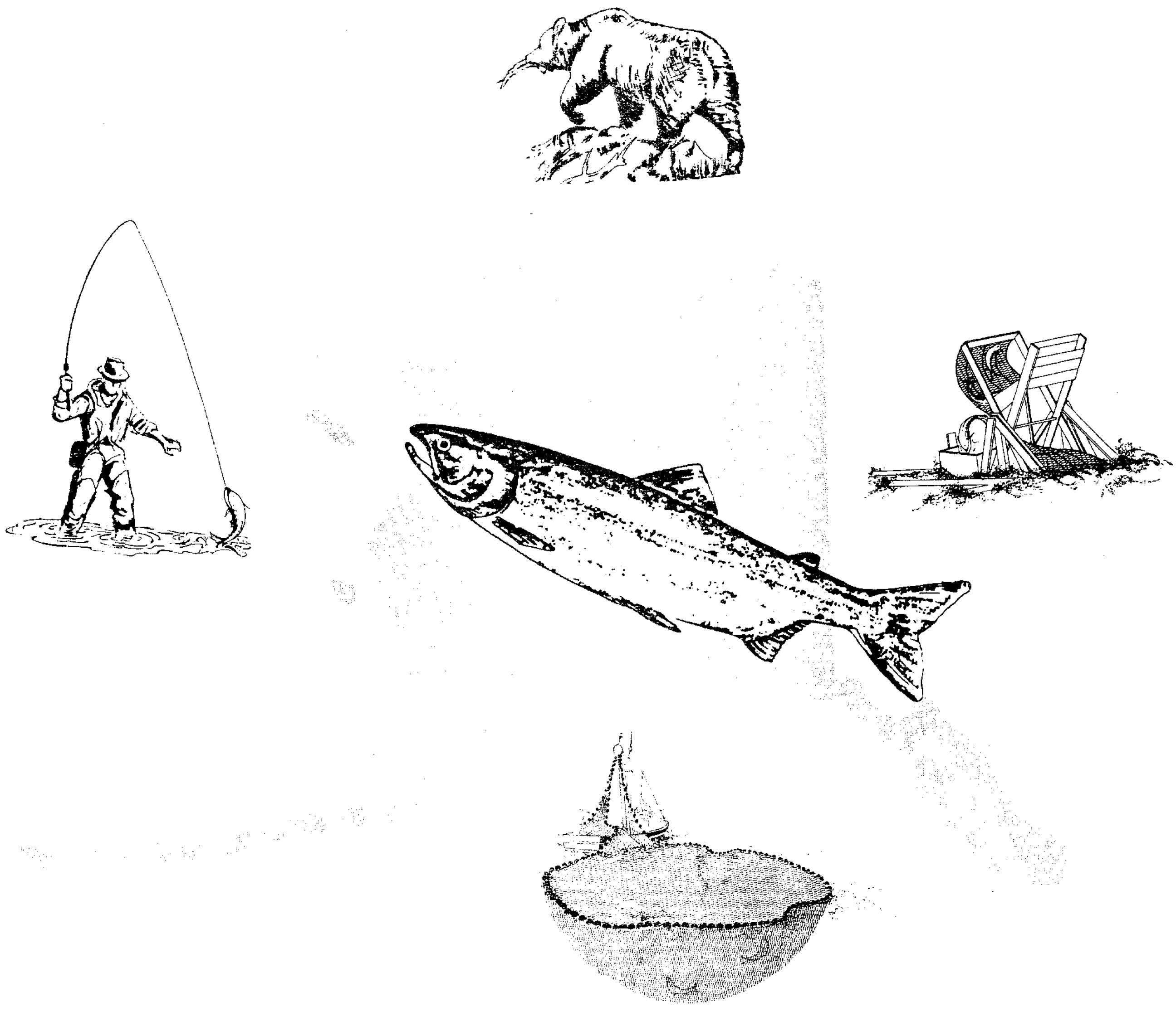
FISH POPULATION CHARACTERISTICS OF ARCTIC NATIONAL WILDLIFE REFUGE COASTAL WATERS, SUMMER 1991

Alaska Fisheries Progress Report Number 94.1



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Fish Population Characteristics of Arctic National Wildlife Refuge Coastal Waters, Summer 1991

Alaska Fisheries Progress Report

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

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ABSTRACT

Fyke nets were used to sample marine and anadromous fishes in protected coastal lagoons and coves adjacent to the Arctic National Wildlife Refuge (Arctic Refuge) from July 12 to September 12, 1991. Crews collected data for analyses of relative abundance and distribution on all species that were caught. In addition, condition, growth, and maturity data were analyzed for five target species: Arctic char *Salvelinus alpinus*, Arctic cisco *Coregonus autumnalis*, Arctic flounder *Liopsetta glacialis*, fourhorn sculpin *Microcephalus quadricornis*, and Arctic cod *Boreogadus saida*. Coastal movements of four target species were examined from recaptured fish marked with dye and Floy anchor tags. Two stations were each sampled within four specific areas: Camden Bay (Simpson Cove), Kaktovik, Jago, and Beaufort lagoons. Concurrent data on the physical habitat were also collected including water temperature, depth, salinity, and wind velocity and direction. Data on ocean currents were collected in Camden Bay.

Nineteen species totaling 80,781 fish were captured. Of the five target species, fourhorn sculpin was the most abundant species, comprising 46% of the total catch. The next most abundant species, each comprising approximately 14% of the total catch, were Arctic cod, Arctic char, and Arctic flounder. Arctic cisco was the least abundant target species. Seasonal mean catch rates for the study area reflected these trends in total catch. Fourhorn sculpin was most abundant (85.80 fish/d) followed by Arctic cod (30.68 fish/d), Arctic char (28.89 fish/d), and Arctic flounder (28.64 fish/d). Arctic cisco $\leq$ 200 mm fork length (FL) and > 200 mm FL averaged 5.01 fish/d and 3.31 fish/d. Individual sampling area and station catches sometimes diverged from the above results. The highest catch rates occurred in Camden Bay at stations SC01 and SC04 ($P < 0.05$) for all target species except Arctic cisco $\leq$ 200 mm FL. Catch rates of this group were highest in Beaufort Lagoon stations BL02 and BL04.

Three modes were identified in the Arctic char length frequency distribution. The proportion of larger Arctic char decreased over the summer as would be expected during their migration back to freshwater rivers for overwintering. Length frequency distributions of Arctic cisco were divided into large and small fish. Young-of-the-year Arctic cisco 50-90 mm FL appeared to arrive in late August in Beaufort Lagoon and spread westward to Jago Lagoon and Camden Bay by September. Arctic cisco between 150 and 250 mm FL were poorly represented throughout the season. Arctic cisco >250 mm FL were widely represented in the Kaktovik/Jago and Simpson Cove sampling areas. Arctic cod and fourhorn sculpin length frequency distributions were similar to those of previous years. Arctic flounder ranged from 27-305 mm TL with larger fish poorly represented in September. Four years of length frequency data indicate that recruitment of Arctic char and fourhorn sculpin has occurred annually while that of Arctic cisco, Arctic flounder, and Arctic cod has occurred irregularly.

Seasonal changes in the weight-length relationship were significant for Arctic char, Arctic cisco, fourhorn sculpin, and Arctic flounder ($P < 0.05$). The latter three species increased in condition, weight at a given length,

between July and September. Arctic cod were absent in July's catch, therefore they were not tested for changes in condition. Weight-length relationships were not significantly different between sexes for Arctic char and fourhorn sculpin ($P > 0.05$), but were significantly different for Arctic cisco and Arctic flounder. Negligible numbers of spawning Arctic char and Arctic cisco were identified in the catch used for condition analysis and therefore did not impact regression equations. Arctic cod were not caught in numbers adequate for analysis. Because we could not identify current year spawners and due to general lack of spawning fish, comparisons were not possible between spawners and non-spawners for July and September. Gonadosomatic indices did not reveal differences between spawners and non-spawners.

Fish ages ranged from 1-13 years for Arctic char, 1-11 years for Arctic cisco, 1-9 years for fourhorn sculpin and 1-18 years for Arctic flounder. These four species exhibited wide overlap in mean lengths-at-age. Estimates of von Bertalanffy parameters and subsequent plots of the fitted curves to the data revealed low values of K (related to growth rate) for Arctic char and Arctic flounder and high values of K for fourhorn sculpin. These differences may indicate slower growth or an underestimate by the model due to large numbers of younger fish for Arctic char and Arctic flounder. The model did not successfully fit to the Arctic cisco age data due to lack of ages 2-4.

Most dye-marked and tagged Arctic char (72%) were recaptured within a few days of capture and within the area of first capture. Other recapture information appeared to agree with previously hypothesized movement patterns. Some Arctic char dispersed east and west from tagging areas. Smaller Arctic cisco (< 200 mm FL) moved west, although no Arctic cisco ≥ 200 mm FL, tagged in 1991 on the Arctic Refuge, were recaptured. Four Arctic cisco, previously tagged in the Prudhoe Bay area, were recaptured in the Arctic Refuge. Based on our recapture information, Arctic flounder and fourhorn sculpin did not make extensive movements.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure *Page*

INTRODUCTION

Since the discovery of oil in Prudhoe Bay in 1968, increased attention has focused on the possibility of commercial quantities of oil and gas lying beneath the coastal plain (Figure 1) of the Arctic National Wildlife Refuge (Arctic Refuge). A report to the U.S. Congress (Clough et al. 1987) indicated a 19% chance of finding economically recoverable oil and gas and described a scenario of how those resources might be extracted 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. Future legislation could allow for exploration and eventual production of oil and gas on the coastal plain and development of coastal support facilities such as ports.

In addition to possible oil production on the coastal plain, a number of oil leases have been sold in federal and state waters adjacent to the Arctic Refuge since the early 1980's. Exploratory wells have been drilled in some of these areas. The Kuvlum oil discovery was made only 16 miles north of the Canning River Delta. Continued exploration in the offshore waters is likely, with possible development of production facilities.

Oil, 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. Anadromous and marine fish species use lagoons and other nearshore brackish water habitat of the coastal Beaufort Sea for feeding during summer (Craig 1984; Frugé et al. 1989; Palmer and Dugan 1990; Underwood et al. 1992).

A brackish water band forms along the Beaufort Sea coast as a result of snow and ice melt in spring. Density gradients keep the freshwater from readily mixing with high salinity marine water and west winds hold this layer of brackish water against the coast (Craig 1984). These areas are important because they are relatively warmer than offshore Beaufort Sea waters and have a high prey concentration (Craig 1984). 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; Frugé et al. 1989; Palmer and Dugan 1990; Underwood et al. 1992). Physical factors that appear to be most important to fishes in these nearshore waters are salinity and temperature (Craig 1984). These factors are determined in part by nearshore, wind-driven ocean currents (Sharma 1979).

Baseline data would allow for an understanding of the biological processes occurring in the coastal waters of the Arctic Refuge. Specifically, data on fish population dynamics and habitat are necessary. These data would also aid in the detection of impacts of oil development, and could lead to remedial action and mitigation when impacts occur.

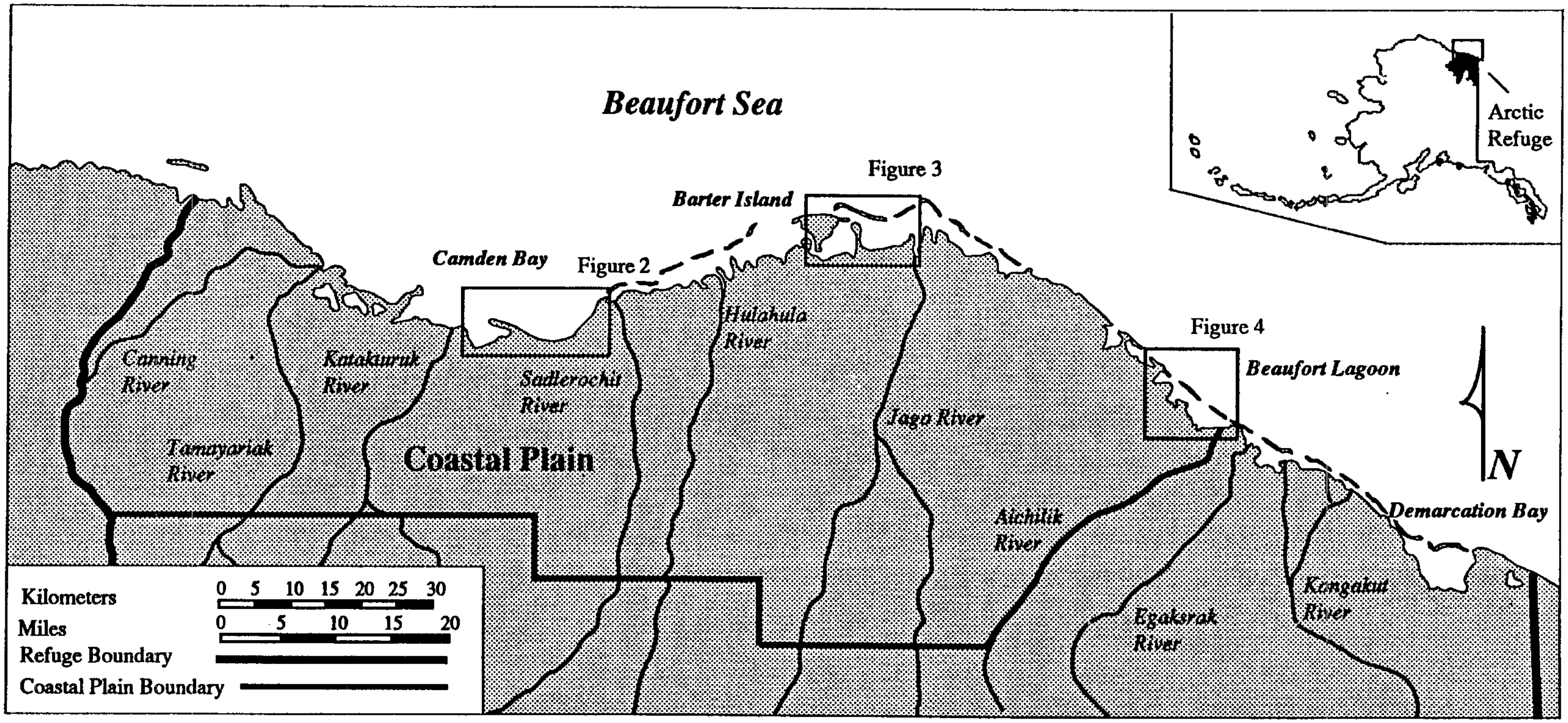

FIGURE 1.- Beaufort Sea coast and coastal plain of the Arctic Refuge and study areas sampled for fish and physical hydrographic characteristics during mid-July through mid-September, 1991.

Fish studies in coastal waters of the Arctic Refuge began in the summer of 1970 with a gill net study that spanned the entire coastal area of the Arctic Refuge (Roguski and Komarek 1971). Baseline data of coastal waters, including Kaktovik Lagoon, were also collected in the 1970's by Ward and Craig (1974) and Griffiths et al. (1977) in response to 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 with fyke nets in 1985 as part of a study of the subsistence fishery there (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 Frugé *in preparation*).

Although the above studies resulted in fisheries information from refuge coastal waters, none provided site-specific data on fish use of the areas identified as possible port sites by Clough et al. (1987), nor did they address the annual variability in fish distribution and abundance that can be substantial in Arctic waters. Information on fish distribution and abundance and related hydrographic characteristics is needed over a several year period in areas of potential development to assess potential impacts on fish populations. Such information could also be used in designing and siting coastal structures and activities of the oil industry while protecting critical fish habitats and migration corridors.

To improve existing baseline data on coastal fish populations and habitats of the Arctic Refuge, the U.S. Fish and Wildlife Service began a 5-year study in 1988. Sampling efforts during 1988 focused on three study areas (Frugé et al. 1989). Two of these areas, Camden Bay and the coastal waters near the bluffs west of Pokok Bay, were thought to be potential port sites. A third study area near Barter Island was comprised of Kaktovik and Jago lagoons. Due to heavy pack ice close to shore at the Pokok bluffs area for most of the summer in 1988, this study area was replaced in 1989 by Beaufort Lagoon, approximately 19 km east of Pokok Bay. Beaufort Lagoon was selected because baseline data were collected at this location in 1984 and 1985 (West and Wiswar 1985; Wiswar and West 1987). This area is also protected by barrier islands and can be sampled regardless of pack ice conditions. In 1990 and 1991, Camden Bay, Kaktovik, Jago and Beaufort lagoons were again selected as study areas.

Our study design examined the fish assemblages in the sampling areas as a community using a relative abundance indicator, catch per unit effort (CPUE). Five target species were identified for closer study. The five species included Arctic char *Salvelinus alpinus*, Arctic cisco *Coregonus autumnalis*, Arctic cod *Boreogadus saida*, fourhorn sculpin *Myoxocephalus quadricornis*, and Arctic flounder *Liopsetta glacialis*. Previous studies indicated these species were appropriate for additional study (West and Wiswar 1985; Wiswar and West 1987; Frugé et al. 1989). The species selected represent both anadromous and marine species, and are: 1) present at all sampling areas, 2) generally abundant, 3) readily sampled by fyke and gill nets, or 4) important for subsistence or commercial fishing (Arctic char and Arctic cisco).

Specific objectives for the five year study of Arctic Refuge coastal waters are 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 fish condition for Arctic char, Arctic cisco, Arctic cod, fourhorn sculpin, and Arctic flounder;

3. Characterize the study areas in terms of water temperature and salinity;

4. Determine current patterns offshore from the Camden Bay and Beaufort Lagoon study areas;

5. Determine the relationships of salinity, temperature, and current patterns to wind direction and velocity in the study areas;

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

This report summarizes fisheries data from 1991 sampling activities for objectives 1 and 2. Our report also briefly describes methodology used to collect hydrographic data, objectives 3-5. Data were collected by our personnel and portions of it will be used to address objective 6 in the final project report. A detailed description of hydrographic data collection methodology, analyses, and results (objectives 3-5), similar to reports for the 1988 and 1989 field seasons (Hale 1990, 1991), will be published separately. Objective 6 will be addressed in the final report, when all catch and habitat data will be analyzed together.

STUDY AREA

Three areas of the Arctic Refuge coast were sampled for fish and hydrographic characteristics: Camden Bay, Kaktovik and Jago lagoons, and Beaufort Lagoon (Figures 2-4). The western most 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 Simpson Cove where maximum depth is approximately 3.4 m (Nautical Chart 16044, U.S. Department of Commerce).

East of Collinson Point, Camden Bay 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 for oil and gas development. Depth in this part of Camden Bay drops off quickly, reaching depths of around 6 m within about 0.5 km from the shore (Nautical Chart 16044, U.S. Department of Commerce). The bottom gradient is less offshore, 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 and Marsh and Carter creeks. Several unnamed smaller streams also drain into the bay. Other major rivers nearby include the Canning River to the west and the Sadlerochit and Hulahula rivers to the east.

Kaktovik and Jago lagoons are located southeast 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 two lagoons become contiguous when the spit is occasionally inundated during periods of high water. Jago Lagoon is separated from the Beaufort Sea by a barrier island, Bernard Spit. The Jago River delta forms the eastern shore of Jago Lagoon.

Jago Lagoon is a limited exchange lagoon (Hachmeister and Vinelli 1984) having only limited alongshore marine water exchange via two openings in the barrier island system 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 River 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 River delta and Jago Spit. Other than the Jago River, there are no prominent streams draining into Jago Lagoon.

Kaktovik Lagoon is a pulsing lagoon, where water exchange is facilitated by changes in water level due to tide and wind (Hachmeister and Vinelli 1984).

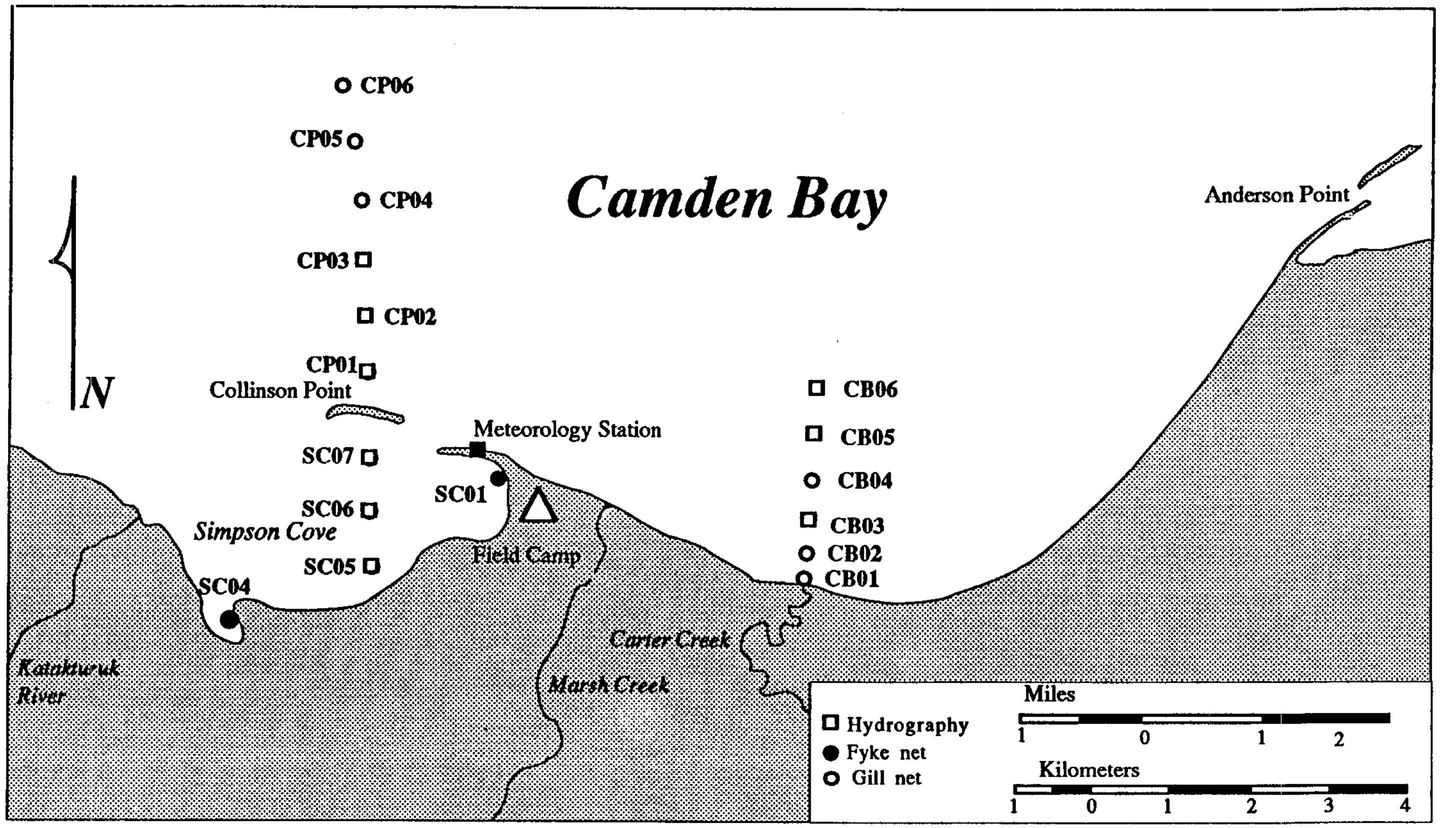

FIGURE 2.- Sampling stations in the Camden Bay study area on the Arctic Refuge during mid-July through mid-September, 1991.

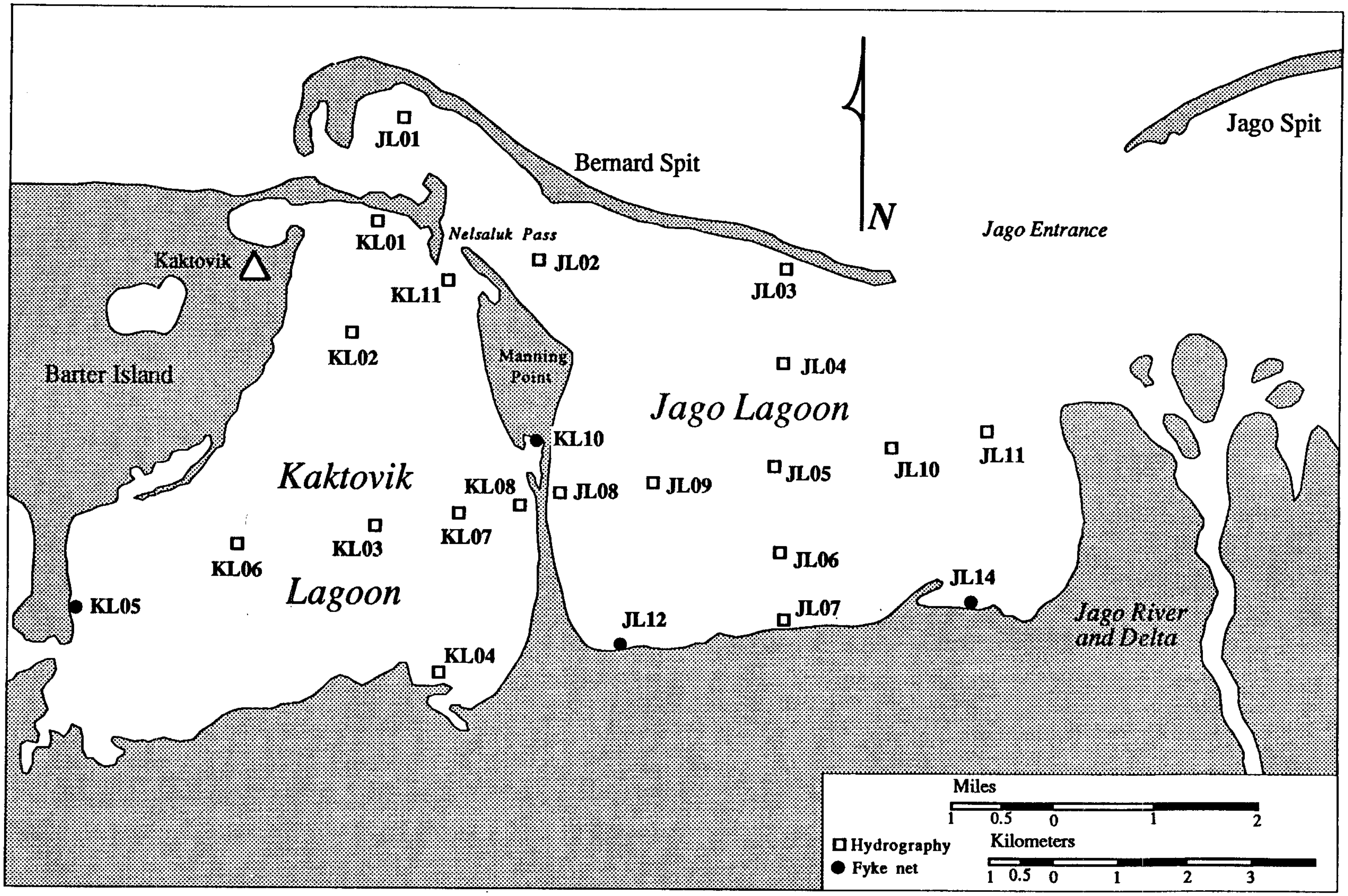

FIGURE 3.– Sampling stations in the Kaktovik and Jago lagoons study area on the Arctic Refuge during mid-July through mid-September, 1991.

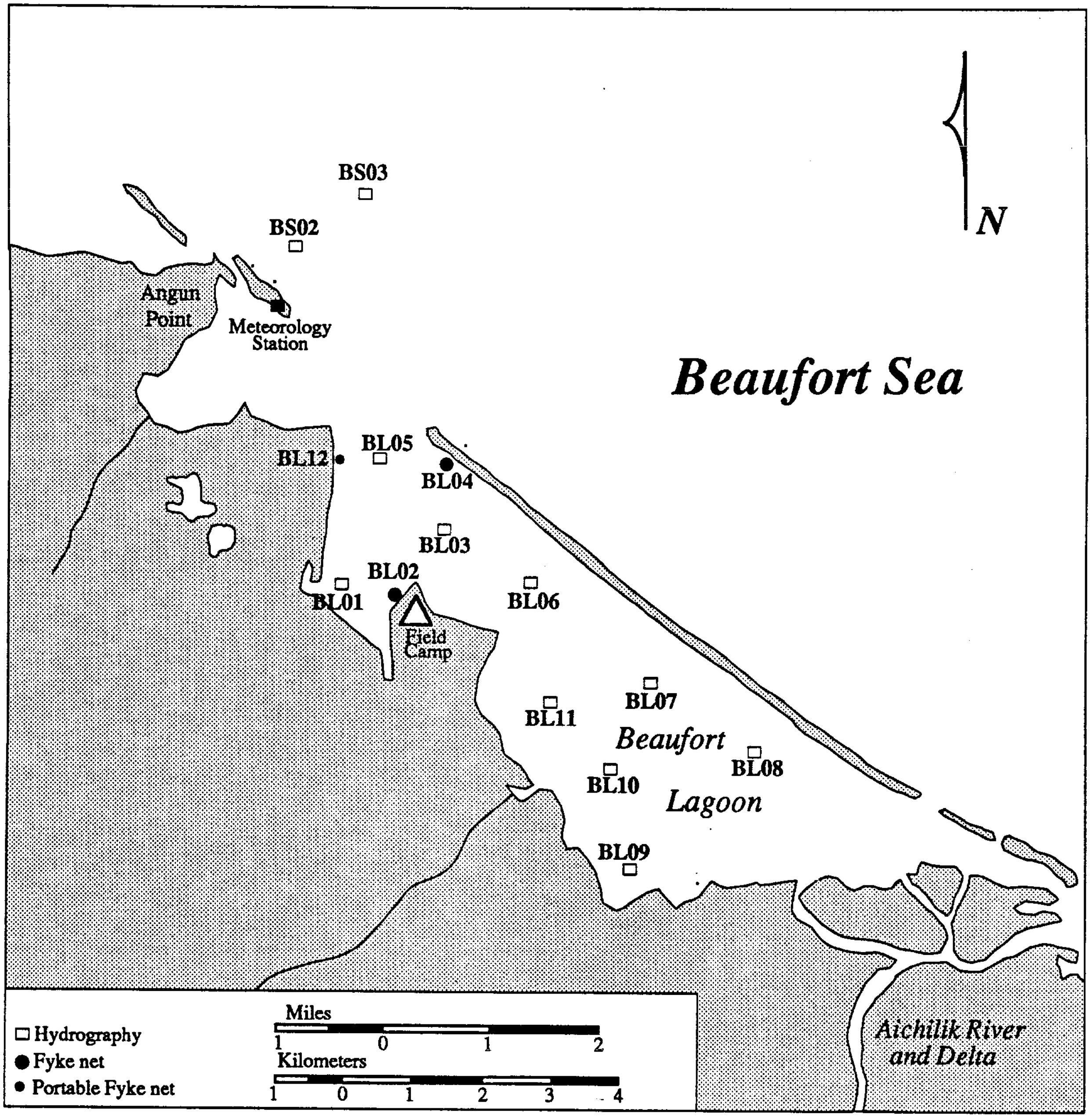

FIGURE 4.– Sampling stations in the Beaufort Lagoon study area on the Arctic Refuge during mid-July through mid-September, 1991.

It has two channels leading to other 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 large streams 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 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. This study area comprises a series of small interconnected narrow lagoons extending eastward to Demarcation Bay. Hachmeister and Vinelli (1984) described Beaufort Lagoon as a limited exchange lagoon. Maximum water depth in Beaufort Lagoon is approximately 4 m (Nautical Chart 16042, U.S. Department of Commerce). Most of the lagoon shoreline is physically similar to that described for Camden Bay, with sand/gravel beaches below tundra bluffs.

Additional information on the physical characteristics of Camden Bay, Kaktovik and Jago lagoons, and Beaufort Lagoon are given by Hale (1990, 1991).

METHODS

SAMPLING GEAR

Standard Fyke Nets

As in 1988, 1989, and 1990, fish were captured using a total of eight standard fyke nets in lagoons and protected nearshore areas in water depths of 1.3 m or less (Figures 2-4 and Table 1). Two fyke nets were each fished Camden Bay, Kaktovik, Jago, and Beaufort lagoons from approximately mid-July through mid-September. Fyke nets were checked daily unless severe weather did not allow safe boat travel.

In Camden Bay, fyke net station (SC01) was established in 1988 in the semi-protected waters of Simpson Cove. Station SC04 was established in 1989. These stations were selected because they had been successfully fished in 1987 and it was thought that additional data could be added to that baseline (Wiswar, U.S. Fish and Wildlife Service, personal communication).

Fyke net stations in Kaktovik Lagoon (stations KL05 and KL10) and Jago Lagoon (stations JL12 and JL14) were originally selected because of their proximity to potential pathways for fish entering and exiting the lagoons. Two stations, KL10 in Nelsaluk Pass and JL14 on the northeast side of Manning Point, were relocated after floating ice proved problematic in the first weeks of 1988. Their new locations were in more protected coves making them less vulnerable to ice but farther from the expected fish pathways (Wiswar, U.S. Fish and Wildlife Service, personal communication).

Two net stations were selected in Beaufort Lagoon. Stations BL02 and BL04 were identical to those of previous studies (West and Wiswar 1985; Wiswar and West 1987; Underwood et al. 1992).

Standard fyke nets consisted of two adjacent traps each constructed with 1.5-m wide and 1.2-m high frames at the mouth. The mesh sizes were 12.5-mm stretch for the traps and 25-mm stretch for the wings and leads. A 61-m lead was anchored between the two traps with the 15-m wings extending from the frames' outside edges opposite to the lead. The lead was set perpendicular to the shoreline with one end anchored to shore. Traps were set offshore (Figure 5). The fyke net was configured such that fish approaching the net were trapped in the cod end on the side from which they entered. All standard 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. Traps, lead, and wings were anchored in place using solid steel rods 3 m in length and 1.5 cm in diameter.

Gill Nets

We intended to set gill nets in the unprotected, deep, open waters of Camden Bay as in past years (Frugé et al. 1989; Palmer and Dugan 1990; Underwood et al. 1992) to examine distribution and directional movements of Arctic char and

TABLE 1.– Sampling station locations, types of data obtained and inclusive dates of sampling, mid-July through mid September 1991.

Station	Sampling area	Latitude	Longitude	Fyke net	CTD[a]	Current meter	Sampling[b] dates
SC01	Camden Bay	69° 58.98′ N	144° 50.20′ W	X	X		Jul 14 - Sep 12
SC04	Camden Bay	69° 57.66′ N	144° 57.00′ W	X	X		Jul 24 - Aug 30
SC05	Camden Bay	69° 58.00′ N	144° 53.12′ W		X		Jul 14 - Sep 08
SC06	Camden Bay	69° 58.42′ N	144° 54.00′ W		X		Jul 14 - Sep 08
SC07	Camden Bay	69° 59.42′ N	144° 54.36′ W		X		Jul 14 - Sep 08
CB02	Camden Bay	69° 58.08′ N	144° 41.83′ W		X	X	Aug 02 - Aug 22
CB06	Camden Bay	69° 59.64′ N	144° 42.07′ W		X	X	Aug 07 - NR[c]
MC01	Camden Bay	69° 58.97′ N	144° 49.05′ W			X	Aug 10 - Aug 22
MC02	Camden Bay	70° 00.30′ N	144° 49.96′ W			X	Aug 09 - NR[c]
KL01	Kaktovik Lagoon	70° 07.94′ N	143° 34.15′ W		X		Jul 12 - Sep 12
KL02	Kaktovik Lagoon	70° 07.12′ N	143° 34.63′ W		X		Jul 14 - Sep 12
KL03	Kaktovik Lagoon	70° 06.00′ N	143° 34.26′ W		X		Jul 14 - Sep 12
KL04	Kaktovik Lagoon	70° 05.08′ N	143° 32.90′ W		X		Jul 14 - Sep 12
KL05	Kaktovik Lagoon	70° 05.44′ N	143° 39.56′ W	X	X		Jul 18 - Sep 12
KL06	Kaktovik Lagoon	70° 05.83′ N	143° 36.65′ W		X		Jul 14 - Sep 12
KL07	Kaktovik Lagoon	70° 06.16′ N	143° 32.72′ W		X		Jul 12 - Sep 12
KL08	Kaktovik Lagoon	70° 06.22′ N	143° 31.28′ W		X		Jul 12 - Sep 12
KL10	Kaktovik Lagoon	70° 06.59′ N	143° 31.00′ W	X	X		Jul 14 - Sep 13
KL11	Kaktovik Lagoon	70° 07.60′ N	143° 32.62′ W		X		Jul 12 - Sep 12
JL01	Jago Lagoon	70° 08.50′ N	143° 33.50′ W		X		Jul 12 - Sep 12
JL02	Jago Lagoon	70° 07.72′ N	143° 31.12′ W		X		Jul 12 - Sep 12
JL03	Jago Lagoon	70° 07.70′ N	143° 26.40′ W		X		Jul 12 - Sep 12
JL04	Jago Lagoon	70° 07.20′ N	143° 26.45′ W		X		Jul 12 - Sep 12
JL05	Jago Lagoon	70° 06.60′ N	143° 26.40′ W		X		Jul 12 - Sep 12
JL06	Jago Lagoon	70° 06.00′ N	143° 26.49′ W		X		Jul 12 - Sep 12
JL07	Jago Lagoon	70° 05.42′ N	143° 26.49′ W		X		Jul 12 - Sep 12
JL08	Jago Lagoon	70° 06.24′ N	143° 30.45′ W		X		Jul 12 - Sep 12

ARCTIC NATIONAL WILDLIFE REFUGE COASTAL FISH STUDY, 1991

TABLE 1.– Continued.

Station	Sampling area	Latitude	Longitude	Fyke net	CTD[a]	Current meter	Sampling[b] dates
JL09	Jago Lagoon	70° 06.41′ N	143° 28.45′ W		X		Jul 12 - Sep 12
JL10	Jago Lagoon	70° 06.71′ N	143° 24.10′ W		X		Jul 12 - Sep 12
JL11	Jago Lagoon	70° 06.88′ N	143° 22.30′ W		X		Jul 12 - Sep 12
JL12	Jago Lagoon	70° 05.22′ N	143° 28.50′ W	X	X		Jul 12 - Sep 12
JL14	Jago Lagoon	70° 05.51′ N	143° 22.23′ W	X	X		Jul 12 - Sep 12
BL01	Beaufort Lagoon	69° 53.43′ N	142° 19.78′ W		X		Jul 20 - Sep 12
BL02	Beaufort Lagoon	69° 53.28′ N	142° 18.59′ W	X	X		Jul 14 - Sep 12
BL03	Beaufort Lagoon	69° 53.81′ N	142° 17.78′ W		X		Jul 20 - Sep 12
BL04	Beaufort Lagoon	69° 54.35′ N	142° 17.23′ W	X	X		Jul 14 - Sep 12
BL05	Beaufort Lagoon	69° 54.38′ N	142° 18.82′ W		X		Jul 20 - Sep 12
BL06	Beaufort Lagoon	69° 53.57′ N	142° 15.87′ W		X		Jul 20 - Sep 12
BL07	Beaufort Lagoon	69° 52.69′ N	142° 13.52′ W		X		Jul 20 - Sep 12
BL08	Beaufort Lagoon	69° 52.15′ N	142° 10.98′ W		X		Jul 20 - Sep 12
BL09	Beaufort Lagoon	69° 51.10′ N	142° 13.72′ W		X		Jul 20 - Sep 12
BL10	Beaufort Lagoon	69° 52.00′ N	142° 13.73′ W		X		Jul 20 - Sep 12
BL11	Beaufort Lagoon	69° 52.52′ N	142° 15.09′ W		X		Jul 20 - Sep 12

[a] CTD – conductivity (salinity), temperature, depth
[b] Sampling by CTD may not correspond exactly with beginning and ending dates for biological sampling.
[c] NR – Not recovered

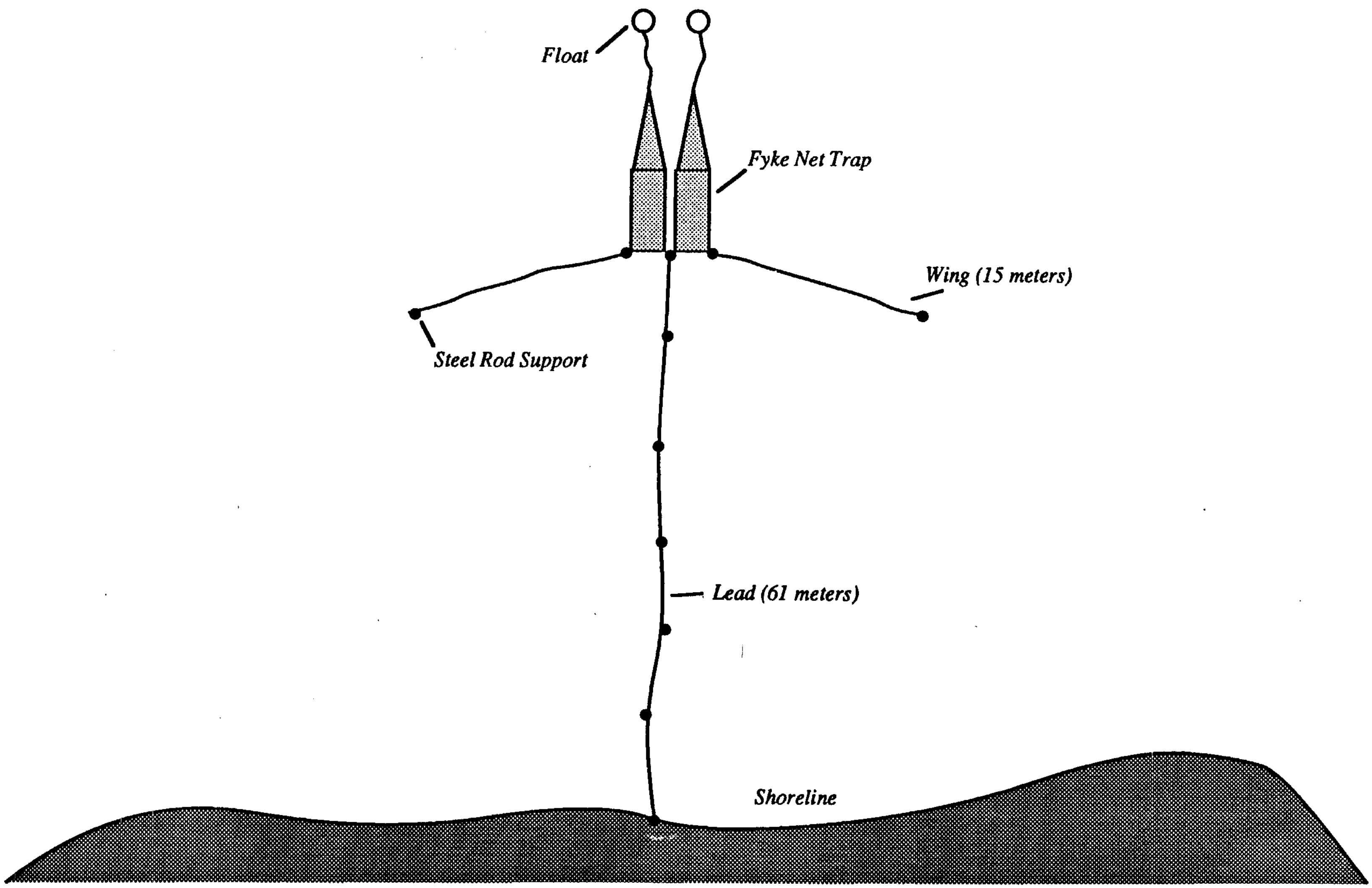

FIGURE 5.- Standard fyke net configuration.

Arctic cisco with increasing depth. However, heavy pack ice persisted throughout the sampling season and did not allow gill nets to be used during 1991.

RELATIVE ABUNDANCE AND DISTRIBUTION

Sample Processing

All fish captured were enumerated by species. The number of fish in unusually large catches (>1000 individuals) were estimated by counting the number of fish in three sub-samples. A sub-sample was defined as the volume required to fill a dip net to a prescribed level. An effort was made to randomly mix the catch prior to obtaining each sub-sample. The average number of fish in the three counted sub-samples was multiplied by the total number of sub-samples to estimate the entire catch. All fish were released except those sacrificed for other analyses. Releases were made offshore, away from the net site to avoid immediate recapture.

Catch Data Analyses

Catches of each species were combined from adjacent fyke net cod ends at each station for a daily total catch. The daily effort for each species was adjusted to 24-h. Arctic cisco were separated into juveniles and adults using a 200 mm fork length (FL) division, and treated as different groups as in previous reports (Frugé et al. 1989; Palmer and Dugan 1990; Underwood et al. 1992). Relative abundance of each species was calculated as catch per unit effort (CPUE) by day (date of net processing) and by season for each sampling area and net station. Daily fyke net CPUE was calculated for each station and each species by dividing the adjusted effort into catch. Species specific seasonal mean daily CPUE's were calculated by summing the daily observations of CPUE and dividing by the total number of days fished, N, at that station. Comparisons between means were done using a Kruskal-Wallis nonparametric test for equality of means, and Scheffé multiple comparisons ($\alpha = 0.05$).

LENGTH FREQUENCY DISTRIBUTIONS

Length frequency distributions for the five target species (Arctic char, Arctic cisco, Arctic cod, fourhorn sculpin, and Arctic flounder) were generated for each study area using standard fyke net data. Fork lengths were measured for Arctic char, Arctic cisco, and Arctic cod and total lengths (TL) for fourhorn sculpin and Arctic flounder. Lengths of at least 25 randomly-selected individuals of each species in each trap were measured daily to the nearest millimeter. All individuals were measured in catches of 25 or less. Fyke net length data for each species were plotted by four periods (July 12-31, August 1-15, August 16-31, and September 1-12) of approximately two-weeks each.

FISH CONDITION

Fish condition (weight of a fish at a given length) and form (rate of increase in weight as a function of length) (Cone et al. 1990) were compared for the five target species following Cone's (1989) suggested method of least squares regression. Fish collected early in the open water season (July 10-24) and those collected late in the season (August 29-September 12) were tested for differences using analysis of covariance ($\alpha = 0.05$). Differences between sexes were compared (Cone 1989) from the July samples at Camden Bay and Beaufort Lagoon using fish sacrificed for other analyses.

Equal sampling of all lengths for a given species was attempted by collecting five fish from each length interval at the three sampling areas during each sampling period. Length intervals were 10 mm for all species except Arctic char, where 25 mm intervals were used because of their larger size range (Anderson and Gutreuter 1983). Fish lengths were measured as described above. Fish weighing less than 1 kg were weighed to the nearest g with an electronic balance. Fish greater than 1 kg were weighed with Pesola spring scales. Weights between 1 and 2 kg were measured to the nearest 50 g; weights greater than 2 kg were measured to the nearest 100 g.

The least squares regression was calculated using the SAS GLM analysis of covariance procedure (SAS Institute Inc. 1988). A natural logarithm transformation was done to linearize the data and stabilize the variance as suggested by Gazey (W.J. Gazey Research, personal communication). The procedure allows for separate evaluations of slopes and intercepts.

AGE AND GROWTH

Collection

To evaluate age and growth, otoliths were sampled from four target species during one 15-day interval (July 14-29) corresponding to the early open-water season. Procedures for sampling fish in predetermined length categories are described in the preceding section. In addition, otoliths of Arctic cisco measuring ≤ 250 mm FL were collected from August 29 to September 12 at Camden Bay and Beaufort Lagoon for within-season growth comparisons. Age data among sexes, stations, and areas were pooled to provide adequate sample sizes for analyses. Because Arctic cod were not captured during either sampling period, no analyses were possible on this species.

Ageing

Pairs of otoliths were removed, stored in 50% isopropyl alcohol, and aged 2 to 3 months later at the Fairbanks field office using procedures outlined from Barber and McFarlane (1987). Whole otoliths were illuminated with a fiber optic light and viewed at low magnification through a dissecting microscope. Ages were assigned based on at least two independent readings. If no age could be assigned for a given pair of otoliths after two independent examinations, a third reader attempted to age the pair. If no consensus was reached among the three readers or if the otoliths were unreadable, the sample was rejected for growth analyses.

Data Analyses

Growth data for the four species were examined for each species by calculating: 1) von Bertalanffy growth model parameters, 2) mean length-at-age for all four species, 3) one-year growth increments of Arctic char and fourhorn sculpin tagged in 1990, and 4) instantaneous growth rates for age 1 Arctic cisco. Only Arctic char and fourhorn sculpin were examined for growth increments from 1990 to 1991 because they were the only species recaptured in 1991. Only age 1 Arctic cisco were used for instantaneous growth because we did not collect any Arctic cisco of ages 0,3, or 4, and only 1 fish at age 2 during the July sampling period.

Growth was examined using the von Bertalanffy growth equation (Ricker 1975):

$$L_t = L\infty(1 - e^{(-k(t-t_0)})$$

fit to age data with a derivative-free, non-linear least-squares regression technique (Proc NLIN, SAS Institute Inc. 1988) where L_t is length (mm) at age t (years), $L\infty$ is the theoretical asymptotic length, K is the growth coefficient related to growth rate, and t_0 is the theoretical age at which length is zero.

Mean lengths-at-age were calculated for each species and examined with respect to overlap of lengths between ages. Age and length frequency distributions plotted to examine agreement of these distributions (number of modes).

Growth increments were calculated for Arctic char and fourhorn sculpin tagged in 1990 and recaptured in 1991. For Arctic char, juvenile and adult mean growth were calculated separately. Arctic char < 350 mm FL (approximately age 7) were considered immature (Craig and McCart 1976). All fourhorn sculpin were tagged as adults (≥ 185 mm TL).

Initial (W_1) and final weight (W_2) for age 1 Arctic cisco collected during early and late sampling periods were calculated from mean length of aged fish using the least-squares regression weight-length relationship described in the preceding section. Instantaneous growth (G) (Bagenal and Tesch 1978) was calculated as follows:

$$G = Log_e(W_2) - Log_e(W_1) / \Delta t$$

where W_1 and W_2 are initial and final calculated weight (g) and change in time, Δt, is an arbitrary constant defined here as the time interval between the mid-points of the early and late sampling periods, a period of 48 days.

MATURITY

Target species sacrificed for the extraction of otoliths were also dissected and examined for sex and level of gonad development. The gonads were removed and weighed to the nearest 0.1 gram. Development levels were classified as immature, mature non-spawner, and mature spawner. Some fish could not be classified as to sex or development level and thus designated "undetermined". Gonadosomatic indices (GSI) were calculated by dividing gonad weight by whole body weight.

FISH MOVEMENTS

Arctic cisco and Arctic char less than 300 mm FL 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; and Kaktovik and Jago lagoons, left caudal peduncle. Arctic char and Arctic cisco greater than 300 mm FL and other target species greater than 200 mm in length were tagged with Floy anchor type tags. Dye marks and tag numbers from recaptured individuals were recorded at the time of capture.

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 and Figures 2-4). These data were also collected at all fyke net stations when nets were checked. Offshore in Camden Bay at Carter Creek (stations CB02 and CB06) and at Marsh Creek (stations MC01 and MC02) 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 containing detailed descriptions of hydrographic and meteorologic methods of data collection, equipment used, summaries, and analyses of these data will be produced.

RESULTS

RELATIVE ABUNDANCE AND DISTRIBUTION

Study Area

Fyke nets were fished for varying number of days at the eight historically fished stations during the 1991 field season (Table 1 and Figures 2-4). Storms kept crews from working and destroyed nets causing variation in the number of days fished at each station. The first nets were operational July 12 and the last nets were removed September 13, 1991. The total number of sampling days at the net stations were as follows: Camden Bay, SC01 55 days, and SC04 32 days; Kaktovik Lagoon, KL05 44 days, and KL10 51 days; Jago Lagoon, JL12 41 days, and JL14 49 days; Beaufort Lagoon, BL02 56 days and BL04 49 days.

Nineteen species of fish were identified in fyke net catches in nearshore Arctic Refuge waters (Table 2). Fourhorn sculpin was the most abundant species, comprising 46% of the total catch (Table 3). The next most abundant species were Arctic char, Arctic cod, and Arctic flounder, each comprising ≈14% of the total catch. Trends in total catch were reflected in the significant differences between daily catch rates for target species (Table 4). Catch rates of fourhorn sculpin were highest, followed by Arctic char and Arctic flounder, which were not significantly different from each other. Arctic cisco ≤ 200 mm FL, Arctic cisco > 200 mm FL, and Arctic cod were the least abundant target species caught during the 1991 field season, and were not significantly different from each other.

Sampling Areas and Stations

In Camden Bay, 18 species of fish were identified. Fourhorn sculpin comprised 40% of the total Camden Bay catch (Table 3; Appendix A). The next most abundant species by catch were Arctic cod (27%), Arctic char (16%), and Arctic flounder (10%). Of the total catch, 57% was from station SC01, and 43% was from station SC04. Daily catch rates differed significantly for species within the sampling area and within stations (Tables 5 and 6). Catch rates indicated that fourhorn sculpin and Arctic char were the most abundant species caught in the Camden Bay sampling area (Table 5). Following in abundance were Arctic flounder and Arctic cod. Arctic cisco ≤ 200 mm FL and Arctic cisco > 200 mm FL were the least abundant species and did not differ significantly.

At station SC04 the most abundant species was fourhorn sculpin, followed by Arctic flounder, Arctic char, and Arctic cod (Table 6). Unlike total catch, sampling area catch rates and station SC04 catch rates, catch rates at station SC01 indicated that Arctic char was the most abundant species. Fourhorn sculpin, Arctic cod, Arctic flounder, and Arctic cisco > 200 mm FL followed in abundance. Arctic cisco ≤ 200 mm FL was the least abundant species (Table 6).

In Kaktovik Lagoon, 15 species of fish were identified. Fourhorn sculpin made up 54% of the total catch (Table 3; Appendix A). The next most abundant species were Arctic flounder (20%), Arctic char (13%), and saffron cod (5%).

TABLE 2.– Fish species captured during fyke net sampling in Arctic Refuge coastal waters during July-September 1991.

Family	Common name	Scientific name
	Anadromous	
Salmonidae	Arctic cisco	*Coregonus autumnalis*
	Least cisco	*Coregonus sardinella*
	Broad whitefish	*Coregonus nasus*
	Arctic char	*Salvelinus alpinus*
	Pink salmon	*Oncorhynchus gorbuscha*
Osmeridae	Rainbow smelt	*Osmerus mordax*
Gasterosteidae	Ninespine stickleback	*Pungitius*
	Freshwater	
Salmonidae	Arctic grayling	*Thymallus arcticus*
	Marine	
Clupeidae	Pacific herring	*Clupea harengus*
Osmeridae	Capelin	*Mallotus villosus*
Gadidae	Arctic cod	*Boreogadus saida*
	Saffron cod	*Eleginus gracilis*
Stichaeidae	Slender eelblenny	*Lumpenus fabricii*
Ammodytidae	Pacific sand lance	*Ammodytes hexapterus*
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 fyke net catch by sampling area and sampling station in Arctic Refuge coastal waters, July-September 1991.

	Camden Bay		Kaktovik Lagoon		Jago Lagoon		Beaufort Lagoon		
Species	SC01	SC04	KL05	KL10	JL12	JL14	BL02	BL04	Total
Arctic cod	7,560	2,815	240	445	68	316	4	6	11,544
Fourhorn sculpin	5,220	10,162	5,285	3,615	2,525	6,216	3,221	861	37,105
Ninespine stickleback	175	151	32	46	83	375	202	43	1,107
Arctic flounder	2,040	1,721	2,153	1,197	597	1,812	1,336	826	11,682
Arctic cisco (≤200 mm)	292	133	38	68	61	218	866	403	2,079
Arctic cisco (>200 mm)	585	31	67	128	107	67	141	232	1,358
Arctic char	5,105	864	1,296	915	603	635	1,253	838	11,509
Saffron cod	260	90	303	530	303	315	600	259	2,660
Rainbow smelt	559	433	8	44	106	93	33	0	1,276
Slender eelblenny	9	0	13	126	1	0	6	3	158
Arctic sculpin	33	2	6	32	0	7	52	7	139
Broad whitefish	1	0	0	2	3	0	1	1	8
Least cisco	67	11	5	5	5	0	5	7	105
Pacific herring	1	0	0	2	0	0	0	0	3
Pink salmon	1	0	0	0	0	0	0	0	1
Capelin	3	0	0	0	1	0	0	0	4
Arctic grayling	2	1	3	4	0	0	4	3	17
Arctic staghorn sculpin	1	0	1	4	1	1	0	1	9
Greenland seasnail	9	0	0	0	0	0	0	0	9
Pacific sand lance	0	0	1	0	0	0	0	0	1
Unidentified sculpin	7	0	0	0	0	0	0	0	7
Totals	22,020	16,414	9,451	7,163	4,464	10,055	7,724	3,490	80,781

TABLE 4.— Comparison of daily catch per unit effort (fish/d) by species in Arctic Refuge coastal waters, July - September, 1991. Species with the same letter are not significantly different (Kruskal-Wallis test, with Scheffé multiple comparisons, $\alpha = 0.05$). N = 377.

Species	Mean fish/d	Scheffé grouping
Fourhorn sculpin	85.80	A
Arctic flounder	28.64	B
Arctic char	28.89	B
Arctic cisco ≤ 200 mm FL	5.01	C
Arctic cisco > 200 mm FL	3.31	C
Arctic cod	30.68	C

TABLE 5.— Comparisons of daily catch per unit effort (fish/d) by species within sampling areas in Arctic Refuge coastal waters, July - September 1991. Species with the same letter are not significantly different (Kruskal-Wallis test, with Scheffé multiple comparisons, $\alpha = 0.05$).

Species	Mean fish/d	Scheffé grouping
	Camden Bay, N = 87	
Fourhorn sculpin	149.66	A
Arctic char	65.54	A,B
Arctic flounder	40.30	B,C
Arctic cod	121.31	C
Arctic cisco > 200 mm FL	6.74	D
Arctic cisco ≤ 200 mm FL	4.37	D
	Kaktovik Lagoon, N = 95	
Fourhorn sculpin	78.55	A
Arctic flounder	31.58	B
Arctic char	21.70	B
Arctic cod	6.56	C
Arctic cisco > 200 mm FL	1.94	C,D
Arctic cisco ≤ 200 mm FL	1.03	D
	Jago Lagoon, N = 90	
Fourhorn sculpin	89.10	A
Arctic flounder	24.37	B
Arctic char	12.46	B
Arctic cisco ≤ 200 mm FL	2.69	C
Arctic cisco > 200 mm FL	1.67	C
Arctic cod	4.25	C
	Beaufort Lagoon, N = 105	
Fourhorn sculpin	36.60	A
Arctic flounder	19.99	A,B
Arctic char	19.12	B
Arctic cisco ≤ 200 mm FL	11.12	C
Arctic cisco > 200 mm FL	3.12	C
Arctic cod	0.08	C

TABLE 6.– Comparison of daily catch per unit effort (fish/d) by species within stations in the Camden Bay sampling area in Arctic Refuge coastal waters, July - September 1991. Species with the same letter are not significantly different (Kruskal-Wallis test, with Scheffé multiple comparison, $\alpha = 0.05$).

Species	Mean fish/d	Scheffé grouping
	Station SC01, N = 55	
Arctic char	90.46	A
Fourhorn sculpin	75.27	A,B
Arctic cod	142.58	B,C
Arctic flounder	34.23	B,C
Arctic cisco > 200 mm FL	10.15	C
Arctic cisco ≤ 200 mm FL	4.77	D
	Station SC04, N = 32	
Fourhorn sculpin	277.53	A
Arctic flounder	50.73	B
Arctic char	22.72	B
Arctic cod	84.74	B
Arctic cisco ≤ 200 mm FL	3.69	C
Arctic cisco > 200 mm FL	0.88	C

Station KL05 produced 57% of the total catch, whereas KL10 produced 43% of the total catch in the lagoon. Within the sampling area and within each station, significant differences were found between daily catch rates for the target species (Tables 5 and 7). In the sampling area fourhorn sculpin was the most numerous species, followed by Arctic flounder and Arctic char (Table 5). The least abundant target species were Arctic cod, Arctic cisco > 200 mm FL, and Arctic cisco ≤ 200 mm FL. A similar pattern was found for both stations KL05 and KL10 (Table 7).

In Jago Lagoon, 14 species of fish were identified. Fourhorn sculpin comprised 60% of the total catch in the sampling area (Table 3; Appendix A). Arctic flounder (17%), Arctic char (9%), and saffron cod (4%) were the next most abundant species. Of the total catch, the majority (69%) was from station JL14, with the remaining (31%) from station JL12. Within the sampling area and within each station, significant differences were found between the daily catch rates for fourhorn sculpin and all other target species (Tables 5 and 8). Following in abundance were Arctic char and Arctic flounder. The least abundant species within the sampling area and at both stations were Arctic cisco > 200 mm FL, Arctic cisco ≤ 200 mm FL, and Arctic cod (Table 8).

In Beaufort Lagoon, 14 species of fish were identified. As in the other sampling areas, fourhorn sculpin was the most abundant species by catch (36%) (Table 3; Appendix A). The next most abundant species by catch were Arctic flounder (19%), Arctic char (19%), and Arctic cisco ≤ 200 mm FL (11%). The majority of the total catch came from station BL02 (69%), with the remainder (31%) from station BL04. Within the sampling area and within the stations significant differences were found between the daily catch rates of the target species (Tables 5 and 9). The sampling area and station BL02 catch rates reflected the trend of total catch in that fourhorn sculpin was the most abundant species. However, at station BL04 Arctic char, Arctic flounder, and fourhorn sculpin were the most abundant species, but did not have catch rates which differed significantly (Table 9). The least abundant of the target species were Arctic cisco ≤ 200 mm FL, Arctic cisco > 200 mm FL, and Arctic cod.

Target Species

During the 1991 field season, Arctic char daily catch rates ranged from 0-843 fish/d, with the highest observation at station SC01 on August 21, 1991. Few Arctic char were present in September, and peak catch rates occurred during August 10-20 for five of the eight stations (Figures 6-9). Significantly higher catch rates of Arctic char occurred in Camden Bay than all other sampling areas (Table 10). Catch rates at station SC01 differed significantly from all other net stations (Table 10). There were no significant differences between stations KL05, BL02, KL10, BL04, JL12, and SC04 for Arctic char.

Daily catch rates of Arctic cisco ≤ 200 mm FL ranged from 0-95 fish/d (Figures 10-13). The highest daily catch rates of Arctic cisco ≤ 200 mm FL occurred after August 10, 1991 at all stations. Stations BL02, BL04, JL14,

TABLE 7.— Comparison of daily catch per unit effort (fish/d) by species within stations in the Kaktovik Lagoon sampling area in Arctic Refuge coastal waters, July - September 1991. Species with the same letter are not significantly different (Kruskal-Wallis test, with Scheffé multiple comparisons, $\alpha = 0.05$).

Species	Mean fish/d	Scheffé grouping
	Station KL05, N = 44	
Fourhorn sculpin	101.76	A
Arctic flounder	42.41	B
Arctic char	28.11	B
Arctic cod	4.54	C
Arctic cisco > 200 mm FL	1.51	C
Arctic cisco ≤ 200 mm FL	0.77	C
	Station KL10, N = 51	
Fourhorn sculpin	58.53	A
Arctic flounder	22.23	B
Arctic char	16.17	B
Arctic cod	8.30	C
Arctic cisco > 200 mm FL	2.32	C
Arctic cisco ≤ 200 mm FL	1.25	C

TABLE 8.— Comparison of daily catch per unit effort (fish/d) by species within stations in the Jago Lagoon sampling area in Arctic Refuge coastal waters, July - September 1991. Species with the same letter are not significantly different (Kruskal-Wallis test, with Scheffé multiple comparisons, $\alpha = 0.05$).

Species	Mean fish/d	Scheffé grouping
	Station JL12, N = 41	
Fourhorn sculpin	56.24	A
Arctic char	13.54	B
Arctic flounder	12.67	B
Arctic cisco > 200 mm FL	2.27	C
Arctic cisco ≤ 200 mm FL	1.31	C
Arctic cod	1.68	C
	Station JL14, N = 49	
Fourhorn sculpin	116.60	A
Arctic flounder	34.17	B
Arctic char	11.55	C
Arctic cisco ≤ 200 mm FL	1.17	D
Arctic cod	6.40	D,E
Arctic cisco > 200 mm FL	3.86	E

TABLE 9.– Comparison of daily catch per unit effort (fish/d) by species within stations in the Beaufort Lagoon sampling area in Arctic Refuge coastal waters, July - September 1991. Species with the same letter are not significantly different (Kruskal-Wallis test, with Scheffé multiple comparisons, $\alpha = 0.05$).

Species	Mean fish/d	Scheffé grouping
	Station BL02, N = 56	
Fourhorn sculpin	54.20	A
Arctic flounder	22.81	B
Arctic char	21.12	B
Arctic cisco ≤ 200 mm FL	14.41	C
Arctic cisco > 200 mm FL	2.19	D
Arctic cod	0.08	E
	Station BL04, N = 49	
Arctic char	16.84	A
Arctic flounder	16.76	A
Fourhorn sculpin	16.48	A
Arctic cisco ≤ 200 mm FL	7.36	B
Arctic cisco > 200 mm FL	4.19	B
Arctic cod	0.07	C

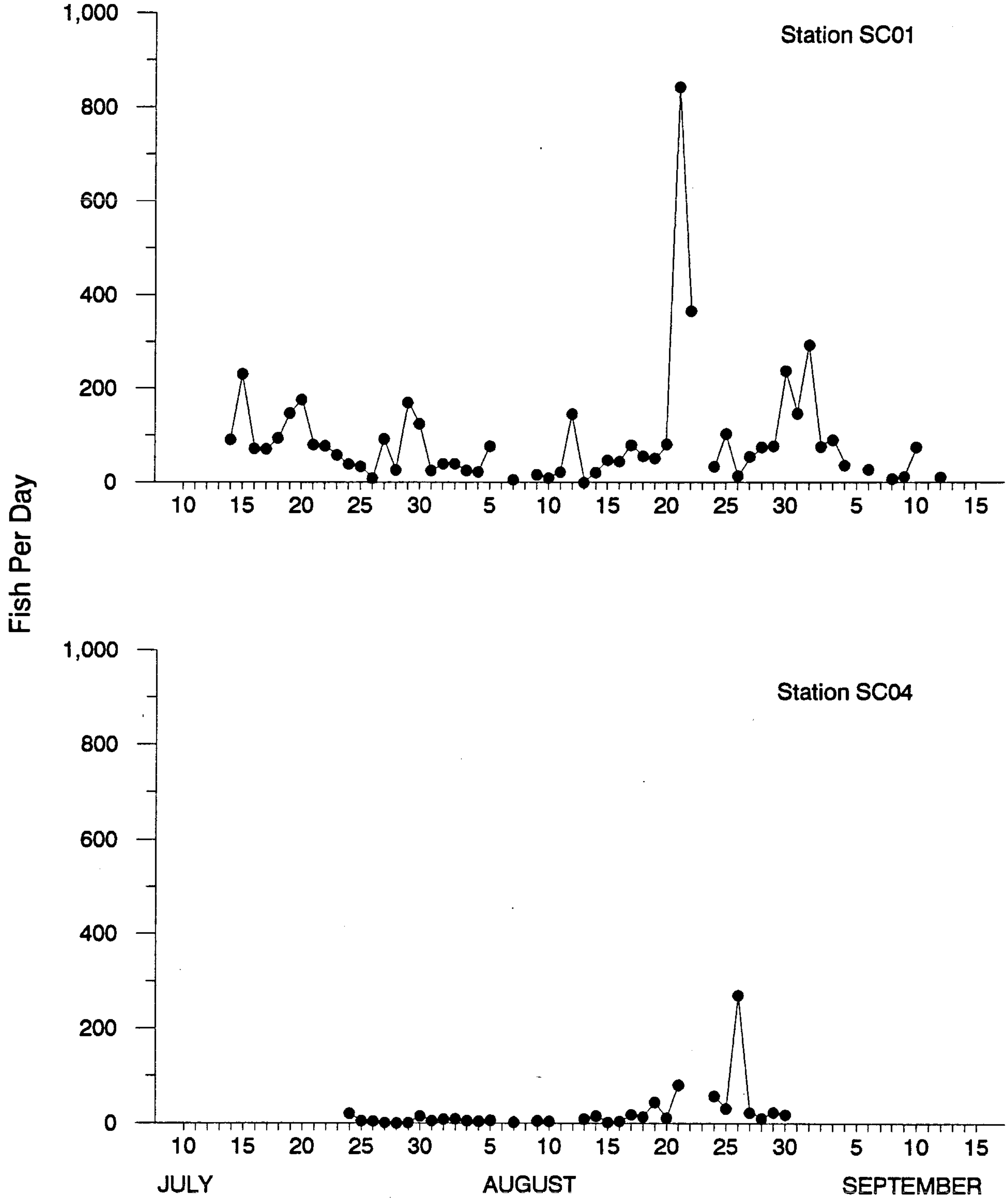

FIGURE 6.— Daily catch per unit of effort (fish/d) for Arctic char at fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1991.

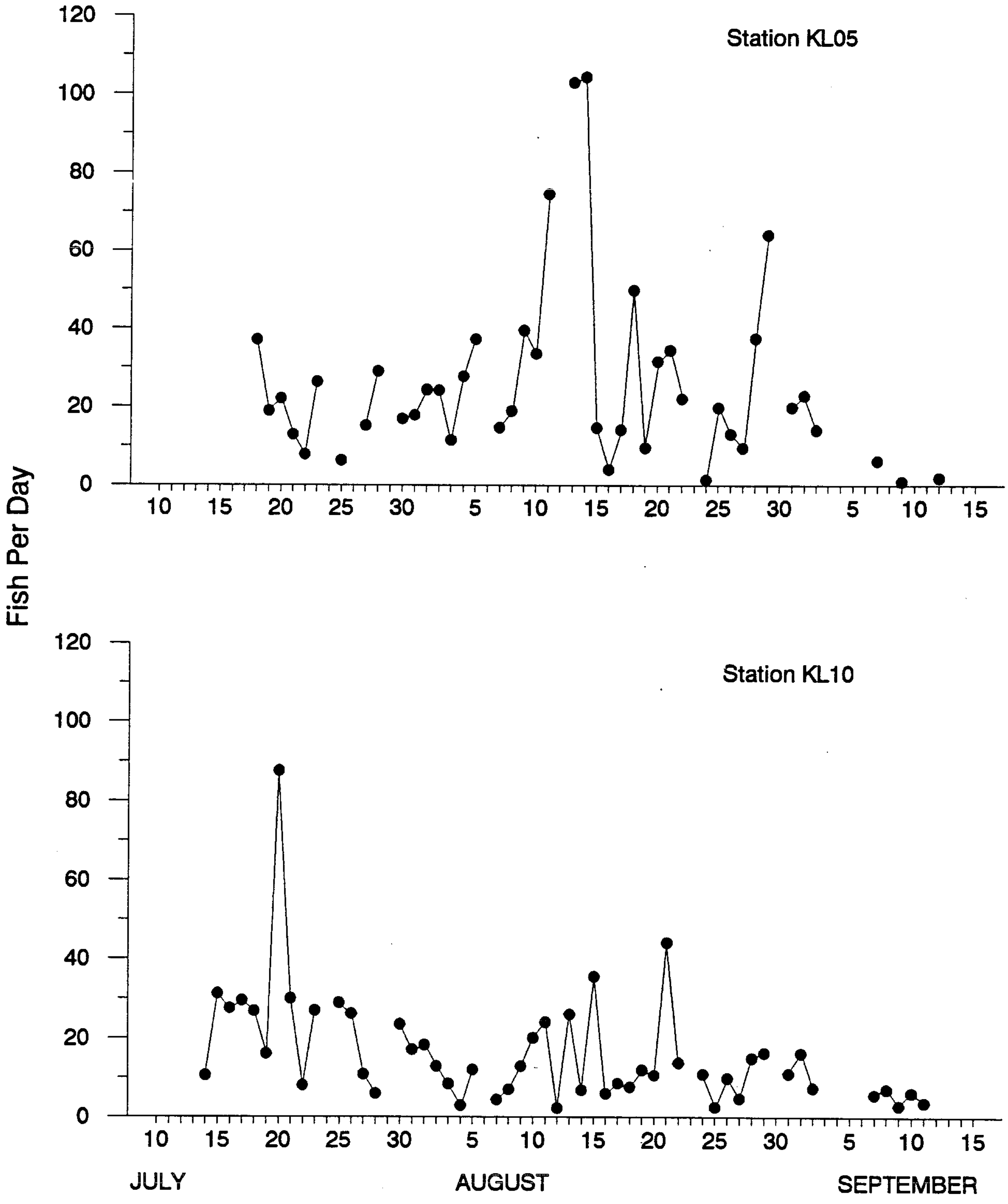

FIGURE 7.— Daily catch per unit of effort (fish/d) for Arctic char at fyke net stations in Kaktovik Lagoon, Arctic Refuge coastal waters, July-September 1991.

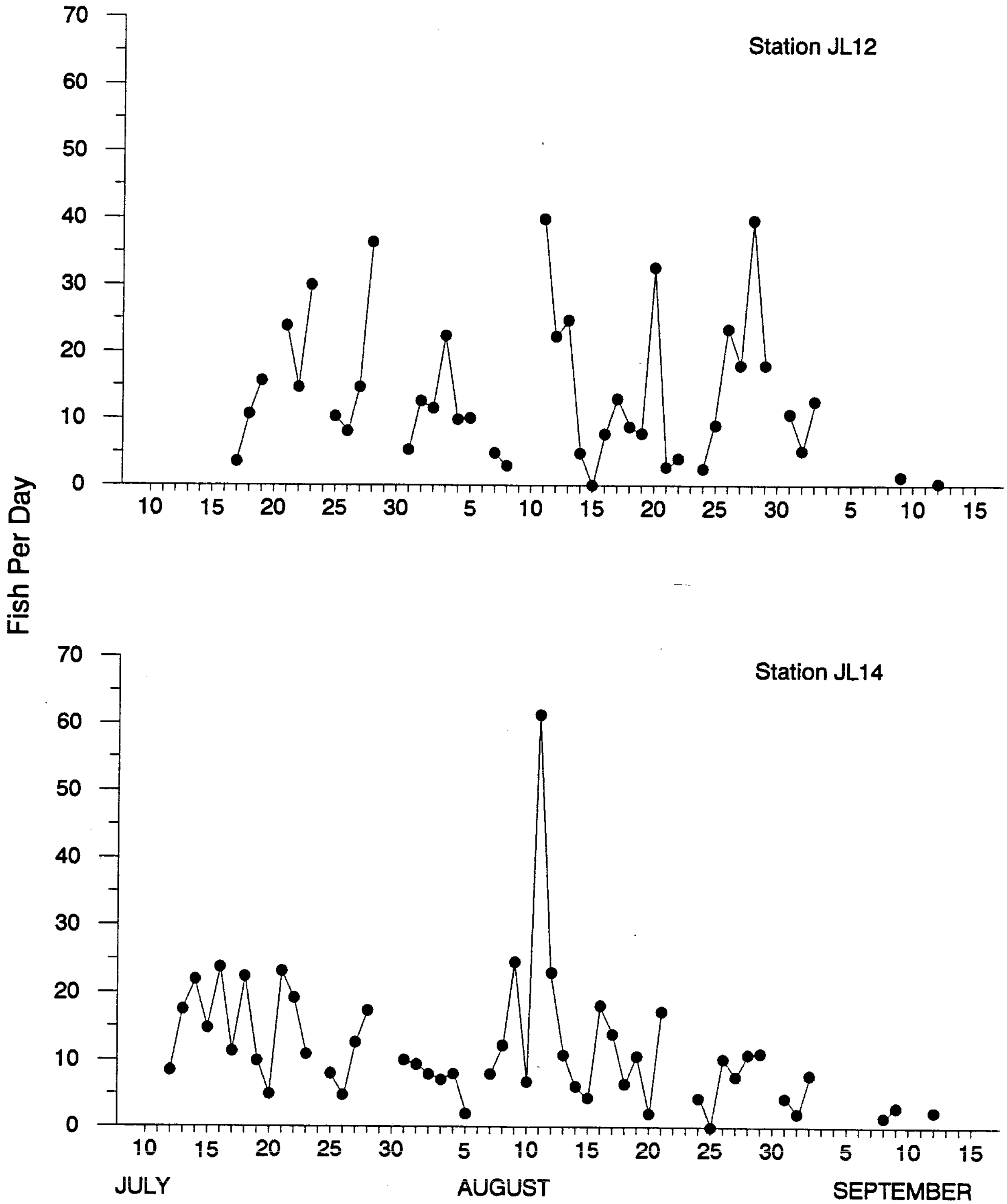

FIGURE 8.— Daily catch per unit of effort (fish/d) for Arctic char at fyke net stations in Jago Lagoon, Arctic Refuge coastal waters, July-September 1991.

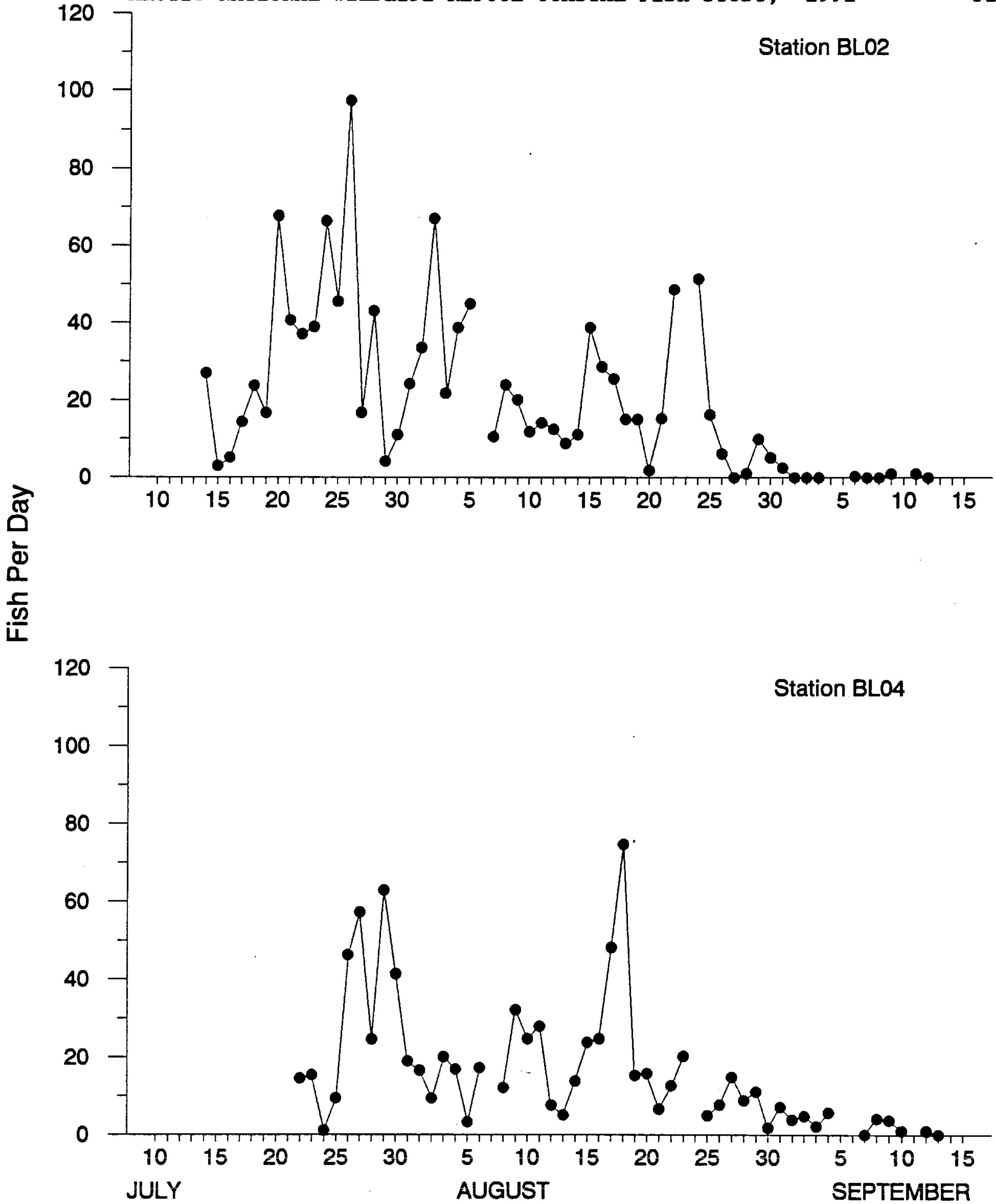

FIGURE 9.– Daily catch per unit of effort (fish/d) for Arctic char at fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1991.

TABLE 10.– Comparison of daily catch per unit effort (fish/d) between sampling areas and between net stations for Arctic char in Arctic Refuge coastal waters, July - September 1991. Between sampling areas, or net stations, those with the same letter are not significantly different (Kruskal-Wallis test, with Scheffé multiple comparisons, $\alpha = 0.05$).

Location	N	Mean fish/d	Scheffé grouping
	Sampling area		
Camden Bay	87	65.54	A
Kaktovik Lagoon	95	21.70	B
Beaufort Lagoon	105	19.12	B,C
Jago Lagoon	90	12.46	C
	Net station		
SC01	55	90.46	A
KL05	44	28.11	B
BL02	56	21.12	B,C
KL10	51	16.17	B,C
BL04	49	16.84	B,C
JL12	41	13.54	B,C
SC04	32	22.72	B,C
JL14	49	11.55	C

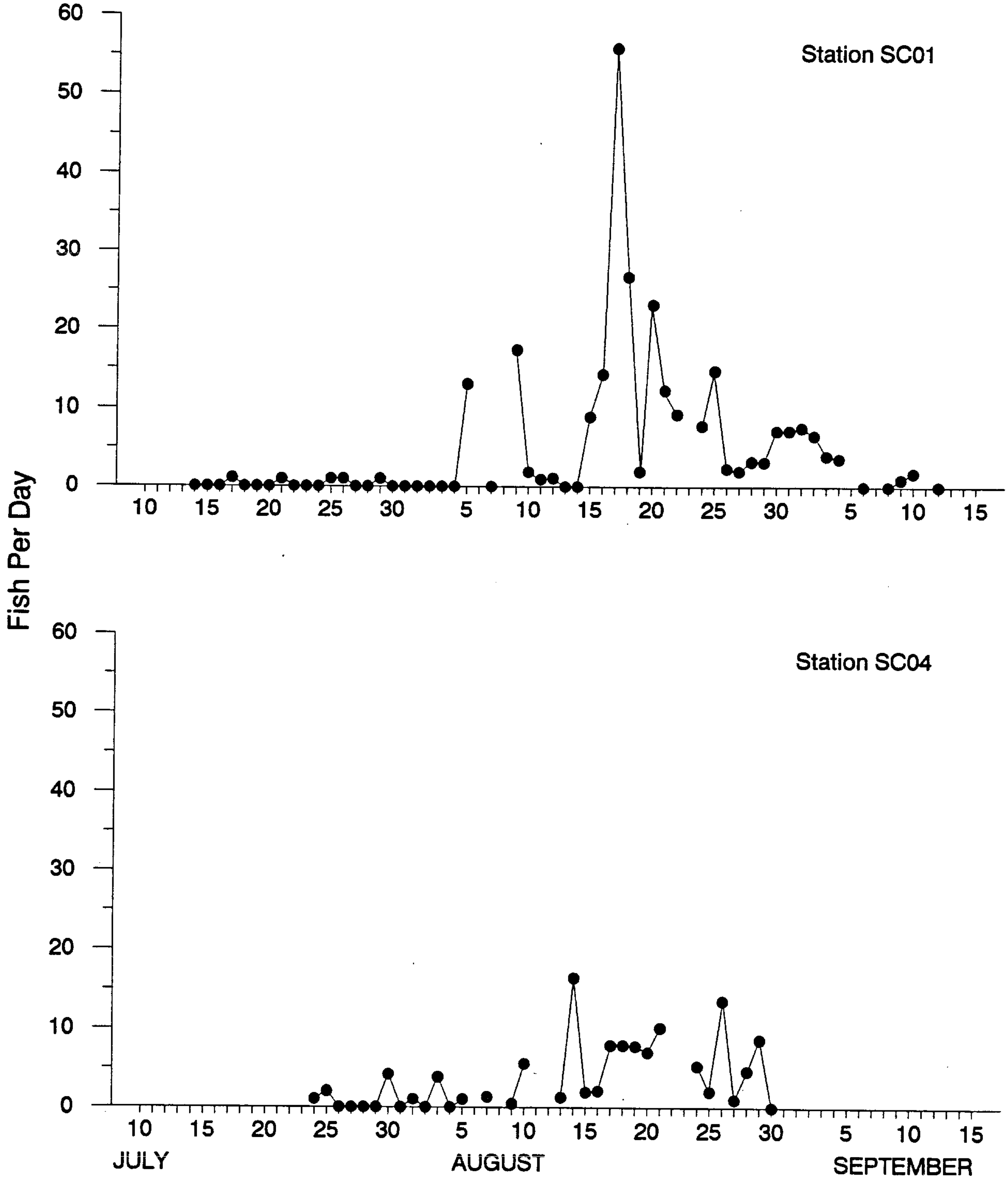

FIGURE 10.— Daily catch per unit of effort (fish/d) for Arctic cisco ≤ 200 mm FL at fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1991.

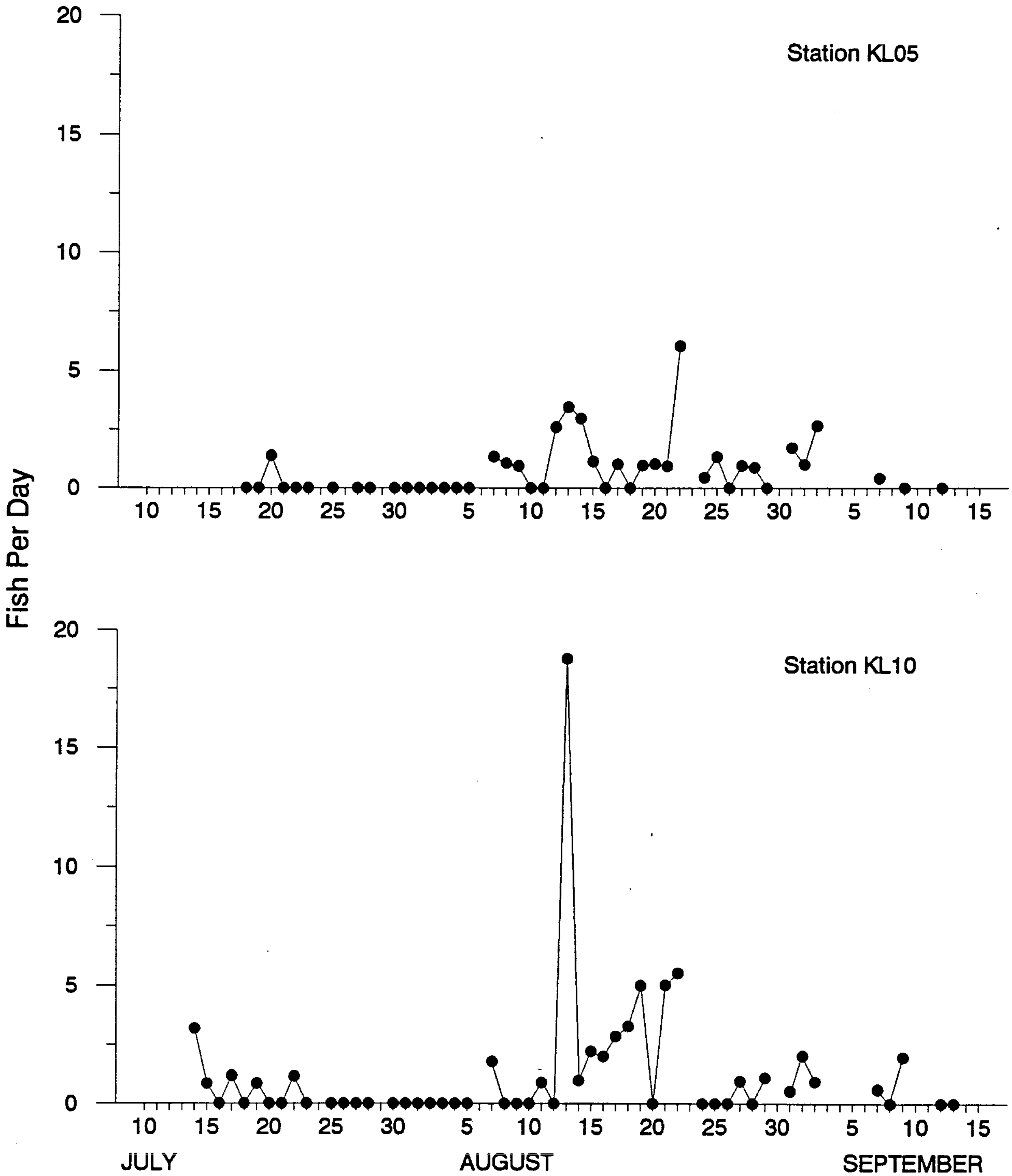

FIGURE 11.— Daily catch per unit of effort (fish/d) for Arctic cisco ≤ 200 mm FL at fyke net stations in Kaktovik Lagoon, Arctic Refuge coastal waters, July-September 1991.

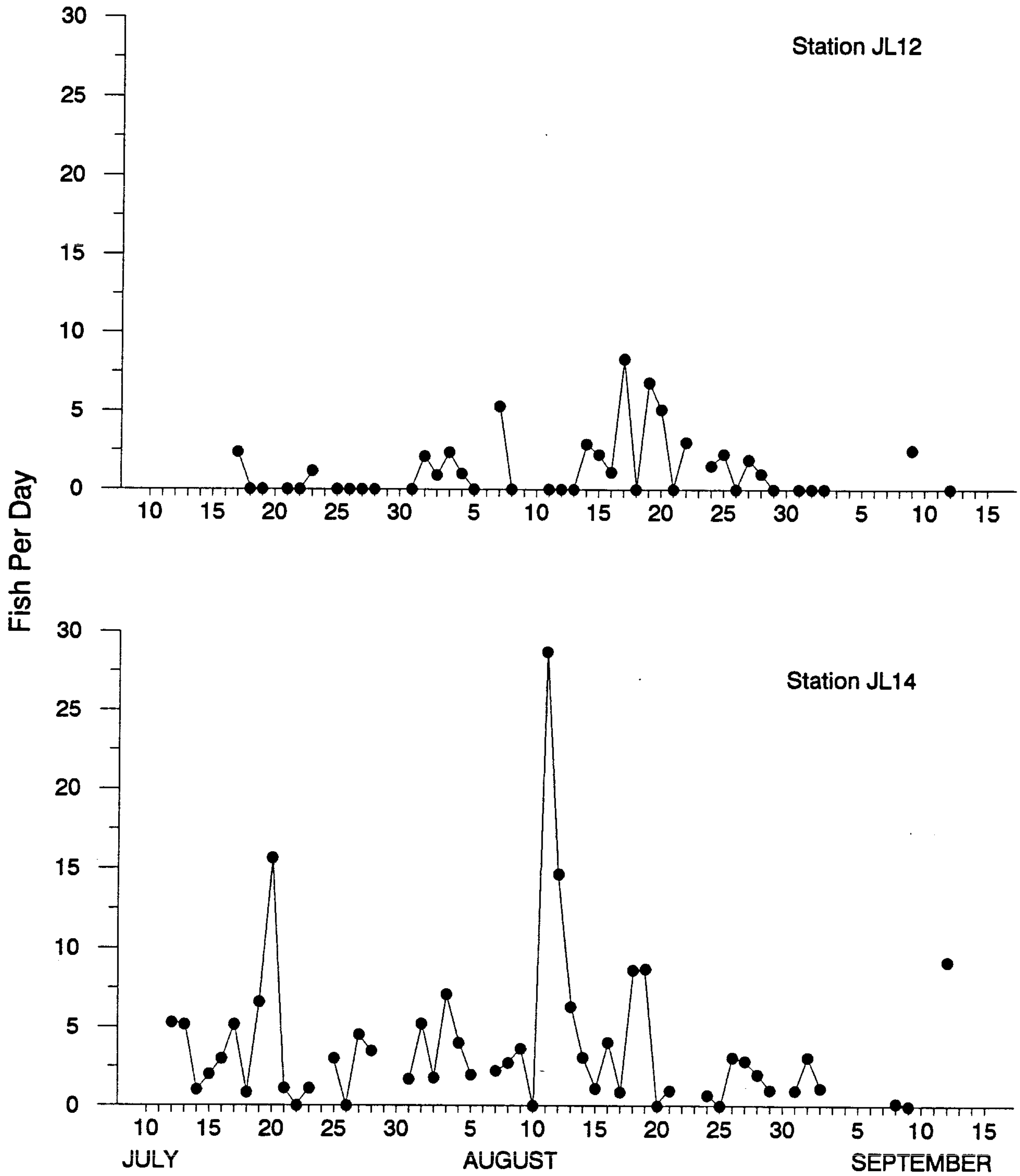

FIGURE 12.– Daily catch per unit of effort (fish/d) for Arctic cisco ≤ 200 mm FL at fyke net stations in Jago Lagoon, Arctic Refuge coastal waters, July-September 1991.

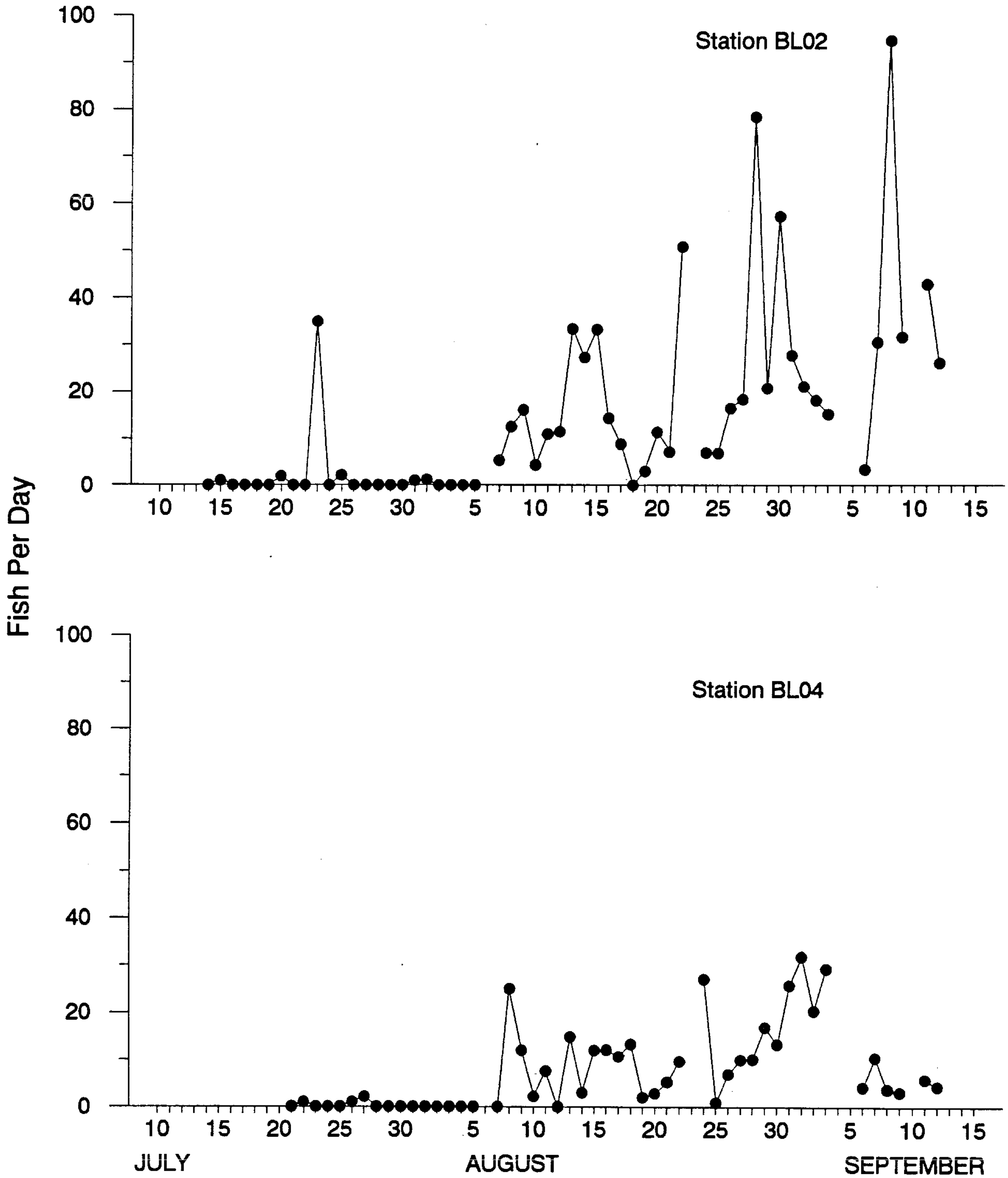

FIGURE 13.- Daily catch per unit of effort (fish/d) for Arctic cisco $\leq$ 200 mm FL at fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1991.

KL10, KL05, and SC04 all had increases in catch rates during August 5 to August 15, 1991. Similar increases occurred at stations SC01 and JL12 between August 15 and 20, 1991. Beaufort Lagoon daily catch rates also showed a consistent trend in that rates tended to be low early in the season and increased in magnitude and variability as the season progressed. Arctic cisco ≤ 200 mm FL sampling area daily catch rates indicated a significantly lower catch rate in Kaktovik Lagoon than all other sampling areas (Table 11). In contrast, catch rates at stations KL05 and KL10 differed significantly only from stations JL14, BL02 and BL04.

Daily catch rates of Arctic cisco > 200 mm FL varied widely, ranging from 0-49 fish/d. Few Arctic cisco > 200 mm FL appear to have been present early in the field season at stations SC04, KL05, KL10, BL02, and BL04 (Figures 14-17). Significantly higher catch rates occurred at Camden Bay compared to Kaktovik and Jago lagoons (Table 12). This trend was also evident in the significantly higher catch rate for station SC01 compared to all other stations. There were no significant differences between Kaktovik, Jago, and Beaufort lagoons, or between stations SC04, KL05, KL10, JL12, JL14, and BL02 for Arctic cisco > 200 mm FL.

Arctic cod daily catch rates varied widely, ranging from 0-1,838 fish/d, with the highest observations in Camden Bay (1,838 fish/d at SC01, and 828 fish/d at SC04). The lowest observations of Arctic cod occurred prior to August 5, 1991 at all stations (Figures 18-21). Maximum catch rates occurred in mid- to late August at all stations, then decreased in September. Daily catch rates were highest in Camden Bay and lowest in Beaufort Lagoon (Table 13). Arctic cod catch rates at stations BL02 and BL04 differed significantly from all other stations except station JL12.

Fourhorn sculpin daily catch rates ranged from 0 (at only two of the eight net stations) to over 1,100 fish/d (1,843 fish/d at JL14 and 1,182 fish/d at SC04). Temporal trends were not readily apparent (Figures 22-25). Beaufort Lagoon had a significantly lower daily catch rate than all other sampling areas (Table 14). Daily catch rates of fourhorn sculpin showed a significantly lower catch rate for station BL04 than any other station.

Arctic flounder daily catch rates were highly variable throughout the field season. Daily catch rates ranged from 0 to 190 fish/d, with four stations, SC01, SC04, KL05, and JL14, having maximum daily catch rates between 186 and 190 fish/d. Expept for station BL04, catch rates reached a maximum in July and then declined during August and September (Figures 26-29). No significant differences were found between sampling area daily catch rates for Arctic flounder (Table 15). The only significant differences between stations occurred between station KL05 and stations JL12 and BL04.

TABLE 11.— Comparison of daily catch per unit effort (fish/d) between sampling areas and between net stations for Arctic cisco ≤ 200 mm FL in Arctic Refuge coastal waters, July - September 1991. Between sampling areas, or net stations, those with the same letter are not significantly different (Kruskal-Wallis test, with Scheffé multiple comparisons, $\alpha = 0.05$).

Location	N	Mean fish/d	Scheffé grouping
		Sampling area	
Beaufort Lagoon	105	11.12	A
Camden Bay	87	4.37	A,B
Jago Lagoon	90	2.70	B
Kaktovik Lagoon	95	1.03	C
		Net station	
BL02	56	14.41	A
BL04	49	7.36	A
JL14	49	3.86	A,B
SC04	32	3.69	A,B,C
SC01	55	4.77	A,B,C,D
JL12	41	1.31	B,C,D
KL10	51	1.25	C,D
KL05	44	0.77	D

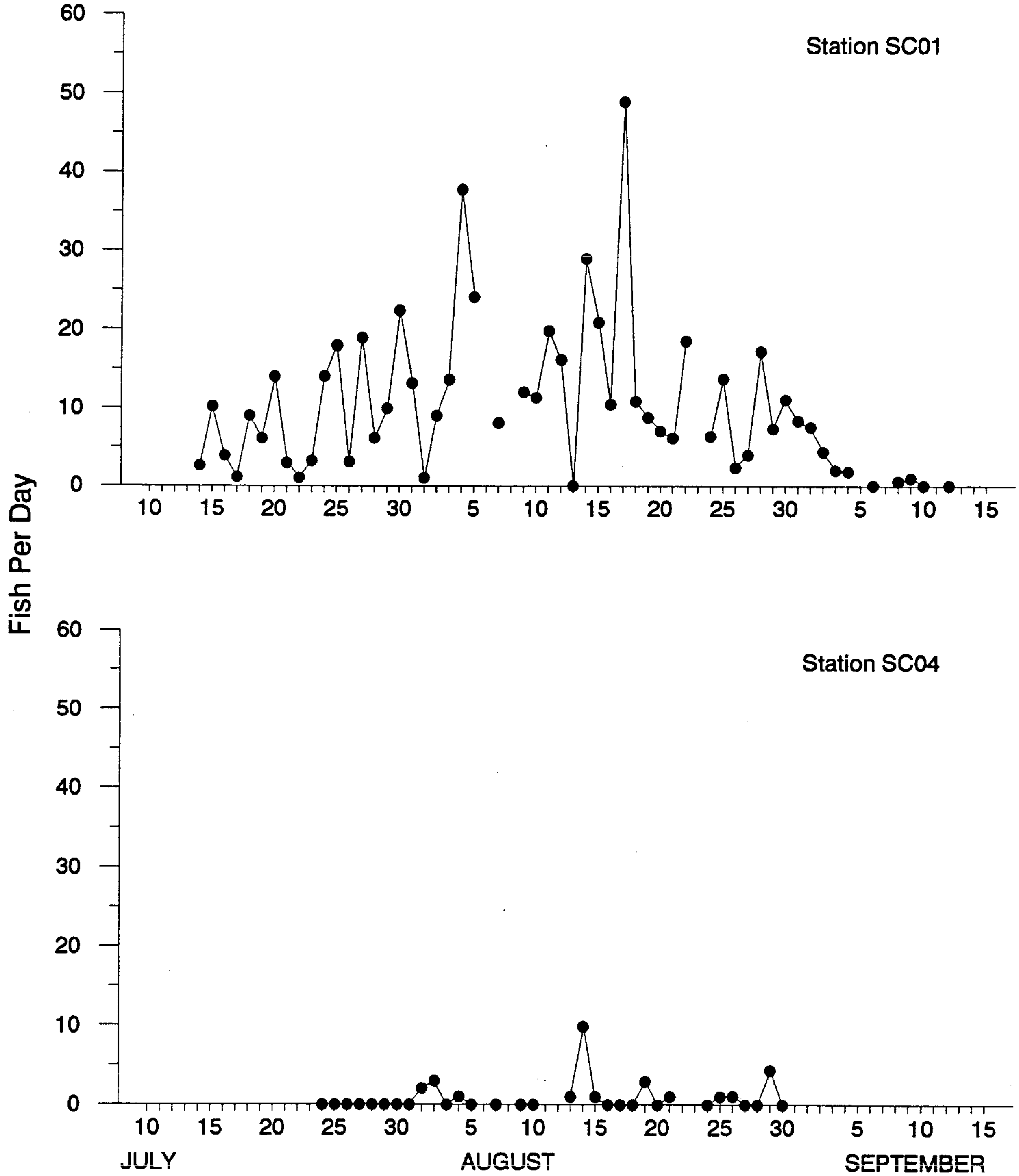

FIGURE 14.— Daily catch per unit of effort (fish/d) for Arctic cisco > 200 mm FL at fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1991.

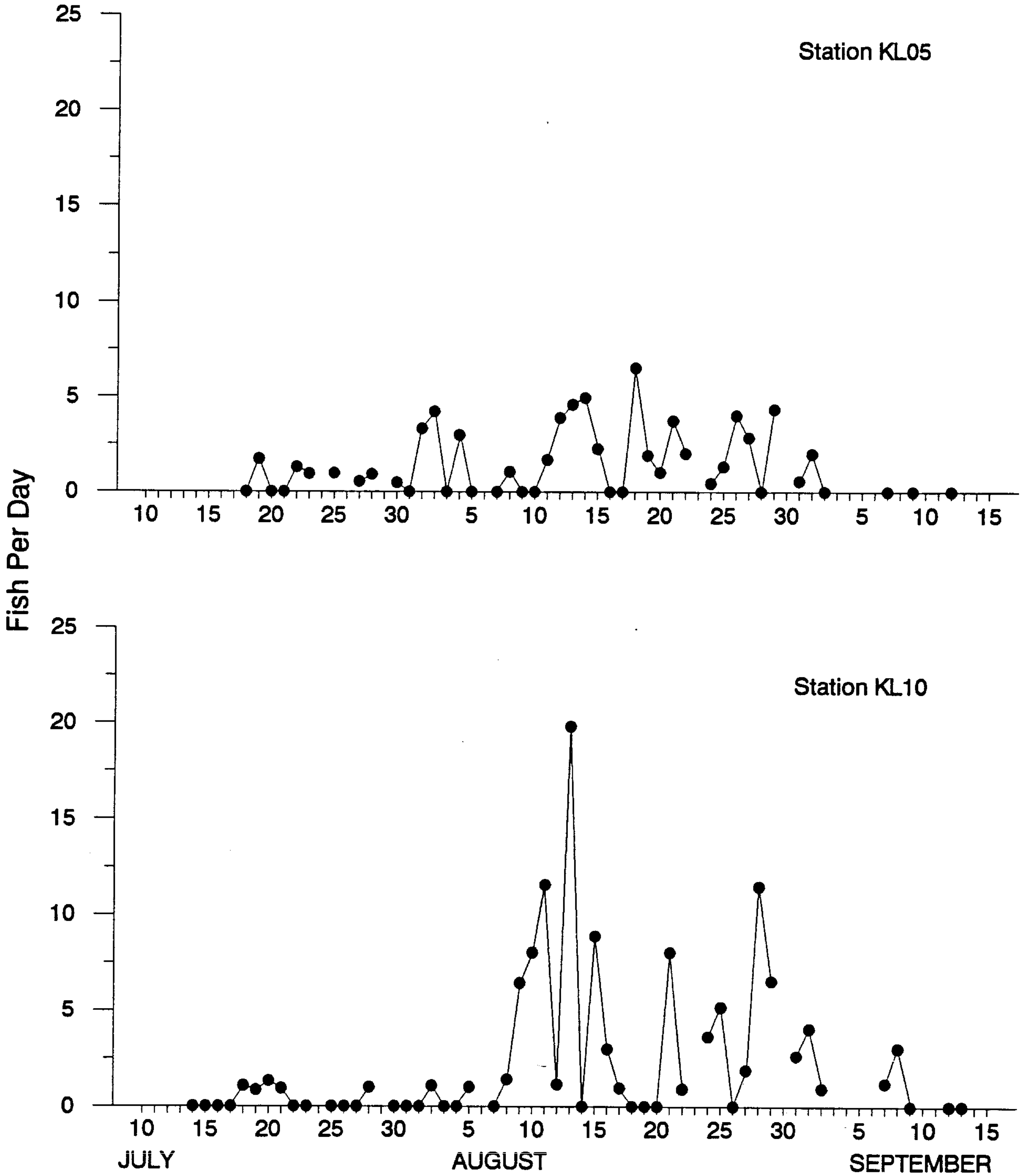

FIGURE 15.— Daily catch per unit of effort (fish/d) for Arctic cisco > 200 mm FL at fyke net stations in Kaktovik Lagoon, Arctic Refuge coastal waters, July-September 1991.

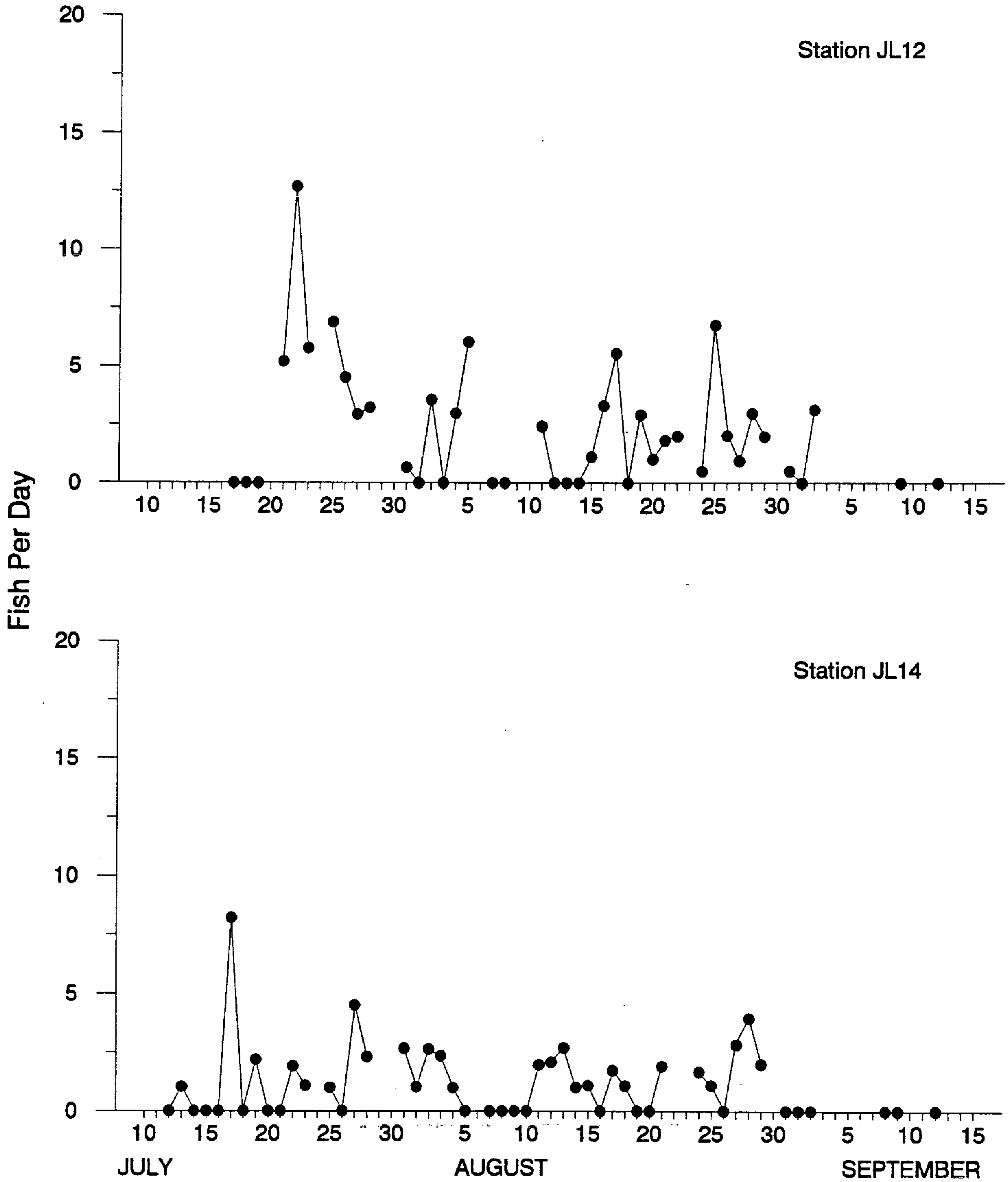

FIGURE 16.— Daily catch per unit of effort (fish/d) for Arctic cisco > 200 mm FL at fyke net stations in Jago Lagoon, Arctic Refuge coastal waters, July-September 1991.

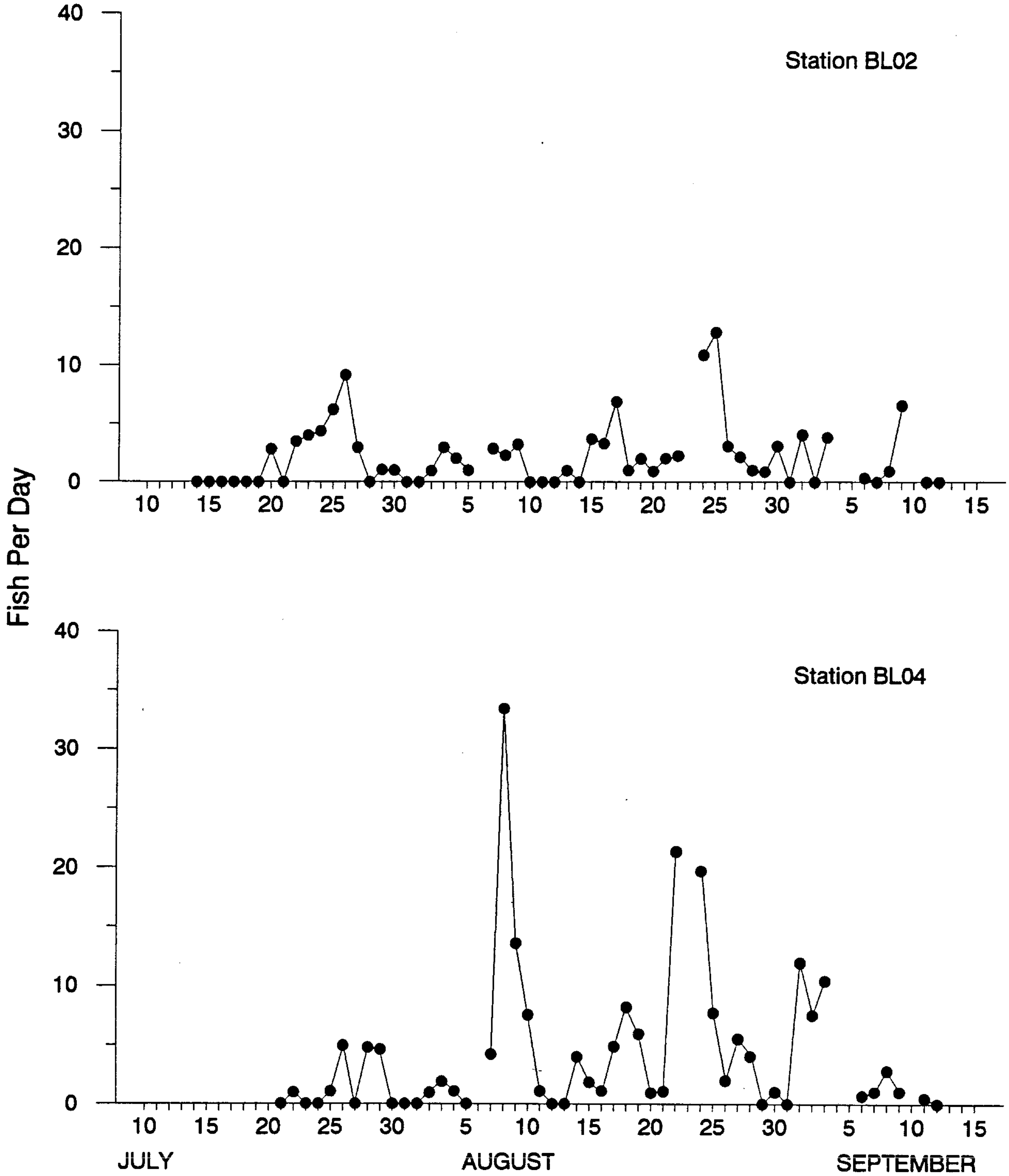

FIGURE 17.- Daily catch per unit of effort (fish/d) for Arctic cisco > 200 mm FL at fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1991.

TABLE 12.— Comparison of daily catch per unit effort (fish/d) between sampling areas and between net stations for Arctic cisco > 200 mm FL in Arctic Refuge coastal waters, July - September 1991. Between sampling areas, or net stations, those with the same letter are not significantly different (Kruskal-Wallis test, with Scheffé multiple comparisons, $\alpha = 0.05$).

Location	N	Mean fish/d	Scheffé grouping
		Sampling area	
Camden Bay	87	6.74	A
Beaufort Lagoon	105	3.12	A,B
Jago Lagoon	90	1.67	B
Kaktovik Lagoon	95	1.94	B
		Net station	
SC01	55	10.15	A
BL04	49	4.19	B
JL12	41	2.27	B,C
BL02	56	2.19	B,C
KL05	44	1.50	B,C
KL10	51	2.32	B,C
JL14	49	1.17	B,C
SC04	32	0.88	C

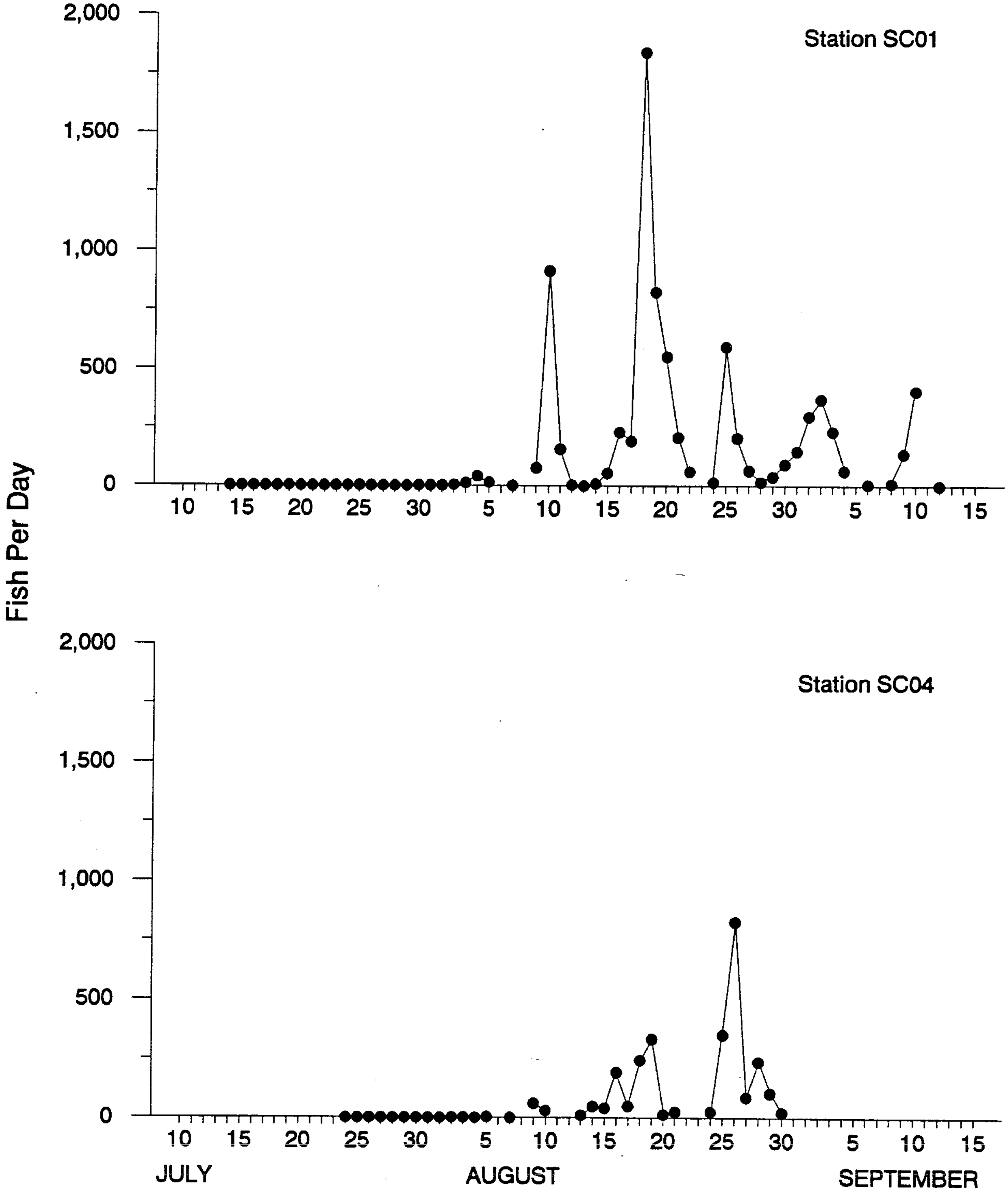

FIGURE 18.— Daily catch per unit of effort (fish/d) for Arctic cod at fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1991.

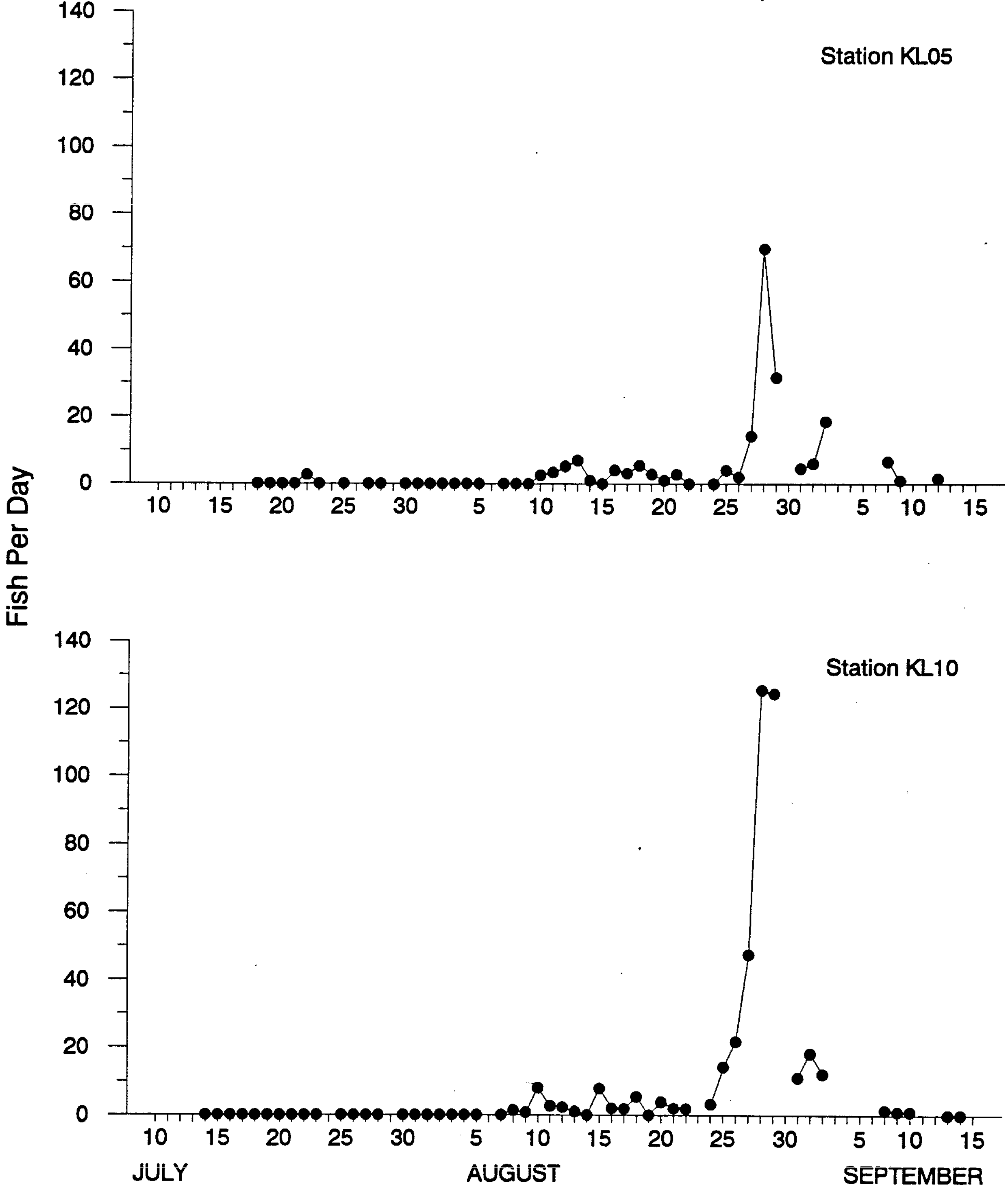

FIGURE 19.— Daily catch per unit of effort (fish/d) for Arctic cod at fyke net stations in Kaktovik Lagoon, Arctic Refuge coastal waters, July-September 1991.

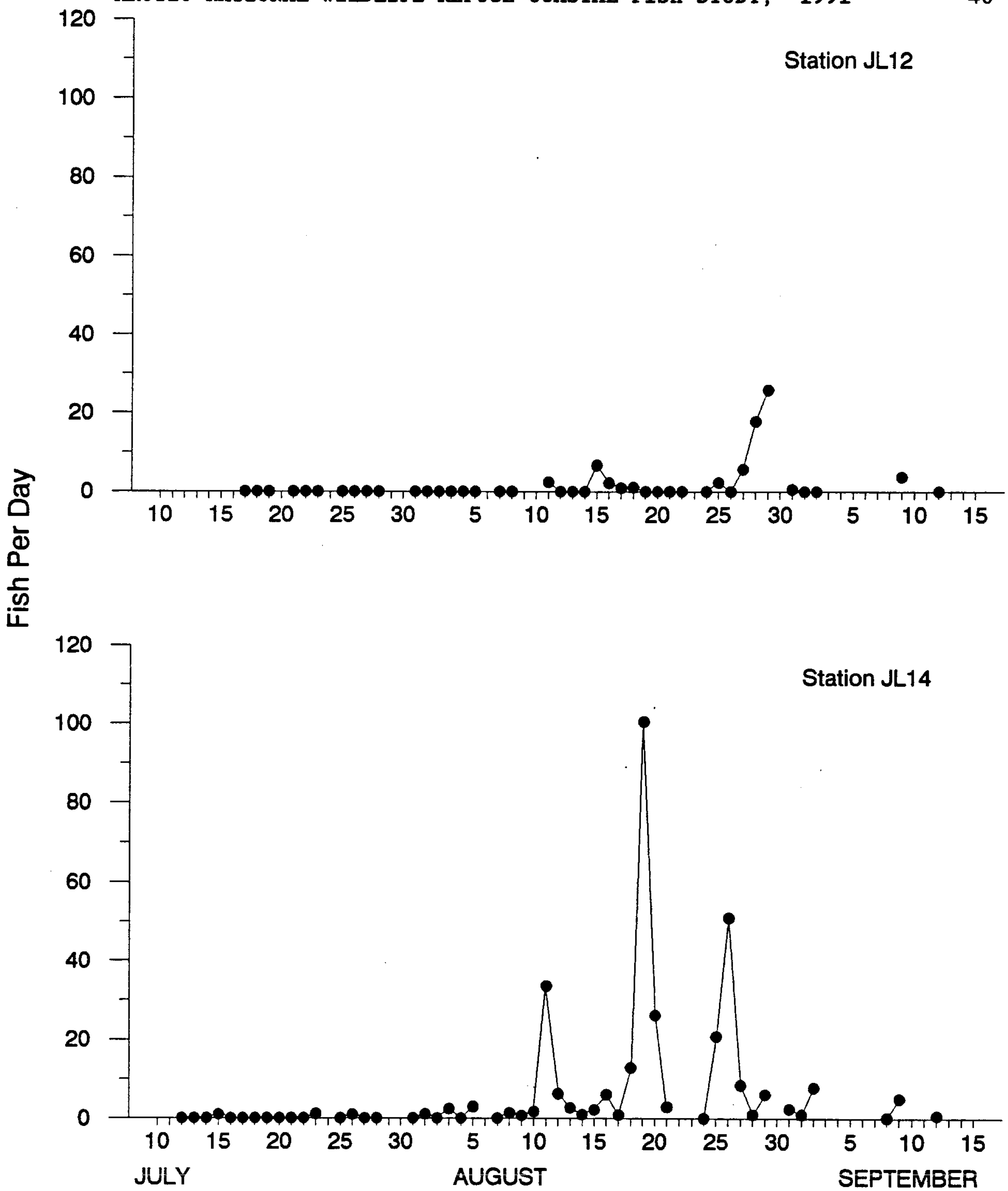

FIGURE 20.- Daily catch per unit of effort (fish/d) for Arctic cod at fyke net stations in Jago Lagoon, Arctic Refuge coastal waters, July-September 1991.

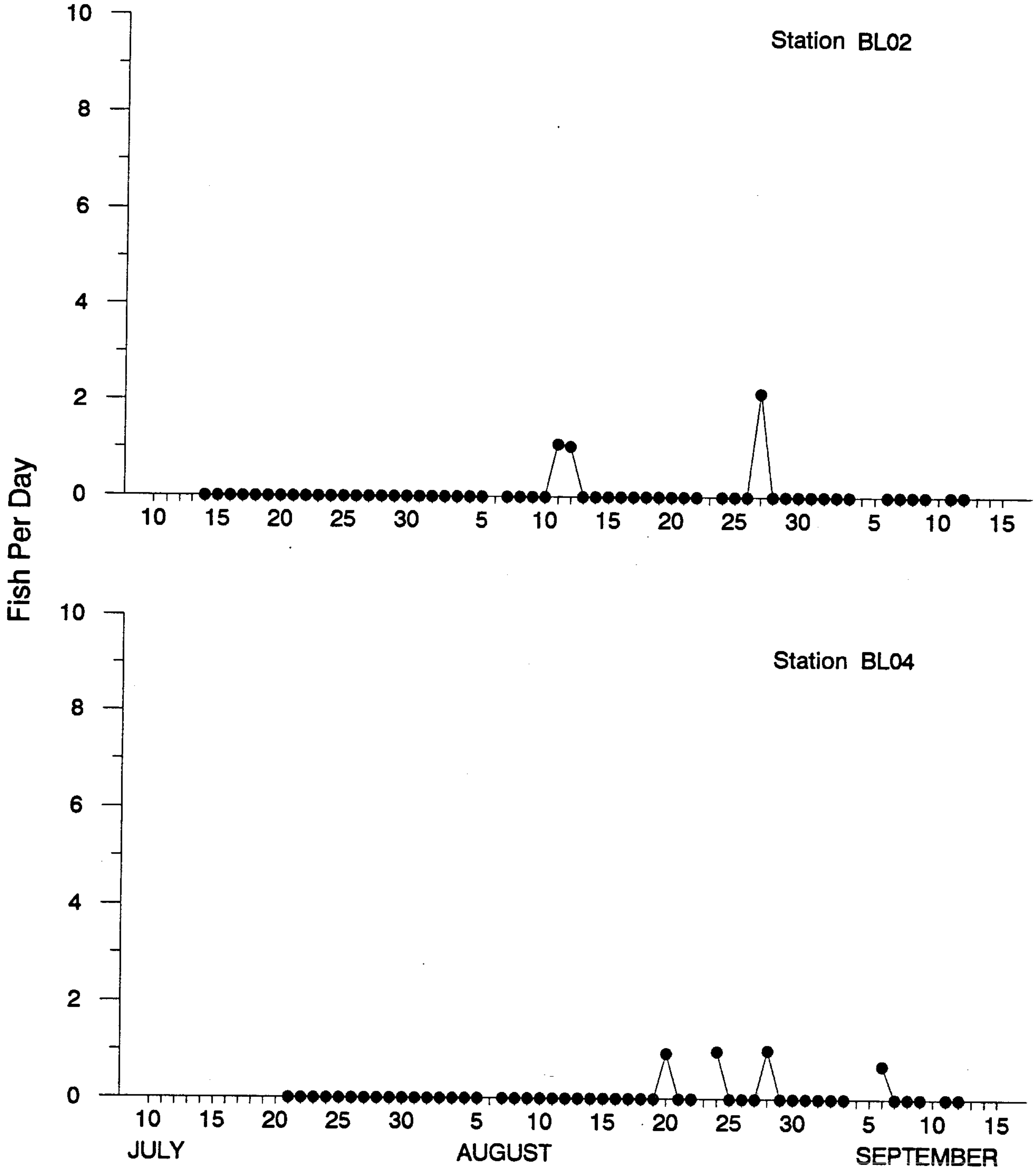

FIGURE 21.— Daily catch per unit of effort (fish/d) for Arctic cod at fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1991.

TABLE 13.— Comparison of daily catch per unit effort (fish/d) between sampling areas and between net stations for Arctic cod in Arctic Refuge coastal waters, July - September 1991. Between sampling areas, or net stations, those with the same letter are not significantly different (Kruskal-Wallis test, with Scheffé multiple comparisons, $\alpha = 0.05$).

Location	N	Mean fish/d	Scheffé grouping
		Sampling area	
Camden Bay	87	121.31	A
Kaktovik Lagoon	95	6.56	B
Jago Lagoon	90	4.25	B
Beaufort Lagoon	105	0.08	C
		Net station	
SC01	55	142.58	A
SC04	39	84.74	A,B
JL14	49	6.40	A,B,C
KL05	44	4.54	A,B,C
KL10	51	8.30	B,C
JL12	41	1.68	C,D
BL04	49	0.07	D
BL02	56	0.08	D

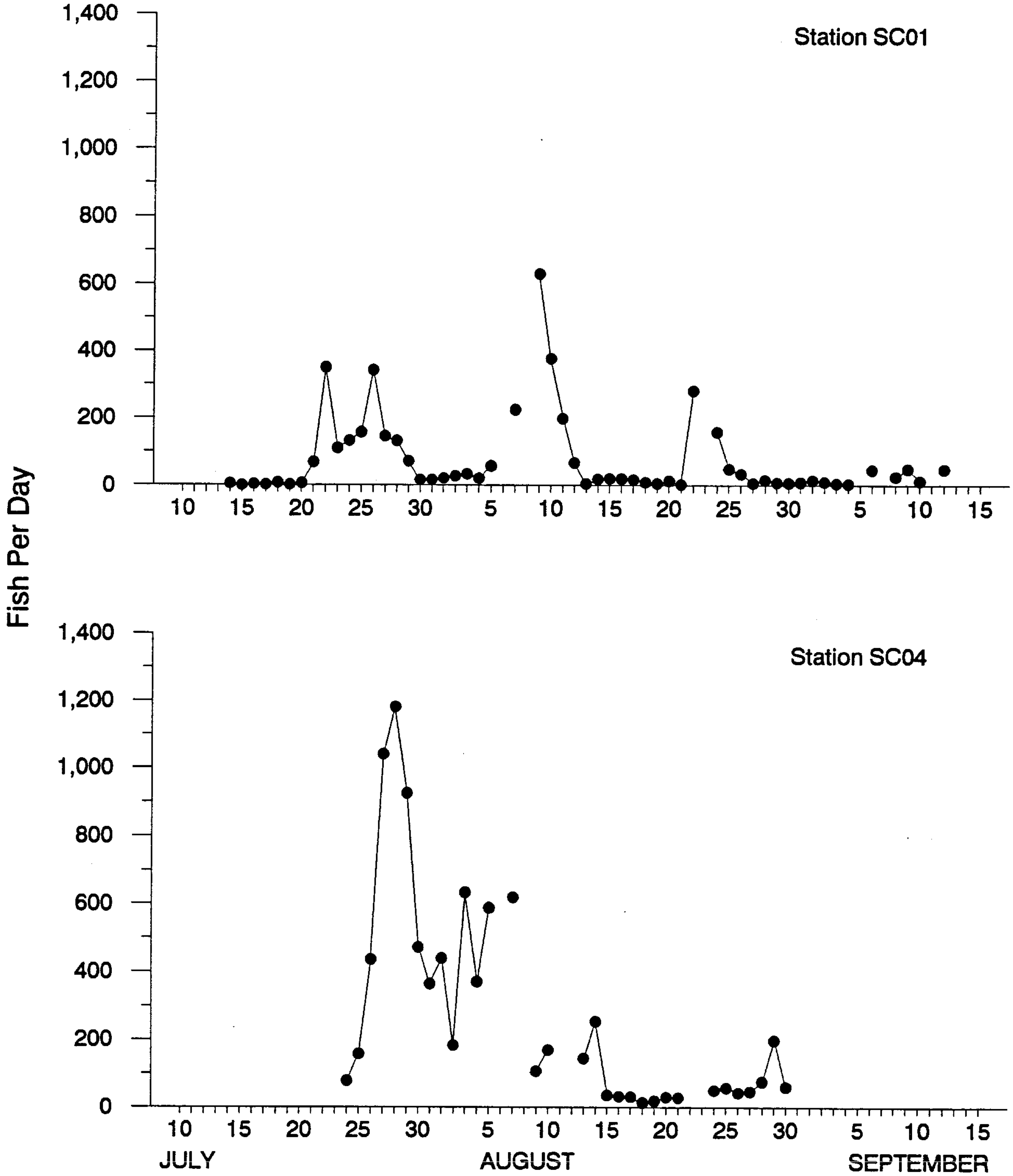

FIGURE 22.— Daily catch per unit of effort (fish/d) for fourhorn sculpin at fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1991.

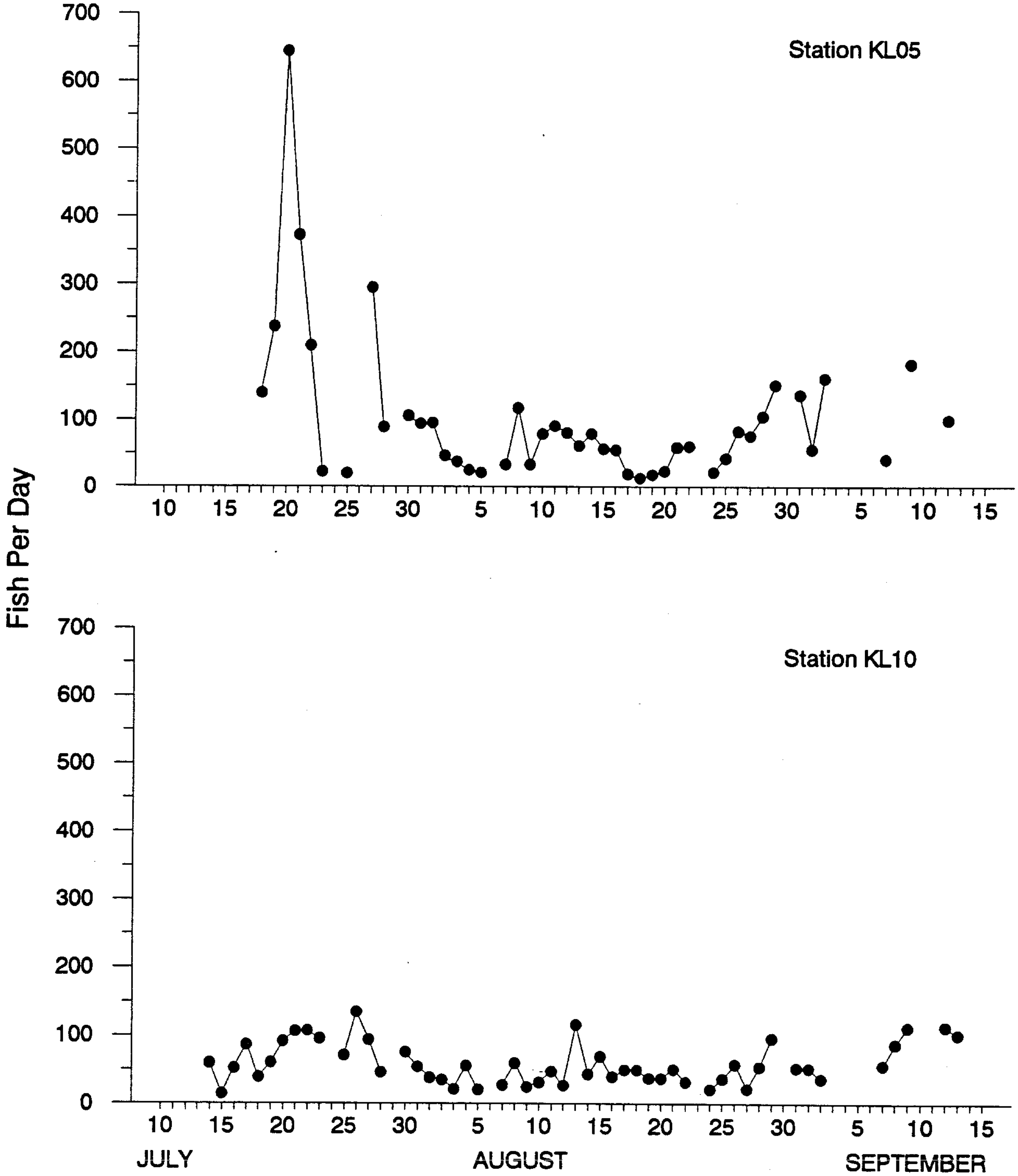

FIGURE 23.- Daily catch per unit of effort (fish/d) for fourhorn sculpin at fyke net stations in Kaktovik Lagoon, Arctic Refuge coastal waters, July-September 1991.

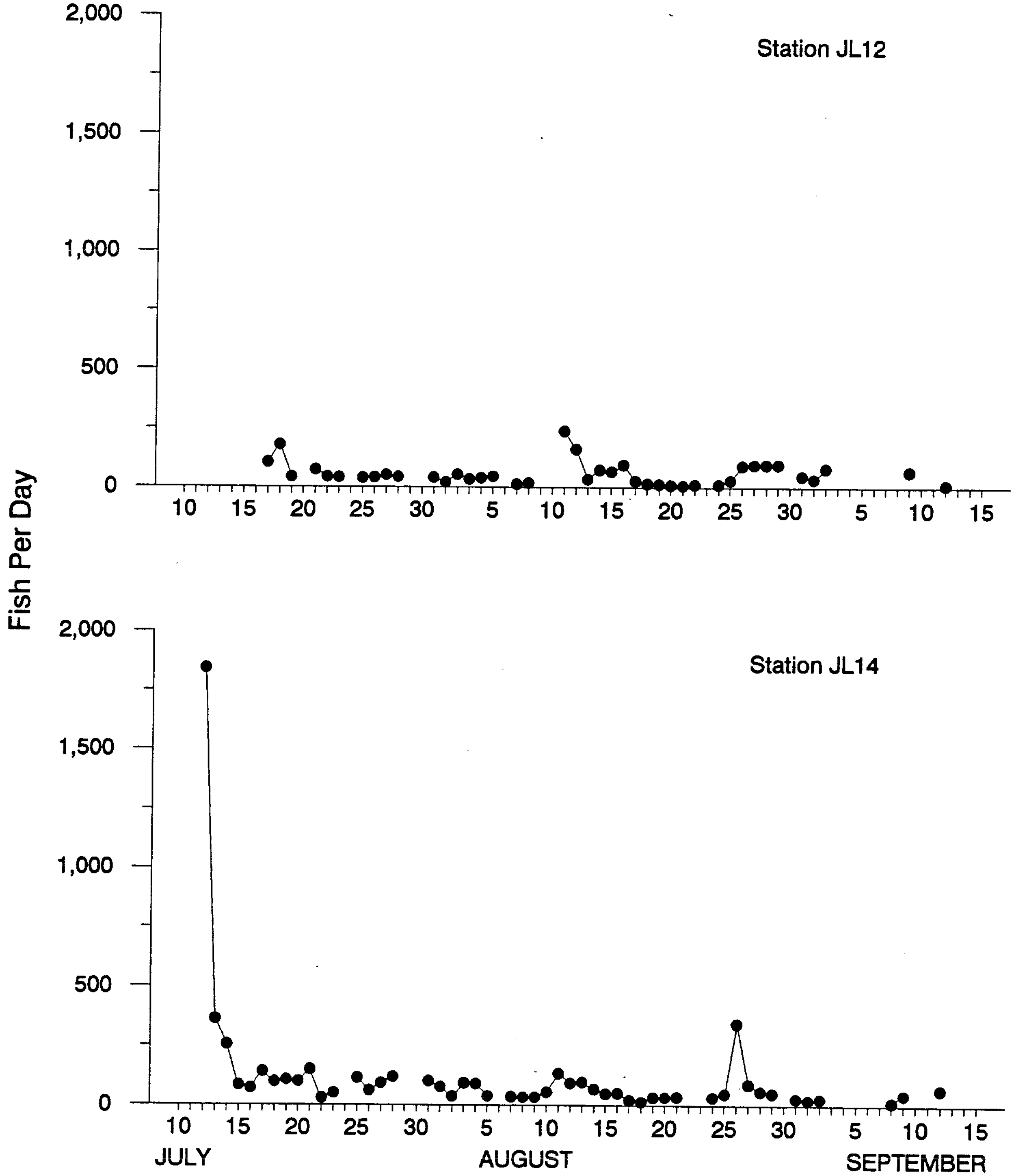

FIGURE 24.— Daily catch per unit of effort (fish/d) for fourhorn sculpin at fyke net stations in Jago Lagoon, Arctic Refuge coastal waters, July-September 1991.

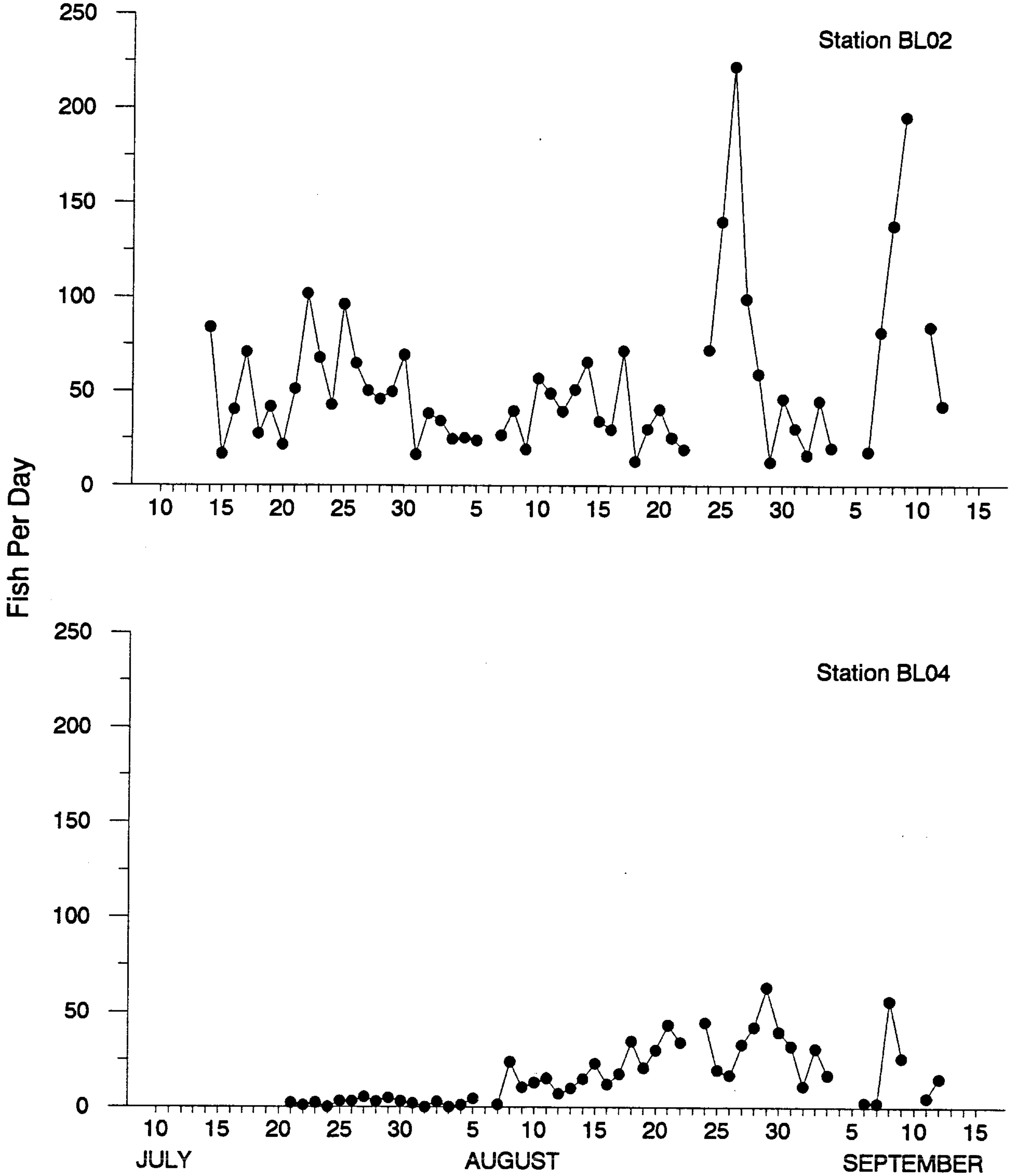

FIGURE 25.- Daily catch per unit of effort (fish/d) for fourhorn sculpin at fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1991.

TABLE 14.— Comparison of daily catch per unit effort (fish/d) between sampling areas and between net stations for fourhorn sculpin in Arctic Refuge coastal waters, July - September 1991. Between sampling areas, or net stations, those with the same letter are not significantly different (Kruskal-Wallis test, with Scheffé multiple comparisons, $\alpha = 0.05$).

Location	N	Mean fish/d	Scheffé grouping
Sampling area			
Kaktovik Lagoon	95	78.55	A
Jago Lagoon	90	89.10	A
Camden Bay	87	149.66	A
Beaufort Lagoon	105	36.60	B
Net station			
SC04	32	277.53	A
KL05	44	101.76	A,B
JL14	49	116.60	A,B
KL10	51	58.53	A,B,C
BL02	56	54.20	B,C
JL12	41	56.24	B,C
SC01	55	75.27	C
BL04	49	16.48	D

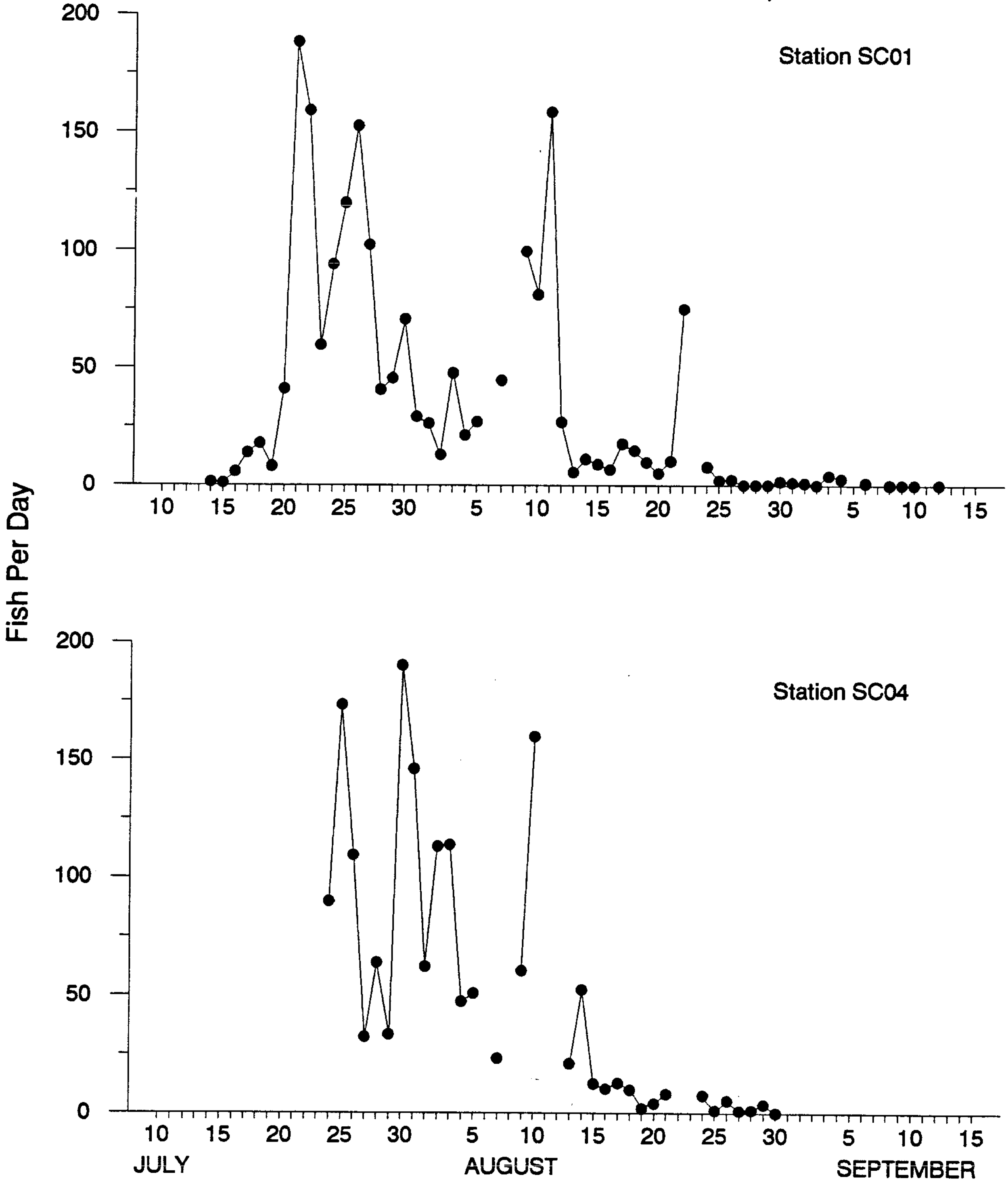

FIGURE 26.— Daily catch per unit of effort (fish/d) for Arctic flounder at fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1991.

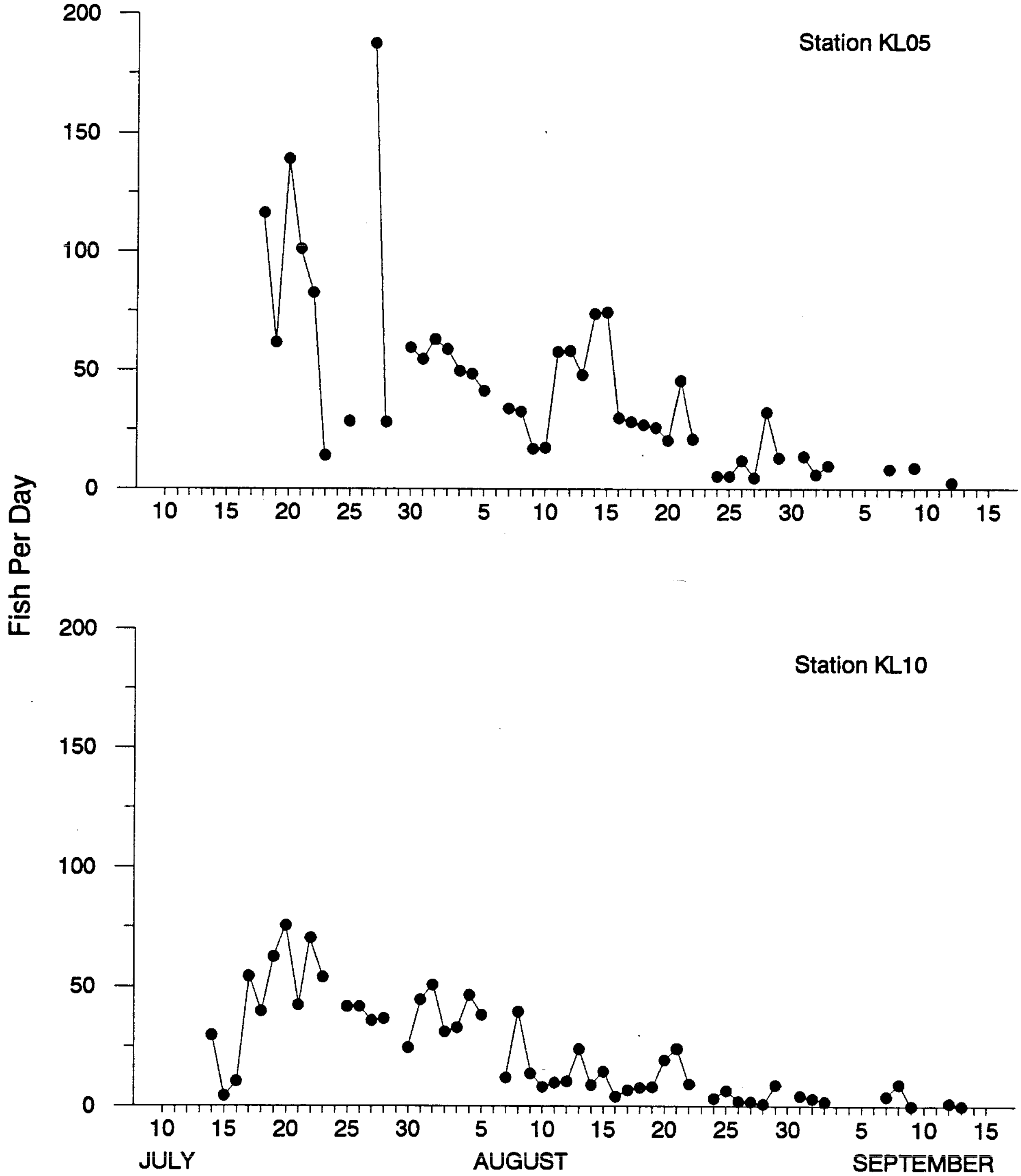

FIGURE 27.— Daily catch per unit of effort (fish/d) for Arctic flounder at fyke net stations in Kaktovik Lagoon, Arctic Refuge coastal waters, July-September 1991.

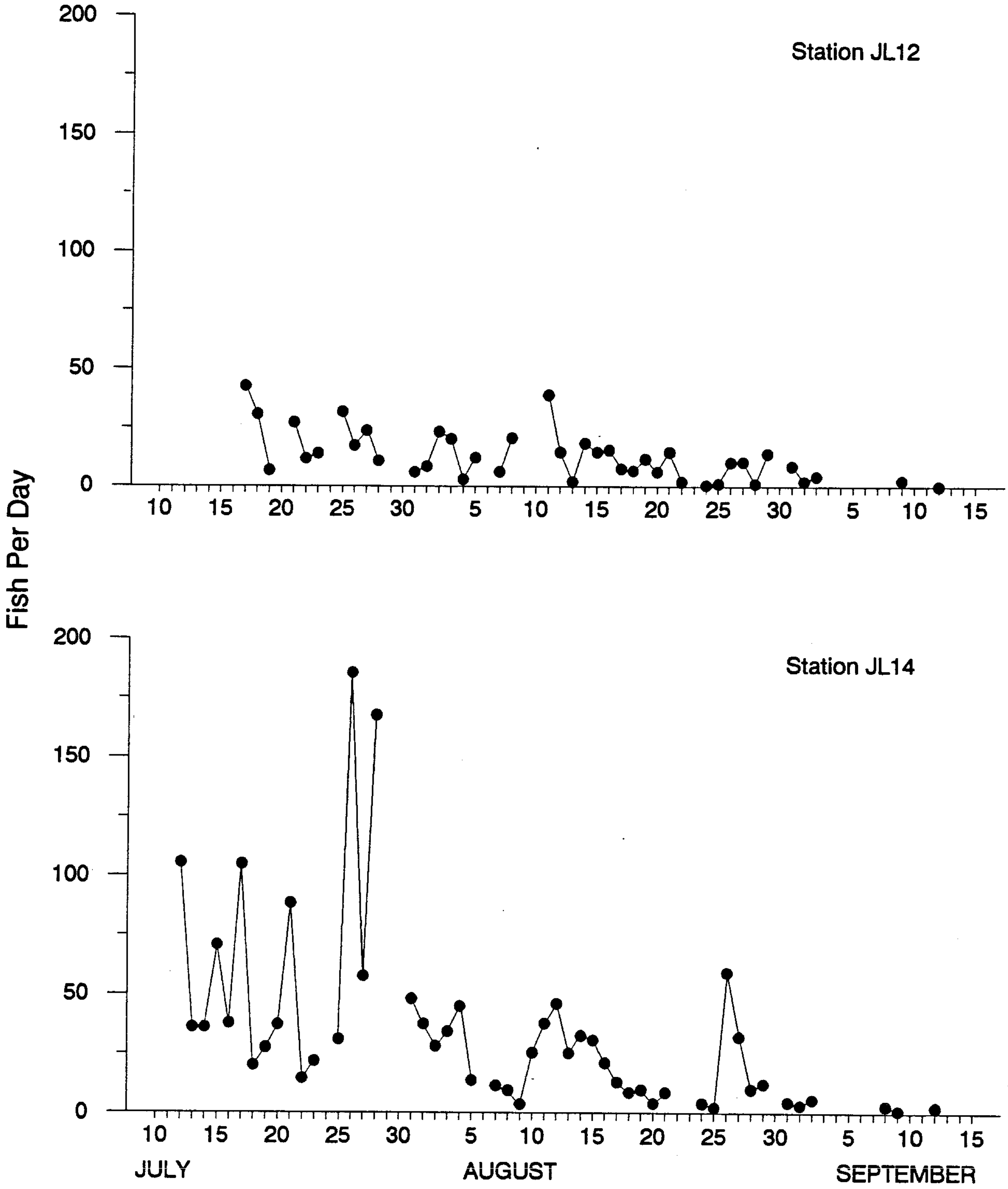

FIGURE 28.- Daily catch per unit of effort (fish/d) for Arctic flounder at fyke net stations in Jago Lagoon, Arctic Refuge coastal waters, July-September 1991.

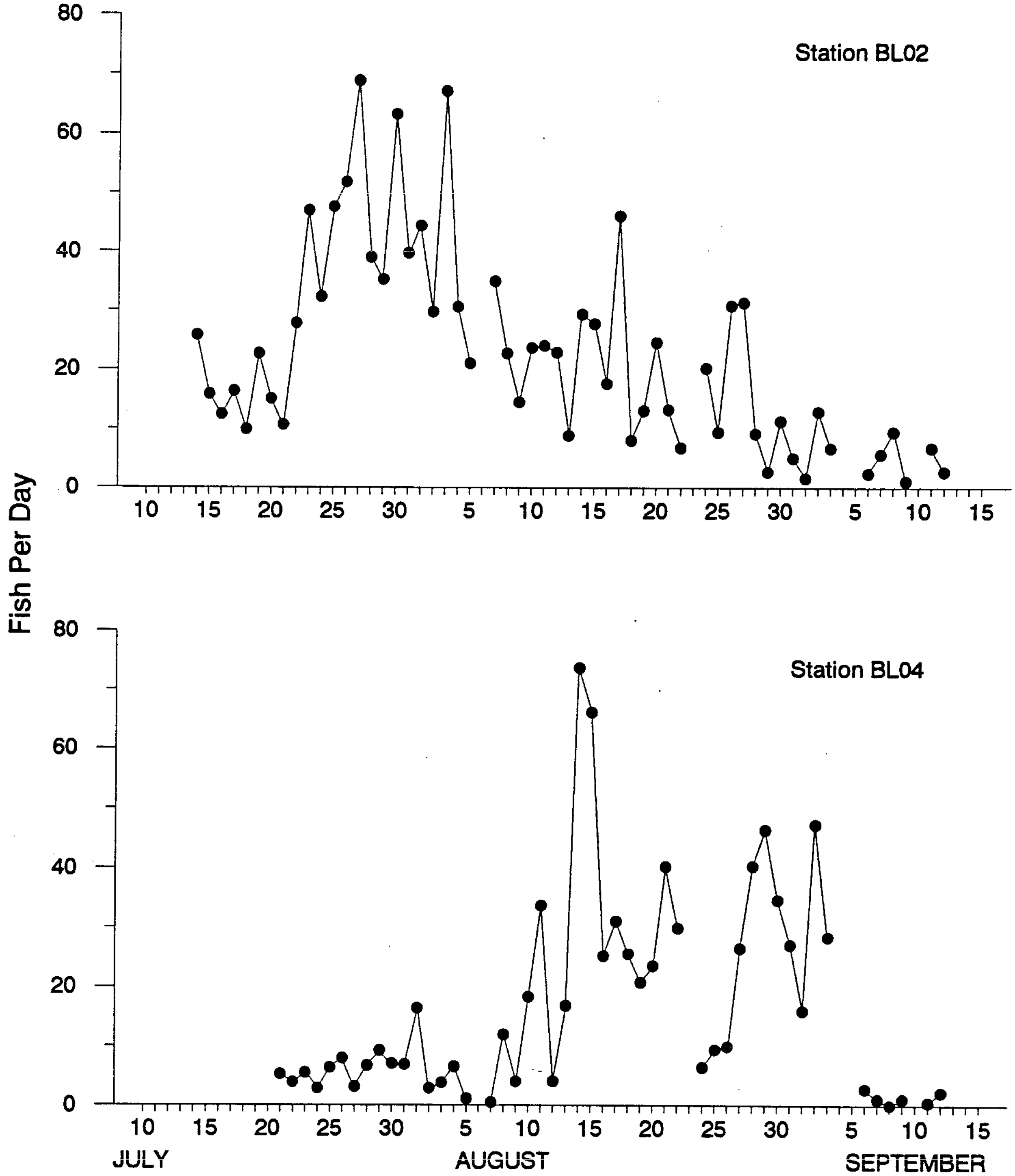

FIGURE 29.— Daily catch per unit of effort (fish/d) for Arctic flounder at fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1991.

TABLE 15.— Comparison of daily catch per unit effort (fish/d) between sampling areas and between net stations for Arctic flounder in Arctic Refuge coastal waters, July - September 1991. Between sampling areas, or net stations, those with the same letter are not significantly different (Kruskal-Wallis test, with Scheffé multiple comparisons, $\alpha = 0.05$).

Location	N	Mean fish/d	Scheffé grouping
	Sampling area		
Camden Bay	87	40.30	A
Kaktovik Lagoon	95	31.58	A
Jago Lagoon	90	24.37	A
Beaufort Lagoon	105	19.99	A
	Net station		
KL05	44	42.41	A
SC04	32	50.72	A,B
JL14	49	34.17	A,B
BL02	56	22.81	A,B
KL10	51	22.23	A,B
SC01	55	34.23	A,B
BL04	49	16.76	B
JL12	41	12.67	B

LENGTH FREQUENCY DISTRIBUTIONS

Arctic char captured during the 1991 field season ranged in size from 61 to 665 mm FL (Figures 30-33). Modal groups were identified between 170 and 220, 275 and 325, and 360 to 400 mm FL. These modal groups were most apparent in the Camden Bay distributions in July (Figure 30). The most commonly seen modal group was the mode from 170 to 220 mm FL which gradually shifted to the right over the course of the summer. This shift is most easily seen in the distributions from Camden Bay. Fish in the mid-size modal group were represented often among the various sampling areas and time periods. Fish in the mid-size modal group were represented most strongly from July through August. Representation of larger fish gradually decreased over the course of the summer, and in September, few fish over 300 mm FL were captured.

Arctic cisco captured during the 1991 field season ranged in size from 47 to 481 mm FL (Figures 34-37). In July, length frequency distributions were generally bimodal with modes at 75 to 125 mm FL and 325 to 425 mm FL. Between July and early August at Camden Bay, the proportions of fish from 350 to 425 mm FL decreased while a distinct group between 275 and 350 mm FL remained evident (Figure 34). In contrast, Arctic cisco in Kaktovik Lagoon between 350 and 400 mm FL were well represented in early August along with a distinct group of fish near 300 mm FL (Figure 35). Arctic cisco grouped around 300 mm FL were not represented until later in August at Jago and Beaufort lagoons. Fish from 150 to 250 mm FL were poorly represented in all areas. Another distinct mode, 50-90 mm FL, appeared at Beaufort Lagoon in late August and September, and in September at Jago Lagoon. Fish from 50-90 mm FL are most likely young-of-the-year (Underwood et al. 1992).

Arctic cod captured during the 1991 field season ranged in size from 48 to 236 mm FL (Figures 38-41). Arctic cod were poorly represented in all areas in July and throughout the field season at Beaufort Lagoon. In Camden Bay the 75-90 mm FL mode was predominant throughout August and September; larger fish skew distributions to the right. In Kaktovik and Jago lagoons, Arctic cod greater than 100 mm FL made up a larger proportion of the catch in early August and a smaller proportion in late August and September.

Fourhorn sculpin captured during the 1991 field season ranged in size from 20 to 319 mm TL (Figures 42-45). A modal group between 50 and 100 mm TL was the most prominent mode in all distributions except in July at Camden Bay and Kaktovik Lagoon. Catches at Camden Bay exhibited bimodal distributions throughout the field season although the proportions of each mode changed. The larger modal group (100-140 mm TL) decreased while the smaller mode (65-85 mm TL) increased. Kaktovik and Jago lagoons had relatively greater proportions of large fish compared to the other areas. Three modes were apparent in catches from these lagoons: 50-90, 100-140, and 160-250 mm TL. Size composition changed little over the course of the season except for the appearance of small fish (<50 mm TL) in September, particularly at Jago Lagoon

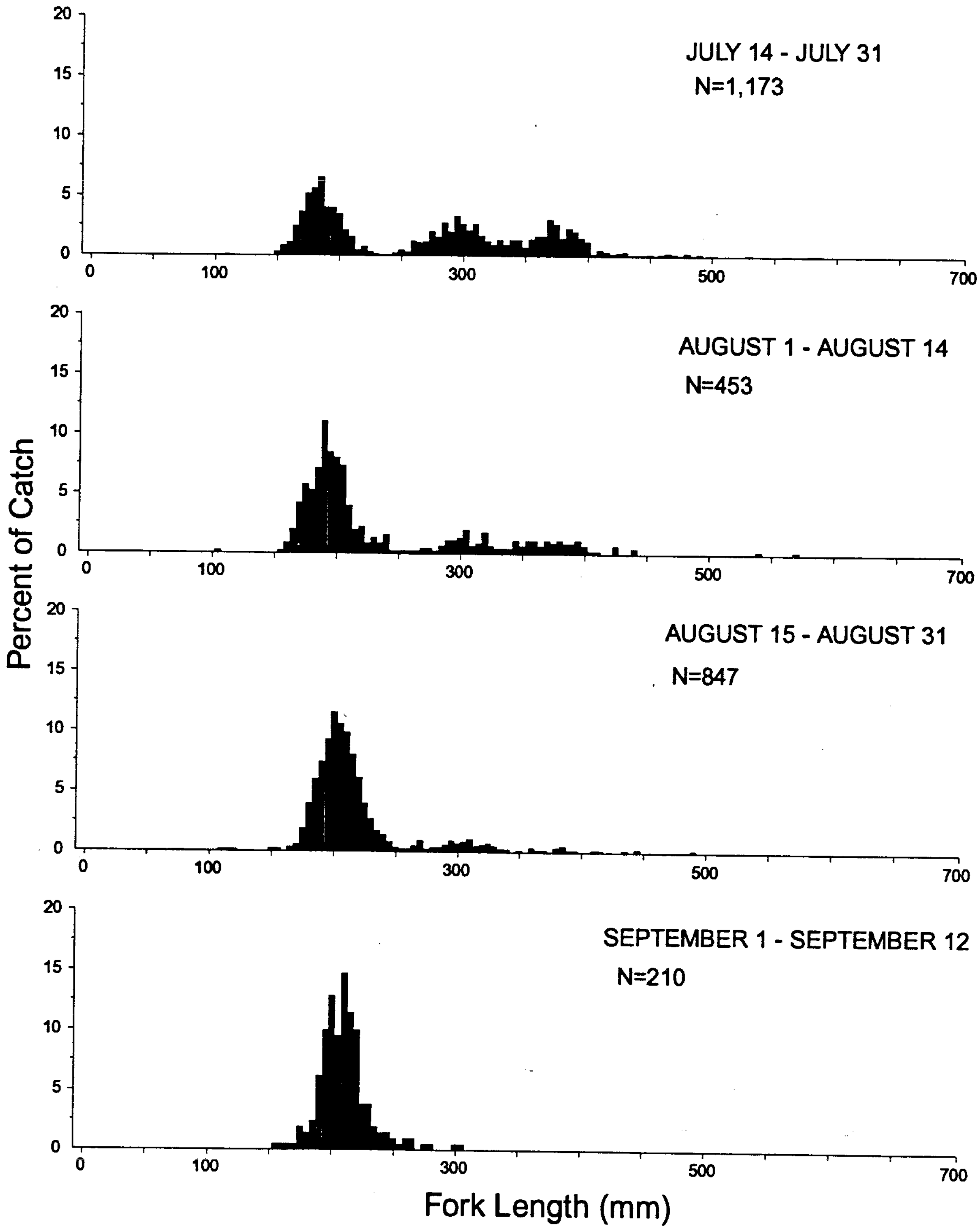

FIGURE 30.– Length frequency of Arctic char captured by fyke nets in Camden Bay, Arctic Refuge coastal waters, July-September 1991.

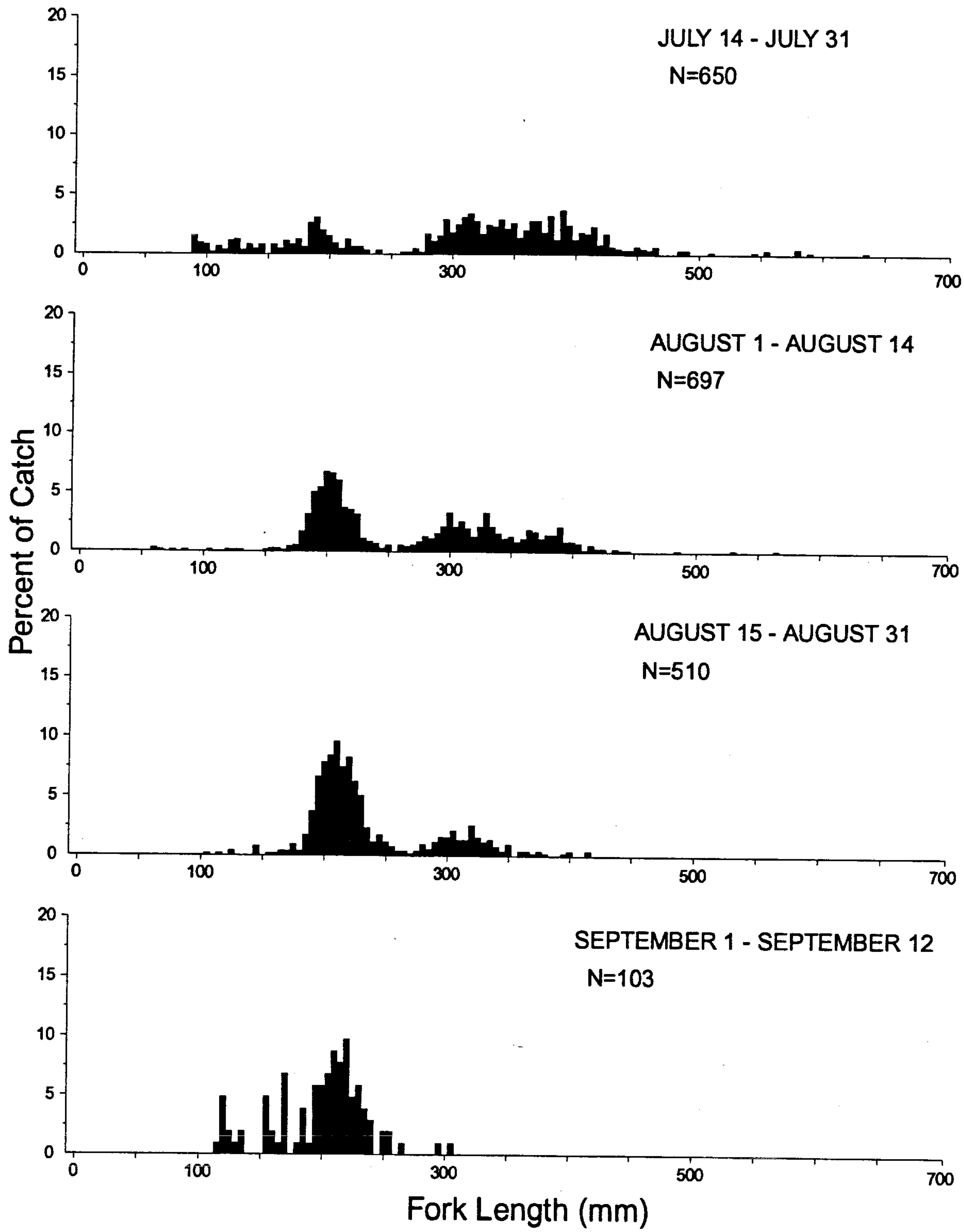

FIGURE 31.- Length frequency of Arctic char captured by fyke nets in Kaktovik Lagoon, Arctic Refuge coastal waters, July-September 1991.

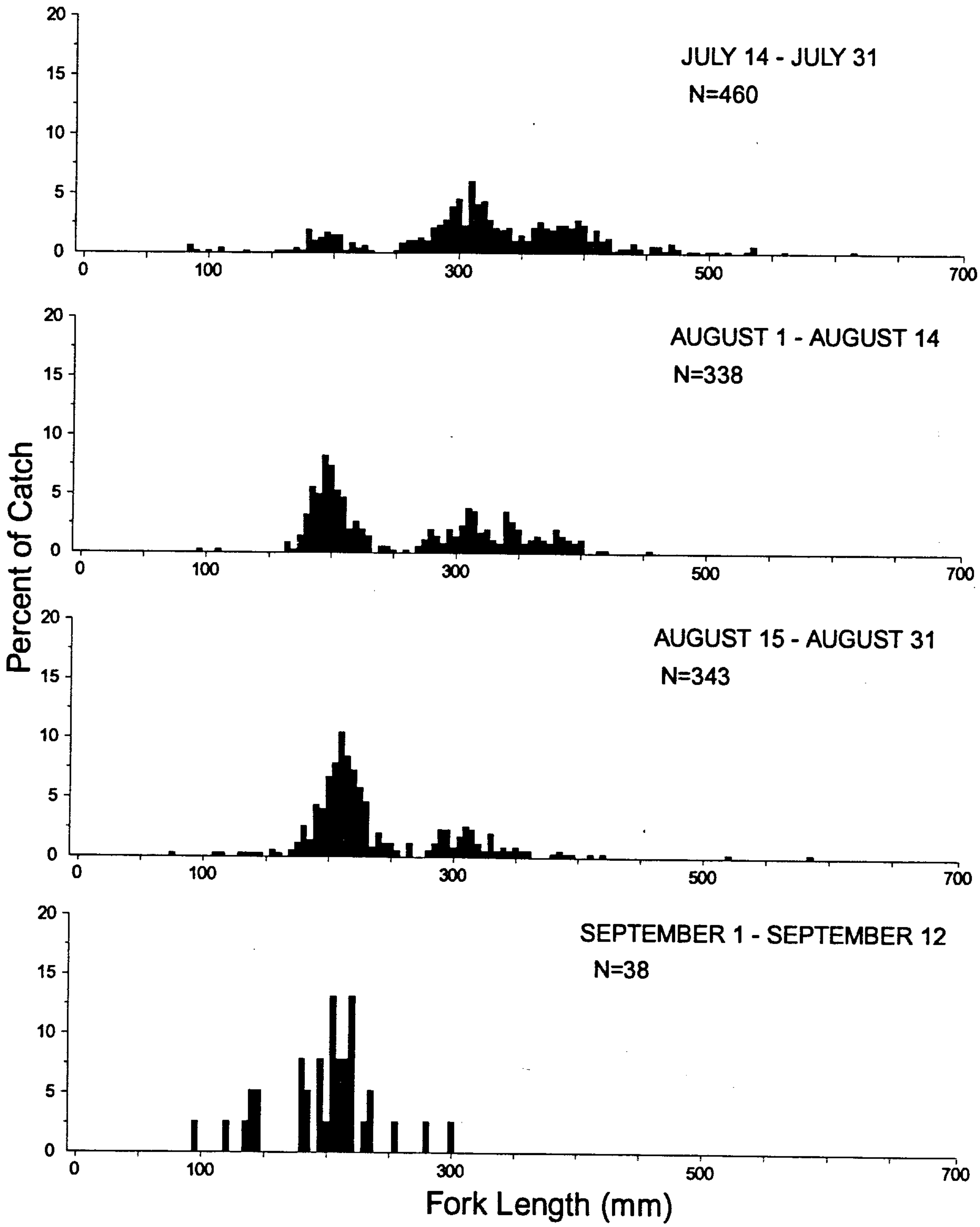

FIGURE 32.— Length frequency of Arctic char captured by fyke nets in Jago Lagoon, Arctic Refuge coastal waters, July-September 1991.

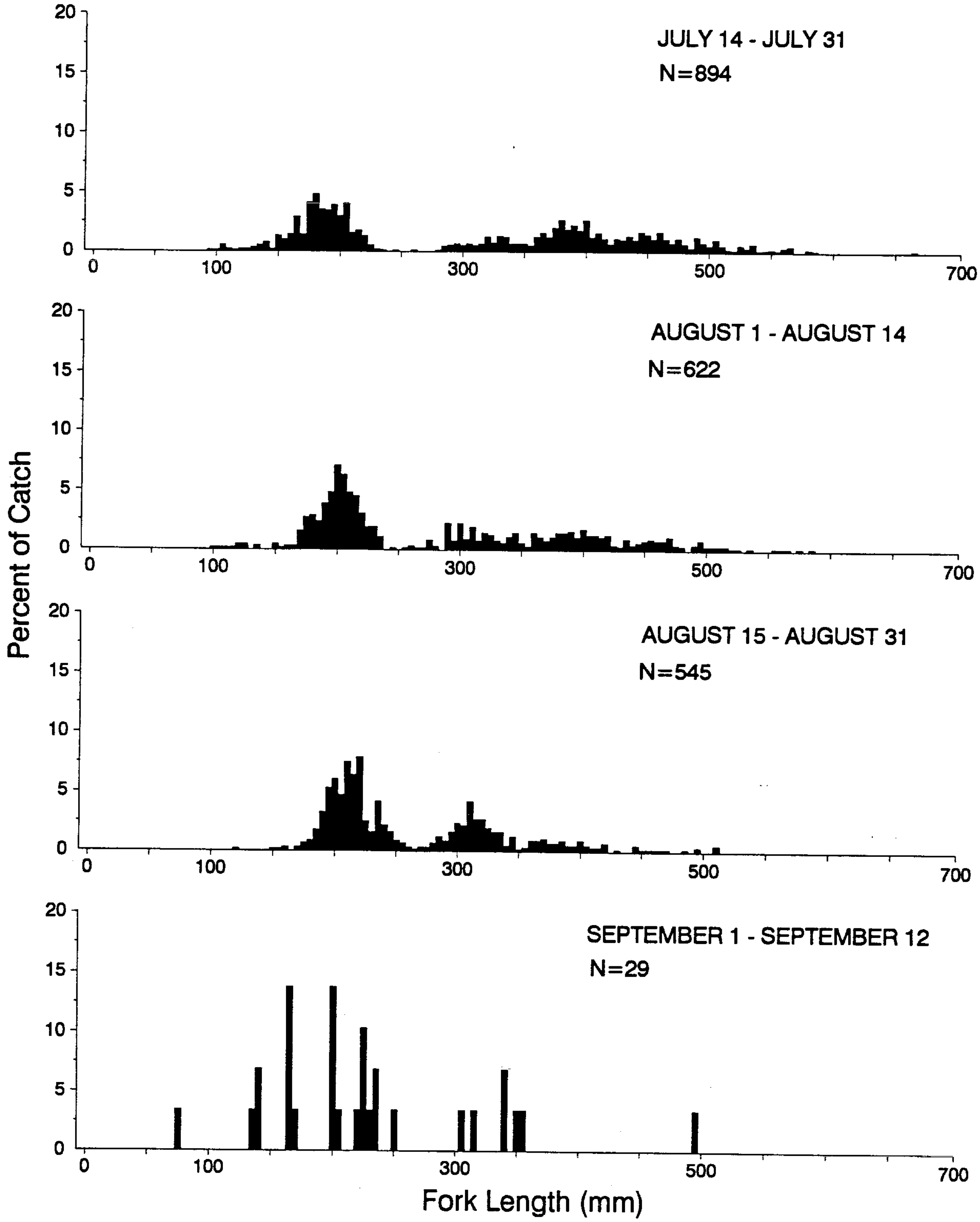

FIGURE 33.— Length frequency of Arctic char captured by fyke nets in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1991.

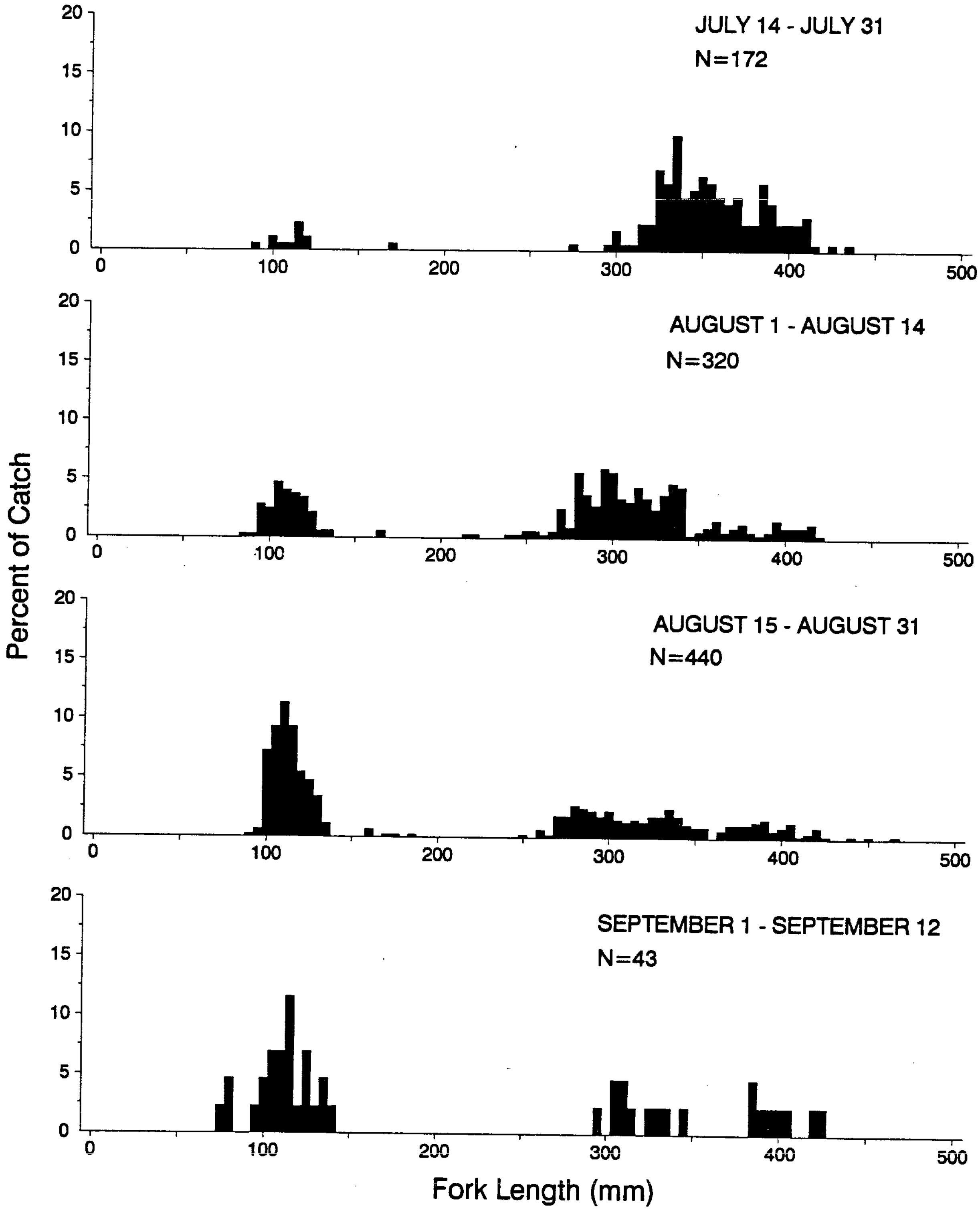

FIGURE 34.- Length frequency of Arctic cisco captured by fyke nets in Camden Bay, Arctic Refuge coastal waters, July-September 1991.