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Fisheries Investigation in Oruktalik Lagoon, Arctic National Wildlife Refuge, Alaska, 1986

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Abstract.—Fishes inhabiting Oruktalik Lagoon, Alaska were sampled between July 5 and September 14, 1986 to determine 1) relative abundance, distribution, and movements, 2) biological characteristics, and 3) relationship between catch rate and hydrologic variables. Fish were captured at three stations by fyke nets with leads extending perpendicular from shore. Sampling at the stations varied between 31 and 58 d. Concurrent physical habitat measurements were surface water temperature and salinity.

Species composition and relative abundance were generally consistent with previous studies in the Beaufort Sea coastal waters. A total of 151,592 fish from thirteen species were caught. The most abundant were: Arctic cisco *Coregonus autumnalis* (young of the year, N = 131,400; juvenile and adult, N = 906), fourhorn sculpin *Myoxocephalus quadricornis* (N = 9,907), Arctic cod *Boreogadus saida* (N = 7,252), capelin *Mallotus villosus* (N = 787), and Dolly Varden *Salvelinus malma* (N = 723).

Young of the year Arctic cisco (< 90 mm fork length) were captured consistently after July 31. Peak abundance occurred at the inner lagoon station between August 25 and September 2 when catch rates ranged from 610 to 26,383 fish/trap/d. Juvenile and adult Arctic cisco were captured throughout the sampling period but not at all stations. Daily catch rates ranged from 0 to 99 fish/trap/d. Most (53%) juveniles and adults were captured at the barrier island station. None of the 755 tagged Arctic cisco were recaptured; indicating a short residency time in Oruktalik Lagoon. Arctic cisco measuring between 333 and 444 mm fork length (FL) were 6 to 12 years old.

Fourhorn sculpin were captured throughout the sampling period. Daily catch rates ranged from 4 to 1,073 fish/trap/d. They were more numerous at the inner lagoon fyke net station. Fourhorn sculpin ranged from 38 to 267 mm total length (TL).

Arctic cod were more numerous in late August through mid-September. Daily catch rates ranged from 0 to 1,042 fish/trap/d. They were captured in greater numbers at one of the barrier island stations. Arctic cod ranged from 50 to 223 mm TL.

Dolly Varden were captured throughout the sampling period. Catch rates ranged from 0 to 35 fish/trap/d. Most (53%) fish were captured at the barrier island station. Dolly Varden (>300 mm FL) were captured from early July through mid-August. After mid-August, smaller size (<300 mm FL) char dominated the catch. Of the 501 char tagged in the lagoon, 32 were recaptured. The time between tagging and recapture ranged between 1 and 18 d; most (80%)

fish were recaptured within 4 d. Dolly Varden ranged from 121 to 638 mm FL. Ages ranged from 1 to 13 years for fish measuring 129 - 623 mm FL.

During the study period, surface water temperature tended to decrease, whereas, salinity increased. Surface water temperatures ranged from 1° to 12°C. Salinity ranged between 3 and 22 ppt.

Correlation coefficients (r) for of the hydrologic variables did not exceed ± 0.60. Dolly Varden catch rates were positively correlated with temperature and negatively correlated with salinity at all three stations. Young of the year Arctic cisco and Arctic cod catch rates were negatively correlated with temperature at all three stations. Fourhorn sculpin were negatively correlated with temperature at two stations.

Introduction

The Alaska National Interest Lands Conservation Act of 1980 provided in Section 1002(c) for biological baseline studies to assess fish and wildlife populations on the coastal plain of the Arctic National Wildlife Refuge (Arctic Refuge). Seismic exploration was used to aid in determining the potential for oil and gas development on the refuge coastal plain and adjacent lands owned by the Kaktovik Inupiat Corporation (KIC). Results of the seismic exploration indicated possibilities for the occurrence of oil and gas in some areas to be high (Clough et al. 1987). Exploratory drilling has already occurred in several areas including Tapkaurak Point on KIC lands adjacent to Oruktalik Lagoon.

Industry activities that could affect fish resources include oil spills, drilling discharges, marine seismic activity, and construction of port facilities, causeways, and pipelines. These activities and structures may hinder or prevent fish migration and degrade physical habitat and hydrologic conditions.

Fisheries investigations were conducted in Oruktalik Lagoon, Alaska to determine use by anadromous and marine fish species. Specific objectives were:

1. Determine relative abundance, distribution, and movements of anadromous and marine fishes.
2. Determine length frequency, age structure, and weight-length relationships for Arctic cisco and Dolly Varden; and length frequency for other species captured.
3. Determine if a relationship exists between fish distribution, abundance and hydrologic variables.

Anadromous and marine fish utilize lagoons and other nearshore coastal habitats for feeding during summer (Craig 1984). Lagoons are important because they are relatively warmer than offshore Beaufort Sea waters and have high concentrations of prey organisms. These conditions facilitate accumulations of fat reserves in fish for overwintering and sexual maturation. Nearshore waters also serve as a migration corridor for anadromous fish.

The major fish species utilizing coastal lagoons along the Arctic Refuge include: Dolly Varden *Salvelinus malma*, Arctic cisco *Coregonus autumnalis*, least cisco *Coregonus sardinella*, fourhorn sculpin *Myoxocephalus quadricornis*, Arctic flounder *Liopsetta glacialis*, Arctic cod *Boreogadus saida*, and capelin *Mallotus villosus* (Roguski and Komarek 1971; Griffiths et al. 1977; Griffiths 1983; West and Wiswar 1985; Wiswar and West 1987). Dolly Varden and Arctic cisco are important in subsistence fisheries by the residents of Kaktovik, Alaska (Jacobson and Wentworth 1982).

Dolly Varden migrate long distances along the Beaufort Sea coast during the open water season (McCart 1980). Within the refuge, Dolly Varden are found in the Canning (Craig 1977), Hulahula, Aichilik, Egaksrak, and Kongakut rivers (Ward and Craig 1974; Smith and Glesne 1983; Daum et al. 1984; West and Wiswar 1985). Dolly Varden tagged in the Sagavanirktok (Furniss 1975) and Firth rivers (Glova and McCart 1974) have also been captured in coastal waters bordering the refuge.

Arctic cisco have international significance as they appear to originate in the Mackenzie River, Canada (Fechhelm and Fissel 1988). They are harvested commercially in the Colville River, Alaska (Alt and Kogl 1973, Gallaway et al. 1983).

Arctic cod is an abundant marine fish in the Beaufort Sea and important prey item for higher trophic level vertebrates (Frost and Lowry 1984).

Study Area

Oruktalik Lagoon (70° 04'N, 142° 56'W) is located approximately 26 km southeast of Barter Island (Figure 1). The lagoon borders the coastal plain of the Arctic Refuge and is separated from the Beaufort Sea by a series of long, narrow barrier islands. The Niguanak River is the only major river flowing into the lagoon (Figure 2). A smaller unnamed tundra stream east of the Niguanak River also flows into the lagoon. Tapkaurak Lagoon is located to the west of Oruktalik Lagoon and Tapkaurak Point acts as a divide between the two lagoons. On the east, Griffin Point extends out close to the barrier island and delineates Oruktalik Lagoon from two smaller lagoons.

The nearshore waters are influenced by a northwesterly longshore current and wind patterns associated with storms (Truett 1981). Oruktalik Entrance allows for exchange of lagoon and nearshore waters. A relatively deep (1.5 m), natural channel occurs through the entrance where large rafts of ice may enter the lagoon during the open water period. Depths in the mid-lagoon are 1.8 to 2.1 m (Mean Lower Low Water; Navigational Chart #16042, National Oceanic and Atmospheric Administration). Oruktalik Lagoon is a limited exchange lagoon (Hachmeister and Vinelli 1984) where the flow of nearshore water is restricted by barrier islands.

Most of Oruktalik Lagoon is covered with fast ice during late winter. The open water season is from late June until mid-September or October. In June, snow melt runoff enters the lagoon from the rivers and accelerates ice melting (Clough et al. 1987).

Methods

Weather and Hydrologic Measurements

Climatological data were obtained from meteorological observations recorded at Barter Island, Alaska (NOAA 1986). Surface water temperature and salinity were measured at each station daily except during periods of severe wind and wave conditions. Water temperature was measured with a standard centigrade thermometer. Salinity was measured with a Yellow Springs Instrument Model 33 salinity-conductivity-temperature meter.

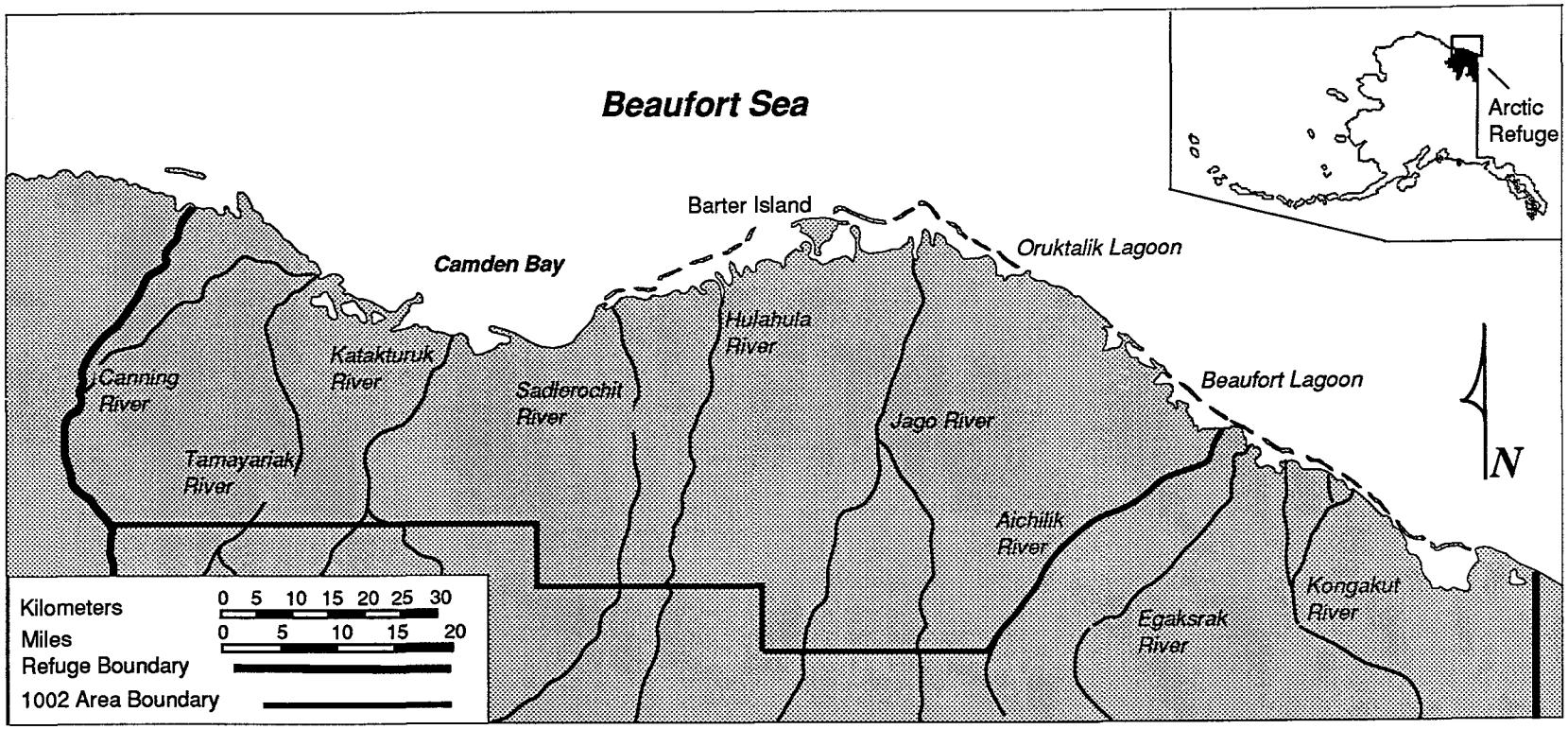

FIGURE 1.—Beaufort Sea coast and coastal plain of the Arctic National Wildlife Refuge.

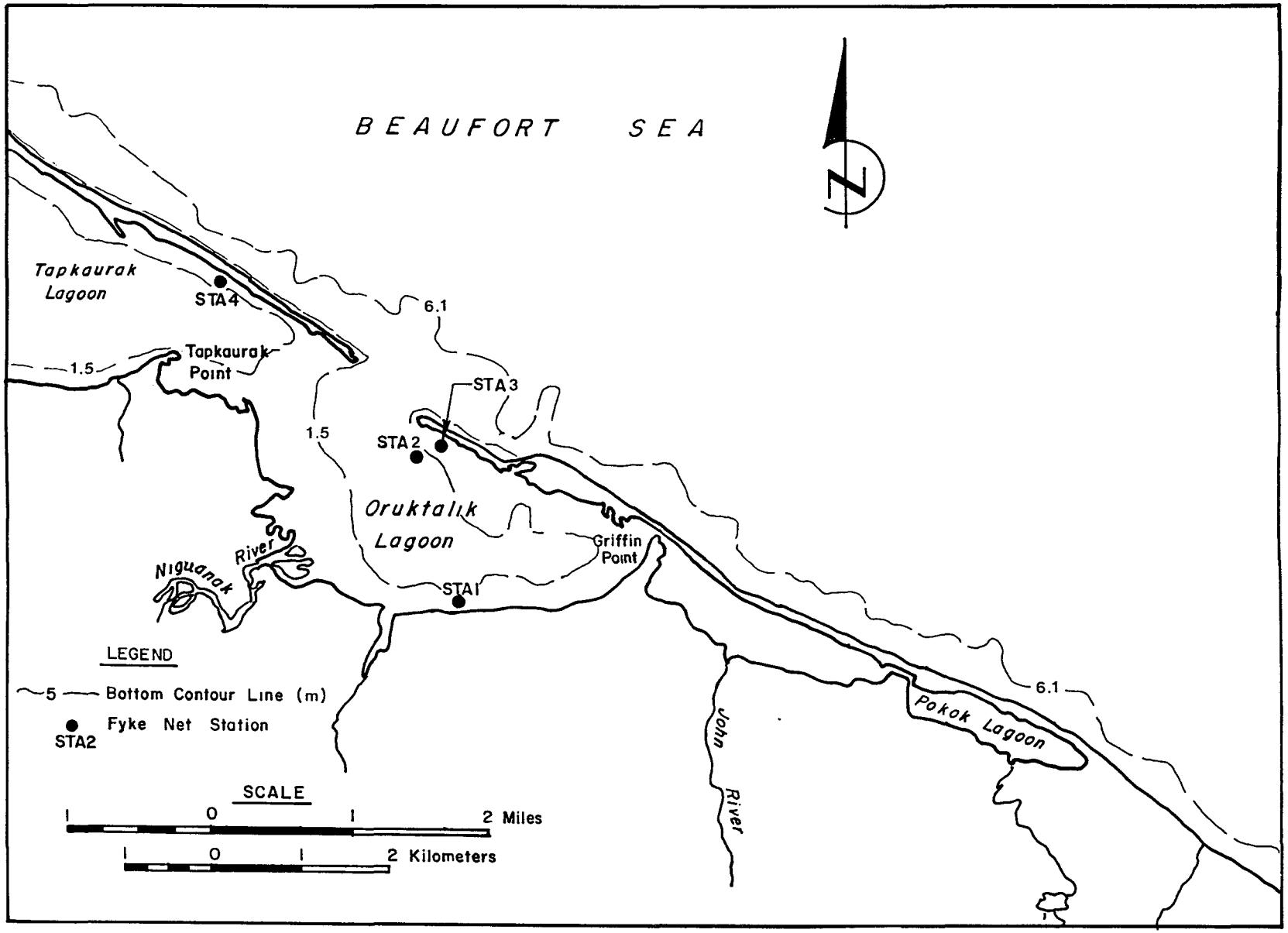

FIGURE 2.—Fyke net stations in Oruktalik Lagoon, Alaska, July - September 1986.

Fyke Net Stations

Three dual trap, directional fyke nets, with 61 m leads and 15 m wings, were deployed from shore (stations 1, 3, and 4; Figure 2). The leads extended perpendicular from shore and traps were set in water less than 1.3 m deep. We intended to establish a mid-lagoon station (station 2) using traps on both ends of the lead; however, one trap never arrived and water was too deep for effective trapping in the middle of the lagoon. We subsequently deployed a lead with one dual trap in 1.8 m of water about 90 m from the barrier island and positioned at somewhat of an oblique angle. A few days after this trap was set, the water mass increased in the lagoon which allowed fish to escape over the top of the trap and lead. Catch data was not analyzed; however, biological data was incorporated with that from other stations.

Deployment of station 4 was delayed until August 5. Originally, we intended to deploy this trap outside the barrier islands; however, this was prevented because of ice movement close to shore. The fyke net was then deployed inside the barrier island to capture tagged fish moving west from station 3 and to increase the total number of fish captured and tagged.

Sampling was conducted from July 5 to September 14, 1986 (Table 1). Due to ice conditions and storms, all stations were not established on the same day nor was sampling continuous.

TABLE 1.—Fishing schedule of fyke net stations in Oruktalik Lagoon, Alaska, summer 1986.

Station	Date	Number of days fished
1	July 5 - September 14	58
3	July 13 - September 14	54
4	August 5 - September 14	31

Fish Sampling

Nets were checked once daily, generally between 1200 and 1800 hrs, except during extremely poor weather conditions. All fish were enumerated by species. Large catches of a species (> 300 fish) were estimated by counting a dip net subsample and multiplying that number by the total number of dip net samples of equal volume.

Fork lengths (FL) or total lengths (TL) for those fish with rounded or truncated caudal fins were measured to the nearest mm. Weights of Arctic cisco and Dolly Varden were estimated to the nearest 5 g using Pesola spring scales with ranges of 0-500 g and 0-2,000 g. When large catches of a species occurred, fish were chosen randomly so that samples were representative of the entire catch.

Numbered Floy FD-67 anchor tags were implanted in Dolly Varden, Arctic and least cisco, and some saffron cod *Eleginus gracilis* to aid in determining fish movements. Fish selected for tagging were greater than 250 mm FL. After biological data were recorded, all fish were transported about 90 m further offshore from the trap and released.

Data Analysis

Catch rate.—Daily catch rate (fish/trap/d) by species at each station was calculated by combining the number of fish from both sides of the trap and then adjusting for 24 hours of fishing effort. Data were not included in the catch rate analysis when severe weather conditions and wave action compromised trap fishing efficiency.

Migration pattern of young of the year Arctic cisco differs from that of adults and juveniles (Gallaway et al. 1983: Fechhelm and Fissel 1987); therefore, Arctic cisco were separated into two groups for the purpose of catch rate analysis. The separation between young of the year and juvenile (age 1) was set at the 90 mm FL interval and was based on length at age information from studies in the Beaufort Sea by Craig and Haldorson (1981), Bond and Erickson (1987), and Whitmus and Parker (1990).

A Wilcoxon paired-sample test (Zar 1984) was used to determine significant differences ($P < 0.05$) in the daily catch of Arctic cisco and Dolly Varden between sides of the trap. We assumed that Arctic cisco and Dolly Varden captured in the east trap at a station were moving west and fish captured in the west trap were moving east.

Biological characteristics.—All fish measured were used to construct length-frequency histograms. Total number of fish and dates of capture used in histograms may exceed the number reported for total catch from fyke net stations and include days not calculated for catch rate (see *Catch rate* above). The length-frequency histogram for young of the year Arctic cisco represents fish captured only from July 24 to August 9.

Three to five Arctic cisco and 5-9 Dolly Varden per week were randomly selected for length-weight relationships and age determination. Length-weight relationships (Ricker 1975) were determined by regressing log-normal transformations of weight on length. Ages of Arctic cisco and Dolly Varden were estimated from otoliths (sagittae). Larger sagittae were broken at the nucleus and burned in an alcohol flame before viewing under reflected light (Barber and McFarlane 1987). When sagittae were too small to be broken, ages were estimated by surface reading.

Catch rates and hydrologic correlations.—Daily catch rates of Dolly Varden, Arctic cisco, fourhorn sculpin, and Arctic cod were regressed on water temperature and salinity to determine correlations (*r;* Zar 1984) between catch rates and these parameters.

Results

Weather

Average ambient air temperatures for July, August, and September 1-14 were 4.3°, 4.1°, and 5.4° C, respectively (NOAA 1986). Winds were generally constant from the southeast. Storms passed through the area on July 23, July 29, August 17, August 19, and August 21-23. The latter was the worst storm and included snow, temperatures below freezing, and wind velocities greater than 80 km/h from the northwest. The storms caused a visible increase in the water mass within the lagoon.

Hydrologic Conditions

Ice covered about 80% of the lagoon on July 2. Open water extended 75 - 125 m from the shoreline around the perimeter. The ice mass in the center of the lagoon moved to within 30 m of shore in early

July making it necessary to disassemble our fish traps several times. Ice did not completely dissipate from the lagoon until July 15.

The overall trend in hydrologic conditions was a decrease in surface water temperature and an increase in salinity (Figure 3). Surface water temperatures in Oruktalik Lagoon were most variable during early to mid-July. At station 1, the temperature ranged from 1.5° to 12°C. Salinity was generally less than 4 ppt until mid-July and then increased to approximately 20 ppt in September. After mid-July and continuing through August 20, water temperature was more stable, generally within a range of 4°-7°C. Salinity was less than 10 ppt until the beginning of August, and then varied between 14 and 22 ppt through mid-September. After the major storm of August 21-23, water temperature decreased to 1°-3°C. Daily temperature and salinity measurements among stations varied only slightly throughout the sampling period (Figure 3).

Catch Results and Biological Characteristics

Thirteen species from a total of 151,592 fish were captured during the study period (Table 2 and 3). Young of the year Arctic cisco were the most numerous fish caught comprising 87% of the total fish captured. Young of the year Arctic cisco were followed in abundance by fourhorn sculpin (6.5%), Arctic cod (4.8%), juvenile and adult Arctic cisco (0.6%), capelin (0.5%), and Dolly Varden (0.5%).

Young of the year Arctic cisco.—Young of the year Arctic cisco (N = 131,400) were first captured on July 24 but capture was discontinuous until August 1. Thereafter, young of the year were caught continuously but not at all stations (Figure 4). Seventy-six percent of the young of the year were captured at station 1 (Table 3). Schools, estimated to contain 100-200 fish, were occasionally observed within one to two meters of the shoreline near the fyke net lead.

The catch rate was 0 - 3,377 fish/trap/d between July 24 and August 18. A strong peak in abundance occurred at station 1 over a 9 d period beginning August 25 when the catch rate ranged from 610 to 26,383 fish/trap/d. A smaller increase in catch rate for a shorter duration (3-4 d) was noted at stations 3 and 4. Eighty-two percent of all young of the year Arctic cisco were captured between August 25 and September 2. The catch rate decreased at all stations in early September.

At station 1, 53% of the fish were captured in the east side trap of the net (Table 4) which differed significantly from the west side ($P < 0.03$). At stations 3 and 4, although the percent catch was greater in the west side of the trap, there was no significant difference ($P > 0.10$). At these two traps, there were two to three days when the catch in the west trap greatly exceeded that in the east.

Young of the year Arctic cisco captured between July 5 and August 9 measured 34 to 89 mm FL (Figure 5). Mean length was 63.5 mm FL (N = 111, SD = 9.86).

Juvenile and adult Arctic cisco.—Juvenile and adult Arctic cisco (N = 906) were captured throughout the sampling period. Most fish (54%) were captured at station 3 (Table 3). Daily catch rates ranged from 0 to 99 fish/trap/d (Figure 6). Variability in catch rates was greater in August at stations 3 and 4. The catch rate was less than 5 fish/trap/d after September 3.

At station 3, 82% of the fish were captured in the east side trap of the net (Table 5) which differed significantly from the west side ($P < 0.001$). At stations 1 and 4, there was no significant difference ($P > 0.07$).

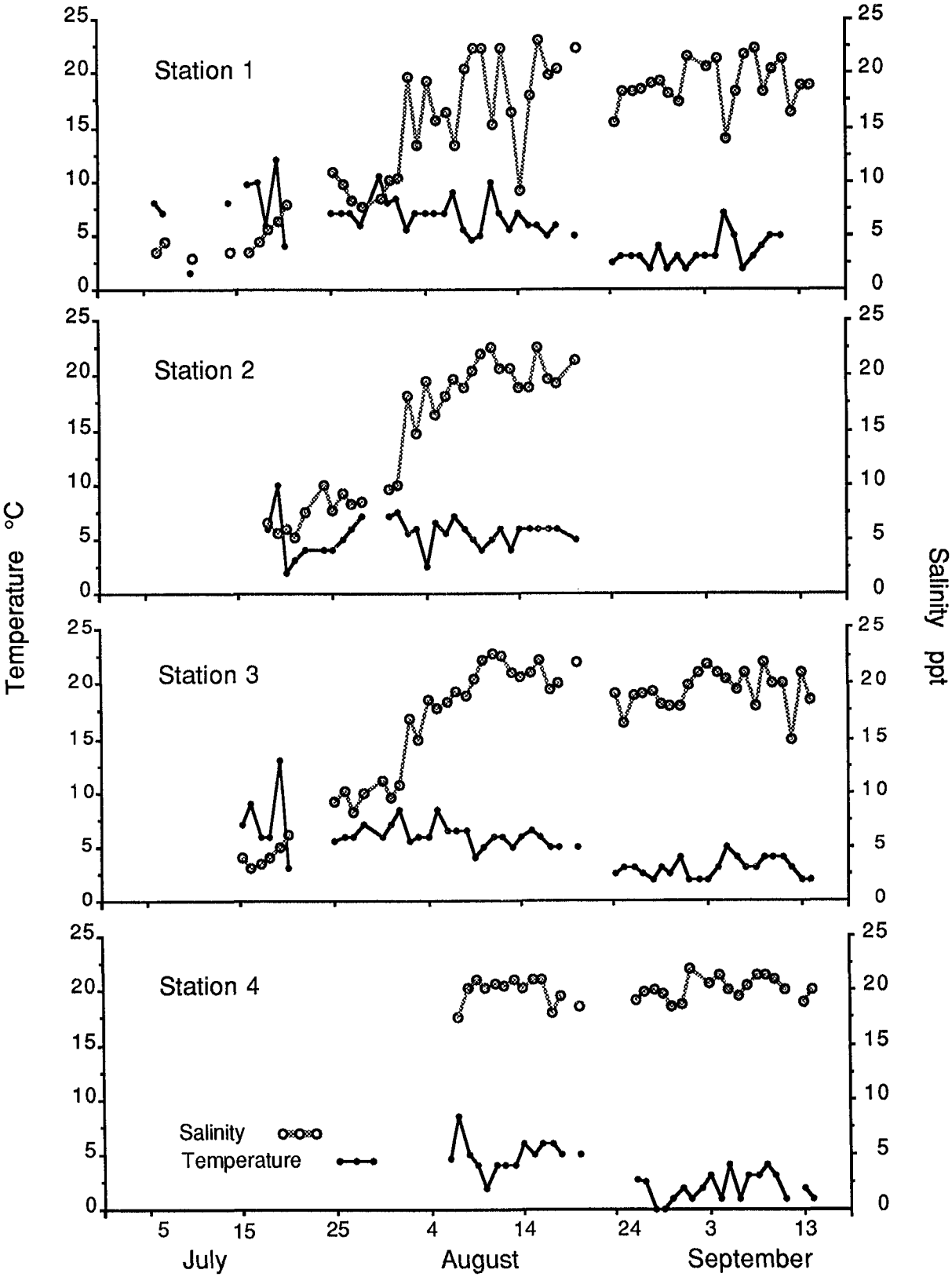

FIGURE 3.—Surface water temperature and salinity at fyke net stations in Oruktalik Lagoon, Alaska, July-September 1986.

Juvenile and adult Arctic cisco ranged from 90 to 475 mm FL (Figure 7). There was a bi-modal length frequency distribution with modes at 135 and 345 mm FL. Twenty-nine fish were examined for age, length and weight at age, and sex (Table 6). Ages ranged from 2 to 15 years and most (53%) were 8 to 10 years old. Sixty-one percent were female. The length-weight relationship for Arctic cisco 333 - 446 mm FL was Log_{10} W = -4.120 + 2.678 (Log_{10} L), (N = 27, r^2 = 0.80, SE(a) = 0.048, SE(b) = 0.268).

None of the 755 Arctic cisco tagged were recaptured within the lagoon. Three fish were recaptured in the Colville River commercial fishery 300 km to the west. One, tagged on August 30, 1986, was recaptured on October 30, 1986. The migration rate was 4.9 km/d. The other two fish, both tagged on August 31, were recaptured in late October 1987 (L. Moulton, Entrix, personal communication).

Three Arctic cisco recaptured in Oruktalik Lagoon in August were from studies to the west near Prudhoe Bay and in Gwydyr Bay (about 225 km and 245 km, respectively). Two fish were tagged in the Prudhoe Bay area during July 1985 and the third fish was tagged in Gwydyr Bay in July 1984 (L. Gilbertson, Envirosphere Company, personal communication).

Fourhorn sculpin.—Fourhorn sculpin (N = 9,907) were captured continuously between July 6 and September 14. Most (77%) were captured at station 1 and 16% at station 3 (Table 3). Daily catch rates ranged from 4 to 1,073 fish/trap/d (Figure 8). At station 1, the catch rate exceeded 100 fish/trap/d on 23 (39%) of the 59 d the trap was fished. In contrast, a catch rate greater than 100 fish/trap/d occurred only twice at station 3 and never occurred at station 4.

Fourhorn sculpins (N = 1,443) ranged from 38 - 267 mm TL (Figure 9). The predominant length group, 50-80 mm, comprised 63% of the fish captured.

Arctic cod.—Arctic cod (N = 7,252) were the second most abundant marine species captured. Fifty percent were captured at station 4, 30% at station 1, and 20% at station 3 (Table 3). Arctic cod were first captured on July 9. From July 9 - August 18, only 151 Arctic cod were caught before the storm. After the storm 7,101 Arctic cod were captured (98%). Daily catch rates were 0-8 fish/d from July 9 through August 18 (Figure 10). Catch rates after August 25 ranged from 0 to 1,042 fish/trap/d. Eighty-four percent of the Arctic cod were captured between August 24 and September 2.

Prior to the storm, Arctic cod ranged from 50 to 132 mm TL (N = 151; Figure 11). After the storm, they became more abundant and larger, ranging from 51 to 223 mm TL (N = 518). Mean length averaged 75.2 mm TL and 105.5 mm TL before and after the storm, respectively.

Capelin.—Capelin (N = 787) was the third most numerous marine species captured. Capelin were first captured on August 1. Most fish (75%) were captured at station 1 (Table 3) where daily catch rates ranged from 0 to 124 fish/trap/d (Figure 12). Highest catch rates occurred in August at all stations. Catch rates decreased to less than 5 fish/trap/d in September.

Capelin (N = 306) ranged from 78 to 160 mm FL (Figure 13). Fish in the 121-140 mm length group comprised 62% of the catch.

Dolly Varden.—Dolly Varden (N = 723) were captured from July 6 through September 13. About 53% of the fish were captured at station 3 and 37% at station 1 (Table 3). Daily catch rates ranged from 0 to 35 fish/trap/d (Figure 14). Highest catch rates occurred in July through mid-August, then decreased to less than 8 fish/trap/d.

At station 3, 83% of the Dolly Varden were captured in the east side trap of the fyke net (Table 7). The catch differed significantly ($P < 0.001$) between the two sides of the net. Fish movement was in a westerly direction toward the lagoon entrance. At stations 1 and 4, there was no significant difference ($P > 0.05$).

Dolly Varden (N = 746) ranged from 121 to 638 mm FL (Figure 15). Several smaller fish still had parr marks. Dolly Varden between 451 and 500 mm FL were the predominant length group (24%) before mid-August. After mid-August, Dolly Varden less than 300 mm FL dominated the catch (72%).

Seventy-nine Dolly Varden were examined for sex and included 49 females, 15 males, and 15 immature (sex undetermined). Age was determined for 71 (Table 8). Ages ranged from 1 to 13 years. The predominant length group of 451-500 mm Fl was composed of 8 and 9 year old fish. Immature fish measured 129 - 273 mm FL and most (53%) were 2 years old. The length-weight relationship for Dolly Varden was $\text{Log}_{10}\ W = -5.080 + 3.021\ (\text{Log}_{10}\ L)$, (N = 79, $r^2 = 0.97$, SE(a) = 0.096, SE(b) = 0.056).

Of the 501 Dolly Varden tagged, we recaptured 29 in Oruktalik Lagoon, three were taken in a subsistence fishery near Griffin Point, and two were caught by sport fishermen at Barter Island 4 and 6 d after being tagged. The migration rate between Oruktalik Lagoon and Barter Island was 4.0 - 6.5 km/d. In the lagoon, the time between tagging and recapture varied from 1 to 18 d. Most of the recaptures (80%) were within 4 d, 40% (N = 12) occurred the day after tagging and 11 of those recaptures were at the same station they were tagged. Dolly Varden tagged at station 1 were caught at station 3 and five char from station 3 were captured at station 1. We recaptured six Dolly Varden that were tagged in Beaufort Lagoon (35 km to the east) in 1985.

Least cisco.—Least cisco (N = 281) were captured from August 3 to September 10. Ninety percent were captured after the storm during an 11 d period between August 25 and September 4. Fifty percent were captured at station 3. Catch rates ranged from 0 to 28 fish/trap/d, with maximum catch rates occurring during late August (Figure 16).

Least cisco (N = 274) ranged from 223 to 368 mm FL (Figure 17). The predominate (70%) length group was 264 - 296 mm FL.

A total of 234 least cisco were tagged. Ten were recaptured in the lagoon, all within 9 d after initial release. Five of the recaptures moved between stations 1 and 3. One fish (281 mm FL) tagged on August 24 was recaptured on September 2 in Foggy Island Bay, 200 km west of Oruktalik Lagoon. The movement rate was 22 km/d.

Saffron cod.—Saffron cod (N = 133) were captured sporadically at all stations after August 1. Fifty percent were captured at station 3. Lengths ranged from 51 to 433 mm TL (N = 135). Three saffron cod were tagged and one fish was recaptured in the lagoon.

Arctic flounder.—Arctic flounder (N = 127) were captured throughout the sampling period. There was no peak period of abundance with the exception of July 19 at station 1, when the catch rate was 14 fish/trap/d (Figure 18). Catch rates were generally 1-3 fish/trap/d. Most (68%) fish were captured at station 1. Arctic flounder ranged from 104 to 282 mm TL (Figure 19).

Ninespine stickleback.—Ninespine stickleback (N = 59) were first captured August 8. About 85% were captured at station 1 (Table 3). Fork lengths ranged from 55 to 86 mm FL (N = 51).

Rainbow Smelt.—Ten rainbow smelt were captured between August 1 and September 1, and ranged from 173 to 239 mm FL.

Snailfish.—Four snailfish were captured between August 20 and September 11. Lengths for two fish measured 75 and 111 mm TL.

Chum salmon.—Two adult chum salmon were captured, one on August 27 and the other on September 3. Fork lengths measured 472 and 555 mm.

Broad whitefish.—One broad whitefish was captured on August 26 and measured 348 mm FL.

Catch Rates and Hydrologic Measurements

Correlation coefficients (r) between catch rate and temperature or salinity did not exceed ± 0.60 (Table 9). Catch rates were positively correlated with temperature for Dolly Varden at all stations and juvenile and adult Arctic cisco at two stations. Catch rate and temperature correlations were negative for young of the year Arctic cisco and Arctic cod at all stations and fourhorn sculpin at two stations.

Catch rates were negatively correlated with salinity for Dolly Varden at all stations and juvenile and adult Arctic cisco and fourhorn sculpins at two stations. Catch rate and salinity correlations were positive for young of the year Arctic cisco and Arctic cod at two stations.

Discussion

The composition of marine and anadromous fish species captured in Oruktalik Lagoon was consistent with findings from previous studies in the coastal waters off the Arctic National Wildlife Refuge (Roguski and Komarek 1971; Ward and Craig 1974; Griffiths et al. 1977; Craig 1983; West and Wiswar 1985; Wiswar and West 1987) where fourhorn sculpin, Arctic cod, Arctic cisco, and Dolly Varden were the most abundant species captured.

Some fish distribution patterns are evident from this study. Young of the year Arctic cisco were most abundant in late August and early September. Arctic cod catch rate increased and larger size fish became more abundant as water temperature decreased and salinity increased. Dolly Varden larger than 300 mm FL were captured less frequently in late August and September when salinities were highest.

The capture of young of the year Arctic cisco in Oruktalik Lagoon was the first record of their presence off the Arctic Refuge coast. Young of the year Arctic cisco recruitment to the central Beaufort Sea from Mackenzie River stocks is believed to be a migration along a wind-aided longshore current (Fechhelm and Fissel 1988). The storm on August 21-23 was from the northwest and may have disrupted the longshore current resulting in young of the year entering the lagoon as a refuge.

In 1986, in Phillips Bay, Yukon Territory, young of the year Arctic cisco catch rates were greatest between August 6 and 18 (Bond and Erickson 1989). Phillips Bay is located about 115 km west of the Mackenzie River delta and 90 km east of Oruktalik Lagoon. If we assume that those fish captured in Phillips Bay comprised the same group captured in Oruktalik Lagoon on August 25 - September 2, the migration rates were 4.7 - 6.4 km/d.

Fourhorn sculpin were the numerically dominant marine species captured in this study and other studies along the Arctic Refuge coast (Griffiths 1983; West and Wiswar 1985; Wiswar and West 1987). In the central Beaufort Sea, fourhorn sculpin are abundant but generally rank second numerically to Arctic cod (Craig and Haldorson 1981; Griffiths et al. 1983; Cannon et al. 1987). The difference in relative abundance between fourhorn sculpin and Arctic cod in Oruktalik Lagoon may in part be due to the type lagoon (Hachmeister and Vinelli 1984), its geometry, and degree of marine water intrusion. Relatively warmer water temperatures and lower salinities are retained in the lagoon in early summer following break-up. As the season progressed, Arctic cod became more abundant in Oruktalik Lagoon as temperatures decreased and salinities increased.

Juvenile and adult Arctic cisco use lagoon habitat shortly after break-up and appear to be one of the earliest arriving fish species found off the Arctic Refuge coast (Roguski and Komarek 1971; Griffiths et al. 1977; West and Wiswar 1985; Wiswar and West 1987). Arctic cisco have been captured as early as June 24 in Beaufort Lagoon when most of the lagoon was covered by ice (West and Wiswar 1985). However, the failure to recapture any of the 755 Arctic cisco tagged in Oruktalik Lagoon suggests that they utilize the lagoon for only a short period of time, and then continue their coastal movements. This is supported by studies the previous two years when fish tagged in Beaufort Lagoon were not recaptured (West and Wiswar 1985; Wiswar and West 1987).

The most frequent length group of Dolly Varden (451-500 mm FL) captured in Oruktalik Lagoon was similar to that found at Beaufort Lagoon in previous years (West and Wiswar 1985; Wiswar and West 1987). After the third week of August, few Dolly Varden over 300 mm FL were captured while smaller size fish (< 300 mm FL) were still present and dominated the catch. The change in catch rate of different size classes of Dolly Varden as the season progressed conforms to what has been observed in the rivers. In late summer, larger Dolly Varden migrate into the rivers to spawn and overwinter before smaller anadromous Dolly Varden arrive (McCart 1980).

Dolly Varden captured inside the barrier island at station 3 apparently were migrating out of Oruktalik Lagoon. Had fish continued westerly along the shoreline, we would have expected to recapture tagged fish from station 3 at station 4 on the other side of the entrance; however, there were no recaptures. Additionally, although directional movement at station 4 was not statistically significant, no tagged fish from station 4 were recaptured at station 3. In Beaufort Lagoon (West and Wiswar 1985; Wiswar and West 1987), a similar movement pattern along the barrier island towards the direction of an entrance was observed.

Only 281 least cisco were captured in Oruktalik Lagoon and all were greater than 220 mm FL. Least cisco do not appear to be abundant off the Arctic Refuge coast (Roguski and Komarek 1971; Griffiths 1983; Griffiths et al. 1977; West and Wiswar 1985; Wiswar and West 1987). Smaller least cisco in the nearshore waters remain closer to the mouths of their natal rivers (Cannon et al. 1987; Bond and Erickson 1989). Least cisco occur in the Mackenzie River, Northwest Territories (Kendel et al. 1975), Canadian lakes west of the Mackenzie River (Mann 1974), the Colville River, Alaska, and many larger streams and lakes to the west (Alt and Kogl 1973; USDI 1979). There are no reports of least cisco utilizing rivers between the Colville and Mackenzie rivers (Ward and Craig 1974; Smith and Glesne 1983; Daum et al. 1984).

Statistically significant correlation coefficients (r) between daily catch rate and water temperature and salinity were found in 11 of the 30 matrices. High variability in the daily catch rates probably account for why more matrices are not statistically significant.

Dolly Varden abundance was correlated with warmer water temperatures and low salinity. Juvenile and adult Arctic cisco exhibited a weak preference for warm brackish water. Overall abundance of anadromous fish species in the Beaufort Sea generally agree with this association (Craig 1984; Craig 1989). However, correlation coefficients in Oruktalik Lagoon for young of the year Arctic cisco displayed an opposite trend. Young of the year Arctic cisco occurred off the Arctic Refuge coast during the later part of the open water season when water temperatures were colder and salinity higher. Their late season migration through nearshore coastal waters may preclude use of habitat with preferred temperature and salinity gradients.

Abundance of fourhorn sculpin and Arctic cod showed a trend towards colder water of higher salinity. Although some correlations are weak, this was seen in eight of the twelve matrices. Marine species tend to increase in abundance in nearshore waters and lagoons during the latter part of the open water season (Craig 1984).

Because of the shallow nature of Oruktalik Lagoon, it is not likely that construction activities would occur that would degrade physical habitat or alter hydrographic conditions. If causeways or port facilities were to be constructed in the area, they would probably be located outside the lagoon where deeper water would not constrain vessel movement. Seismic activities on the Arctic coastal plain, in nearshore coastal areas, and in lagoons of the Arctic Refuge have occurred in winter when ice thickness is at a maximum and fish are absent. In contrast, an oil spill could be detrimental and have long term effects on the lagoon habitat and fish using the lagoon. In cold arctic waters, evaporation of toxic aromatic hydrocarbons occur at a slow rate and, therefore may persist in the water column (Howarth 1991). In time, these toxins will settle out into the sediment. During break-up in subsequent summers, shorefast ice in Oruktalik Lagoon may disturb these sediments through scouring and ice gouging resulting in resuspending the toxins in the water column. Additionally, dissipation of oil out of Oruktalik Lagoon would further be impaired by the limited exchange of water out of the lagoon.

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TABLE 2.—Fish species captured in Oruktalik Lagoon, Alaska, July - September 1986.

Family	Common name	Scientific name
	Anadromous	
Salmonidae	Arctic cisco	*Coregonus autumnalis*
	Least cisco	*Coregonus sardinella*
	Broad whitefish	*Coregonus nasus*
	Dolly Varden	*Salvelinus malma*
	Chum salmon	*Oncorhynchus keta*
Osmeridae	Rainbow smelt	*Osmerus mordax*
Gasterosteidae	Ninespine stickleback	*Pungitius pungitius*
	Marine	
Cottidae	Fourhorn sculpin	*Myoxocephalus quadricornis*
Gadidae	Arctic cod	*Boreogadus saida*
	Saffron cod	*Eleginus gracilis*
Osmeridae	Capelin	*Mallotus villosus*
Pleuronectidae	Arctic flounder	*Liopsetta glacialis*
Cylopteridae	Snailfish	*Liparis* sp.

TABLE 3.—Total catch and mean daily catch per unit effort (fish/trap/d) from fyke net stations in Oruktalik Lagoon, Alaska, July - September 1986.

Species	Station 1		Station 3		Station 4		Total
	Number caught	Fish/trap/d	Number caught	Fish/trap/d	Number caught	Fish/trap/d	
Anadromous							
Arctic cisco young of the year	99,231	1677.8	25,200	459.3	6,939	218.7	131,400
Arctic cisco juvenile and adult	166	2.9	496	9.4	244	7.4	906
Dolly Varden	278	4.8	380	7.2	65	2.0	723
Least cisco	76	1.4	138	2.6	67	2.0	281
Ninespine stickleback	50	<0.1	6	<0.1	3	<0.1	59
Rainbow smelt	4	<0.1	6	<0.1	0	0	10
Chum salmon	1	<0.1	0	0	1	<0.1	2
Broad whitefish	1	<0.1	0	0	0	0	1
Marine							
Fourhorn sculpin	7,615	135.5	1,610	30.1	682	20.7	9,907
Arctic cod	2,182	39.1	1,471	27.5	3,599	112.2	7,252
Capelin	569	9.7	151	2.7	67	2.2	787
Saffron cod	49	<0.1	68	<0.1	16	0.5	133
Arctic flounder	90	1.6	23	0.4	14	0.4	127
Snailfish	0	0	2	<0.1	2	<0.1	4

TABLE 4.—Comparison of the percent catch of young of the year Arctic cisco in different sides of fyke nets in Oruktalik Lagoon, Alaska, July - September 1986. Asterisk (*) denotes statistically significant ($P < 0.05$, Wilcoxon signed-rank test) difference between west and east side of trap.

	Percent of fish captured/trap	
Station	West side	East Side
1*	47	53
3	64	36
4	74	26

TABLE 5.—Comparison of the percent catch of juvenile and adult Arctic cisco in different sides of fyke nets in Oruktalik Lagoon, Alaska, July - September 1986. Asterisk (*) denotes statistically significant ($P < 0.05$, Wilcoxon signed-rank test) difference between west and east side of trap.

	Percent of fish captured/trap	
Station	West side	East Side
1	54	46
3*	18	82
4	60	40

TABLE 6.—Age specific length and weight for Arctic cisco captured in Oruktalik Lagoon, Alaska, July and August 1986. Age determined from sagittae.

	Fork length (mm)				Weight (g)			
Age	N	Mean	Range	SD	N	Mean	Range	SD
1	0				0			
2	1	145			1	30		
3	0	0			0	0		
4	0	0			0	0		
5	1	201			1	80		
6	1	333			1	445		
7	2	348.5	335-362	19.1	2	512.5	475-550	53.0
8	3	378.3	343-414	35.5	3	575.0	450-680	116.3
9	9	383.8	356-405	16.2	9	619.4	480-740	99.8
10	4	401.8	372-429	24.0	4	823.8	605-1050	210.5
11	1	446			1	845		
12	2	408.0		0	2	700.0	690-710	14.1
13	0	0			0	0		
14	1	431			1	715		
15	4	431.5	414-444	13.8	3	840.0	705-940	121.3

TABLE 7.—Comparison of the percent catch of Dolly Varden in different sides of fyke nets in Oruktalik Lagoon, Alaska, July - September 1986. Asterisk (*) denotes statistically significant ($P < 0.05$, Wilcoxon signed-rank test) difference between west and east side of trap.

	Percent of fish captured/trap	
Station	West side	East side
1	60	40
3*	17	83
4	65	35

TABLE 8.—Age specific length and weight for Dolly Varden captured in Oruktalik Lagoon, Alaska, July - September 1986. Age determined from sagittae.

		Fork length (mm)			Weight (g)		
Age	N	Mean	Range	SD	Mean	Range	SD
1	2	133.0	129-137	11.3	22.0	12-32	14.1
2	8	159.8	139-184	13.2	36.4	22-60	11.1
3	5	222.4	212-238	10.5	99.0	80-130	22.5
4	7	244.0	154-298	46.8	158.6	50-250	62.0
5	8	281.8	227-341	45.9	229.3	115-375	102.4
6	7	389.0	323-433	37.7	507.9	325-650	127.9
7	3	425.7	380-475	47.6	706.7	430-950	261.6
8	12	485.1	409-550	43.7	1132.1	510-1520	326.8
9	12	509.9	456-569	32.9	1358.3	890-1980	346.2
10	5	568.4	550-595	23.4	1980.0	1690-2250	203.3
11	1	623			2250		
12	0	0			0		
13	1	524			1450		

TABLE 9.—Correlation coefficient (r) matrix of catch rates for major species captured in Oruktalik Lagoon, Alaska, July - September 1986, by station versus water temperature and salinity. Asterisks (*) denotes statistically significant ($P < 0.05$) correlation coefficient.

	Station 1		Station 3		Station 4	
Species	Temperature (°C)	Salinity (ppt)	Temperature (°C)	Salinity (ppt)	Temperature (°C)	Salinity (ppt)
Arctic cisco young of the year	-0.38*	0.23	-0.36*	0.18	-0.13	-0.16
Arctic cisco juvenile and adult	-0.01	-0.22	0.01	0.29	0.10	-0.26
Dolly Varden	0.24	-0.60*	0.45*	-0.47*	0.42*	-0.17
Fourhorn sculpin	0.06	-0.19	-0.40*	0.32*	-0.49*	-0.13
Arctic cod	-0.41*	0.21	-0.44*	0.17	-0.28	-0.18

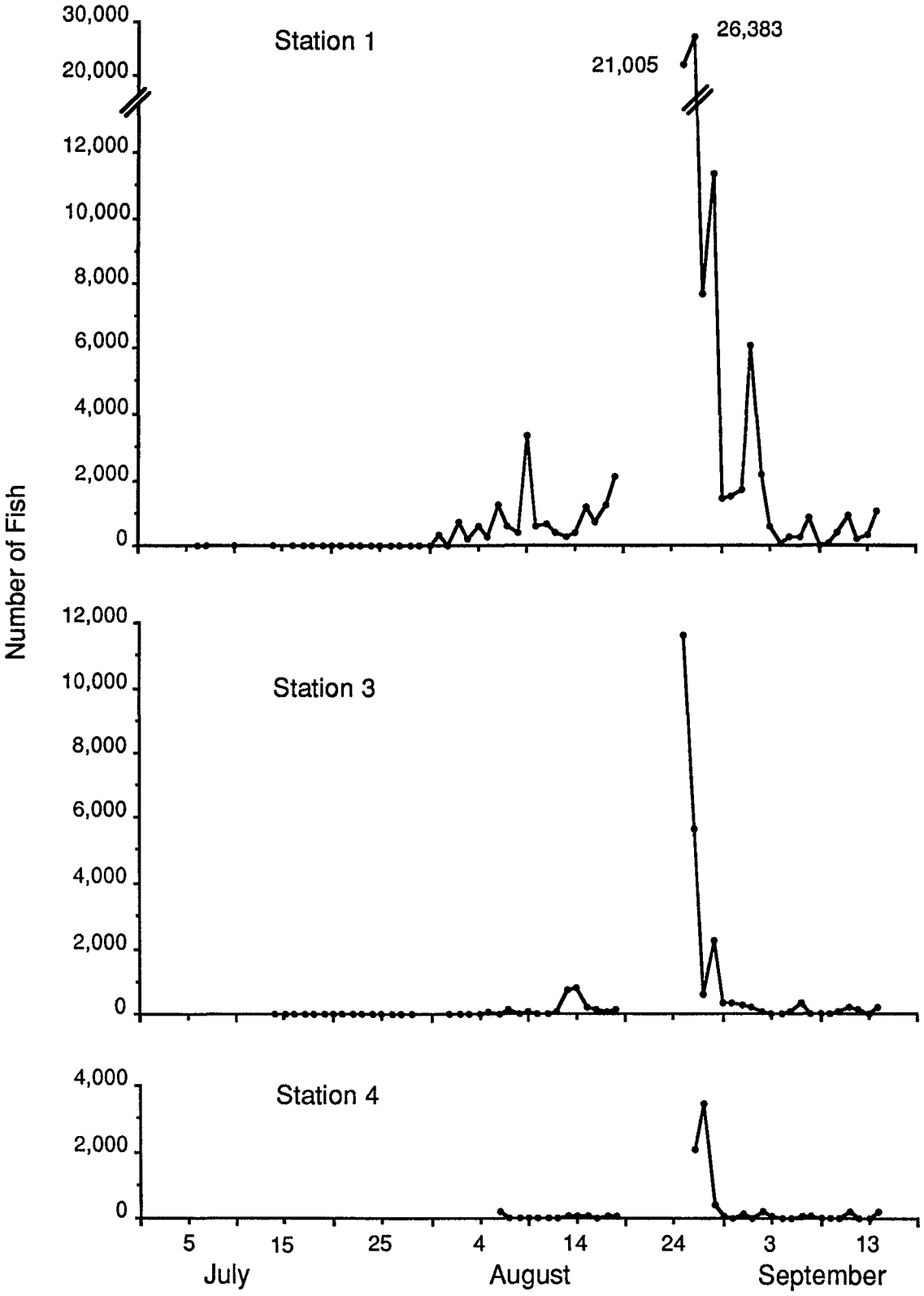

FIGURE 4.—Daily catch rate of young of the year Arctic cisco at fyke net stations in Oruktalik Lagoon, Alaska, July-September 1986.

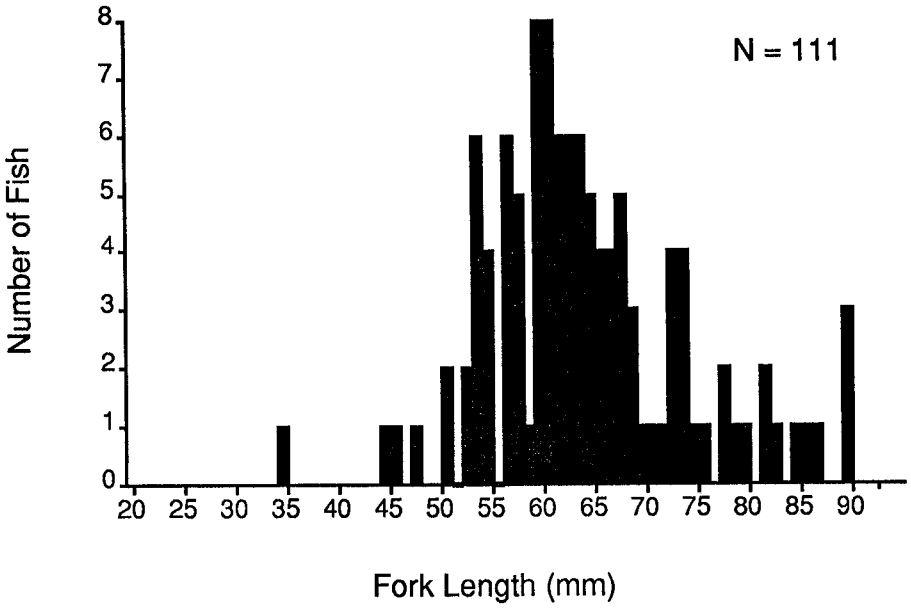

FIGURE 5.—Length frequency of young of the year Arctic cisco captured in Oruktalik Lagoon, Alaska, July 5 - August 9, 1986.

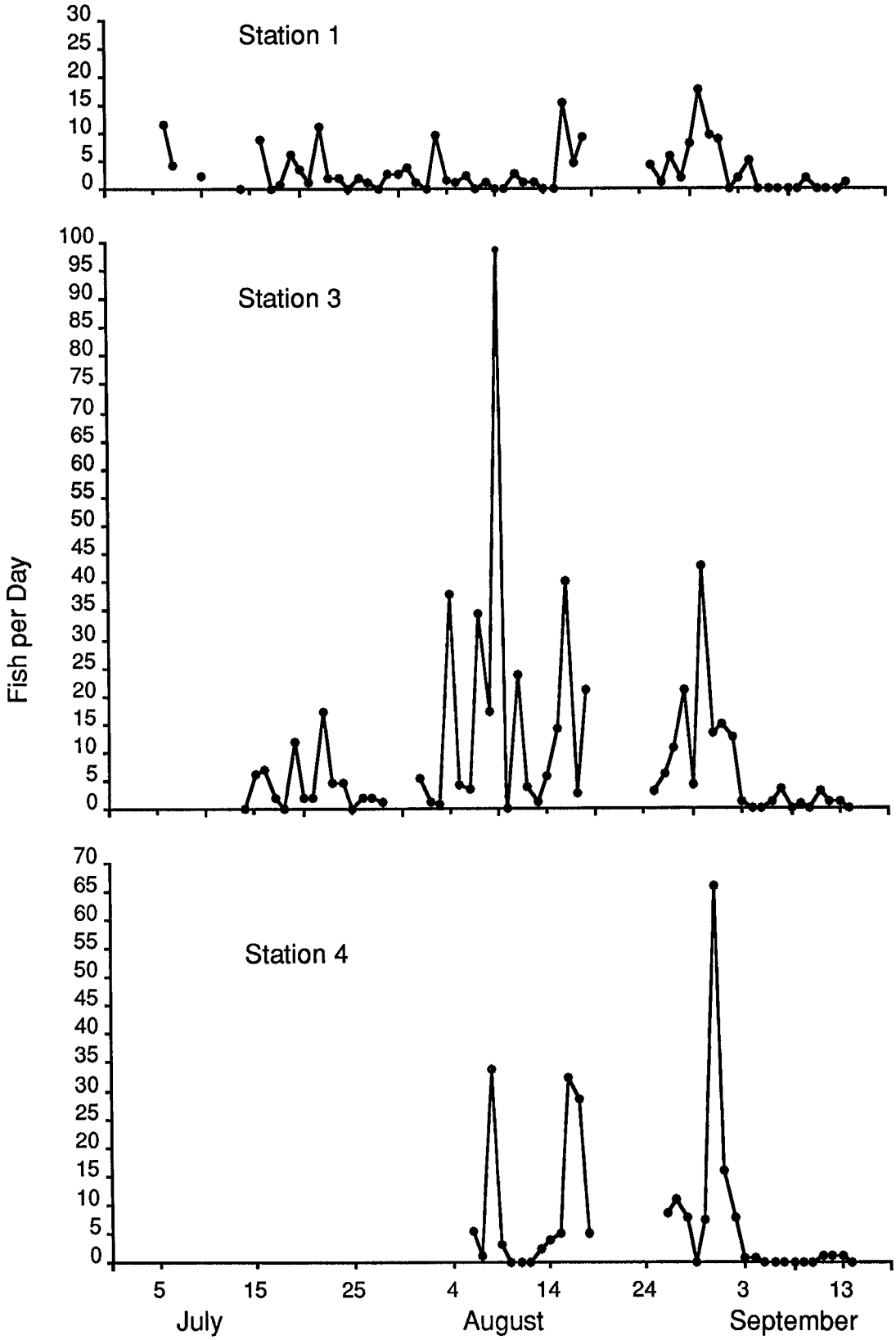

FIGURE 6.—Daily catch rate of juvenile and adult Arctic cisco at fyke net stations in Oruktalik Lagoon, Alaska, July-September 1986.

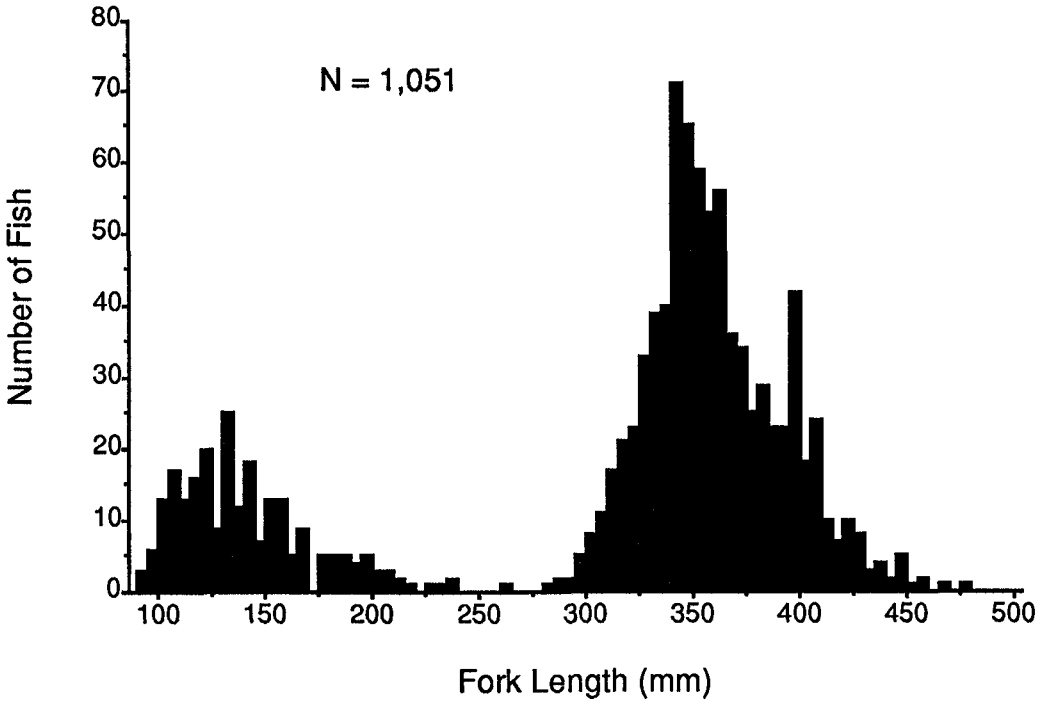

FIGURE 7.—Length frequency of juvenile and adult Arctic cisco captured in Oruktalik Lagoon, Alaska, July-September 1986.

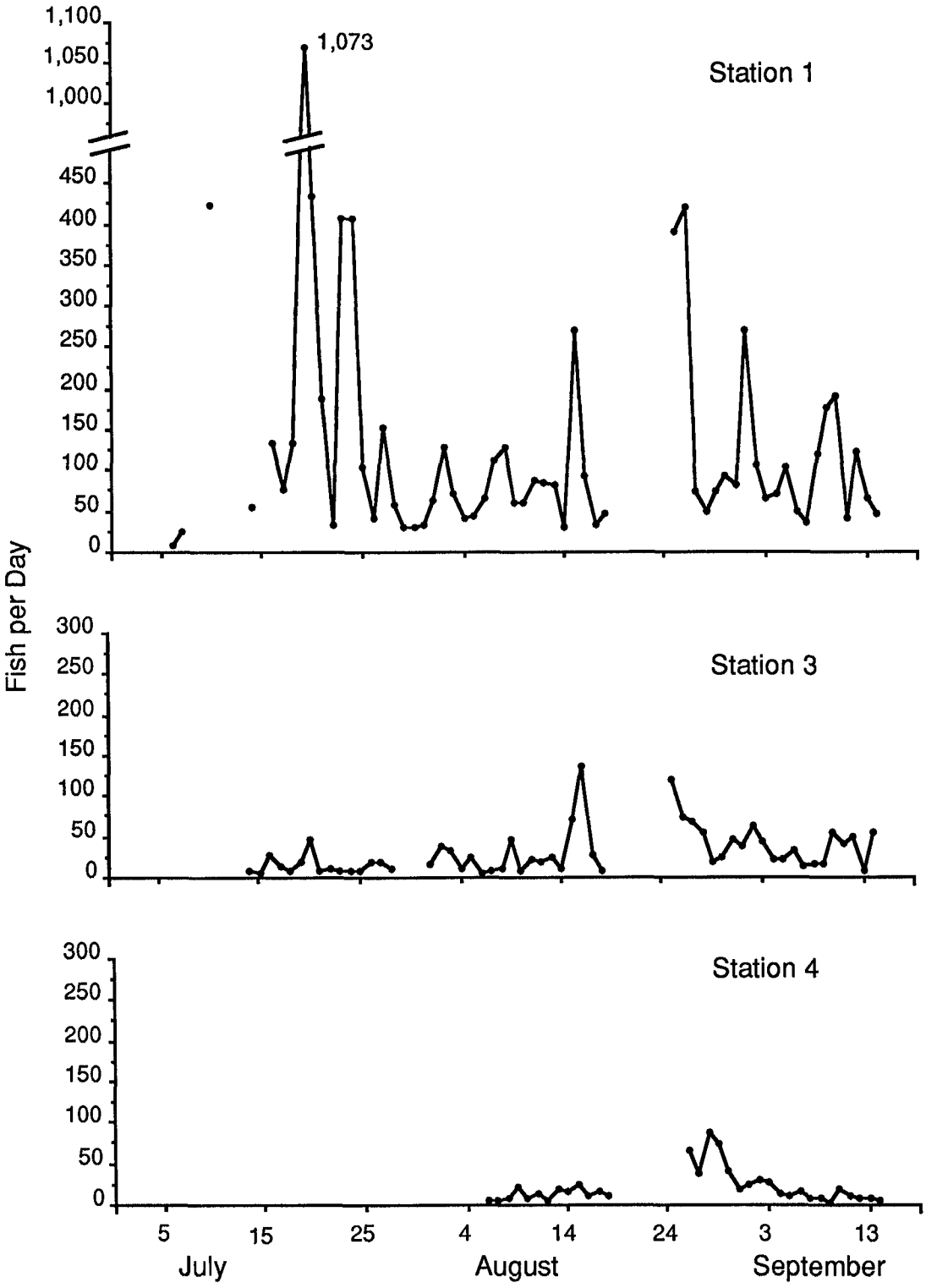

FIGURE 8.—Daily catch rate of fourhorn sculpin at fyke net stations in Oruktalik Lagoon, Alaska, July-September 1986.

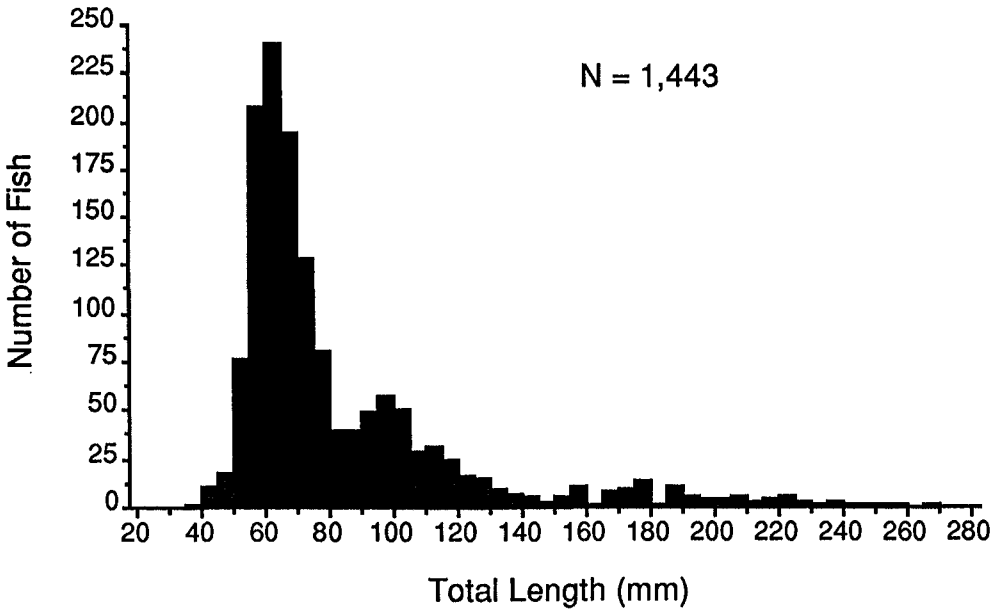

FIGURE 9.—Length frequency of fourhorn sculpin captured in Oruktalik Lagoon, Alaska, July-September 1986.

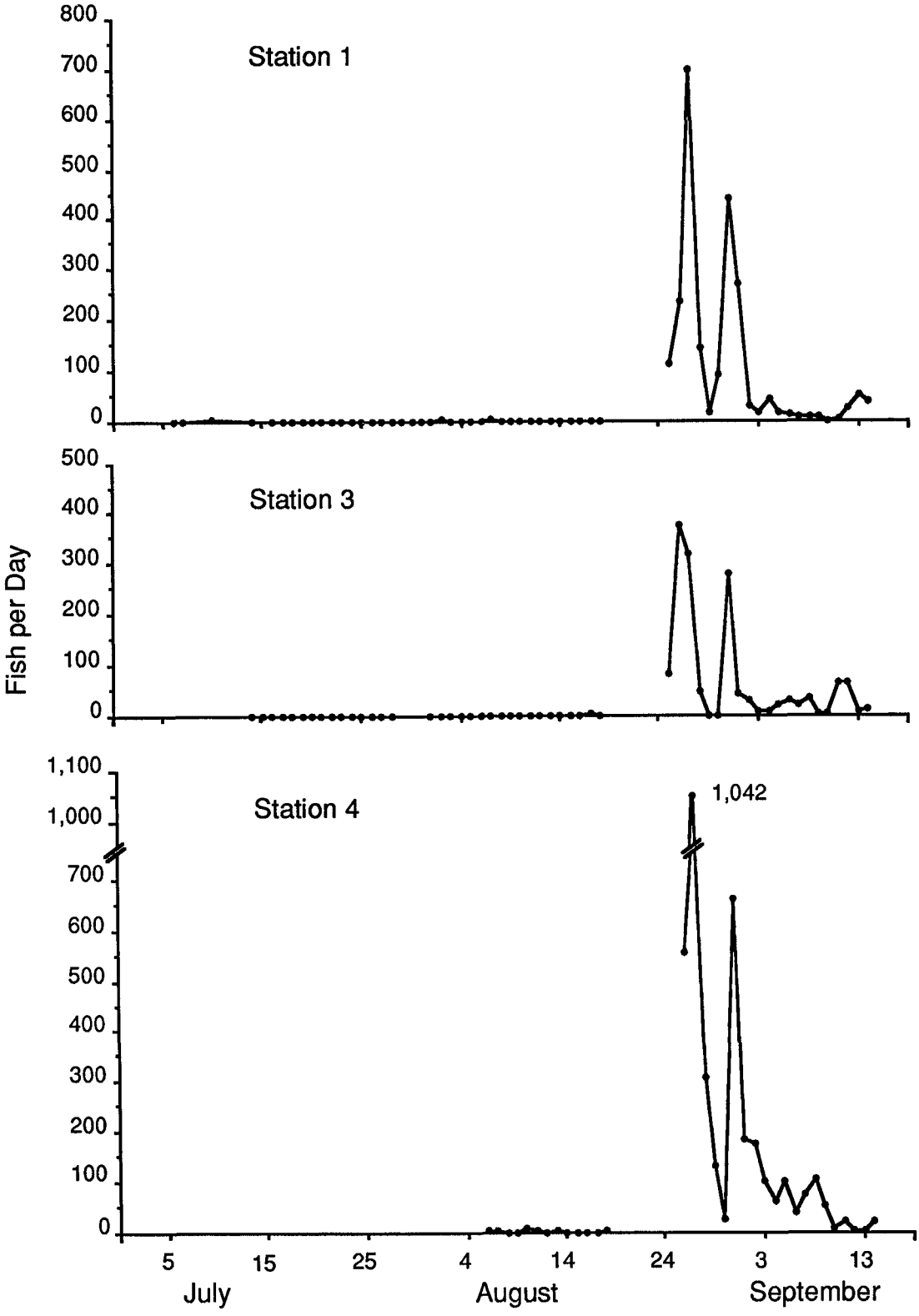

FIGURE 10.—Daily catch rate of Arctic cod at fyke net stations in Oruktalik Lagoon, Alaska, July-September 1986.

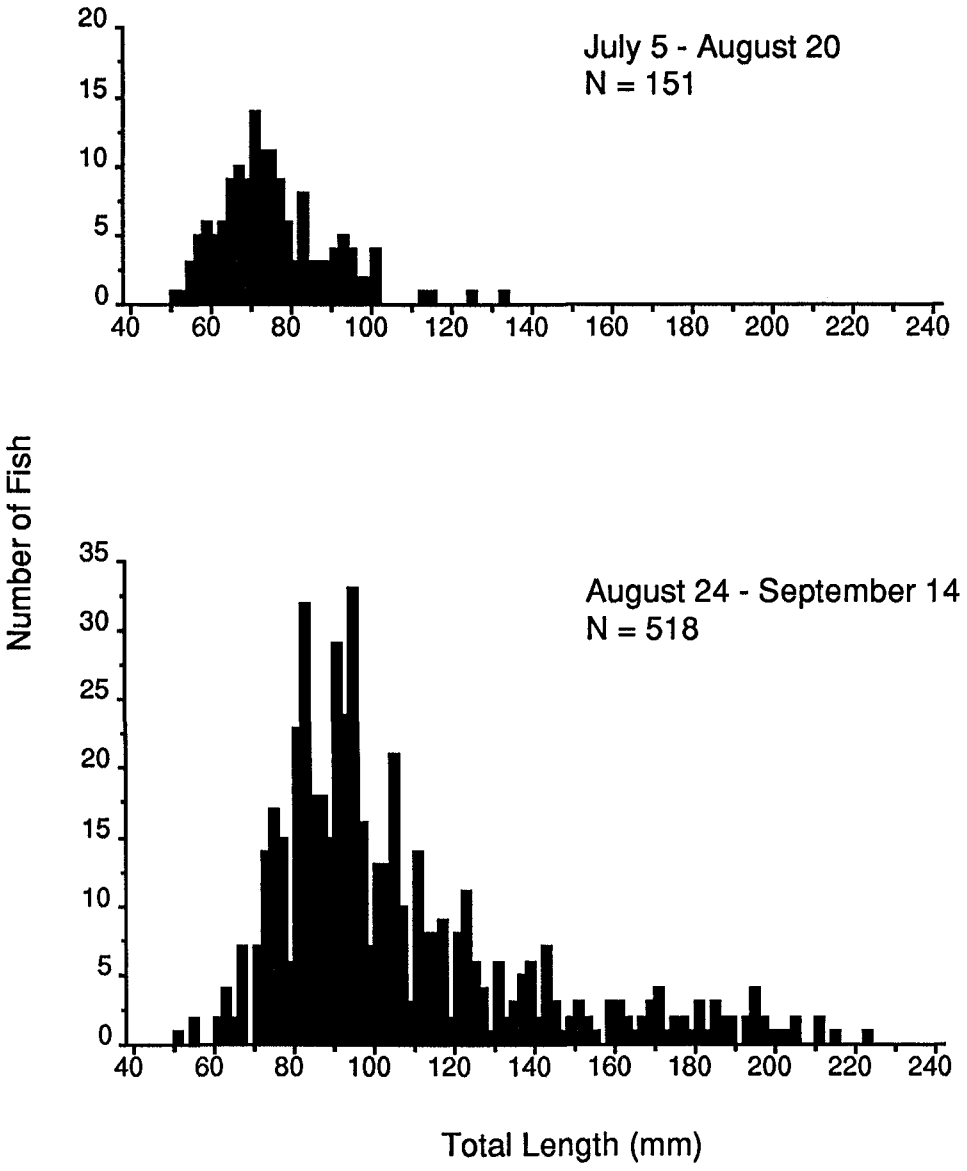

FIGURE 11.—Length frequency of Arctic cod captured in Oruktalik Lagoon, Alaska, July-September 1986.

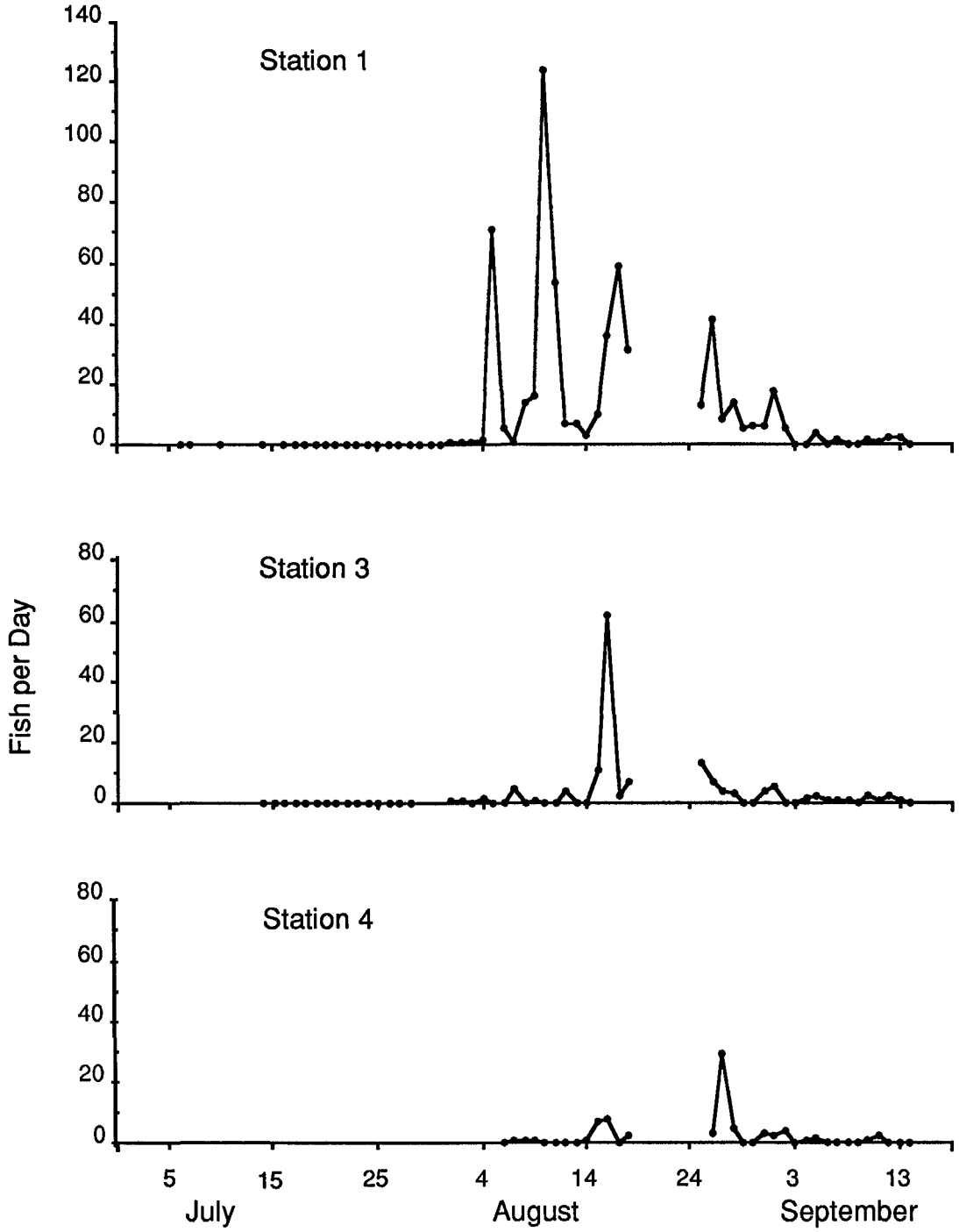

FIGURE 12.—Daily catch rate of capelin at fyke net stations in Oruktalik Lagoon, Alaska, July-September 1986.

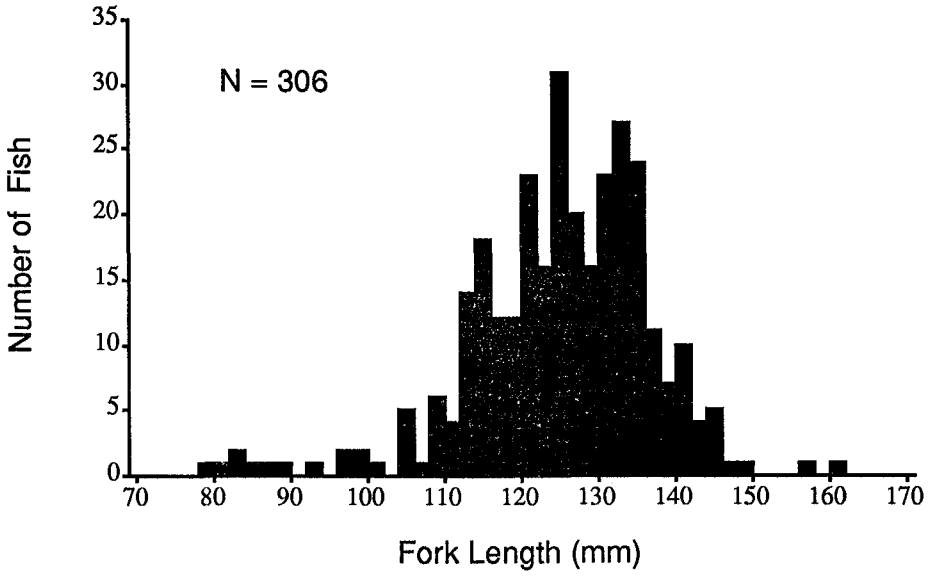

FIGURE 13.—Length frequency of capelin captured in Oruktalik Lagoon, Alaska, July-September 1986.

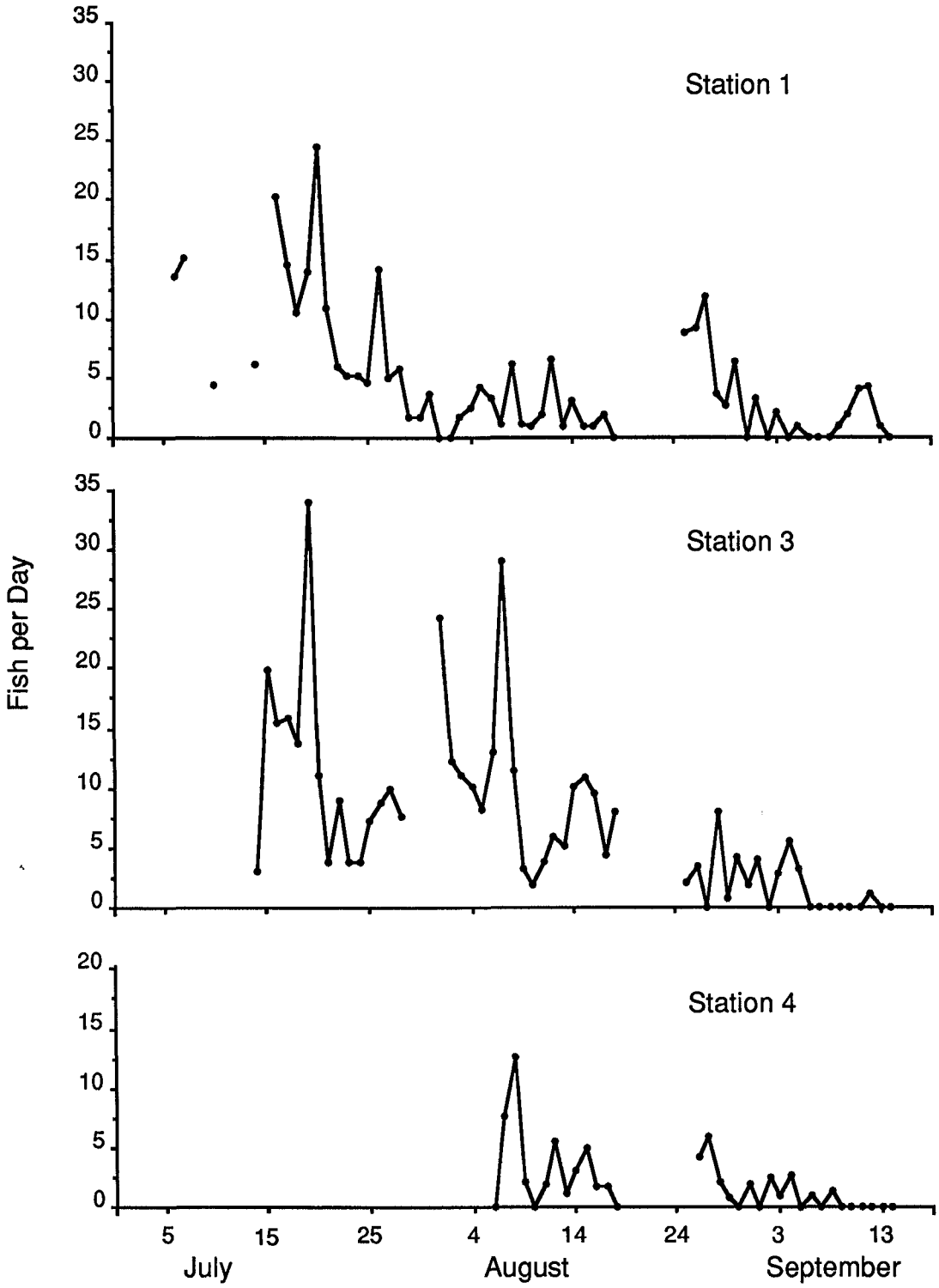

FIGURE 14.—Daily catch rate of Dolly Varden at fyke net stations in Oruktalik Lagoon, Alaska, July-September 1986.

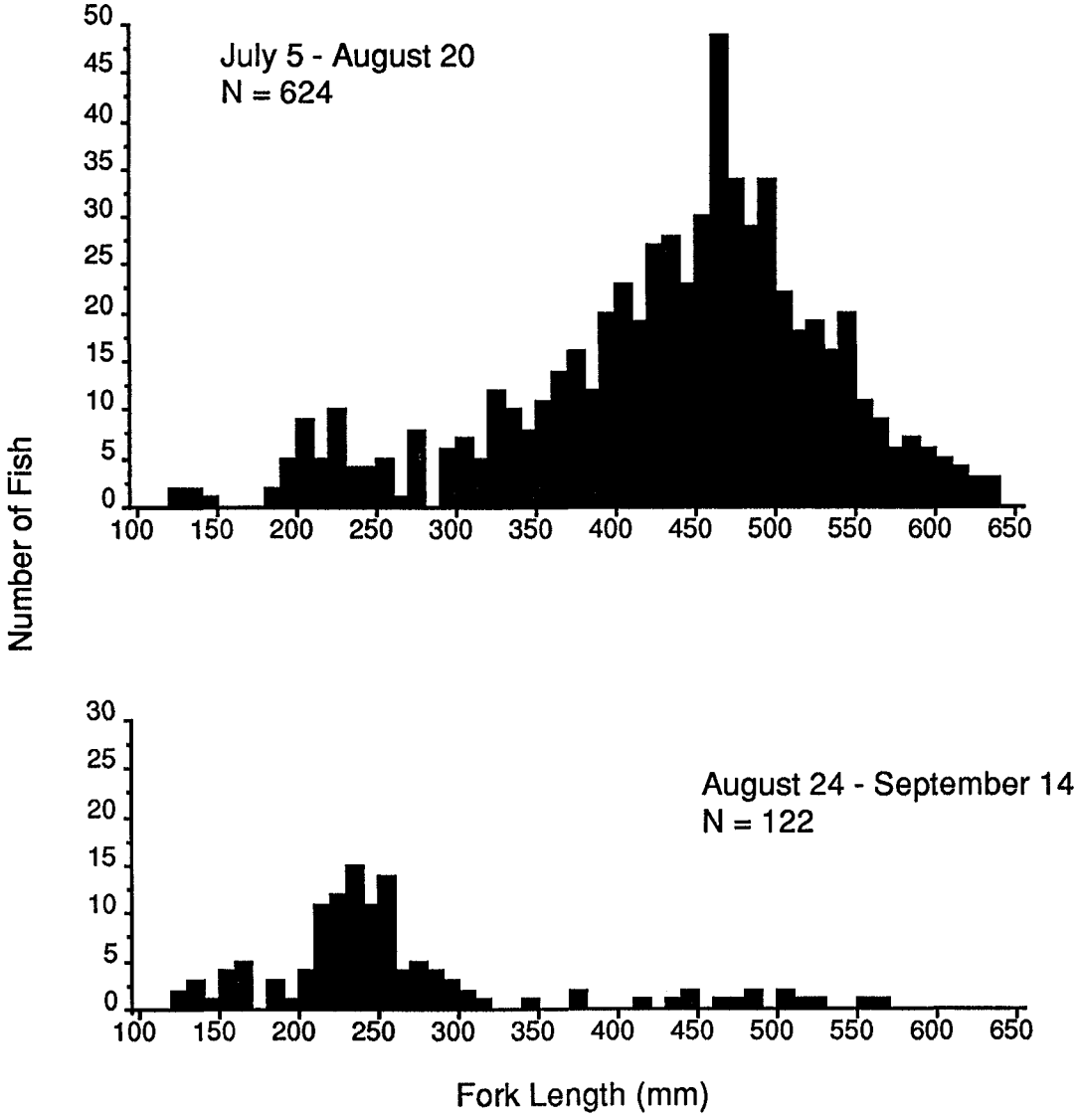

FIGURE 15.—Length frequency of Dolly Varden captured in Oruktalik Lagoon, Alaska, July-September 1986.

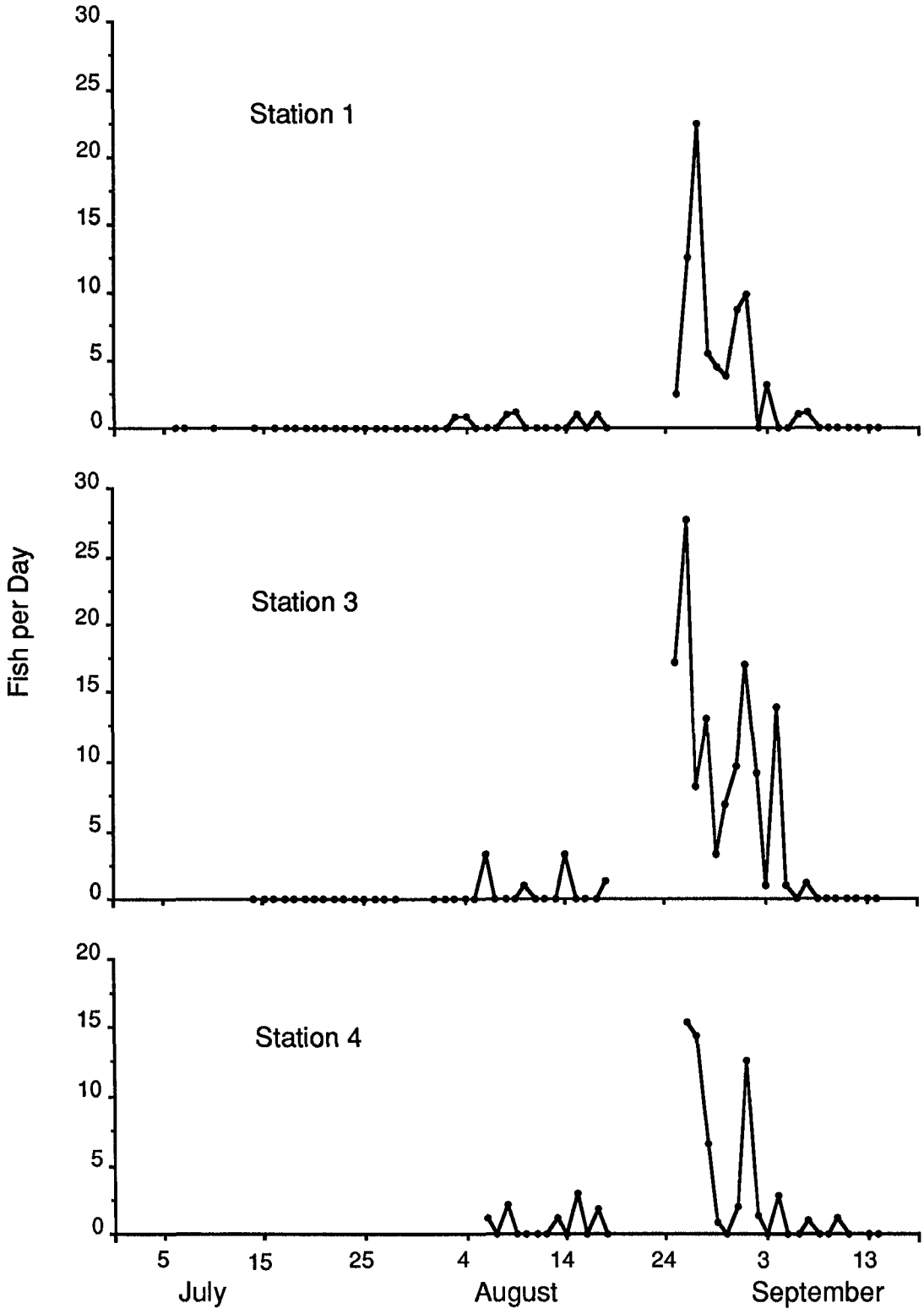

FIGURE 16.—Daily catch rate of least cisco at fyke net stations in Oruktalik Lagoon, Alaska, July-September 1986.

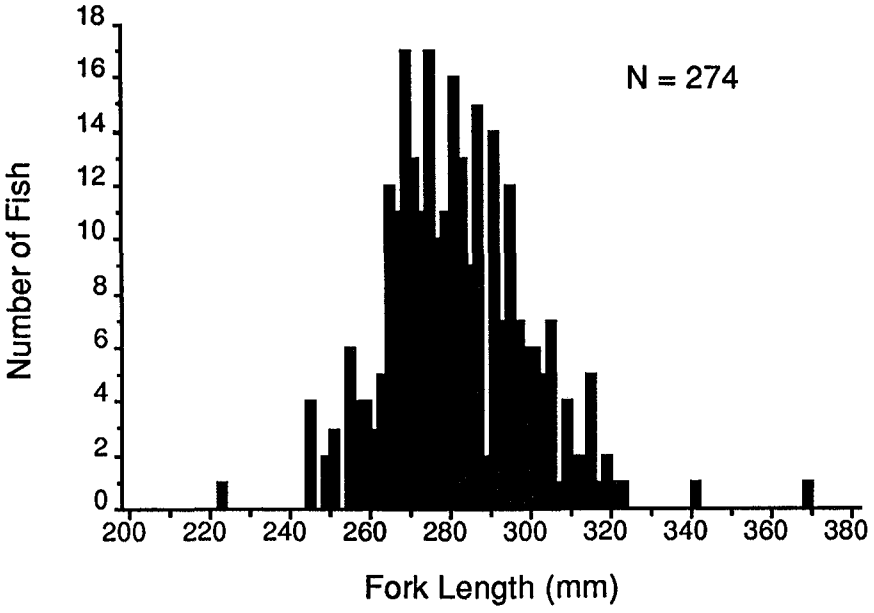

FIGURE 17.—Length frequency of least cisco captured in Oruktalik Lagoon, Alaska, July-September 1986.

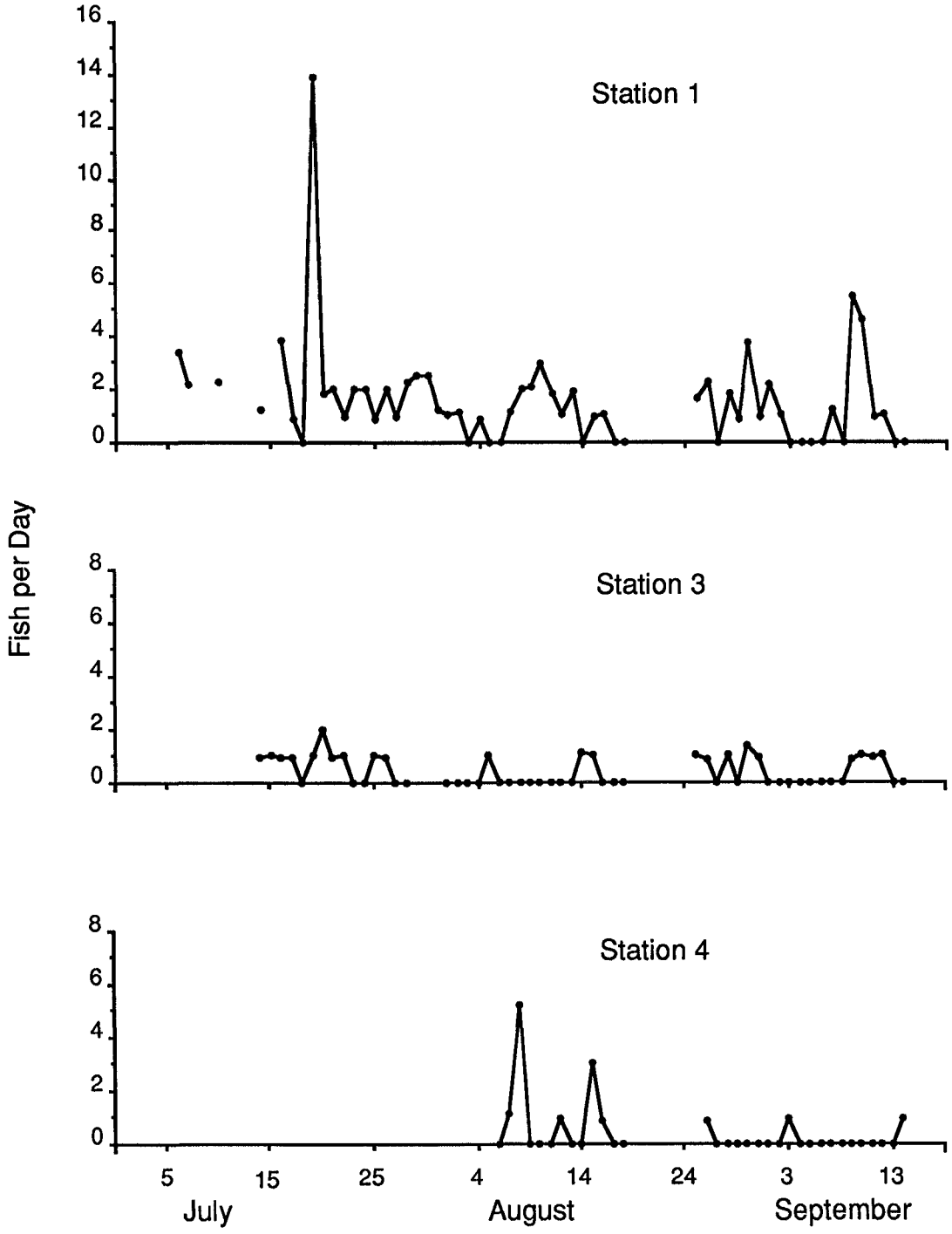

FIGURE 18.—Daily catch rate of Arctic flounder at fyke net stations in Oruktalik Lagoon, Alaska, July-September 1986.

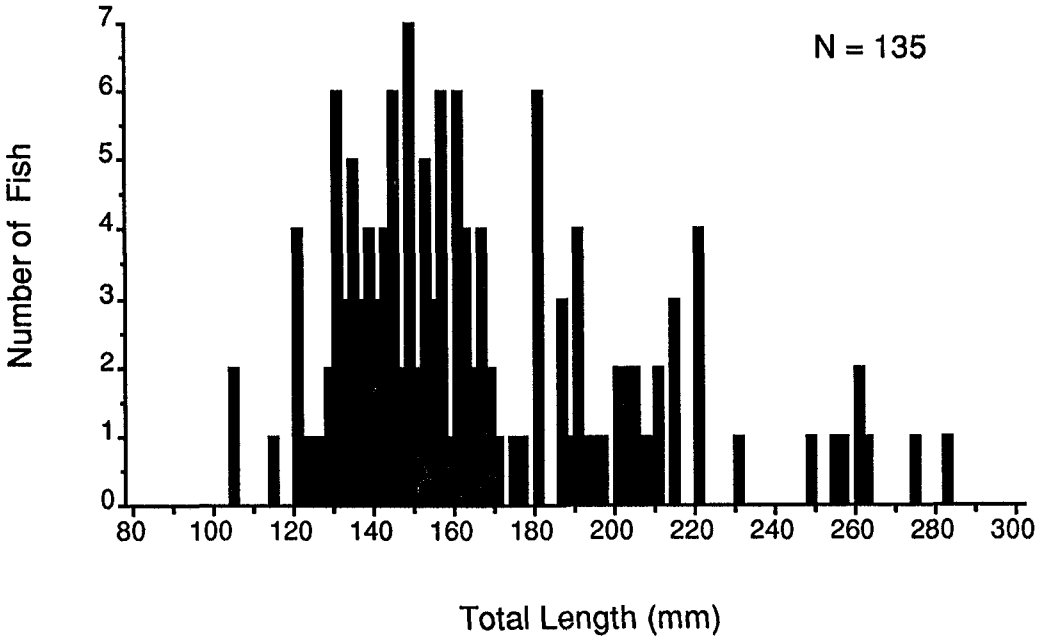

FIGURE 19.—Length frequency of Arctic flounder captured in Oruktalik Lagoon, Alaska, July-September 1986.