautical Chart 16043, U.S. Department of Commerce) (Figure 7). Most of the shoreline of these two lagoons is physically similar to that described for Camden Bay, being sand/gravel beach below tundra bluffs. The southwestern shore of Kaktovik Lagoon along the southeastern part of Barter Island has less beach area and the bluffs are lower in elevation than most of the rest of the shoreline.

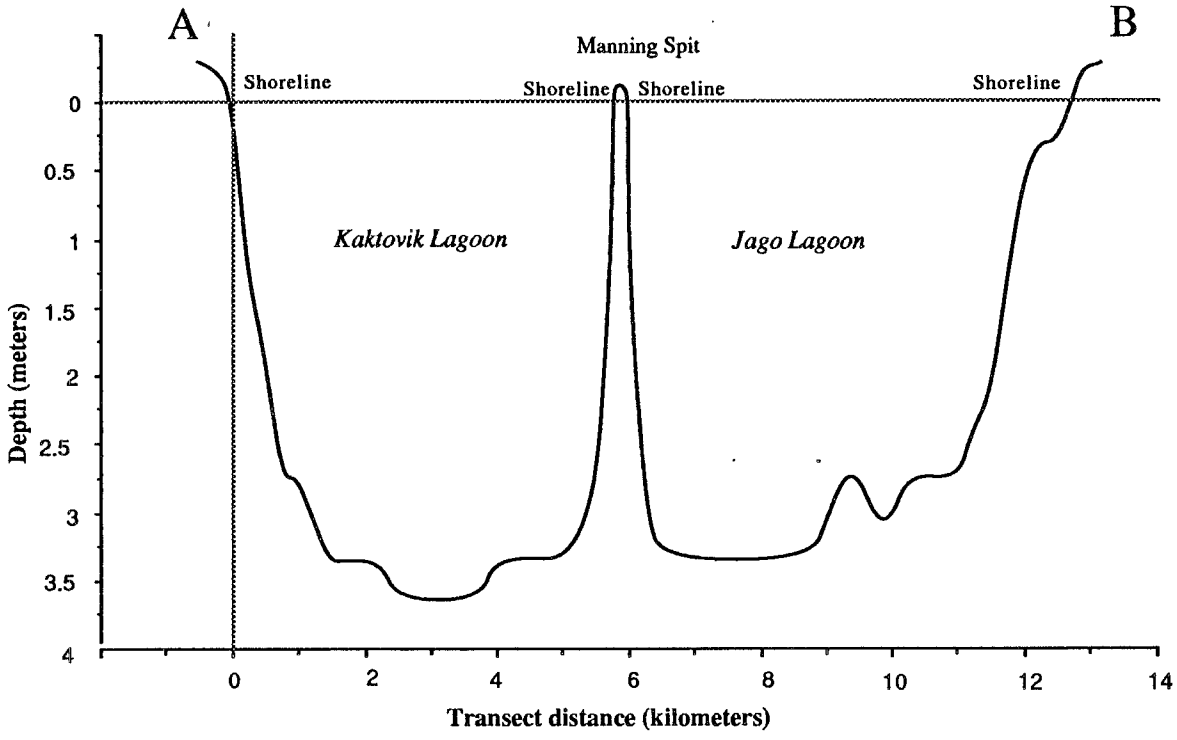

FIGURE 7.—Depth profile across Kaktovik and Jago lagoons (letters at the ends of the profile correspond to points identified in Figure 4).

Methods

Fish Sampling

Fyke Nets.—Fish were captured using fyke nets in lagoons and protected nearshore areas in water depths of 1.3 m or less (Table 1; Figures 2-4). Fyke nets were dual trap type with one 61-m lead and two 15-m wings. The lead was set perpendicular to and with one end anchored to shore and the traps set offshore (Figure 8). The traps, lead and wings were anchored in place using solid steel rods 3 m in length and 1.5 cm in diameter. Fyke nets were checked once daily, unless severe weather precluded safe travel. All fish captured were enumerated by species. The sizes of unusually large catches (>1000 individuals) of some species (normally Arctic cisco, Arctic cod, and fourhorn sculpin) were estimated by counting the number in three subsamples (defined by volume as the amount required to fill a dip net to a prescribed level). An effort was made to randomly mix the catch prior to obtaining each subsample. The average number of fish per counted subsample was multiplied by the total number of subsamples to estimate the entire catch. Fish larger than 250 mm fork length (usually much less numerous than the smaller individuals) were individually counted and not included in subsamples, and the numbers of these individually counted fish were added to the subsample estimates. Fork lengths of at least 25 randomly-selected individuals of each species in each net's catch were measured to the nearest millimeter; all individuals were measured if total catch for a species was 25 or less. All fish were released except those sacrificed for other analyses described below.

Gill Nets.—Gill nets were used to sample fish in unprotected, deeper open waters of Camden Bay and the Pokok Bluffs area (Table 1; Figures 2-3). The gill nets consisted of five panels; each panel measured 7.6 m in length and 2.4 m in depth. Each panel was a different mesh size: 19 mm; 25 mm; 38 mm; 51 mm; and 64 mm. Mesh panels were randomly-placed within each net during net construction. Gill net sampling stations were located in water depths of 2.4 m, 4.9 m, and 7.3 m. In order to sample the entire water column at the 4.9 and 7.3 m depths, nets were attached to each other vertically (i.e., 2 nets at the 4.9 m depth and 3 nets at the 7.3 m depth) (Figure 9). Each end of a gill net was held in place by a Danforth anchor, with the float line attached to buoys. Nets were set perpendicular to the shoreline, though the nets often drifted away from this orientation because of currents and/or wave action. Three replicate net sets were made at each gill net station, with the replicates set end-to-end rather than side-by-side to reduce gear competition. An alternate day schedule was originally planned for fishing gill nets. However, frequency of sets was less than this because of problems caused by weather and ice. Net sets ranged from 2 to 7.4 hours and averaged 3.5 hours duration. All fish captured in gill nets were enumerated, measured (fork length) to the nearest millimeter and released if in relatively good condition. If more than 25 individuals were captured in a particular panel, only 25 randomly-selected individuals were measured. The mesh size and depth zone of capture (i.e., 0-2.4 m, 2.4-4.9 m, 4.9-7.3 m) for each fish were also recorded.

Fish Sample Processing.—Fish movements were assessed by marking fish captured in both fyke and gill nets. Salmonid individuals greater than approximately 80 mm (3 in) fork length were marked either by fin clipping or by application of alcian blue dye using Syrijet® Mark III dental injectors (Mizzy, Inc.). Fish marked at the three different study sites were distinguished by clipping or applying dye at the base of different fins as follows: Camden Bay, left pelvic; Pokok Bay, right pelvic; Kaktovik and Jago lagoons, adipose. Individuals of other common species greater than 250 mm fork length were tagged using numbered fluorescent orange anchor tags (Floy Manufacturing Company). Dye marks, fin clips and tag numbers from recaptured individuals were recorded at the time of capture. The fin marking was used on anadromous species because local residents objected to tagging. However, some individuals of these species were tagged in September following the period of most intensive domestic fishing activity.

During each month of sampling, at least 20 individuals of the primary species (Arctic char, Arctic cisco, least cisco, Arctic cod, fourhorn sculpin, and Arctic flounder) were sacrificed in each study area for weight, maturity

TABLE 1.—Sampling station locations, types of data obtained at each, and inclusive dates of sampling, mid-July through mid-September 1988.

Station	Area	Latitude	Longitude	Fyke net	Gill net	STD[a]	Current meter	Sampling dates[b]
SC01	Camden Bay	69° 58.98' N	144° 50.20' W	X		X		July 20 - September 14
CB01	Camden Bay	69° 58.10' N	144° 42.13' W		X	X		July 30 - September 12
CB02	Camden Bay	69° 58.17' N	144° 42.13' W		X	X	X	July 30 - September 12
CB03	Camden Bay	69° 58.50' N	144° 42.13' W			X		August 7 - August 27
CB04	Camden Bay	69° 58.93' N	144° 42.13' W		X	X		July 30 - September 12
CB05	Camden Bay	69° 59.32' N	144° 42.13' W			X		August 7 - August 25
CB06	Camden Bay	69° 59.60' N	144° 42.13' W			X	X	August 6 - September 12
PB01	Pokok Bay	69° 57.65' N	142° 32.40' W	X		X		July 18 - September 14
PB02	Pokok Bay	69° 58.17' N	142° 34.55' W	X		X		August 13 - September 14
PB03	Pokok Bay	69° 58.62' N	142° 32.72' W			X		August 14 - September 9
PB04	Pokok Bay	69° 59.13' N	142° 34.08' W			X		August 14 - September 13
PB05	Pokok Bay	69° 58.27' N	142° 33.05' W			X	X	August 11 - September 13
PK01	Pokok Bluffs	70° 00.87' N	142° 37.73' W		X			August 2 and 10
PK02	Pokok Bluffs	70° 00.87' N	142° 38.10' W		X			August 2
PK03	Pokok Bluffs	70° 00.97' N	142° 37.35' W		X			August 2
KL01	Kaktovik Lagoon	70° 07.94' N	143° 34.15' W			X		August 7 - September 12
KL02	Kaktovik Lagoon	70° 07.12' N	143° 34.63' W			X		August 7 - September 12
KL03	Kaktovik Lagoon	70° 06.00' N	143° 34.26' W			X		August 7 - September 12
KL04	Kaktovik Lagoon	70° 05.08' N	143° 32.90' W			X		August 7 - September 12
KL05	Kaktovik Lagoon	70° 05.44' N	143° 39.56' W	X		X		July 13 - September 14
KL06	Kaktovik Lagoon	70° 05.83' N	143° 36.65' W			X		August 7 - September 12
KL07	Kaktovik Lagoon	70° 06.16' N	143° 32.72' W			X		August 7 - September 12
KL08	Kaktovik Lagoon	70° 06.22' N	143° 31.28' W			X		August 7 - September 12
KL09	Kaktovik Lagoon	70° 07.23' N	143° 32.20' W	X				July 10 - July 17
KL10	Kaktovik Lagoon	70° 06.59' N	143° 31.00' W	X		X		July 18 - September 12
KL11	Kaktovik Lagoon	70° 07.60' N	143° 32.62' W			X	X	August 11 - September 14

TABLE 1.—Continued.

Station	Area	Latitude	Longitude	Fyke net	Gill net	STD[a]	Current meter	Sampling dates[b]
JL01	Jago Lagoon	70° 08.50' N	143° 33.50' W			X		August 7 - September 12
JL02	Jago Lagoon	70° 07.72' N	143° 31.12' W			X	X	August 2 - September 13
JL03	Jago Lagoon	70° 07.70' N	143° 26.40' W			X		August 7 - September 12
JL04	Jago Lagoon	70° 07.20' N	143° 26.45' W			X		August 7 - September 12
JL05	Jago Lagoon	70° 06.60' N	143° 26.40' W			X		August 7 - September 12
JL06	Jago Lagoon	70° 06.00' N	143° 26.49' W			X		August 7 - September 12
JL07	Jago Lagoon	70° 05.42' N	143° 26.49' W			X		August 7 - September 12
JL08	Jago Lagoon	70° 06.24' N	143° 30.45' W			X		August 7 - September 12
JL09	Jago Lagoon	70° 06.41' N	143° 28.45' W			X		August 7 - September 12
JL10	Jago Lagoon	70° 06.71' N	143° 24.10' W			X		August 7 - September 12
JL11	Jago Lagoon	70° 06.88' N	143° 22.30' W			X		August 7 - September 12
JL12	Jago Lagoon	70° 05.22' N	143° 28.50' W	X		X		July 12 - September 13
JL14	Jago Lagoon	70° 05.51' N	143° 22.23' W	X		X		July 15 - September 13

[a]STD = salinity, temperature, depth

[b]Sampling by STD may not correspond exactly with beginning and ending dates for biological sampling.

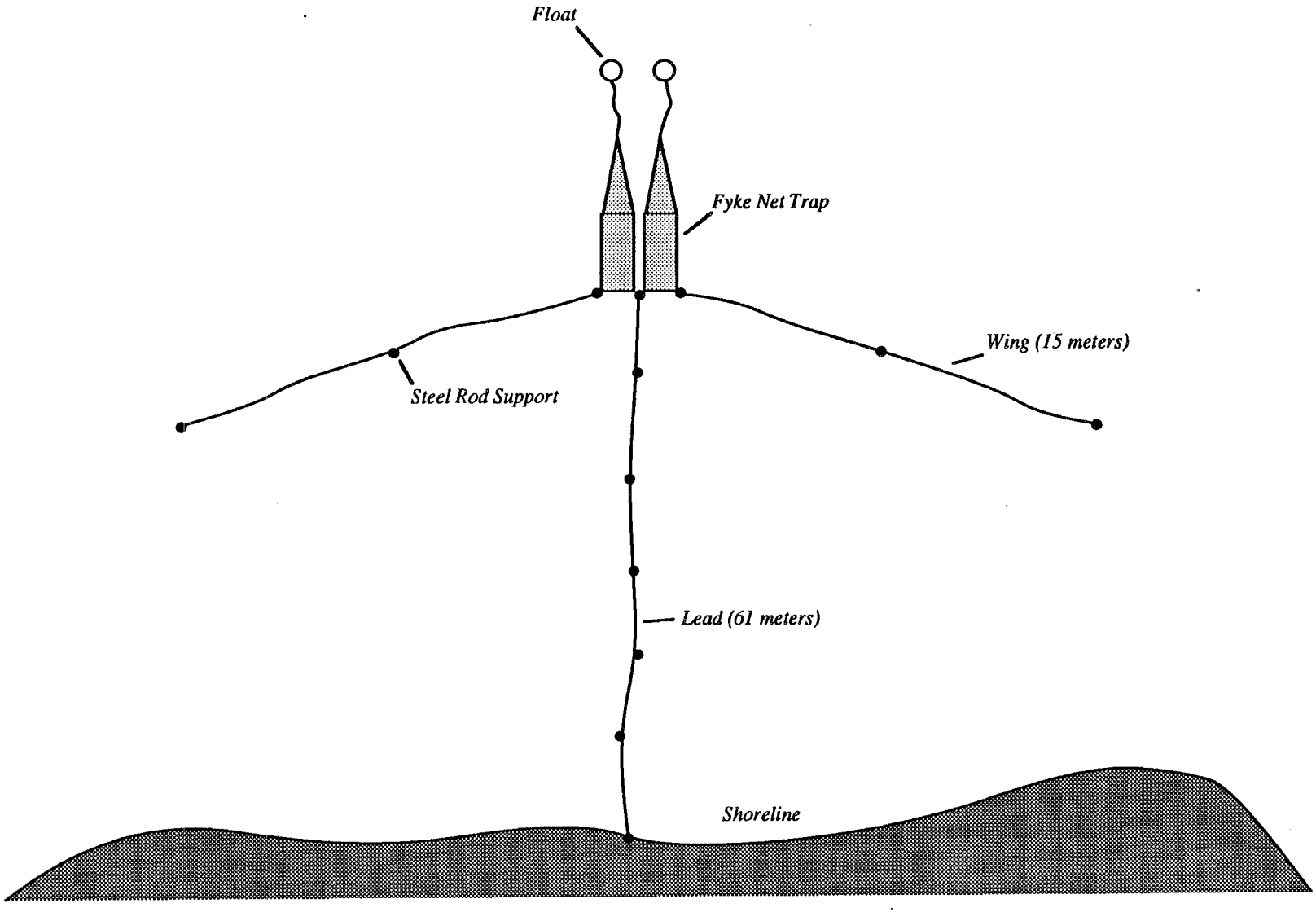

FIGURE 8.—Typical fyke net sampling configuration.

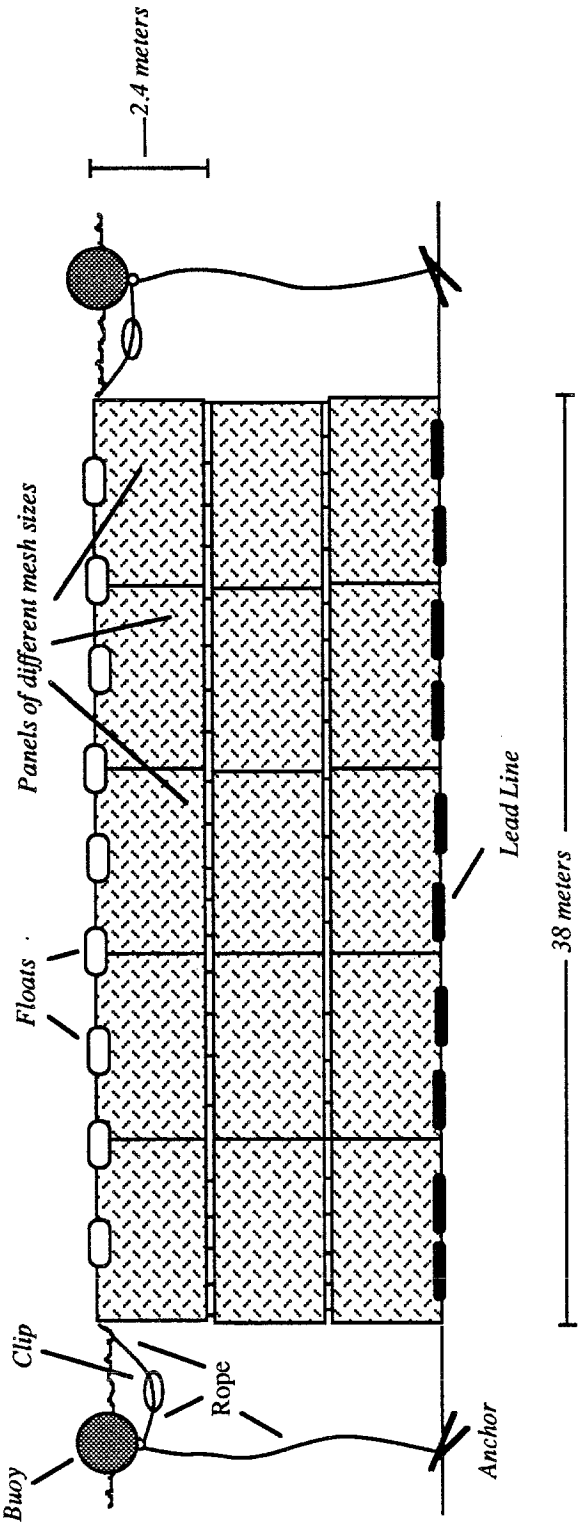

FIGURE 9.—Gill net configuration (arrangement for fishing 7.3 meters depth is shown).

stage, and age analyses. While length was not rigidly stratified for sample selection, an effort was made to select specimens representative of the length range present in the catches. Specimens were taken back to camp for these analyses. Weights were determined using Pesola® spring scales to different levels of precision depending upon fish size. Fish weights up to 5 g were measured to the nearest 0.05 g; weights between 5 and 30 g were measured to the nearest 0.5 g; weights between 30 and 500 g were measured to the nearest 5 g; weights between 500 g and 1 kg were measured to the nearest 10 g; and weights between 1 and 2 kg were measured to the nearest 50 g. Sexual maturity stage was subjectively determined by gonadal examination using the criteria in an eight-point maturity scale presented by Holden and Raitt (1974).

Otoliths were removed, stored in isopropyl alcohol and aged following the field season. Whole otoliths were illuminated with a fiber optic light and viewed at low magnification through a dissecting microscope. If ages could not be assigned using surface reading techniques, otoliths were broken through the nucleus and burned in an alcohol flame before viewing (Barber and McFarlane 1987). Ages were assigned based on at least two independent readings.

Hydrographic and Meteorologic Sampling

Depth profiles of salinity and temperature were collected at specific hydrographic stations using *in situ* electronic instruments (Table 1; Figures 2-4). These data were also collected at all biological sampling stations when nets were checked. At other stations continuous records of salinity, temperature, current direction and current velocity were made using moored current meters. Measurements of air temperature, wind direction, wind velocity, and barometric pressure were recorded at Camden Bay and Pokok Bay with portable meteorological stations. Similar meteorological data for the Barter Island area were obtained from the National Weather Service. A separate progress report will contain more detailed descriptions of hydrographic and meteorologic data collection methods as well as provide data summaries and analyses for these data.

Data Analysis

Fish Catch, Abundance, Distribution and Movements.—Numbers of each species captured were combined from both fyke net traps for a daily total catch at each station. Catch for each species was then adjusted for fishing effort to catch per 24-hour period (=catch/day). Days when wave action had changed the fishing effectiveness of the traps were not included in the data analysis nor were periods when, due to severe weather conditions, traps were not checked for a time period greater than 54 hours. For analysis purposes, Arctic cisco were separated into two groups, those less than 200 mm and those 200 mm or greater in fork length. Length-at-age data for Arctic cisco in Beaufort Sea coastal waters indicate that individuals smaller than 200 mm are most likely Age 3 and younger while fish larger than this are mostly Age 4 and older, though considerable overlap exists among age groups (Craig and Haldorson 1981; Whitmus et al. 1987). Our intent in selecting this break point was to segregate the younger fish, which are thought to move westward through refuge waters during summer (Gallaway et al. 1983), from the older fish which are thought to move eastward. Relative abundance through the sampling period for the target species (Arctic char, Arctic cisco, least cisco, Arctic cod, fourhorn sculpin and Arctic flounder) at the different sampling stations was plotted on line graphs as catch per unit effort. Fish distribution was determined by comparing average relative abundance between the sampling stations. Recapture locations of marked fish were compared with marking locations to determine if movement had occurred.

Fish length frequency.—Fork length frequency histograms for Arctic char, Arctic cisco, least cisco, Arctic cod, fourhorn sculpin, and Arctic flounder were generated for each study area using fyke and gill net data. Student's t-test was used to compare the mean lengths of Arctic char, Arctic cisco and least cisco captured in fyke and gill nets. Length data from the two gear types were combined if no significant differences ($P<0.05$) were found. Data were plotted as numerical frequencies.

Arctic cod, Arctic flounder and fourhorn sculpin length data were combined over the entire sampling period for each area. Length data for Arctic char, Arctic cisco and least cisco were plotted by four two-week periods in each area to analyze seasonal patterns since these species are thought to be more mobile than the marine species. Histogram interval widths and number of intervals for each species were determined using standard fisheries techniques (Anderson and Gutreuter 1983). Intervals used were 10 mm for Arctic flounder, Arctic cod and fourhorn sculpin, 15 mm for Arctic cisco and least cisco, and 25 mm for Arctic char. Additional histograms combining all length data from all stations were plotted for these species using 1 or 2 mm intervals to more precisely detect age modes.

Fish Weight-Length Relationships and Condition Factors.—Weight-length relationships were described for Arctic char, Arctic cisco, least cisco, Arctic cod, Arctic flounder and fourhorn sculpin using the growth model

$$W = aL^b,$$

where a and b are constants derived from regressing the logarithms (base 10) of weight (W) and fork length (L) (Ricker 1975). Functional regressions and intercepts were estimated using geometric mean (GM) regression techniques (Ricker 1973,1975).

Allometric condition factors (Kn) were calculated for selected fishes using the equation

$$Kn = W/aL^b,$$

where W is the wet weight (g) and L is the fork length (mm) and a and b are constants derived from the weight-length relationship (Ricker 1975). Condition factors were calculated for immature and adult fishes during two time periods (July 17-August 15 and August 16-September 14). The basis for categorizing individuals as immature or adult was whether the gonads appeared to be developing. We chose to use the division between Stage II (maturing virgin) and Stage III (developing) in the eight-point maturity scale of Holden and Raitt (1974) as the break point between immature and adult. Time periods were chosen to divide the field season into two approximately equal periods. Condition factors were compared statistically between time periods using the Student's t test ($P<0.05$).

Results

Fish Relative Abundance, Distribution and Movements

Fyke nets were set at eight stations (Table 1; Figures 2-4) from approximately mid-July to mid-September. One fyke net was fished in Camden Bay (Simpson Cove, Station SC01) for 47 days. Three fyke nets were set in Kaktovik Lagoon. One of these (Station KL09) was fished for only about a week and then permanently removed because of ice floes drifting into the net. Fyke nets were fished at 2 other stations in Kaktovik Lagoon (KL05 and KL10) for most of the field season, 52 and 55 days, respectively. The fyke net lead at Station KL10 was only 30 m instead of the normal 61 m because of the steepness of the bottom gradient in this area. Two fyke nets were fished in Jago Lagoon, stations JL12 and JL14; these were fished for 45 and 51 days, respectively. Two fyke net sets, stations PB01 and PB02, were fished in Pokok Bay for 54 and 31 days, respectively. There were periods when wave action caused the fyke net traps to collapse, compromising their fishing effectiveness. Fish captured during these periods were not included in catch per unit effort analyses.

Eighteen fish species were captured by fyke net in Arctic Refuge coastal waters during the summer of 1988 (Table 2). Seven species captured were anadromous and ten were marine. The only freshwater species captured was Arctic grayling. Arctic cod was the most abundant species collected (38% of total catch), followed by small (<200 mm fork length) Arctic cisco (27%), fourhorn sculpin (22%), Arctic char (4%), ninespine stickleback (3%), and Arctic flounder (3%) (Tables 3 and 4). One species, the Arctic staghorn sculpin, had been taken in refuge waters only once previously (Wiswar and Fruge *In preparation*); seven were captured in the present study. Some eelblennies and sculpins were recorded as "unidentified" by two of the field crews; many of those individuals were not preserved for later identification, hence they remain in the analyses as "unidentified". The unidentified eelblennies were most likely slender eelblennies, though the stout eelblenny *(Lumpenus medius)* has also been recorded from Arctic Refuge coastal waters (Griffiths et al. 1977). The unidentified sculpins were most likely either Arctic sculpins or Arctic staghorn sculpins. Because sampling at Station KL09 spanned such a short portion of the open water period, catches from that station were not considered comparable with catches from the other stations and are not reported here.

Fifteen species were captured by fyke net at Camden Bay (Table 3). Arctic cod, the most abundant, comprised 75% of the total catch; average daily catch rate for this species was 337.7 fish/day (Table 4). Catch rates for small Arctic cisco, fourhorn sculpin, and Arctic char exceeded 10 fish/day. Daily catch rate of Arctic cod at Camden Bay was seven times greater than that of the next most abundant species.

In the Kaktovik and Jago lagoons study area seventeen species were captured (Table 3). In both lagoons fourhorn sculpin were most abundant comprising 40% of the total catch from the two lagoons. Average daily catch rate over the entire study area for this species was 56.4 fish/day followed by 33.6 fish/day for Arctic cod and 23.9 fish/day for small Arctic cisco (Table 4). These were the only species for which the mean daily catch rate for the entire study area exceeded 10 fish/day. Arctic char were relatively more abundant in Kaktovik Lagoon (average 13.3 fish/day) than in Jago Lagoon (4.3 fish/day) as were Arctic flounder (10.1 fish/day in Kaktovik Lagoon compared with 2.1 fish/day in Jago Lagoon). However, ninespine stickleback were relatively more abundant in Jago Lagoon (11.5 fish/day) than in Kaktovik Lagoon (3.9 fish/day).

Fourteen species were captured at Pokok Bay with the catch being dominated by small Arctic cisco (60% of total catch and average daily catch rate of 156.4 fish/day) (Tables 3 and 4). Next in abundance were Arctic cod (76.8 fish/day), fourhorn sculpin (23.0 fish/day), and Arctic flounder (5.8 fish/day). The relatively low number of Arctic char captured in Pokok Bay is notable. This species was ranked eighth in abundance in this study area compared with its being fourth in abundance in the other two study areas. Mean daily catch rate for Arctic char was only 2.0 fish/day in Pokok Bay.

TABLE 2.—Fish species captured in Arctic Refuge coastal waters during July-September 1988.

Family	Common Name	Scientific Name
	Anadromous	
Salmonidae	Arctic cisco	*Coregonus autumnalis*
	Least cisco	*Coregonus sardinella*
	Broad whitefish	*Coregonus nasus*
	Arctic char	*Salvelinus alpinus*
	Chum salmon	*Oncorhynchus keta*
Osmeridae	Rainbow smelt	*Osmerus mordax*
Gasterosteidae	Ninespine stickleback	*Pungitius pungitius*
	Freshwater	
Salmonidae	Arctic grayling	*Thymallus arcticus*
	Marine	
Clupeidae	Pacific herring	*Clupea harengus*
Osmeridae	Capelin	*Mallotus villosus*
Gadidae	Arctic cod	*Boreogadus saida*
	Saffron cod	*Eleginus gracilis*
Stichaeidae	Slender eelblenny	*Lumpenus fabricii*
Cottidae	Fourhorn sculpin	*Myoxocephalus quadricornis*
	Arctic sculpin	*Myoxocephalus scorpioides*
	Arctic staghorn sculpin	*Gymnocanthus trucuspis*
Cyclopteridae	Greenland sea snail	*Liparis tunicatus*
Pleuronectidae	Arctic flounder	*Liopsetta glacialis*

TABLE 3.—Total catch from fyke net sampling stations in Arctic Refuge coastal waters, July-September 1988.

	Camden Bay	Kaktovik Lagoon		Jago Lagoon		Pokok Bay		
	Station	Stations		Stations		Stations		
Species	SC01	KL05	KL10	JL12	JL14	PB01	PB02	Total catch
Arctic cod	15,897	988	1,883	1,573	3,151	393	4,432	28,317
Arctic cisco (<200 mm)	2,255	914	1,655	1,021	1,716	6,929	5,649	20,139
Fourhorn sculpin	2,116	5,609	1,663	2,618	3,052	772	964	16,794
Arctic char	543	1,107	316	284	197	138	46	2,631
Ninespine stickleback	192	64	350	209	1,156	60	235	2,266
Arctic flounder	59	1,045	65	58	260	227	224	1,938
Saffron cod	125	161	108	78	88	140	243	943
Arctic cisco (≥200 mm)	137	201	78	46	74	277	54	867
Rainbow smelt	48	28	13	27	153	28	81	378
Least cisco	101	31	46	27	25	31	33	294
Unidentified eelbleeny	75	0	4	0	8	1	0	88
Arctic sculpin	12	12	12	10	7	13	9	75
Capelin	54	0	0	6	5	3	6	74
Slender eelblenny	24	4	16	5	2	0	0	51
Unidentified sculpin	0	0	4	0	0	11	18	33
Broad whitefish	9	0	3	6	4	3	4	29
Pacific herring	0	1	2	0	0	1	5	9
Arctic staghorn sculpin	0	0	1	1	0	3	1	6
Kelp snailfish	4	0	0	0	0	0	0	4
Arctic grayling	2	1	0	0	0	0	0	3
Chum salmon	0	1	0	0	0	0	0	1
Total catch	21,653	10,167	6,219	5,969	9,898	9,030	12,004	74,940

TABLE 4.—Mean daily catch per unit effort (fish/day) from fyke net sampling stations in Arctic Refuge coastal waters, July-September 1988.

	Camden Bay	Kaktovik Lagoon		Jago Lagoon		Pokok Bay	
	Station	Stations		Stations		Stations	
Species	SC01	KL05	KL10	JL12	JL14	PB01	PB02
Arctic cod	337.7	17.4	34.0	31.7	51.1	7.4	146.3
Arctic cisco (<200 mm)	46.4	16.9	30.6	20.5	27.7	130.3	182.6
Fourhorn sculpin	43.2	100.3	30.3	51.4	43.5	14.5	31.6
Arctic char	11.7	20.8	5.6	5.5	3.0	2.6	1.5
Ninespine stickleback	3.7	1.2	6.5	4.2	18.8	1.1	7.8
Arctic flounder	1.2	18.9	1.1	1.2	3.1	4.3	7.4
Saffron cod	2.6	2.9	2.0	1.4	1.3	2.6	8.0
Arctic cisco (≥200 mm)	3.0	3.9	1.4	0.9	1.1	5.2	1.8
Rainbow smelt	0.9	0.5	0.2	0.6	1.6	0.5	2.7
Least cisco	2.2	0.6	0.8	0.6	0.4	0.6	1.1
Unidentified eelbleeny	1.6	0	0.1	0	0.1	<0.1	0
Capelin	1.2	0	0	0.1	0.1	0.1	0.2
Arctic sculpin	0.3	0.2	0.2	0.2	0.1	0.2	0.3
Slender eelblenny	0.5	<0.1	0.3	0.1	<0.1	0	0
Unidentified sculpin	0	0	0.1	0	0	0.2	0.6
Broad whitefish	0.2	0	0.1	0.1	0.1	0.1	0.1
Pacific herring	0	<0.1	<0.1	0	0	<0.1	0.2
Arctic staghorn sculpin	0	0	<0.1	<0.1	0	0.1	<0.1
Kelp snailfish	0.1	0	0	0	0	0	0
Arctic grayling	<0.1	<0.1	0	0	0	0	0
Chum salmon	0	<0.1	0	0	0	0	0

Some temporal as well as distributional trends in relative abundance were apparent for a number of species. The paragraphs that follow describe these trends for the six major species targeted in this study.

Arctic cod.—Though Arctic cod were captured at all sampling stations, this species was by far most abundant in Camden Bay, where average daily catch rate was 337.7 fish/day (Table 4). Although the next highest average daily catch rate(146.3 fish/day) occurred at Station PB02 in Pokok Bay, this figure was largely attributable to an anomalously high catch rate of over 3000 fish/day on August 21 (Figure 10). Catch rates at this station on most other days were less than 50 fish/day, as were catch rates at the other Pokok Bay station (PB01). Catch rates of Arctic cod at Kaktovik and Jago lagoon stations averaged 17.4 and 51.1 fish/day, respectively.

Catch rates of Arctic cod were consistently highest, though variable at Station SC01. This was the only station where catch rates exceeded 500 fish/day on more than 2 days. In all study areas abundance of Arctic cod tended to increase during August, but declined in September. The anomalous catch rate exceeding 3000 fish/day at Station PB02 was the highest recorded for Arctic cod among the stations.

Arctic cisco.—Though captured in all study areas, small Arctic cisco (<200 mm) were most abundant in Pokok Bay where daily catch rates averaged 182.6 fish/day at Station PK02 and 130.3 fish/day at Station PK01 (Table 4). Average station catch rates in Kaktovik and Jago lagoons ranged from 16.9 to 30.6 fish/day. Although average daily catch rate at Station SC01 was 46.4 fish/day this value was inflated by an anomalously high catch rate exceeding 1200 fish/day that occurred on July 26. Excluding this single high catch value, catch rates were all less than 100 fish/day.

The peak catch rate of 1367 fish/day for small Arctic cisco occurred at Station PB02 on August 24 (Figure 11). At both stations in Pokok Bay catch rates usually exceeded 50 fish/day with a trend toward highest abundance with catch rates exceeding 400 fish/day on several days during the latter part of August. Catch rates declined at both stations to less than 200 fish/day during the first half of September. In Kaktovik and Jago lagoons catch rates exceeded 100 fish/day on several days; otherwise they were below 50 fish/day for most of the summer. Except for the very high catch rate on July 26, the catch rate at Station SC01 never exceeded 100 fish/day and was usually less than 50 fish/day.

Large Arctic cisco (≥200 mm) were captured at all stations, but uniformly in relatively moderate numbers (Table 4). This size group of Arctic cisco ranked eighth in in terms of total numbers of individuals captured (Table 3). Highest average daily catch rates were at Station PB01 in Pokok Bay (5.2 fish/day) and Station KL05 in Kaktovik Lagoon (3.9 fish/day). Average catch rate at Station SC01 was 3.0 fish/day; at all other stations average catch rate was less than 2 fish/day.

Distinct temporal abundance trends for this size group of Arctic cisco are difficult to discern. The peak catch rate of over 65 fish/day occurred at Station PB01 on September 11. Catch rate at this station was less than 20 fish/day during the rest of the sampling period (Figure 12). Catch rate never exceeded 20 fish/day at Station PB02. At Station SC01 a trend toward peak abundance in late August is somewhat apparent, although catch rates were quite variable. However, large Arctic cisco were essentially absent from catches at this station after August 29. In Kaktovik Lagoon, relatively high catch rates (20-30 fish/day) occurred July 18-24 at Station KL05. During the rest of the sampling period catch rates were less than 10 fish/day at this station. At KL10 catch rate peaked at about 15 fish/day on August 28. In Kaktovik Lagoon large Arctic cisco were essentially absent from catches after September 9. Catch rates in Jago Lagoon were rather sporadic and low (<10 fish/day) throughout the sampling period; few large Arctic cisco were captured in this area after August 29. In contrast to the other study areas, at Pokok Bay large Arctic cisco were captured as late as September 11.

Fourhorn sculpin.—Fourhorn sculpin abundance was relatively high in all study areas but average catch rate was highest (100.3 fish/day) at Station KL05 in Kaktovik Lagoon (Table 4). Average daily catch rates ranged from 30.3 to 51.4 at the other stations in the Kaktovik and Jago lagoons study area. Average catch rate was

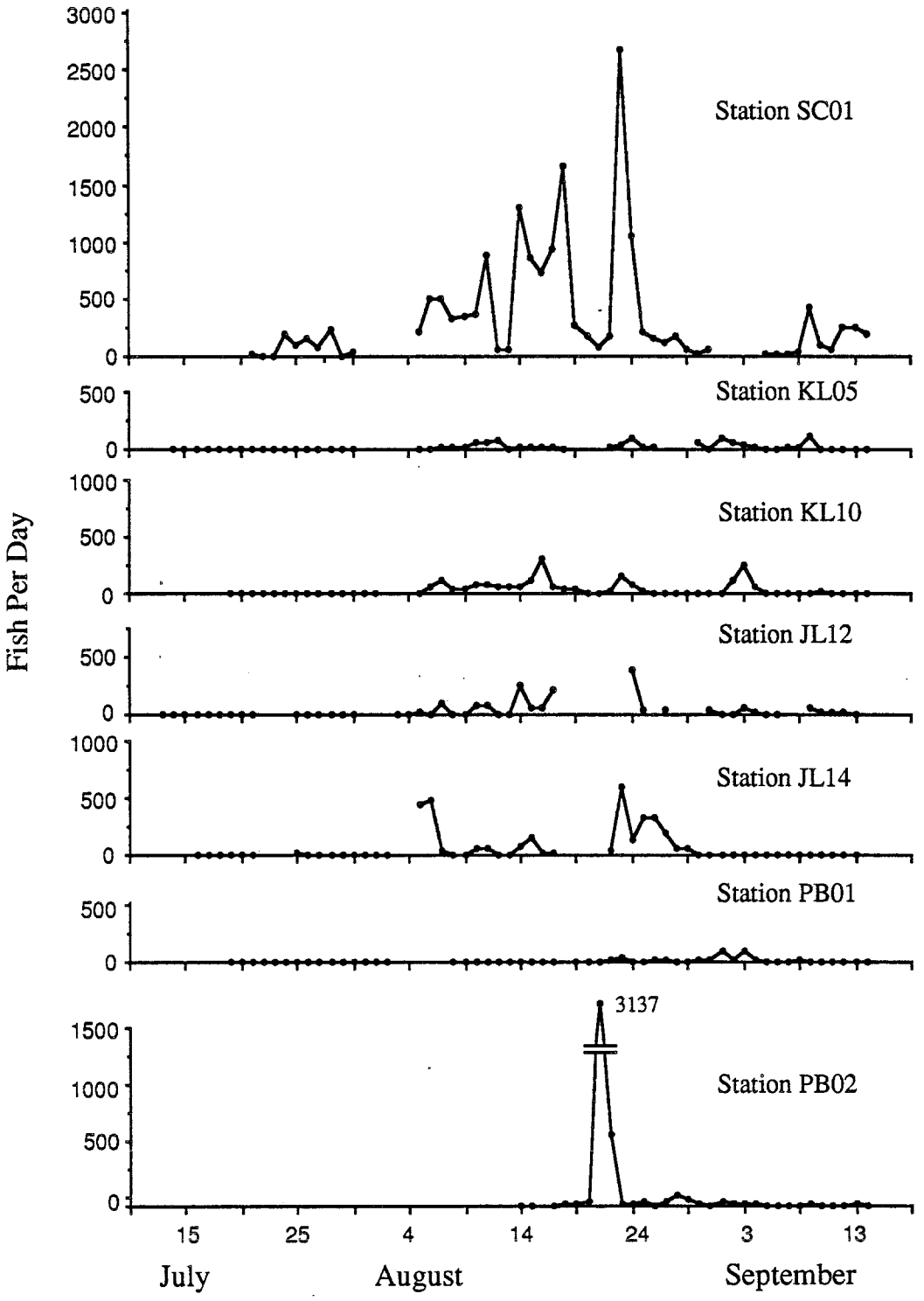

FIGURE 10.—Daily catch per unit of effort (fish/day) for Arctic cod at fyke net stations in Arctic Refuge coastal waters, July-September 1988.

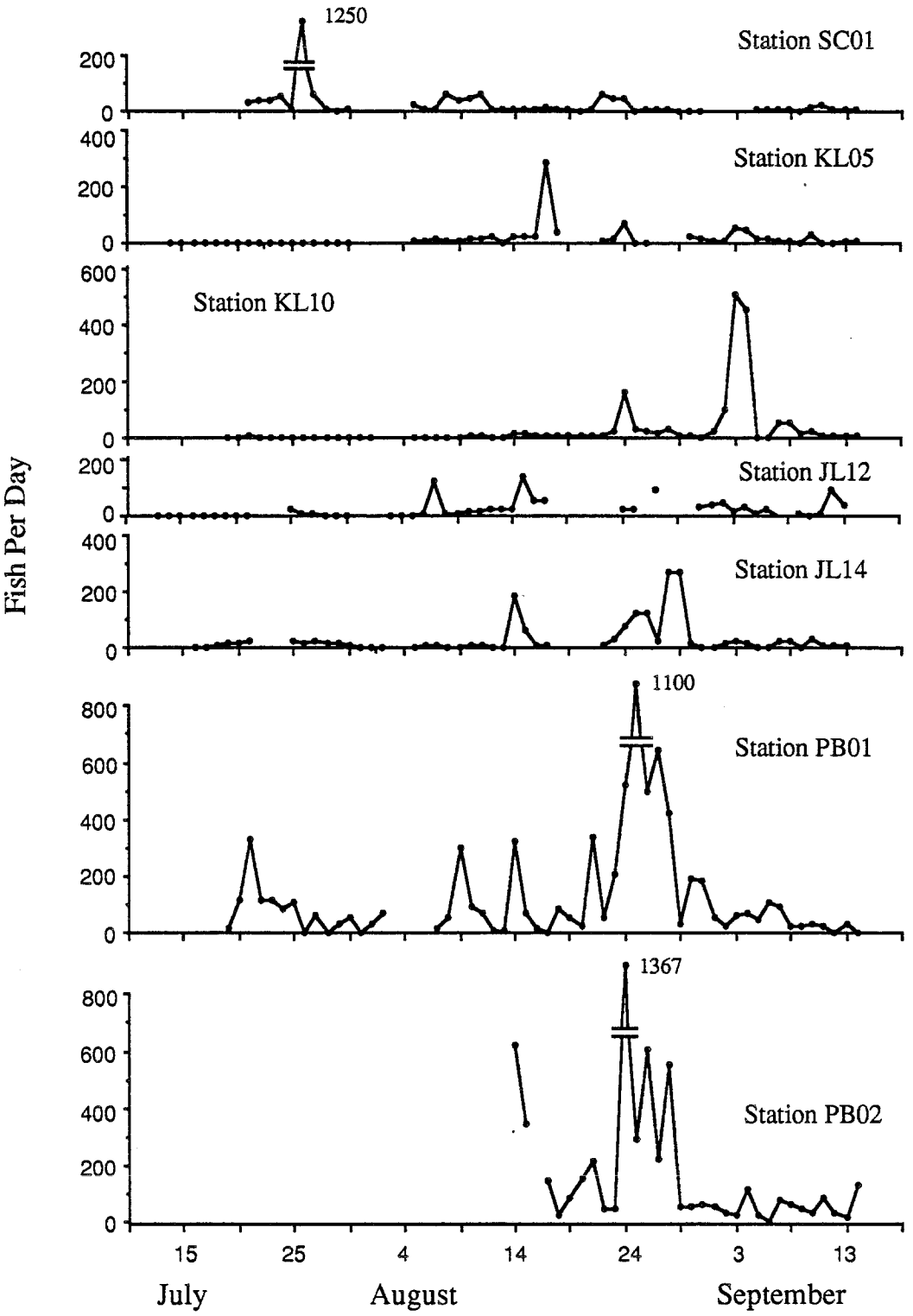

FIGURE 11.—Daily catch per unit of effort (fish/day) for small Arctic cisco (<200 mm fork length) at fyke net stations in Arctic Refuge coastal waters, July-September 1988.

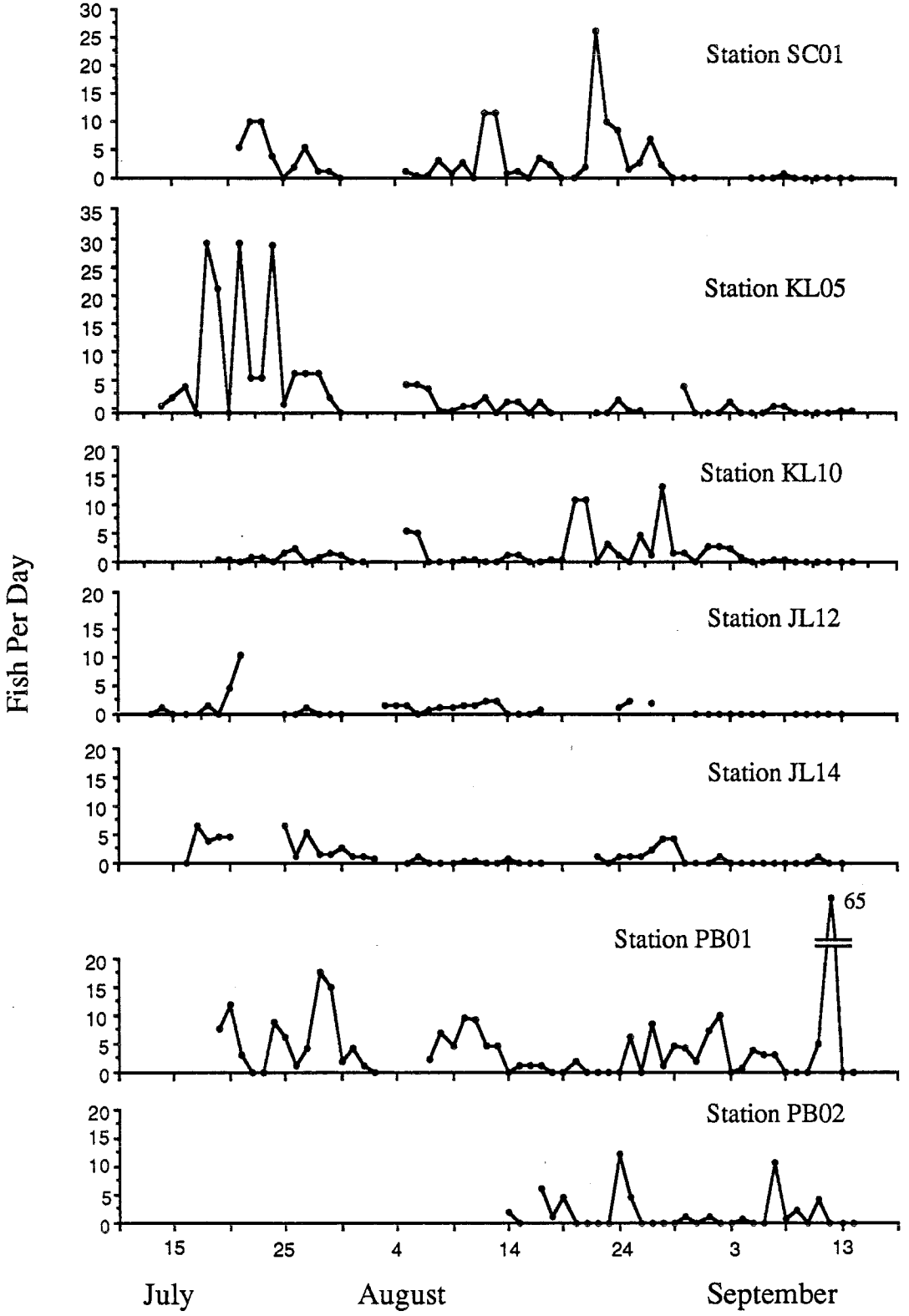

FIGURE 12.—Daily catch per unit of effort (fish/day) for large Arctic cisco (≥200 mm fork length) at fyke net stations in Arctic Refuge coastal waters, July-September 1988.

43.2 fish/day in Camden Bay. This species was less abundant in the Pokok Bay study area with average daily catch rates of 14.5 fish/day at Station PB01 and 31.6 fish/day at PB02.

Highest catch rate for fourhorn sculpin (523 fish/day) occurred on September 10 at Station JL12 (Figure 13). However, catch rate at that station exceeded 100 fish/day on only eight days compared with 17 days at Station KL05 where the species was most abundant. Catches in Kaktovik and Jago lagoons showed an increasing trend as the summer progressed, though this trend was not apparent at Camden Bay or Pokok Bay. Peak catch rates at Station SC01 (approximately 250 fish/day) occurred on July 22-23. Catch rates exceeded 100 fish/day on only 3 other days at that station. Except for a catch rate of approximately 150 fish/day that occurred on August 1, catch rate at Station PB01 never exceeded 50 fish/day and were usually less than 25 fish/day. Catch rate was somewhat higher at Station PB02 where daily catch rate exceeded 50 fish/day on 6 days.

Arctic char.—Arctic char were captured in all study areas but were most abundant in Kaktovik Lagoon and Camden Bay (Table 4). Highest catch rates were 20.9 and 11.7 fish/day at Stations KL05 in Kaktovik Lagoon and SC01 in Camden Bay, respectively. At Jago Lagoon, Pokok Bay and Station KL10 in Kaktovik Lagoon catch rates averaged less than 6 fish/day.

Catch rates were extremely variable in all study areas but tended to be highest in July and August, then declined in late August through mid-September (Figure 14). The two highest daily catch rates were recorded at Station SC01 (84 fish/day) on August 22 and at Station KL05 (65 fish/day) on July 25. At the other five stations catch rates never exceeded 25 fish/day.

Arctic flounder.—Arctic flounder were most abundant at Kaktovik Lagoon Station KL05 where average catch rate was 18.9 fish/day (Table 4). In comparison, the catch rates at the other stations in the Kaktovik and Jago lagoons ranged from 1.1 to 3.1. Average daily catch rate at Camden Bay Station SC01 was 1.2 fish/day. At Pokok Bay catch rates for Arctic flounder were 4.3 (Station PB01) and 7.4 (Station PB02) fish/day.

Arctic flounder tended to decrease in abundance as the summer progressed; however, this was more apparent at those stations where the species was captured in larger numbers (KL05, PB01, PB02) (Figure 15). Though catch rate was extremely variable throughout the summer at Station KL05, catch rate peaked at near 90 fish/day on July 25 and exceeded 20 fish/day on 16 days between July 14 and August 26. After that date catch rate never exceeded 20 fish/day. In sharp contrast to catch rates at Station KL05, catch rate at Station KL10 never exceeded 10 fish/day and was usually less than 5 fish/day. At the Jago Lagoon stations catch rate exceeded 20 fish/day on only one occasion. Catch rates were less than 10 fish/day on most days. Similarly low catch rates were seen at Camden Bay where catch rate exceeded 10 fish/day on July 24 but were generally less than 5 fish/day during the rest of the summer. At Station PB01 catch rates between 5 and 40 fish/day occurred during the period July 21-August 10 but dropped below 5 fish/day thereafter. At Station PB02 catch rates between 5 and 50 fish/day were recorded until August 29 and then dropped to less than 5 fish/day.

Least cisco.—Least cisco were captured sporadically and in relatively moderate numbers in all of the study areas. This species ranked tenth in terms of total numbers of individuals captured (Table 3). Average daily catch rate was highest at Camden Bay (2.2 fish/day) followed by Pokok Bay Station PB02 (1.1 fish/day) (Table 4). At all other stations average daily catch rates were less than 1 fish/day.

The highest catch rate (15 fish/day) for least cisco occurred on August 6 at Station SC01 in Camden Bay (Figure 16). Relatively high catch rates (>5 fish/day) occurred between August 6 and 22, though catch rate was variable during this period and on some days was less than 2 fish/day. This species was absent from fyke net catches in Camden Bay after August 24. Catch rates between 3 and 10 fish/day occurred on 1-5 days at each of the four stations in Kaktovik and Jago lagoons, though were generally less than 3 fish/day. In the Pokok Bay study area catch rates between 3 and 7 fish/day occurred on two days at Station PB01 and three days at Station PB02; otherwise catch rates were less than 3 fish/day.

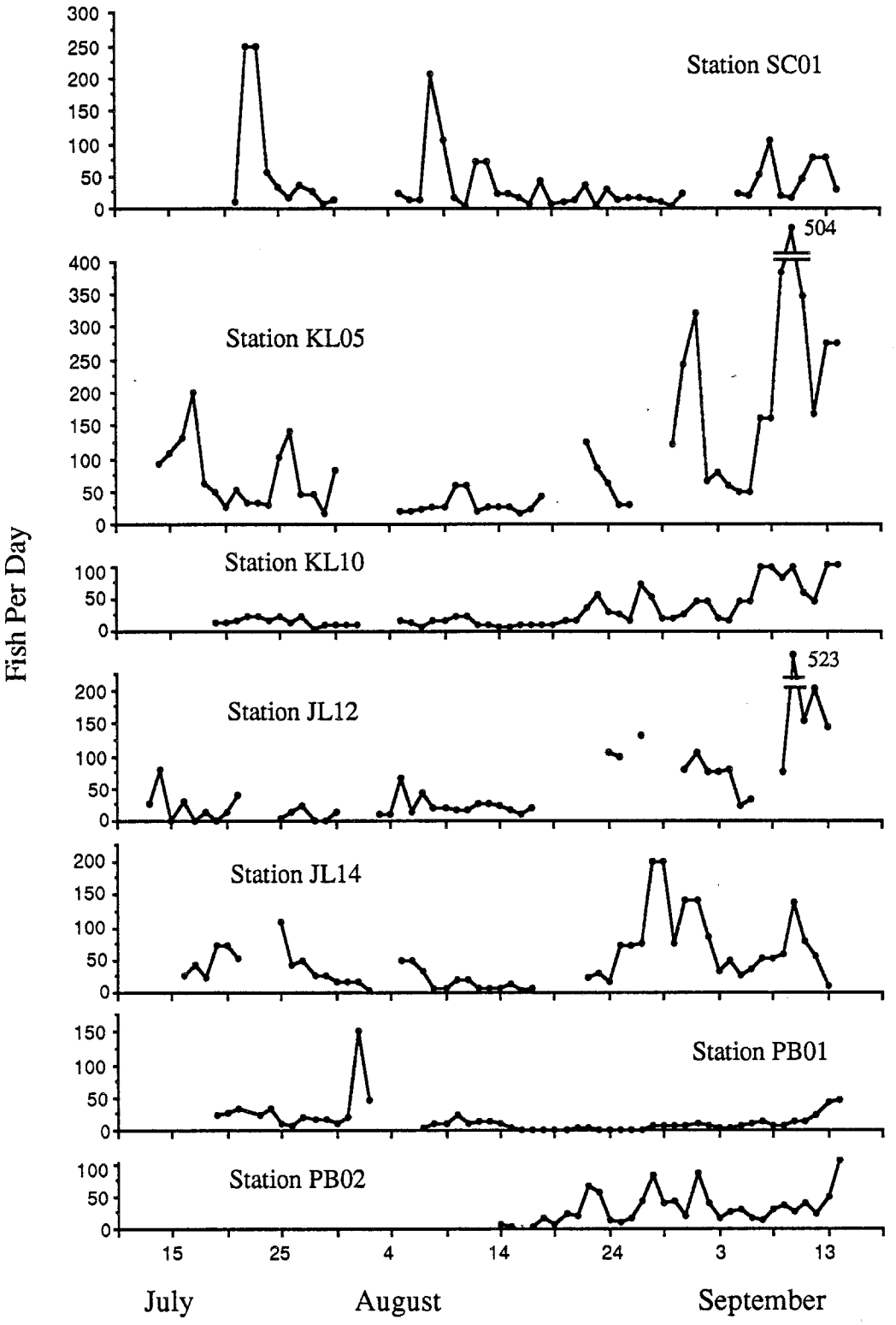

FIGURE 13.—Daily catch per unit of effort (fish/day) for fourhorn sculpin at fyke net stations in Arctic Refuge coastal waters, July-September 1988.

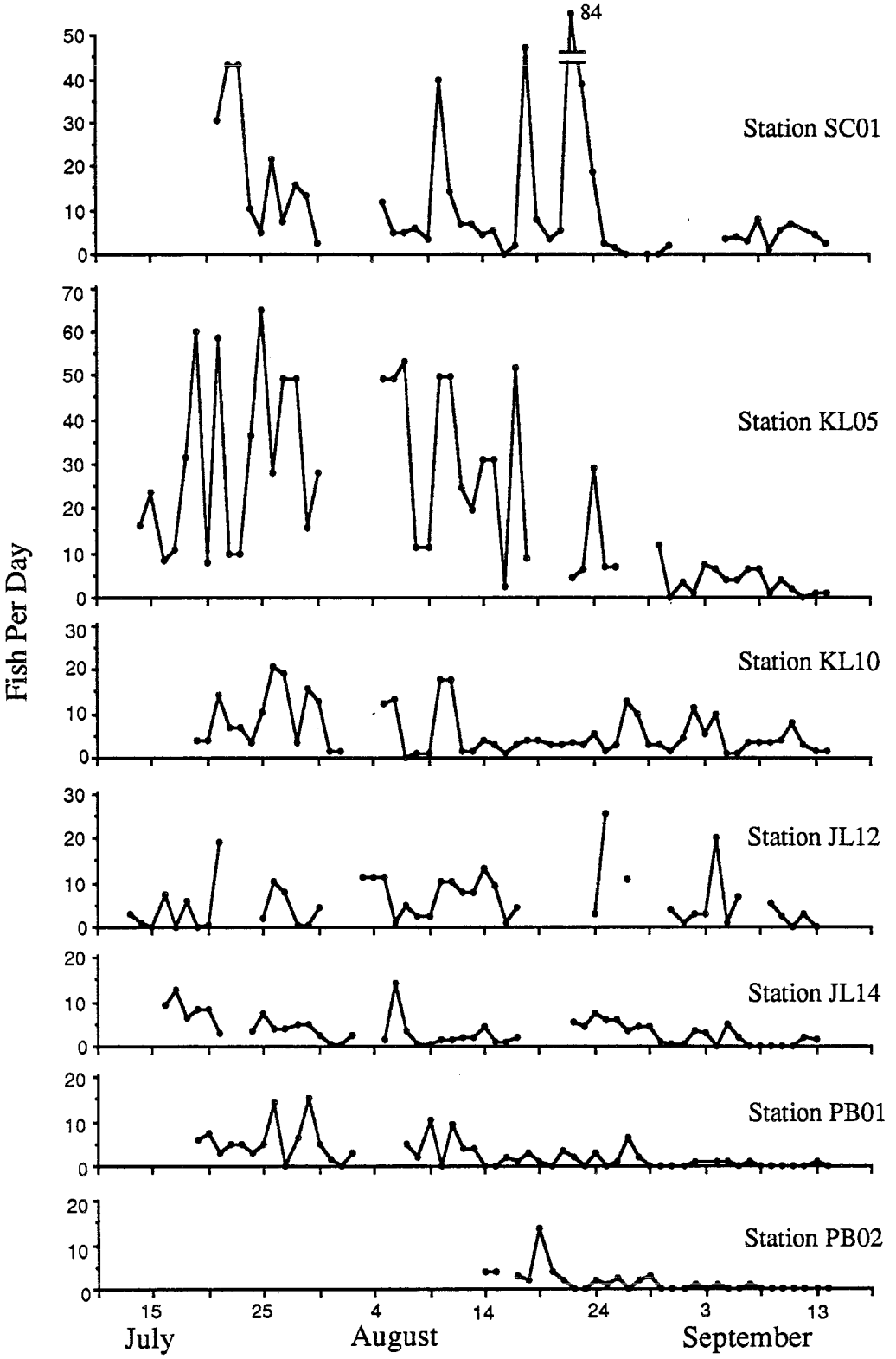

FIGURE 14.—Daily catch per unit of effort (fish/day) for Arctic char at fyke net stations in Arctic Refuge coastal waters, July-September 1988.

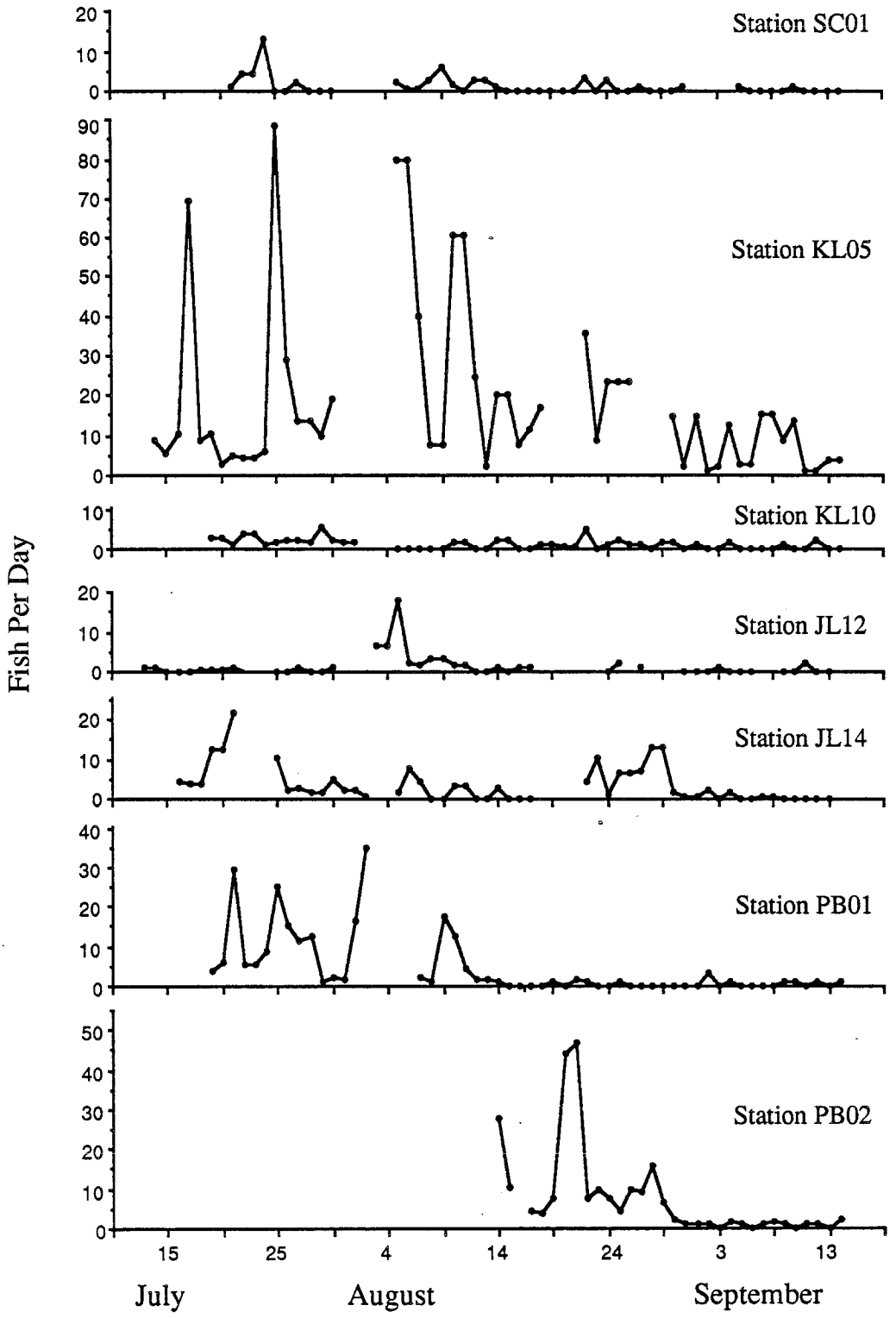

FIGURE 15.—Daily catch per unit of effort (fish/day) for Arctic flounder at fyke net stations in Arctic Refuge coastal waters, July-September 1988.

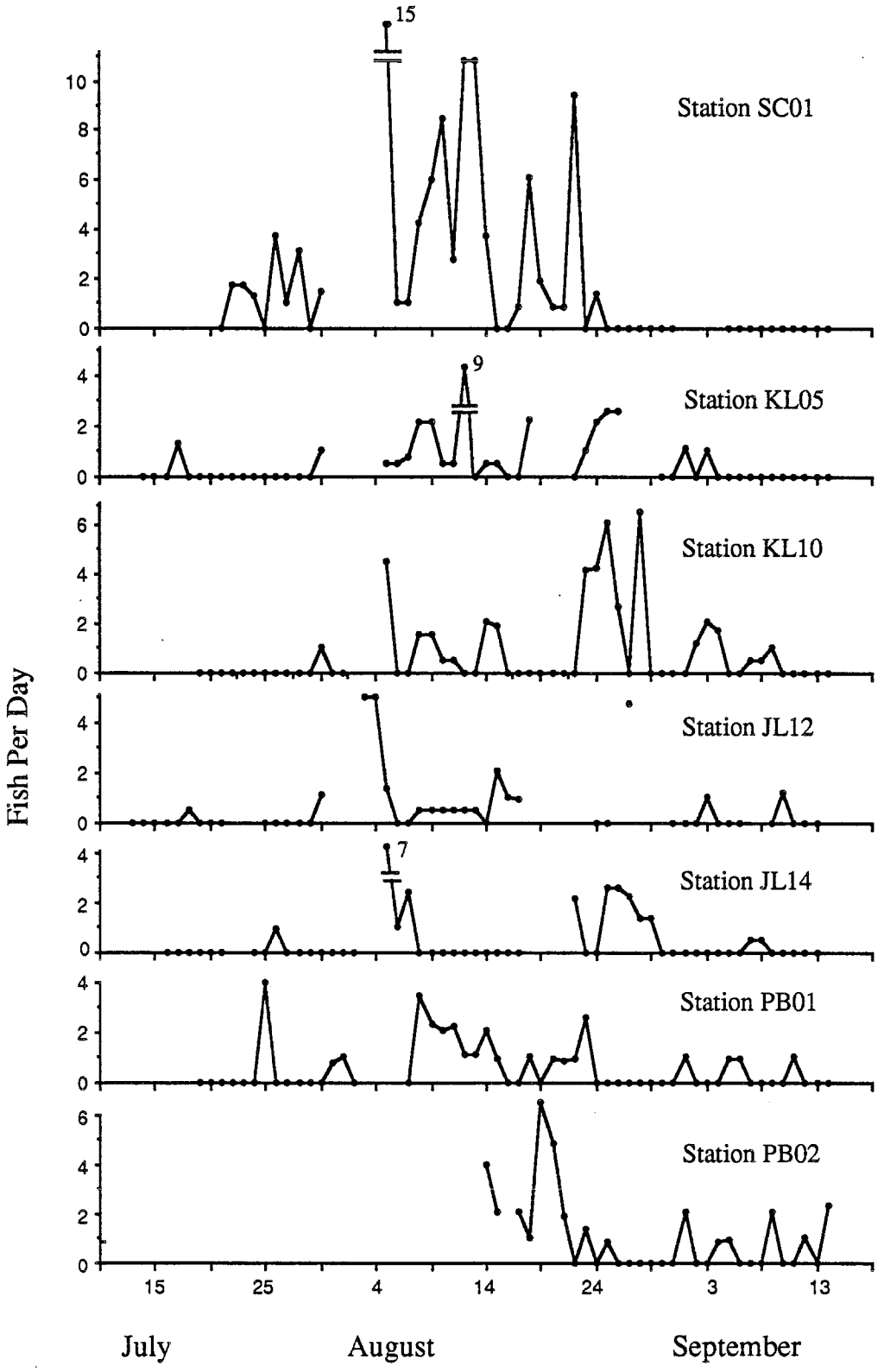

FIGURE 16.—Daily catch per unit of effort (fish/day) for least cisco at fyke net stations in Arctic Refuge coastal waters, July-September 1988.

Gill net sampling.—Gill nets were set at three stations in Camden Bay during the period July 30-September 12: 15 days at Station CB01, 11 days at CB02 and 11 days at CB04 (Table 1; Figure 2). At Camden Bay gill net sets were 1.9-7.4 hours duration with a mean fishing time of 3.4 hours. Gill net sets were made at Pokok Bluffs stations PK01, PK02 and PK03 on August 2 (Table 1; Figure 3). Another set was made at Station PK01 on August 10. Because the pack ice stayed close to shore in the Pokok Bluffs area for almost the whole summer period, no other sets could be made in this area. Gill net sets at Pokok Bay were 3.1-4.0 hours duration with a mean fishing time of 3.6 hours.

Arctic cisco, Arctic char, and least cisco were the only species captured by gill net. A total of 263 Arctic cisco, 221 Arctic char, and 17 least cisco were captured at Camden Bay. Catch rates for each species averaged less than one fish per hour of fishing time (Table 5).

For Arctic char mean catch per unit effort in the upper 2.4 m of the water column varied little with distance from shore. Catch rates averaged 0.58 fish/hour at Station CB01 (approximately 90 m from shore) and 0.44 fish/hour at stations CB02 (approximately 200 m from shore) and CB04 (approximately 1.6 km from shore).

With respect to depth distribution the gill net catch rates for Arctic char showed pronounced differences. At stations CB02 and CB04 averages of only 0.04 and 0.06 fish/hour, respectively, were captured in the 2.4-4.9 m depth interval compared to averages of 0.44 fish/hour captured in the upper 2.4 m at both stations. At Station CB04 no Arctic char were captured in the 4.9-7.3 m depth interval.

Differences in mean catch rate with respect to distance from shore were more pronounced for Arctic cisco than for Arctic char. At Station CB01 average catch rate for Arctic cisco in the upper 2.4 m of the water column was 0.77 fish/hour. Average catch rate for this depth interval at CB02 was 0.46 fish/hour and at CB04 average catch rate was 0.29 fish/hour.

Fewer Arctic cisco were captured in the deeper waters than in the upper 2.4 m. At Station CB02 an average of 0.13 fish/hour were captured in the 2.4-4.9 m depth interval compared to 0.46 fish/hour in the upper 2.4 m. At Station CB04 mean catch rates for Arctic cisco at the 2.4-4.9 m and 4.9-7.3 m intervals were both 0.02 fish/hour, compared to 0.29 fish/hour in the upper 2.4 m.

Though the gill net catch data for least cisco showed lower catch rates with distance from shore, the differences in mean catch rate were minimal. Average catch rate for least cisco in the upper 2.4 m of the water column at Station CB01 was 0.06 fish/hour compared with 0.02 fish/hour at Station CB02. No least cisco were captured at Station CB04 in any depth interval. At Station CB02 fewer than 0.01 fish/hour were captured in the 2.4-4.9 m depth interval compared to 0.02 fish/hour in the upper 2.4 m.

Gill nets were fished on only two days at Pokok Bluffs. A total of 25 Arctic cisco and 9 Arctic char were caught on August 2 and 10. All of the Arctic char and most of the Arctic cisco were collected in the upper 2.4 m of the water column. One Arctic cisco was captured in the 2.4-4.9 m depth interval. Stations PK01 and PK02 were both approximately 160 m from shore. Station PK03 was approximately 430 m offshore. Three Arctic char were captured at Station PK01, one was captured at Station PK02 and five were captured at Station PK03. Almost all of the Arctic cisco were collected at Station PK01; one was captured at PK02.

Movements.—A total of 5,304 individuals from 10 species were marked or tagged during the summer of 1988 (Table 6). Of these fish, 3,952 were fin clipped, 862 were marked with alcian blue dye, and 490 were tagged. Most recaptured fin-marked fish were recaptured in the same study areas where they were marked; only five were recaptured in study areas different from that of marking (Table 6). One of these was an Arctic char (300 mm fork length) that had been marked in Camden Bay and recaptured in Kaktovik Lagoon on August 24. Two fin-marked Arctic cisco were recaptured at different sites: one marked at Pokok Bay was recaptured at Camden Bay on September 11 and measured 139 mm fork length; another, marked at Camden Bay, was recaptured in Pokok Bay on September 1 and measured 392 mm fork length. A least cisco that had been marked at Camden Bay was

TABLE 5.—Means and ranges for catch per unit of effort (CPUE) (catch/hour), total catch, total effort (hours) and total number of gill nets (N) set in Camden Bay, Alaska, July-September 1988.

	Station														
	CB01					CB02					CB04				
Species, depth interval	Mean CPUE	CPUE range	Total catch	Total effort	N	Mean CPUE	CPUE range	Total catch	Total effort	N	Mean CPUE	CPUE Range	Total catch	Total effort	N
Arctic char															
0-2.4 m	0.58	0-7.56	90	148.9	43	0.44	0-6.72	53	113.3	33	0.44	0-3.49	62	106.8	33
2.4-4.9 m						0.04	0-0.94	6	113.3	33	0.06	0-0.77	10	106.8	33
4.9-7.3 m											0.00	—	0	106.8	33
Arctic cisco															
0-2.4 m	0.77	0-6.51	135	148.9	43	0.46	0-4.96	61	113.3	33	0.29	0-4.33	42	106.8	33
2.4-4.9 m						0.13	0-1.31	18	113.3	33	0.02	0-0.39	3	106.8	33
4.9-7.3 m											0.02	0-0.70	4	106.8	33
Least cisco															
0-2.4 m	0.06	0-0.71	14	148.9	43	0.02	0-0.43	2	113.3	33	0.00	—	0	106.8	33
2.4-4.9 m						<0.01	0-0.15	1	113.3	33	0.00	—	0	106.8	33
4.9-7.3 m											0.00	—	0	106.8	33

TABLE 6.—Number of fish marked and recaptured by location and method during summer 1988, Arctic Refuge coastal waters.

			Recapture area					
	Mark method		Camden Bay		Kaktovik/Jago Lagoons		Pokok Bay	
Area, species	Fin mark[a]	Tag	Fin mark	Tag	Fin mark	Tag	Fin mark	Tag
Camden Bay								
Arctic cisco	805	0	7	0	0	0	1	0
Arctic char	545	0	4	0	0	0	0	0
Least cisco	71	0	0	0	1	0	0	0
Fourhorn sculpin	2	10	0	0	0	0	0	0
Broad whitefish	4	0	0	0	0	0	0	0
Arctic flounder	0	2	0	0	0	0	0	0
Arctic grayling	0	2	0	0	0	0	0	0
Rainbow smelt	0	1	0	0	0	0	0	0
Kaktovk/Jago Lagoons								
Arctic cisco	1246	10	0	0	18	0	0	0
Arctic char	972	0	1	0	52	0	0	0
Arctic flounder	0	107	0	0	0	0	0	0
Fourhorn sculpin	9	89	0	0	1	4	0	0
Least cisco	76	0	0	0	1	0	0	0
Broad whitefish	7	0	0	0	0	0	0	0
Arctic cod	5	0	0	0	0	0	0	0
Rainbow smelt	3	0	0	0	0	0	0	0
Saffron cod	1	0	0	0	0	0	0	0
Arctic grayling	0	1	0	0	0	0	0	0
Pokok Bluff/Bay								
Arctic cisco	904	122	1	0	0	0	32	0
Arctic char	136	1	0	0	0	0	11	0
Arctic flounder	0	76	0	0	0	0	0	2
Fourhorn sculpin	0	66	0	0	0	0	0	1
Least cisco	28	3	0	0	1	0	3	0
Totals	4814	490	13	0	74	4	46	3

[a]Fins were marked either by clipping or by applying alcian blue dye at the bases of the fins.

recaptured in Kaktovik Lagoon on August 24. Another least cisco, marked in Pokok Bay was recaptured in Jago Lagoon on August 29. These least cisco were 316 and 320 mm fork length, respectively. Because fin marking provided no way of distinguishing between individual fish, dates of marking, at-large times and movements of recaptured fish between stations in the study areas could not be determined.

Only nine fish marked with anchor tags were recaptured during the 1988 open-water field season (Table 7). These included one Arctic cisco, one least cisco, five fourhorn sculpin and two Arctic flounder. An Arctic cisco and least cisco were recaptured that had been tagged in the Prudhoe Bay area by LGL Ecological Research Associates, Inc. in 1988 and 1982, respectively. The Arctic cisco was originally tagged on August 20, 1988, and was recaptured 14 days later approximately 161 km east of Prudhoe Bay in Kaktovik Lagoon—a travel rate of 11.5 km/day. The recaptured least cisco was marked by LGL on August 19, 1982 and recaptured on July 24, 1988 in Camden Bay. Length at tagging for this fish was recorded as 360 mm fork length. At recapture it measured only 362 mm fork length after six years at large.

Five fourhorn sculpins tagged in Kaktovik and Jago lagoons in 1988 were recaptured in these lagoons. Three of the sculpins were recaptured at their respective tagging stations. One of the sculpins had moved from Jago Lagoon (Station JL12) to Kaktovik Lagoon (Station KL05) after 24 days at large. Another fourhorn sculpin tagged at Station KL05 on August 30 was recaptured in a gill net on September 9 by a local resident of Kaktovik at Pipsuk Point in Kaktovik Lagoon, approximately 7 km northeast of the tagging site. Two Arctic flounder tagged at Station PB02 in August 1988 in Pokok Bay were recaptured at the same station 8 and 17 days later.

Fish Length Frequency

Arctic char.—Arctic char ranged from 71 to 734 mm fork length in the three study areas during the summer of 1988. Since mean fork length of Arctic char collected by fyke net was not significantly different from mean fork length of fish collected by gill net (Student's t, $P<0.01$), the data on length frequency were pooled between the two gear types. Sixty-seven percent of the Arctic char measured were captured with fyke nets. Gill netting accounted for the remaining 33% of the Arctic char measured. A pooled length frequency histogram for all Arctic char measured in this study is presented in Appendix 1.

Arctic char between 175 and 249 mm fork length were dominant at Camden Bay and Kaktovik and Jago lagoons throughout the sampling period (Figures 17-18). At Kaktovik and Jago lagoons secondary frequency peaks occurred in the interval 275-324 mm fork length during the period July 11-August 15. These secondary frequency peaks were not apparent during the period August 16-September 14. At Pokok Bay, the dominant size groups were less distinct, with fish between 200 and 374 mm fork length being most abundant; the pronounced frequency peak in the 175-249 mm fork length interval present in the other two study areas was noticeably absent (Figure 19). Arctic char in Pokok Bay exhibited the broadest size range (85-642 mm) among char from the three coastal study areas. Few char greater than 300 mm were captured in any of the areas in September.

Arctic cisco.—Arctic cisco ranged from 31 to 490 mm fork length in the three study areas. Ninety-six percent of the Arctic cisco measured were captured with fyke nets. The remaining four percent were captured with gill nets. A pooled length frequency histogram for all Arctic cisco captured by fyke net in this study is presented in Appendix 2.

At Camden Bay (Simpson Cove) the fyke net captured Arctic cisco were mostly in the 120-149 mm and 375-389 mm size intervals (Figure 20). Compared with the other two study areas no pronounced frequency modes were apparent. No Arctic cisco greater than 200 mm fork length were captured at Camden Bay during the period September 1-September 14. At Kaktovik and Jago lagoons length frequency distribution during the period July 11-31 was similar to that at Camden Bay (Figures 21). During the following period, August 1-15, fish 120-134 mm fork length were dominant. During the period August 16-September 14 Arctic cisco 60-89 mm were most

TABLE 7.—Summary of tagging and recapture location data for fish recaptured in Arctic Refuge coastal waters, summer 1988.

Species, tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)[b]	Length at recapture (mm)[b]	Tag number
Arctic cisco							
Prudhoe Bay, Station 220	08/20/88	KL10	09/02/88	175	357	359	LGL 03150
Least cisco							
Prudhoe Bay, Station 212	08/19/82	SC01	07/24/88	130	360	362	LGL 8209250
Fourhorn sculpin							
KL10	07/27/88	KL10	08/14/88	0	273	270	FWS 9124
JL12	08/02/88	KL05	08/26/88	8	245	246	FWS 9156
KL10	08/08/88	KL10	09/14/88	0	273	273	FWS 9492
KL05	08/30/88	Pipsuk Point, Kaktovik Lagoon	09/05/88	7	242	Unknown	FWS 9464
PB02	09/02/88	PB02	09/14/88	0	234	232	FWS 9342
Arctic flounder							
PB02	08/28/88	PB02	09/14/88	0	256	256	FWS 9305
PB02	08/20/88	PB02	08/28/88	0	202	202	FWS 9382

[b]Fork lengths.

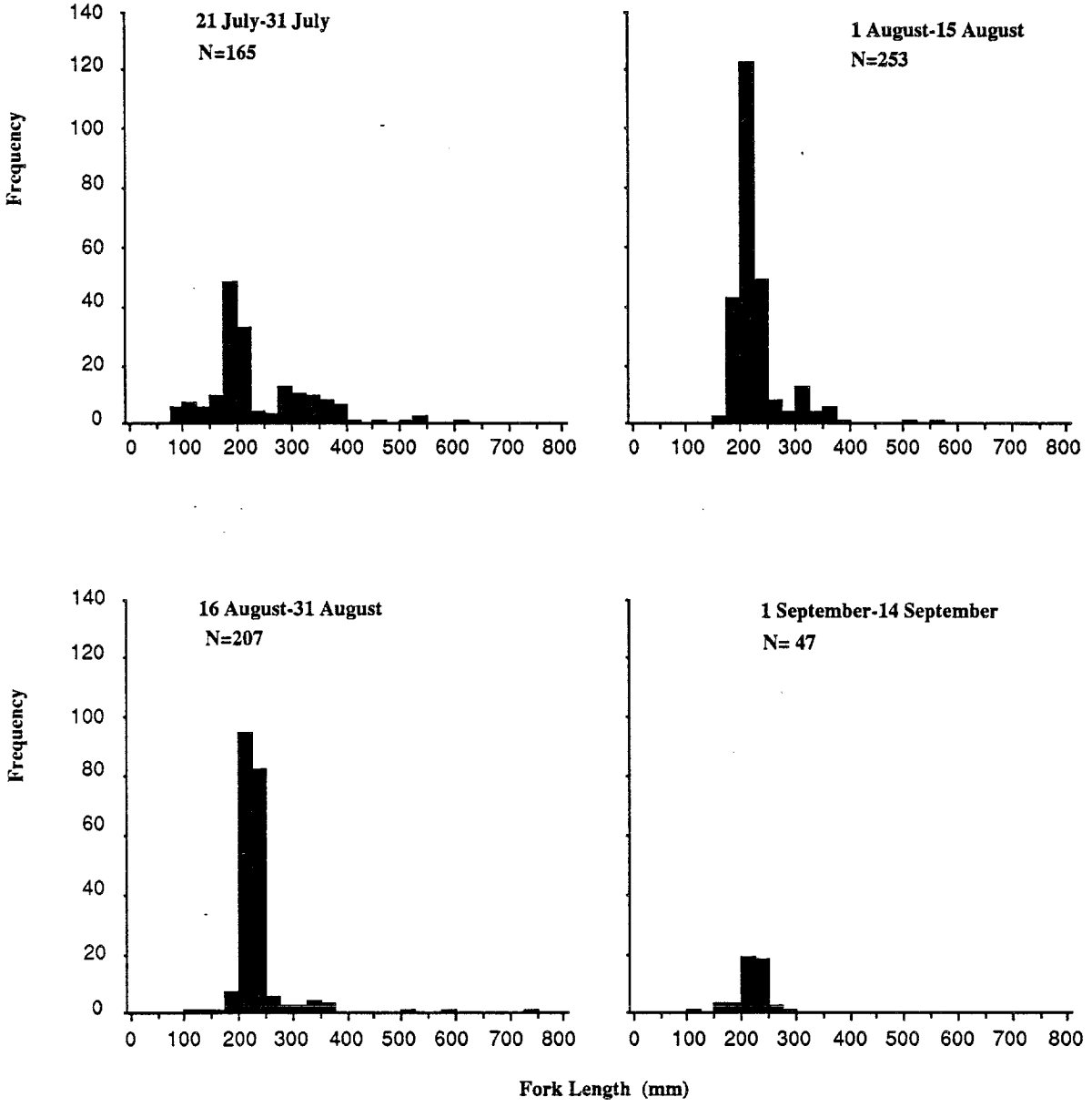

FIGURE 17.—Length frequency of Arctic char captured by fyke and gill nets in Camden Bay, Alaska, July-September 1988.

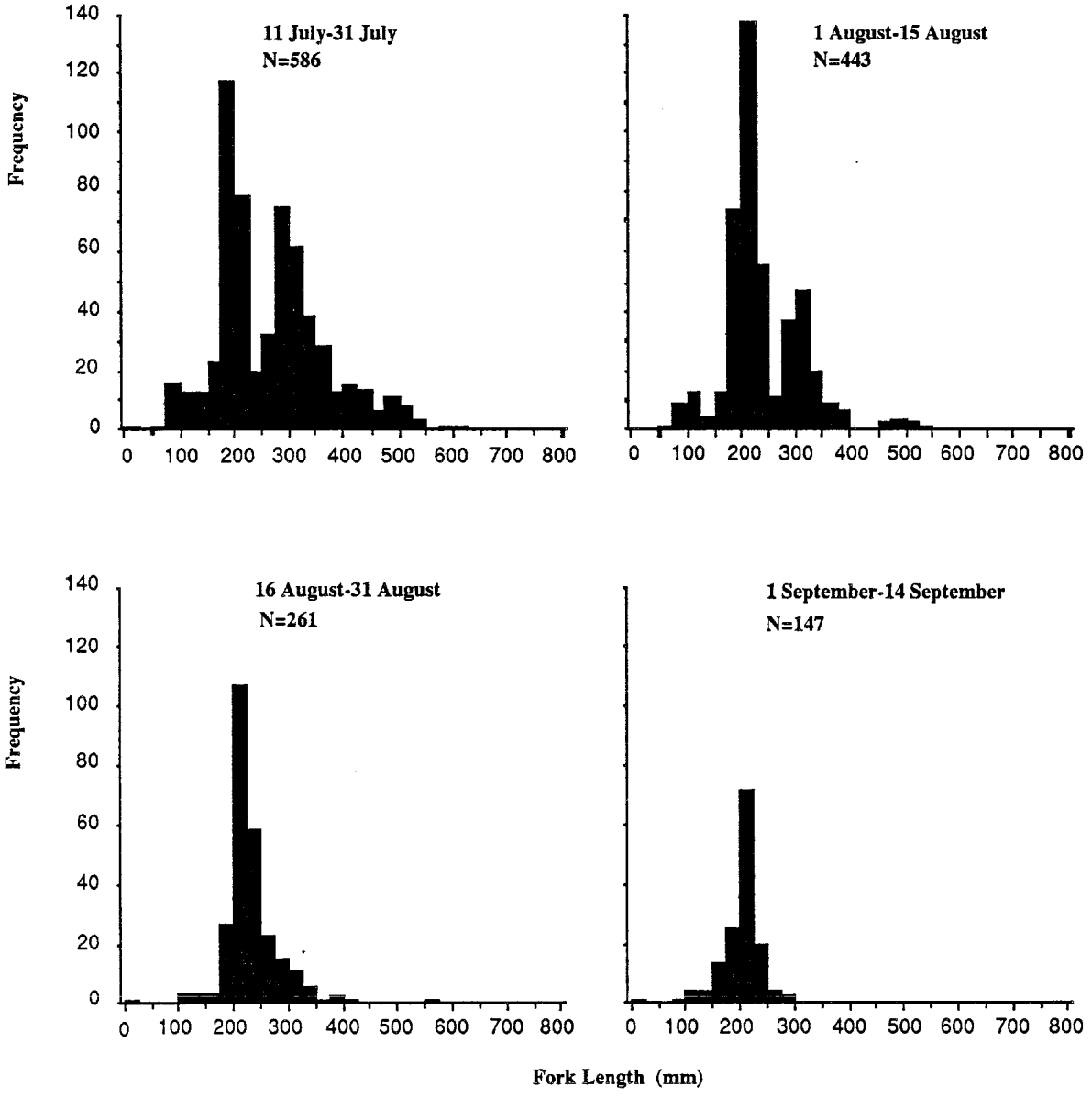

FIGURE 18.—Length frequency of Arctic char captured by fyke and gill nets in Kaktovik and Jago lagoons, Alaska, July-September 1988.

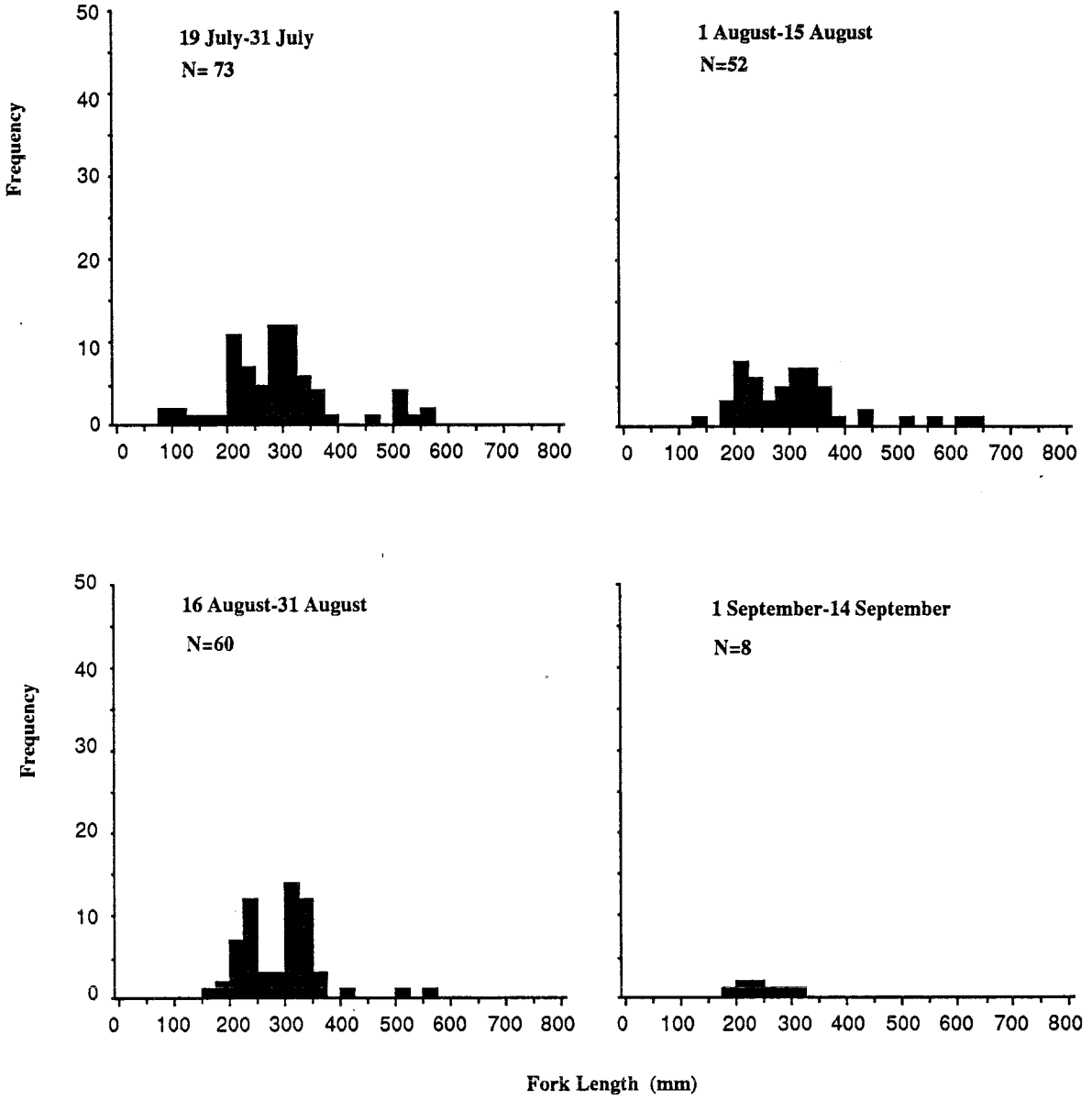

FIGURE 19.—Length frequency of Arctic char captured by fyke and gill nets in Pokok Bay, Alaska, July-September 1988.

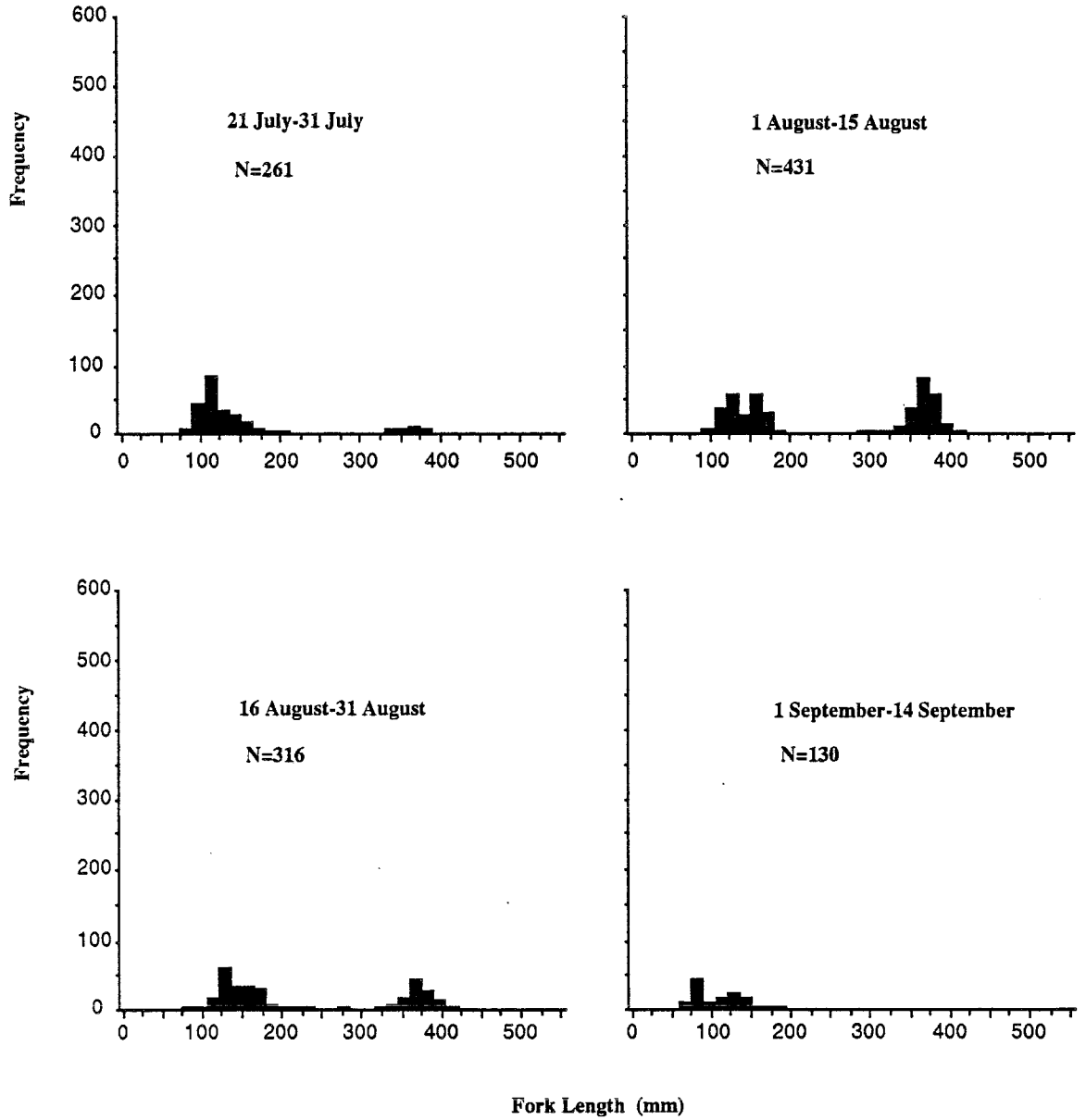

FIGURE 20.—Length frequency of Arctic cisco captured by fyke nets in Camden Bay, Alaska, July-September 1988.

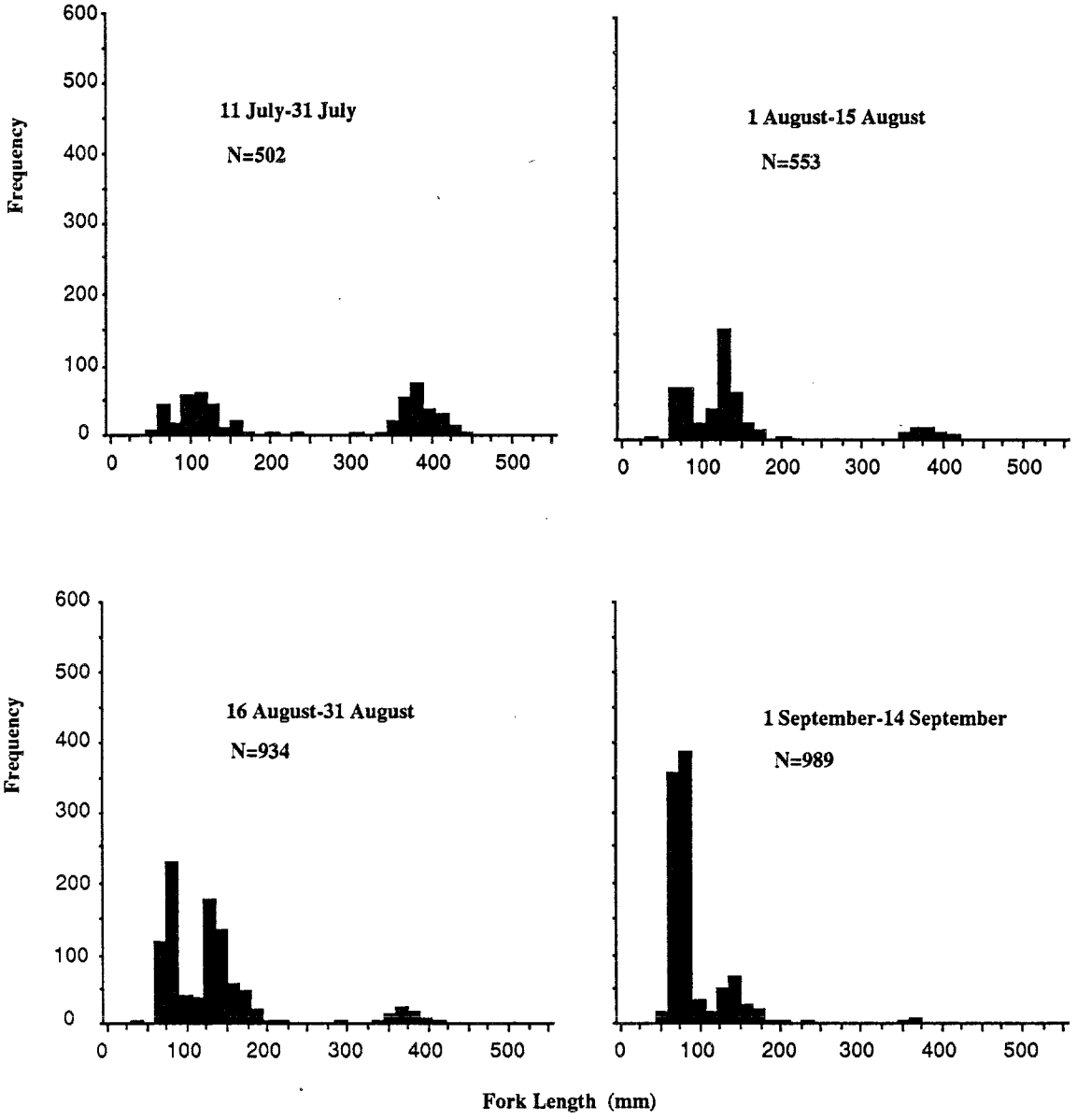

FIGURE 21.—Length frequency of Arctic cisco captured by fyke nets in Kaktovik and Jago lagoons, Alaska, July-September 1988.

abundant in these lagoons. At Pokok Bay length frequency distribution during the first portion of the study period (July 11-31) was similar to that seen at Kaktovik and Jago lagoons during the corresponding period (Figure 22). During August 1-15 Arctic cisco 60-89 mm were more abundant than those of other sizes, though fish in the 120-134 mm fork length interval were also prominent in the catches. During the period August 16-September 14 fish in the former size group were clearly dominant. Arctic cisco in intermediate size classes (200-324 mm) were captured in very low numbers in all study areas.

Arctic cisco captured by gill nets in Camden Bay during 1988 ranged between 164 and 425 mm fork length. A total of 263 Arctic cisco were captured by gill net in Camden Bay from August 7 to September 9, of which 99% were captured in August. Arctic cisco 375-389 mm fork length were the dominant size group (Figure 23).

Least cisco.—Least cisco ranged between 77 and 458 mm fork length in the three study areas. Ninety-four percent of the fish measured were captured in fyke nets. The remaining 6% were captured in variable mesh gill nets. A pooled length frequency histogram for all least cisco captured by fyke net and measured in this study is presented in Appendix 3. As with Arctic cisco, few intermediate size least cisco (175-274 mm) were captured.

Least cisco captured by fyke nets in the three study areas were mostly in the size ranges 120-179 mm and 250-354 mm (Figures 24-26). In Camden Bay prominent modes occurred in the 280-299 mm interval during the last two weeks of July and August. Only one least cisco was captured in Camden Bay during September.

In Kaktovik and Jago lagoons fyke net catches of least cisco were dominated by fish in the 285-299 mm interval during the month of August. Relatively few least cisco were collected during July and September in Kaktovik and Jago lagoons.

During July and the first half of August the only least cisco collected in Pokok Bay by fyke net were in the 270-329 mm size interval with relatively few individuals collected during July. During mid-August through mid-September catches also included fish 100-179 mm fork length.

Least cisco captured by gill nets in Camden Bay during 1988 ranged between 280 and 392 mm fork length. Least cisco were captured by gill net only during the period August 7-19. Fish 285-329 mm fork length were the dominant size group (Figure 27).

Arctic cod.—Arctic cod ranged between 21 and 347 mm fork length in the three study areas. The length frequency data for Arctic cod were skewed toward smaller fish. Arctic cod size ranges appeared similar in the three study areas, with the majority of fish captured measuring 60-175 mm fork length (Figure 28). In all areas a single frequency mode occurred in the 80-89 mm length interval. One Arctic cod 347 mm long was captured in Jago Lagoon on August 21. Arctic cod less than 60 mm were generally not captured except for one fish measuring 21 mm taken in Kaktovik Lagoon on August 6. A pooled length frequency histogram for all Arctic cod measured in this study is shown in Appendix 4.

Fourhorn sculpin.—Fourhorn sculpin captured by fyke nets in the three study areas ranged between 30 and 318 mm fork length. The dominant frequency mode for fourhorn sculpin catches in Kaktovik and Jago lagoons was in the 160-169 mm fork length interval (Figure 29); however, two other modes were apparent at 70-79 mm and 110-119 mm. At Camden Bay two of these frequency modes (70-79 mm and 110-119 mm fork length) were apparent, but the 160-169 mm fork length mode that was dominant at Kaktovik and Jago lagoons was not present. At Pokok Bay a single length frequency mode for fourhorn sculpin was present at 70-79 mm fork length. Fourhorn sculpin in Pokok Bay averaged 25 mm less than sculpin captured in either Kaktovik and Jago lagoons or Camden Bay. A pooled length frequency histogram for all fourhorn sculpin measured in this study is presented in Appendix 5.

Arctic flounder.—Arctic flounder captured in fyke nets in the three study areas ranged in fork length from 20 to 395 mm. Length distribution for Arctic flounder in the length range 100-299 mm approached a normal

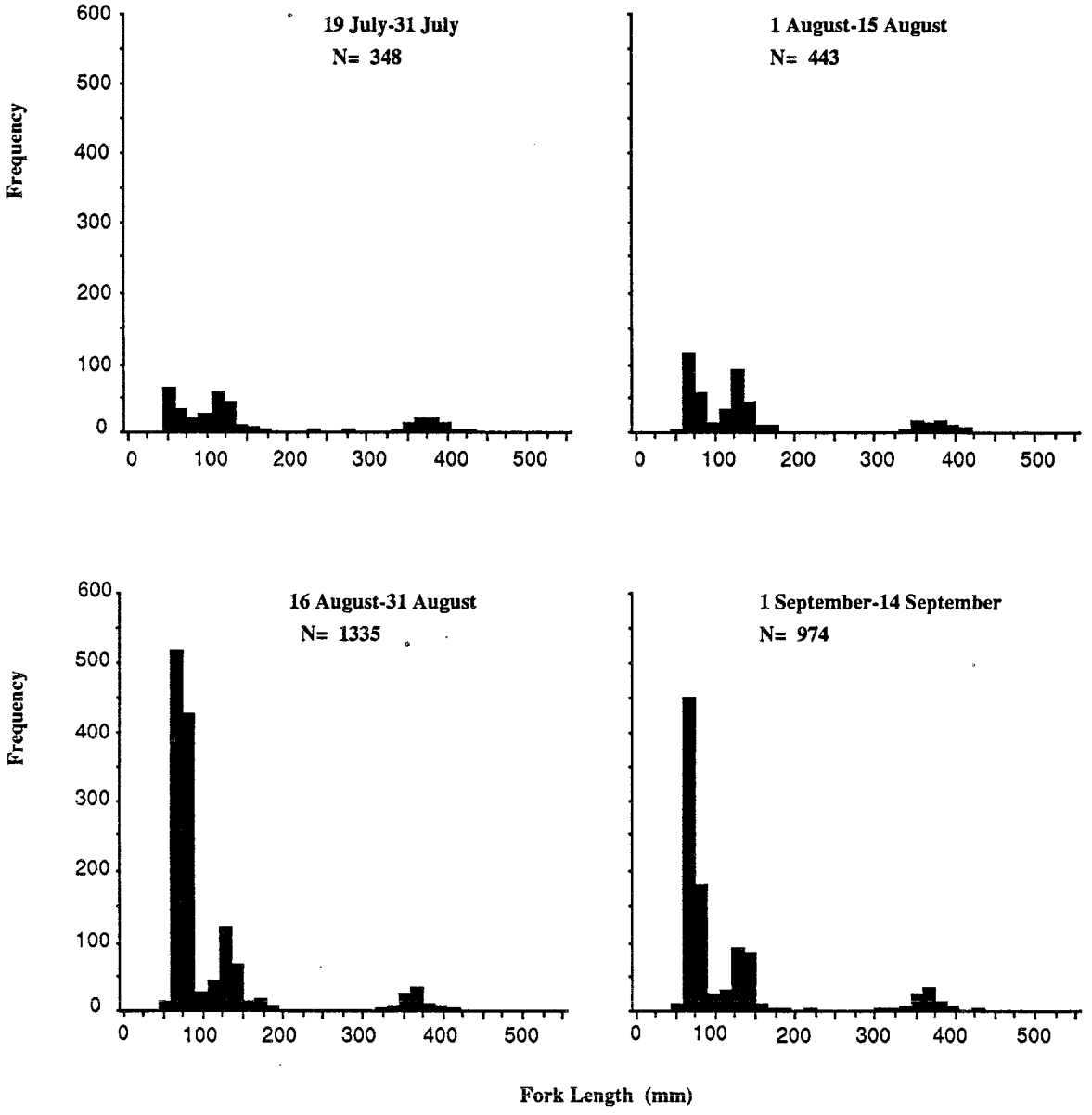

FIGURE 22.—Length frequency of Arctic cisco captured by fyke nets in Pokok Bay, Alaska, July-September 1988.

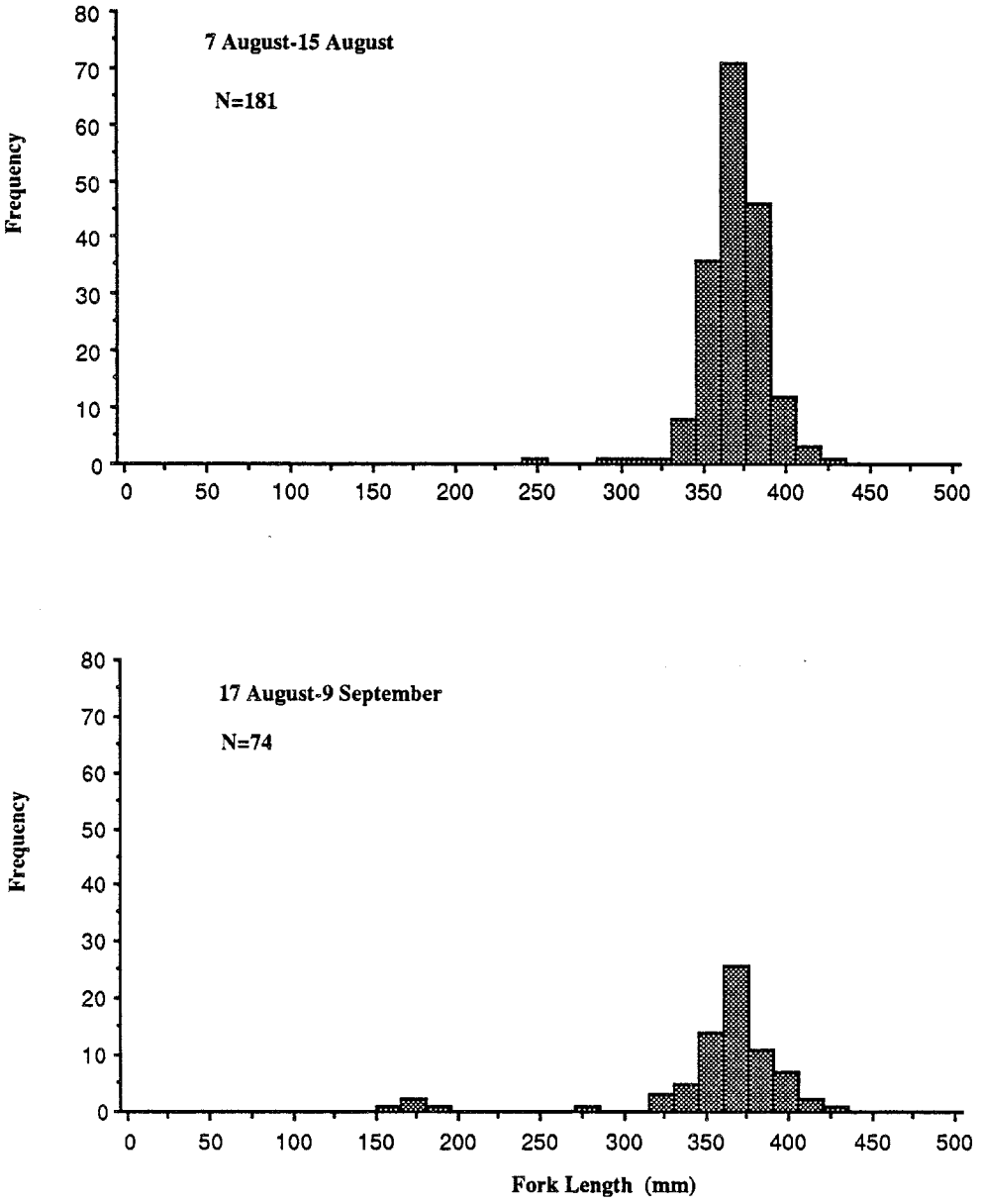

FIGURE 23.—Length frequency of Arctic cisco captured by gill nets in Camden Bay, Alaska, August-September 1988.

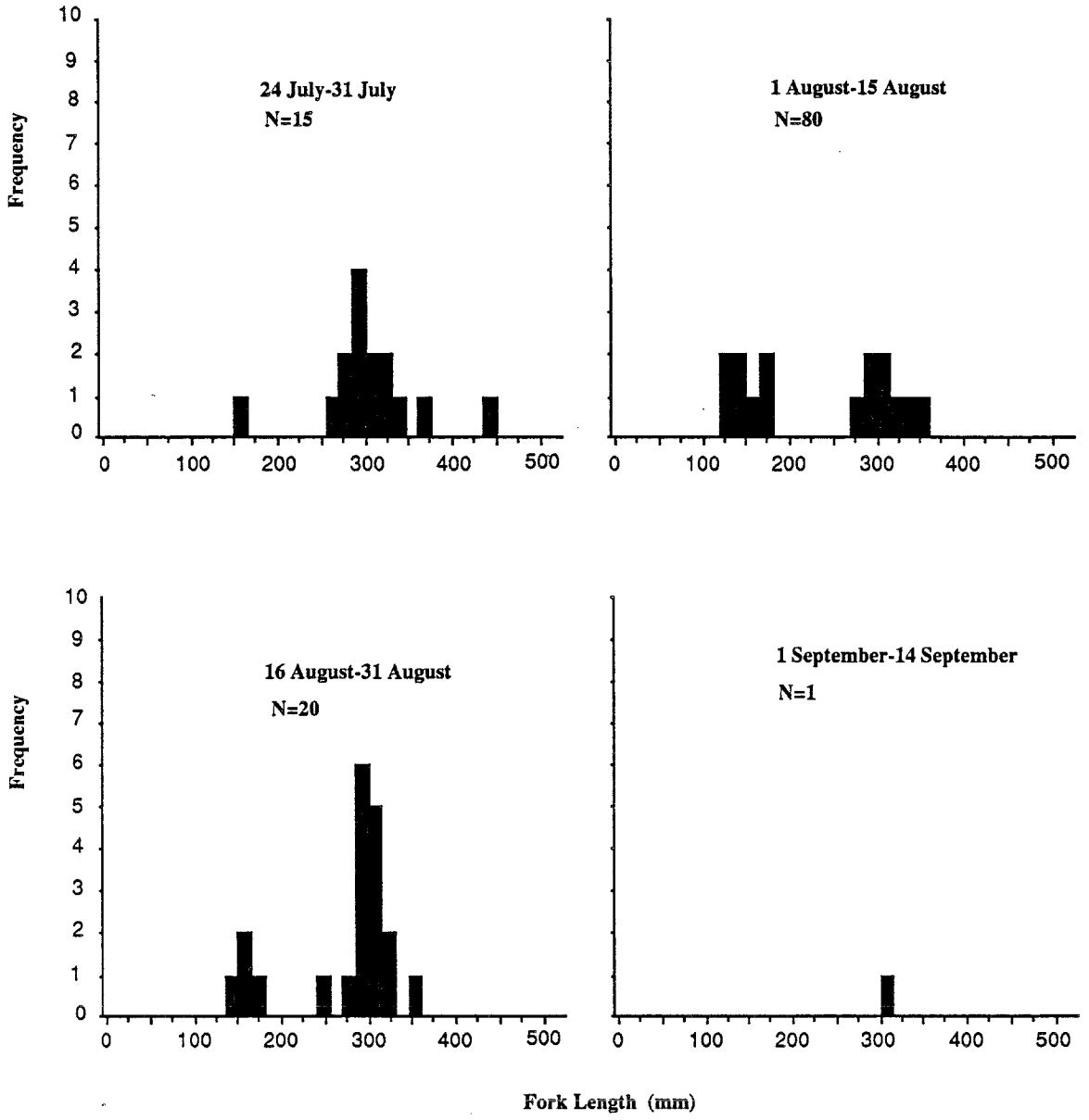

FIGURE 24.—Length frequency of least cisco captured by fyke nets in Camden Bay, Alaska, July-September 1988.

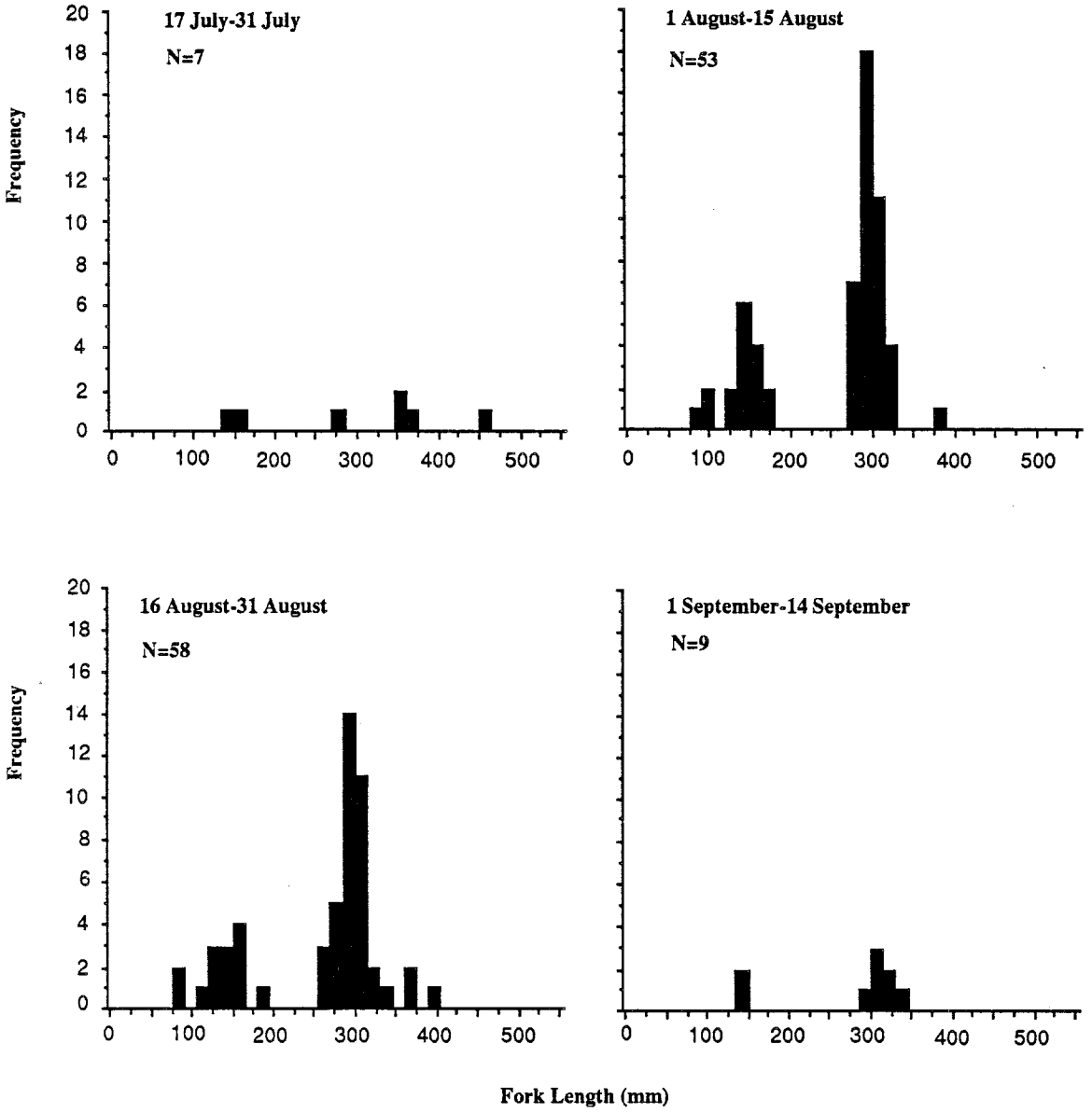

FIGURE 25.—Length frequency of least cisco captured by fyke nets in Kaktovik and Jago lagoons, Alaska, July-September 1988.

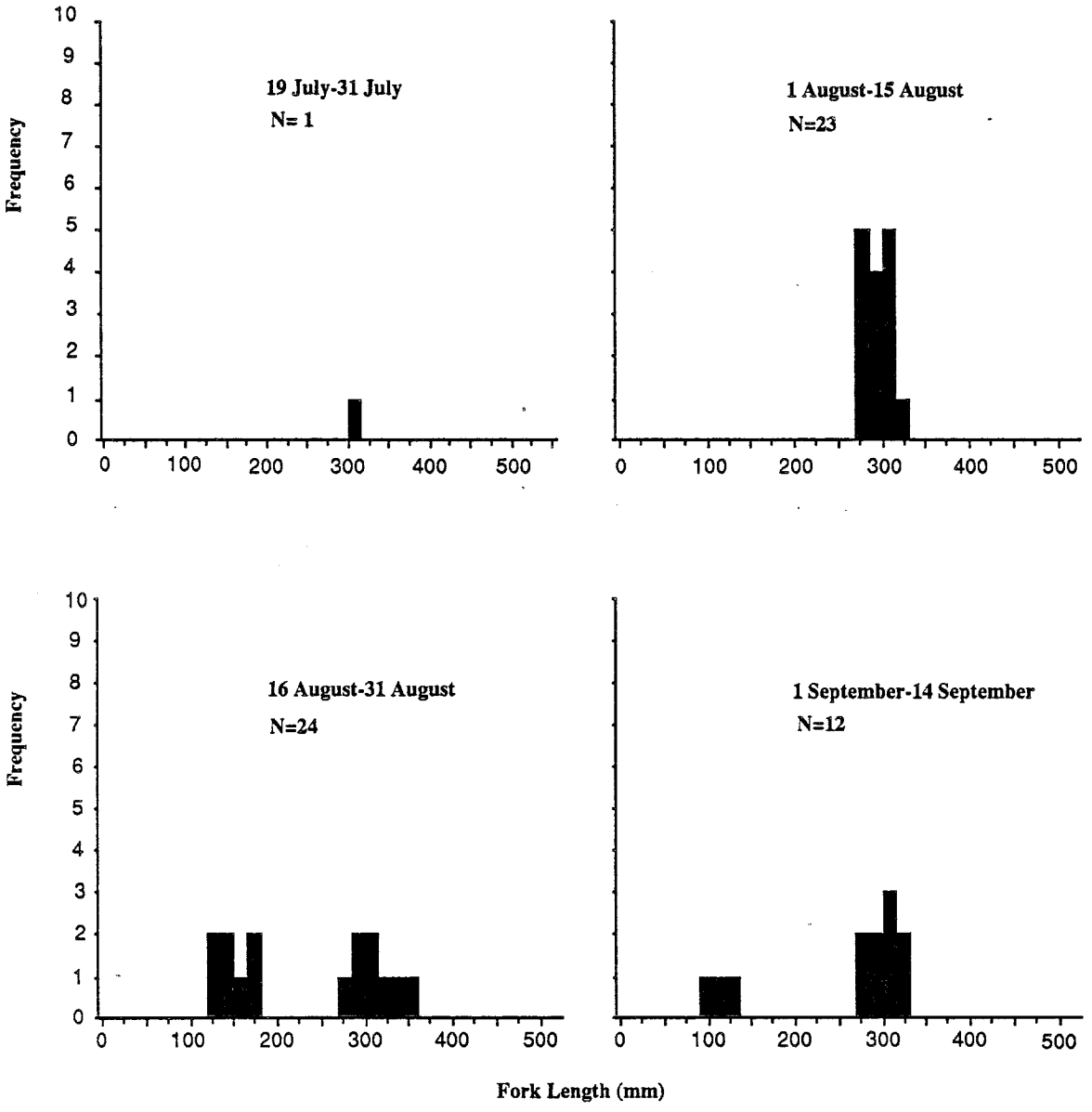

FIGURE 26.—Length frequency of least cisco captured by fyke nets in Pokok Bay, Alaska, July-September 1988.

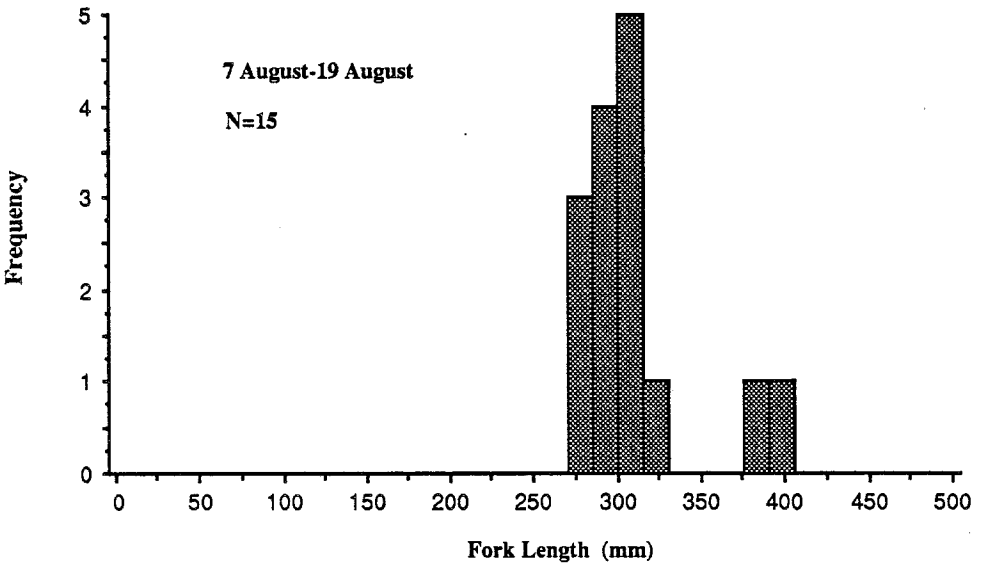

FIGURE 27.—Length frequency of least cisco captured by gill nets in Camden Bay, Alaska, August 1988.

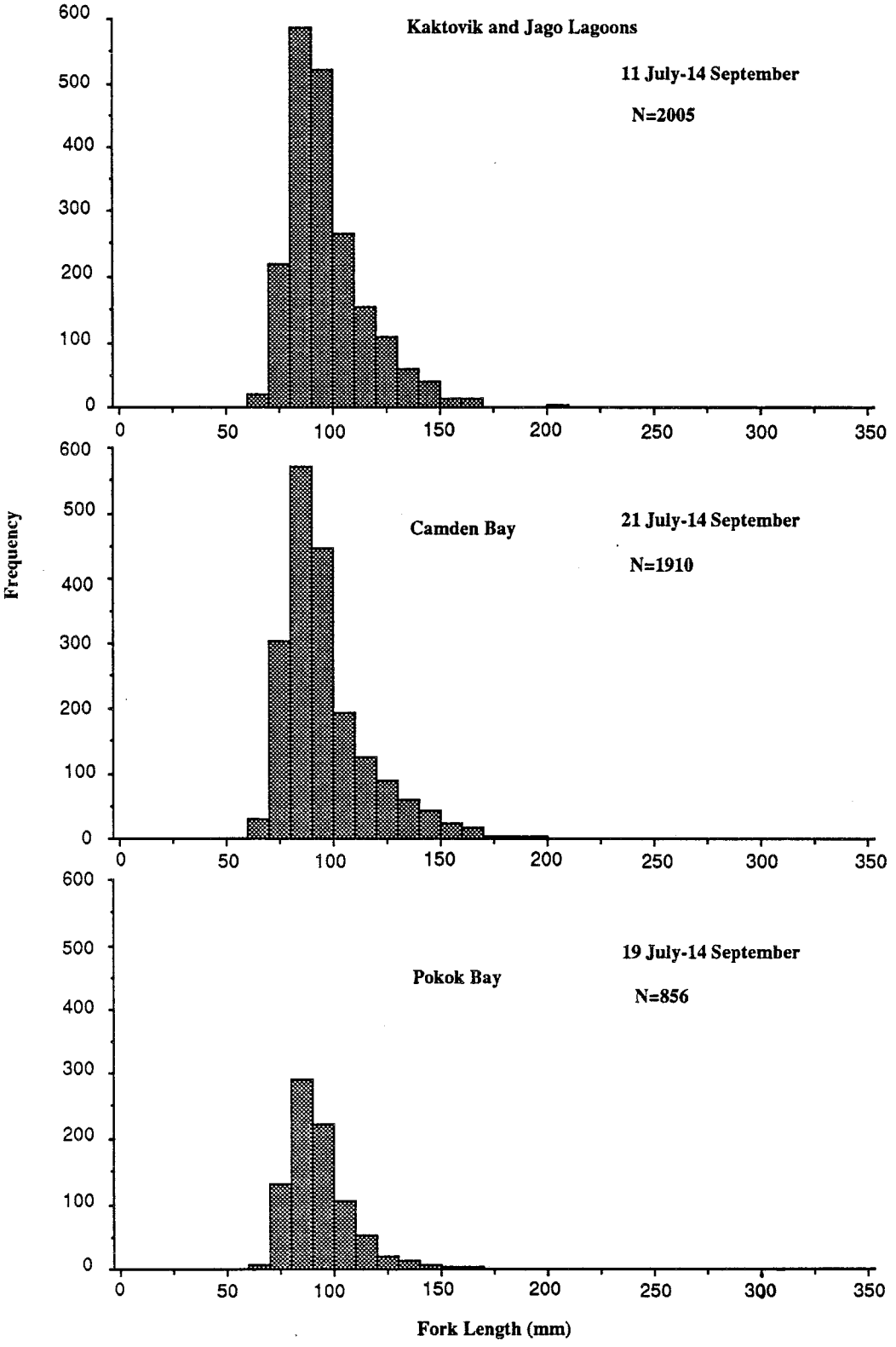

FIGURE 28.—Length frequency of Arctic cod captured by fyke nets in three different study areas in Arctic Refuge coastal waters, July-September 1988.

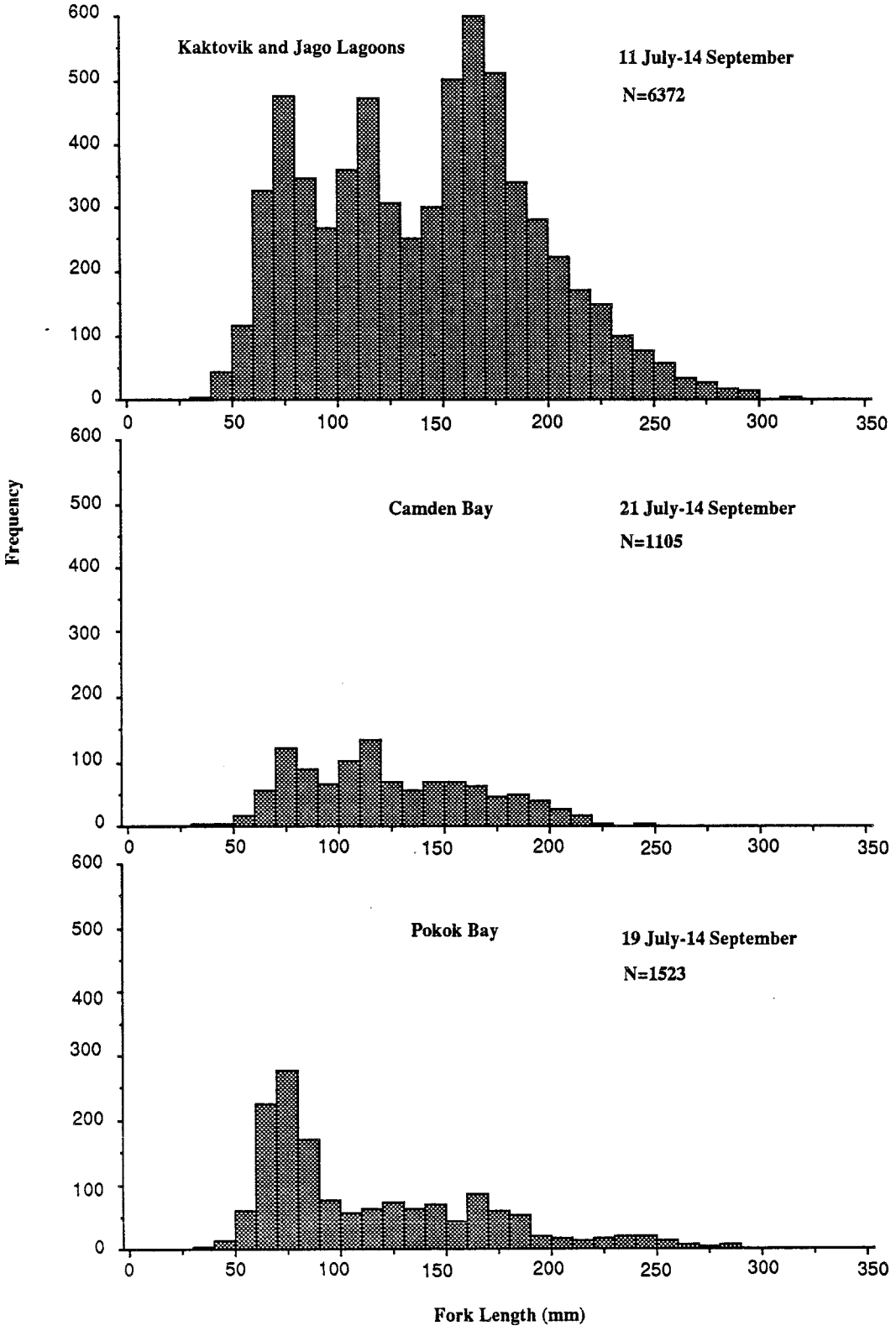

FIGURE 29.—Length frequency of fourhorn sculpin captured by fyke nets in three different study areas in Arctic Refuge coastal waters, July-September 1988..

distribution at Kaktovik and Jago lagoons and at Pokok Bay; as such, these data reflected a marked skewness toward fish larger than 150 mm (Figure 30). Arctic flounder greater than 200 mm fork length comprised 46% of the catches at all stations combined. A pooled length frequency histogram for all Arctic flounder measured in this study is presented in Appendix 6.

At Kaktovik and Jago lagoons the major frequency mode occurred at 200-209 mm. No distinct length frequency modes were apparent from the Camden Bay data, though most fish captured there were 140-259 mm fork length. Two modes occurred in the Pokok Bay data at 40-49 mm and 190-209 mm.

Fish Weight-Length Relationships and Condition Factors

All six primary species (Arctic char, Arctic cisco, least cisco, Arctic cod, fourhorn sculpin, Arctic flounder) demonstrated allometric growth, increasing in weight at a faster rate than growth in fork length (Figures 31 and 32). Values for slope (b) ranged from 3.04 for Arctic cod to 3.58 for fourhorn sculpin. Correlation coefficients for the regressions of the logarithms of weight and length were high, ranging from 0.95 to 0.99.

Allometric condition factors (Kn) for immature and adult Arctic char, Arctic cisco, least cisco, Arctic cod, fourhorn sculpin, and Arctic flounder ranged from 0.91 to 1.11 with the majority of values greater than 1.0 (Table 8). Condition factors for immature and adult Arctic char and immature fourhorn sculpin were significantly greater ($P<0.05$) during the second half of the field season, increasing from values less than 0.97 to values greater than 1.07.

Fish Age

Ages of Arctic char estimated from otolith samples ranged from 1 to 15 years with the majority of fish (95%) estimated at Age 6 or less (Table 9). Fork lengths of Arctic char generally covered a wide range within each age class, and considerable overlap occurred among age classes. Ageing of the other species from which otoliths were collected (Arctic cisco, least cisco, Arctic cod, fourhorn sculpin, and Arctic flounder) was not yet complete at the time this progress report was published. This information will be provided in a subsequent report.

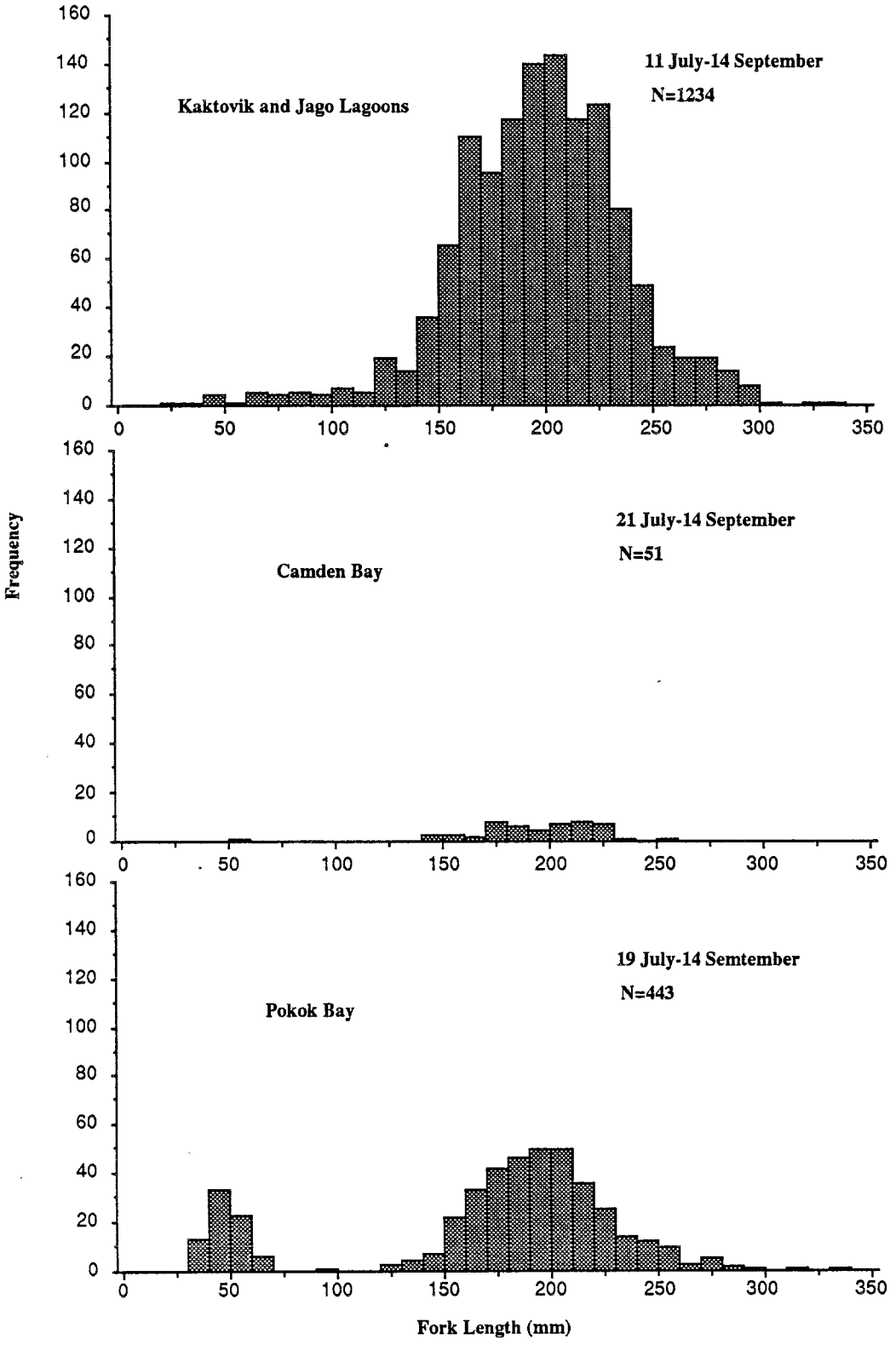

FIGURE 30.—Length frequency of Arctic flounder captured by fyke nets in three different study areas in Arctic Refuge coastal waters, July-September 1988.

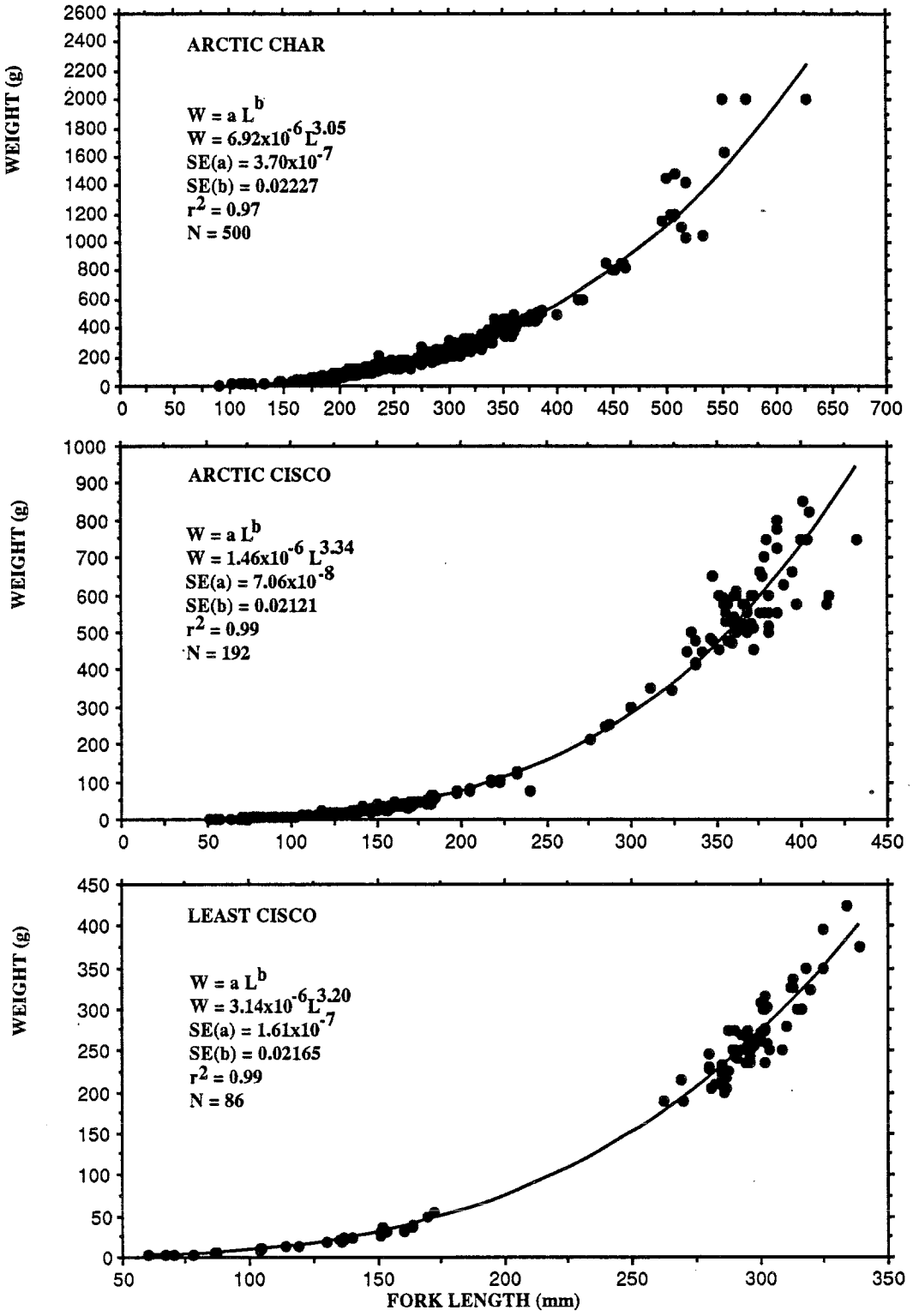

FIGURE 31.—Weight-length relationships for Arctic char, Arctic cisco, and least cisco collected at coastal sampling locations during 1988.

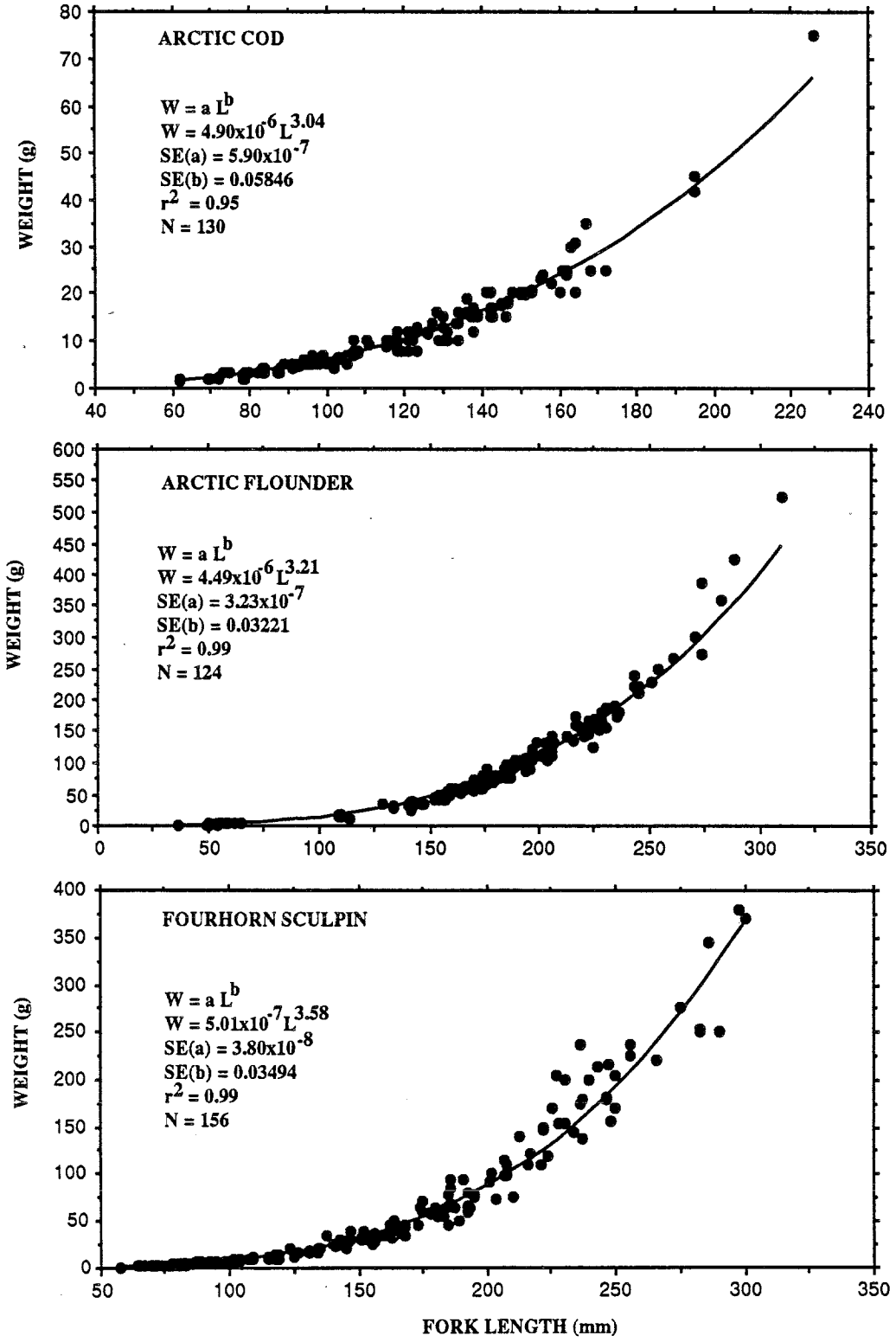

FIGURE 32. —Weight-length relationships for Arctic cod, Arctic flounder, and fourhorn sculpin collected at coastal sampling locations during 1988.

TABLE 8.—Mean condition factors (Kn) for immature and adult Arctic char, Arctic cisco, least cisco, Arctic cod, fourhorn sculpin, and Arctic flounder collected at coastal sampling locations during two time periods in 1988. Asterisks denote significant differences between time periods (P<0.05)

	Time period				
	July 17-August 15		August 16-September 14		
Species, maturity stage	Kn	N	Kn	N	
Arctic char					
Immature	0.91	193	1.08	253	*
Adult	0.95	45	1.10	9	*
Arctic cisco					
Immature	1.05	86	1.02	65	
Adult	1.03	22	1.11	19	
Least cisco					
Immature	1.03	19	0.97	8	
Adult	1.02	28	1.03	31	
Arctic cod					
Immature	1.03	57	1.02	44	
Adult	1.00	4	0.91	25	
Fourhorn sculpin					
Immature	0.96	35	1.10	38	*
Adult	1.01	39	1.02	44	
Arctic flounder					
Immature	1.01	43	1.00	28	
Adult	1.02	28	1.06	25	

TABLE 9.—Mean fork length at various ages for Arctic char collected at coastal sampling locations during 1988.

Age	Mean fork length	N	Length range	Standard deviation
1	97	1		
2	154	13	103-223	41
3	221	187	132-310	31
4	258	161	180-400	48
5	306	50	214-533	54
6	320	21	175-386	57
7	420	5	343-504	56
8	485	9	418-572	44
9	439	3	306-550	101
10	514	1		
11	576	2	532-620	44
13	505	1		
15	628	1		

Discussion

Of the 18 species collected in 1988, six species (Arctic cod, Arctic cisco, fourhorn sculpin, Arctic char, ninespine stickleback and Arctic flounder) comprised 97% of the catch. This is consistent with findings of previous studies in the Arctic Refuge area (Roguski and Komarek 1971; Ward and Craig 1974; Griffiths et al. 1977; Craig 1983; Griffiths 1983; Nelson et al. 1986; West and Wiswar 1985; Wiswar and West 1987; Wiswar et al. *in preparation*; Wiswar and Fruge *in preparation*). Fish species consistently most abundant in these studies were Arctic cod, Arctic cisco, fourhorn sculpin, Arctic char and Arctic flounder. Though care must be exercised in comparing catches from different studies due to differences in gear types, seasonal sampling periods, study areas and habitat types sampled, some interesting variations in relative abundance among species are evident when comparing our results with some of these studies. In 1988, ninespine stickleback was the fifth most abundant species collected; far more abundant than reported in any previous study. Capelin dropped from second most abundant species at Camden Bay in 1987 (Wiswar and Fruge *in preparation*) to ninth in abundance at this location in 1988. Arctic sculpin, a species rarely encountered in previous Arctic Refuge coastal fish studies, was more abundant in terms of average catch per unit effort than capelin in 1988 and was found at all fyke net sampling stations.

Some major distributional patterns are evident from the 1988 data. Arctic cod, overall the most abundant species, were more abundant in Camden Bay than in the other areas, whereas small (<200 mm) Arctic cisco were more abundant in Pokok Bay. Fourhorn sculpin, Arctic char and Arctic flounder were clearly more abundant at Station KL05 in Kaktovik Lagoon than at any other station. Arctic char were noticeably less abundant at Pokok Bay than in the other areas. Least cisco were more abundant in Camden and Pokok bays than in Kaktovik and Jago lagoons. Ninespine stickleback were most abundant at Station JL14 in Jago Lagoon. Eelblennies and capelin were most abundant at Camden Bay, and the Greenland sea snail was found only in that area. Arctic staghorn sculpin, a species previously found only in Camden Bay in 1987 (Wiswar and Fruge *in preparation*), were collected at Pokok Bay and Kaktovik and Jago lagoons in 1988.

An observation of particular interest during 1988 concerns the differences in relative abundance observed for several species between the two sampling stations in Kaktovik Lagoon. Station KL05 was located along the southeastern shore of Barter Island while KL10 sampled waters in a semi-isolated cove south of Drum Island. Fourhorn sculpin were roughly three times more abundant, Arctic char roughly four times more abundant and Arctic flounder over 17 times more abundant at KL05. Conversely, ninespine stickleback were over 5 times more abundant and Arctic cod and small (<200 mm) Arctic cisco almost twice as abundant at KL10. These data must be considered preliminary since they represent a single field season. Furthermore, the fyke net lead at Station KL10 was only approximately 30 m compared to the approximately 60 m lead at Station KL05. While we are not sure what effect this difference may have in comparing the catches between the two stations, the data suggest an interesting subject for future analyses of differences in habitat types in Arctic Refuge coastal waters. Data on salinity and temperature patterns may suggest some explanations for the differences. Analyses of those data are not yet complete.

Another interesting observation was the much greater abundance of small Arctic cisco at Pokok Bay compared to the other two study areas. A related observation was that fewer than 100 small Arctic cisco were captured by fish studies in the Prudhoe Bay area west of the refuge during the summer of 1988 (D. Schmidt, personal communication). It is possible that such differences may have been related to meteorological and oceanographic conditions during the summer of 1988. If surface currents were predominantly from the west these currents could have hindered the westward movement of young Arctic cisco from the Mackenzie River during the summer of 1988, resulting in the distribution pattern observed in coastal waters of Arctic Refuge and the Prudhoe Bay area. Such effects on movement of young Arctic cisco have been proposed by Fechhelm and Fissel (1988) as an explanation for poor recruitment to the Arctic cisco fishery in the Colville River delta. Subsequent analyses of

synoptic meteorologic and hydrographic data should help to validate or discount this explanation for the distribution pattern observed for small Arctic cisco during the summer of 1988.

Gill net data collected in Camden Bay in 1988 suggest that Arctic char, Arctic cisco and least cisco are found predominantly in the upper portion (less than 2.4 meters depth) of the water column in offshore waters. Though no strong differences are apparent in catch rates of Arctic char in gill nets fished at three different distances from shore (approximately 90, 200 and 1,600 m), the data for Arctic cisco indicate decreasing abundance with distance from shore. Data for least cisco indicate a similar, though less pronounced, trend. Craig and Haldorson (1981) found that anadromous species were 24 times more abundant in gill nets set near shore than in the middle of Simpson Lagoon. Those authors also fished a 122-m gill net with one end near shore and the other end extended perpendicularly offshore. Approximately six times as many anadromous fish were captured in the first 40 m of gill net (shore end) than in the last 40 m (seaward end).

Few (3%) of the fish marked for movement studies in 1988 were recaptured. Most recaptures of fin-marked fish occurred in the same study areas where the fish were marked. Only four fin-marked fish were recaptured in different areas. Two least cisco, one marked in Camden Bay and the other in Pokok Bay, were recaptured in the Kaktovik and Jago lagoons study area. An Arctic cisco measuring 139 mm fork length that had been marked in Pokok Bay was recaptured in Camden Bay. Another Arctic cisco measuring 392 mm fork length that was marked at Camden Bay was recaptured at Pokok Bay. These movements are consistent with current migration theories for this species in Beaufort Sea coastal waters (Gallaway et al. 1983). The younger fish (ages 0-1) are believed to migrate westward from the Mackenzie River to overwintering areas in the Colville and Sagavanirktok River deltas, while older fish are believed to move back toward the Mackenzie River upon attaining maturity (Ages 7-9). The capture in Arctic Refuge waters during 1988 of an Arctic cisco (359 mm fork length) that had been tagged in the vicinity of Prudhoe Bay is also consistent with this migration theory.

Of the five tag recaptured fourhorn sculpins, three were recaptured at the stations where these individuals were tagged. However, two were recaptured in different areas. One had moved from Jago Lagoon to Kaktovik Lagoon and the other had moved approximately 7 km north from Station KL05 where it was marked. Only two tagged Arctic flounder were recaptured, both at the stations where they had been tagged. Few other data are available on movements of these species. Craig and Haldorson (1981) recaptured one Arctic flounder and 13 fourhorn sculpin in Simpson Lagoon. The Arctic flounder was recaptured at the site where it was tagged, as were 11 of the fourhorn sculpins; two of the sculpins had moved across the lagoon. Numerous individuals of both species were tagged and recaptured in Camden Bay in 1987 (Wiswar and Fruge *in preparation*). Recaptures in that study were all at the stations where the individuals had been tagged.

Length frequency analyses demonstrated a distinct paucity of Arctic cisco and least cisco in intermediate size ranges (200-325 mm for Arctic cisco; 175-275 mm for least cisco). Similar results have been reported for Arctic cisco (Griffiths et al. 1977; West and Wiswar 1985; Wiswar and West 1987; Wiswar et al. *in preparation*) and least cisco (Wiswar et al. *in preparation*) in other studies in Arctic Refuge coastal waters. The reasons for these phenomena are uncertain. Length frequency data for anadromous fishes in Beaufort Sea coastal waters are difficult to interpret without the benefit of data from previous years for comparison because many of these species are subject to "boom or bust" cycles and frequent years of poor recruitment.

Length frequency data also indicate that larger Arctic char (>300 mm) became less abundant in Arctic refuge coastal waters as the season progressed. Individuals larger than 300 mm were generally not captured after the end of August, though smaller fish were still relatively common. These results are consistent with findings of

Griffiths et al. (1977) in Kaktovik Lagoon. Such results might indicate that larger fish leave coastal waters to return to overwintering/spawning streams sooner than the smaller fish.

Weight-length regression coefficients estimated for Arctic char, Arctic cisco, least cisco, Arctic cod, fourhorn sculpin and Arctic flounder during 1988 fit within the wide range of values reported for these species in Beaufort Sea coastal waters (Glova and McCart 1974; Griffiths et al. 1975; Craig and Haldorson 1981; Craig et al. 1982; Moulton et al. 1986; Bond and Erickson 1987; Whitmus et al. 1987). The values of the growth exponent (b) in the weight-length relationships reported for fourhorn sculpin in these studies have generally been higher than for the other species, ranging from 3.20 to 3.58. Conversely, b values for Arctic char have been lowest, ranging from 2.73 to 3.21. The range of b values reported for other species is 2.99-3.38.

Allometric condition factors increased significantly for immature and adult Arctic char and immature fourhorn sculpin between the first and second halves of the sampling period. Similar comparisons for adult fourhorn sculpin and immature and adult Arctic cisco, least cisco, Arctic cod, and Arctic flounder did not show significant differences. The results obtained for Arctic char and immature fourhorn sculpin stated above are consistent with what one expects to observe in condition factor changes over the course of the summer open-water period. Reasons for the insignificant differences in condition factor between the two portions of the sampling period for the other species remain uncertain.

Ages of Arctic char collected during 1988 ranged from 1 to 15 years, and lengths within each age class generally covered a wide range with considerable overlap occurring among age classes. Age-length relationships of this nature are common among Arctic fishes (Johnson 1972) and have been reported for several coastal populations of Arctic char (Griffiths et al. 1975, 1977; Craig 1977; Wiswar and West 1985). Some factors which probably contribute to the variability observed in age-length relationships of coastal Arctic char populations include: (1) the number of summers spent feeding in coastal waters; (2) the mixture of char from several different populations in the samples; and (3) the number of times different fish have spawned.

In summary, no sound conclusions or management recommendations can be made from the 1988 fish studies in Arctic Refuge coastal waters, though some interesting phenomena were observed. Integration of the 1988 data with data from subsequent years and more thorough analysis and comparison of these data with results of previous studies in Arctic Refuge coastal waters will be the subject of a final report on this study program.

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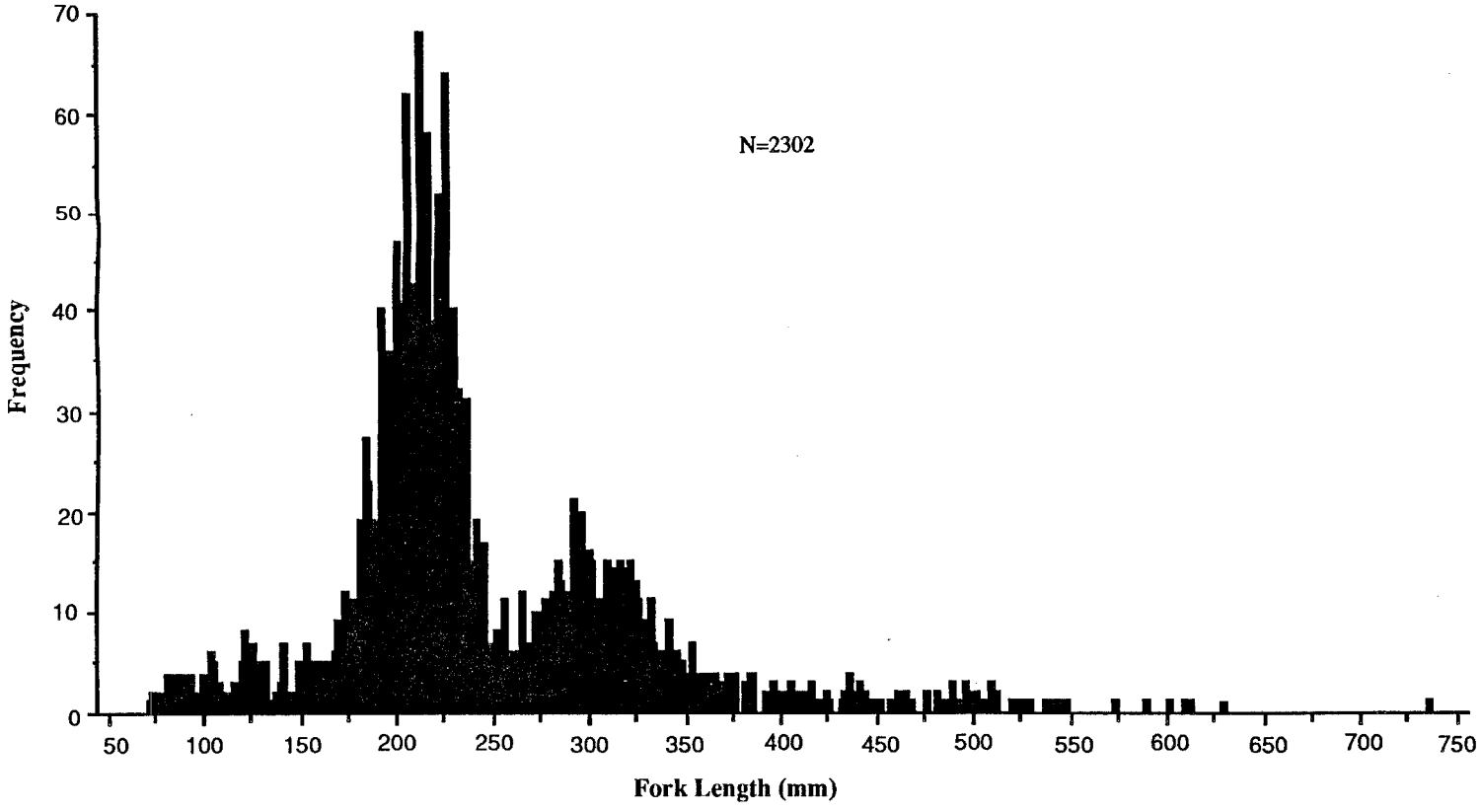

APPENDIX 1.—Length frequency of Arctic char captured in Arctic Refuge coastal waters, July-September 1988.