FISH POPULATION CHARACTERISTICS OF ARCTIC NATIONAL WILDLIFE REFUGE COASTAL WATERS, SUMMER 1989

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Fish Population Characteristics of Arctic National Wildlife Refuge Coastal Waters, Summer 1989

Progress Report

DOUGLAS E. PALMER
and
LARRY J. DUGAN

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

Fishery Assistance Office
U.S. Fish and Wildlife Service
101 12th Avenue, Box 17, Room 222
Fairbanks, Alaska 99701

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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 three gill net stations during the summer 1989 open-water season (approximately mid-July through mid-September). Specific study areas included Camden Bay, Kaktovik, Jago, and Beaufort lagoons. Concurrent physical habitat measurements in each study area included water temperature and salinity. Current direction and velocity and wind direction and velocity were monitored at Camden Bay and Beaufort Lagoon. Twenty-two 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)*. Seven species were collected by gill net with Arctic cisco and Arctic char comprising 97% of the gill net catch.

Species composition and relative abundance were generally consistent with findings of previous studies in Beaufort Sea coastal waters, though temporal and spatial variations in abundance were observed for some species. Abundance of capelin *(Mallotus villosus)* has decreased substantially over the last two years at Camden Bay, dropping from second in abundance in 1987 to fourteenth in 1989. Overall, Arctic cod, Arctic flounder, large Arctic cisco (>200 mm), fourhorn sculpin, and ninespine stickleback were three to eleven times more abundant in 1989 than reported in 1988. Conversely, catches of small Arctic cisco (<200 mm) in 1989 were four times lower than those observed in 1988. Catch of Arctic char in 1989 was nearly identical to the catch observed in 1988.

Gill net sampling in Camden Bay indicated that Arctic cisco and Arctic char generally were more abundant nearshore. Vertical distribution of the catch indicated that both species were more abundant in the upper 2.4 meters of the water column.

Eastward movements up to 120 km were documented for two and three year old Arctic cisco. Conversely, movements of Arctic flounder and fourhorn sculpin were very localized.

Length frequency data are presented for Arctic char, Arctic cisco, Arctic cod, fourhorn sculpin, and Arctic flounder. Arctic char larger than 350 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 cisco were absent from catches in all study areas despite pronounced frequency modes for both smaller and larger size groups.

The sex ratio of fish collected during 1989 was generally in favor of females except for Arctic cisco where males barely outnumbered females. Gonadosomatic indices indicated that approximately 10% of the Arctic char and 4% of the Arctic cisco examined were spawners of the year.

Weight-length relationships for Arctic char, Arctic cisco, Arctic cod, fourhorn sculpin, and Arctic flounder were within the ranges reported for these species in Beaufort Sea coastal waters. Relative condition (Kn) of these species generally increased over the course of the summer for both immature and adult fishes. Age determinations made for Arctic char, Arctic cisco, and fourhorn sculpin indicated that length ranges within each age class were wide with considerable overlap among 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 (Arctic Refuge) since discovery of the Prudhoe Bay oilfield in 1968 (Figure 1). 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. If legislation is passed in the future which allows exploration and eventual production of oil and gas 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 material spills.

Reliable baseline data are necessary for detecting and mitigating 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 coastal waters of the refuge 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 distribution and abundance, which can be substantial in coastal Beaufort Sea waters. Information on fish distribution and abundance and related hydrographic characteristics over a several year period in areas of potential development is needed to assess potential impacts on fish populations. Such

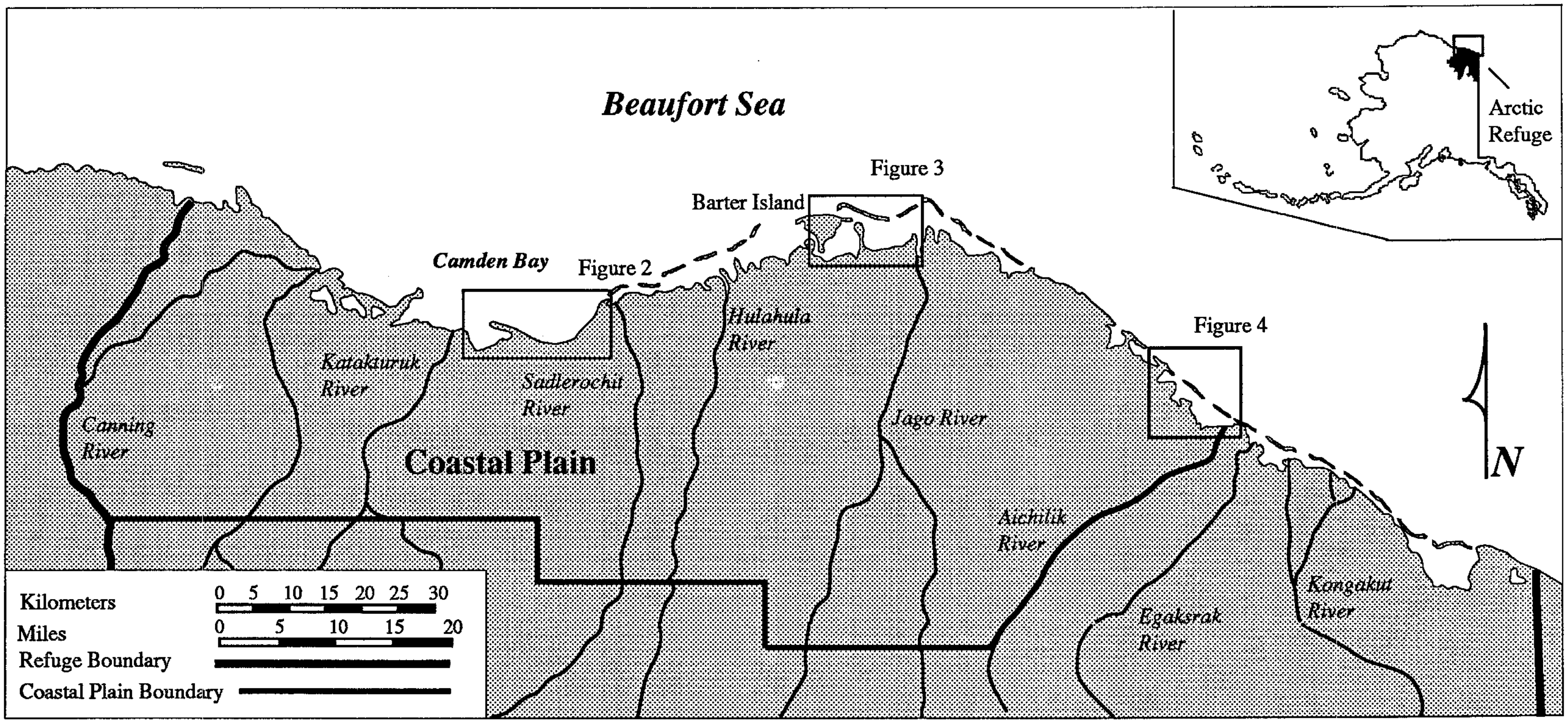


FIGURE 1.—Beaufort Sea coast and coastal plain of the Arctic Refuge and study areas sampled for fish and physical hydrographic characteristics during mid-July through mid-September 1989.

information could also be utilized in designing and siting coastal structures and activities so that critical fish habitats and migration corridors are protected. 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. Sampling efforts during 1988 focused on three study areas (Fruge et al. 1989). Two of these areas, Camden Bay and the Pokok Bluffs/Bay area, are potential port sites. A third study area was comprised of Kaktovik and Jago lagoons. Due to heavy concentrations of pack ice close to shore at the Pokok Bluffs area for almost the whole summer period in 1988, this study area was abandoned in 1989. Beaufort Lagoon, approximately 19 km east of the Pokok Bluff area, replaced Pokok Bluff/Bay as a study area in 1989. Beaufort Lagoon was selected as a study area because some baseline data was collected at this location in 1984-85. This area is also protected by barrier islands and can be sampled regardless of pack ice conditions. Specific objectives during 1989 were as follows:

1. Determine relative abundance, distribution, and movement patterns for anadromous and marine fish species.

2. Determine length frequency, age structure, weight-length relationships, and condition factors for Arctic char *(Salvelinus alpinus)*, Arctic cisco *(Coregonus autumnalis)*, Arctic cod *(Boreogadus saida)*, fourhorn sculpin *(Myoxocephalus quadricornis)*, and Arctic flounder *(Liopsetta glacialis)* in Arctic Refuge coastal waters during the open-water season.

3. Characterize the Camden Bay, Kaktovik/Jago, and Beaufort lagoon study areas in terms of water temperature and salinity during the open water season.

4. Determine current patterns in the Camden Bay and Beaufort Lagoon offshore study areas during the open water season.

5. Determine the relationships of salinity, temperature, and current patterns to wind direction and velocity at the various study locations.

6. Test the hypothesis that relationships exist between fish distribution and abundance and hydrographic characteristics; and determine the nature of these relationships.

This report summarizes fisheries data from 1989 sampling activities. Data on hydrographic characteristics is currently being analyzed and 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, Beaufort Lagoon, 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).

Camden Bay east of Collinson Point consists of a broad 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). The bottom gradient is less 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 1-2 m high, although 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.

Kaktovik and Jago lagoons are located immediately southeast and east of Barter Island (Figure 3). 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.

Jago Lagoon is a limited exchange lagoon (Hachmeister and Vinelli 1984) and 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.

Kaktovik Lagoon is a pulsing lagoon (Hachmeister and Vinelli 1984) and has two channels leading to outside waters. The primary channel, known as Nelsaluk Pass, connects Kaktovik and Jago lagoons. Another shallow channel at the southwest end of Kaktovik Lagoon opens to waters west of Barter Island. No streams of any consequence empty into Kaktovik Lagoon.

Maximum water depth in Kaktovik and Jago lagoons is approximately 4 m (Nautical Chart 16043, U.S. Department of Commerce). 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.

The Beaufort Lagoon study area (Figure 4) is centered approximately 55 km southeast of Kaktovik and extends from Angun Point eastward to the Aichilik River delta. The study area makes up the western portion of Beaufort Lagoon which is actually a series of small interconnected narrow lagoons extending eastward to Demarcation Bay. Hachmeister and Vinelli (1984) described Beaufort Lagoon as a limited exchange lagoon in that it has only limited longshore current exchange via several openings in the barrier island system. Maximum water depth in Beaufort Lagoon is approximately 4 m (Nautical Chart 16042, U.S. Department of Commerce). Most of the lagoon's shoreline is physically similar to that described for Camden Bay, being sand/gravel beach below tundra bluffs.

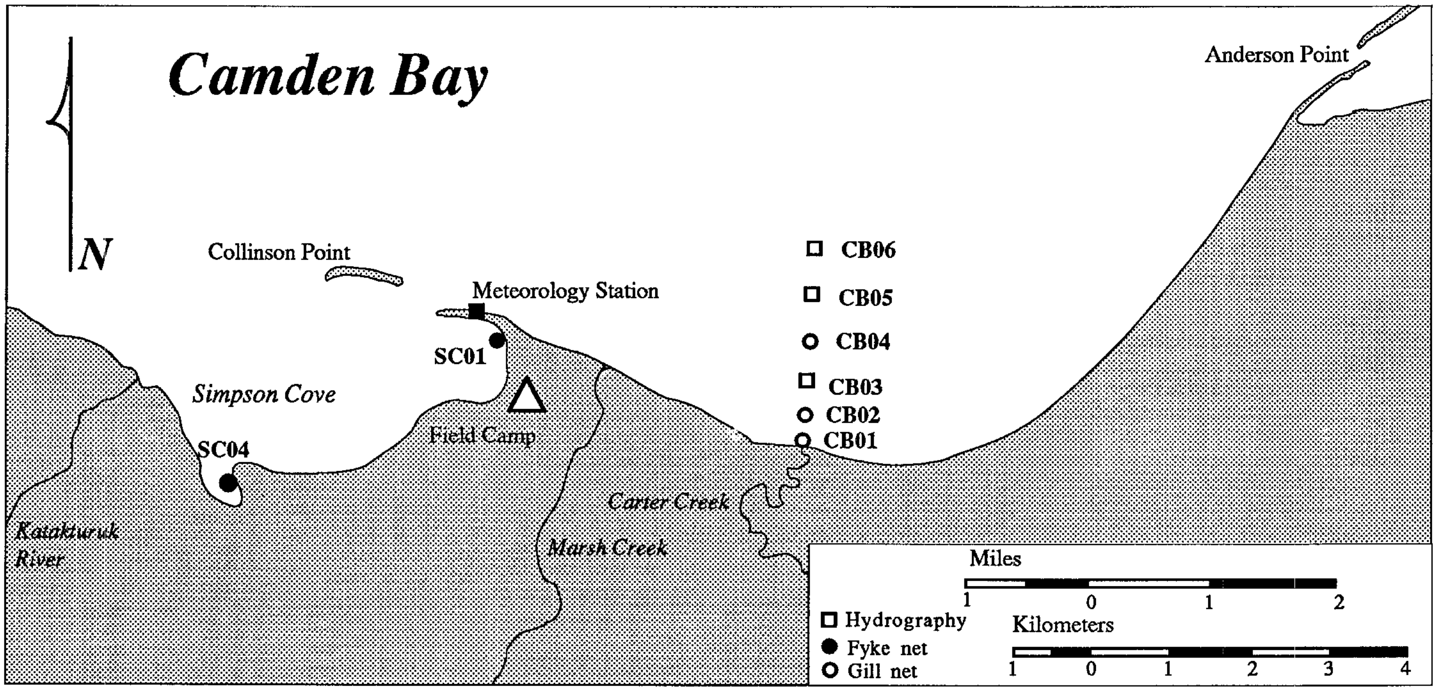


FIGURE 2.—Sampling stations in the Camden Bay study area on the Arctic Refuge during mid-July through mid-September 1989.

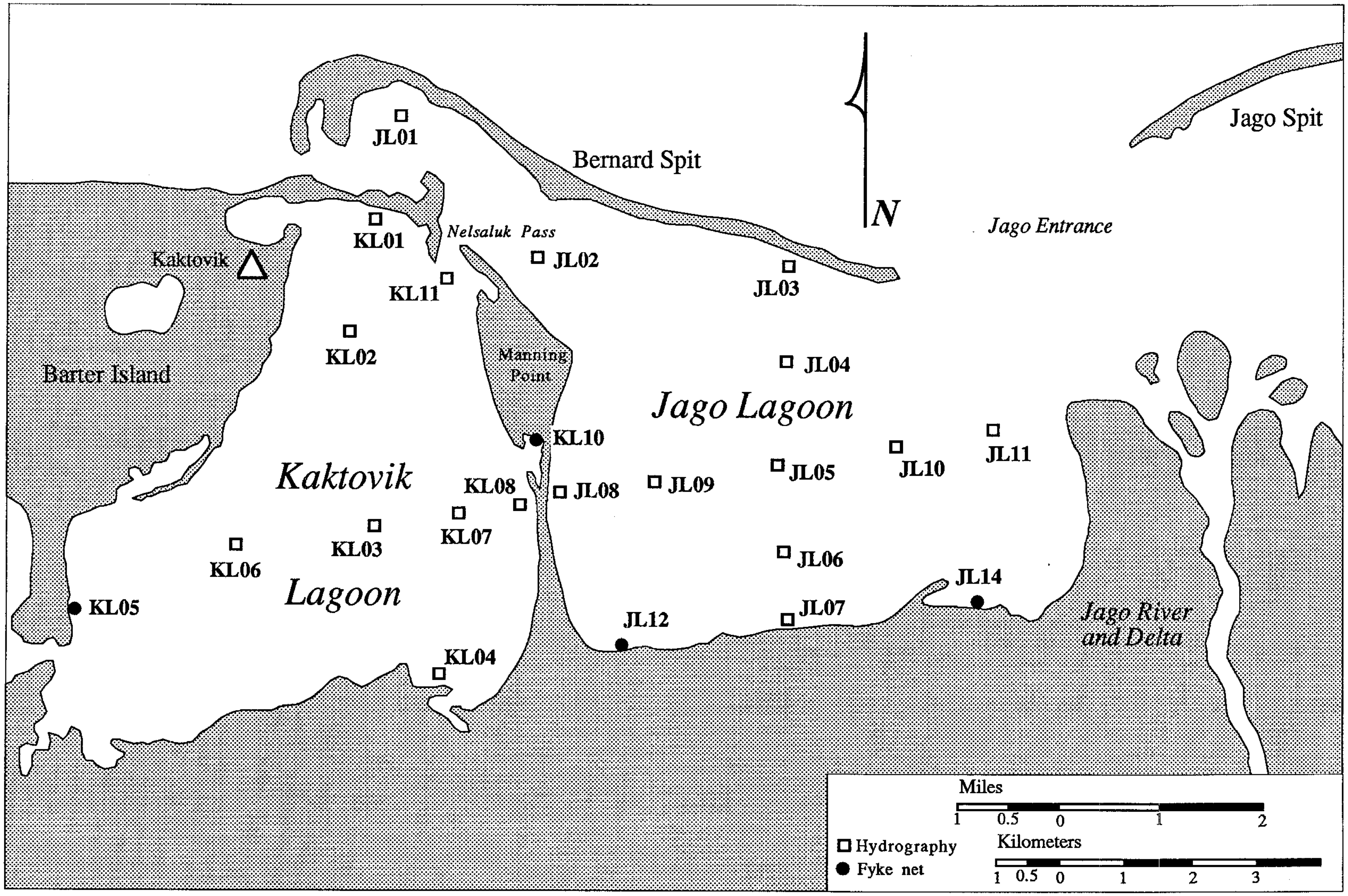


FIGURE 3.—Sampling stations in the Kaktovik and Jago lagoons area on the Arctic Refuge during mid-July through mid-September 1989.

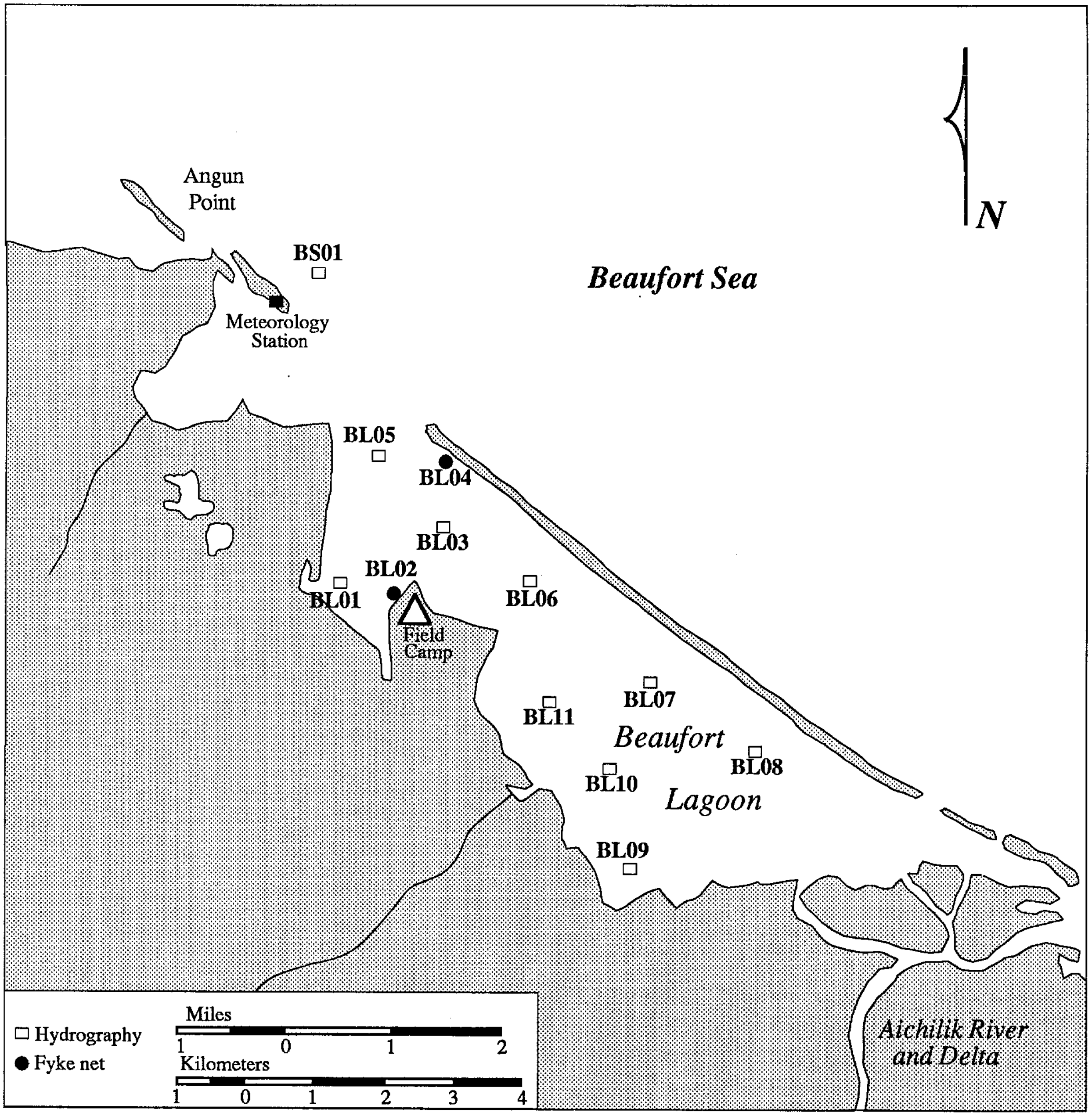


FIGURE 4.—Sampling stations in the Beaufort Lagoon study area on the Arctic Refuge during mid-July through mid-September 1989.

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 (Figures 2-4). Fyke nets were fished from approximately mid-July through mid-September at Camden Bay (Simpson Cove, stations SC01 and SC04), Kaktovik Lagoon (stations KL05 and KL10), and Jago Lagoon (stations JL12 and JL14). Fyke nets at Beaufort Lagoon (stations BL02 and BL04) were fished during three separate sampling periods, each approximately seven days in duration (July 18-24, August 11-17, and September 2-10)(Table 1). 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 5). All fyke nets were fished with leads fully extended except at Station KL10 where only 30 m of lead was used because of the steep bottom gradient at this site. 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. 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 (Table 1; Figure 2). 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 (Station CB01), 4.9 m (Station CB02), and 7.3 m (Station CB04). 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 6). 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 they 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. Gill nets generally were fished every other day between July 18 and September 9; however, severe weather periodically interrupted this schedule. Duration of net sets ranged from 1 to 7.8 hours and averaged 3.1 hours. All fish captured in gill nets were enumerated, measured (fork length) to the nearest millimeter, and released if in relatively good condition. The depth zone where each fish was captured (i.e., 0-2.4 m, 2.4-4.9 m, 4.9-7.3 m) was also recorded.

Fish Movements.—Juvenile Arctic cisco less than approximately 250 mm fork length were marked using alcian blue dye applied with a high pressure Syrijet® dental injector (Mizzy, Inc.). Fish marked at the three different study sites were distinguished by applying dye at the base of different fins as follows: Camden Bay, left pelvic; Beaufort Lagoon, right pelvic; Kaktovik and Jago lagoons, caudal. Dye marks and tag numbers (fish tagged in previous years) from recaptured individuals were recorded at the time of capture. Dye marking was used during 1989 because local residents objected to external tagging.

Age and Growth.—Fish were collected during three 15-day periods corresponding to early, middle, and late portions of the open water season to evaluate weight-length relationships, condition, sexual maturity, and age structure of primary species (Arctic char, Arctic cisco, Arctic cod, Arctic flounder,

TABLE 1.—Sampling station locations, types of data obtained at each, and inclusive dates of sampling, mid-July through mid-September 1989.

Station	Area	Latitude	Longitude	Fyke net	Gill net	CTD[a]	Current meter	Sampling dates[b]
KL01	Kaktovik Lagoon	70° 07.94' N	143° 34.15' W			X		July 23 - September 13
KL02	Kaktovik Lagoon	70° 07.12' N	143° 34.63' W			X		July 23 - September 13
KL03	Kaktovik Lagoon	70° 06.00' N	143° 34.26' W			X		July 23 - September 13
KL04	Kaktovik Lagoon	70° 05.08' N	143° 32.90' W			X		July 23 - September 13
KL05	Kaktovik Lagoon	70° 05.44' N	143° 39.56' W	X		X		July 16 - September 13
KL06	Kaktovik Lagoon	70° 05.83' N	143° 36.65' W			X		July 23 - September 13
KL07	Kaktovik Lagoon	70° 06.16' N	143° 32.72' W			X		July 23 - September 13
KL08	Kaktovik Lagoon	70° 06.22' N	143° 31.28' W			X		July 23 - September 13
KL10	Kaktovik Lagoon	70° 06.59' N	143° 31.00' W	X		X		July 13 - September 14
KL11	Kaktovik Lagoon	70° 07.60' N	143° 32.62' W			X		July 23 - September 13
JL01	Jago Lagoon	70° 08.50' N	143° 33.50' W			X		July 23 - September 13
JL02	Jago Lagoon	70° 07.72' N	143° 31.12' W			X		July 23 - September 13
JL03	Jago Lagoon	70° 07.70' N	143° 26.40' W			X		July 23 - September 13
JL04	Jago Lagoon	70° 07.20' N	143° 26.45' W			X		July 23 - September 13
JL05	Jago Lagoon	70° 06.60' N	143° 26.40' W			X		July 23 - September 13
JL06	Jago Lagoon	70° 06.00' N	143° 26.49' W			X		July 23 - September 13
JL07	Jago Lagoon	70° 05.42' N	143° 26.49' W			X		July 23 - September 13
JL08	Jago Lagoon	70° 06.24' N	143° 30.45' W			X		July 23 - September 13
JL09	Jago Lagoon	70° 06.41' N	143° 28.45' W			X		July 23 - September 13
JL10	Jago Lagoon	70° 06.71' N	143° 24.10' W			X		July 23 - September 13
JL11	Jago Lagoon	70° 06.88' N	143° 22.30' W			X		July 23 - September 13
JL12	Jago Lagoon	70° 05.22' N	143° 28.50' W	X		X		July 15 - September 14
JL14	Jago Lagoon	70° 05.51' N	143° 22.23' W	X		X		July 13 - September 14

TABLE 1.—Continued.

Station	Area	Latitude	Longitude	Fyke net	Gill net	CTD[a]	Current meter	Sampling dates[b]
SC01	Camden Bay	69° 58.98' N	144° 50.20' W	X		X		July 13 - September 15
SC04	Camden Bay	69° 57.66' N	144° 57.00' W	X		X		July 18 - September 17
CB01	Camden Bay	69° 58.10' N	144° 42.13' W		X	X		July 18 - September 9
CB02	Camden Bay	69° 58.17' N	144° 42.13' W		X	X	X	July 18 - September 9
CB03	Camden Bay	69° 58.50' N	144° 42.13' W			X		July 21 - September 9
CB04	Camden Bay	69° 58.93' N	144° 42.13' W		X	X		July 18 - September 9
CB05	Camden Bay	69° 59.32' N	144° 42.13' W			X		July 21 - September 9
CB06	Camden Bay	69° 59.60' N	144° 42.13' W			X	X	July 21 - September 9
BL01	Beaufort Lagoon	69° 53.43' N	142° 19.78' W			X		July 19 - September 10[c]
BL02	Beaufort Lagoon	69° 53.28' N	142° 18.59' W	X		X		July 18 - September 10[c]
BL03	Beaufort Lagoon	69° 53.81' N	142° 17.78' W			X		July 19 - September 10[c]
BL04	Beaufort Lagoon	69° 54.35' N	142° 17.23' W	X		X		July 18 - September 10[c]
BL05	Beaufort Lagoon	69° 54.38' N	142° 18.82' W			X		July 19 - September 10[c]
BL06	Beaufort Lagoon	69° 53.57' N	142° 15.87' W			X		July 19 - September 10[c]
BL07	Beaufort Lagoon	69° 52.69' N	142° 13.52' W			X		July 20 - September 10[c]
BL08	Beaufort Lagoon	69° 52.15' N	142° 10.98' W			X		July 20 - September 10[c]
BL09	Beaufort Lagoon	69° 51.10' N	142° 13.72' W			X		July 20 - September 10[c]
BL10	Beaufort Lagoon	69° 52.00' N	142° 13.73' W			X		July 20 - September 10[c]
BL11	Beaufort Lagoon	69° 52.52' N	142° 15.09' W			X		July 20 - September 10[c]
BS01	Beaufort Sea	69° 55.85' N	142° 29.35' W				X	August 4 - September 11

[a]CTD = salinity, temperature, depth

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

[c]Beaufort Lagoon locations were sampled intermittently throughout the summer (July 18-24, August 11-17, September 2-10).

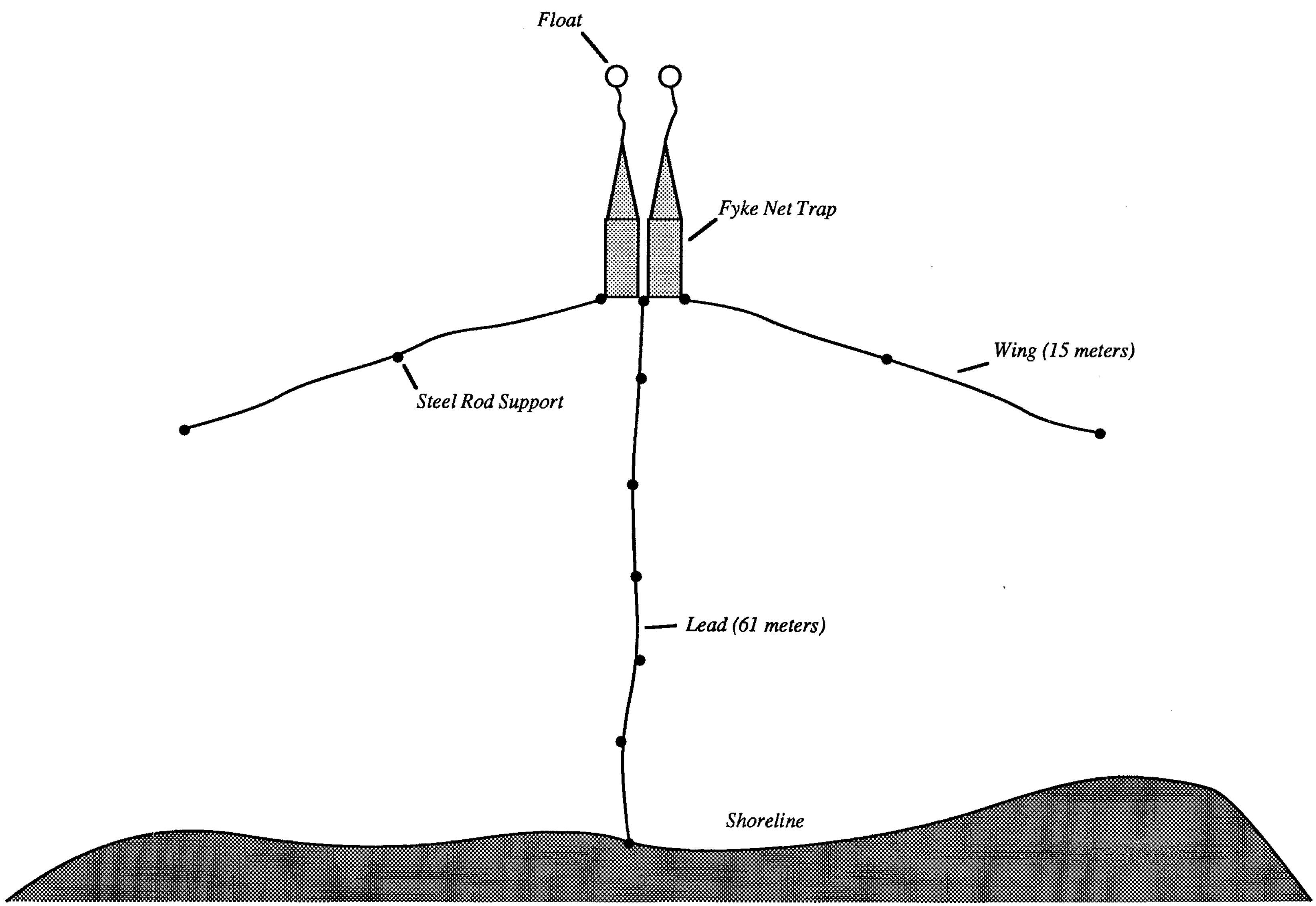


FIGURE 5.—Typical fyke net sampling configuration (not to scale).

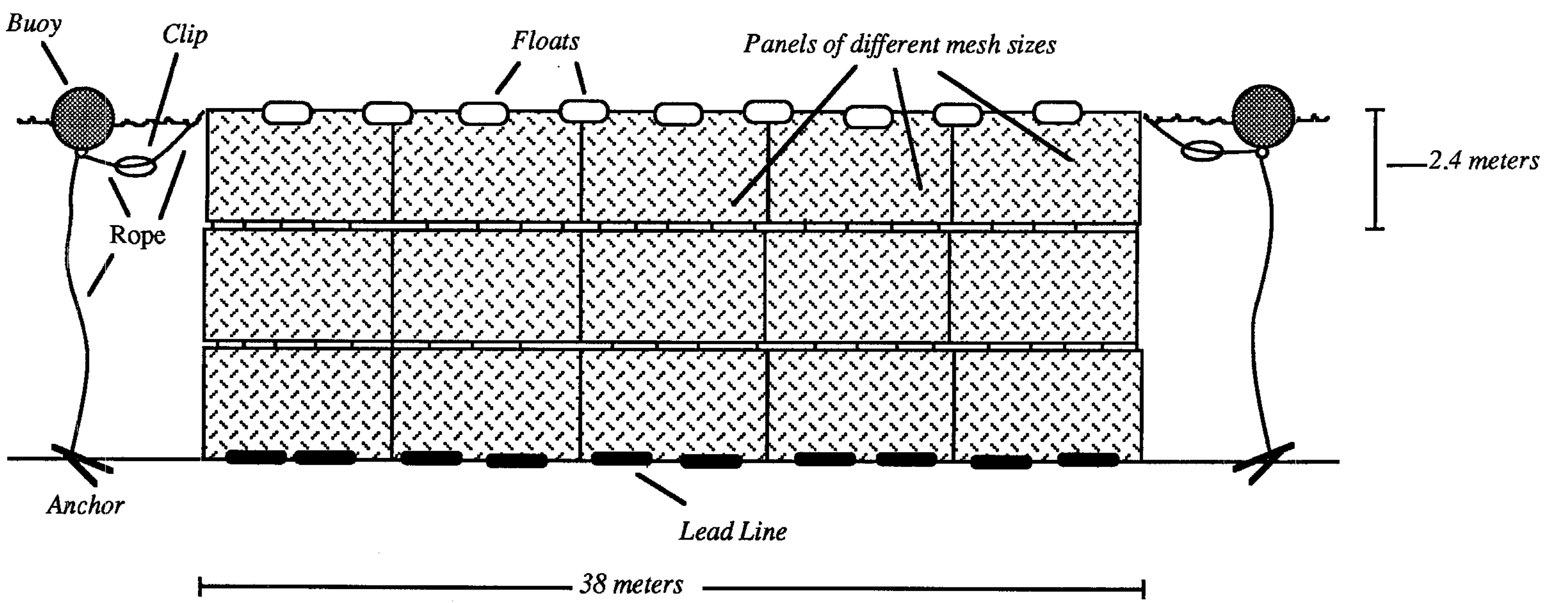


FIGURE 6.—Gill net configuration (arrangement for fishing 7.3 meters depth is shown).

and fourhorn sculpin). The three 15-day periods at Camden Bay and Kaktovik and Jago lagoons were: July 10-24, August 4-18, and August 29-September 12. The 7-day sampling periods at Beaufort Lagoon also fell within these sampling periods. To ensure equal sampling of all lengths of fish for a given species, we attempted to collect five fish from each length interval during each 15-day sampling period. Appropriate length intervals were established for each species using the method described by Anderson and Gutreuter (1983).

Fish sacrificed were taken to camp for processing. Fork lengths were measured to the nearest millimeter. Fish less than 500 g were weighed to the nearest gram with an electronic balance. Fish weights of 500 g or more were determined using Pesola® spring scales to different levels of precision depending upon fish size. Fish weights between 500 g and 1 kg were measured to the nearest 10 g; weights between 1 and 2 kg were measured to the nearest 50 g; and weights greater than 2 kg were measured to the nearest 100 g.

Each sacrificed fish was sexed and classified as either immature or adult based on visual examination of the gonads. The basis for categorizing individuals as immature or adult was whether the gonads appeared to be developing (Snyder 1983). To provide a more quantitative assessment of the degree of sexual development and to classify Arctic char and Arctic cisco as either spawners or non-spawners, gonads were removed and weighed fresh (nearest 0.1 g). Body and gonad weight were then used to calculate a gonadosomatic index (GSI) for each fish which is the weight of the gonads expressed as a percentage of the body weight. Gonadosomatic indices described by Bond and Erickson (1987) were used as guidelines to distinguish spawners from non-spawners. In addition to GSI, mean ova diameters were estimated for female Arctic char which appeared to be mature spawners. Ova were randomly selected and placed on a 10 cm egg board to estimate mean ova diameter.

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. Readings from otoliths collected during 1988 and 1989 were combined to increase sample sizes for length-at-age relationships.

Hydrographic and Meteorologic Sampling

Depth profiles of salinity and temperature were collected at specific hydrographic stations using electronic conductivity-temperature-depth (CTD) recorders (Table 1; Figures 2-4). These data were also collected at all biological sampling stations when nets were checked. At Camden Bay (stations CB02 and CB06) and offshore at Beaufort Lagoon (Station BS01) continuous records of salinity, temperature, current direction, and current velocity were collected using moored current meters. Measurements of air temperature, wind direction, wind velocity, and barometric pressure were recorded at Camden Bay and Beaufort Lagoon with portable meteorological stations. A separate progress report will contain more detailed descriptions of hydrographic and meteorologic data collection methods as well as provide summaries and analyses for these data.

Data Analysis

Fish Catch, Abundance and Distribution.—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 adjusted for fishing effort to catch per 24-hour period. Days when wave action 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 48 hours. Because juvenile and adult Arctic cisco exhibit distinctly different migration patterns, these fish were separated into two groups, those less than 200 mm and those 200 mm or greater in fork length. Relative abundance of target species (Arctic char, Arctic cisco, Arctic cod, fourhorn sculpin and Arctic flounder) was plotted on line graphs as catch per unit effort over time and by sampling station. Significant differences in catch rates among gill net stations for Arctic cisco and Arctic char were assessed by one-way analysis of variance (ANOVA) and Newman-Keuls multiple range tests ($P<0.05$).

Length frequency.—Fork length frequency histograms for Arctic char, Arctic cisco, Arctic cod, fourhorn sculpin, and Arctic flounder were generated for each study area using fyke net data. Length data for each species were plotted by four two-week periods at Camden Bay and Kaktovik/Jago lagoons. Length frequency data at Beaufort Lagoon were plotted for each of the three time periods sampled (July 18-24, August 11-17, and September 2-10). Histogram interval widths and number of intervals for each species were determined using the procedure described by Anderson and Gutreuter (1983). Intervals used were 10 mm for Arctic flounder, Arctic cod, and fourhorn sculpin; 15 mm for Arctic cisco; and 25 mm for Arctic char. Additional histograms combining length data from all fyke net stations were plotted for these species using 2 mm intervals and are presented as appendices. Length frequency histograms also were generated for Arctic char and Arctic cisco with gill net data collected in Camden Bay.

Weight-Length Relationships and Condition Factors.—Weight-length relationships were described for Arctic char, Arctic 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).

Relative condition factors (Kn) were calculated for selected fishes at each sampling location using the equation

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

where W is the weight (g) and L is the fork length (mm) and a and b are constants derived from the weight-length relationship (Anderson and Gutreuter 1983). Condition factors were calculated for immature and adult fishes during early, middle, and late time periods (July 10-24, August 4-18, and August 29-September 12). Condition factors for adult Arctic char and Arctic cisco were calculated separately for spawners and non-spawners. Differences in condition among time periods at each sampling location were assessed by one-way analysis of variance (ANOVA) and Newman-Keuls multiple range tests ($P<0.05$).

Results

Relative Abundance and Distribution -Fyke Nets

Fyke nets were fished at eight stations (Table 1; Figures 2-4) during the 1989 field season (approximately mid-July to mid-September). Two fyke nets were fished in Camden Bay (Simpson Cove) at stations SC01 and SC04 for 65 and 62 days, respectively. Fyke net effort at each of the four stations in Kaktovik and Jago lagoons (KL05, KL10, JL12, and JL14) ranged between 60 and 64 days. Two fyke nets were fished for 23 days at stations BL02 and BL04 in Beaufort Lagoon; however, this effort occurred during three separate sampling periods (July 18-24, August 11-17, and September 2-10).

Twenty-two fish species were captured in Arctic Refuge coastal waters during the summer of 1989 (Table 2). Nine species captured were anadromous and 12 were marine. The only freshwater species captured was Arctic grayling. Arctic cod was the most abundant species collected in fyke nets (68% of the total catch), followed by fourhorn sculpin (16%), ninespine stickleback (8%), Arctic flounder (3%), small (<200 mm fork length) Arctic cisco (2%) , large (≥ 200 mm fork length) Arctic cisco (1%), and Arctic char (1%)(Table 3). A few eelblennies and sculpins were recorded as "unidentified" by the field crews and were not preserved for later identification. Although these unidentified fish were most likely slender eelblenny, Arctic sculpin, or Arctic staghorn sculpin, they will remain as "unidentified" in the analyses. All pink and chum salmon captured during 1989 were adults.

Twenty-one fish species were captured by fyke nets at Camden Bay (Table 3). Arctic cod was the most abundant species comprising 89% of the total catch; mean daily catch rate for this species was 1746.9 fish/day (Table 4). Mean daily catch rate for Arctic cod at Camden Bay was eleven times greater than fourhorn sculpin, the next most abundant species. Fourhorn sculpin comprised 8% of the total catch and had an average daily catch rate of 157.9 fish/day. Average catch rates for ninespine stickleback, Arctic flounder, and small and large Arctic cisco exceeded 11 fish/day, but were less than 5 fish/day for Arctic char. Least cisco were captured sporadically and in relatively low numbers at Camden Bay, but were more abundant here than any other study area. Average catch rate of least cisco at Camden Bay was 0.4 fish/day with highest catches occurring from late August through mid-September.

Nineteen fish species were captured at Kaktovik Lagoon with fourhorn sculpin, ninespine stickleback, and Arctic flounder comprising 92% of the total catch (Table 3). Average catch rates for fourhorn sculpin, ninespine stickleback, and Arctic flounder were 126.3, 63.9, and 39.3 fish/day, respectively (Table 4). Average catch rates for Arctic cod, small and large Arctic cisco, Arctic char, and saffron cod ranged from 1.5 to 8.2 fish/day.

Ninespine stickleback and fourhorn sculpin were the dominant species at Jago Lagoon comprising 81% of the catch (Table 3). Average catch rates for these two species were 136.3 and 127.6 fish/day, respectively (Table 4). Small Arctic cisco, Arctic flounder, and Arctic cod were next in abundance with average catch rates of 18.3, 12.2, and 10.3 fish/day, respectively. Average catch rates for Arctic char and large Arctic cisco were less than 9 fish/day.

Fourteen fish species were captured at Beaufort Lagoon with fourhorn sculpin, Arctic flounder, and small Arctic cisco comprising 40.1, 20.7, and 17.9% of the catch, respectively (Table 3). Average daily catch rate for fourhorn sculpin (77.7 fish/day) was approximately twice that of Arctic flounder (40.2 fish/day) and small Arctic cisco (34.8 fish/day) (Table 4). Average catch rate for ninespine stickleback was 14.6 fish/day and catch rates for Arctic cod, large Arctic cisco, and Arctic char were less than 7 fish/day.

Temporal and spatial trends in relative abundance were apparent for a number of species. The following describes these trends for five major species targeted in this study.

TABLE 2.—Fish species captured in Arctic Refuge coastal waters during July-September 1989.

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*
	Pink salmon	*Oncorhynchus gorbuscha*
Osmeridae	Rainbow smelt	*Osmerus mordax*
Gasterosteidae	Ninespine stickleback	*Pungitius pungitius*
	Threespine stickleback	*Gasterosteus aculeatus*
	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*
Ammodytidae	Pacific sand lance	*Ammodytes hexapterus*
Hexagrammidae	Whitespotted greenling	*Hexagrammos stelleri*
Cottidae	Fourhorn sculpin	*Myoxocephalus quadricornis*
	Arctic sculpin	*Myoxocephalus scorpioides*
	Arctic staghorn sculpin	*Gymnocanthus trucuspis*
Cyclopteridae	Greenland seasnail	*Liparis tunicatus*
Pleuronectidae	Arctic flounder	*Liopsetta glacialis*

TABLE 3.—Total catch from fyke net sampling stations in Arctic Refuge coastal waters, July-September 1989.

	Camden Bay Station		Kaktovik Lagoon Station		Jago Lagoon Station		Beaufort Lagoon Station		
Species	SC01	SC04	KL05	KL10	JL12	JL14	BL02	BI04	Total catch
Arctic cod	159,719	42,665	75	93	635	520	43	36	203,786
Fourhorn sculpin	9,098	9,193	5,775	8,103	7,708	6,595	1,607	1,268	43,347
Ninespine stickleback	212	1,530	6,400	619	6,815	8,464	445	94	24,579
Arctic flounder	247	1,241	3,494	823	326	1,042	1,015	472	8,660
Arctic cisco (< 200 mm)	608	714	96	272	1,404	644	1,113	173	5,024
Arctic cisco (≥ 200 mm)	539	868	77	222	468	188	9	231	2,602
Arctic char	276	216	386	513	632	320	65	110	2,518
Saffron cod	62	59	83	250	134	188	355	46	1,177
Rainbow smelt	48	822	2	11	43	126	24	8	1,084
Slender eelblenny	143	11	9	14	3	6	1	2	189
Arctic sculpin	32	2	13	14	69	12	9	35	186
Broad whitefish	29	23	3	13	9	7	0	0	84
Least cisco	11	31	2	7	2	1	0	2	56
Pacific herring	12	27	0	3	1	0	0	0	43
Pink salmon	4	18	3	3	1	2	0	0	31
Capelin	15	6	0	0	6	0	0	0	27
Arctic grayling	5	2	2	2	0	0	1	0	12
Threespine stickleback	6	0	2	1	0	1	1	0	11
Arctic staghorn sculpin	3	0	0	2	3	0	0	0	8
Unidentified sculpin	0	0	0	1	0	0	3	3	7
Greenland seasnail	0	4	0	0	1	0	0	0	5
Chum salmon	1	0	0	1	1	0	0	0	3
Pacific sand lance	0	0	1	0	1	0	0	0	2
Unidentified eelblenny	0	0	0	1	0	0	0	0	1
Whitespotted greenling	1	0	0	0	0	0	0	0	1
Total catch	171,071	57,432	16,423	10,968	18,262	18,116	4,691	2,480	299,443

TABLE 4.—Mean daily catch per unit effort (fish/day) from fyke net sampling stations in Arctic Refuge coastal waters, July - September 1989.

	Camden Bay			Kaktovik Lagoon			Jago Lagoon			Beaufort Lagoon		
	Station			Station			Station			Station		
Species	SC01	SC04	Combined	KL05	KL10	Combined	JL12	JL14	Combined	BL02	BL04	Combined
Arctic cod	2,642.6	770.0	1,746.9	1.4	1.6	1.5	11.5	9.1	10.3	2.2	2.1	2.1
Fourhorn sculpin	150.5	165.9	157.9	109.0	142.5	126.3	139.9	115.6	127.6	82.0	72.9	77.7
Ninespine stickleback	3.5	27.6	15.0	120.8	10.9	63.9	123.7	148.4	136.3	22.7	5.4	14.6
Arctic flounder	4.1	22.4	12.8	65.9	14.5	39.3	5.9	18.3	12.2	51.8	27.1	40.2
Arctic cisco (< 200 mm)	10.1	12.9	11.4	1.8	4.8	3.3	25.5	11.3	18.3	56.8	9.9	34.8
Arctic cisco (≥ 200 mm)	8.9	15.7	12.1	1.5	3.9	2.7	8.5	3.3	5.9	0.5	13.3	6.5
Arctic char	4.6	3.9	4.2	7.3	9.0	8.2	11.5	5.6	8.5	3.3	6.3	4.7
Saffron cod	1.0	1.1	1.0	1.6	4.4	3.0	2.4	3.3	2.9	18.1	2.6	10.8
Rainbow smelt	0.8	14.8	7.5	<0.1	0.2	0.1	0.8	2.2	1.5	1.2	0.5	0.9
Slender eelblenny	2.4	0.2	1.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Arctic sculpin	0.5	<0.1	0.3	0.2	0.2	0.2	1.3	0.2	0.7	0.5	2.0	1.2
Broad whitefish	0.5	0.4	0.4	0.1	0.2	0.1	0.2	0.1	0.1	0	0	0
Least cisco	0.2	0.6	0.4	<0.1	0.1	0.1	<0.1	<0.1	<0.1	0	0.1	0.1
Pacific herring	0.2	0.5	0.3	0	0.1	<0.1	<0.1	0	<0.1	0	0	0
Pink Salmon	0.1	0.3	0.2	0.1	0.1	0.1	<0.1	<0.1	<0.1	0	0	0
Capelin	0.2	0.1	0.2	0	0	0	0.1	0	0.1	0	0	0
Arctic grayling	0.1	<0.1	0.1	<0.1	<0.1	<0.1	0	0	0	0.1	0	<0.1
Threespine stickleback	0.1	0	0.1	<0.1	<0.1	<0.1	0	<0.1	<0.1	0.1	0	<0.1
Arctic staghorn sculpin	0.1	0	<0.1	0	<0.1	<0.1	0.1	0	<0.1	0	0	0
Unidentified sculpin	0	0	0	0	<0.1	<0.1	0	0	0	0.2	0.2	0.2
Greenland seasnail	0	<0.1	<0.1	0	0	0	<0.1	0	<0.1	0	0	0
Chum salmon	<0.1	0	<0.1	0	<0.1	<0.1	<0.1	0	<0.1	0	0	0
Pacific sand lance	0	0	0	<0.1	0	<0.1	<0.1	0	<0.1	0	0	0
Unidentified eelblenny	0	0	0	0	<0.1	<0.1	0	0	0	0	0	0
Whitespotted greenling	<0.1	0	<0.1	0	0	0	0	0	0	0	0	0

Arctic char.—Abundance of Arctic char was relatively low (<12 fish/day) at all sampling stations (Table 4). Highest average catch rates were 11.5 fish/day at Jago Lagoon (Station JL12) and 9.0 fish/day at Kaktovik Lagoon (Station KL10). Average catch rates at Camden Bay and Beaufort Lagoon were less than 5 fish/day.

Catch rates of Arctic char were extremely variable at all study areas but tended to be slightly higher in July and August (Figures 7-9). The highest catch rates were recorded at Kaktovik and Jago lagoons at Station KL05 (53 fish/day) on July 18, Station JL12 (38 fish/day) on August 16, and Station JL14 (47 fish/day) on August 15. The catch rate never exceeded 25.0 fish/day at Station KL10. Although the relative abundance of Arctic char was higher at Kaktovik and Jago lagoons than the other study areas, catch rates were still less than 7 fish/day on most days.

Arctic cisco.—Some of the highest catch rates for small Arctic cisco (<200 mm) were during late August and early September (Figures 10-12). The highest catch during this time period was 317 fish/day at Station BL02 in Beaufort Lagoon. Peak catches at Jago Lagoon during this time period exceeded 100 fish/day; whereas, peak catches at Camden Bay and Kaktovik Lagoon were approximately 50 fish/day. Abundance of small Arctic cisco during July was generally low at all sampling locations except Camden Bay where daily catch rates ranged up to 60 fish/day.

Although Beaufort Lagoon was sampled on an intermittent basis throughout the summer it appears that small Arctic cisco were more abundant here than at other sampling locations. Average catch rate of small Arctic cisco at Station BL02 in Beaufort Lagoon was 56.8 fish/day (Table 4). The next highest catch rate was 25.5 fish/day in Jago Lagoon (Station JL12) followed by 12.9 fish/day in Camden Bay (Station SC04). All other fyke net stations had average daily catch rates less than 12 fish/day. Overall, average catch rates for small Arctic cisco at Beaufort Lagoon were approximately ten times higher than Kaktovik Lagoon, three times higher than Camden Bay, and two times higher than Jago Lagoon.

Large Arctic cisco (≥200 mm) were captured at all stations in relatively moderate numbers (Table 4). Average catch rates at fyke net stations in Camden Bay ranged from 8.9 fish/day (Station SC01) to 15.7 fish/day (Station SC04). Average catches at Kaktovik and Jago lagoons ranged from 1.5 fish/day (Station KL05) to 8.5 fish/day (Station JL12), and at Beaufort Lagoon, from 0.5 fish/day (Station BL02) to 13.3 fish/day (Station BL04). Overall, catch rates of large Arctic cisco at Camden Bay were two times higher than any other study location.

Daily catch of large Arctic cisco fluctuated widely throughout the summer (Figures 13-15). The highest daily catch rate was 191 fish/day at Jago Lagoon (Station JL12) on August 16, but on most days the average catch was less than 20 fish/day. Relatively high catch rates ranging as high as 65 fish/day were also recorded at Camden Bay (Station SC04) during late August, then sharply declined to less than 5 fish/day. At Beaufort Lagoon, the highest daily catch (100 fish/day) occurred at Station BL04 on July 18; excluding this single high catch value, catch rates were all less than 25 fish/day.

Arctic cod.—Arctic cod were far more abundant at fyke net stations in Camden Bay than at other sampling locations during 1989. Average catch rates at stations SC01 and SC04 were 2,642.6 and 770.0 fish/day, respectively (Table 4). These averages are high because of anomalously high catches exceeding 2,500 fish/day during August 20-21 and September 6-8 (Figure 16). Overall, catch rates of Arctic cod at fyke net stations in Camden Bay exceeded 500 fish/day on 17 days.

The highest catch rates reported for other sampling locations were 90 fish/day at Jago Lagoon (Station JL12) on August 31 and 25 fish/day at Beaufort Lagoon (Station BL04) on September 8 (Figures 17 and 18). Average catch rates of Arctic cod at fyke net stations in Kaktovik, Jago, and Beaufort lagoons ranged from 1.4 to 11.5 fish /day. Arctic cod at Jago Lagoon were roughly seven times more abundant than recorded at Kaktovik Lagoon and five times higher than Beaufort Lagoon. Arctic cod were most abundant at all study locations during late August and early September. Prior to this time, few Arctic cod were captured at any location except Camden Bay.

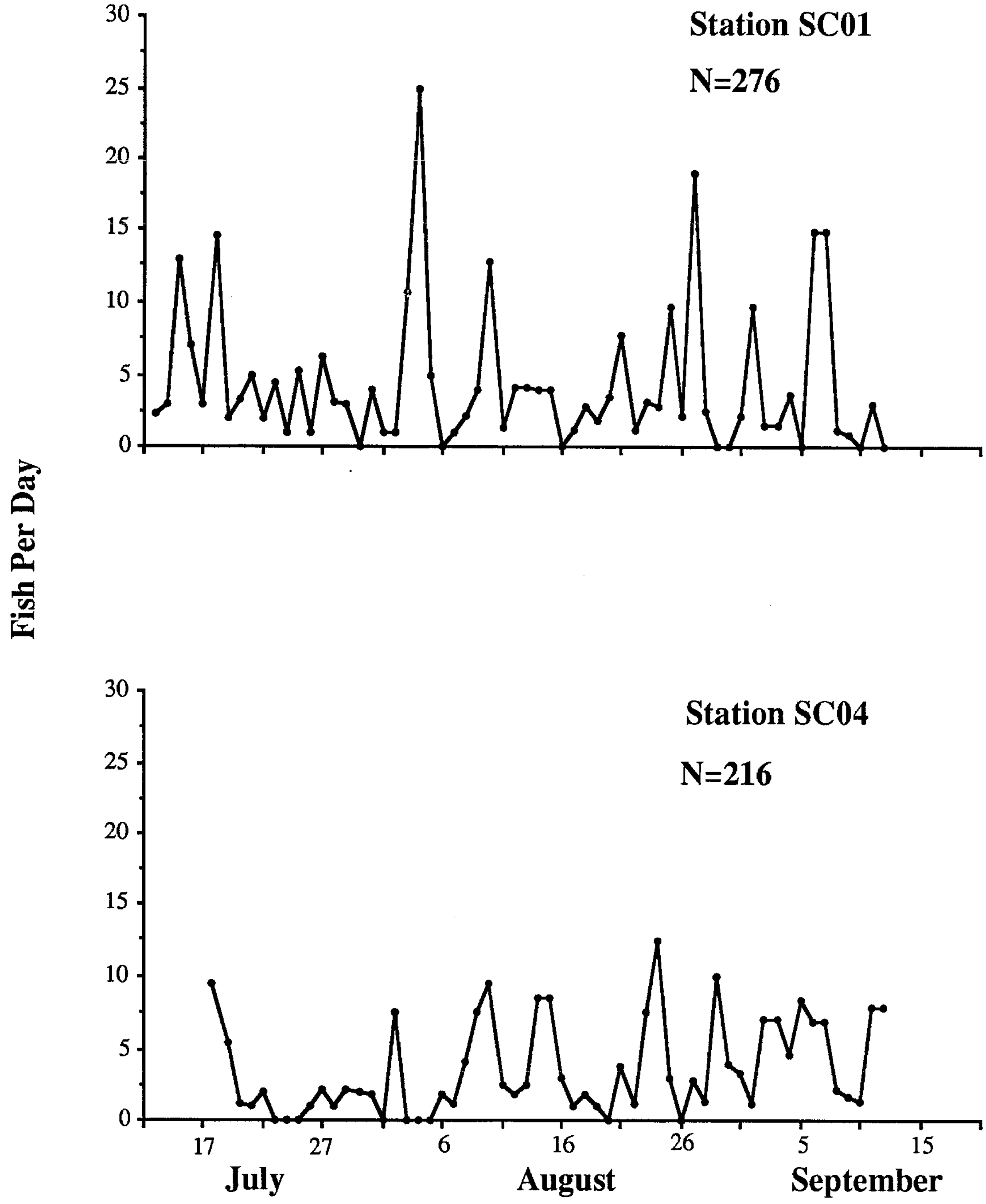


FIGURE 7.—Daily catch per unit effort (fish/day) for Arctic char at fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1989.

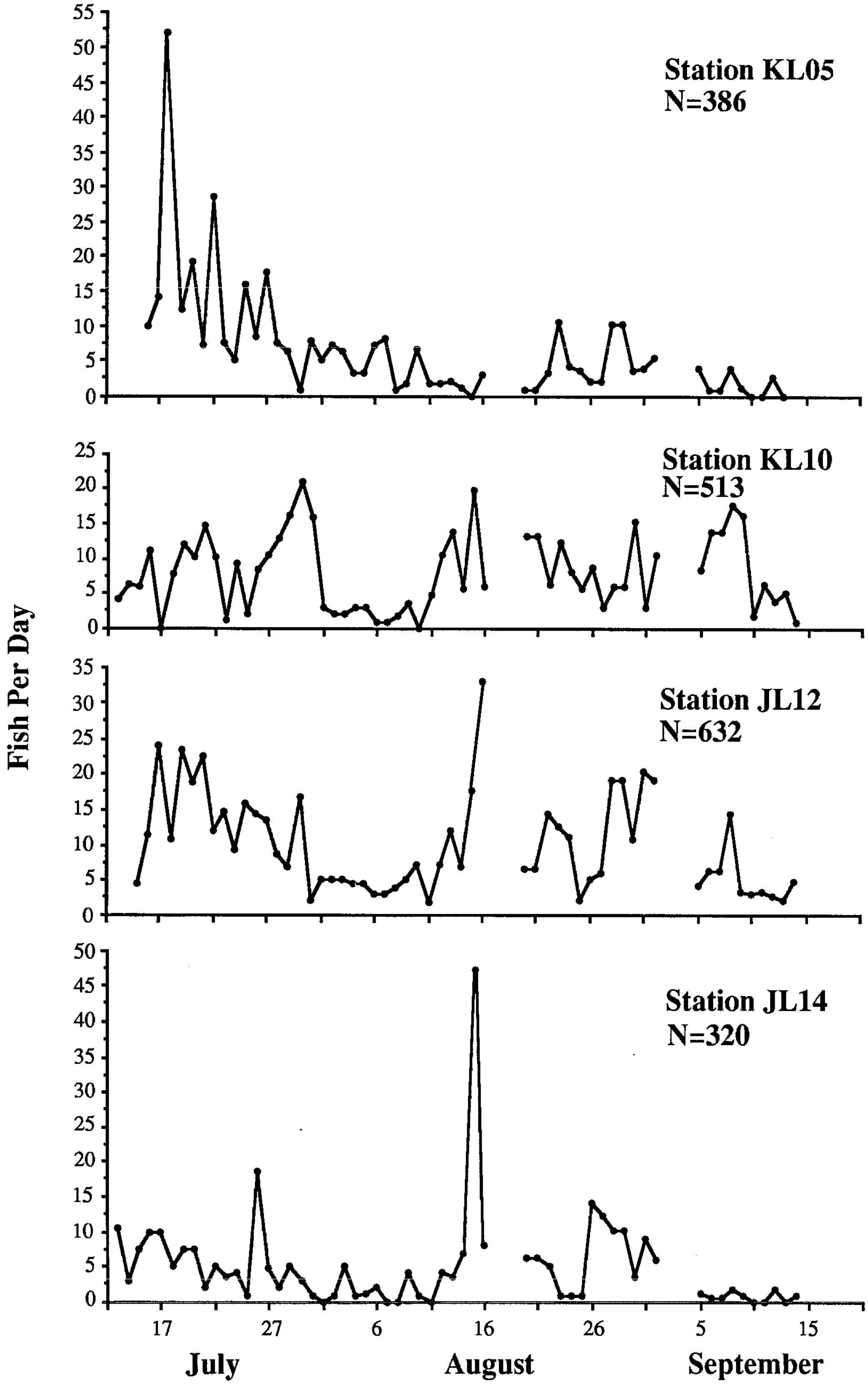


FIGURE 8.—Daily catch per unit effort (fish/day) for Arctic char at fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1989.

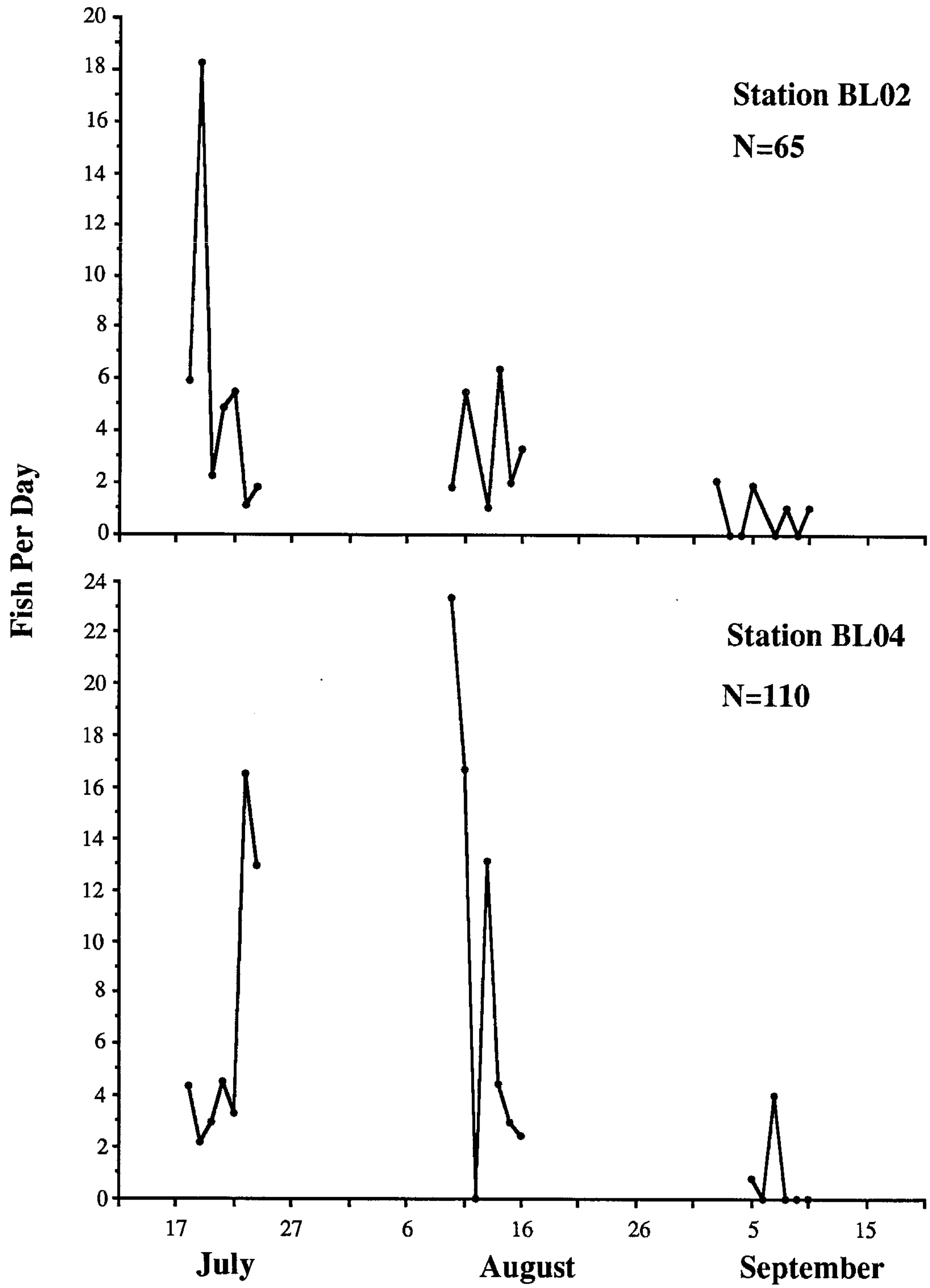


FIGURE 9.—Daily catch per unit effort (fish/day) for Arctic char at fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1989.

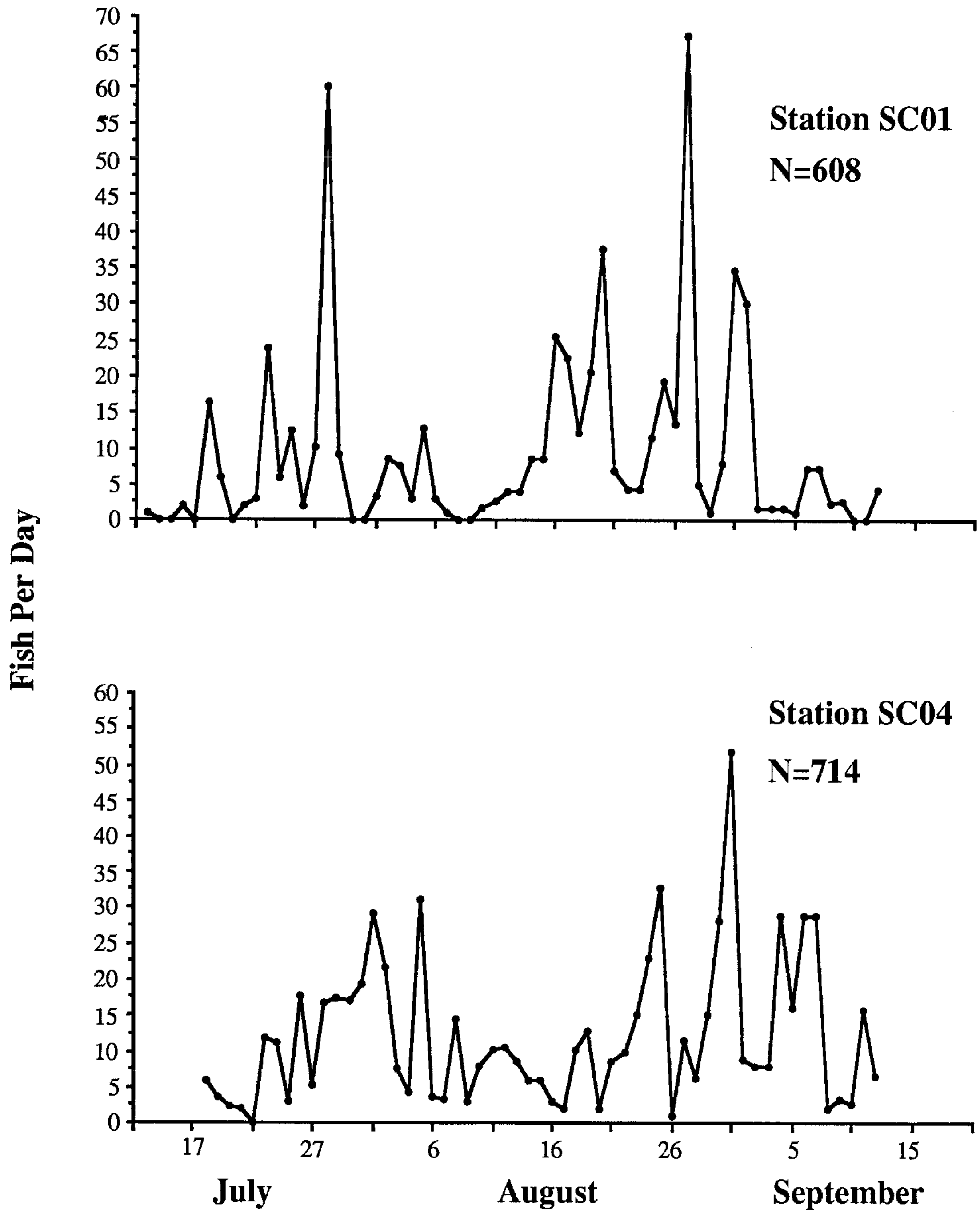


FIGURE 10.—Daily catch per unit effort (fish/day) for small Arctic cisco (<200 mm fork length) at fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1989.

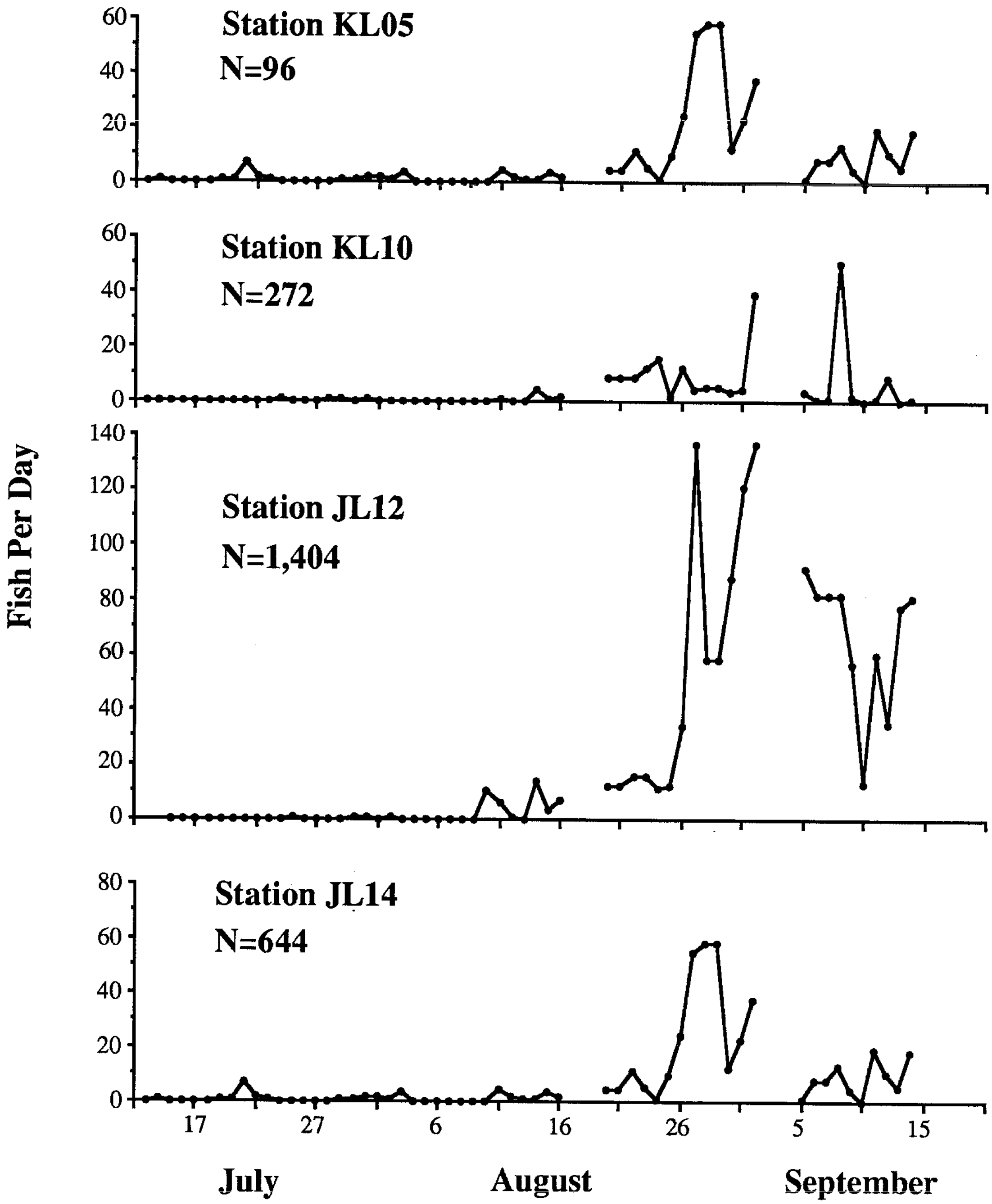


FIGURE 11.—Daily catch per unit effort (fish/day) for small Arctic cisco (<200 mm fork length) at fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1989.

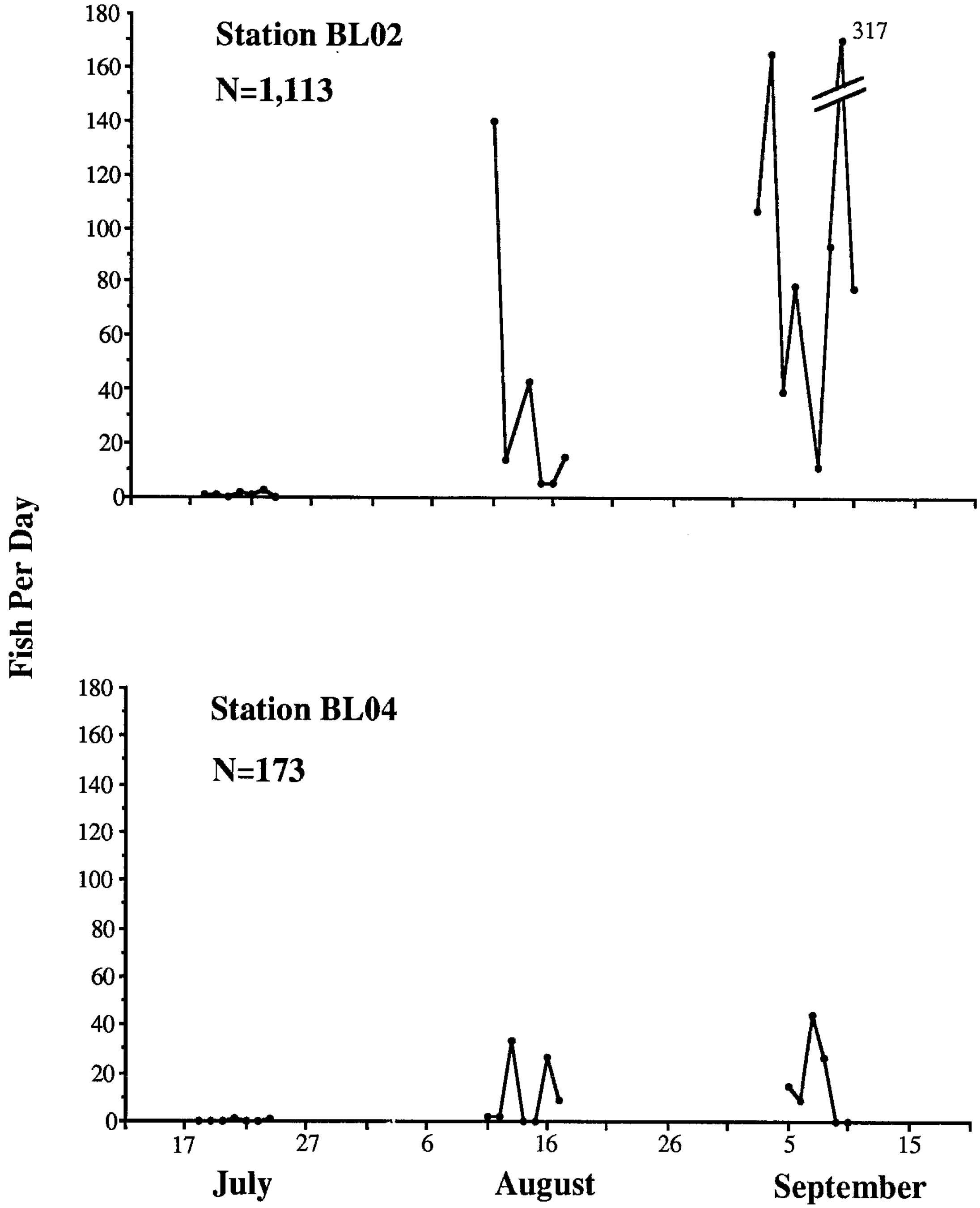


FIGURE 12.—Daily catch per unit effort (fish/day) for small Arctic cisco (<200 mm fork length) at fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1989.

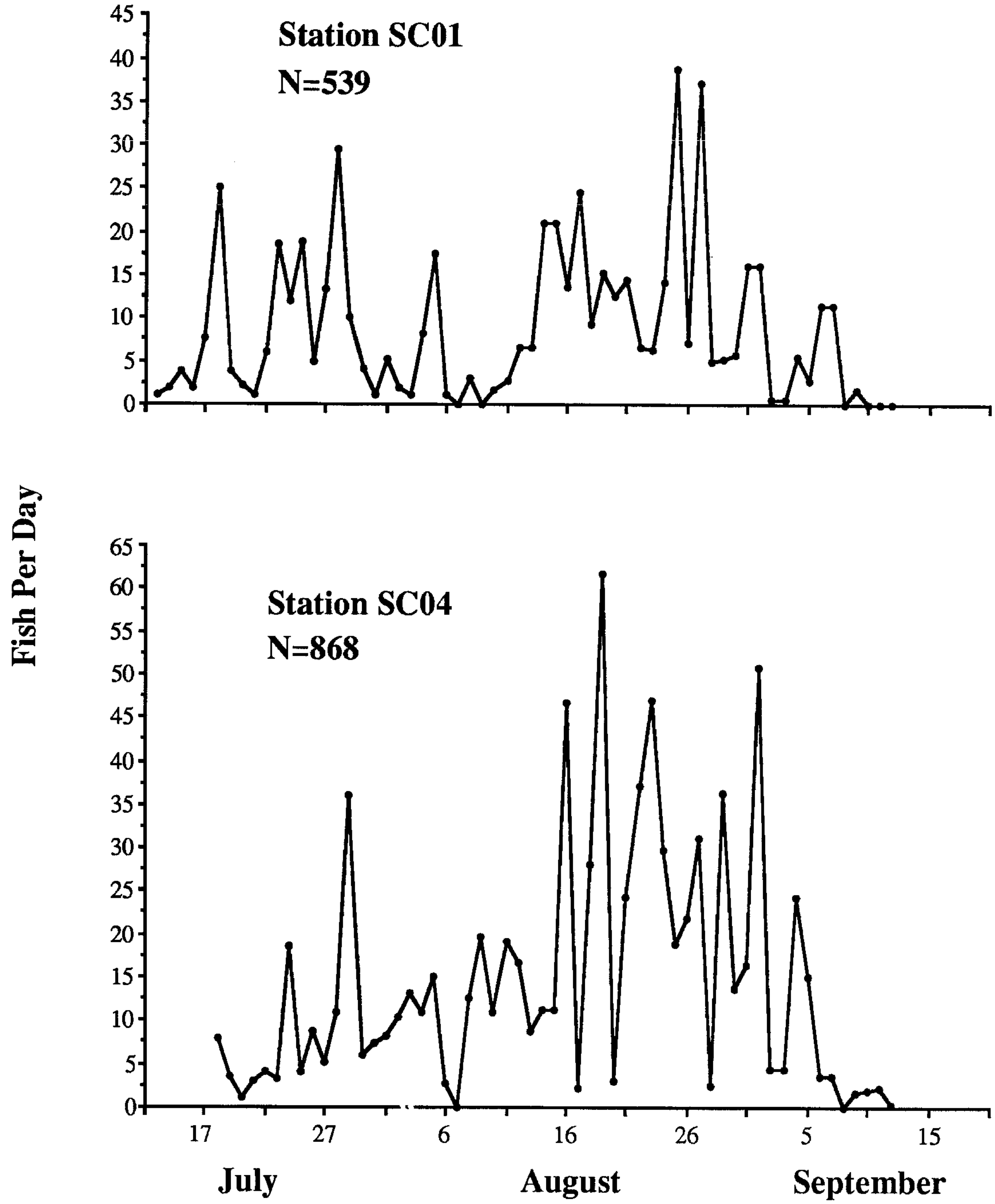


FIGURE 13.—Daily catch per unit effort (fish/day) for large Arctic cisco (≥200 mm fork length) at fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1989.

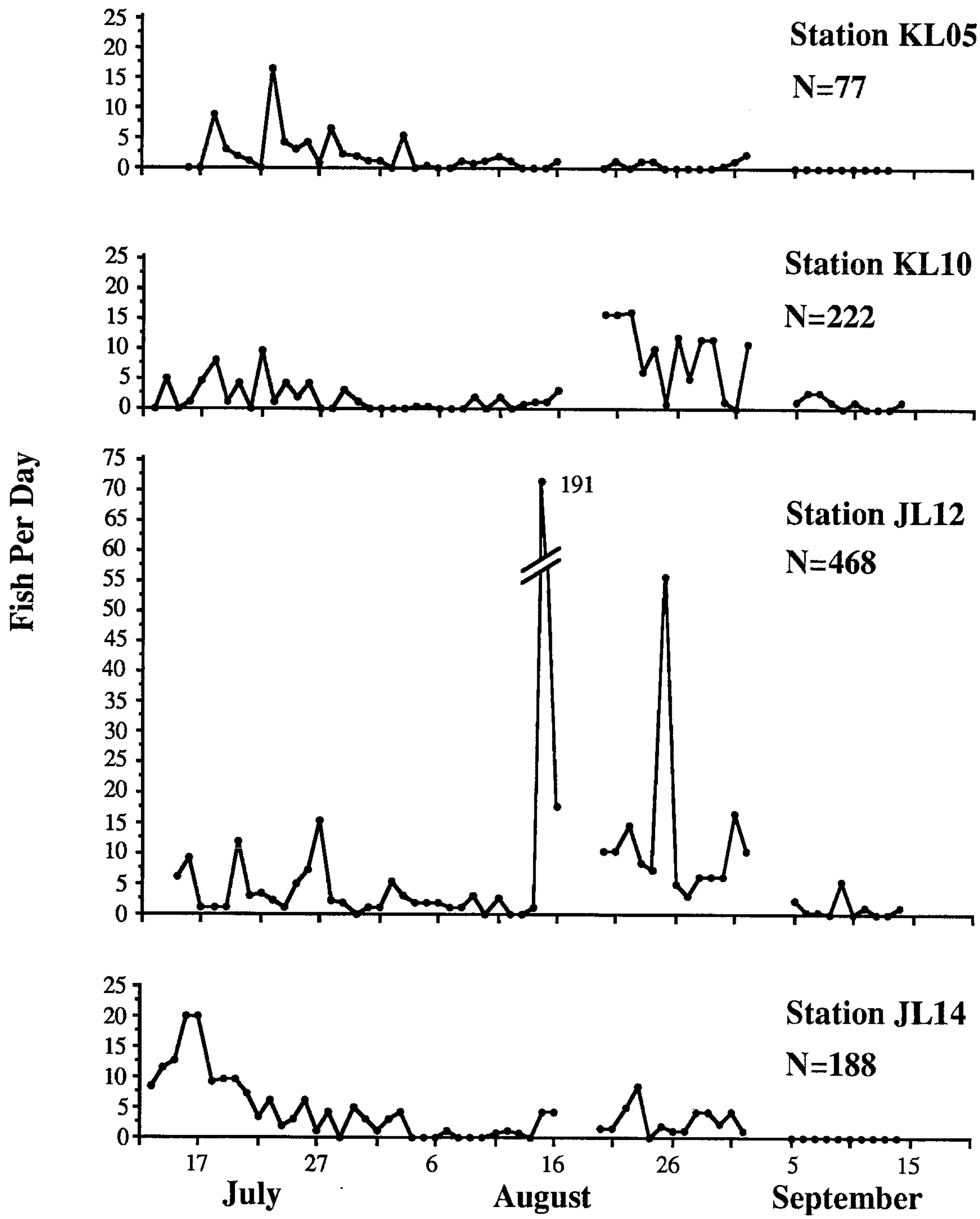


FIGURE 14.—Daily catch per unit effort (fish/day) for large Arctic cisco (≥200 mm fork length) at fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1989.

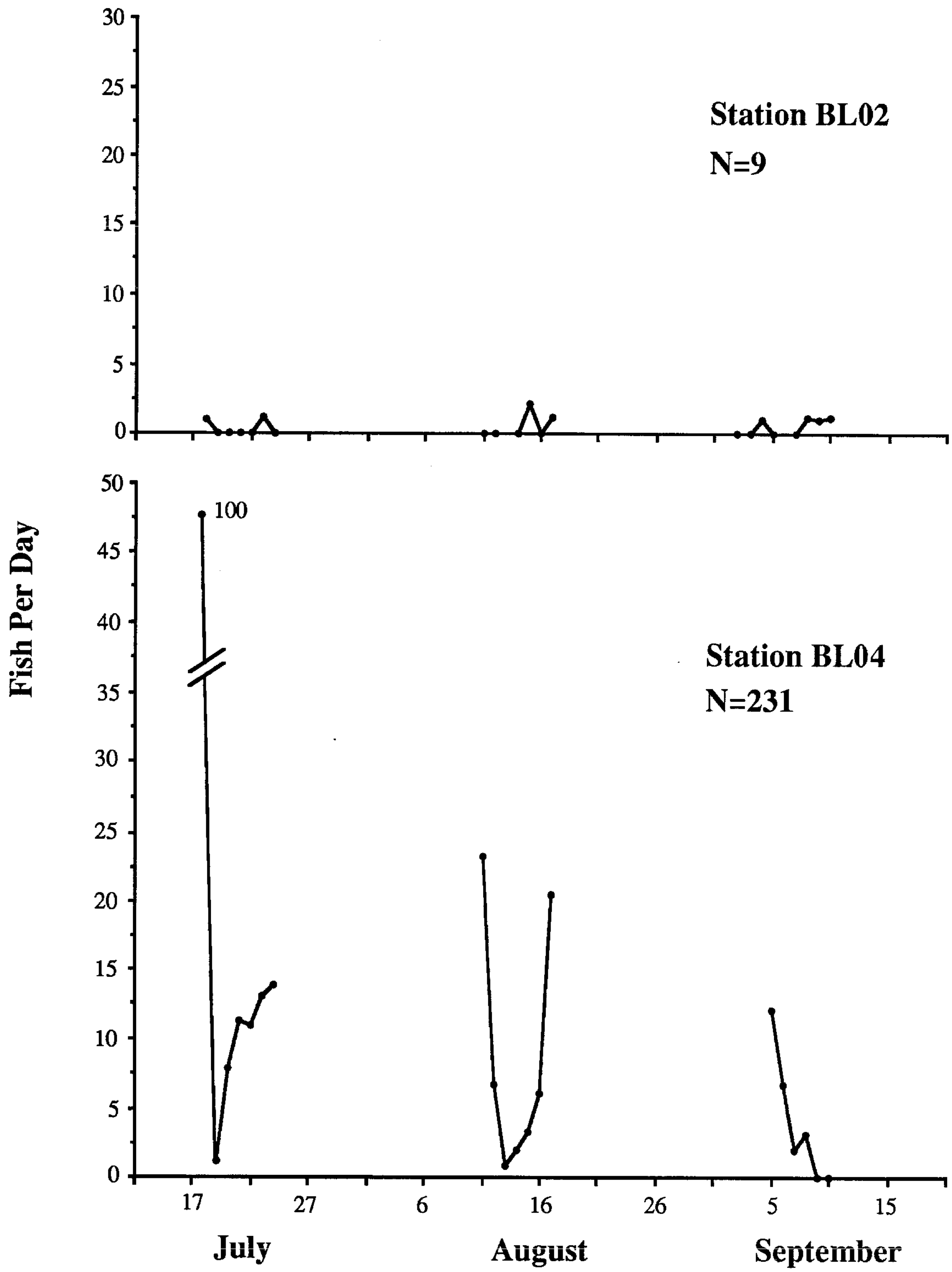


FIGURE 15.—Daily catch per unit effort (fish/day) for large Arctic cisco (≥200 mm fork length) at fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1989.

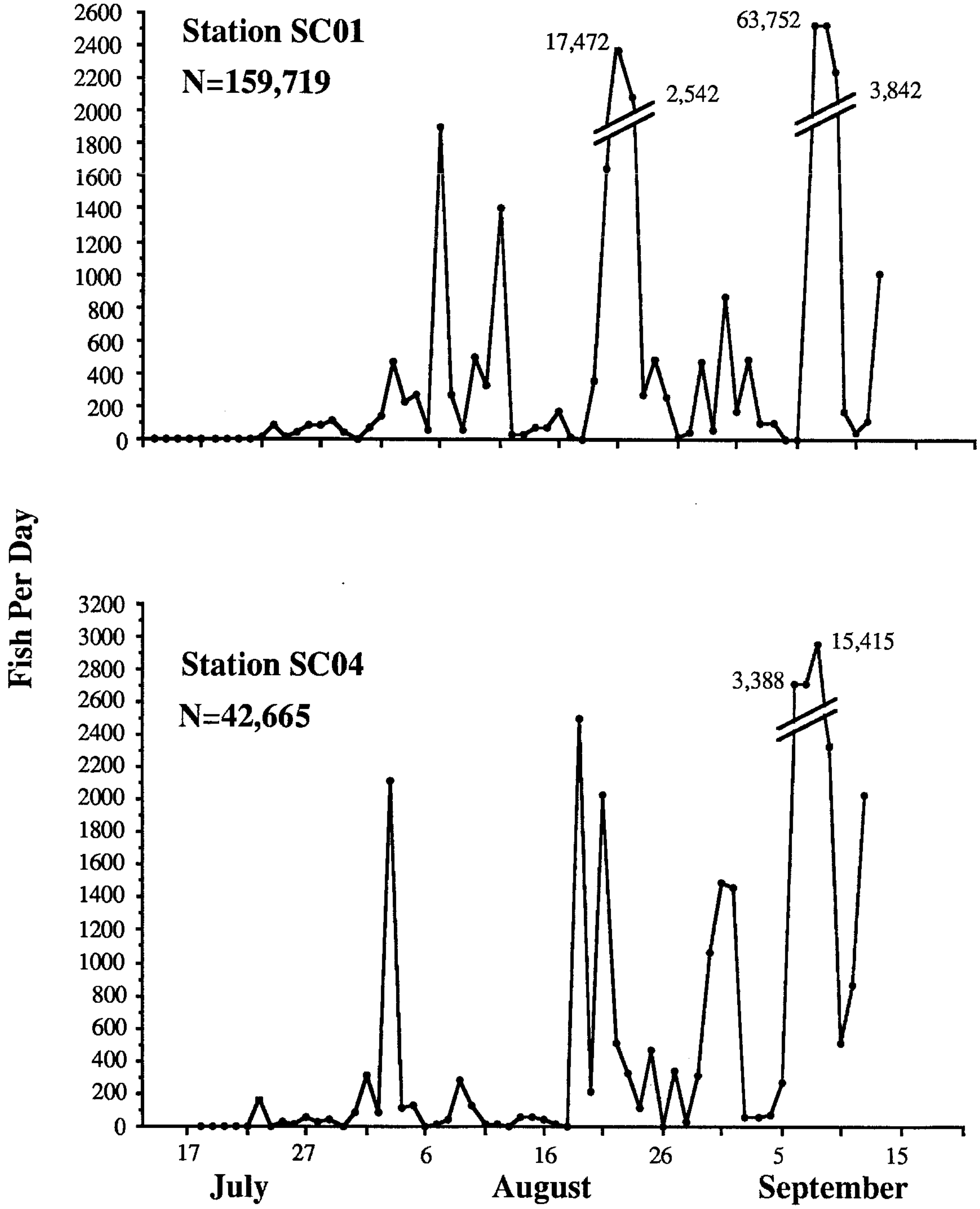


FIGURE 16.—Daily catch per unit effort (fish/day) for Arctic cod at fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1989.

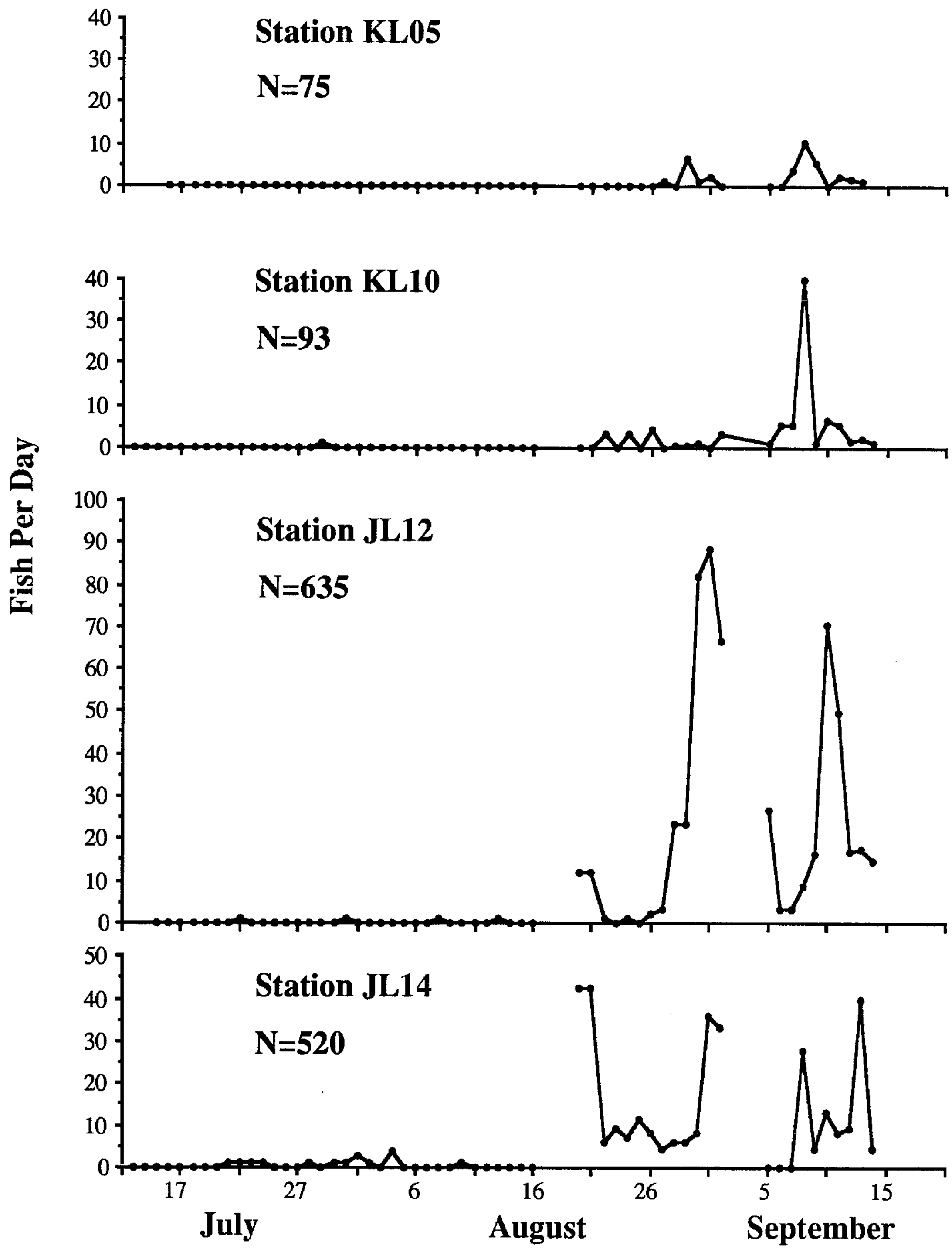


FIGURE 17.—Daily catch per unit effort (fish/day) for Arctic cod at fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1989.

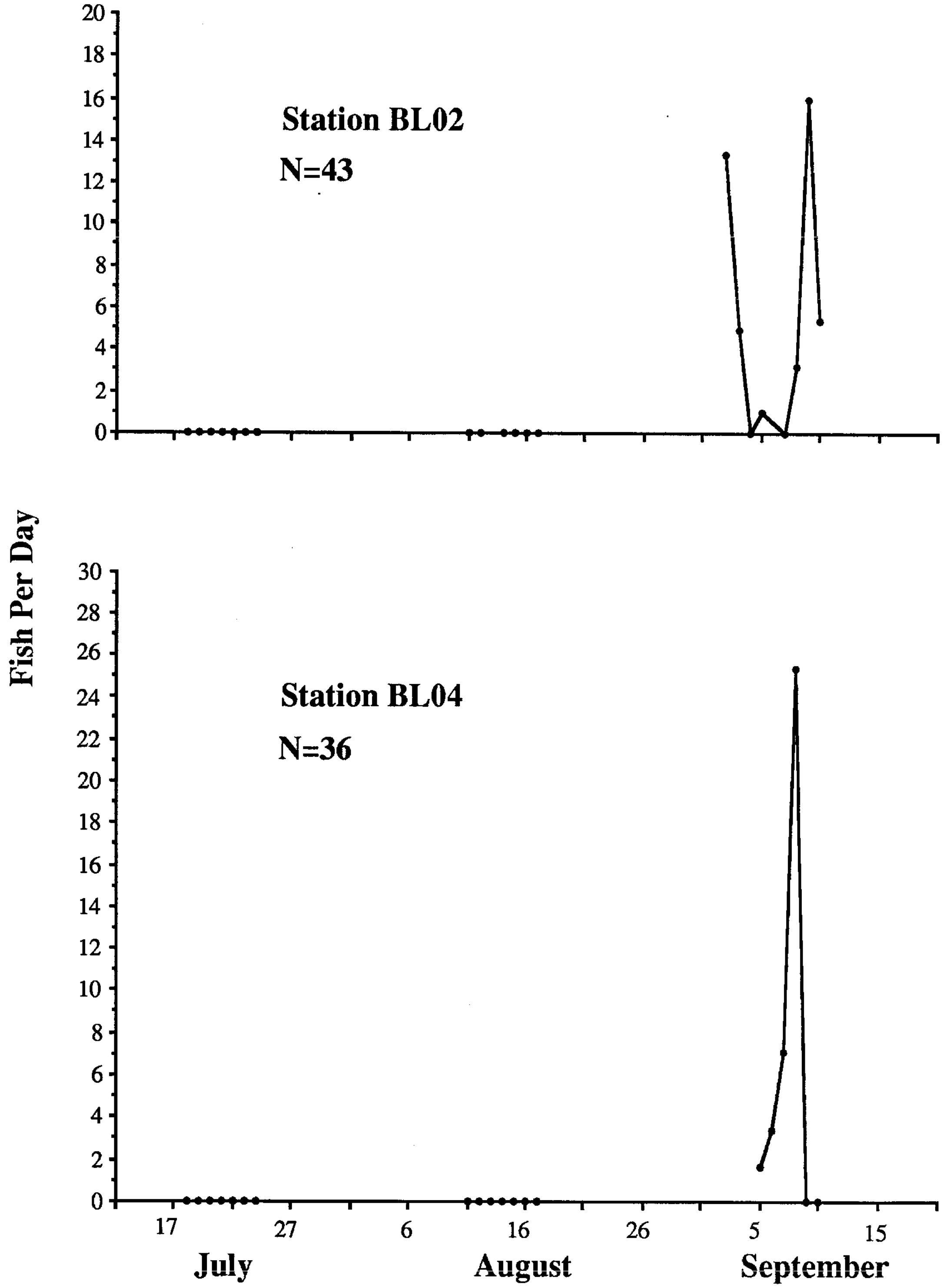


FIGURE 18.—Daily catch per unit effort (fish/day) for Arctic cod at fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1989.

Fourhorn sculpin.—Abundance of fourhorn sculpin was relatively high in all study areas but the highest average catch rate (165.9 fish/day) was at Station SC04 in Camden Bay (Table 4). Average catch rates at stations located in Kaktovik and Jago lagoons ranged from 109.0-142.5 fish/day. Fourhorn sculpin were less abundant at Beaufort Lagoon where average catch rate was 77.7 fish/day.

Peaks in fourhorn sculpin abundance were variable among locations but generally occurred either during July or mid-August (Figures 19-21). The highest daily catch rate (682.5 fish/day) was on August 12 at Station SC01 in Camden Bay. Catch rates exceeding 500 fish/day were observed at Station SC01 on July 17 and August 14 and at Station SC04 on July 20 and July 26. At Kaktovik and Jago lagoons, catches exceeding 500 fish/day occurred in August at stations KL10 and JL12. Unlike other stations in Kaktovik and Jago lagoons, peak catches of nearly 400 fish/day were observed at Station KL10 during July. At Beaufort Lagoon, the highest catch rates of fourhorn sculpin were recorded during September at stations BL04 (300 fish/day) and BL02 (150 fish/day).

Arctic flounder.—Arctic flounder were captured at all sampling stations, but were most abundant at Station KL05 in Kaktovik Lagoon where the average catch rate was 65.9 fish/day (Table 4). The next highest average catch rates were at stations BL02 (51.8 fish/day) and BL04 (27.1 fish/day) in Beaufort Lagoon. High catch rates at Beaufort Lagoon were the result of large catches of young-of-the-year flounder (238-466 fish/day) during three days in September (Figure 22). Excluding these high catches of young-of-the-year fish, catch rates were generally less than 50 fish/day. Average catch rates at Camden Bay and Jago Lagoon were 12.8 and 12.2 fish/day, respectively.

Abundance of Arctic flounder decreased at some locations as summer progressed (Figures 23 and 24). In Kaktovik Lagoon (Station KL05), catches of Arctic flounder frequently exceeded 100 fish/day during July and August then decreased to less than 25 fish/day during September. This pattern of temporal abundance also was observed in Jago Lagoon (Station JL14) and Camden Bay (Station SC04); however, highest catches at these locations rarely exceeded 100 fish/day.

Relative Abundance and Distribution - Gill Nets

A total of 451 fish were caught in 190 gill net sets in Camden Bay during 1989. Seven fish species were captured with Arctic cisco and Arctic char comprising 97% of the total catch. Other fish captured included seven fourhorn sculpin, three pink salmon, three Pacific herring, one least cisco, and one Arctic sculpin.

Arctic cisco were more abundant at nearshore stations in Camden Bay (Table 5). Catch rates for Arctic cisco in the upper 2.4 m of the water column at Station CB01 (1.52 fish/hour) were significantly greater ($P<0.05$) than catch rates at stations CB02 (0.42 fish/hour) and CB04 (0.02 fish/hour). Similarly, at depths of 2.4-4.9 m, catch rates of Arctic cisco at Station CB02 (0.14 fish/hour) were significantly greater ($P<0.05$) than catch rates at Station CB04 (0.01 fish/hour). Catches of Arctic cisco were generally higher early in the season with 79% of the fish caught prior to August 12.

Mean catch rates of Arctic char were also slightly higher at nearshore stations; however, no significant differences were detected. Mean catch rate in the upper 2.4 m of the water column at stations CB01, CB02, and CB04 were 0.16, 0.19, and 0.02 fish/hour, respectively. Though few fish were caught at the 7.3 m contour, vertical distribution of the catch at the 4.9 m contour indicated a preference for the upper water column. Like Arctic cisco, the majority (89%) of Arctic char were captured prior to August 12.

Movements

Because of mechanical problems with the dental injectors used to administer dye marks, only 284 small Arctic cisco (<200 mm) were dye marked at Camden Bay during 1989. No fish were dye marked at Beaufort, Kaktovik, or Jago lagoons. Four (1.4%) of the fish marked at Camden Bay (Simpson Cove) traveled approximately 55 km to the east and were recaptured at fyke net stations in Kaktovik and Jago lagoons. In addition to these recaptured fish, four small Arctic cisco dye marked by LGL

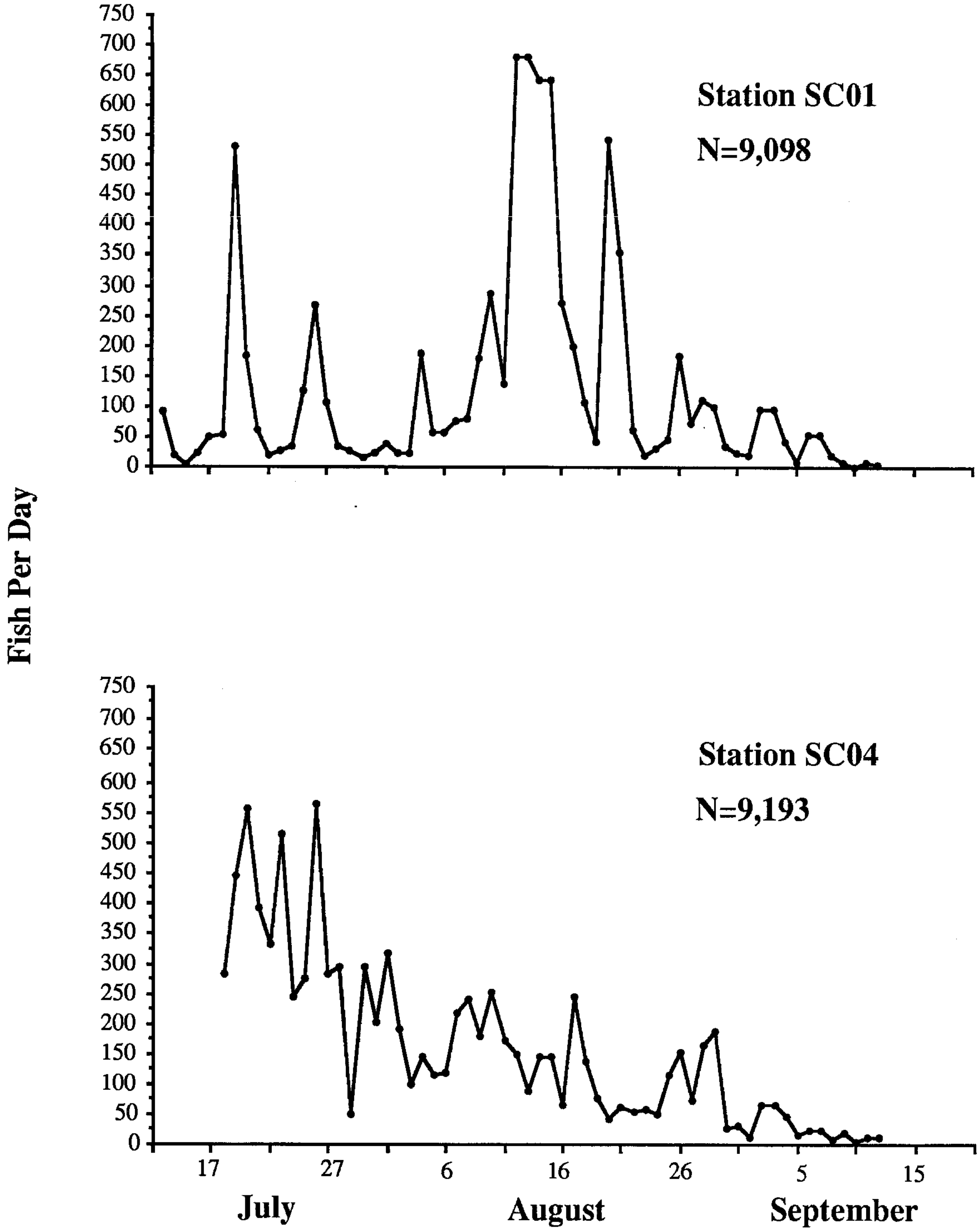


FIGURE 19.—Daily catch per unit effort (fish/day) for fourhorn sculpin at fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1989.

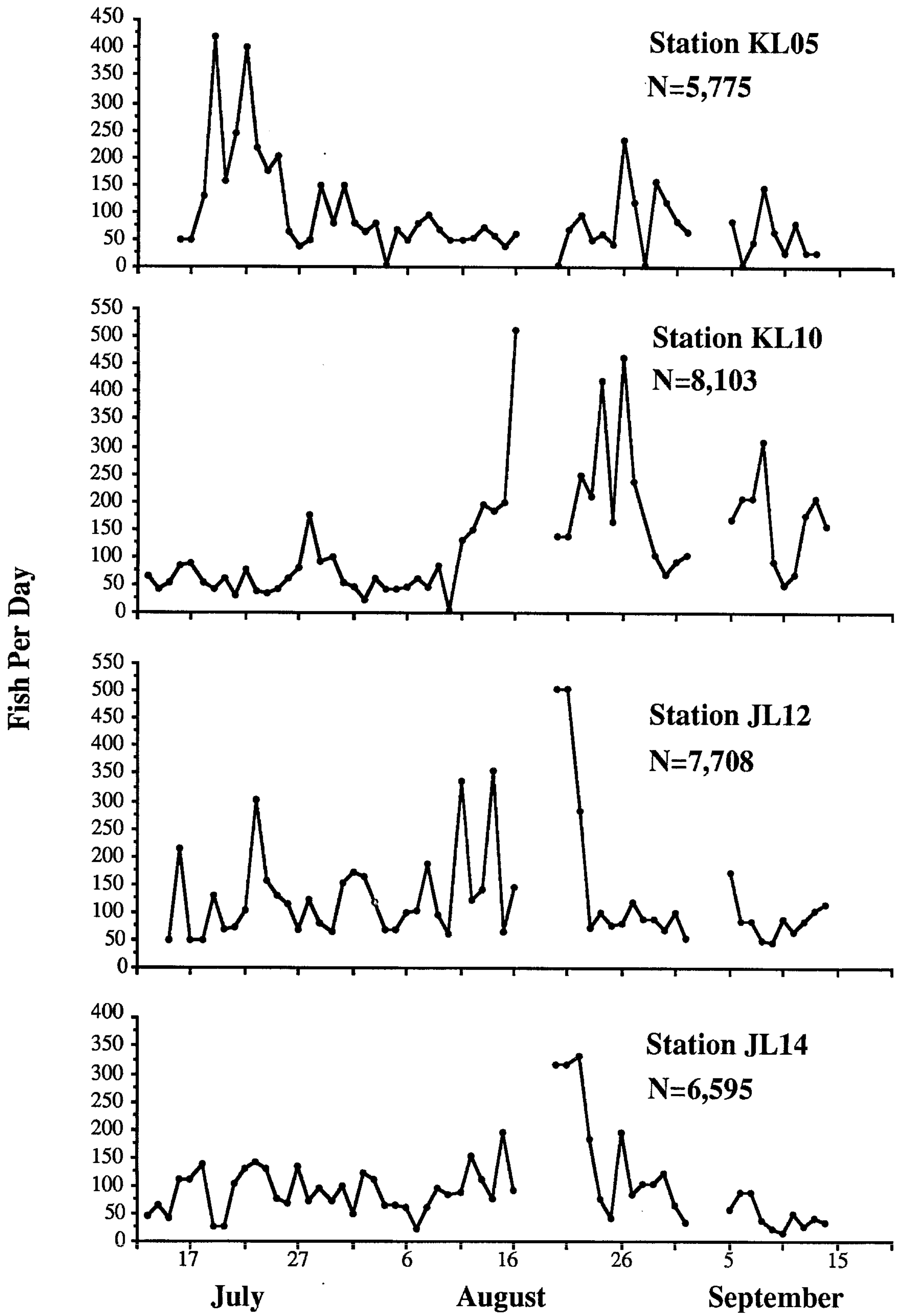


FIGURE 20.—Daily catch per unit effort (fish/day) for fourhorn sculpin at fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1989.

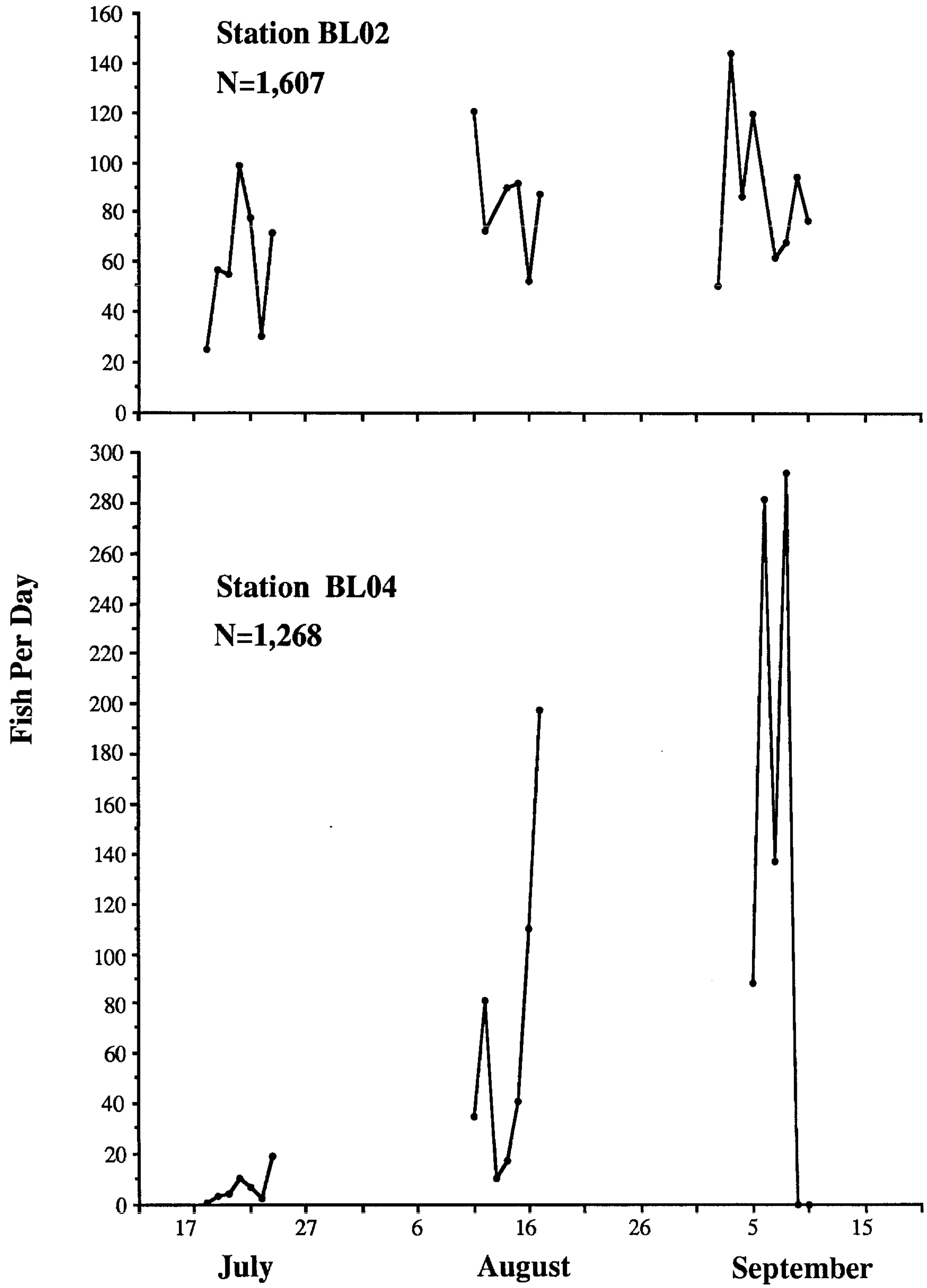


FIGURE 21.—Daily catch per unit effort (fish/day) for fourhorn sculpin at fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1989.

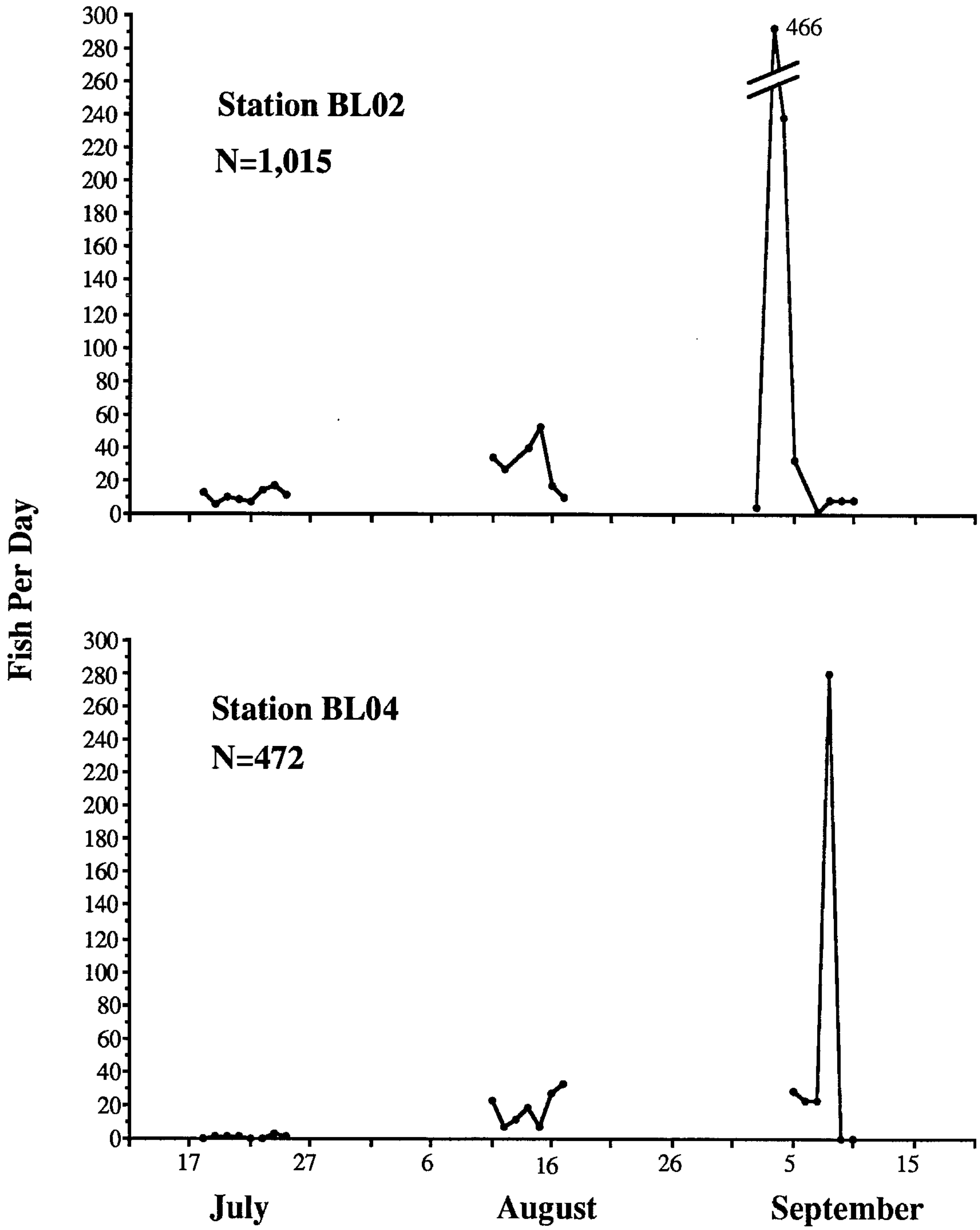


FIGURE 22.—Daily catch per unit effort (fish/day) for Arctic flounder at fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1989.

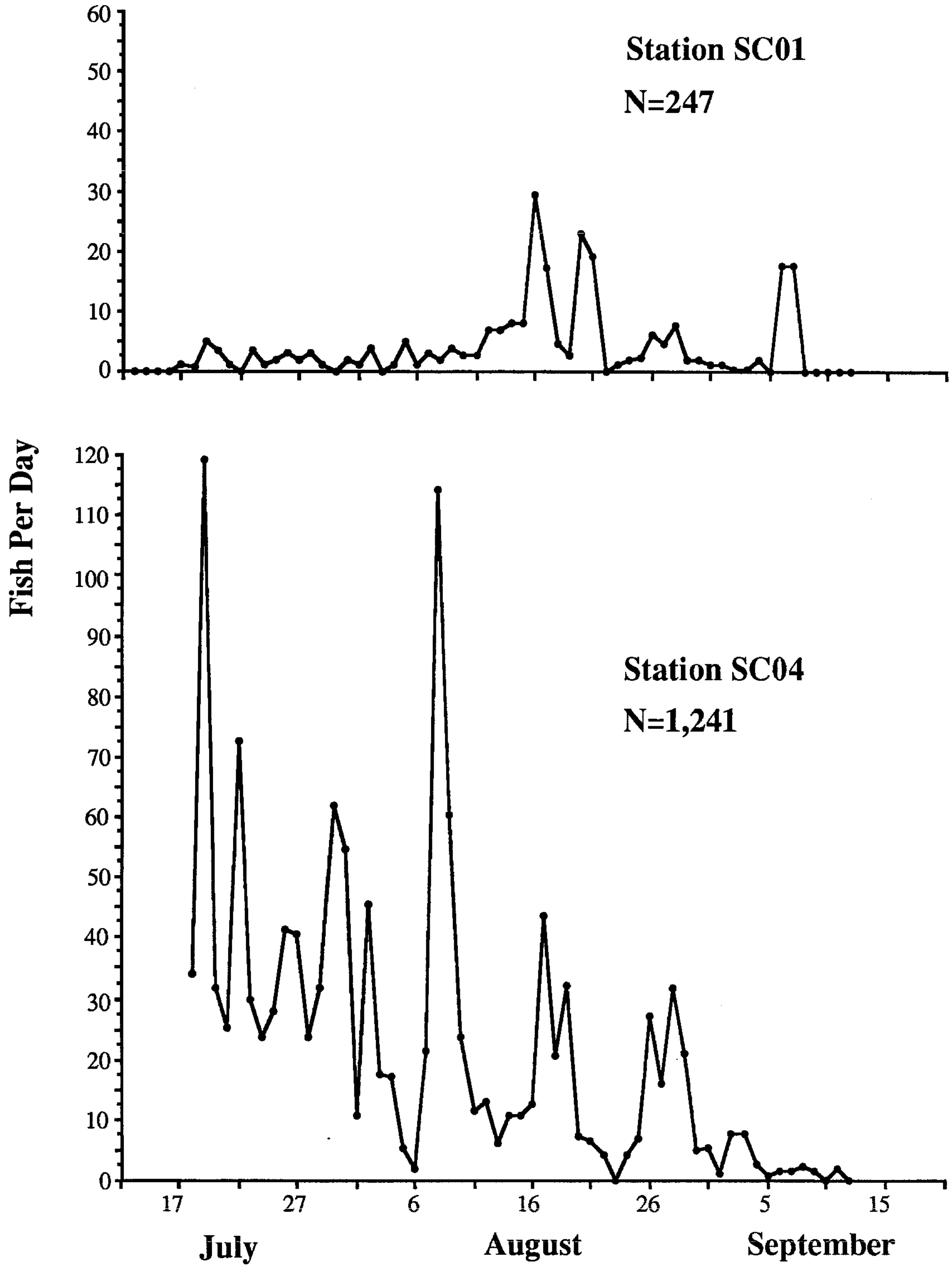


FIGURE 23.—Daily catch per unit effort (fish/day) for Arctic flounder at fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1989.

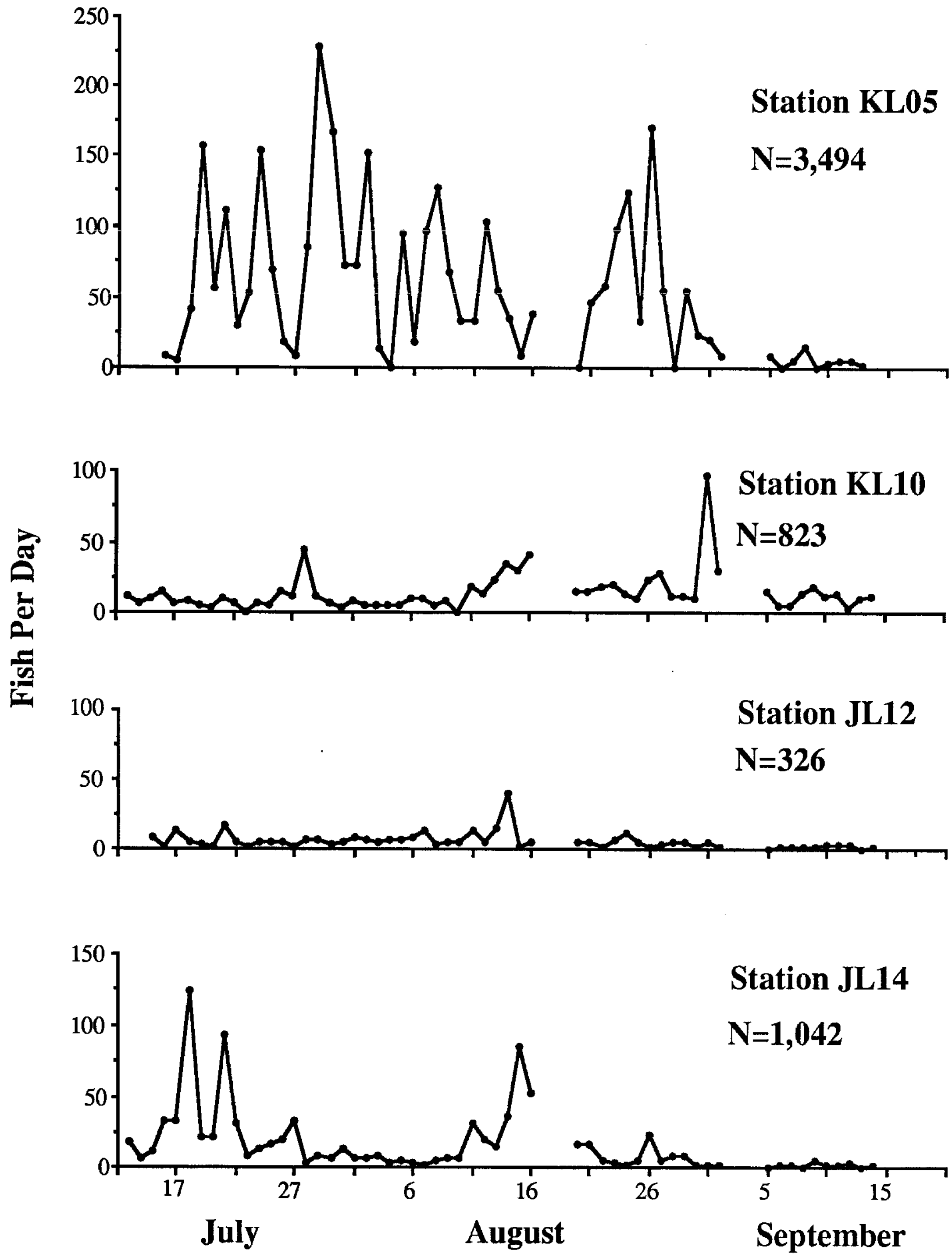


FIGURE 24.—Daily catch per unit effort (fish/day) for Arctic flounder at fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1989.

TABLE 5.—Mean (± SE) catch per hour (CPUE), CPUE range, total catch, and total effort (hours) for gill nets set in Camden Bay, Alaska, July-September 1989. Mean CPUE values along a row without a letter in common are significantly different (Newman-Keuls multiple range test, P<0.05).

Depth interval and variable	Station		
	CB01	CB02	CB04
	Arctic char		
0 - 2.4 m			
Mean CPUE	0.16 ± 0.07z	0.19 ± 0.10z	0.02 ± 0.01z
CPUE range	0 - 3.36	0 - 6.00	0 - 0.64
Total catch	25	37	4
Total effort	222.1	244.2	260.6
2.4 - 4.9 m			
Mean CPUE		0.05 ± 0.02z	0.01 ± 0.01z
CPUE range		0 - 0.81	0 - 0.37
Total catch		9	1
Total effort		244.2	260.6
4.9 - 7.3 m			
Mean CPUE			0.05 ± 0.04
CPUE range			0 - 2.58
Total catch			8
Total effort			260.6
	Arctic cisco		
0 - 2.4 m			
Mean CPUE	1.52 ± 0.34z	0.42 ± 0.11y	0.02 ± 0.01y
CPUE range	0 - 17.00	0 - 5.43	0 - 0.35
Total catch	234	86	3
Total effort	222.1	244.2	260.6
2.4 - 4.9 m			
Mean CPUE		0.14 ± 0.04z	0.01 ± 0.01y
CPUE range		0 - 1.62	0 - 0.37
Total catch		28	1
Total effort		244.2	260.6
4.9 - 7.3 m			
Mean CPUE			0.00
CPUE range			
Total catch			0
Total effort			260.6

Ecological Research at Prudhoe Bay in 1989 were recaptured at our fyke net stations. Three of these fish were recaptured at Camden Bay (Simpson Cove) and one was recaptured in Jago Lagoon. Recaptured Arctic cisco ranged from 169-229 mm in fork length.

No fish were marked with external tags in 1989; however, 24 fish tagged in previous years were recaptured (Table 6). Eighteen of the fish recaptured were Arctic flounder and fourhorn sculpin which were tagged in Kaktovik and Jago lagoons in 1988. Thirteen of these fish were recaptured at their original tagging location and the others traveled short distances within Kaktovik and Jago lagoons. Two Arctic char that were tagged in the Hulahula and Aichilik rivers were recaptured in nearby coastal lagoon areas. Two Arctic cisco were recaptured in 1989. One was tagged at Camden Bay (Simpson Cove) in 1987 and recaptured in the same area in 1989. The second Arctic cisco, originally tagged at Oruktalik Lagoon in 1986, traveled approximately 75 km and was recaptured in a gill net at Camden Bay on July 26. A saffron cod tagged at Oruktalik Lagoon in 1986 was recaptured in Kaktovik Lagoon. Distance between tagging and recapture locations was approximately 30 km. The longest distance traveled (175 km) was by a broad whitefish which was tagged near West Dock in Prudhoe Bay and recaptured in Kaktovik Lagoon.

Length Frequency - Fyke Nets

Arctic char.—Arctic char captured in fyke nets during 1989 ranged from 53 to 704 mm fork length (Figures 25-27; Appendix 1). Arctic char between 150 and 249 mm fork length were dominant throughout the summer at all study areas. Larger Arctic char (>400 mm) were caught at all study areas; however, the number of fish in this size group steadily decreased as the summer progressed.

Arctic cisco.—Arctic cisco ranged from 35 to 566 mm fork length at the three study areas (Figures 28-30; Appendix 2). Three distinct size groups (75-119 mm, 150-239 mm, and 330-419 mm) were apparent at all locations. At Camden Bay, Arctic cisco in the 150-239 mm and 330-419 mm size groups were prevalent from July 13 through August 15. Smaller fish (75-119 mm) began entering the catch in mid-August and by September these fish dominated the Arctic cisco catch. At Kaktovik, Jago, and Beaufort lagoons, length frequency distributions were similar to Camden Bay with two exceptions. Arctic cisco in the 150-239 size group were not a dominant component of the catch at Kaktovik, Jago, and Beaufort lagoons until mid-August. Also, smaller Arctic cisco (75-119 mm) appeared as a dominant component of the catch two weeks earlier than at Camden Bay. Few Arctic cisco between 240 and 329 mm were collected at any study area.

Arctic cod.—Arctic cod captured during 1989 ranged from 41 to 278 mm fork length (Figures 31-33; Appendix 3). Two modal groups were apparent at all study areas, one at 80-89 mm and the other at 110-129 mm. At Camden Bay, the length frequency distribution of Arctic cod was similar throughout the summer. The length frequency distribution of fish at Kaktovik and Jago lagoons was similar to Camden Bay; however few Arctic cod entered the catch until mid-August. This trend also was observed at Beaufort Lagoon with no fish caught prior to September.

Fourhorn sculpin.—Fourhorn sculpin captured in fyke nets during 1989 ranged between 19 and 296 mm fork length (Figures 34-36; Appendix 4). Small fourhorn sculpin between 50 and 89 mm fork length were dominant at Beaufort, Kaktovik, and Jago lagoons. Fish in this size group also appeared as a frequency peak at Camden Bay, but were not as prevalent as fish in the 100-129 mm size group. Fourhorn sculpin between 150 and 219 mm fork length were more prevalent at Kaktovik and Jago lagoons than at other locations. Little change was observed throughout the summer in the length frequency distribution of fourhorn sculpin at each study area.

Arctic flounder.—Arctic flounder ranged from 22 to 310 mm fork length at the three study areas (Figures 37-39; Appendix 5). Three modal groups were apparent at most locations. In Camden Bay, Kaktovik and Jago lagoons, the dominant size group for Arctic flounder was 150-259 mm with a secondary peak at 60-109 mm. The third size group (20-49 mm) representing young-of-the-year fish was apparent at Kaktovik, Jago, and Beaufort lagoons by mid-August. These smaller young-of-the-year fish never entered the catch at Camden Bay. Except for young-of-the-year, proportions of various

TABLE 6.—Summary of tagging and recapture location data for fish recaptured in Arctic Refuge coastal waters, summer 1989.

Species and tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)[a]	Length at recapture (mm)[a]	Tag number
Arctic cisco							
Oruktalik Lagoon	08/16/86	CB01	07/26/89	75.0	364	389	FWS 07522
SC01	07/12/87	SC04	08/24/89	4.2	366	396	FWS 10024
Arctic char							
Hulahula River	09/07/83	JL14	07/13/89	30.0	377	618	FWS 05610
Aichilik River	08/15/84	BL02	07/18/89	7.0	467	503	FWS 03437
Arctic flounder							
KL10	08/14/88	JL12	08/01/89	9.0	290	285	FWS 09192
JL14	07/27/88	JL12	09/04/89	0.0	255	255	FWS 09109
JL14	08/06/88	JL14	07/20/89	0.0	230	237	FWS 09203
JL14	08/06/88	JL14	07/21/89	0.0	230	237	FWS 09203
KL05	09/08/88	JL14	07/21/89	12.5	245	247	FWS 09496
KL05	09/08/88	JL14	07/24/89	12.5	225	225	FWS 09499
JL14	07/20/88	JL14	07/26/89	0.0	260	260	FWS 09070
JL14	09/02/88	JL14	08/03/89	0.0	268	270	FWS 09478
JL14	07/20/88	JL14	08/15/89	0.0	260	260	FWS 09070
KL05	07/30/88	KL05	07/30/89	0.0	201	210	FWS 09136
KL10	07/29/88	KL05	08/05/89	5.5	241	246	FWS 09118
KL05	08/06/88	KL05	08/13/89	0.0	202	207	FWS 09215
KL05	08/18/88	KL05	08/16/89	0.0	284	290	FWS 09186
KL05	08/18/88	KL05	08/19/89	0.0	230	229	FWS 09177
KL05	08/06/88	KL05	08/29/89	0.0	225	232	FWS 09249
KL05	08/15/88	KL10	07/31/89	5.5	261	248	FWS 09188

TABLE 6.—Continued.

Species and tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)[a]	Length at recapture (mm)[a]	Tag number
Fourhorn sculpin							
JL14	09/01/88	JL14	07/30/89	0.0	274	284	FWS 09469
JL14	09/01/88	JL14	08/02/89	0.0	282	294	FWS 09475
Saffron cod							
Oruktalik Lagoon	08/20/86	KL05	08/23/89	30.0	427	475	FWS 07688
Broad whitefish							
Prudhoe Bay (West Dock)	07/29/88	KL10	07/17/89	175.0	446	438	LGL 02875

[a] Fork length

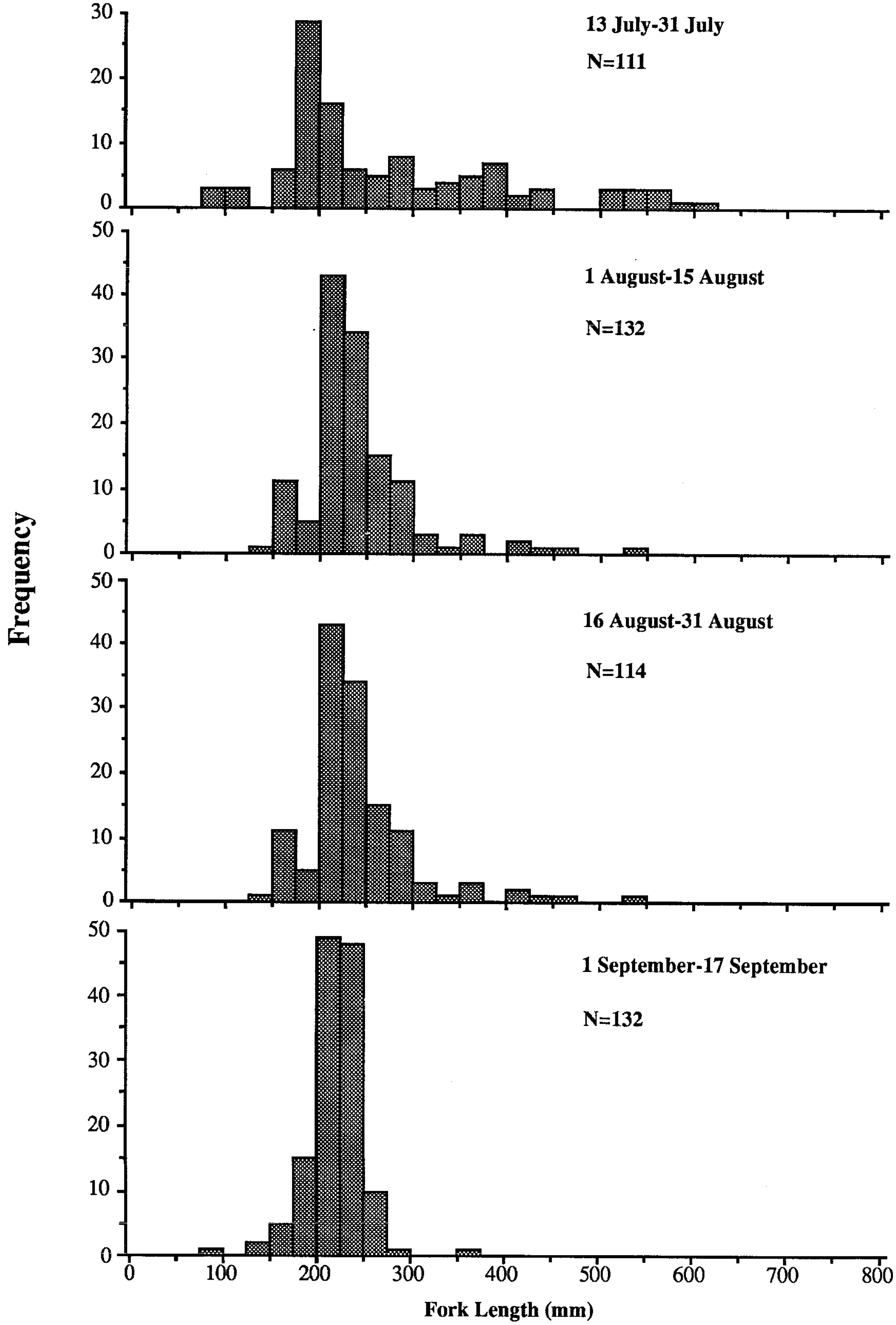


FIGURE 25.—Length frequency of Arctic char captured by fyke nets in Camden Bay, Alaska, July-September 1989.

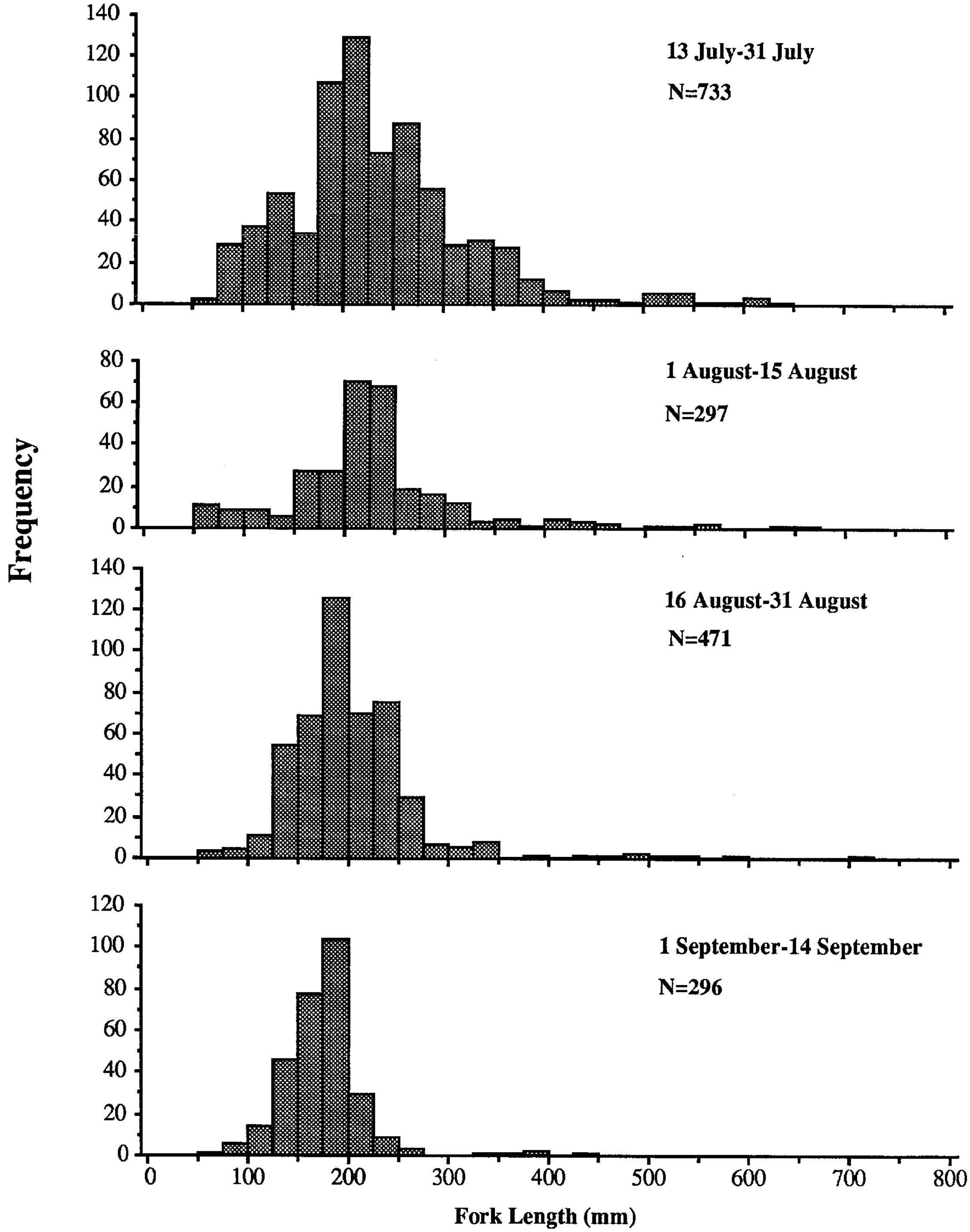


FIGURE 26—Length frequency of Arctic char captured by fyke nets in Kaktovik and Jago lagoons, Alaska, July-September 1989.

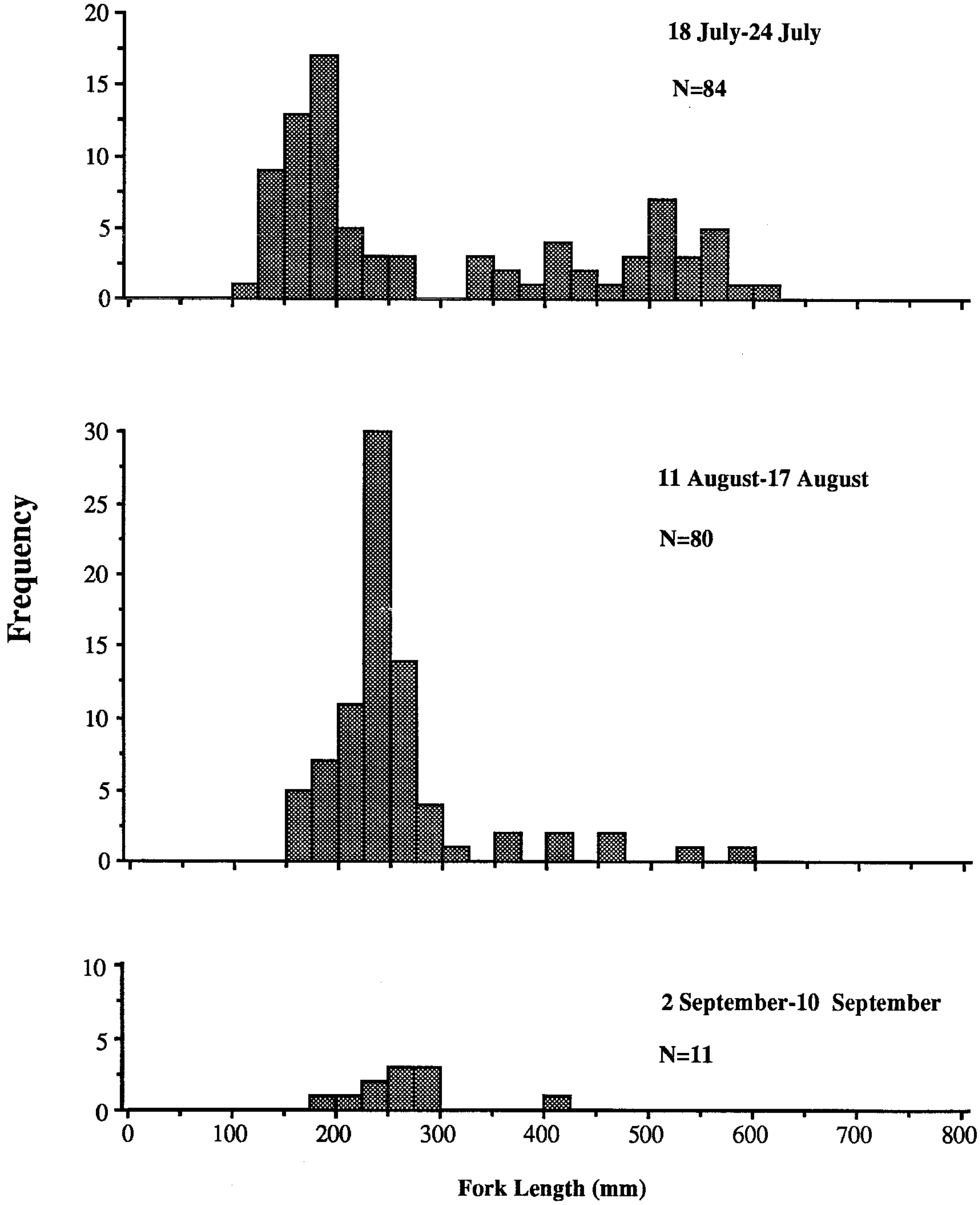


FIGURE 27.—Length frequency of Arctic char captured by fyke nets in Beaufort Lagoon, Alaska, July-September 1989.

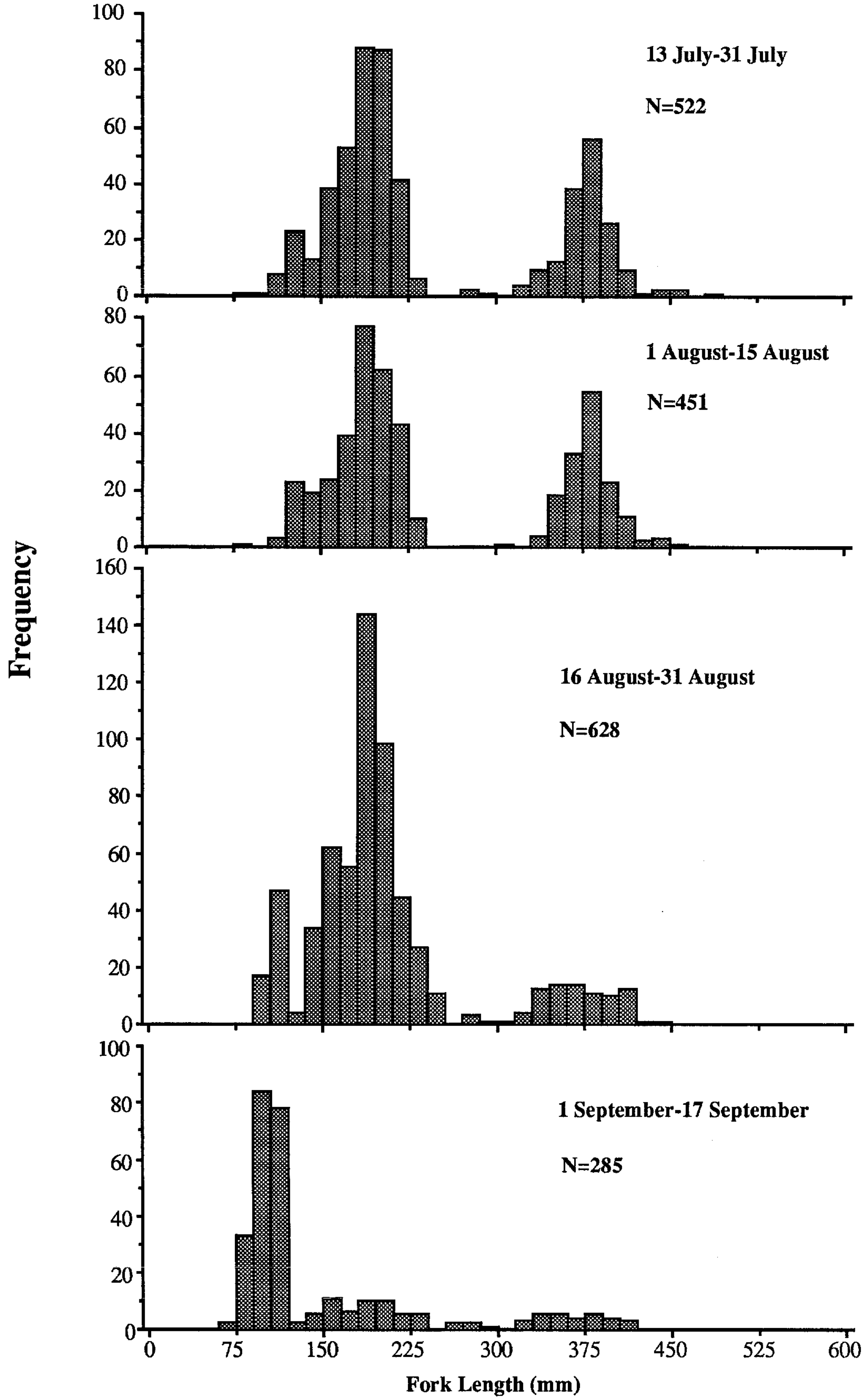


FIGURE 28.—Length frequency of Arctic cisco captured by fyke nets in Camden Bay, Alaska, July-September 1989.

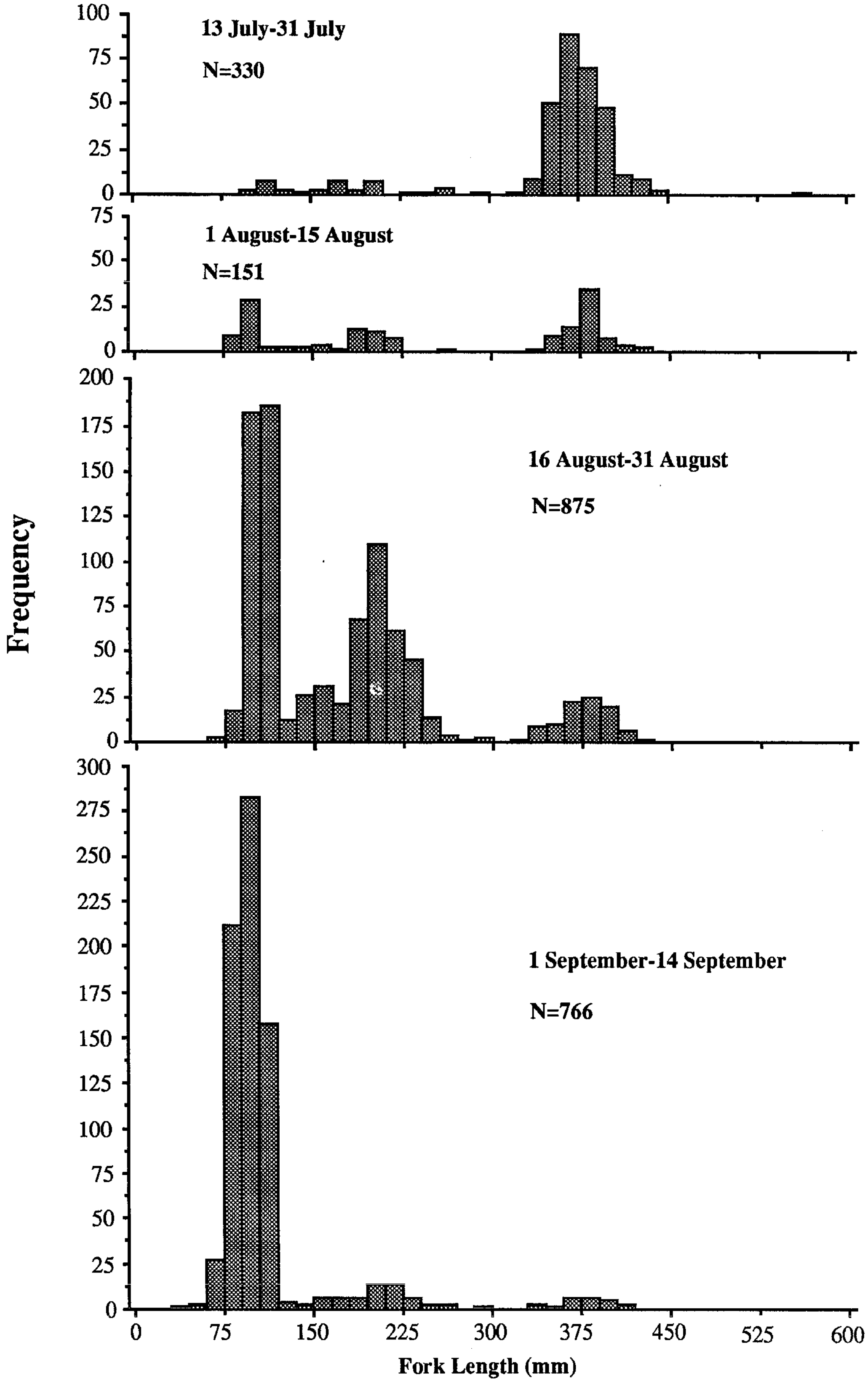


FIGURE 29.—Length frequency of Arctic cisco captured by fyke nets in Kaktovik and Jago lagoons, Alaska, July-September 1989.

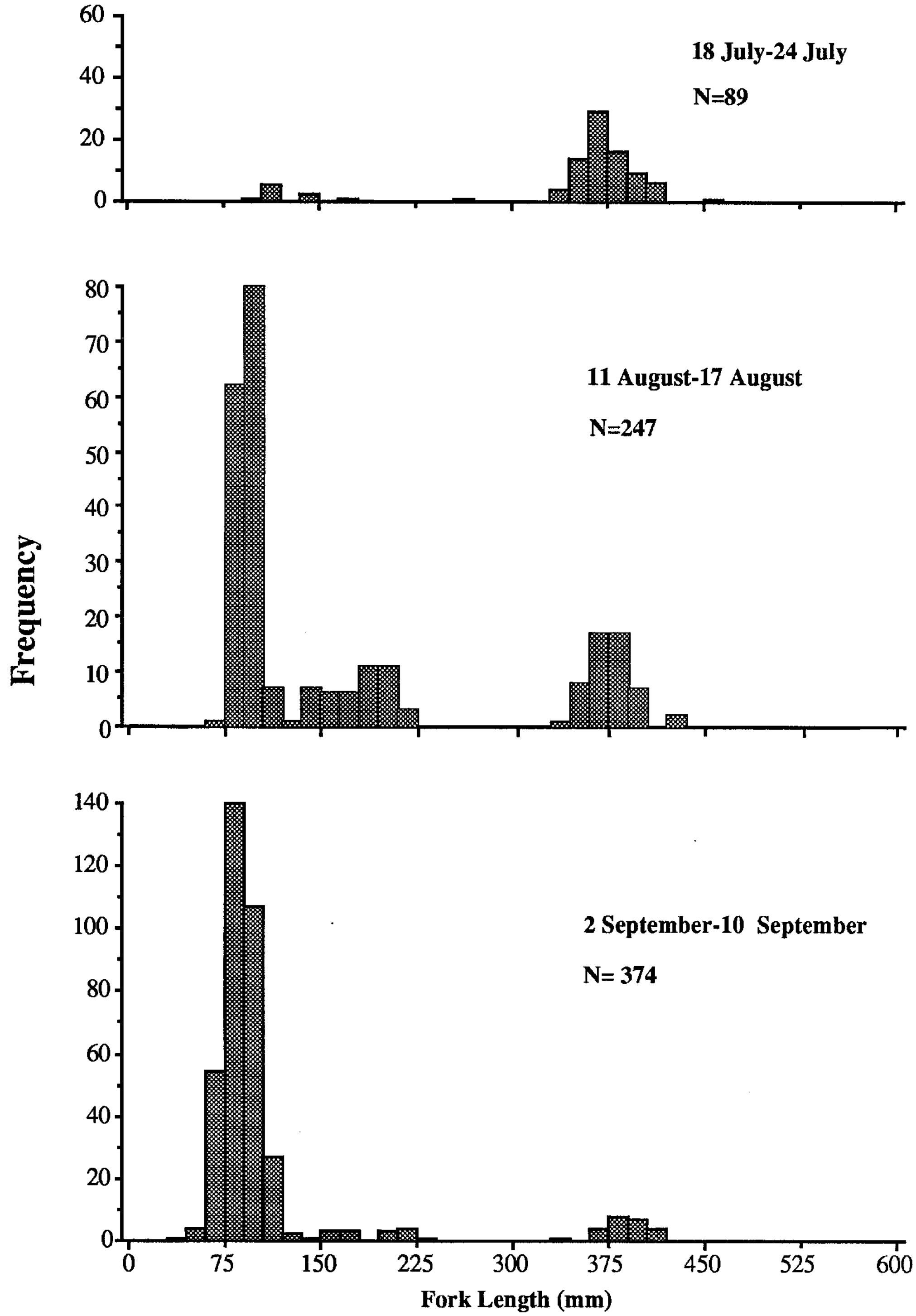


FIGURE 30.—Length frequency of Arctic cisco captured by fyke nets in Beaufort Lagoon, Alaska, July-September 1989.

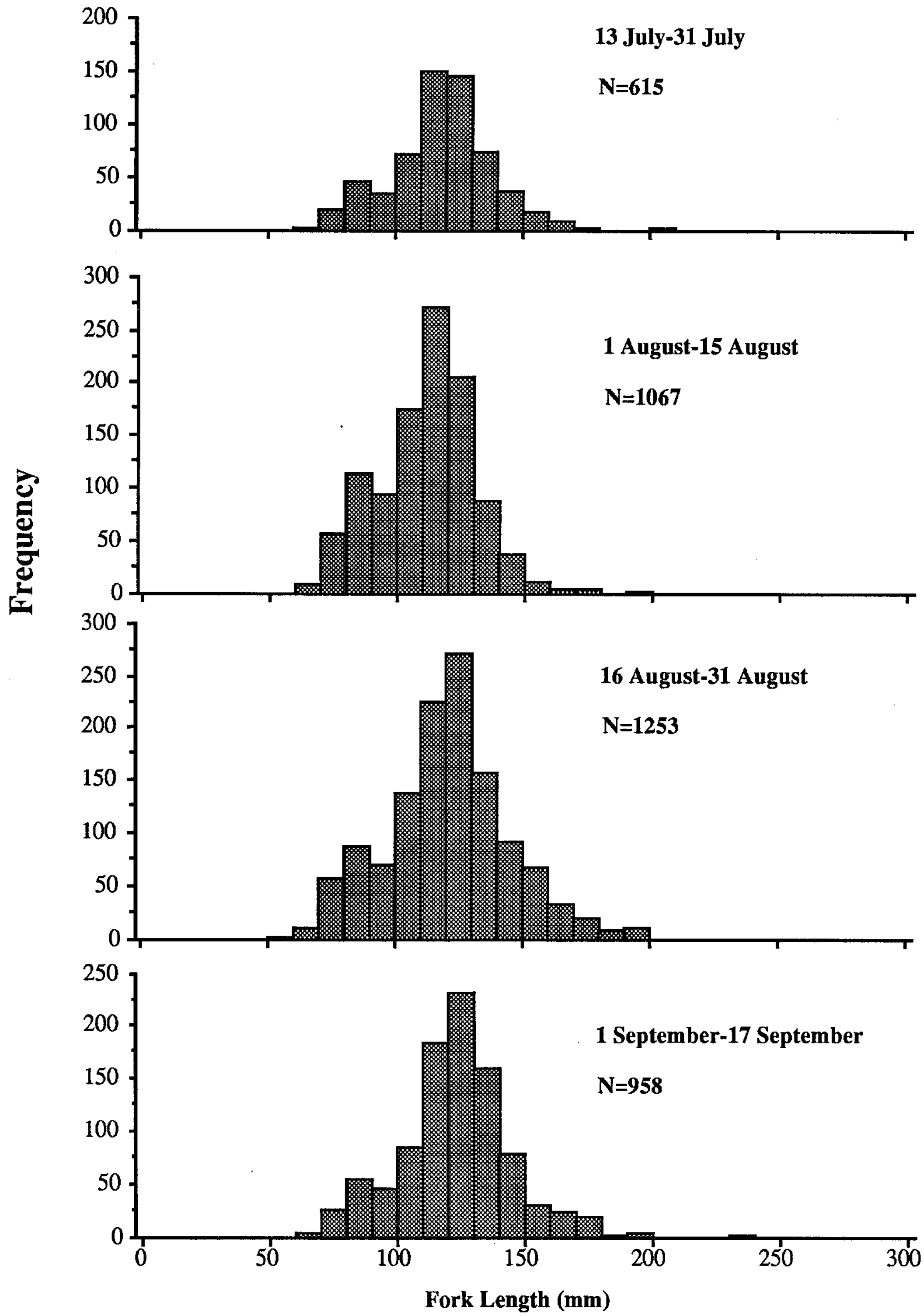


FIGURE 31.—Length frequency of Arctic cod captured by fyke nets in Camden Bay, Alaska, July-September 1989.

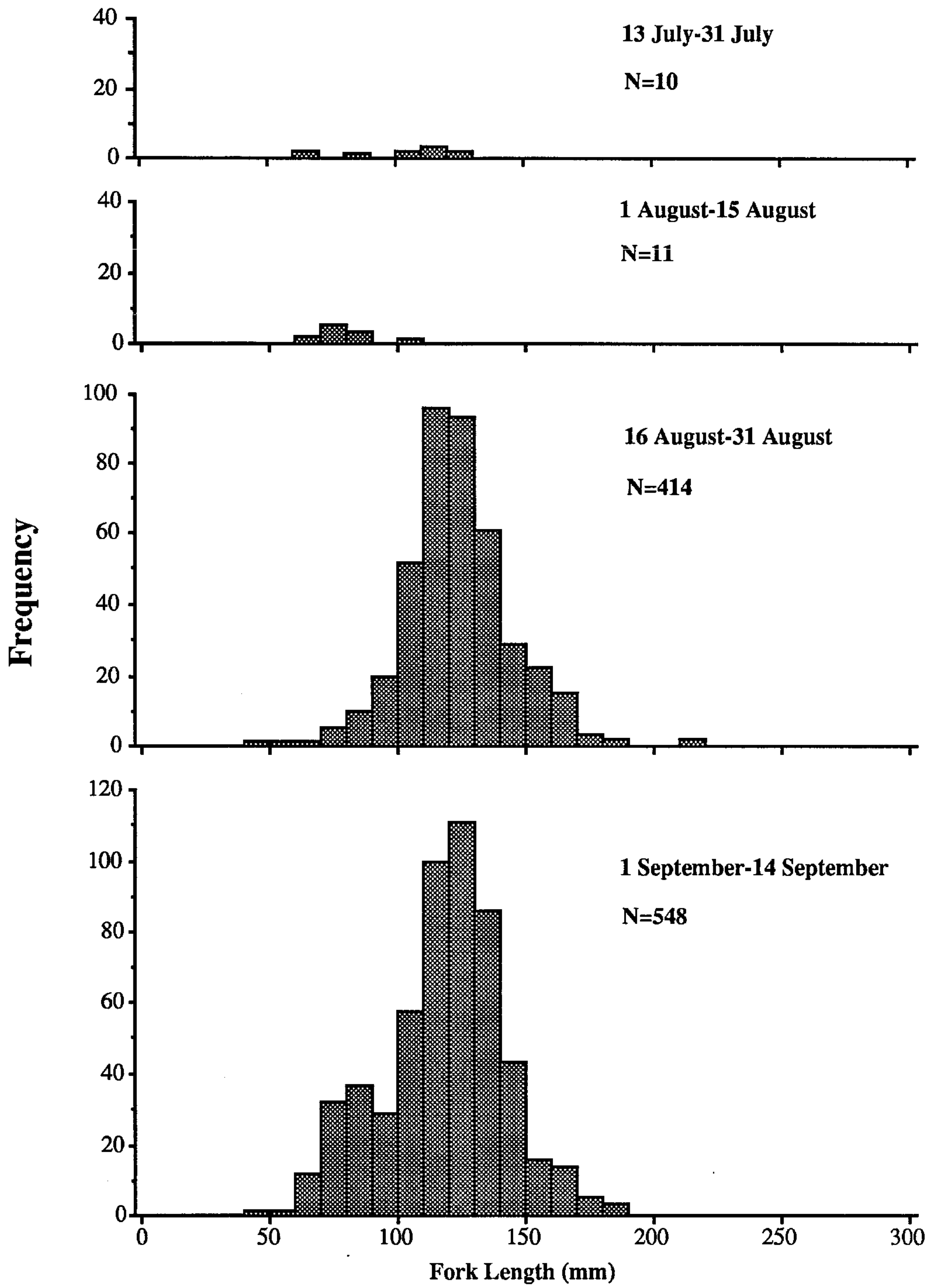


FIGURE 32.—Length frequency of Arctic cod captured by fyke nets in Kaktovik and Jago lagoons, Alaska, July-September 1989.

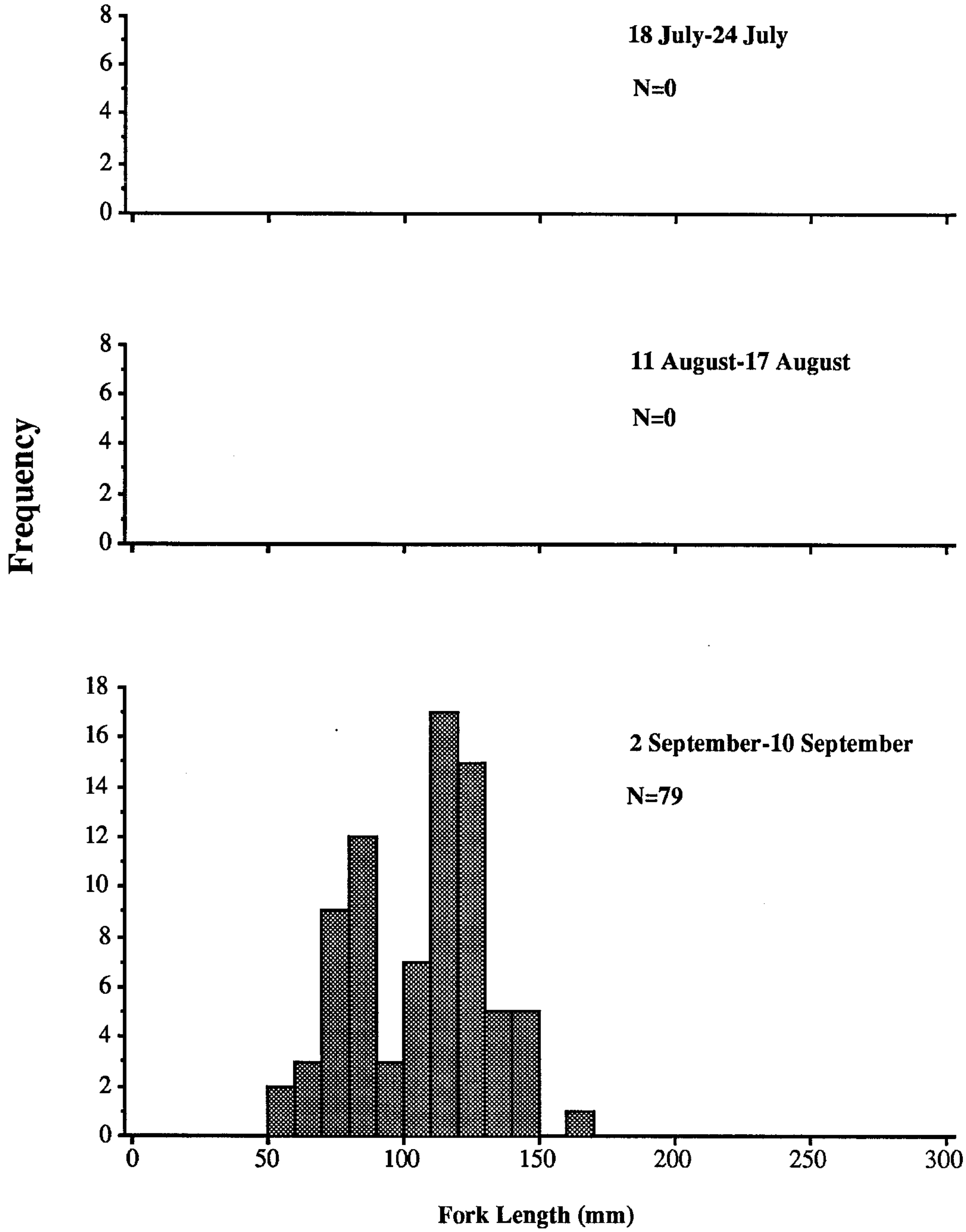


FIGURE 33.—Length frequency of Arctic cod captured by fyke nets in Beaufort Lagoon, Alaska, July-September 1989.

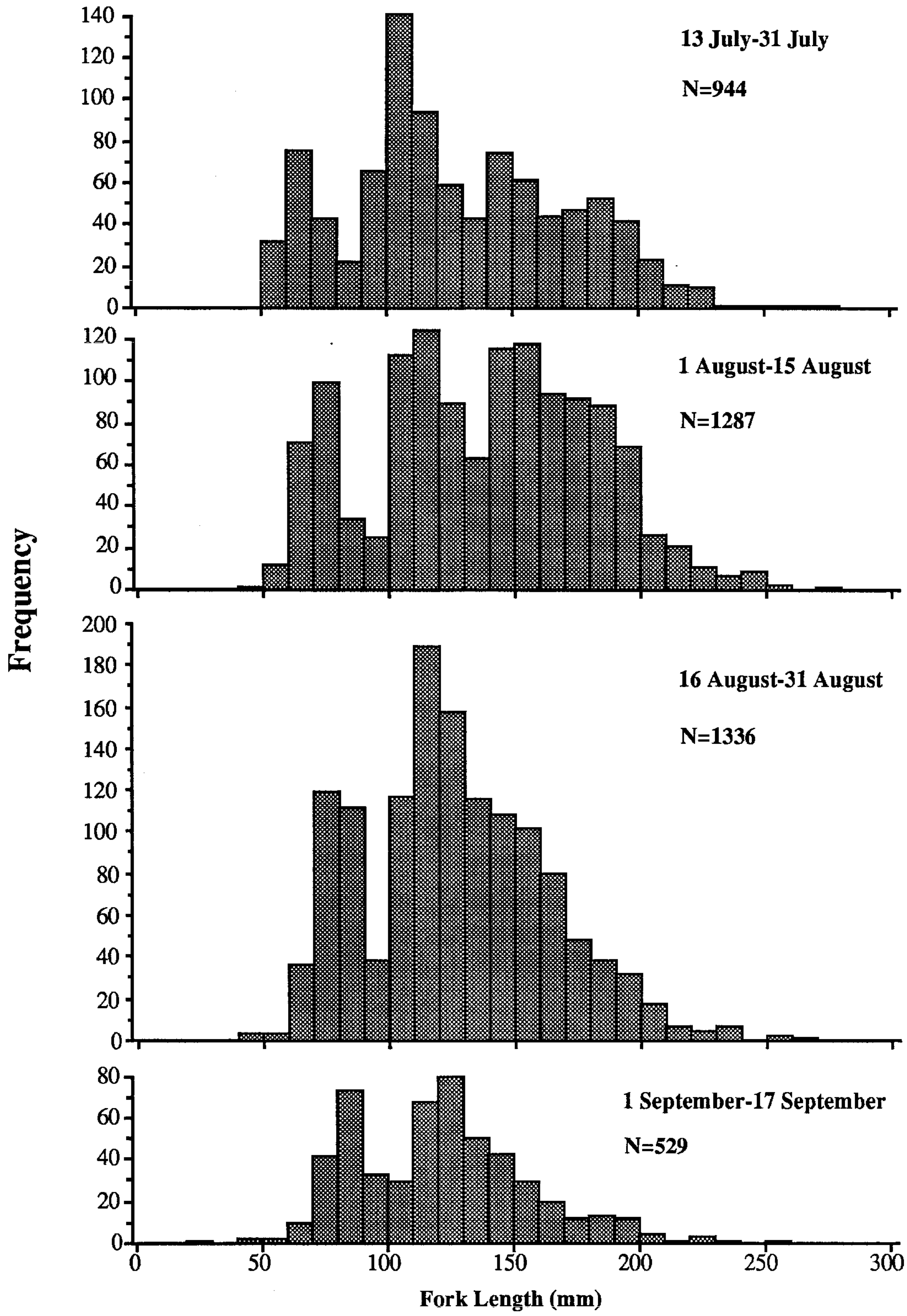


FIGURE 34.—Length frequency of fourhorn sculpin captured by fyke nets in Camden Bay, Alaska, July-September 1989.

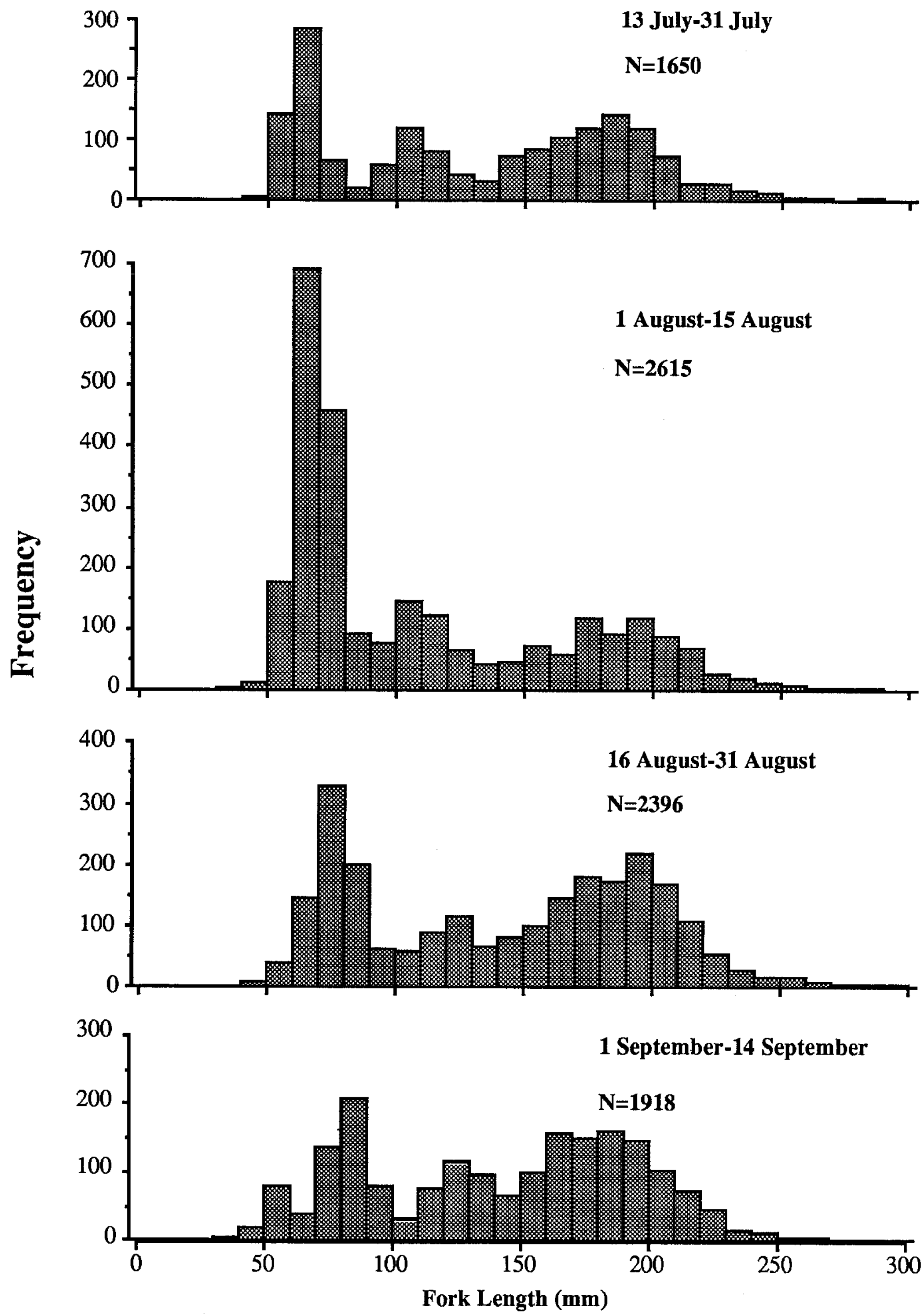


FIGURE 35.—Length frequency of fourhorn sculpin captured by fyke nets in Kaktovik and Jago lagoons, Alaska, July-September 1989.

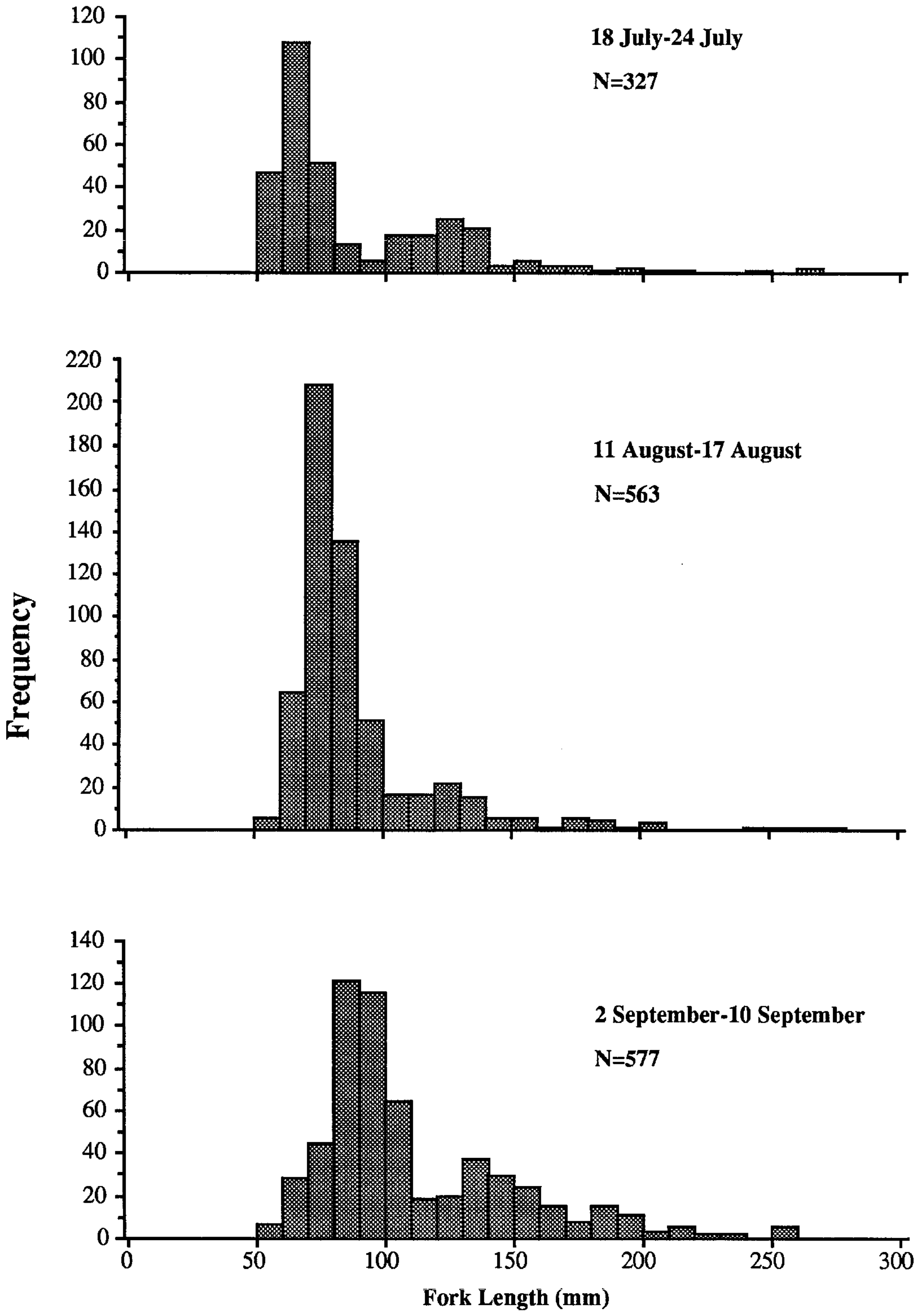


FIGURE 36.—Length frequency of fourhorn sculpin captured by fyke nets in Beaufort Lagoon, Alaska, July-September 1989.

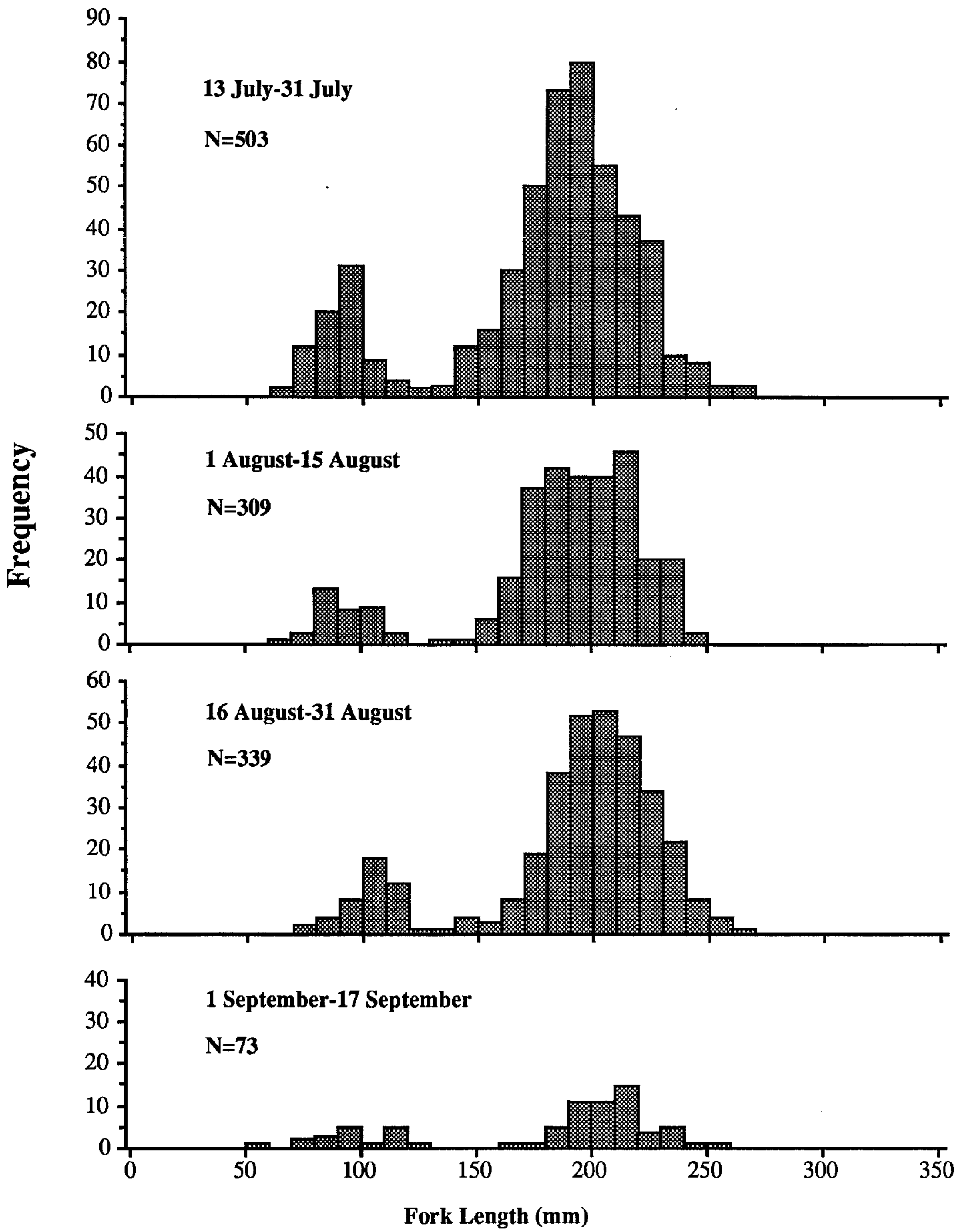


FIGURE 37.—Length frequency of Arctic flounder captured by fyke nets in Camden Bay, Alaska, July-September 1989.

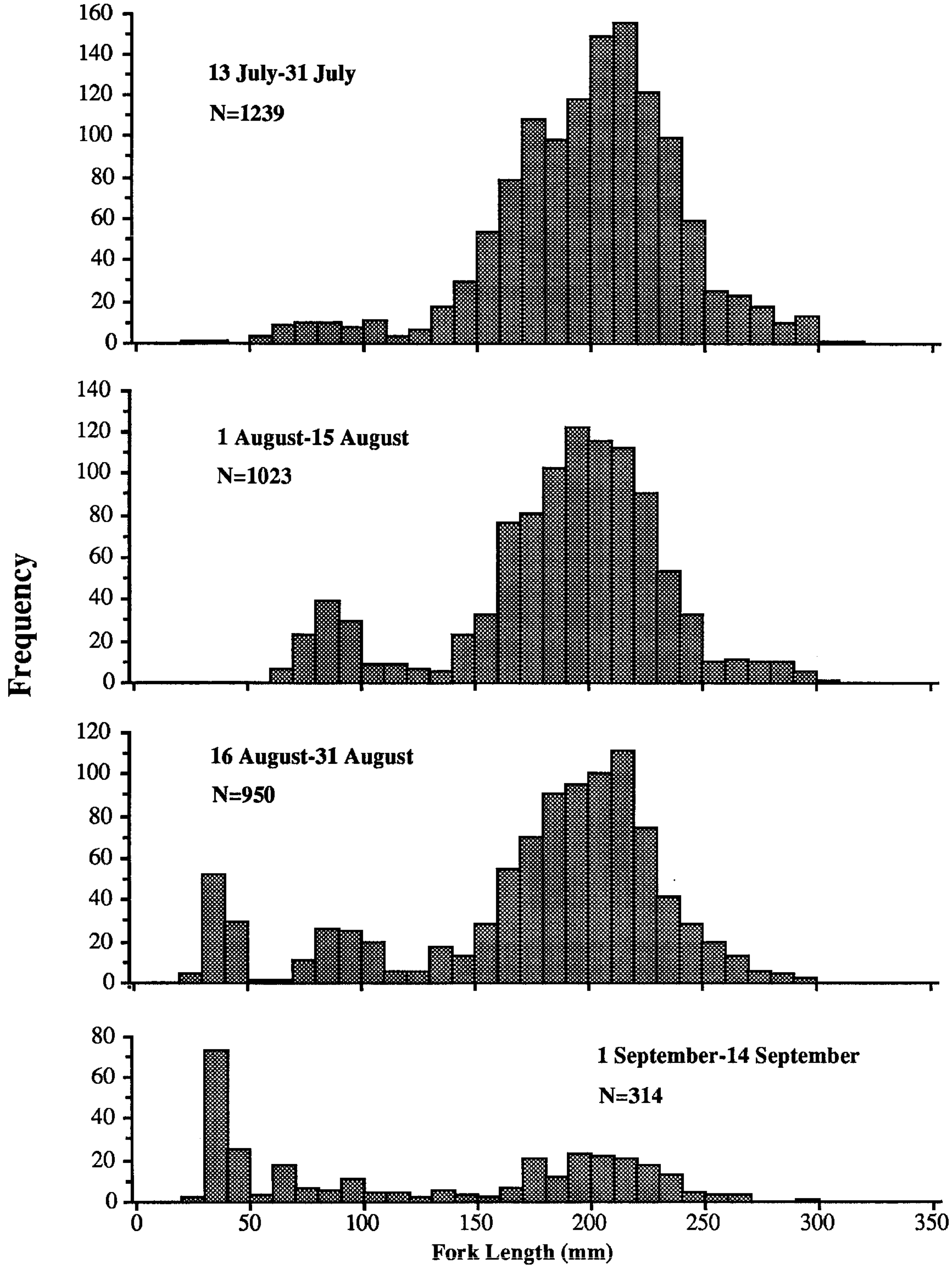


FIGURE 38.—Length frequency of Arctic flounder captured by fyke nets in Kaktovik and Jago lagoons, Alaska, July-September 1989.

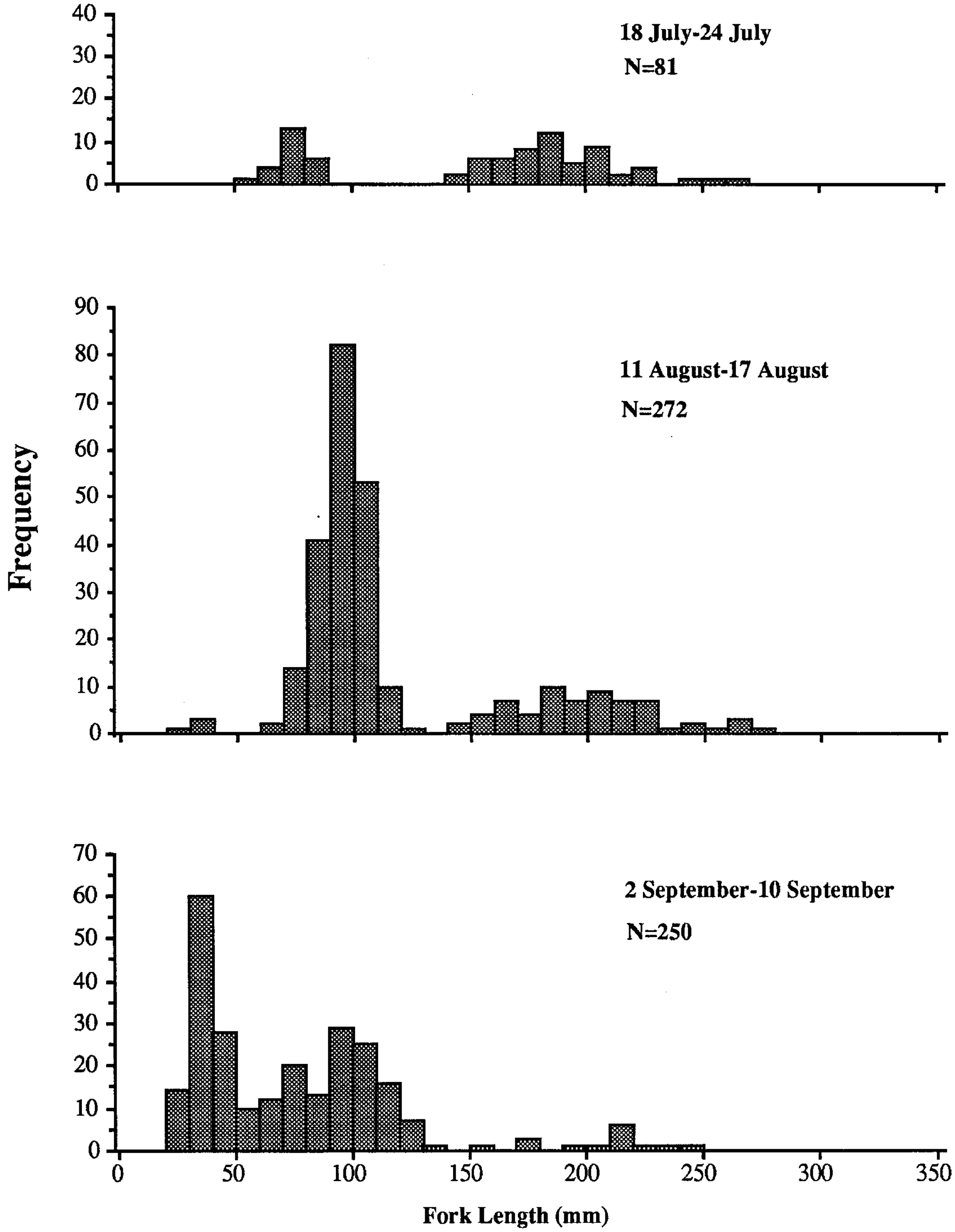


FIGURE 39.—Length frequency of Arctic flounder captured by fyke nets in Beaufort Lagoon, Alaska, July-September 1989.

size groups were similar throughout the summer within each area.

Length Frequency - Gill Nets

The length distribution of Arctic char captured in gill nets at Camden Bay was similar to the length distribution in fyke nets. Arctic char captured in gill nets during 1989 ranged from 172 to 595 mm fork length with fish from the 200-249 mm size group dominating the catch (Figure 40).

Gill nets were not effective in capturing smaller Arctic cisco. Arctic cisco captured in gill nets ranged from 174 to 442 mm fork length with 96% of the fish in the 315 to 439 size group (Figure 40). Only 14 of the Arctic cisco captured in gill nets were less than 300 mm fork length.

Sex and Maturity

The sex ratio of fish collected at coastal sampling locations during 1989 generally favored females. Females comprised 73% of all Arctic char for which sex was determined (N=97). The sex ratio for Arctic cod, Arctic flounder, and fourhorn sculpin also favored females which comprised 64 (N=92), 58 (N=161), and 54% (N=328) of the fish, respectively. Females accounted for 49% of the Arctic cisco for which sex was determined (N=164).

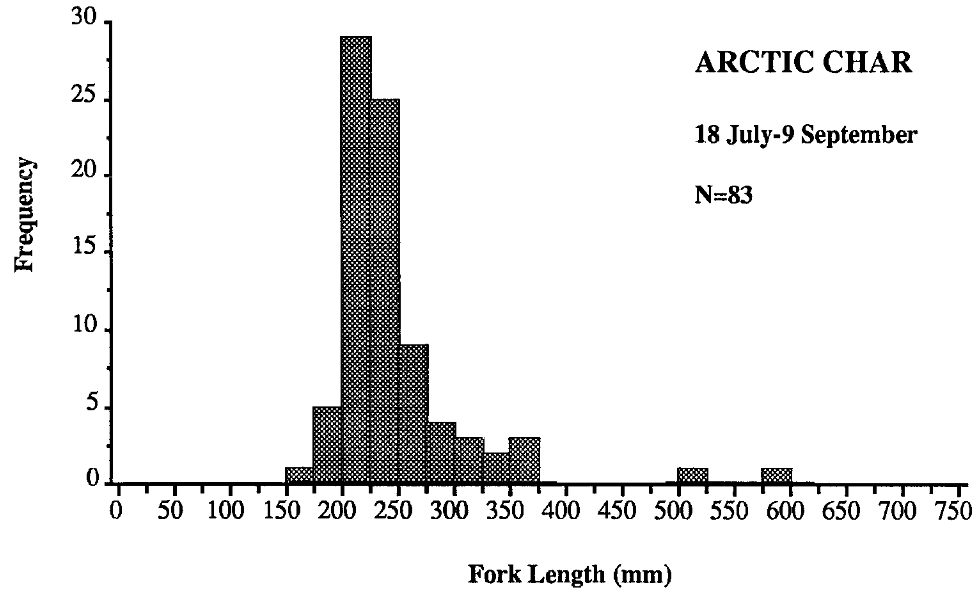
Gonadosomatic indices (GSI) calculated for Arctic char and Arctic cisco during 1989 indicated that only a small percentage of fish were mature spawners (Table 7). Approximately 10% of the Arctic char and 4% of the Arctic cisco examined were mature spawners. Arctic char GSI values for spawning females ranged from 2.10 to 5.78 with a mean of 4.02. Egg diameters for a sample of these fish (N=4) varied from 2.50 to 2.86 mm with a mean of 2.66 mm. Female spawners were older and larger than non-spawning fish with an average age of 10.4 and a mean fork length of 526 mm. Mean GSI for Arctic char male spawners was 2.94 with a range of 1.14 to 5.79. Like females, male spawners were generally older and larger than non-spawners; however, differences were not as pronounced as with females. All of the Arctic char classified as mature spanwers were collected during July and early August.

Arctic cisco GSI values for spawning females ranged from 2.96 to 5.80 with a mean of 3.92. Mean GSI and condition factor (Kn) for female spawners were clearly higher than values for non-spawners; however, mean length and age for spawners and non-spawners were similar. Mean GSI for Arctic cisco male spawners was 0.76 with a range of 0.71-0.84. All male and female Arctic cisco classified as spawners were captured during mid-July and were 9-10 years old.

Weight-Length Relationships and Condition Factors

Weight-length relationships computed for Arctic char, Arctic cisco, Arctic flounder, Arctic cod, and fourhorn sculpin during 1989 indicated allometric growth for all species except Arctic cod (Figures 41 and 42). Values for slope (b) ranged from 2.93 for Arctic cod to 3.41 for fourhorn sculpin. Correlation coefficients for the regressions ranged from 0.96 to 0.99.

Relative condition factors (Kn) generally increased throughout the summer for immature and adult fishes collected during 1989 (Table 8). Condition factors for Arctic char and Arctic cisco showed significant increases ($P<0.05$) throughout the summer for both immature and adult non-spawners. Condition factors for Arctic char spawners were comparable to values calculated for non-spawners; however, no significant difference was detected, probably because of small sample sizes. Arctic cisco spawners only were collected during the early time period. Marine species which displayed significant increases ($P<0.05$) in condition during the summer sampling periods included immature Arctic cod and adult Arctic flounder. No significant difference in condition was detected among sampling periods for adult Arctic cod and fourhorn sculpin or immature Arctic flounder. Differences in condition among sampling locations were not apparent for any species except fourhorn sculpin. Immature fourhorn sculpin at Camden Bay had a mean condition factor of 0.78 during the middle time period which was significantly lower than values computed at Kaktovik-Jago (1.10) and Beaufort lagoons (1.09).



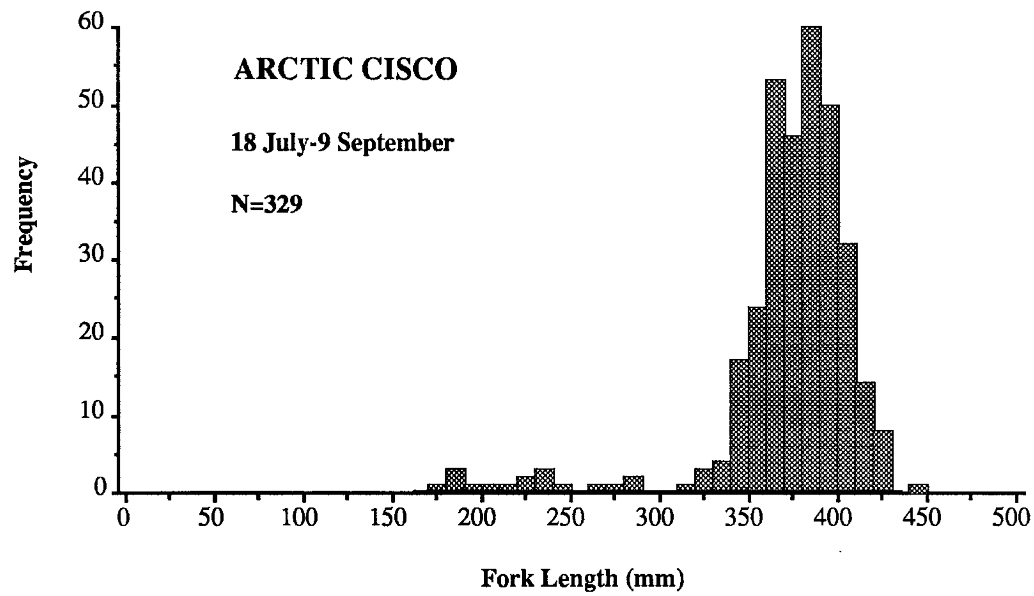
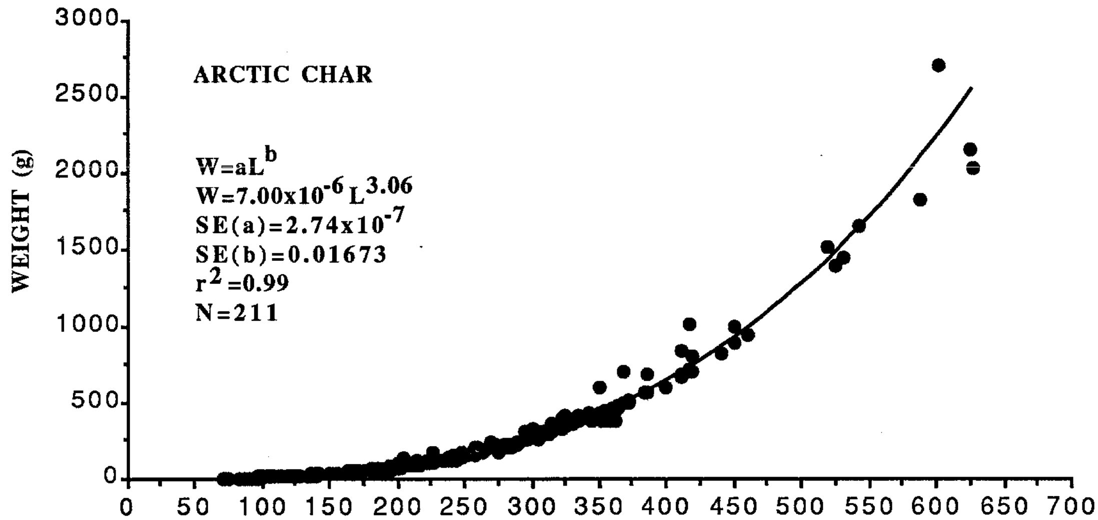


FIGURE 40.—Length frequency of Arctic char and Arctic cisco captured by gill nets in Camden Bay, Alaska, July-September 1989.

Table 7.—Mean gonadosomatic indices (GSI), fork length, age, and condition factor (Kn) for spawning and non-spawning Arctic char and Arctic cisco collected at coastal sampling locations during 1989.

Species and spawning condition	N	GSI			Fork length			Age			Kn		
		Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Arctic char													
Non-spawning females	60	0.27	0.18	0.05-0.92	278	73.3	139-500	4.6	1.3	2-10	1.04	0.13	0.82-1.57
Spawning females	5	4.02	1.36	2.10-5.78	526	66.0	418-625	10.4	2.2	7-13	1.00	0.09	0.85-1.11
Non-spawning males	15	0.12	0.11	0.02-0.43	329	95.9	195-588	5.3	1.8	3-11	1.02	0.14	0.85-1.42
Spawning males	3	2.94	2.04	1.14-5.79	346	126.3	168-451	7.0	2.8	3-9	1.06	0.14	0.95-1.26
Arctic cisco													
Non-spawning females	72	0.80	0.39	0.07-1.82	384	44.9	237-455	9.3	2.1	4-14	1.01	0.13	0.69-1.28
Spawning females	3	3.92	1.33	2.96-5.80	381	11.3	365-390	9.3	0.5	9-10	1.19	0.08	1.09-1.37
Non-spawning males	79	0.21	0.13	0.04-0.67	327	58.8	148-438	7.3	2.2	2-12	1.09	0.12	0.68-1.33
Spawning males	3	0.76	0.06	0.71-0.84	359	3.3	355-363	9.3	0.5	9-10	1.11	0.01	1.10-1.13



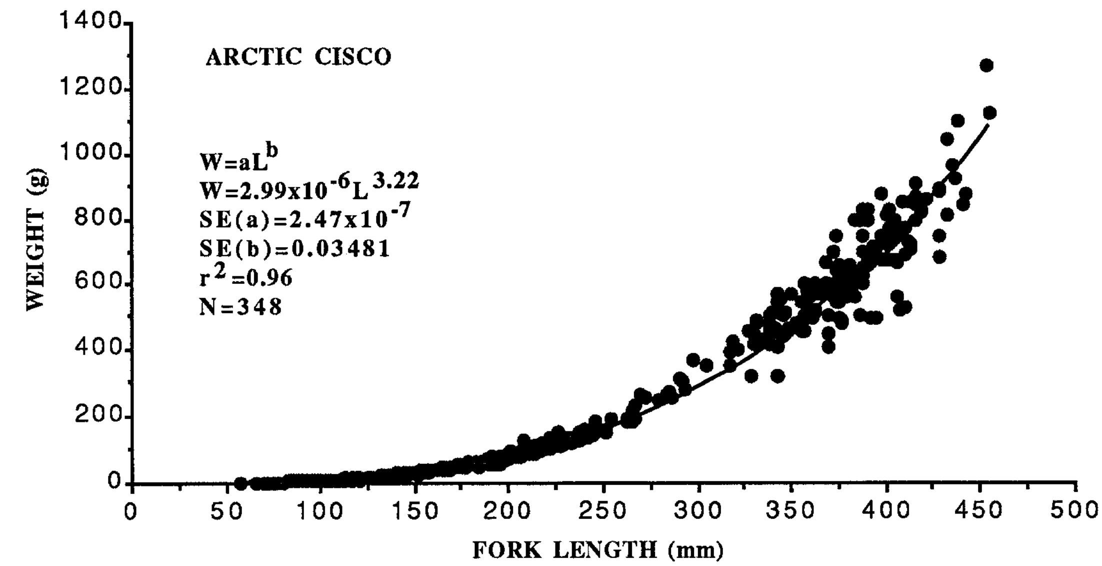


FIGURE 41.—Weight-length relationships for Arctic char and Arctic cisco collected at coastal sampling locations during 1989.

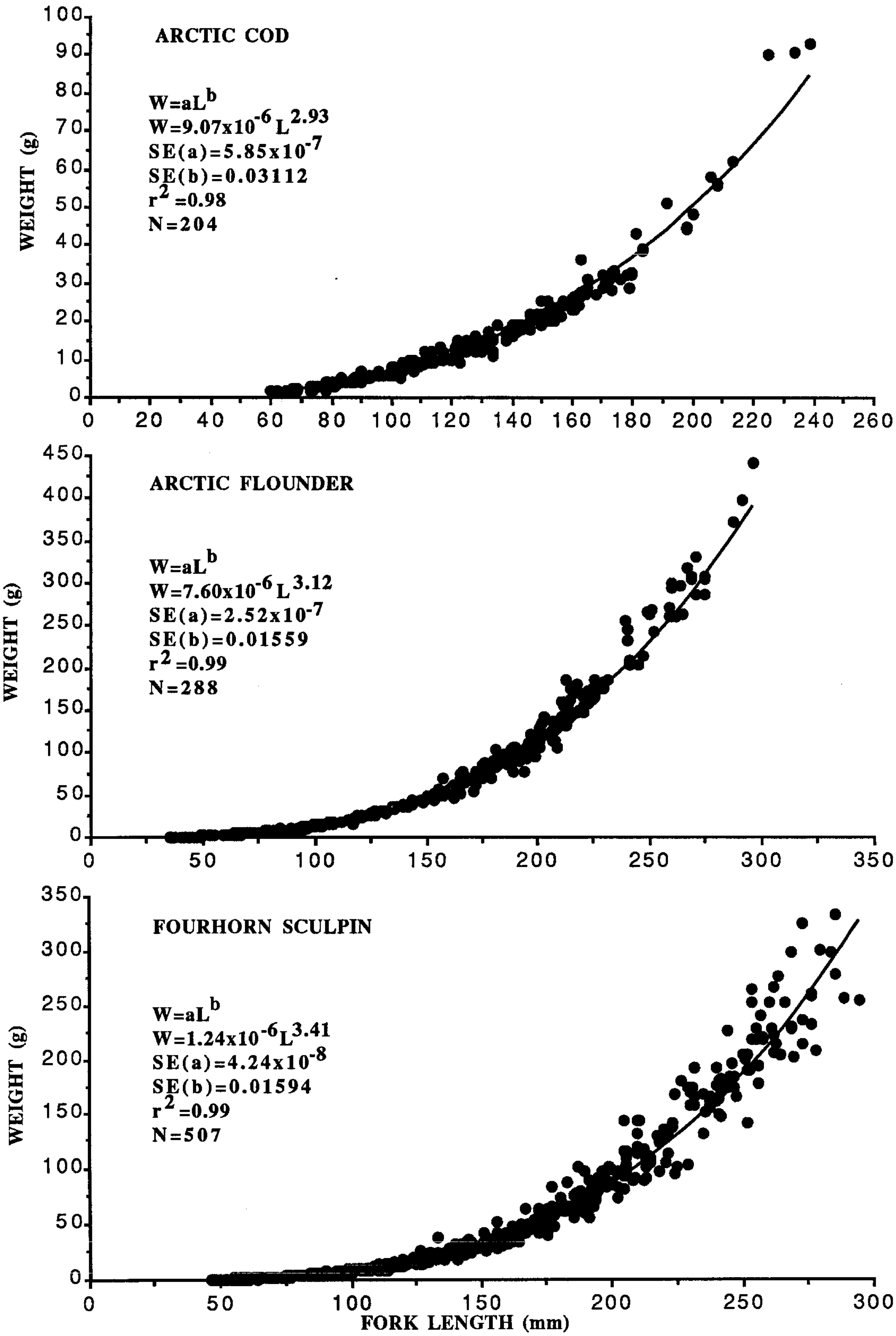


FIGURE 42.—Weight-length relationships for Arctic cod, Arctic flounder, and fourhorn sculpin collected at coastal sampling locations during 1989.

TABLE 8.—Mean condition factors (Kn) for immature and adult Arctic char, Arctic cisco, Arctic cod, Arctic flounder, and fourhorn sculpin collected at coastal sampling locations during early (July 10-24), middle (August 4-18), and late (August 29 - September 12) time periods in 1989. At each sampling location, means along a row without a letter in common are significantly different (Newman-Keuls multiple-range test, P<0.05). Sample sizes (N) are in parentheses.

	Camden Bay			Kaktovik-Jago lagoons			Beaufort Lagoon			All locations combined		
	Time period			Time period			Time period			Time period		
Species and maturity	Early	Middle	Late	Early	Middle	Late	Early	Middle	Late	Early	Middle	Late
Arctic char												
Immature	0.90z (5)	1.10y (17)	1.07y (10)	0.97z (35)	1.04y (32)	1.06y (27)				0.96z (40)	1.06y (49)	1.06y (37)
Adult non-spawner	0.90z (6)	1.06y (19)	1.03y (5)	0.97z (24)	1.02z (7)	1.21y (11)				0.96z (30)	1.05y (26)	1.15x (16)
Adult spawner	0.97z (1)	1.03z (2)		1.02z (5)	1.26z (1)	1.11z (2)				1.01z (6)	1.11z (3)	1.11z (2)
Arctic cisco												
Immature	0.99z (35)	1.01z (36)	1.11y (54)	1.08z (16)	1.16z (21)	1.06z (29)				1.02z (51)	1.07zy (57)	1.09y (83)
Adult non-spawner	0.96z (17)	1.08y (43)	1.09y (46)	0.96z (32)	1.05z (2)	1.06z (10)				0.96z (49)	1.07y (45)	1.09y (56)
Adult spawner	1.15 (6)									1.15 (6)		
Arctic cod												
Immature	1.01z (37)	0.98z (40)	1.11y (28)							1.01z (37)	0.98z (40)	1.11y (28)
Adult	1.02z (15)	0.95z (25)	1.04z (46)							1.02z (15)	0.95z (25)	1.04z (46)
Arctic flounder												
Immature					1.02z (20)	1.04z (18)	0.99z (13)	1.02z (25)	1.05z (52)	0.99z (13)	1.02z (45)	1.04z (70)
Adult					1.02z (38)	1.01z (25)	0.97z (39)	1.07y (44)	1.10y (14)	0.97z (39)	1.05y (82)	1.04y (39)
Fourhorn sculpin												
Immature	1.10z (21)	0.78y (21)	0.98x (15)	1.12z (27)	1.10z (21)	1.16z (23)	1.04z (13)	1.09z (17)	1.02z (15)	1.10z (61)	0.99y (59)	1.07z (53)
Adult	1.04z (33)	1.03z (52)	0.98z (27)	1.04z (35)	0.99z (47)	1.12y (38)	0.97z (29)	1.04z (29)	1.03z (44)	1.02z (97)	1.02z (128)	1.05z (109)

Age

Age determinations were made on otoliths from 641 Arctic char, 527 Arctic cisco, 680 fourhorn sculpin, 322 Arctic cod, and 373 Arctic flounder collected during 1988 and 1989. Age-length relationships for these five species are presented in Tables 9-13.

TABLE 9.—Mean fork length at various ages for Arctic char collected at coastal sampling locations during 1988 and 1989.

Age	N	Mean fork length	SD	Length range
1	19	89	10.5	70-107
2	39	132	28.1	101-223
3	217	216	33.5	106-310
4	220	255	44.7	171-369
5	82	300	52.2	181-410
6	31	323	54.9	173-386
7	7	431	21.8	400-460
8	8	436	68.5	306-508
9	6	486	46.1	418-550
10	4	512	38.3	450-553
11	4	564	43.8	505-620
12	2	549	23.5	525-572
13	2	579	46.5	532-625

TABLE 10.—Mean fork length at various ages for Arctic cisco collected at coastal sampling locations during 1988 and 1989.

Age	N	Mean fork length	SD	Length range
0	55	74	9.6	52-100
1	76	117	19.8	83-162
2	79	149	18.7	100-197
3	59	184	18.3	135-222
4	47	219	21.3	167-266
5	20	311	32.5	233-329
6	3	320	45.8	269-380
7	28	339	13.3	317-369
8	51	366	16.8	339-416
9	49	377	19.3	332-429
10	34	382	20.2	342-416
11	16	403	27.1	323-442
12	5	418	12.1	401-438
13	4	429	16.2	413-455
14	1	454		

TABLE 11.—Mean fork length at various ages for fourhorn sculpin collected at coastal sampling locations during 1988 and 1989.

Age	N	Mean fork length	SD	Length range
0	8	44	6.9	36-58
1	120	71	12.4	50-107
2	144	104	22.4	59-172
3	141	149	24.7	73-214
4	139	185	26.3	103-251
5	59	222	26.7	174-286
6	32	245	24.2	181-289
7	24	256	22.4	205-298
8	7	253	12.5	230-269
9	4	282	12.7	266-300
10	2	258	37.0	221-295

TABLE 12.—Mean fork length at various ages for Arctic cod collected at coastal sampling locations during 1988 and 1989.

Age	N	Mean fork length	SD	Length range
1	37	78	10.2	61-102
2	123	96	16.5	60-142
3	96	129	16.1	93-167
4	48	158	19.6	123-208
5	15	182	22.1	155-234
6	3	234	15.2	213-249

TABLE 13.—Mean fork length at various ages for Arctic flounder collected at coastal sampling locations during 1988 and 1989.

Age	N	Mean fork length	SD	Length range
0	10	39	7.1	31-55
1	34	61	12.5	36-89
2	56	92	16.4	59-127
3	13	100	11.9	76-118
4	2	107	3.0	104-110
5	9	132	13.6	118-168
6	3	135	4.5	129-140
7	11	164	31.2	114-225
8	38	183	25.2	144-266
9	84	195	28.0	143-263
10	72	198	30.1	142-298
11	28	223	32.8	154-274
12	3	244	12.3	229-259
14	1	245		
16	2	276	6.0	270-282
17	2	274	14.0	260-288
18	2	272	1.5	270-273
19	1	274		
24	1	310		
28	1	291		

Discussion

Of the 22 fish species collected in 1989, six (Arctic cod, fourhorn sculpin, ninespine stickleback, Arctic flounder, Arctic cisco, and Arctic char) comprised 99% of the catch. This is consistent with our findings in 1988 (Fruge et al. 1989) and previous studies of Beaufort Sea coastal waters (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 Fruge *in preparation*; Wiswar and West 1987; Wiswar et al. *in preparation*).

Variations in relative abundance are evident for some species when comparing the 1989 findings with other studies. Overall, Arctic cod were seven times more abundant in 1989 than in 1988. Arctic cod were more abundant at Camden Bay and less abundant at the other study areas in 1989 than reported in the previous year. Craig et al. (1982) reported much more dramatic fluctuations in relative abundance of Arctic cod from year to year than what we observed. The number of Arctic cod captured by fyke nets in Simpson Lagoon increased from 767 fish in 1977 to 139,790 fish in 1978.

Abundance of Arctic cod tended to increase in late summer with peak catches occurring after August 20. At Camden Bay, roughly 127,500 Arctic cod were captured in 1989 during a 48 hour period in early September. An increase in abundance of Arctic cod at Camden Bay in late summer was consistent with 1988 findings and previous studies conducted by Wiswar and Fruge in 1987 (*in preparation*) and Craig et al. (1982). The importance of the nearshore habitat and the factors that influence temporal abundance and spatial distribution patterns of Arctic cod are not clear at this time. However, we are attempting to correlate relative abundance with oceanographic variables as the data become available.

Large Arctic cisco (≥ 200 mm) were three times more abundant in Arctic refuge coastal waters in 1989 than reported in 1988. Conversely, catches of small Arctic cisco (<200 mm) in 1989 were four times lower than those observed in 1988. Differences in abundance of large and small Arctic cisco between years may be related to: 1) changes in the proportion of Arctic cisco migrating offshore; 2) fluctuations in year class strength; or 3) timing of fish movements through Arctic Refuge coastal waters.

Temporal abundance trends for small Arctic cisco (< 200 mm) were similar in both 1988 and 1989 with peak catches occurring in late August. Movements of Arctic cisco into lagoons in late summer may be a response to decreasing photoperiod and changes in oceanographic conditions. Decreasing temperatures and increasing salinity levels in nearshore coastal waters usually occur in September because intrusions of cold marine waters are closer to shore (Moulton et al. 1986). Lagoons in the Arctic Refuge are probably warmer and less saline than marine waters during this time period. Griffiths and Gallaway (1982) reported abundance levels of anadromous fish were typically positively correlated with temperature and negatively correlated with salinity. In areas where the water was colder and more saline, densities of Arctic cisco were lower.

Relative abundance and distribution patterns of Arctic char in 1989 were analogous to patterns observed in 1988. During both years, Arctic char were most abundant at Kaktovik and Jago lagoons with these lagoons accounting for over 72% of the Arctic char captured. Arctic char were most abundant at Jago Lagoon in 1989 but were most abundant at Kaktovik Lagoon in 1988. Catch rates at Station KL05 in Kaktovik Lagoon dropped from 20.8 fish/day in 1988 to 7.3 fish/day in 1989. Conversely, catch rates at Station JL12 in Jago Lagoon increased from 5.5 fish/day in 1988 to 11.5 fish/day during 1989. The higher abundance of Arctic char in Kaktovik and Jago lagoons is probably related to the proximity of these lagoons to the Hulahula River, an important Arctic char river system.

Arctic flounder were roughly four times more abundant in Arctic Refuge coastal waters in 1989 than reported in 1988. During both years, Arctic flounder were clearly more abundant at Station KL05 in Kaktovik Lagoon. Seasonal trends in catch were similar for both years with peak catches generally occurring prior to mid August. One exception to this seasonal trend was at Beaufort Lagoon in 1989 where several hundred young-of-the-year flounder were captured in early September.

Ninespine stickleback were roughly eleven times more abundant in Arctic Refuge coastal waters during 1989 than in 1988. Highest catches during both years were in Jago Lagoon. Higher abundance of ninespine stickleback in Jago Lagoon is probably related to the large resident population of ninespine stickleback in the Jago River. Ninespine stickleback was the dominant species captured in freshwater surveys of the Jago River in 1989 (Corning *in preparation*). Ninespine stickleback were most abundant in Jago Lagoon during late August. Higher abundance during this time of year is consistent with findings of Gallaway and Britch (1983), who found that ninespine stickleback migrate into coastal waters to avoid being trapped in small tundra streams which freeze during winter. Also, higher abundance of ninespine stickleback in Jago Lagoon in August may be related to avoidance of high salinity levels reported in Kaktovik Lagoon. Salinity levels as high as 37 ppt have been recorded during August in Kaktovik Lagoon (Griffiths et al. 1977). Although salinity information is not yet available for 1989, some inferences can be made from the 1988 data. During August in 1988, salinity concentrations on the bottom of Kaktovik Lagoon were two times higher than Jago Lagoon (Hale 1990). If similar conditions existed in 1989, then the lower salinity levels in Jago Lagoon may have been a contributing factor to the greater abundance of ninespine stickleback in this area.

Least cisco were less abundant in 1989 than reported in 1988. Most least cisco were captured at Camden Bay in late August. Least cisco are uncommon in Arctic Refuge waters (Wiswar and West 1987; Fruge et al. 1989) and tend to be commonly captured in coastal areas near the Colville River west of Prudhoe Bay and in the Mackenzie River area in Canada (Craig and McCart 1976).

Relative abundance of capelin has decreased at Camden Bay since 1987. Capelin dropped from second in abundance at Camden Bay in 1987 (Wiswar and Fruge *in preparation*) and ninth in abundance in 1988 (Fruge et al. 1989) to fourteenth in abundance in 1989. The reason for the decrease in abundance of capelin is not clear, but Arctic fishes are subject to boom and bust cycles because of several years of poor recruitment (Craig and McCart 1976; Craig and Haldorson 1981).

Gill net data collected in Camden Bay in 1989 were consistent with 1988 findings. Arctic cisco and Arctic char were found predominately in the upper 2.4 m of the water column in nearshore waters. Griffiths et al. (1977) reported that Arctic cisco and Arctic char were more abundant in nearshore gill net sets than offshore sets in Kaktovik Lagoon; similar results were reported for Nunaluk Lagoon in Canada (Griffiths et al. 1975). Craig and Haldorson (1981) reported that anadromous species were 24 times more abundant in gill nets nearshore than in the middle of Simpson Lagoon. Those authors also fished a 122-m gill net perpendicular to shore. Approximately six times as many anadromous fish were captured in the first 40 m of gill net than in the last 40 m (seaward end). In 1988, few Arctic char and Arctic cisco were captured with a purse seine fished between the 4 and 13 m isobaths west of Barter Isaland (Thorsteinson et al. *in preparation*). The catch was dominated by capelin (74%) and Arctic cod (24%) with Arctic char and Arctic cisco comprising only 1.5% and 0.08% of the catch, respectively.

The recapture of eight dye marked Arctic cisco (<200 mm) in this study was the first time that two and three year old fish were documented moving east through Arctic Refuge coastal waters. It was not possible to document westward movement in refuge waters since no fish were marked in areas other than Camden Bay. Also, none of our dye marked Arctic cisco were reported in fyke net catches at Prudhoe Bay. Eastward movement of two and three year old fish in Beaufort Sea coastal waters has not been previously reported; however, migration patterns for other ages of Arctic cisco have been noted. Fechhelm and Fissel (1988) indicated that young-of-the-year originating in Canada are aided in their westward dispersal into Alaskan waters via wind-driven longshore currents. Gallaway et al. (1983) believe that older Arctic cisco (age 7-9; >350 mm) move east toward the Mackenzie River upon attaining maturity.

In contrast to Arctic cisco which exhibited extensive longshore movements in 1989, movement patterns of fourhorn sculpin and Arctic flounder in 1989 were very localized. Localized movement patterns have been reported for these species in Arctic Refuge coastal waters (Fruge et al. 1989) and in Simpson Lagoon (Craig and Haldorson 1981). Few fourhorn sculpin and Arctic flounder tagged in these studies were recaptured outside of the lagoon or nearshore area.

Two Arctic char captured at coastal sampling locations in 1989 were originally tagged in freshwater rivers in the Arctic Refuge. Movements of these fish appear consistent with findings of genetic stock identification work which concluded that most Arctic char captured in Arctic Refuge coastal waters originate from river systems within the refuge (Everett and Wilmot *in preparation*).

Length frequency data indicate that larger Arctic char (>350 mm) became less abundant in Arctic Refuge coastal waters as the season progressed. Individuals larger than 350 mm generally were not captured after the end of August, though smaller fish were still relatively common. These results are in agreement with 1988 findings and with Griffiths et al. (1977). Such results indicate that larger fish return to spawning and overwintering areas sooner than smaller fish.

Arctic cisco captured in 1989 consisted of three distinct size groups (75-119 mm, 150-239 mm, and 330-419 mm) with a distinct paucity of fish 240-329 mm. This type of length frequency distribution was observed in 1988 and in other studies in Arctic Refuge coastal waters (Griffiths et al. 1977; West and Wiswar 1985; Wiswar and West 1987). Conversely, coastal studies in the Prudhoe Bay area (Cannon et al. 1987; Whitmus et al. 1987) have reported fish in the 240-329 mm size group as a dominant component in fyke net catches. The prevalence of fish in this size group suggests that the Prudhoe Bay area is an important rearing area for these fish.

The sex ratio of fish collected at coastal sampling locations during 1989 was similar to sex ratios reported from Phillips Bay, Yukon in 1985 (Bond and Erickson 1987). At Phillips Bay, females were the most prevalent sex for Arctic char (72%), fourhorn sculpin (66%), and Arctic flounder (70%). Our findings were similar with female Arctic char, fourhorn sculpin, and Arctic flounder comprising 73, 54, and 58% of the fish, respectively. The sex ratio for Arctic cisco was in favor of males at both Phillips Bay (61%) and Arctic Refuge coastal waters (51%).

Gonadosomatic indices (GSI) calculated for adult Arctic char and Arctic cisco during 1989 indicated that only a small percentage of adult fish captured at coastal sampling locations were mature spawners. In our study, only 4% of the male and female Arctic cisco were considered mature spawners. Spawners comprised a larger portion of the Arctic cisco at Phillips Bay (Bond and Erickson 1987) with 7% of the males and 16% of the females considered mature fish. For Arctic char, 19% of the males and 8% of the females were considered mature spawners in our study. At Phillips Bay, the percentage of Arctic char males (19%) considered sexually mature was identical to our study; however, approximately 33% of the females were mature spawners. Many factors could account for differences in the number of spawners observed in our study and at Phillips Bay including: (1) proximity to spawning rivers; (2) mixture of fish from different stocks utilizing each area; and (3) timing and duration of the field season at each location.

Weight-length regression coefficients estimated for Arctic char, Arctic cisco, Arctic cod, fourhorn sculpin, and Arctic flounder during 1989 generally were lower than values obtained in 1988 but fit within the 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). Estimated values for growth exponents (b) in 1989 generally ranged from 0.09 to 0.17 lower than values obtained in 1988 (Fruge et al. 1989). This was true for all species except Arctic char which had a 0.01 increase in the growth exponent in 1989. Little difference was observed in the growth exponent of Arctic char between years probably because of the large sample size (N=500) used to determine the weight-length regression in 1988. The sample size for Arctic char in 1988 was more than twice that used to estimate regressions for other species. The growth exponents in 1989 are probably better estimates than values obtained in 1988 because all length groups of fish were sampled equally. In addition, electronic balances were used in 1989 to obtain accurate weights on fish weighing less than 500 g. In 1988, length was not rigidly stratified for sample selection and weights of all fish were determined with Pesola® spring scales.

Relative condition factors (Kn) generally increased over the coarse of the summer open-water period for immature and adult fishes collected during 1989. Overall, condition factors for Arctic char, Arctic cisco, Arctic cod, fourhorn sculpin, and Arctic flounder were higher during late August and early

September than during July. This was true for all immature and adult fishes examined except immature fourhorn sculpin. In 1988, condition factors were higher late in the summer for all fish examined except immature Arctic cisco and Arctic flounder and adult Arctic cod.

Age-length relationships derived for Arctic char, Arctic cisco, and fourhorn sculpin in 1989 are similar to relationships reported for other Beaufort Sea locations (Craig and Mann 1974; Griffiths et al. 1975, 1977; Craig 1977; Lawrence et al. 1984; Wiswar and West 1985; Bond and Erickson 1987; Whitmus et al. 1987). For each species, lengths within each age class cover a wide range with overlap occurring among age classes. Age-length relationships of this nature are common among Arctic fishes (Johnson 1972).

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References

Anderson, R.O. and S.J. Gutreuter. 1983. Length, weight, and associated structural indices. Pages 283-300 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

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

Bond, W.A. and R.N. Erickson. 1987. Fishery data from Phillips Bay, Yukon, 1985. Canadian Data Report of Fisheries and Aquatic Sciences Number 635, Winnipeg, Manitoba.

Cannon, T.C., B. Adams, D. Glass, and T. Nelson. 1987. Fish distribution and abundance. Chapter 1 *in* Volume 7, 1985 Final report for the Endicott Environmental Monitoring Program. U.S. Department of the Army, Corps of Engineers, Anchorage, Alaska.

Clough, N.K., P.C. Patton, and A.C. Christiansen, editors. 1987. Arctic National Wildlife Refuge, Alaska, coastal plain resource assessment: report and recommendation to the Congress of the United States and final legislative environmental impact statement. U.S. Fish and Wildlife Service, U.S. Geological Survey, U.S. Bureau of Land Management, Washington, D.C.

Corning, R. *In Preparation.* Fish investigations of the Jago and Katakturuk river drainages, 1002 Area of the Arctic National Wildlife Refuge. U.S. Fish and Wildlife Service, Alaska Fisheries Technical Report, Anchorage, Alaska.

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

Craig, P.C. 1983. Aquatic survey of the Kaktovik dredging operation. Unpublished Report to the Materials Source Division, North Slope Borough, Barrow, Alaska.

Craig, P.C. 1984. Fish use of coastal waters of the Alaskan Beaufort Sea: a review. Transactions of the American Fisheries Society 113(3):265-282.

Craig, P.C. and G.J. Mann. 1974. Life history and distribution of the Arctic cisco (*Coregonus autumnalis*) along the Beaufort Sea coastline in Alaska and the Yukon Territory. Canadian Arctic Gas Study, Limited/Alaska Arctic Gas Study Company. Biological Report Series 20, Calgary, Alberta.

Craig, P.C. and P. McCart. 1976. Fish use of nearshore coastal waters in the western Arctic: Emphasis on anadromous species. Pages 361-388 *in* D.W. Hood and D.C. Burrell, editors. Assessment of the Arctic marine environment. Institute of Marine Science, University of Alaska, Fairbanks, Alaska.

Craig, P.C., W.B. Griffiths, L. Haldorson, and H. McElderry. 1982. Ecological studies of Arctic cod *(Boreogadus saida)* in Beaufort Sea coastal waters, Alaska. Canadian Journal of Fisheries and Aquatic Science 39:395-406.

Craig, P.C. and L. Haldorson. 1981. Beaufort Sea barrier island-lagoon ecological process studies: final report, Simpson Lagoon. Part 4. Fish. Pages 384-678 *in* Environmental assessment, Alaskan continental shelf. Bureau of Land Management and National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program, Final Report, Volume 7, Anchorage, Alaska.

Everett, R.J. and R.L. Wilmot. *In Preparation*. Genetic identification of mixed stocks of Arctic char from coastal areas of the Beaufort Sea. U.S. Fish and Wildlife Service, Final Report, Anchorage, Alaska.

Fechhelm, R.G. and D.B. Fissel. 1988. Wind-aided recruitment of Canadian Arctic cisco *(Coregonus autumnalis)* into Alaskan waters. Canadian Journal of Fisheries and Aquatic Sciences 45:906-910.

Fruge, D.J., D.W. Wiswar, L.J. Dugan, and D.E. Palmer. 1989. Fish population characteristics of Arctic National Wildlife Refuge coastal waters, summer 1988. U.S. Fish and Wildlife Service, Progress Report, Fairbanks, Alaska.

Gallaway, B.J. and R.P. Britch. 1983. Environmental summer studies (1982) for Endicott development, Volume III, Fish ecology. Prepared by LGL Associates Inc. and Northern Technical Services for Sohio Petroleum Company, Anchorage, Alaska.

Gallaway, B.J., W.B. Griffiths, P.C. Craig, W.J. Gazey, and J.W. Helmericks. 1983. An assessment of the Colville River delta stock of Arctic cisco -- migrants from Canada? Pages 4-23 *in* B.J. Gallaway, R.G. Fechhelm and W.H. Neill, editors. Contributions to the science of environmental impact assessment: Three papers on the Arctic cisco *(Coregonus autumnalis)* of northern Alaska. University of Alaska Biological Papers Number 21, Fairbanks, Alaska.

Glova, G. and P.J. McCart. 1974. Life history of Arctic char *(Salvelinus alpinus)* in the Firth River, Yukon Territory. Canadian Arctic Gas Study, Limited/Alaska Arctic Gas Study Company. Biological Report Series 20, Calgary, Alberta.

Griffiths, W.B. 1983. Fish. Chapter 3 *in* J.C. Truett, editor. Environmental characterization and biological use of lagoons in the eastern Beaufort Sea. National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program, Final Report 24, Anchorage, Alaska.

Griffiths, W.B., P.C. Craig, G.L. Walder, and G.J. Mann. 1975. Fisheries investigations in a coastal region of the Beaufort Sea (Nunaluk Lagoon, Yukon Territory). Canadian Arctic Gas Study, Limited/Alaska Arctic Gas Study Company. Biological Report Series 34, Calgary, Alberta.

Griffiths, W.B., J.K. Denbeste, and P.C. Craig. 1977. Fisheries investigations in a coastal region of the Beaufort Sea (Kaktovik Lagoon, Alaska). Chapter 2 *in* P. McCart, editor. Fisheries investigations along the north slope from Prudhoe Bay, Alaska, to the Mackenzie Delta, N.W.T. Canadian Arctic Gas Study, Limited/Alaska Arctic Gas Study Company. Biological Report Series 40, Calgary, Alberta.

Griffiths, W.B. and B.J. Gallaway. 1982. Fish monitoring program, Prudhoe Bay waterflood project. Prepared for Woodward-Clyde Consultants, Anchorage, Alaska.

Hachmeister, L.E. and J.B. Vinelli. 1984. Physical oceanography. Chapter 7 *in* J.C. Truett, editor. Environmental characterization and biological use of lagoons in the eastern Beaufort Sea. National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program, Final Report 24, Anchorage, Alaska.

Hale, D.A. 1990. A description of the physical characteristics of nearshore and lagoonal waters in the eastern Beaufort Sea. Draft Report for U.S. Fish and Wildlife Service. Ocean Assessments Division, National Oceanic and Atmospheric Administration, Anchorage, Alaska.

Johnson, L. 1972. Keller Lake: Characteristics of a culturally unstressed salmonid community. Journal of the Fisheries Research Board of Canada 29:731-740.

Lawrence, M.J., G. Lacho, and S. Davies. 1984. A survey of the coastal fishes of the southeastern Beaufort Sea. Canadian Technical Report of Fisheries and Aquatic Sciences Number 1220, Winnipeg, Manitoba.

Moulton, L.L., B.J. Gallaway, M.H. Fawcett, W.B. Griffiths, K.R. Critchlow, R.G. Fechhelm, D.R. Schmidt, and J.S. Baker. 1986. 1984 central Beaufort Sea fish study. Final report to U.S. Army Corps of Engineers, Anchorage, Alaska.

Nelson, T., T.C. Cannon, W.R. Olmstek, and K.C. Wiley. 1986. Surveys of domestic and commercial fisheries in the central and eastern Beaufort Sea. Part 4 *in* Endicott environmental monitoring program, 1985, final draft report. Envirosphere Company, Bellevue, Washington.

Ricker, W.E. 1973. Linear regressions in fishery research. Journal of the Fisheries Research Board of Canada 30:409-434.

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

Roguski, E.A. and E. Komarek. 1971. Monitoring and evaluation of Arctic waters with emphasis on the north slope drainages: Arctic Wildlife Refuge study. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report 1970-1971. Project F-9-3, 12 (G-III-A), Juneau, Alaska.

Sharma, G.D. 1979. The Alaskan shelf: hydrographic, sedimentary, and geochemical environment. Springer-Verlag, New York.

Snyder, D.E. 1983. Fish eggs and larvae. Pages 165-197 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Thorsteinson, L.K., L.E. Jarvela, D.A. Hale. *In Preparation.* Arctic fish habitat use investigations: nearshore studies in the Alaskan Beaufort Sea, summer 1988. Draft Report for Minerals Management Services. National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program, Anchorage, Alaska.

Ward, D. and P. Craig. 1974. Catalogue of streams, lakes, and coastal areas in Alaska along routes of the proposed gas pipeline from Prudhoe Bay to the Alaska/Canadian border. Canadian Arctic Gas Study, Limited/Alaska Arctic Gas Study Company. Biological Report Series 19, Calgary, Alberta.

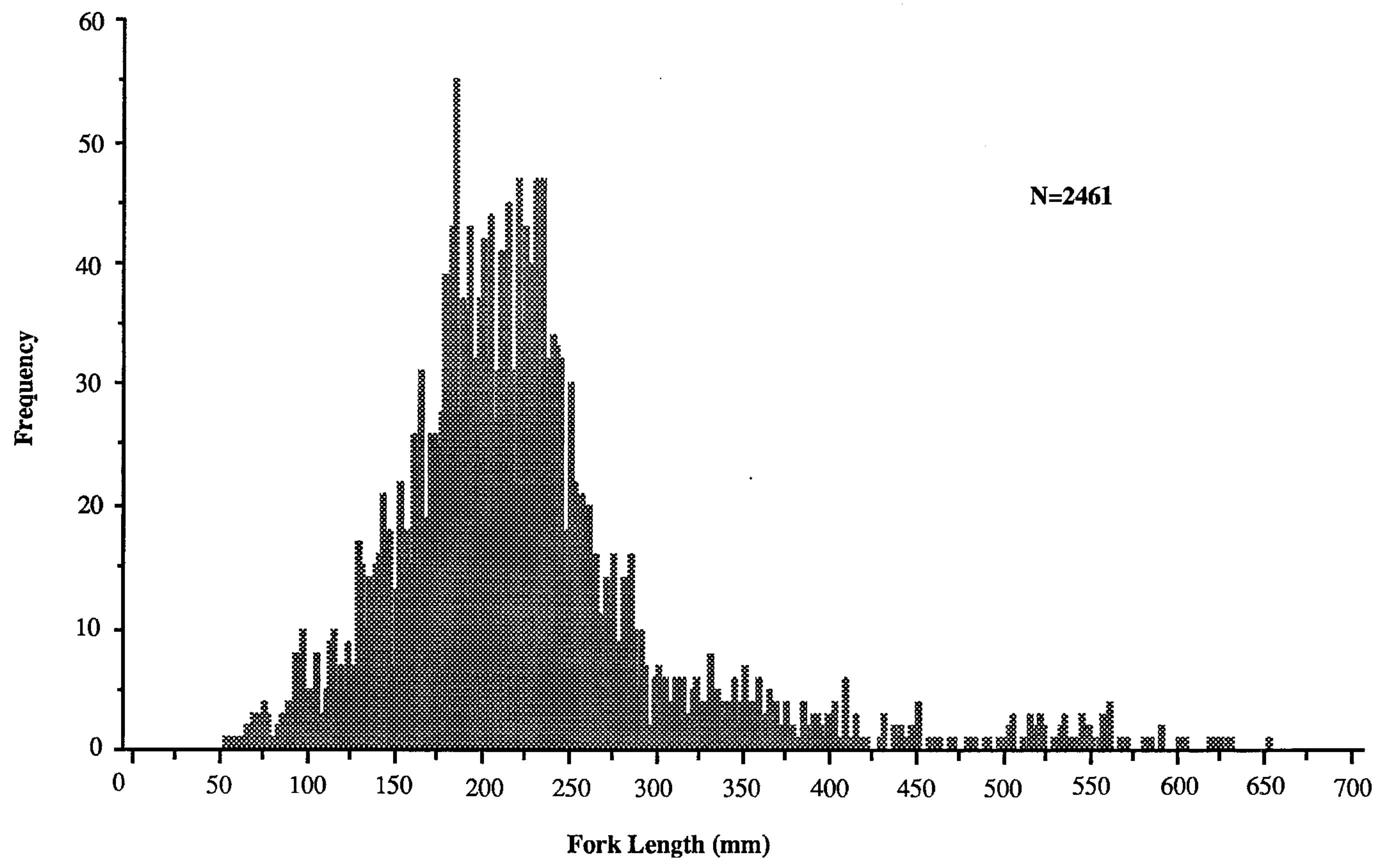
West , R.L. and D.W. Wiswar. 1985. Fisheries investigations on the Arctic National Wildlife Refuge, Alaska, 1984. Pages 729-777 *in* G.W. Garner and P.E. Reynolds, editors. Arctic National Wildlife Refuge coastal plain resource assessment: 1984 update report, baseline study of the fish, wildlife and their habitats. U.S. Fish and Wildlife Service, Anchorage, Alaska.

Whitmus, C.J., T.C. Cannon, and S.S. Parker. 1987. Age, growth, and condition of anadromous fish. Chapter 5 *in* Volume 7, 1985 Final report for the Endicott Environmental Monitoring Program. U.S. Department of the Army, Corps of Engineers, Anchorage, Alaska.

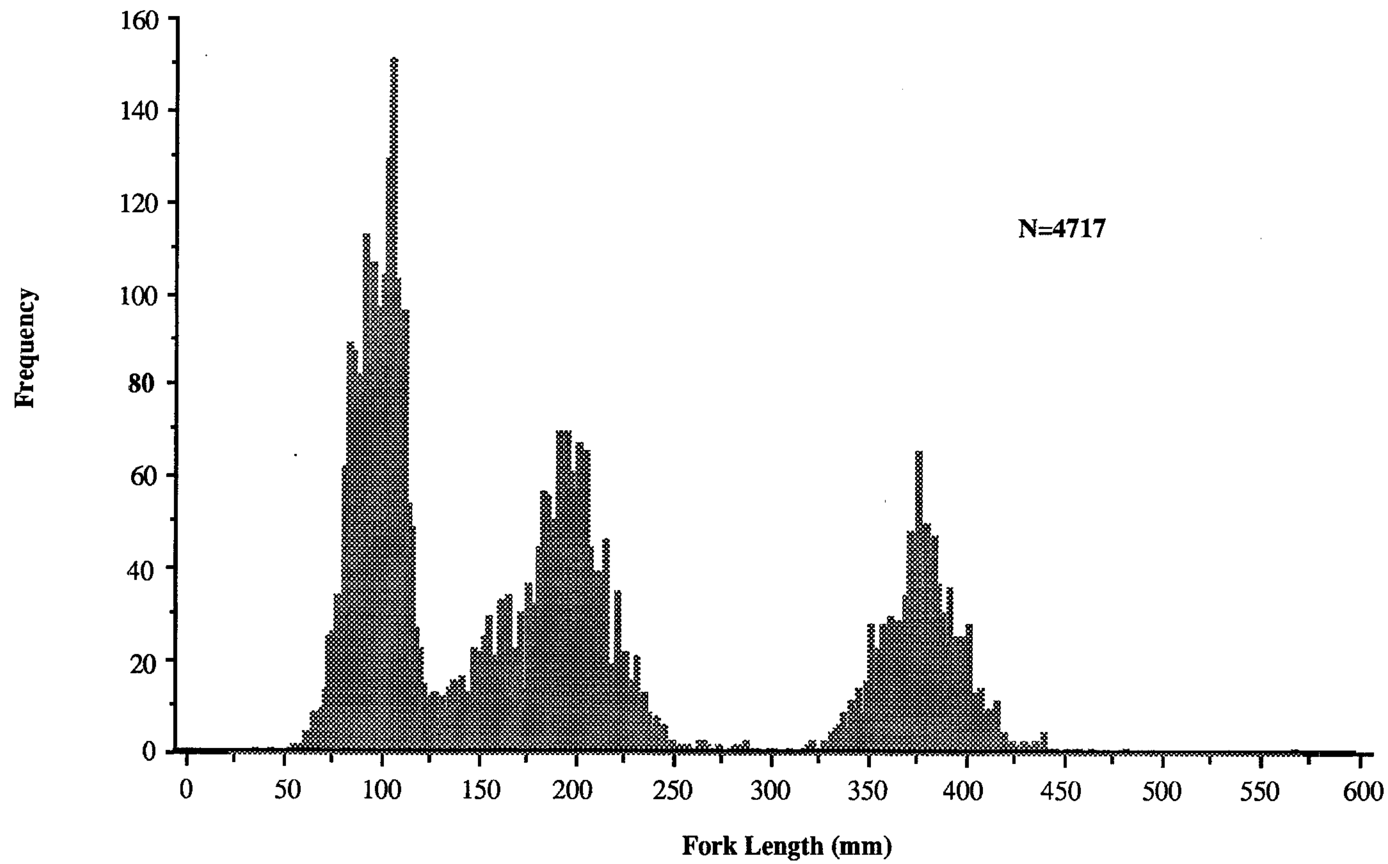
Wiswar, D.W. and D.J. Fruge. *In Preparation.* Fisheries investigations in Camden Bay, northeastern Alaska, 1987. U.S. Fish and Wildlife Service, Alaska Fisheries Technical Report, Fairbanks, Alaska.

Wiswar, D.W. and R.L. West. 1987. Fisheries investigations in Beaufort Lagoon, Arctic National Wildlife Refuge, Alaska, 1985. Pages 778-800 *in* G.W. Garner and P.E. Reynolds, editors. Arctic National Wildlife Refuge coastal plain resource assessment: 1985 update report, baseline study of the fish, wildlife, and their habitats. U.S. Fish and Wildlife Service, Anchorage, Alaska.

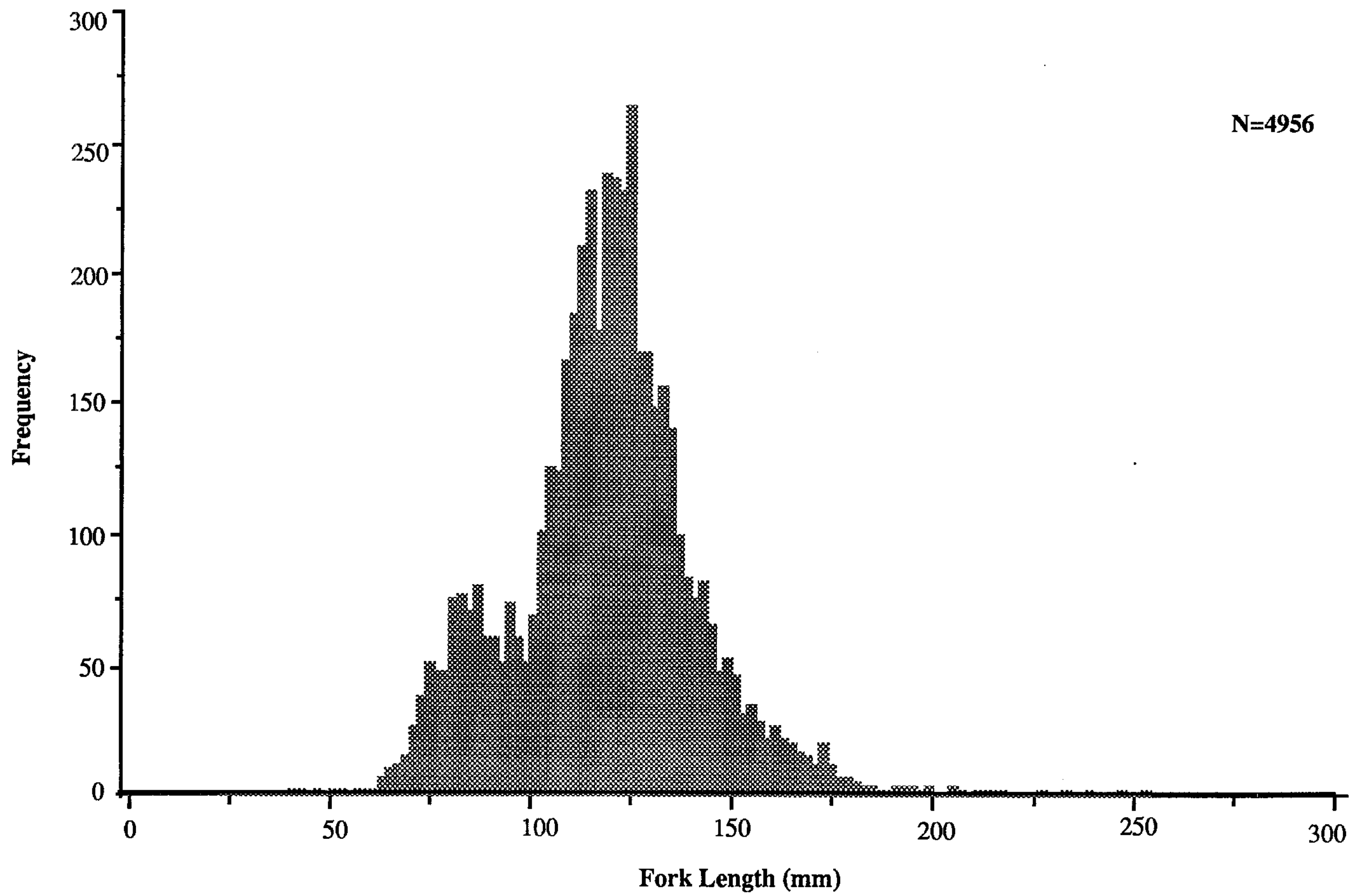
Wiswar, D.W., R.L. West, and W.N. Winkelman. *In Preparation.* Fisheries investigations in Oruktalik Lagoon, Arctic National Wildlife Refuge, Alaska, 1986. U.S. Fish and Wildlife Service, Alaska Fisheries Technical Report, Fairbanks, Alaska.



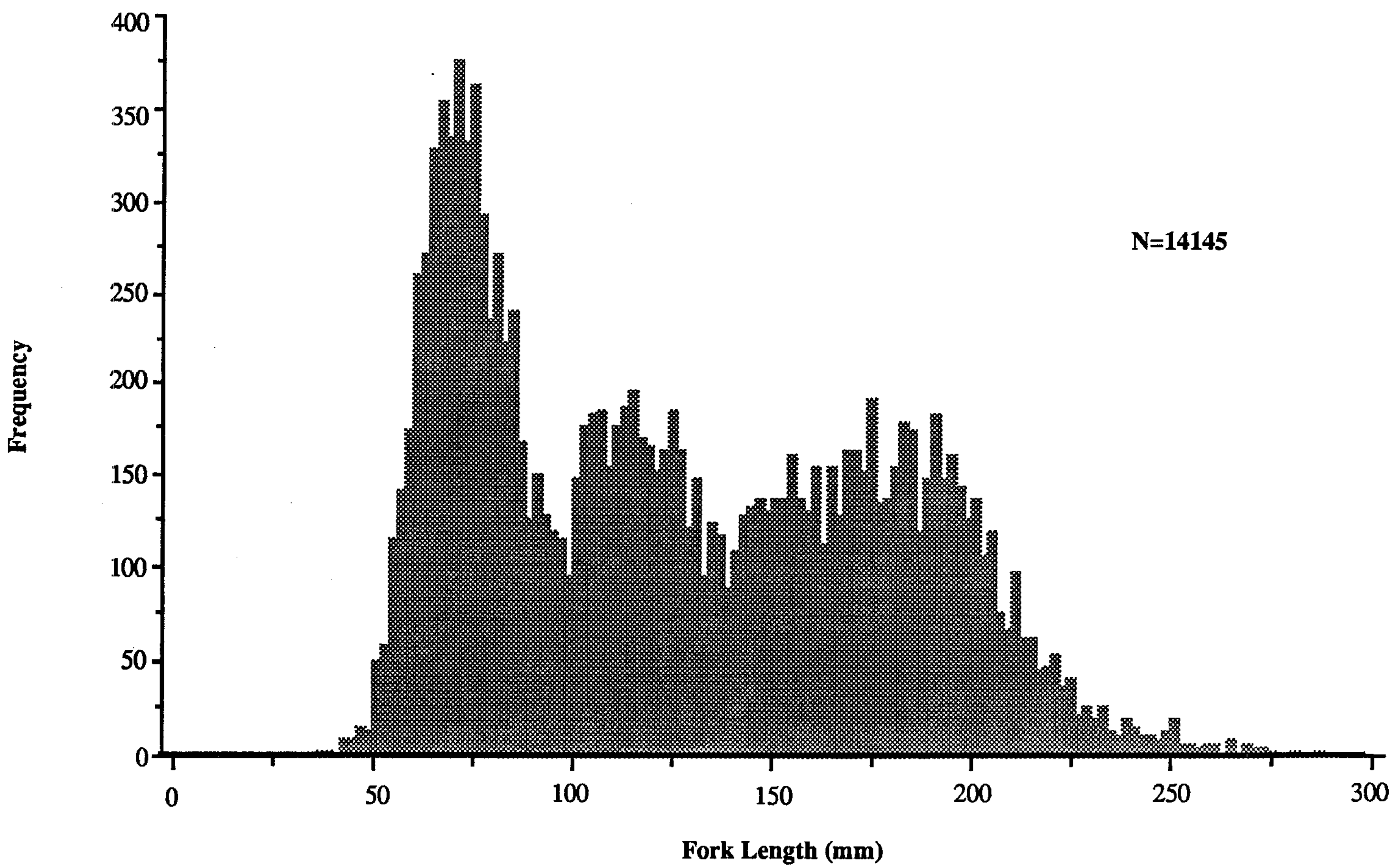
APPENDIX 1.—Length frequency (2mm increments) of Arctic char captured by fyke nets in Arctic Refuge coastal waters, July-September 1989.



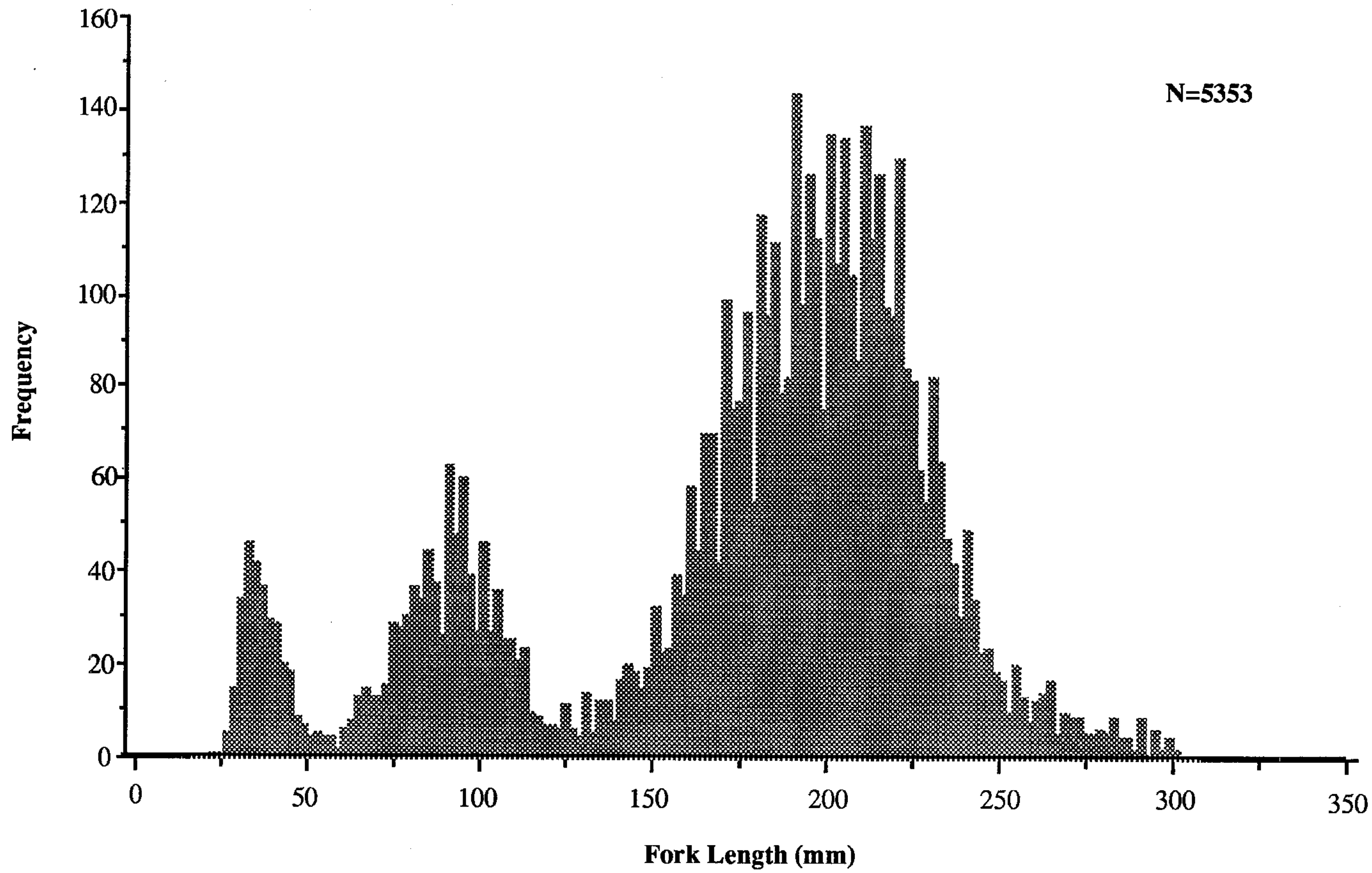
APPENDIX 2.—Length frequency (2 mm increments) of Arctic cisco captured by fyke nets in Arctic Refuge coastal waters, July-September 1989.



APPENDIX 3.—Length frequency (2 mm increments) of Arctic cod captured by fyke nets in Arctic Refuge coastal waters, July-September 1989.



APPENDIX 4.—Length frequency (2mm increments) of fourhorn sculpin captured by fyke nets in Arctic Refuge coastal waters, July-September 1989.



APPENDIX 5.—Length frequency (2 mm increments) of Arctic flounder captured by fyke nets in Arctic Refuge coastal waters, July-September 1989.