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Young-of-the-Year Cod (*Boreogadus*) in Lancaster Sound and Western Baffin Bay

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ABSTRACT. Over 85% of all ichthyoplankton found in the study area in 1976 and 1978 were young-of-year (Y-O-Y) *Boreogadus*. Most of the remainder were seasnails (Cyclopteridae). Densities of Y-O-Y cod were related to season, depth, and (to a lesser degree) year and location. From June to at least mid-August, Y-O-Y cod were normally most abundant at 10-20 m depth and rare or absent at the immediate surface. Densities decreased below ~20 m and no Y-O-Y cod were caught at depths >250 m. After mid-August densities decreased at all depths sampled. More Y-O-Y cod may have been present in the study area in 1976 than in 1978, and Y-O-Y were significantly longer at a given date in 1976 than in 1978.

Key words: arctic cod, *Boreogadus*, ichthyoplankton, larval fish, juvenile fish, growth, depth distribution, Lancaster Sound, Baffin Bay

RÉSUMÉ. Les *Boreogadus* nés au cours de l'année représentaient plus de 85% du total de l'ichtyoplancton trouvé dans le territoire à l'étude en 1976 et 1978. Les autres espèces appartenaient, pour la majeure partie, à la famille des Cyclopteridae. La densité des populations de morue née au cours de l'année dependait de la saison, la profondeur et (dans une moindre mesure) de l'année et la position. De juin jusqu'à tout au moins la mi-août, la morue née au cours de l'année était généralement plus abondante à une profondeur de 10 à 20 m et rare ou absente près de la surface. Les densités ont diminué sous ~20 m et aucune ne fut trouvées plus profondément que 250 m. Après la mi-août, les densités ont diminuées à toutes les profondeurs échantillonnées. Plus de morue nées au cours de l'année peuvent avoir été présentes dans le territoire à l'étude en 1976 qu'en 1978, et celles-ci étaient significativement plus longues à une date donnée en 1976 qu'en 1978.
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INTRODUCTION

While knowledge of arctic cod, *Boreogadus saida* (Lepechin), in North American waters is growing (Quast, 1974; Bohn and McElroy, 1976; Bain *et al.* 1977; Bain and Sekerak, 1978; Den Beste and McCart, 1978; Frost *et al.*, 1978; Hunter, 1979; Lear, 1979; Miller, 1979; Tarbox and Thorne, 1979; Wolotira *et al.*, 1979; Buchanan and Foy, 1980; Lilly, 1980; Wells, 1980; Lowry and Frost, 1981; Bradstreet, 1982; Craig *et al.*, 1982), most data remain in unpublished reports and working papers. Vast geographic areas remain unstudied and basic elements of the life history of arctic cod are little understood.

Although arctic cod are little used by man, they are an extremely important link in the transfer of energy from lower trophic levels to seabirds and marine mammals. Arctic cod are eaten by white whales, narwhals, ringed, bearded and harp seals, walruses (occasionally), thick-billed and common murres, black guillemots, black-legged kittiwakes, northern fulmars, arctic terns, and glaucous, Sabine's, ivory and Ross's gulls (Andriashev, 1964; Quast, 1974; Bradstreet, 1976, 1977, 1979, 1980; Divoky, 1978; Lowry *et al.*, 1978, 1980; Springer and Roseneau, 1978; Davis *et al.*, 1980; Bradstreet and Cross, 1982; Finley and Gibb, in press). Arctic cod form a significant fraction of the food consumed by many of the above animals. The arctic cod is especially important because it is the only relatively abundant fish in many arctic areas and few alternate food sources appear to exist. It is circumpolar in distribution and has been found as far north as 88°N latitude (Kleinenberg *et al.*, 1964).

Arctic cod in the Barents, Kara, Laptev and East Siberian seas have received more scientific attention than those in seas around North America. A generalized account of their life history can be drawn from European and Soviet literature. Although details may vary, this probably also applies to North American arctic waters. The general consensus is that arctic cod spawn between December and March (Jensen, 1948; Andriashev, 1964; Hognestad, 1968a, b; Ponomarenko, 1968), although spawning in October and November near Novaya Zemlya was reported by Kleinenberg *et al.* (1964).

The only identified spawning area in the North American Arctic is in Stefansson Sound in the Alaskan Beaufort Sea (Craig *et al.*, 1982); however, efforts to define spawning areas have been minimal. After field efforts in late November 1976 and late February and April 1977, Bain and Sekerak (1978) assumed that waters near Cornwallis Island were not utilized by arctic cod for spawning, as no adults or eggs were collected and young-of-the-year were first captured in April.

Arctic cod eggs are buoyant and range from 1.5 to 1.9 mm in diameter (Russell, 1976). Laboratory experiments indicate that the incubation period for arctic cod eggs is 26-35 d when held at a mean temperature of 0°C (Aronovich *et al.*, 1975) but incubation may be considerably longer at the subzero temperatures of winter sea water. From data on spawning period and first appearance of larvae in the Barents Sea, Rass (1968) suggested that the natural incubation period was 45-90 d. According to Rass (1968), newly emerged larvae are about 5.5 mm long, post-larvae are 6-30 mm, and transformation to the juvenile (fry) stage occurs when the young are 30-50 mm long. Baranenkova *et al.* (1966) reported newly emerged larvae as small as 3.5 mm in length. Ocean currents undoubtedly transport planktonic stages of arctic cod over consider-

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able distances. See Fissel *et al.* (1982) for a description of currents in the Baffin Bay-Lancaster Sound area.

Growth of young cod is relatively rapid and one-year-olds are commonly 70-100 mm in length (Hognestad, 1968b; Craig *et al.*, 1982). However, arctic cod are short-lived; five- to six-year-old fish are rare and specimens over 300 mm long are uncommon. Sexual maturity is commonly attained by age 3 yr and males tend to mature earlier than females (Craig *et al.*, 1982). Behavior and movement patterns of arctic cod are complicated and poorly known. Large 'pre-spawning' concentrations have been reported in coastal regions of the Barents Sea (Ponomarenko, 1968). Concentrations of arctic cod also occur in the North American Arctic (Craig *et al.*, 1982; Finley and Gibb, in press), but information is insufficient to predict where such concentrations are most likely to occur.

This paper concerns arctic cod in Lancaster Sound and western Baffin Bay during a limited portion of their life cycle — generally from July to early October in the first year of life. During this period a variety of planktonic or semi-planktonic stages can be present at the same time. Size of available specimens indicates that the majority are postlarvae. Available information from other North American areas is also discussed.

MATERIALS AND METHODS

1976

Six stations in Lancaster Sound (Fig. 1) were sampled from the M/V *Theta* on five occasions in 1976: 22-28 July, 3-8 August, 16-22 August, 27 August-1 September, 7-13 September. During the third period the station near Cape Sherard could not be occupied due to ice conditions; nearby waters (Station CSA) were sampled instead. No special efforts to obtain ichthyoplankton were routinely performed in 1976, but young fish were relatively common in samples collected with zooplankton sampling gear. The sampling program at each station consisted of vertical tows through the upper 150 m and horizontal tows immediately below the surface and at 10, 50 and 150 m depths.

A 0.5 m diameter plankton net (239 μm mesh) equipped with an Inter Ocean Model 313 flowmeter was used. For horizontal tows, the open net was lowered to the desired depth, towed from the stern of the ship for 10 min at ~5.6 km/h, closed, and brought to the surface. Approximate tow depths were maintained by measurement of wire angle and adjustment of length of wire. Occasional horizontal tows with a Miller sampler (760 μm mesh) were also performed from the stern of the ship at depth 10 m and towing speed 7.4 km/h; see Miller (1961) for a description of the sampler.

1978

In 1978, 32 stations (Fig. 2) were sampled from the starboard side of the M/V *Theron* between 23 July and 10 October. Most stations were sampled only once. Ichthyoplankton samples were obtained by towing six Miller samplers (760 μm mesh) horizontally and simultaneously at approximate depths of 0, 10, 17, 34, 102 and 170 m. The samplers were set as rapidly as possible and towed for 15 min at ~7.4 km/h. No flowmeters or closing devices were

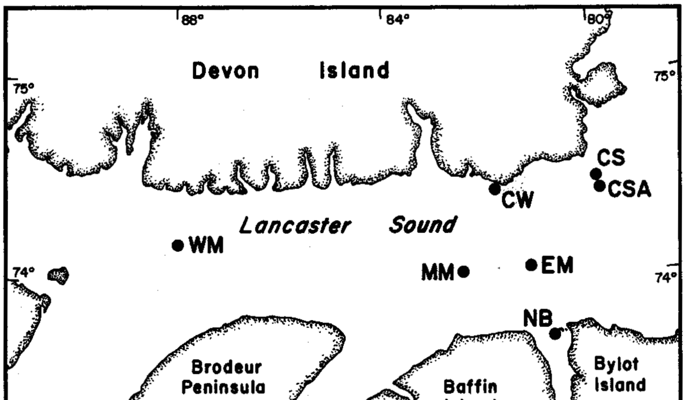

FIG. 1. Sampling stations in Lancaster Sound, 22 July to 13 September 1976. Normal sampling consisted of horizontal 0.5 m diameter plankton net tows at 0, 10, 50 and 150 m depths.

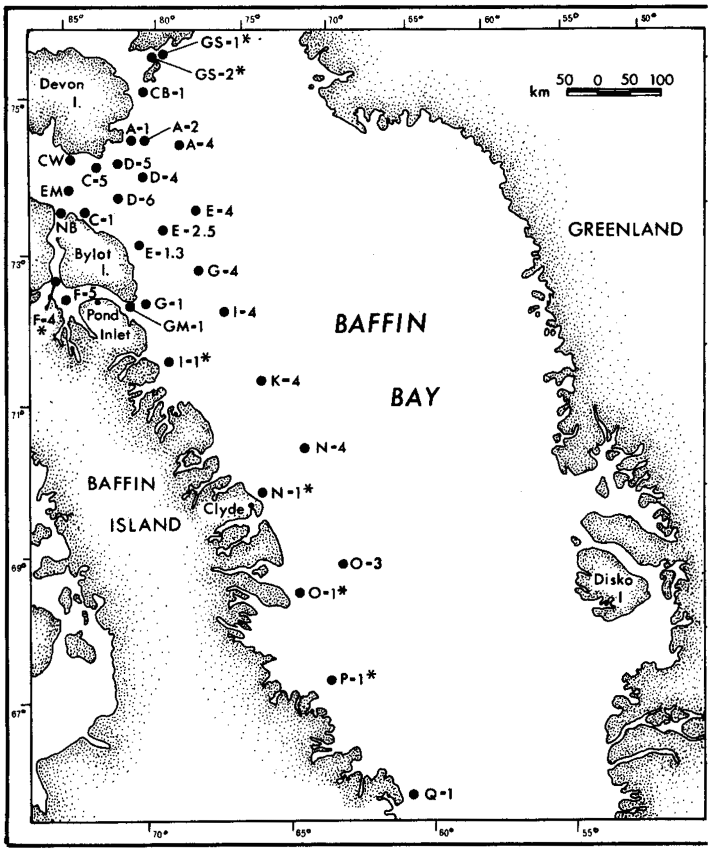

FIG. 2. Ichthyoplankton sampling locations in eastern Lancaster Sound and western Baffin Bay, 23 July to 10 October 1978. Normal sampling consisted of horizontal Miller tows at 0, 10, 17, 34, 102 and 170 m depths. Stations where only 0 and 10 m depths were sampled are indicated by asterisks.

used and volume filtered was calculated using mouth area of sampler (0.01 m^2) and the duration and speed of tow.

The full complement of samples was not obtained at all stations and depths in 1978 (0 m, n = 51; 10 m, n = 40; 17 m, n = 40; 34 m, n = 40; 102 m, n = 40; 170 m, n = 37). When fewer than five of the six normal sampling depths were sampled at any time or station, the data were excluded. Three replicate samples were obtained from each normal sampling depth at stations D-5 and A-2 on 22 and 25 August, respectively. Other samples were not replicated.

In 1978, ichthyoplankton were also sometimes captured during zooplankton sampling with vertically towed nets (see Buchanan and Sekerak, 1982). Ichthyoplankton data from these samples are used qualitatively when appropriate.

Processing and Identification

All samples were preserved in 10% buffered formalin. Storage time varied from 1 to 4 mo before ichthyoplankton were identified, enumerated, measured (total length to nearest mm) and weighed (± 1 mg). Den Beste and McCart (1978) reported a 5-6% shrinkage in the total length of Y-O-Y cod (n = 10) after 20 days; hence lengths presented here are underestimates.

At present, identification of northern cods, especially young specimens, is difficult because of lack of published information, absence of collections from many arctic regions, and variability in characteristics of specimens that are available. Representative specimens of Y-O-Y cod from Lancaster Sound — Baffin Bay (this study) and the Beaufort Sea (LGL Ltd., in prep.) were examined by J. Richard Dunn (National Marine Fisheries, Seattle, WA, pers. comm.). Although specimens from the Beaufort Sea were identified as *B. saida*, specific identification of the specimens from the present study area was not possible because of slight differences in their morphology. The collection contained very small numbers (<1%) of *Arctogadus* but was dominated by *Boreogadus*. Present knowledge suggests that *B. saida* is the only abundant cod in most regions of the North American High Arctic that have been studied; hence the dominance of a different species in ichthyoplankton collections is improbable. Nevertheless, the Y-O-Y cod collected from Baffin Bay and Lancaster Sound are hereafter referred to as *Boreogadus* (with the knowledge that the collection also contained small numbers of *Arctogadus*).

Evaluation of Methodology

Miller (1961) reported that differences between measured and theoretical filtration rates were negligible with Miller samplers. However, the above sampling method did introduce errors through contamination and underestimation of volume filtered. Filtration probably was minimal while lowering the samplers, because setting speed was similar to ship speed. Upon retrieval the samplers were towed from their sampling depths diagonally to the surface. The volume of water filtered during this passage

TABLE 1. Estimated volume (m^3) of water filtered by Miller samplers between nominal sampling depths and surface, and its contribution to total volume filtered

Sampling depth	Extra distance travelled (m)	Estimated volume filtered above nominal sampling depth	Estimated total volume filtered	% of total volume filtered above nominal sampling depth
0	0	0	18.50	0
10	58	0.58	19.08	3.1
17	97	0.97	19.47	5.2
34	194	1.94	20.44	10.5
102	580	5.80	24.30	31.4
170	966	9.66	28.16	52.2

was estimated from the lengths of wire deployed. The estimated volume of water filtered above nominal sampling depths is small for shallow water tows but significant at 100 m depths (Table 1). All ichthyoplankton densities were calculated using the estimated total volumes filtered shown in Table 1. Contamination is discussed below.

Emphasis during both the 1976 and 1978 studies was on wide geographic coverage and few replicate samples were taken. Direct comparisons between years are confounded by some differences in sampling gear and depths sampled; also, the study areas overlapped only slightly. A few of the data allow comparisons of the efficiency of horizontally towed Miller samplers and 0.5 m diameter plankton nets in capturing Y-O-Y cod. In 1978, replicate samples were collected with the two samplers at two stations; Miller samplers yielded significantly higher density estimates (Mann-Whitney U = 0; n = 6, 6; P = 0.002) than did plankton nets. Lengths of cod caught in the two samplers were similar (t = 1.71, df = 30, P>0.05) but the sample sizes were small. In 1976, paired Miller and plankton net samples were taken at 10 m depth at some stations. Miller samplers produced higher density estimates (Wilcoxon matched-pairs test, t = 39, n = 18, P<0.05). Analysis of covariance showed no significant difference in lengths of cod caught in the two samples in 1976 (P>>0.1), but the slope of the length *vs.* date relationship was significantly higher for cod from the Miller samples (P = 0.04). Thus, the few data available suggest that more, but not larger, Y-O-Y cod are caught by Miller samplers than by 0.5 m diameter plankton nets.

RESULTS AND DISCUSSION

Ichthyoplankton in Lancaster Sound and western Baffin Bay was dominated by cod in both 1976 (86% of total catch) and 1978 (87%). Seasnails (Cyclopteridae) accounted for most of the remaining catch in both years while sculpins (Cottidae) and alligator fish (Agonidae) were rare. Similarly, in the western Canadian Arctic, Hunter (1979) reported that arctic cod was the most abundant species captured in Amundsen Gulf in 1973 (90% of total catch) and in Mackenzie Bay in 1975 (73%). Arctic cod were proportionately less abundant in Mackenzie Bay in 1974 (7%) and in Amundsen Gulf in 1977 (24%), possibly because of the presence of large amounts of brackish water and the few samples taken. Arctic cod accounted for 76% of the ichthyoplankton taken from the Labrador Sea in 1979 (Buchanan and Foy, 1980). Similarly high contributions have been recorded in most North American arctic areas that have been studied (eastern Chukchi Sea, Quast, 1974; Wellington Channel and Resolute Passage, Bain *et al.*, 1977; Brentford Bay, Boothia Peninsula, Thomson *et al.*, 1978).

Time of Year

When depth-weighted data from all stations are considered, the apparent densities of Y-O-Y cod decreased markedly from midsummer to autumn in both 1976 and 1978 (Fig. 3). In 1976, the Spearman rank correlation between densities at 10 m depth and date was -0.50 (df = 28, $P<0.005$). In 1978, the correlation was -0.47 (df = 32, $P<0.005$). Although few stations were sampled repeatedly in 1978, the decrease in catch as the season progressed was probably not attributable to any confounding geographic effect; only 39% of the total sampling effort was expended from 23 July to 19 August, but this effort yielded 80% of the total catch. In 1976, the same stations were sampled repeatedly over time, and geographic area was largely eliminated as a variable.

The apparent decrease in cod densities over time may be due, in part, to (1) natural mortality and (2) increased efficiency in net avoidance as the fish become larger and more active. Both factors should act in a progressive nature, and do not explain the rather sudden decrease in densities of planktonic cod after mid-August. In late summer and fall, Y-O-Y cod probably begin to cease their planktonic existence and seek substrates, inshore or shelf waters, or perhaps deeper waters; my data are insufficient to clarify this matter. However, off Newfoundland and Labrador, acoustic surveys and trawl catches in October 1978 documented that many arctic cod (often 10-20 cod/m^2) occur at 100-200 m (Miller, 1979). Apart from a few large specimens, these concentrations were composed of Y-O-Y specimens (total lengths 35-64 mm, mode = 45-49 mm). These lengths are close to those given by Rass (1968) for the point at which the young change from the postlarval to the juvenile (fry) stage; the latter are capable of active swimming and are no longer strictly planktonic. Thus, both schooling and descent into deeper waters may occur in late summer and fall.

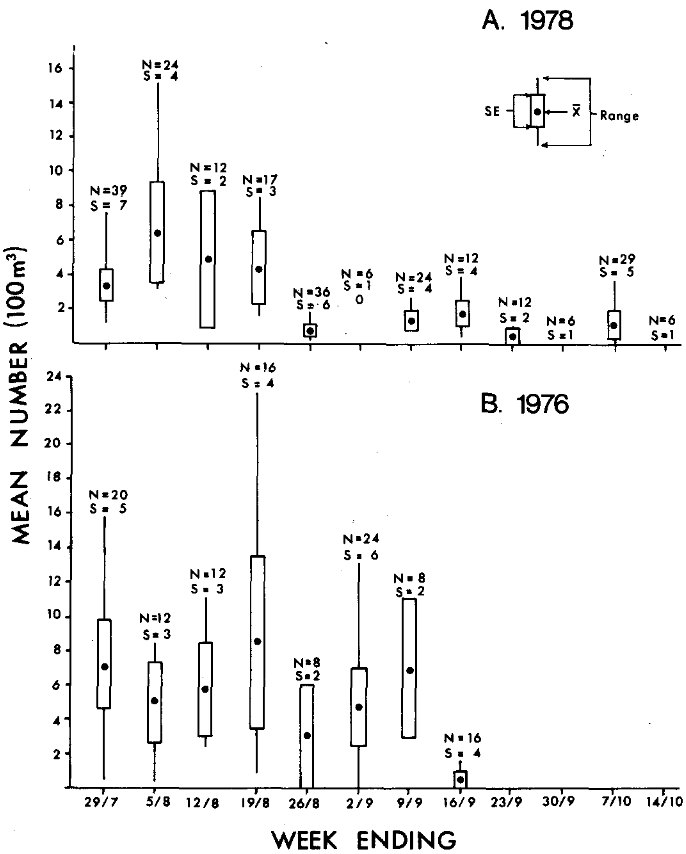

FIG. 3. Depth-weighted mean density (no. 100 m^{-3}) of Y-O-Y cod in (A) the upper 170 m of water in eastern Lancaster Sound and western Baffin Bay during 1978, and (B) the upper 150 m of water in Lancaster Sound during 1976. N = no. of samples, S = no. of stations.

Comparisons Between Years

Direct comparison of densities of Y-O-Y cod during 1976 and 1978 in the Lancaster Sound-western Baffin Bay area is difficult (see Methods) but if uncontrolled variables are ignored, general sampling suggests that Y-O-Y were slightly more abundant in Lancaster Sound in 1976 than in eastern Lancaster Sound-western Baffin Bay in 1978 (Fig. 3). The lower density estimates in 1978 were derived from Miller samplers; the somewhat higher estimates in 1976 were from plankton nets, which are presumably less efficient (see Methods). This suggests that more Y-O-Y cod were present in the general region in 1976 than in 1978. However, daily depth-weighted mean densities did not

TABLE 2. Density (no·100 m^{-3}) of Y-O-Y cod collected with Miller samplers at a depth of 10 m in 1976 and 1978

Week ending	Density 1976	Density 1978
29 Jul	34.0	14.0
5 Aug	70.8	65.6
12 Aug	12.2	62.8
19 Aug	34.0	57.6
26 Aug	13.1	10.5
2 Sep	3.9	0
9 Sep	0	8.7
16 Sep	3.5	5.8
Overall mean	21.44	28.00
SD	23.89	28.23

TABLE 3. Mean density (no·100 m^{-3}) of Y-O-Y cod in relation to depth

Lancaster Sound - 1976					E Lancaster Sound, W Baffin Bay - 1978				
	No. samples		Density[a]			No. samples		Density[b]	
Depth (m)	Taken	With cod	Mean	SD	Depth (m)	Taken	With cod	Mean	SD
0	30	6	0.73	3.10	0	40	2	3.11	14.37
10	30	16	10.40	22.46	10	38	21	19.84	31.30
50	30	21	6.40	6.96	17	40	19	7.44	11.67
150	30	10	1.22	3.08	34	40	8	1.72	3.77
					102	40	4	0.72	2.78
					170	37	3	0.38	1.39

[a] 1976 data are from horizontal tows with a 0.5 m zooplankton net. Friedman test comparing densities at different depths gave $\chi_r^2 = 18.39$, df = 3, $P<0.001$. The density at 10 m was significantly higher than that at 0 m, and the density at 50 m was significantly higher than densities at 0 and 150 m ($P<0.05$ in each case; multiple comparisons based on Friedman rank sums [Hollander and Wolfe, 1973]).
[b] 1978 data are from Miller samplers. Friedman $\chi_r^2 = 26.9$, df = 5, $P<0.001$. The density at 10 m was significantly higher ($P<0.05$) than densities at 0, 34, 102 and 170 m (multiple comparison procedure). Densities at deeper depths are probably overestimated in 1978 (see text).

differ significantly between years either up to 19 August (6.77 ± SD 6.20 cod·100 m^{-3} in 1976 *vs*. 4.66 ± 4.07 in 1978; Mann-Whitney $U = 78$; $n = 15, 13$; $P>0.1$) or after 19 August (3.76 ± 4.44 in 1976 *vs*. 2.65 ± 3.28 in 1978; $U = 45$; $n = 12, 8$; $P>0.1$). Also, a small set of better-standardized data (obtained with Miller samplers at 10 m depth in both years, and matched by date) shows no significant differences between years (Table 2).

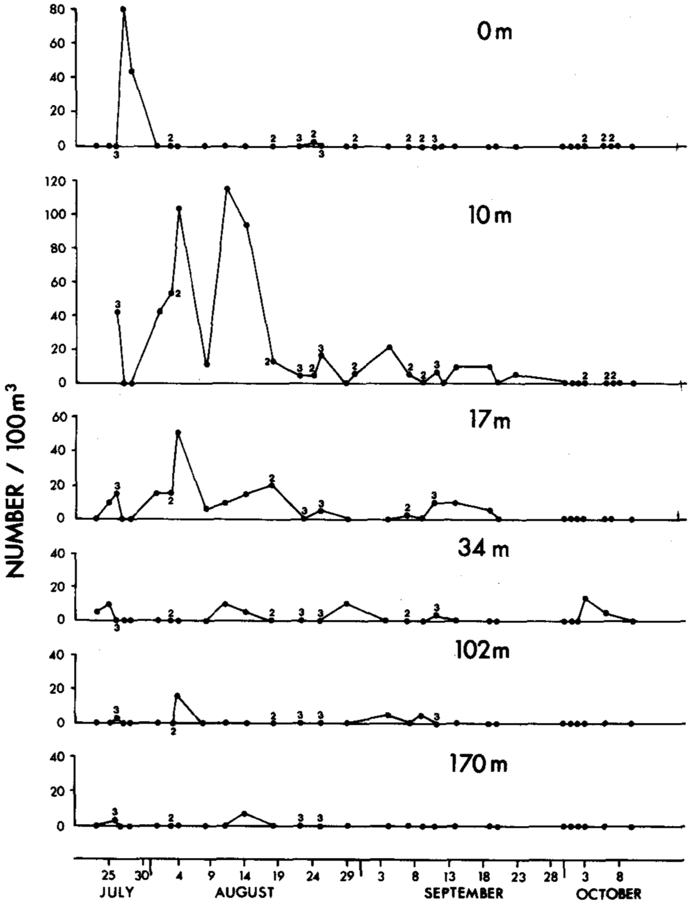

FIG. 4. Depth distribution of Y-O-Y cod in relation to date, 1978. Each point represents a single sample, except where otherwise indicated.

Depth

Based on data from all stations, densities of Y-O-Y cod differed significantly among the depths sampled (Friedman tests, $P<0.0001$ in both 1976 and 1978). In 1978, significantly ($P<0.05$) higher densities were apparent from Miller samples taken at 10 m than from those at 0, 34, 102 and 170 m (Table 3, Fig. 4). In 1976, horizontal plankton tows showed that the mean density was again highest at a depth of 10 m; multiple comparisons showed significant differences between densities at 10 *vs*. 0 m, 50 *vs*. 0 m, and 50 *vs*. 150 m ($P<0.05$ in each case).

Miller samples taken in 1978 at depths other than 0 m probably were contaminated as they were raised through water above their designated sampling depth (Table 1). Despite this, the 1978 data (as well as the 1976 data, which came from closing nets) show that density decreased with depth below about 10 m. Because abundance decreased with increasing depth, the contamination in 1978 would have caused overestimates of cod in deeper waters. Thus the pronounced decrease in densities below 10 m depths is real. If contamination had been avoided in 1978, even larger differences might have been evident.

TABLE 4. Number of Y-O-Y cod collected at various depth intervals with 0.5 m diameter vertically-towed plankton nets in 1978

	Depth (m)				
	50 to 0	150 to 50	250 to 150	1200 or bottom to 250	Bottom to 1200 (depth permitting)
No. of Y-O-Y arctic cod	18	0	1	0	0
No. of samples	43	42	42	39	1
Cod/sample	0.42	0.00	0.02	0.00	0.00

Data from vertical tows with 0.5 m diameter plankton nets in 1978 also indicate that Y-O-Y cod were most common in shallow water (Table 4). These are apparently the first data concerning distribution of Y-O-Y cod throughout an entire water column of considerable depth. Clearly, Y-O-Y cod are surface dwellers and are not normally found below depths of ~250 m.

Hunter (1979) also found Y-O-Y cod to be concentrated in the upper waters of the southeast Beaufort Sea. He suggested that the depth-density relationship for Y-O-Y arctic cod can be approximated by

$$\text{density} = a + b \ln(\text{depth}).$$

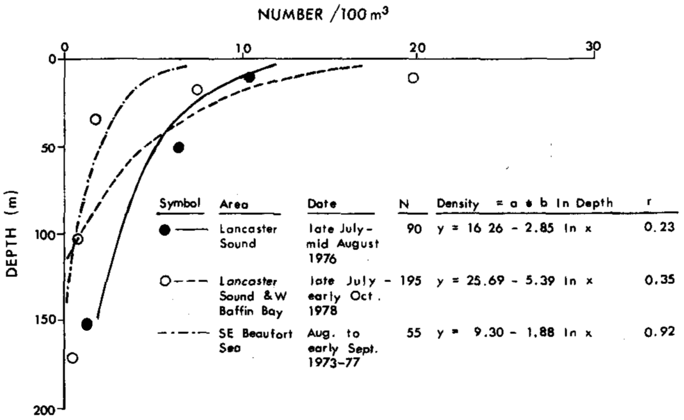

FIG. 5. Depth-density relationships for Y-O-Y cod. Closed and open circles represent observed mean densities. Beaufort Sea data are from Hunter (1979); his high correlation coefficient suggests that his curve and coefficient were calculated from mean values, not from his N = 55 original density estimates.

Figure 5 shows his curve plus similar curves for my data. It should be noted that these general relationships apply to only a small portion of the year (July to perhaps October). Also, the high correlation coefficient of Hunter (1979) suggests that his curve and coefficient were calculated from mean values. Furthermore, even during those months, densities are subject to annual and regional differences.

Description of the "normal" depth distribution of Y-O-Y cod is confounded by radical variations in some circumstances. For example, uncommonly high densities of up to 80 Y-O-Y·m^{-3} were encountered at the immediate surface at stations D-4 and EM on 27 and 28 July in 1978 (Fig. 4); no cod were captured at any other depth sampled at these two stations. Similarly, Den Beste and McCart (1979) reported high densities (61 and 93 arctic cod·100 m^{-3}) at depths 1-2 m in Nachvak Fiord, Labrador, in July and August 1978; no samples were taken in deeper waters. These figures are dwarfed by results from Thomson *et al.* (1978) in Brentford Bay, Boothia Peninsula, where limited sampling (n = 3 Miller samples) at the immediate surface on 30 August and 1 September 1977 yielded 220-610 Y-O-Y·100 m^{-3}. On that occasion, sampling was initiated because Y-O-Y were seen at the immediate surface. The wakes of small loosely aggregated schools were plainly visible and several hundred Y-O-Y were collected by dip net. One sample at a depth of 10 m yielded a density estimate of only 30 Y-O-Y·100 m^{-3}, suggesting that the Y-O-Y were indeed concentrated at the immediate surface. The weather in Brentford Bay at the time was unusually warm (surface water temperature 3.3°C), sunny and windless. Surface water temperature at D-4 in 1978 was also warm (2.3°C), but equally warm temperatures were observed at other stations where surface concentrations of cod did not occur. Other factors, including sea state and light, may interact and promote concentration of Y-O-Y cod in surface waters. Quast (1974) hypothesized a negative phototaxic response for Y-O-Y cod. My results suggest that, if such a response is present, it apparently can be reversed by unusual circumstances.

In summary, during mid- to late summer Y-O-Y cod are normally concentrated somewhere between 0 and 17 m in the water column. Highest mean catch rates have been at 10 m, but concentrations can occur at other depths, including the surface. Off Labrador, concentrations of Y-O-Y have been found at 100-200 m in the fall (Miller, 1979).

Geographic Area

As previously explained, only broad comparisons of densities of Y-O-Y cod within different regions of the 1978 study area can be made due to lack of sample replication. Densities did not differ significantly among (1) offshore waters of Baffin Bay, (2) waters near Bylot and Baffin islands, and (3) waters near southeast Devon Island (Kruskal-Wallis test, H = 1.21, df = 2, P>0.5). In 1976, when six stations in Lancaster Sound were each sampled on five occasions, significant among-station differences in depth-integrated densities were suggested (H = 11.52, df = 5, P<0.05) but no one station was significantly different from any other specific station according to the conservative Dunn's multiple comparison procedure (Hollander and Wolfe, 1973 — critical value for P<0.05 = 15.87; highest test statistic = 15.6).

Because cod eggs are buoyant and Y-O-Y are planktonic for several months, it can be expected that regional differences in abundance become less marked and perhaps eliminated as currents transport the young. In addition, few studies have been sufficiently intense and extensive in geographic coverage to document any regional differences in abundance that might occur. Buchanan and Foy (1980) noted large differences in densities of Y-O-Y cod in offshore *vs.* nearshore waters of the Labrador Sea (Table 5) but, due to extreme variation in numbers of cod in samples from similar stations, significant differences were evident only when densities in bays and fiords were compared with those at the farthest offshore stations. Hunter (1979) reported large differences in the densities of Y-O-Y arctic cod in different parts of the southeast Beaufort Sea; however, he suggested that the differences were probably attributable to changes in the salinity regimes in Mackenzie Bay in 1974 (very brackish) and 1975, and not to geographic area *per se*.

TABLE 5. Mean densities of Y-O-Y cod in the North American Arctic and Subarctic. All densities are means of depth-weighted averages except for Simpson Lagoon and the Labrador Sea. All samplers were towed horizontally except in the Labrador Sea

Area	Depth range sampled (m)	Collection method	No. of samples	Dates	Density (no·100^{-3})	Source
Wellington Channel, near Cornwallis I.	0 to 25	Miller samplers	72	June 1976	31.0	Bain *et al.*, 1977
Resolute Passage, near Cornwallis I.	0 to 25	Miller samplers	23	early July 1976	2.0	Bain *et al.*, 1977
Brentford Bay, Boothia Peninsula	1 to 10	Miller samplers	3	30 Aug 1977	242.5	Thomson *et al.*, 1978
Simpson Lagoon, Beaufort sea, Alaska	0	Faber net	22	July and Aug 1977	8.2	Craig and Griffiths, 1978
			45	July and Aug 1978	0.2	Craig *et al.*, 1982
			14	Sept 1977	0.92	Craig and Griffiths, 1978
			12	Sept 1978	0	Craig *et al.*, 1982
SE Beaufort Sea	0 to 180	Isaacs-Kidd mid-water trawl	55	Aug to early Sept 1973-1975, 1977	0.18	Hunter, 1979
E. Chukchi Sea, Alaska	2 to 45	Isaacs-Kidd	80	late Sept to mid-Oct 1970	2.8	Quast, 1974
Labrador Sea						
Bays and Fiords	0 to 125	Double oblique Bongo tows	153	early Aug to early Sept 1979[1]	33.93	Buchanan and Foy, 1980
2-10 km offshore	0 to 112	Double oblique Bongo tows	20	mid-July to early Sept 1979	32.89	Buchanan and Foy, 1980
25 km offshore	0 to 123	Double oblique Bongo tows	20	mid-July to early Sept 1979	14.34	Buchanan and Foy, 1980
55 km offshore	0 to 125	Double oblique Bongo tows	20	mid-July to early Sept 1979	4.20	Buchanan and Foy, 1980
90 km offshore	0 to 162	Double oblique Bongo tows	18	mid-July to early Sept 1979	3.44	Buchanan and Foy, 1980
130 km offshore	0 to 126	Double oblique Bongo tows	18	mid-July to early Sept 1979	1.45	Buchanan and Foy, 1980
Lancaster Sound	0 to 150	0.5 m plankton nets	92	late July to mid-Aug 1976	6.77	Present study
E Lancaster Sound and W Baffin Bay	0 to 170	Miller samplers	134	late July to mid-Aug 1978	4.66	Present study
Lancaster Sound	0 to 150	0.5 m plankton nets	24	mid-Aug to mid-Sept 1976	3.76	Present study
E Lancaster Sound and W Baffin Bay	0 to 170	Miller samplers	101	mid-Aug to mid-Sept 1978	2.65	Present study

Arctic cod Y-O-Y have been reported from most North American arctic areas where appropriate studies have been performed (Table 5). The variable methods, depth and dates of sampling make direct comparison between most studies impossible, but results can be compared in a general way if biases are borne in mind. (The taxonomic difficulties mentioned previously must also be considered.) The very high densities of Y-O-Y cod in the surface water of Brentford Bay are discussed above; they represent an unusual behavior pattern and are not comparable with other data sets. Y-O-Y densities in Wellington Channel are also considerably higher than those reported from other regions, but that study was conducted in June — earlier in the year than any other study in Table 5. By July and early August, natural mortality could reduce densities to the range found during this study in Lancaster Sound and western Baffin Bay (e.g., Jones and Hall [1974] estimate a general larval mortality rate of 2-10% per day for marine teleosts). Densities in nearshore waters of the Labrador Sea in mid- to late summer of 1979 appear to be especially high in comparison to other areas and those in the southeast Beaufort Sea appear to be especially low. The low densities found in Resolute Passage, adjacent to Wellington Channel, may have been due to a local disturb-

Table 6. Linear regression of total length of Y-O-Y cod (mm) on day of the year for several collections from the North American Arctic

Area	Range of collection dates	Regression line	Correlation r	n	P
Wellington Channel (Bain *et al.*, 1977)	13 June-5 July 1976	y=0.143x-15.1	0.273	14.1	<0.005
Simpson Lagoon, Beaufort Sea, Alaska (from data in Craig and Griffiths, 1978)	21 July-29 Sept 1977	y=0.173x-24.6	0.624	80	<0.001
Labrador Sea (Buchanan and Foy, 1980)	16 July-12 Sept 1979	y=0.23x-30.27	0.449	8250	<0.001
Amundsen Gulf, SE Beaufort Sea (Hunter, 1979)	6 Aug-12 Sept 1979	y=0.60x-118.5*		not given	
Lancaster Sound (present study)	22 July-13 Sept 1976	y=0.304x-49.51	0.858	407	<0.001
E Lancaster Sound-W Baffin Bay (present study)	23 July-6 Oct 1978	y=0.248x-41.16	0.769	184	<0.001
E Lancaster Sound and nearshore Bylot Island (present study)	23 July-6 Oct 1978	y=0.267x44.46	0.782	52	<0.001
W Baffin Bay (present study)	23 July-6 Oct 1978	y=0.293x-51.42	0.818	124	<0.001

*Estimated from Fig. 2 in Hunter (1979).

ance in the water column; sampling probably took place during a period of strong wind-induced upwelling (Bain *et al.*, 1977), and the shallow waters sampled probably had recently upwelled from deeper areas where Y-O-Y are scarce. The most pertinent conclusion that can be drawn from Table 5 is that Y-O-Y cod are widely distributed in North American arctic waters, where they are normally a dominant component of the ichthyoplankton.

Size Distribution

The length-frequency distributions of Y-O-Y cod captured in Lancaster Sound-western Baffin Bay in 1976 and 1978 were similar in that modal length was 11-13 mm in each collection (Fig. 6). The greater frequency of larger Y-O-Y (34-42 mm) in 1978 is to be expected, because sampling in 1978 continued later into the fall.

The generalized length-frequency distributions shown in Fig. 6 do not represent the range of sizes present at any one time. Growth of Y-O-Y cod is rapid during summer (see below), and in 1976 the 11-13 mm size class dominated only in late July and early August (Fig. 7). The presence of 11-13 mm cod in large numbers for a relatively brief part of the study period was the dominant factor determining the generalized length-frequency distribution. Most of the larger specimens (>20 mm) obtained in 1976 and 1978 were collected after early August.

In 1976, the distribution of sizes in the collection obtained by Miller samplers appears more normal than that in the collection obtained by 0.5 m diameter plankton nets (Fig. 6). However, the sizes of Y-O-Y cod collected by the two samplers were not significantly different (see Methods).

Reported modal sizes of Y-O-Y cod from the Beaufort Sea are substantially larger than those from Lancaster Sound-western Baffin Bay and the Labrador Sea (Fig. 6), but the differences are at least partly due to date of collection. For example >70% of those collected from Amundsen Gulf in 1973 were obtained from 31 August to 9 September; hence a comparatively large modal size is to be expected (cf. Fig. 7). In addition, an Isaacs-Kidd trawl, which could be more efficient in capturing large Y-O-Y cod, was used in the Beaufort Sea.

Even larger Y-O-Y cod have been reported, primarily from fall or early winter collections. Miller (1979) found many Y-O-Y cod of lengths 35-64 mm (mode 45-49 mm) in October off southern Labrador and northern Newfoundland. Quast (1964) reported a modal size of 44 mm in the eastern Chukchi Sea from late September to mid-October.

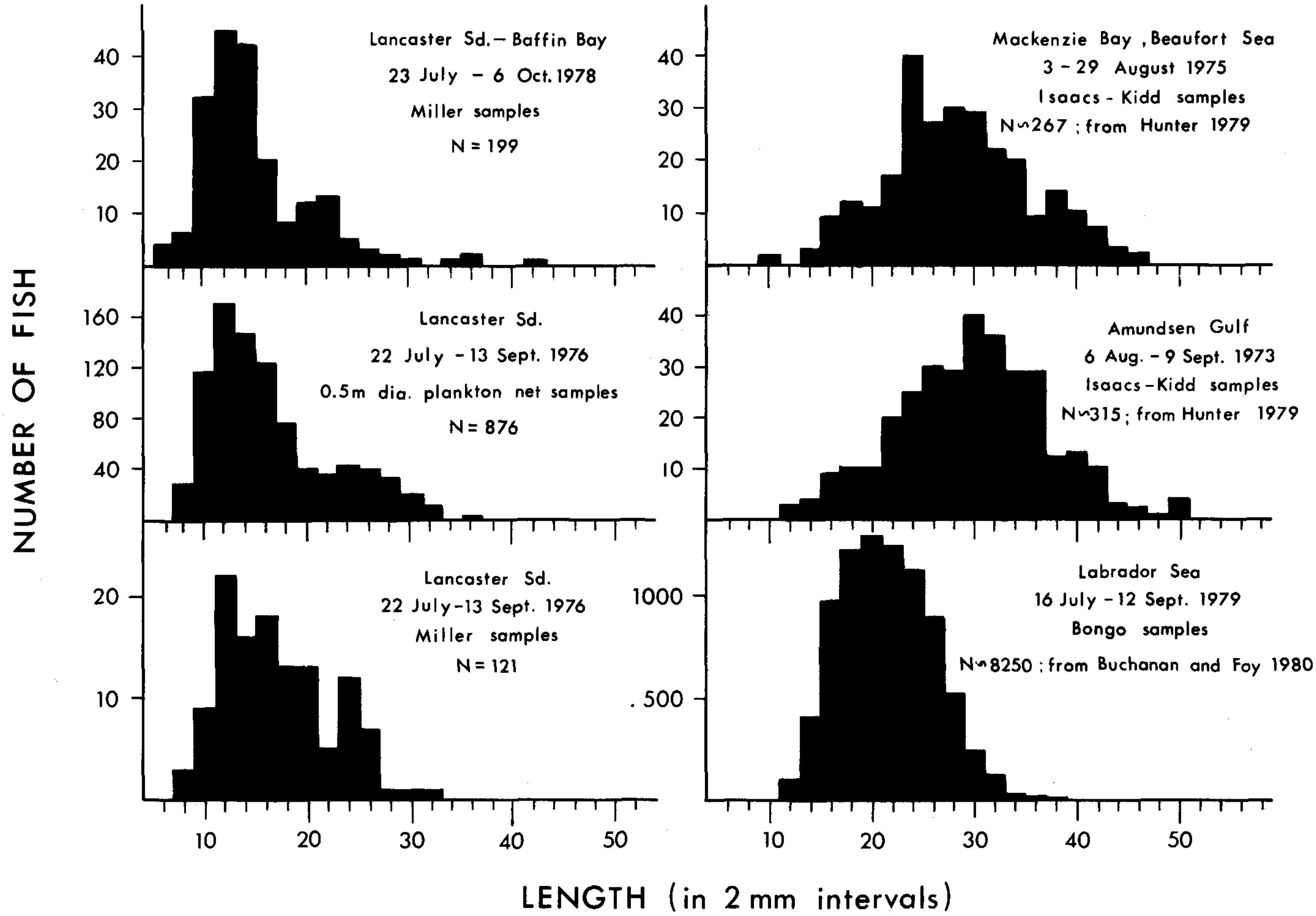

FIG. 6. Length-frequency distributions of Y-O-Y arctic cod and cod from various North American arctic and subarctic areas. Present data based only on undamaged specimens.

Craig *et al.* (1982) commented on the unusually large size (52-60 mm) of three Y-O-Y caught in November in the Alaskan Beaufort Sea, and Hunter (1979) captured small numbers of slightly shorter specimens in August or early September in Amundsen Gulf.

Comparisons of the size frequency distributions of Y-O-Y cod in different areas are confounded by (1) their relatively fast growth rate, (2) different study periods, (3) unequal sampling (and catches) through the various study periods, and (4) differences in sampling depths, techniques and equipment. Item (4) is likely the most critical since it negates the validity of most comparisons even when other factors can be controlled.

Growth

First and last captures of Y-O-Y cod in 1978 occurred on 23 July and 6 October. Based on a linear regression equation for length *vs.* day (Fig. 8), mean total length increased from 9 to 28 mm during this 76-d period. Growth during this period was probably not uniform and the scatter of points in Figure 8 suggests faster growth in late summer. This was also suggested, but not conclusively proved, by Baranenkova *et al.* (1966) and Buchanan and Foy (1980). However, linear expressions best fit the data at hand, perhaps due to the paucity of specimens from September and October.

Linear regression equations for length *vs.* day of capture for other collections suggest that growth of Y-O-Y cod varies considerably among areas, and also varies in similar areas in different years (Table 6, Fig. 9). Y-O-Y were significantly longer at a given date in Lancaster Sound in 1976 than in eastern Lancaster Sound-western Baffin Bay in 1978 (ANACOVA: df = 1, 588; F = 55.12; P<0.001). This comparison may be biased by the different types of sampling gear used in 1976 and 1978, but previous analyses suggest that total lengths of Y-O-Y from Miller samplers and plankton nets did not differ significantly.

The greater lengths found in 1976 compared with 1978 appeared to be a year (or, less likely, gear) effect rather than an area effect. The 1978 samples were separated into two groups — those taken within Lancaster Sound and near the coast of Bylot Island (stations NB, CW, EM, C-1,

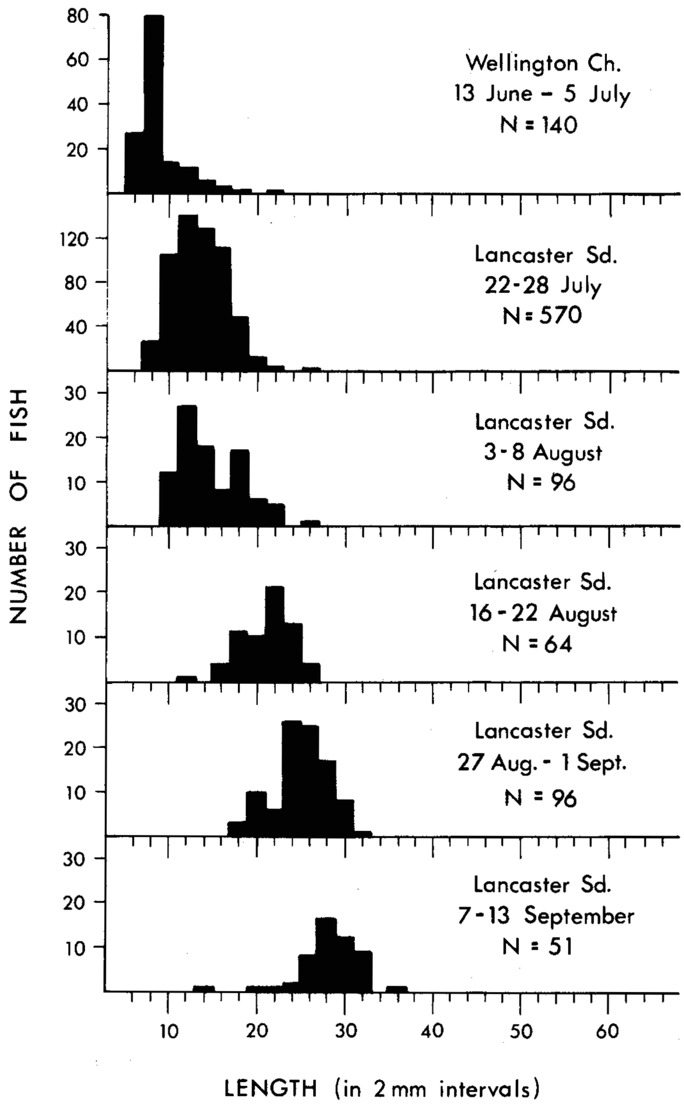

FIG. 7. Length-frequency distributions of Y-O-Y cod collected from Wellington Channel and Lancaster Sound during various date ranges in 1976. Wellington Channel data are from Bain *et al.* (1977).

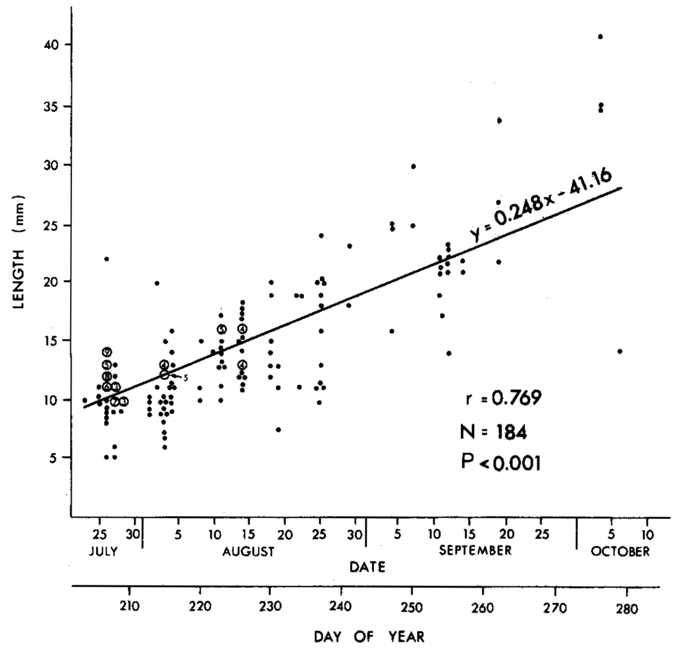

FIG. 8. Date-length relationship for Y-O-Y cod in eastern Lancaster Sound and western Baffin Bay, 1978. Dots represent single fish unless otherwise indicated.

C-5, E1.3, G-1) and those from the remainder of western Baffin Bay (see Fig. 2). Samples from Eclipse Sound and Pond Inlet were not included in either group. Total lengths of Y-O-Y in the two areas were very similar (ANACOVA; df = 1, 170; F = 0.11; P>0.75; Table 6). There is, therefore, no evidence that geographic variations within the 1978 study area affected the 1976 *vs.* 1978 comparison; conversely there is strong evidence that Y-O-Y cod were larger in Lancaster Sound in 1976 than in 1978 (ANACOVA; df = 1, 352; F = 271.6; P<0.001). Ice breakup in 1978 was much later than in 1976, and pan ice was more or less constantly present in 1978 (McLaren, 1982). There are also indications that zooplankton and to a lesser extent phytoplankton were less abundant in 1978 (Sekerak *et al.*, 1979). However, a much more exhaustive study is necessary to elucidate relationships among the physical environment, lower trophic levels and growth of Y-O-Y cod.

The unusually rapid growth of Y-O-Y in Amundsen Gulf (Hunter, 1979) remains unexplained. It may be an artifact of the short sampling period in Hunter's study. In the case of the Lancaster Sound-western Baffin Bay data, when linear regressions are calculated for short time steps (Fig. 10), the apparent growth rate of Y-O-Y increases substantially in late summer and approaches the rate described by Hunter (1979) for a similar period. Differences in sampling gear must also be borne in mind. The Isaacs-Kidd trawl used in the Beaufort Sea could be more efficient in capturing Y-O-Y, especially larger specimens. If so, small Y-O-Y would have been over-sampled in this study, with corresponding underestimation of growth rate.

Present data combined with those obtained nearby by Bradstreet (1982) indicate that growth of Y-O-Y cod continues during winter, but at a slower rate. The mean fork length of 1+ year-old arctic cod captured by Bradstreet during June 1979 near the Pond Inlet ice edge was in the 59-61 mm category. Lengths of Y-O-Y cod increased roughly 0.25 mm$\cdot$d^{-1} during the summer of 1978 (Fig. 8). If growth continued at this rate from mid-October to June (about 229 days), 1+ year-old cod would theoretically be ~87 mm long in June. Crude approximation suggests that the mean winter growth in length may be about 65% of that during summer. Moskalenko (1964) also reported that growth of Y-O-Y arctic cod continues during winter.

CONCLUDING REMARKS

Growth of Y-O-Y cod has been shown to vary annually and probably also geographically. Annual and geographic variations in the abundance of Y-O-Y cod are probable but

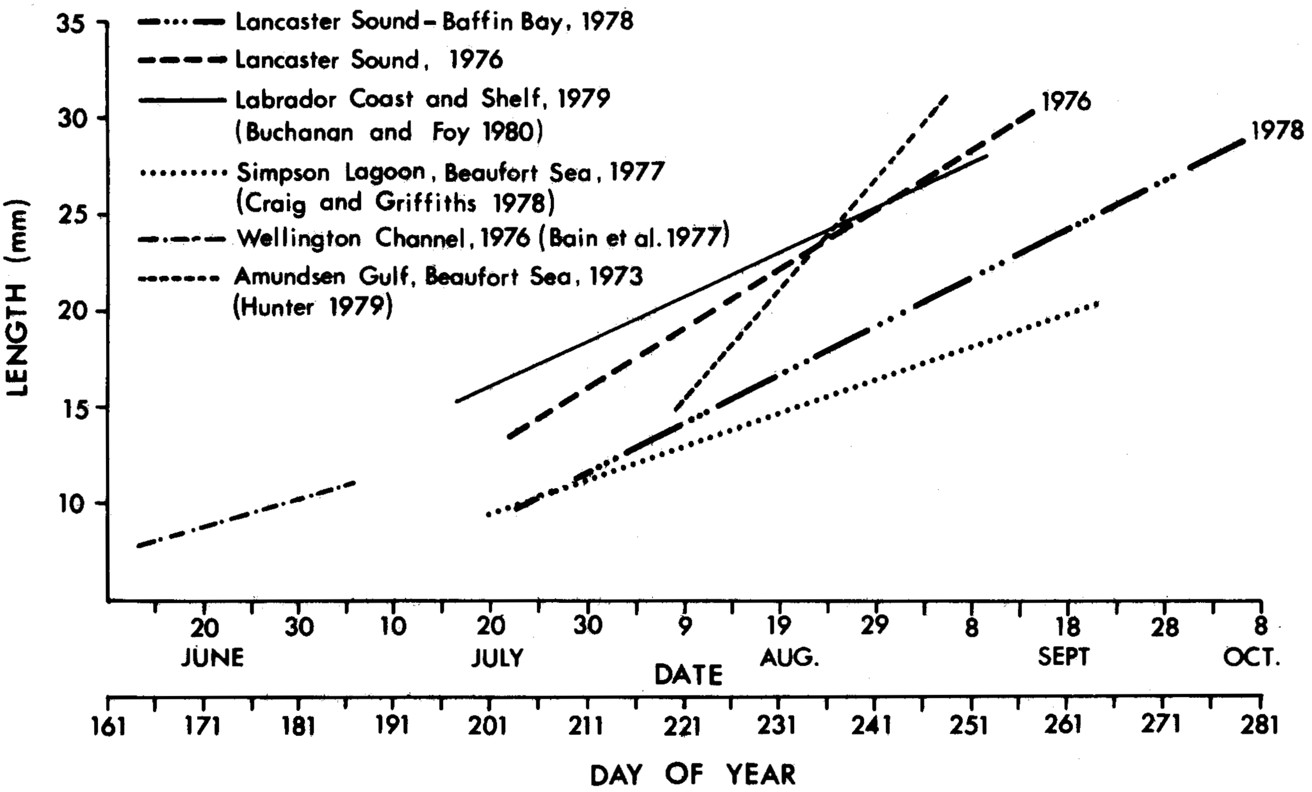

FIG. 9. Growth of Y-O-Y arctic cod and cod from various arctic and subarctic locations.

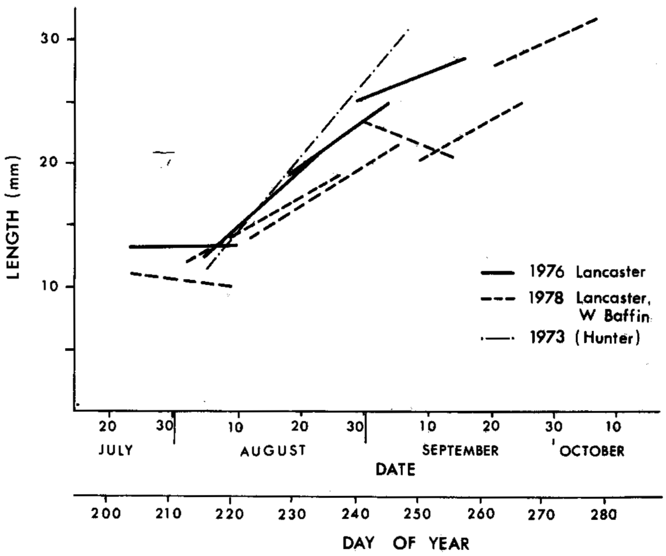

FIG. 10. Apparent growth of Y-O-Y cod in short time stages.

poorly documented. In spring and for most of the summer Y-O-Y are planktonic and are found primarily in surface waters. The planktonic Y-O-Y become highly dispersed; they presumably can be transported considerable distances from the spawning areas. In the present study area transport would be predominantly southward (Fissel *et al.*, 1982). Information presented by Miller (1979) suggests that juvenile arctic cod descend to deeper water and perhaps school in late summer and fall. Slow northward migrations of immature Atlantic cod (*Gadus morhua*) to their spawning areas off Labrador and Newfoundland have been reported (May, 1966; Bulatova, 1971). Arctic cod could utilize a similar mechanism to maintain populations in suitable northern areas.

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REFERENCES

ANDRIASHEV, A.P. 1964. Fishes of the northern seas of the U.S.S.R. Israel Program for Scientific Translations, Jerusalem.

ARONOVICH, T.M., DOROSHEV, S.I., SPECTOROVA, L.V. and MAKHOTIN, V.M. 1975. Egg incubation and larval rearing of navaga (*Eleginus navaga* Pall.), polar cod (*Boreogadus saida* Lepechin) and arctic flounder (*Liopsetta glacialis* Pall.) in the laboratory. Aquaculture 6:233-242.

BAIN, H. and SEKERAK, A.D. 1978. Aspects of the biology of arctic cod, *Boreogadus saida*, in the central Canadian Arctic. Unpubl. Rep. by LGL Ltd., Toronto, for Polar Gas Project, Toronto. 104 p. [Available in Library, Arctic Institute of North America, University of Calgary, Calgary, Alberta T2N 1N4.]

BAIN, H., THOMSON, D., FOY, M. and GRIFFITHS, W. 1977. Marine ecology of fast-ice-edges in Wellington Channel and Resolute Passage, N.W.T. Unpubl. Rep. by LGL Ltd., Toronto, for Polar Gas Project, Toronto. 262 p. [Available in Library, Arctic Institute of North America, University of Calgary, Calgary, Alberta T2N 1N4.]

BARANENKOVA, A.S., PONOMARENKO, V.P. and KHOKHLINA, N.S. 1966. The distribution, size and growth of the larvae and fry of *Boreogadus saida* (Lep.) in the Barents Sea. Fisheries and Marine Service Translation Series No. 4025 (1977). 37 p.

BOHN, A. and McELROY, R.O. 1976. Trace metals (As, Cd, Cu, Fe and Zn) in the arctic cod, *Boreogadus saida*, and selected zooplankton from Strathcona Sound, northern Baffin Island. Journal of the Fisheries Research Board of Canada 33:2836-2840.

BRADSTREET, M.S.W. 1976. Summer feeding ecology of seabirds in eastern Lancaster Sound, 1976. Unpubl. Rep. by LGL Ltd., Toronto, for Norlands Petroleums Ltd., Calgary. 187 p. [Available in Library, Arctic Institute of North America, University of Calgary, Calgary, Alberta T2N 1N4.]

———. 1977. Feeding ecology of seabirds along fast-ice-edges in Wellington Channel and Resolute Passage, N.W.T. Unpubl. Rep. by LGL Lt., Toronto, for Polar Gas Project, Toronto. 149 p. [Available in Library, Arctic Institute of North America, University of Calgary, Calgary, Alberta T2N 1N4.]

———. 1979. Feeding ecology of seabirds in northwest Baffin Bay, 1978. Unpubl. Rep. by LGL Ltd., Toronto, for Petro-Canada, Calgary. 65 p. [Available from Pallister Resource Management Ltd., 3rd floor, 700-6 Ave. S.W., Calgary, Alberta T2P 0T8.]

———. 1980. Thick-billed murres and black guillemots in the Barrow Strait area, N.W.T., during spring: diets and food availability along ice edges. Canadian Journal of Zoology 58:2120-2140.

———. 1982. Occurrence, habitat use, and behavior of seabirds, marine mammals, and arctic cod at the Pond Inlet ice edge. Arctic 35(this issue).

——— and CROSS, W.E. 1982. Trophic relationships at high arctic ice edges. Arctic 35 (this issue).

BUCHANAN, R.A., CROSS, W.E. and THOMSON, D.H. 1977. Survey of the marine environment of Bridport Inlet. Melville Island. Unpubl. Rep. by LGL Ltd., Toronto, for Petro-Canada, Calgary. 265 p. [Available in Library, Arctic Institute of North America, University of Calgary, Calgary, Alberta T2N 1N4.]

BUCHANAN, R.A. and SEKERAK, A.D. 1982. Vertical distribution of zooplankton in eastern Lancaster Sound and western Baffin Bay, July-October 1978. Arctic 35 (this issue).

BUCHANAN, R.A. and FOY, M.G. 1980. Offshore Labrador biological studies 1979: plankton. Unpubl. Rep. by Atlantic Biological Services Ltd., St. John's, for Total Eastcan Explorations Ltd., Calgary. 293 p. [Available in Library, Arctic Institute of North America, University of Calgary, Calgary, Alberta T2N 1N4.]

BULATOVA, A.Y. 1971. Estimation of young cod in the Labrador and Newfoundland areas in 1961-1967. Fisheries Research Board of Canada Translation Series 1917. 26 p. (Trudy PINRO No. 23, 1968, p. 262-278).

CRAIG, P.C. and GRIFFITHS, W. 1978. Beaufort Sea barrier island — lagoon ecological process studies. III. Ecology of fishes in Simpson Lagoon, 1977. In: Environmental Assessment of the Alaskan Continental Shelf. Annual Report of the Principal Investigators. Vol. 7. National Oceanic and Atmospheric Admin., Boulder, CO. 587-664.

CRAIG, P.C., GRIFFITHS, W., HALDORSON, L. and McELDERRY, H. 1982 (in press). Ecological studies of arctic cod (*Boreogadus saida*) in Beaufort Sea coastal waters, Alaska. Canadian Journal of Fisheries and Aquatic Sciences.

CRAIG, P.C. and HALDORSON, L. 1981. Beaufort Sea barrier island-lagoon ecological process studies. Final report, Simpson Lagoon. Part 4. Fish. In: Environmental Assessment of the Alaskan Continental Shelf. Final Report of the Principal Investigators. Vol. 7. National Oceanic and Atmospheric Admin., Boulder, CO. 384-678.

DAVIS, R.A., FINLEY, K.J. and RICHARDSON, W.J. 1980. The present status and future management of arctic marine mammals in Canada. Science Advisory Board of the Northwest Territories. Report No. 3. Dept. of Information, Government of the N.W.T. 93 p.

DEN BESTE, J. and McCART, P.J. 1978. Nearshore marine fisheries investigations in coastal areas of southeast Baffin Island. Unpubl. Rep. by Aquatic Environments Ltd. for Esso Resources Canada Ltd., Aquitaine Co. of Canada Ltd. and Canada-Cities Serv. Ltd. 154 p. APOA Rep. No. 146-6. [Available from APOA Information Service, P.O. Box 1281, Station "M", Calgary, Alberta T2P 2L2.]

———. 1979. Studies of the plankton, benthic fauna, and macroalgae of Nachvak Fiord, Labrador. Unpubl. Rep. by Aquatic Environments Ltd. for Esso Resources Canada Ltd., Aquitaine Co. of Canada Ltd. and Canada-Cities Serv. Ltd. 135 p. APOA Rep. No. 146-5. [Availability as above.]

DIVOKY, G. 1978. The distribution, abundance and feeding ecology of birds associated with pack ice. In: Environmental Assessment of the Alaskan Continental Shelf. Annual Report of the Principal Investigators. Vol. 2. National Oceanic and Atmospheric Admin., Boulder, CO. 167-509.

FINLEY, K.J. and GIBB, E.J. In press. Summer diet and feeding behaviour of harp seals in the Canadian High Arctic. In: Lavigne, D.M., Ronald, K. and Stewart, R.E.A. [eds.]. The Harp Seal. The Hague: Dr. W. Junk, Publishers.

FISSEL, D.B., LEMON, D.D. and BIRCH, J.R. 1982. Major features of the summer near-surface circulation of western Baffin Bay, 1978 and 1979. Arctic 35 (this issue).

FROST, K., LOWRY, L. and BURNS, J. 1978. Offshore demersal fishes and epibenthic invertebrates of the northeastern Chukchi and western Beaufort seas. In: Environmental Assessment of the Alaskan Continental Shelf. Annual Report of the Principal Investigators. Vol. 1. National Oceanic and Atmospheric Admin., Boulder, CO. 231-265.

HOGNESTAD, P.T. 1968a. Polar cod, *Boreogadus saida* Lep., in Norwegian waters. Astarte 31:1-3.

———. 1968b. Observations on polar cod in the Barents Sea. Rapports et Proces-Verbaux des Réunions Conseil International pour l'Exploration de la Mer 158:126-130.

HOLLANDER, M. and WOLFE, D.A. 1973. Nonparametric Statistical Methods. New York: Wiley.

HUNTER, J.G. 1979. Abundance and distribution of arctic cod, *Boreogadus saida*, in the southeastern Beaufort Sea. CAFSAC Res. Doc. No. 79/39. 6 p. + Figs.

JENSEN, Ad. S. 1948. Contributions to the ichthyofauna of Greenland, 8-24. Spolia Zoologica Musei Hauniensis 9. 182 p.

JONES, R. and HALL, W.B. 1974. Some observations on the population dynamics of the larval stage in the common gadoids. In: Blaxter, J.H.S. [ed.]. The Early Life History of Fish. New York: Springer-Verlag, 87-102.

KLEINENBERG, S.E., YABLOKOV, A.V., BEE'KONVICH, B.M. and TARASEVICH, M.N. 1964. Beluga (*Delphinapterus leucas*) investigation of the species. Israel Program for Scientific Translations, Jerusalem (1969). 376 p.

LEAR, W.H. 1979. Distribution, size and sexual maturity of arctic cod (*Boreogadus saida*) in the Northwest Atlantic during 1959-1978. CAFSAC Res. Doc. No. 79/7. 40 p.

LILLY, G.R. 1980. The food of arctic cod, *Boreogadus saida* (Lepechin), off Labrador in the autumn. CAFSAC Res. Doc. No. 80/4. 6 p.

LOWRY, L.F. and FROST, K.J. 1981. Distribution, growth, and foods of arctic cod (*Boreogadus saida*) in the Bering, Chukchi, and Beaufort seas. Canadian Field-Naturalist 95(2):186-191.

_____ and BURNS, J.J. 1978. Trophic relationships among ice-inhabiting phocid seals. In: Environmental Assessment of the Alaskan Continental Shelf, Annual Report of the Principal Investigators. Vol. 1. National Oceanic and Atmospheric Admin., Boulder, CO. 161-230.

MAY, A.W. 1966. Biology and fishery of Atlantic cod (*Gadus morhua morhua* L.) from Labrador. Ph.D. thesis, McGill University, Montreal, P.Q. 225 p.

McLAREN, P.L. 1982. Spring migration and habitat use by seabirds in eastern Lancaster Sound and western Baffin Bay. Arctic 35 (this issue).

MILLER, D. 1961. A modification of the small Hardy plankton sampler for simultaneous high-speed plankton hauls. Bulletin of Marine -Ecology 5(45): 165-172.

MILLER, D.S. 1979. An acoustic estimate of juvenile arctic cod (*Boreogadus saida*) abundance in ICNAF Divisions 2J and 3K, 1978. CAFSAC Res. Doc. No. 70/12.

MOSKALENKO, D. 1964. On the biology of the polar cod, *Boreogadus saida*. Voprosy Ikhtiologii 32:433-443.

PONOMARENKO, V.P. 1968. Some data on the distribution and migrations of polar cod in the seas of the Soviet Arctic. Rapports et Proces -Verbaux des Réunions Conseil International pour l'Exploration de la Mer 158:131-133.

QUAST, J.C. 1974. Density distribution of juvenile arctic cod, *Boreogadus saida*, in the eastern Chukchi Sea in the fall of 1970. Fisheries Bulletin 72:1094-1105.

RASS, T.S. 1968. Spawning and development of polar cod. Rapports et Proces-Verbaux des Réunions Conseil International pour l'Exploration de la Mer 158:135-137.

RUSSELL, F.S. 1976. The Eggs and Planktonic Stages of British Marine Fishes. New York: Academic Press.

SEKERAK, A.D., BUCHANAN, R.A., FOY, M.G., BAIN, H., WALDER, G.L. and STALLARD, H.E. 1979. Studies of plankton in northwest Baffin Bay and adjacent waters, July-October 1978. Unpubl. Rep. by LGL Ltd., Toronto, for Petro-Canada, Calgary. 412 p. [Available from Pallister Resource Management Ltd., 3rd floor, 700-6 Ave., S.W., Calgary, Alberta T2P 0T8.]

SPRINGER, A.M. and ROSENEAU, D.G. 1978. Ecological studies of colonial seabirds at Cape Thomson and Cape Lisburne, Alaska. In: Environmental Assessment of the Alaskan Continental Shelf. Annual Report of the Principal Investigators. Vol. 2. National Oceanic and Atmospheric Admin., Boulder, CO. 839-960.

TARBOX, K. and THORNE, R. 1979. Measurements of fish densities under the ice in the Beaufort Sea near Prudhoe Bay, Alaska. Rep. by Woodward-Clyde Consultants for Prudhoe Bay Unit Waterflood Project. 111 p.

THOMSON D., CROSS, W.E., BAIN, H. and PATTERSON, L. 1978. Aspects of the spring and summer marine environment of Brentford Bay, Boothia Peninsula, N.W.T. Unpubl. Rep. by LGL Ltd., Toronto, for Polar Gas Project, Toronto. 203 p. [Available in Library, Arctic Institute of North America, University of Calgary, Calgary, Alberta T2M 1N4.]

WELLS, R. 1980. Age and growth of arctic cod (*Boreogadus saida*) taken off Labrador in September 1978. CAFSAC Res. Doc. No. 80/5. 4 p.

WOLOTIRA, R., SAMPLE, T. and MORIN, M. 1979. Baseline studies of fish and shellfish resources of Norton Sound and the southeastern Chukchi Sea. In: Environmental Assessment of the Alaskan Continental Shelf. Final Report of the Principal Investigators. Vol. 6. National Oceanic and Atmospheric Admin., Boulder, CO. 258-572.