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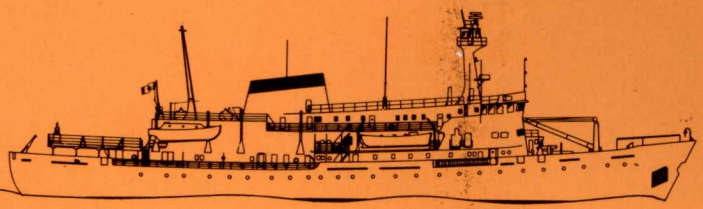
Review of Current Information on Arctic Cod (Boreogadus saida Lepechin) and Bibliography

D. Sameoto

April 1984



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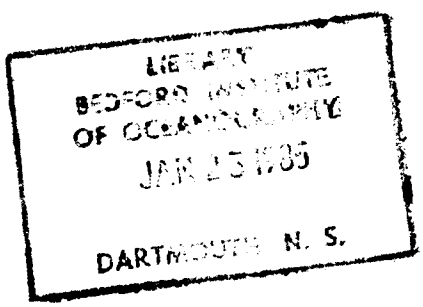

INTRODUCTION

The Arctic cod, Boreogadus saida (Lepechin), is one of the most important organisms in the food chain of the Canadian Arctic Seas. It is the major link in the transfer of energy from the secondary producers, the zooplankton, to the top level carnivores the seabirds and marine mammals. The importance of the arctic cod in the diet of the thick-billed murres, the black guillemots, black-legged kittiwakes, beluga whales and ring seals is well documented (Bradstreet 1977). Harp seals and bearded seals also feed on the arctic cod in Russian waters (Andriashev 1964) and it is documented that the harp seal in Canadian Arctic waters feed on the cod (Sargent 1973). Cod have been found in the stomachs of arctic char (Ellis 1962 Moove and Moore 1974) and also are believed to a food source for the larger cod species, the plaice and ruff. The narwal are also reported to feed on cod (Hay 1980). Because of its importance in the arctic food chain, concern has been expressed to the effect of an oil spill on the Arctic cod. In an effort to answer some of these concerns, this report was prepared to summarize the current state of knowledge on the biology and the distribution of the arctic cod in Canadian waters.

Taxonomy

The following description of the arctic cod was taken from Leim and Scott (1966). The arctic cod is slender and slightly compressed with a slender caudal peduncle (Fig. 1). The body depth is approximately 16% of the total length and the head length is about 22% of the total length. The snout is rounded with the lower jaw projecting beyond the upper jaw. The angle of the mouth extends to under the middle of the eye. The chin barbel

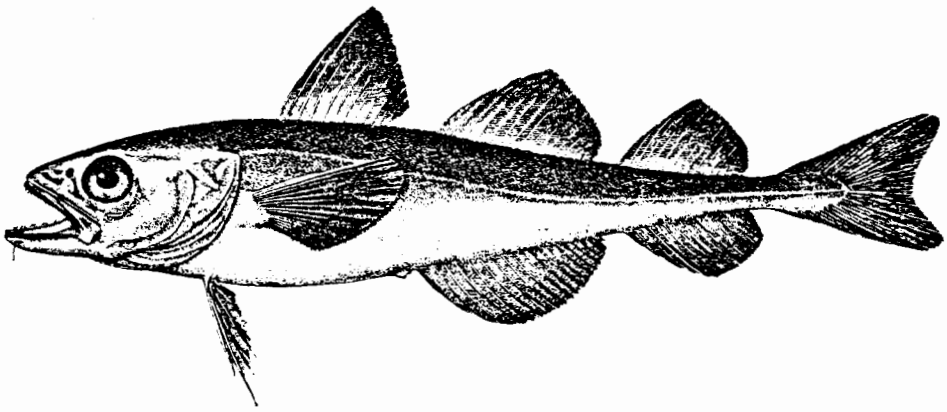

Figure 1. Boreogadus saida (Lepechin). Drawing taken from Leim and Scott (1966).

is short and thin, its length is usually less than the diameter of the eye pupil. The arctic cod is distinguished from other related species by its fork tail and slender body. Only it and the pollock combined three dorsal fins and a very small barbel; whereas, the pollock has a small pelvic and much deeper body than the Arctic cod. The cod's colour is uniformly brownish above and silvery below with many fine black points scattered over the back. The lateral line is discontinuous along its entire length, it descends steeply to the medium line of the body behind the first dorsal fin, it is sinuous and variable. The scales are small. The arctic cod is smaller than other species of cod with body length generally ranging from 130 to no greater than 320 mm. The only species the arctic cod could be confused with are the Atlantic and Greenland cods. Both of these species have tails which are only slightly concave. In addition, their bodies are much deeper, relative to the total length than the Arctic cod (Leim and Scott 1966).

Geographic Distribution

The arctic cod have a circumpolar distribution (Fig. 2) preferring colder arctic water which is believed to account for their increased abundance north of the Arctic Circle (Jensen 1948). They have been reported from regions along the coast near shore, as well as ranging well out to sea. Their southern distribution is influenced by cold water. During years when the cold water extends southward the southerly range of the arctic cod increases (Andriashev, 1964). In the North American Arctic, the arctic cod has been reported from the Arctic Islands region of Baffin Bay, the coast of Greenland, Hudson Bay, the coast of Labrador and the Gulf of St. Lawrence (Fig. 2).

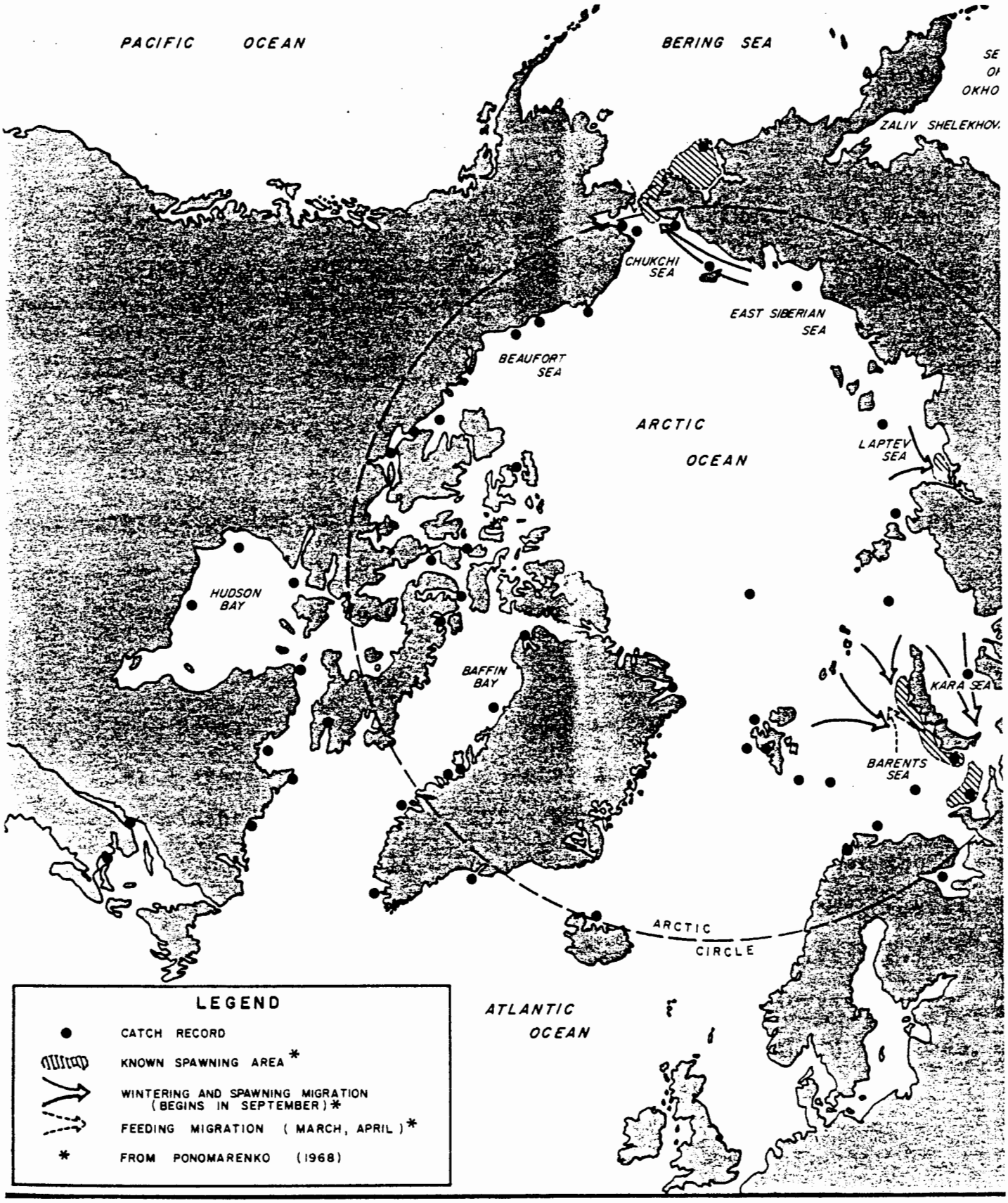

Figure 2. Map of the Arctic Region Illustrating Catch Records, Known Spawning Grounds, General Migratory Routes and the Circumpolar Distribution of arctic cod. Taken from Bain and Sekerak (1978).

During the autumn arctic cod tend to concentrate in large numbers and move into coastal regions. This behaviour is believed to be a temperature response prior to spawning, since they appear to seek waters with a temperature of 0°C to 4°C (Hognestad 1968b and Rass, 1968). These spawning concentrations have been found in most years in the northeastern part of Barents Sea during September and October (Ponomarenko, 1968) and near Spitzbergen (Hognestad 1968b). In addition, the arctic cod show extensive migrations in the Soviet Arctic Region. These migrations are believed to be related to feeding and spawning behaviour (Ponomarenko 1968). In the Canadian waters (Fig. 3), arctic cod have been collected from depths ranging from 100 to 300 m in Strathcona Sound during August (Bohn and McElroy 1976). Evidence based on gill netting and jigging in the Resolute and Allen Bay area during July found very few cod. After July cod older than one year increased substantially (Bain and Sekerak 1978). By the middle of July, cod were abundant in cracks in the ice near Resolute Bay. By August, schools up to 3000 fish were seen in the region of Allen Bay. However, by September they appeared to have left this region. Surveys in November around Cornwallis Island found no evidence of large numbers of cod older than one year. Scuba diving observations suggested that only small cod of one year old were found in the regions of Resolute Bay between December and June. This evidence suggests that a seasonal pattern to the movements to and from Allen Bay and Resolute Bay (Bain and Sekerak 1978). Adult cod have been collected at a depth of 300 m in Strathcona Sound, at 930 m in Baffin Bay (Jensen 1948), and 400 m in Chukchi Bay and the Beaufort Sea (Frost et al. 1978). Adult and sub-adult fish were captured in a Yankee Otter Trawl along the northern Grand Banks and along the northeastern Newfoundland Shelf, Labrador Shelf and off Baffin Island and Davis Strait

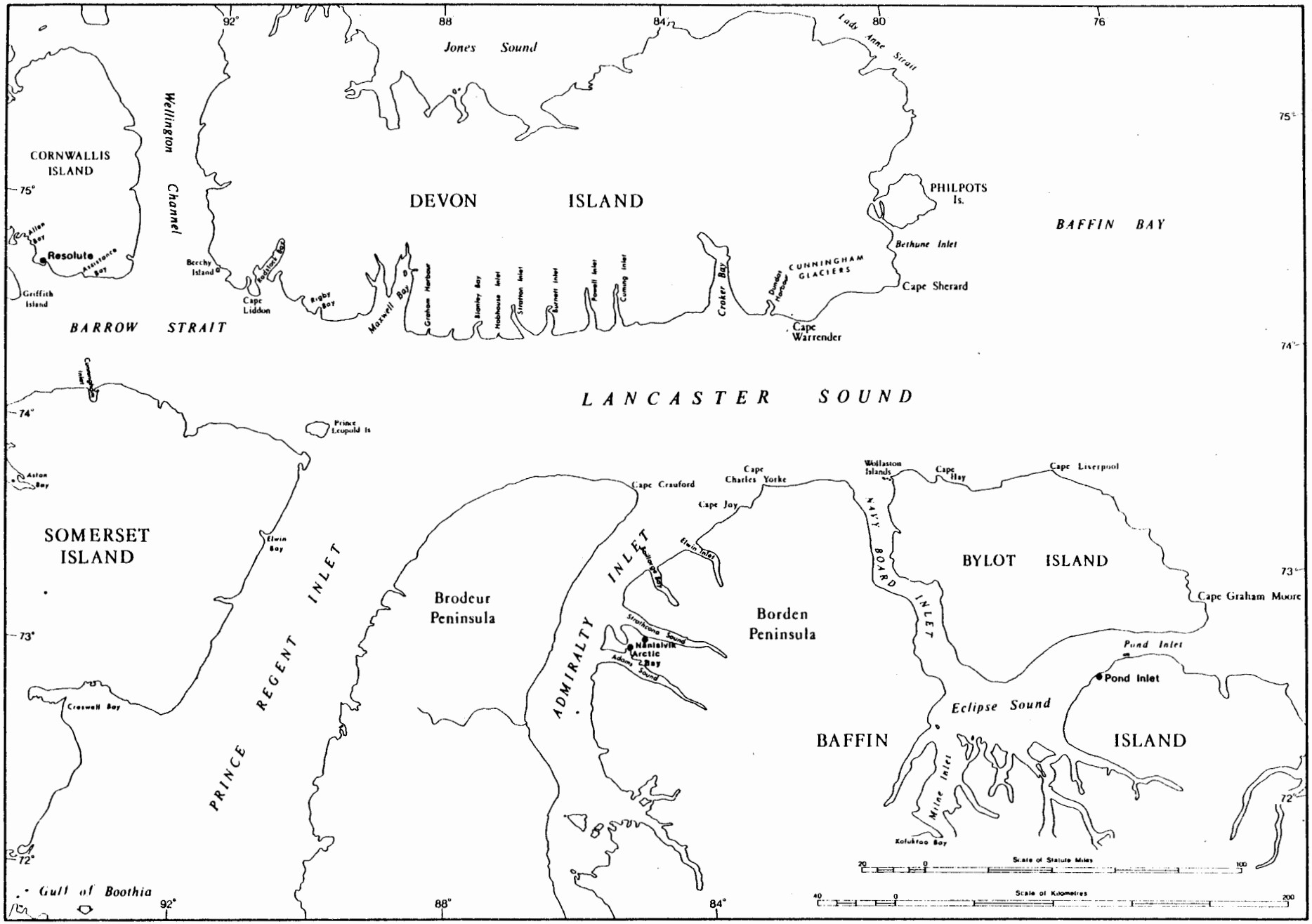

Figure 3. Lancaster Sound Region showing areas where arctic cod have been found.

(Lear 1979). These fish were caught at a depth ranging from 116 to 143 m. The results of this study indicated that the cod are highly concentrated in schools during the pre-spawning and spawning times. Arctic cod have never been found on Flemish Cap or the northern Nova Scotia Shelf and rarely found on the southern half of Grand Banks or the Gulf of St. Lawrence. The largest catches of arctic cod occurred during September surveys in the region of northern Labrador. Cod were trawled at various times and locations at depths ranging from 100 to depths as great as 750 m. In all cases the fish were found in water which had a temperature less than 3.5°C and usually between 2.5° and -1°C. The largest number of fish caught for a 30 minute tow generally occurred at depths between 100 and 250 m. The water temperature at this depth ranged from -0.03 to 0.03°C. The maximum of fish caught per 30 min. tow was along the coast of Northern Labrador (Fig. 4) (Lear 1979).

Life Cycle

Three discrete arctic cod spawning grounds are known to occur in Soviet Arctic waters (Bain and Sekerak 1978) but no information exists about the timing or the extent of arctic cod spawning in the North American Arctic. Time of spawning is presumed to be the same in both the Soviet and North America Arctic waters, the winter period between December and March. However, in Soviet Arctic it has been reported that the cod also spawn in October and November. There is disagreement as to where spawning occurs whether it is in the coastal region or open sea along ice edges.

The young-of-the-year arctic cod (Y-O-Y) are planktonic but they assume a benthic habitat after the first year of life. No evidence of spawning condition occurs in the gonads of the arctic cod until September.

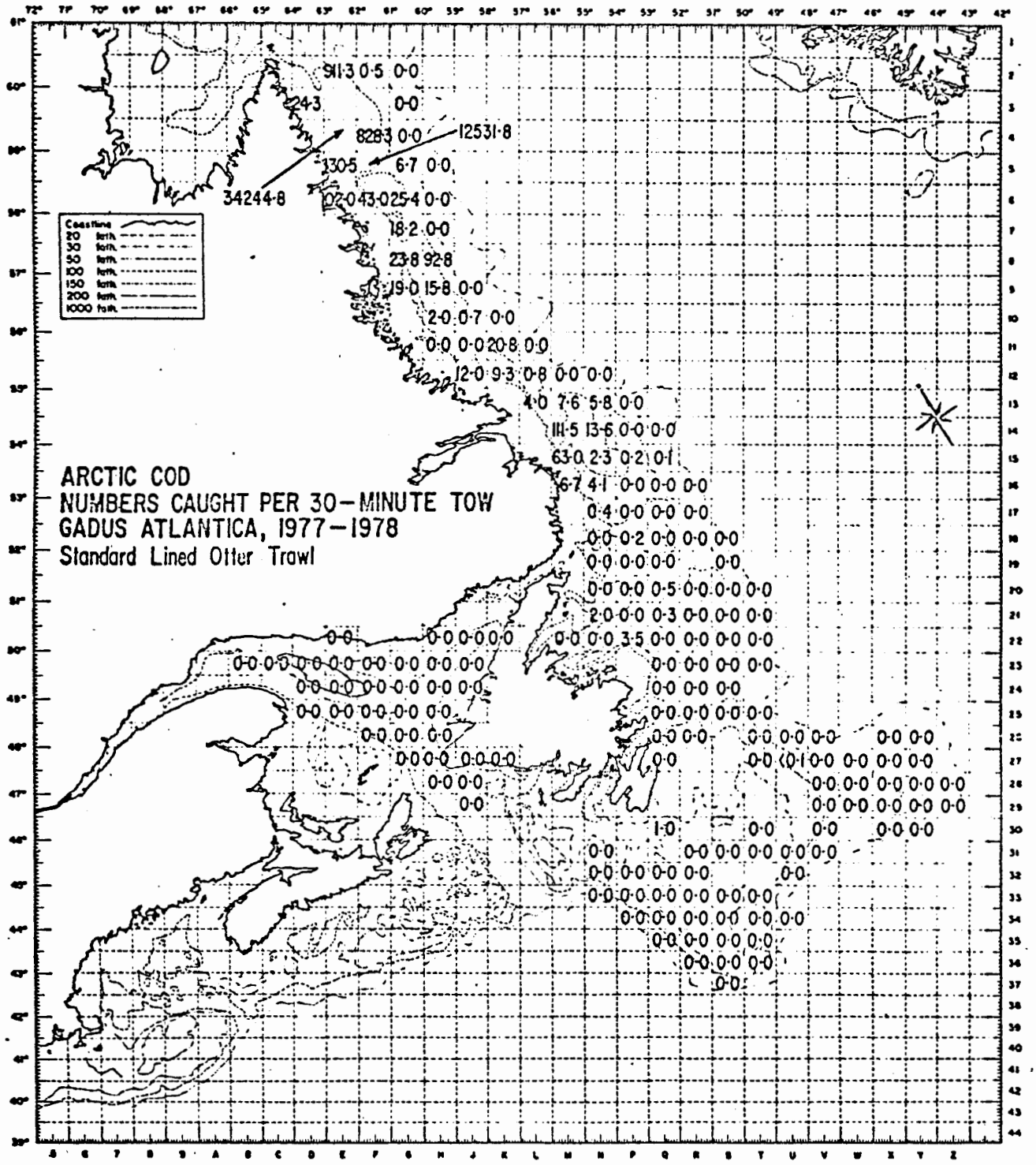

Figure 4. Average number of Arctic Cod caught by 1/2° lat. 1° long. rectangles per 30-minute otter trawling tows of the Gadus Atlantica (Cruises 3-6, 8, 9, 12, 13) during 1977-78. Taken from Lear (1979).

Surveys of coastal waters off Cornwallis Island and Allen Bay during the winter months produce no evidence of spawning or large groups of arctic cod. The newly hatched larvae are approximately 3.5 to 5.5 mm in length and at the end of the first growing season may attain a length of up to 70 mm. The maximum size is reached after 5 years and is approximately 240 mm but occasionally as large as 320 mm. Otolith annular ring readings have proved successful for the aging of the cod stocks. A comparison of the North American Arctic and the Bering Sea showed a slight difference in growth but this was not statistically significant (Bain and Sekerak 1978).

The arctic cod in the Soviet Arctic are believed to become mature at an age of about four years and reproduce only once in their lifetime (Nikol'skii 1961); whereas other workers (Craig et al. 1982 and Lear 1979) have suggested that they may mature as early as two years. Bain and Sekerak (1978) did not capture spawning animals, therefore had difficulty in assessing the age at which the arctic cod in Canadian waters matured. Therefore, it is not known exactly at what age the arctic cod in the Canadian Arctic mature. The mean gonad weight to body ratios, however, do suggest that development of gonads towards a spawning condition occurs in August and that the male cod mature sooner than females and that after spawning the gonads of mature cod regress to a state indistinguishable from gonads of immature cod. The Russian data (Nicholskii 1961 and Barenenkova et al. 1966) indicated that arctic cod spawn near the end of December to the end of March with the peak spawning between January and February. The only mature females collected in the Beaufort Sea by Craig et al. (1982) were collected in February. There is no published data on the time or location of spawning of cod populations in North American waters. No

evidence was found that cod spawned in the region of Allen and Resolute Bays (Bain and Sekerak 1978). Cod eggs (1.6 - 1.8 mm dia., Andriyashev 1964) are buoyant and planktonic as are the young of the year for the first growing season. The number of eggs shed by a female is reported to range between 9000 and 21000 (Andriyashev 1964). The eggs are the largest among the gadoid eggs ranging in size from 1.5 to 1.9 mm in diameter. Laboratory experiments indicate that the incubation time for the eggs is 26 to 35 days at 0°C but incubation may be considerably longer at sub-zero temperatures (Sekerak 1982).

Data on spawning period and the first appearance of larvae in the Bering Sea suggest that the natural incubation period is 45 to 90 days. The post-larvae are 6 to 30 mm in length and transformation to juveniles occurs when the young are 30 to 50 mm long. Growth of young cod in the first year is very rapid ranging in length after one year between 70 and 100 mm. The cod are shortlived and may not live longer than 5 or 6 years. Specimens over 300 mm are very uncommon.

In Lancaster Sound and western Baffin Bay the ichthyoplankton are dominated by arctic cod with the sea snail genus Liparis being the second most common fish larva. The cod accounted for 76% of the ichthyoplankton in the Labrador Sea in 1979 (Sekerak 1982). Densities of cod larvae decrease significantly from mid-summer to autumn in the water column. This was attributed to natural mortality and increased efficiency in net avoidance as fish became larger but did not totally explain the sudden decrease in densities after mid-August. It was believed that this was primarily the result of the fishes moving to deeper water. There was evidence from catches of arctic cod found off the coast of Labrador that they move to a depth of 100 to 200 m as once they reach a length of 35 to

60 mm (Miller 1979). At this length they become post-larvae and juvenile stages which actively swim and school and therefore are no longer planktonic as they move into deeper waters, this most likely occurs in late summer and early fall. Sampling with plankton nets indicated that cod larvae were slightly more abundant in Lancaster Sound than in Baffin Bay. The larvae were concentrated in the top ten meters of the water and were seldom found below a depth of 250 metres. The water temperature in which they were found ranged between 2 and 3.5°C. On several stations in Baffin Bay sampled by Sekerak (1982) at different times no significant difference larval concentration was found between stations. Since the cod eggs are buoyant and planktonic for several months it is expected that regional differences in abundance would be less marked due to currents transporting the larvae and eggs. However, other studies have found large differences in density of young of the year cod offshore versus nearshore waters. In the Labrador Sea and numbers decrease dramatically beyond 25 kilometers from shore. After that point numbers remain relatively stable through a distance of 120 kilometers from the Labrador Coast (Buchanan and Foy 1980).

Sampling in the region of Frobisher Bay, Den Beste and McCart (1978) found the arctic cod was the only pelagic species regularly caught but these were primarily Y-O-Y. The adult cod that were caught were in coastal locations with water temperatures of 1-3°C whereas the Y-O-Y were found over a wider range of temperature 1-8°C. The Y-O-Y caught in August and September were approximately 16 mm in length. Age length relationships showed that the cod in this region were smaller than those of the Beaufort Sea. The age length relationship for cod in the Baffin Island area showed that at age 6 they reached a maximum length of 240 mm, and at age 3 approximately 190 mm. Craig et al. (1982) found the cod were tolerant of a wide

range of temperature (0.5° - 12.5°C) and salinities (1-29°/$_{oo}$). Miller (1979) found young of the year cod with lengths of 39 to 64 mm which was similar to 44 mm larvae found in the eastern Chukchi Sea from late September to mid-October. It was estimated that cod increased in size at approximately 0.25 mm per day during the first year and generally reached a length of 87 mm by June of the following year. Estimates of winter growth suggests that the length may be 65% of the growth during the summer. Moskalenko (1964) reported that the growth of cod continued during the winter. Baranenkova et al. (1966) stated that cod spawn in coastal regions near fast ice from where eggs were dispersed as well as the larvae to the open sea. They suggested that larvae begin to descend to the bottom layers after reaching a length of approximately 30 to 35 mm and that after the first year of life the fish was approximately 66 to 77 mm in length. Bain et al. (1977) using gillnets and a cod trawl sampling in relatively shallow waters, no deeper than 20 m, found that all the cod except one were caught with bottom trawls. All young of the year were caught in open water during horizontal tows for zooplankton and ichthyoplankton. Maximum catches of ichthyoplankton occurred between 7.5 and 15 m depth, a maximum density of one per m^3 was found at a depth of 10 m in the Wellington Channel. The mean density per sampling site ranged from .01 to 0.5 cod larvae per m^3. No young of the year were caught in vertical plankton tows through the ice and no significant relationship was found between the proximity of ice edges and the abundance of the arctic cod.

Arctic cod eggs incubation period lasted 26-35 days, at 0°C (Aronovich et al. 1975) but incubating may be considerably longer at sub zero temperatures. Cod larvae started feeding on natural plankton consisting of Paracalanus and Pseudocalanus nauplii approximately 12 to 14 days

after hatching at 2 to 4°C.

The identification of Boreogadus saida larvae is difficult because of a lack of published information and the scarcity of collections from different regions of the Arctic and variability in characteristics of specimens. Sekerak (1982) mentioned that it was not possible to do specific identification of larvae he collected because of slight differences in morphology. His collections contained small numbers, less than 1%, of Arctogadus but were dominated by Boreogadus and he stated that the present knowledge suggests that Boreogadus saida is the only abundant cod in regions of North American high arctic that have been studied and therefore the dominance of a different species of cod in ichthyoplankton collected is highly improbable. Sekerak (1982) found the growth of young of the year cod to vary annually and geographically.

Diet

Bain and Sekerak (1978) reported the diet of cod in Allen and Resolute Bay Regions was similar to that reported from other areas of the Arctic and consisted primarily of amphipods and copepods with amphipods dominating the diet of the larger fish. Together these two taxa represented about 93% to 100% of the diet. Amphipods contributed the greatest to the diet of the cod in early July and mid-September samples; whereas, copepods dominated the samples in August. In terms of weight of the total diet, the amphipods were the major contributors. Arctic cod also consumed a proportion of small fish which tended to increase in importance during the latter part of the sampling period which was late September. No clear relationship was found between sex or size and diet, but evidence suggested that the feeding habits changed as the fish became larger. Food items of

the young of the year were primarily phytoplankton, copepod nauplii and eggs. The diet of fish less than 100 mm in length, consisted primarily of copepods, although a few mysids were also eaten. Larger organisms are more important in fish greater than 100 mm in size as evidence by the increase importance of amphipods. However, all the fish collected for this study were collected in shallow environments and this may not reflect feeding habits of cod found in deeper waters. Stomachs of cod indicated that they consumed large numbers of invertebrates that were typical of near shore areas where they were captured. Most of these fish were observed and captured using SCUBA equipment. Cod collected by gillnets in water very close to shore, at a depth of 10 m, contained pelagic animals such as the amphipod, Parathemisto, pteropods, mysids as well as young of the year arctic cod. In terms of biomass Parathemisto was the most important item. It appears that the cod will feed on most of the organisms present in the region regardless of the type of habitat they are found in. Food items of artic cod from other regions included phytoplankton, zooplankton, small bottom crustaceans, fish eggs, shrimp, young of the year cod (Andriashev, 1964), larval and adult shrimp and fish (Kleinenberg et al., 1969) copepods, primarily Calanus finmarchicus, larvaceans and amphipods (Hognestad, 1968a). Ponomarenko (1967) stated that cod larvae fed on copepod eggs, nauplii and copepodites. Craig (1982) found that arctic cod in nearshore waters fed primarily on mysids, amphipods and copepods with mysids being slightly more important. Den Beste and McCart (1978) working in the Frobisher Bay region found that cod up to lengths of 79 to 140 mm contained a high percentage of Calanus finmarchicus, Mysis mixta, Calanus hyperboreus and Microcalanus. The two most important items were Calanus finmarchicus and Mysis mixta. Bradstreet and Cross (1980) found that copepods and

amphipods dominated the diet of arctic cod regardless of the age or size of the fish. Mysids were the third most important component by dry weight. Cod taken near shore had higher amounts of copepods and amphipods per stomach than offshore cod. Amphipods were more important near shore than in the offshore area. Harpacticoid and cyclpoid copepods were found in greater numbers in one year old cod than in older fish. The size of the copepods and amphipods ingested increased with the size of the fish for both offshore and nearshore cod. Of the Calanus species, it appeared that Calanus glacialis and C. hyperboreus were the main food items and copepodite stages five and six predominated. The dominant size groups of the amphipod, Parathemisto were the 3 to 6 mm size classes. The stomachs of a number of cod collected from the under surface of offshore landfast ice and from the ice edge near Bylot Island showed that copepods and amphipods dominated the diet. Regardless of the age class of the fish or location, copepods occurred in all stomachs examined in large numbers and comprised the majority of the dry weight diet (Bradstreet and Cross, 1982). Amphipods were the second most important item and mysids were the third most important on a dry weight basis. Studies of the diet of arctic cod from deep offshore waters (Bohn and McElroy 1967; Frost et al. 1968; Hognestad 1968) found that copepods were the dominant food item. In offshore fish the mean lengths of the consumed copepods were significantly correlated with the length of the fish. The composition of the offshore diet of cod in the under side of the ice suggested that they fed mainly on zooplankton (Bradstreet and Cross 1980).

Predators of Arctic Cod

The artic cod are preyed upon by virtually all large marine birds and marine mammals as well as the large fish in the Arctic Region therefore

are considered a "key species" in the ecosystem. The thick-billed murres feed on cod near the fast ice edges and it has been estimated that the murres harvest from a region of the ice edge 9.6 kilometer in length up to 17,660 arctic cod daily per linear kilometer of ice edge (Bradstreet 1977). It has been estimated that 1.4 million arctic cod and posssibly about ten times that number are consumed by seabirds along fast ice edges within a thirty-five day period. Cod are also the dominant food organisms for marine seals, Beluga and narwal whales and it is highly likely that the arctic cod concentrations are a major factor in affecting the distributions of these animals during the summer months. The importance of arctic cod to the diet of kittiwakes, murres, guillemots and marine mammals such as seals and narwals have been investigated by Bradstreet (1980) and Hay (1980). All of these animals depend on the arctic cod as a main component of their diet and it is believed that the arctic cod is a biological pivot of the lives of many of the marine vertebrates. Bradstreet (1977) showed that only 1% of the young of the year cod eaten by birds were shorter than 40 mm. These cod were found in the stomachs of kittwakes, murres and guillemots. The size range of cod most frequently eaten by all birds ranged between 50 and 70 mm in length but fish up to 200 mm were also commonly eaten. Bradstreet (1980) looked at the diet of seabirds near ice edges and found that 74% of the dry weight of the diet of guilleomots was arctic cod. The offshore murres took 96% of the diet as cod.

Association with Ice

The young of the year of arctic cod are planktonic but they assume a benthic habit after the first year of life. It is believed they are associated with the bottom and occasionally with the under surface of the

ice. Arctic cod, particularly the first year group are associated with ice ridges where they are fed on by many of the seabirds (Bradstreet 1977). Two year old and older cod form schools which utilize the nearshore shallow regions during the summer period from July to September. However, the proportion of the total population that participates in concentrations near shore is unknown. No concentration of cod have been found under solid ice during April, June or July and repeated SCUBA dives indicated that cod populations are very sparsely distributed at this time under the ice (Bain and Sekeraka, 1978). There is little evidence from the Canadian Arctic that there is any significant concentrations of cod in these areas of continuous ice. Scuba divers have observed cod ranging from 50 to 200 mm in size positioned in openings in small holes in icebergs near the air water interface. However, these observations did not indicate large concentrations of fish. Therefore, the conclusions were that the cod had no particular attraction to the undersurface of ice, especially when the ice is a continuous sheet. However, if cod do form schools and because of the very large area of ice, these schools could have been missed by diving in limited areas. If possible the low densities of cod observed under the ice may represent the normal distribution for the species for the period prior to spawning. There is some indication that the distribution of cod may differ significantly in different ice conditions. In spring seabirds concentrate along fast ice edges and an analysis of seabirds' stomachs suggested that they are feeding on cod. This indirect evident suggests that the arctic cod are more abundant along ice edges than in open water. However, the type of habit of the arctic cod on which the murres were feeding on was unknown. But evidence suggested that they may be higher concentrations of cod along ice edges than under continuous ice. However, fishing for cod in

these regions by towing for over five hours by trawling adjacent to the ice did not catch any cod nor did gill nets. Cod were abundant in ice cracks in fast ice remaining in the bays during September, but not all cod in Allen Bay were found to be associated ice cracks. Some were concentrated in estuaries and swimming up streams some moved up beyond the range of high tides. Unfortunately the salinity of the streams was unknown, but Craig et al. (1982) reported the cod tolerated salinities as low as $1°/_{oo}$. Up to 3,000 cod were found stranded on a beach in tidal pools. Cod had been reported to be stranded on the beach in different areas of the Arctic Islands. One belief is that they strand themselves in an attempt to escape from whales (Bain and Sekerak, 1978). Bradstreet (1982) reported concentrations of cod in ice regions of rafted ice as observed by SCUBA divers. Cod were present on all ridges examined with abundances of approximately 15 fish in 30 m distance in large ice blocks 10 m to a side in spaces approximately 20 cm high in these blocks. Divers saw very few cod under smooth land fast ice. Cod appeared to be seen more frequently in narrow cracks, less than 6 cm wide, than wider cracks. The cod they captured offshore tended to be smaller and younger than inshore cod. Divers failed to find any relationship between the numbers of arctic cod and the distance to the ice edge. Craig and Haldorson (1981) found that cod were associated with ice but catch data also showed that fish were present in ice free areas near shore. The young of the year occurred at distances of approximately 100 to 150 km off shore in the Beaufort and Chukchi Sea. Older cod, ages 1 to 3 years, were abundant in Simpson Lagoon in August and September. The general pattern of distribution suggested that cod migrated from offshore to coastal waters in the fall. In November to early February, during under ice sampling, they found spawning males under the

ice in February and found spawning females during April and May. Nikol'skii (1961) reports that the arctic cod remain close to the ice edges during the summer in the Barent Sea along the ice edges.

Summary

The current literature has demonstrated the following points with respect to the biology of the arctic cod.

1. Arctic cod are found globally above the Arctic Circle and occasionally found south of the Arctic Circle in the Canadian waters.
2. Large concentrations of adult cod are found along the coastal regions of northern Labrador. But no data exists on the population size or distribution of adult stocks above latitude 60°.
3. Cod spawn at age 2-4 years and it is believed they spawn only once in their life.
4. Larvae have been found at all locations north of the Arctic Circle when looked for, suggesting a very wide geographic distribution of the species.
5. Spawning probably occurs in the February to April period in Canadian waters.
6. Eggs are planktonic and develope in 26-35 days at 0° C.
7. Larvae are planktonic until they reach a length of 30-50 mm and are concentrated in the top 10 to 20 m of water.
8. Fish over 30-50 mm in length move into deeper water leaving the top 25 m.
9. After one year's growth the fish are between 70 and 100 mm in length and older fish over 300 mm in length are rare.
10. Schools of sub-adults and mature fish are found at depths between 100 and 750 m with most concentrated in the 100-250 m depth range in water with a temperature of less than 3.5° C.
11. Larvae feed on phytoplankton when very young, but feed on

11. microzooplankton as they grow larger. The size of the prey of the young fish increases in size as the fish increase in length with copepods making up the bulk of the diet of the fish. Larger fish consume amphipods and mysids in addition to copepods.
12. Some young-of-the-year and older fish are associated with drift ice usually in ice cracks and pitted ice, but few fish are found under smooth landfast.
13. The percentage of the total population of fish that are associated with the ice is not known.
14. A large number of species of sea birds and mammals feed on either the larvae or adult cod at some time during their life cycle.

Results from Unpublished Marine Ecology Laboratory Studies

Results from acoustic observations using a 120 kHz sounder in the Lancaster and Jones Sound regions (Fig. 5) during August, 1980 and 1983, showed that the larval and juvenile cod were concentrated in the warm water layer above the thermocline which is generally in the top 40 m. No quantitative estimates of the population size were made from the acoustic data but information on their geographic distribution was obtained. It was found that the highest concentrations of Y-O-Y cod were found in the Maxwell Bay region (Fig. 3) with the numbers of fish per unit area decreasing to the southern side of Lancaster Sound as well as decreasing towards the mouth of the sound. The fish were found in a layer of relative uniform density over very wide areas (tens of kilometers). The fish were found in water that was between -1° and 3°C with the largest concentrations found in the warmer water. This water layer above the thermocline contained the lowest denisties of copepods but was the favoured habitat of the pteropods Clione and Limacina as well as the Parathemisto species of amphipods.

Large collections of zooplankton and ichthyoplankton samples were taken during August of 1980 and 1983 in the region of northern Baffin Bay, Lancater Sound, Jones Sound and Hudson Strait. These samples, collected with the BIONESS, are the most complete set of samples on the vertical distribution of these groups of animals ever taken. In addition,temperature, salinity and chlorophyll concentration data in the sampled areas were also gathered. Samples were collected with two mesh sizes 243 μm and 30 μm mesh which means that a complete data set on the abundance and types of food organisms available to the larvae also exists.

Some analysis of the data have been completed for the 1980 data however much remains to be done with regard to the cod larvae. No analysis

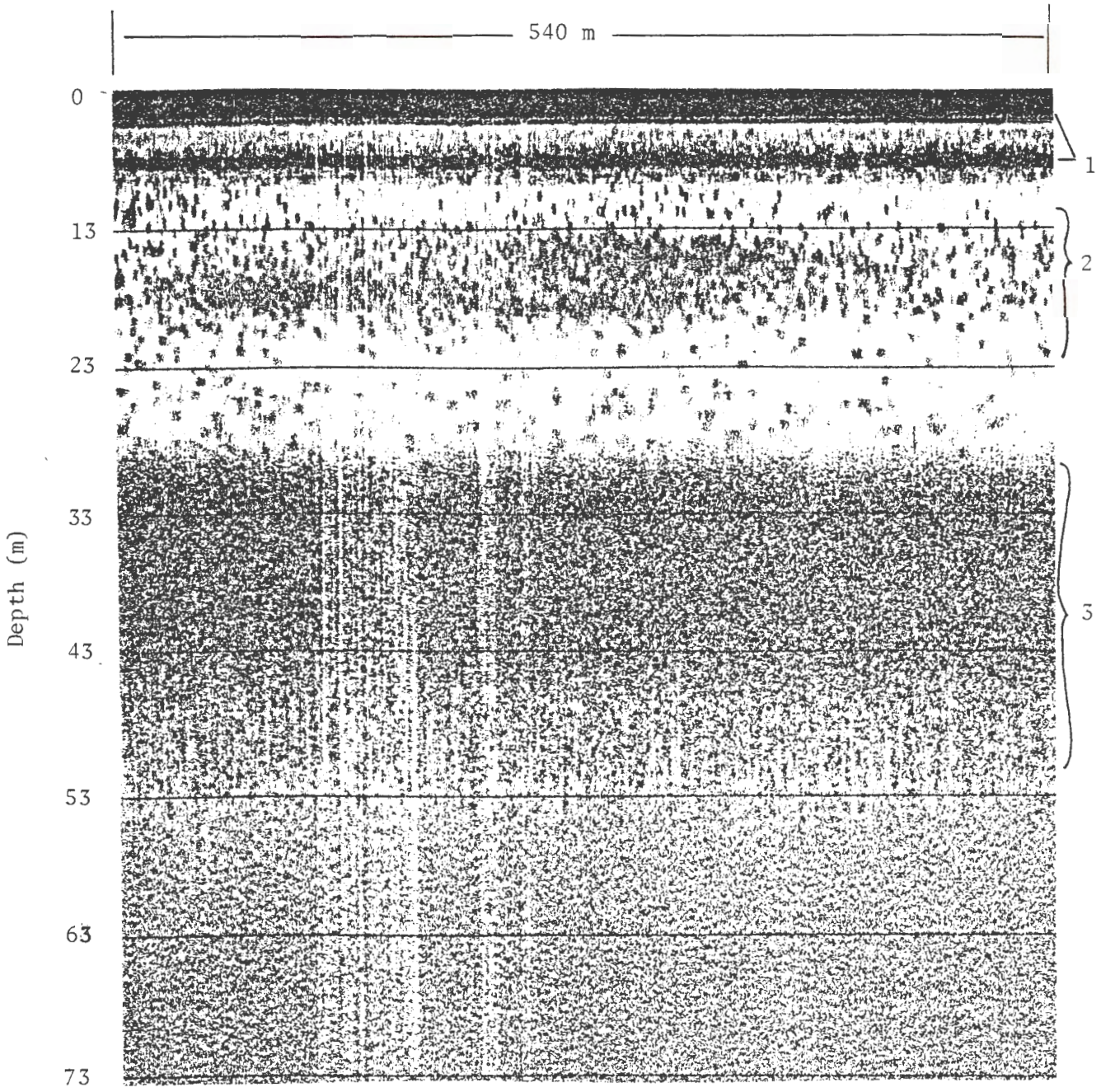

Figure 5. Echogram (120 KHz) in Jone Sound of arctic cod (5-28 m) and zooplankton (28-53 m). (1 - Noise; 2 - Cod; 3 - Zooplankton)

has been started on the samples collected during 1983.

These data have the potential to give accurate estimates of the larval cod population in the sampled regions, the type of water they are associated with as well as the types and concentration of food organisms they prey on. However, these data may not be analysed since neither the resources nor the personnel exist at MEL to complete this work in the foreseeable future.

Preliminary results form the 1980 data showed that the larvae were concentrated in most regions in the upper layers above the thermocline usually in the top 20 m of water. The results of 32 surface tows taken from regions of Baffin Bay, Lancaster Sound and Jones Sound and Kane Basin showed that the cod larvae are not found in the top 20 cm of the surface waters.

There were very low concentrations of larvae found in northern Baffin Bay (with cod found at only 2 out of 9 stations) and at these stations the concentration in the top 20 m was 0.007 m^3 (or a density of .01/m^2 for Baffin Bay).

The highest concentrations were found in Lancaster Sound (Fig. 6) where the concentrations ranged from 0.01 to 0.7 larvae per m^{-3} in the upper layers of water. Larvae were found on all nine stations sampled in the sound. The concentrations per m^2 ranged from 0.1 to 22 with a mean of 4.7 per m^2, the cod were the most abundant larvae collected and were 4 times as abundant as the next common species the sea snail Liparis.

Relationship between the concentrations of larvae and the concentration of zooplankton collected in a 243 μm mesh nets showed a significant negative correlation which is puzzling since it was expected that the larval numbers would be greater in areas and at depths that contained

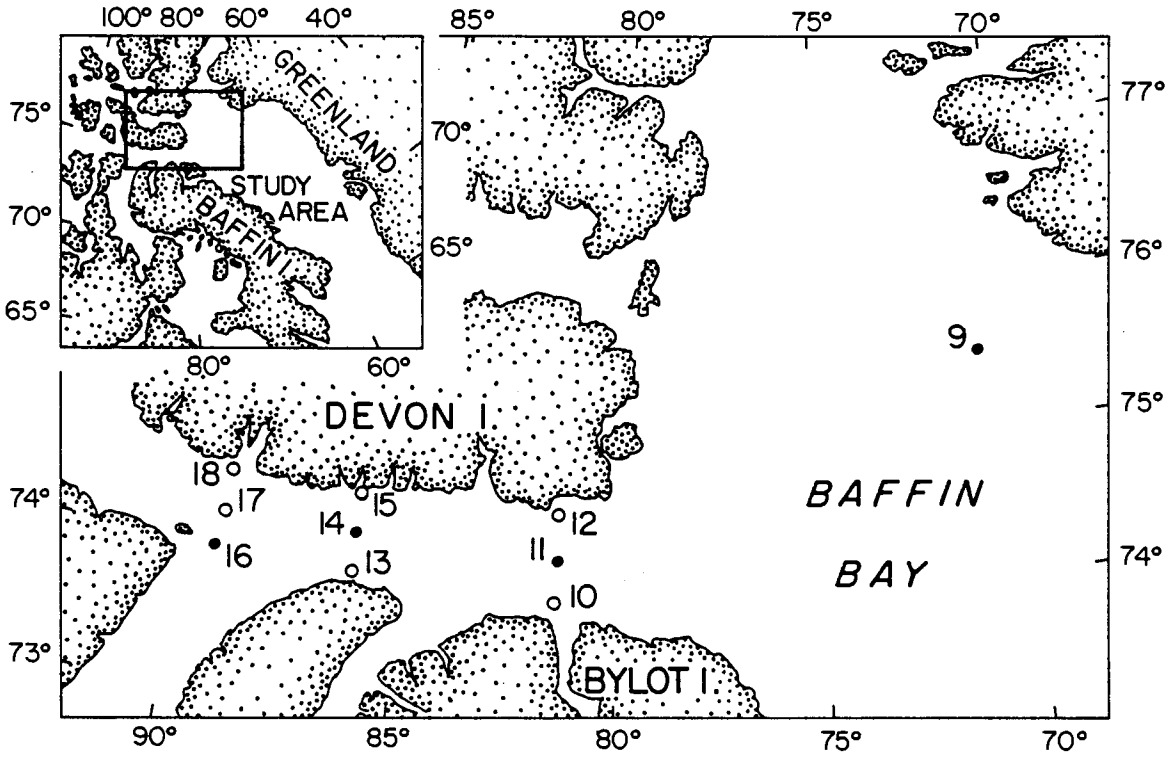

Figure 6. Stations on which microzooplankton, macrozooplankton and arctic code larvae samples were taken.

larger concentrations of potential food organisms. A similar negative relationship between the larvae and microzooplankton (between 243 μm and 30 μm diameter) was also found. These results suggested that the feeding habits are more complex than initially thought. Aronovich (1975)stated that the larvae feed on phytoplankton, copepod eggs and nauplii but the spacial association between the larvae the their food is not a simple one.

There was an increase in the total length of the larvae with depth suggesting that as the larvae age they move to deeper water. The size frequency histograms (Fig. 7) showed only one population mode with a normal distribution which suggests there was only one spawning period for the fish in Lancaster Sound. The size distribution was similar to that found by Sekerak (1982) for the early part of August in the same region.

One fish was caught at a depth of 400 m was 56 mm long which suggested that the one year and older fish may be found in the deep areas of the Sound.

The ice drift patterns in Lancaster Sound (Milne and Smiley 1978) showed a strong drift from west to east during the months of November to mid June. During mid August there existed additional surface flows out of Prince Regent Inlet in to Lancaster Sound plus a westerly flow of water from Baffin Bay along the northern side of Lancaster Sound to the position of the eastern end of Somerset Island, there the flow turned south and was then carried east along the main flow through the sound.

Milne and Smiley (1978) estimated that theoretical baroclinic flow from west to east through Lancaster Sound to be between 1.1 and 3.0 cm per sec. which translates into a daily flow rate of 950 to 2592 m per day. Superimposed upon these flows were the barotropic flows which may increase these values. But only taking the baroclinic flow into consideration

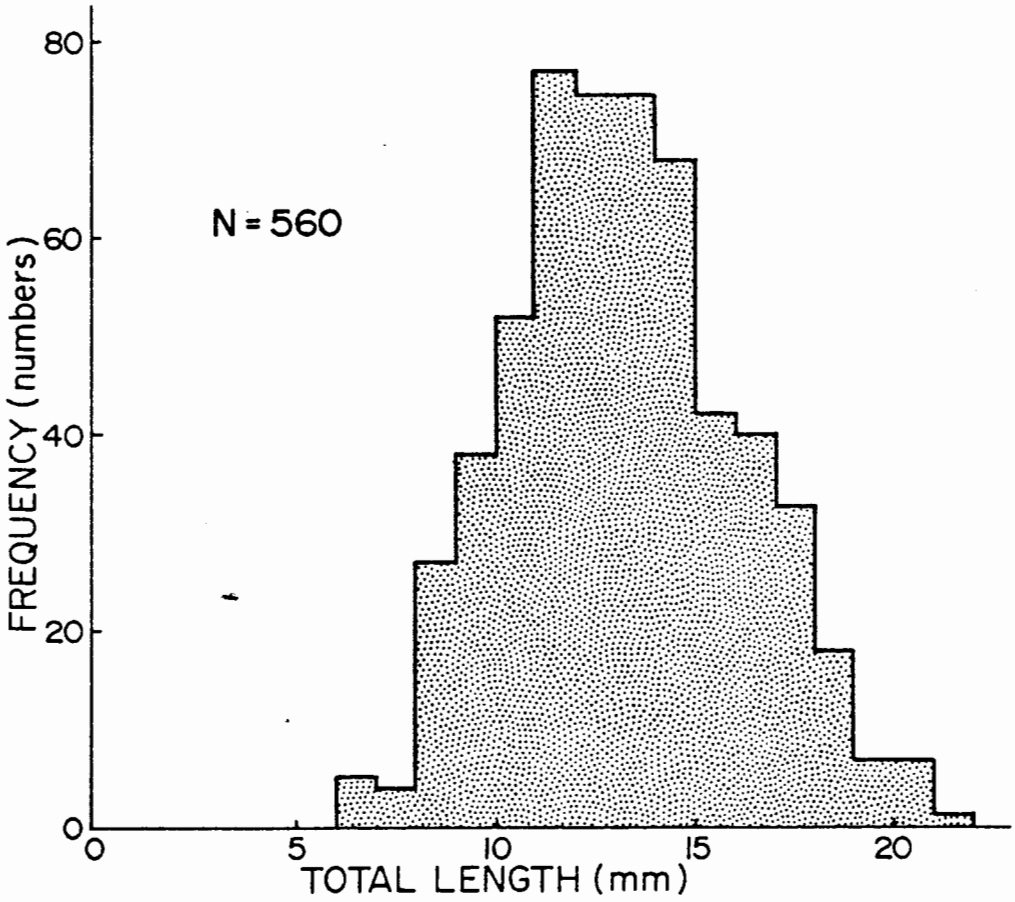

Figure 7. Total length vs frequency histogram for larval arctic cod population collected in August 1980.

combined with the time it takes the cod eggs to hatch in the cold winter water (45 to 90 days) it is possible that the eggs could be transported a distance between a minimum of 427 km to a maximum of 2332 km from the time they were released to time they hatch if they were not confined to inlets or bays in which the flow was much reduced. The point of this calculation is to show that the eggs and larvae found in Lancaster Sound between March and June may have come from as far to the west as the Beaufort Sea. The situation during August and September may be different in the eastern half of Lancaster Sound. It is possible that cod larvae from Baffin Bay are carried into the sound by this current. In addition, the outflow from Prince Regent Inlet could conceivably be an additional source of cod larvae into the sound during the summer. This information suggests that the origins and the size of the larval cod population in Lancaster Sound are influenced by biological and physical events outside of the sound.

Possible effect on an Oil Spill on Arctic Cod

The effect of a localized oil spill on arctic cod populations would be minimal. If the spill occurred during the winter under the ice the eggs and very young larvae would be the most susceptible to damage. But since both stages are pelagic and the oil would be confined to the upper water column next to the ice, there would probably be little effect on these stages. However, even if there was a kill of eggs and larvae, it would have a short term effect for in a region as physically dynamic as the major sounds, the circulation would ensure that new eggs and larvae would soon re-populate the region.

The adult fish associated with the ice would likely leave the region contaminated by the oil and move to another area or into deeper

water and therefore would likely not be effected. The fact that the eggs, larvae, young of the year and older fish are widespread in the Arctic and that the adult fish appear to migrate over wide geographic areas suggests that a local oil spill either in the winter or summer should have little lasting impact on arctic cod populations.

Most of the adult cod population is probably not associated with ice since the evidence showed these fish are usually found in deep water (ie. more than 100 m). The fish in the shallow areas that appear to be associated with the ice may also spend much of their time on the bottom as evidenced by the benthic food organisms in fish collected near the ice. The impact of oil pollution would influence primarily the surface water and under-side of the ice, and it is most likely that any fish in this habitat would quickly move down to the bottom out of harm's way.

The evidence of large scale migrations of adult fish suggests a great amount of population mixing in the arctic cod into different sounds and inlets. This also means that any disturbance to the cod by pollution would be temporary since new population of fish would return to the affected area as soon as the pollution was gone.

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