NAFO Sci. Coun. Studies, 3: 7–27

A Review of the Biology and Fisheries for Roundnose Grenadier, Greenland Halibut and Northern Shrimp in Davis Strait

D. B. Atkinson, W. R. Bowering and D. G. Parsons[1]
Northwest Atlantic Fisheries Center
P. O. Box 5667, St. John's, Newfoundland, Canada A1C 5X1

and

Sv. Aa. Horsted
Grønlands Fiskeriundersøgelser
Tagensvej 135, Copenhagen N, Denmark

and

J. P. Minet
Institut Scientifique et Technique des Pêches Maritimes
B. P. 1240, Saint Pierre, St. Pierre et Miquelon

Abstract

Three species of commercial importance inhabit the region between Baffin Island and West Greenland in NAFO Subareas 0 and 1: roundnose grenadier, Greenland halibut and northern shrimp. The roundnose grenadier, *Coryphaenoides rupestris*, is a deepwater species found in depths greater than 350 m where the temperature ranges from 3.0° to 4.4° C. Little is known about reproduction, feeding and migration of the species in the area. There has been a directed fishery since 1968, almost entirely by USSR vessels, and annual catches have fluctuated between 3,000 and 12,000 tons. Management of the fishery began with a total allowable catch of 10,000 tons in 1975, and the TAC has remained at 8,000 tons annually since 1977. The Greenland halibut, *Reinhardtius hippoglossoides*, is also a deepwater species inhabiting depths to 1,500 m at temperatures of 1° to 4° C. It is distributed widely along the west coast of Greenland, particularly in the deepwater fjords, and off Baffin Island south of the Davis Strait Ridge. Juvenile Greenland halibut (<30 cm long) are abundant on the continental shelf off Baffin Island. Spawning occurs in deepwater areas of Davis Strait, and the larvae are carried by currents to shallow-water nursery areas along West Greenland, particularly north of Disko Bay, and the banks off Baffin Island. The main food item in the diet is shrimp. Nominal catches in the region during 1969–78 have ranged from 2,000 to 25,000 tons, taken mainly by USSR trawlers offshore and Greenland longliners and gillnetters in coastal waters. Management of the stock in Subareas 0 and 1 was initiated with a TAC of 20,000 tons in 1976, and a TAC of 25,000 tons has been in effect since 1979. The northern shrimp, *Pandalus borealis*, is also distributed widely in coastal and offshore waters of West Greenland and off Baffin Island in depths of 150–500 m at temperatures from 1° to 4° C, with the major concentrations located in the area overlapping Div. 1B, 1A and 0A. Nursery grounds are located in relatively shallow areas (150–200 m) along West Greenland, from which the young ultimately recruit to the fishable populations in deeper water along the slopes of the banks. The total catch in the region increased rapidly from 10,000 tons in 1972 to 50,000 tons in 1976 due almost entirely to the development of the offshore fishery. Inshore catches remained relatively constant (7,000–10,000 tons) during the period. Conservation measures were first implemented in 1977, and catches on the offshore grounds in Subareas 0 and 1 have been regulated by an annual TAC of 29,500 tons since 1979.

Introduction

During the early 1970's, when the International Commission for the Northwest Atlantic Fisheries (ICNAF) began to monitor fish stocks more closely and imposed total allowable catches (TACs), certain species found in the area between Baffin Island and Greenland were considered as separate stocks and were managed accordingly. The extension of fisheries jurisdiction to 200 miles by Canada, United States of America and member states of the European Economic Community (EEC) in 1977 necessitated the establishment of a new international fisheries convention, and the Northwest Atlantic Fisheries Organization (NAFO) was founded to manage the stocks outside the 200-mile zones. The mandate of the Scientific Council of NAFO includes the provision of scientific advice for management of stocks partly or totally outside the 200-mile zones and of stocks within those zones at the request of the coastal states concerned. In 1979, the original ICNAF boundary line between Subareas 0 and 1 was changed to coincide with the median line between Canada and Greenland (Fig. 1). Canada and the EEC have agreed to share control of the stocks overlapping the new boundary line in Subareas 0 and 1 on the basis of management advice provided by the Scientific Council of NAFO.

[1] Authorship in alphabetical order.

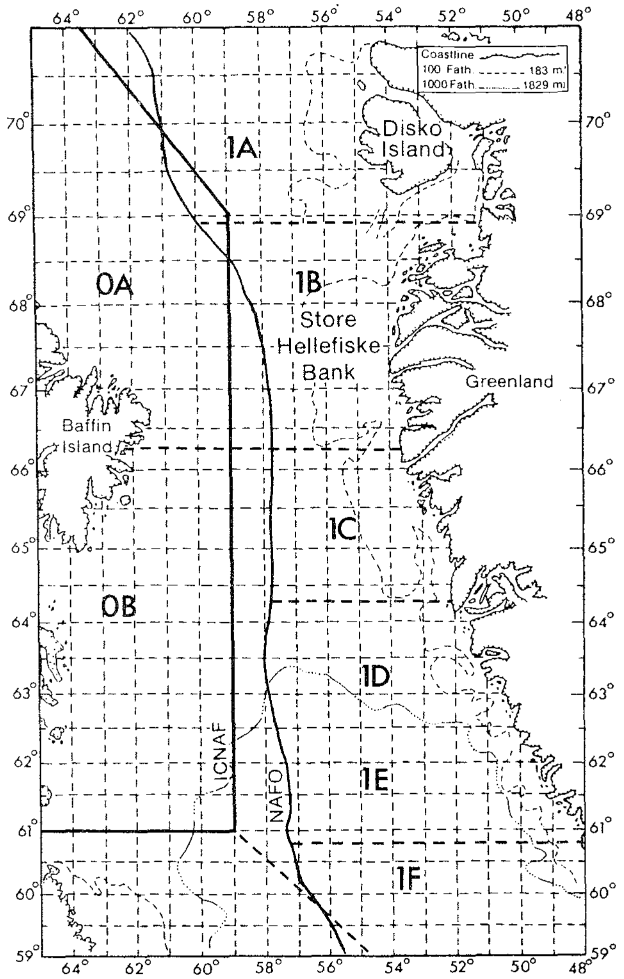

Fig. 1. Map of Subareas 0 and 1 showing the divisions and boundary lines mentioned in the text.

Of the species occurring on both sides of the new boundary, only three are at present of commercial interest, namely roundnose grenadier, *Coryphaenoides rupestris*, Greenland halibut, *Reinhardtius hippoglossoides*, and northern shrimp, *Pandalus borealis*. Early in 1980, Canada and the EEC agreed that objective scientific criteria should be established to aid in allocating the TACs for these joint stocks. Consequently, a working group of Canadian and EEC scientists was convened to review the existing data base. This paper is a review of the biology and fisheries for these species and represents the current state of knowledge of the stocks in Subareas 0 and 1.

Roundnose Grenadier

General biology

At least seven species of grenadier have been reported to occur in the Northwest Atlantic (Leim and Scott, 1966), but at present only one, the roundnose grenadier, *Coryphaenoides rupestris* Gunnerus, is considered to be available in significant quantities for exploitation. It is distributed on both sides of the North Atlantic in depths from 350 to 2500 m, and possibly deeper. In the Northwest Atlantic, the greatest concentrations are found in the area from the Davis Strait Ridge (66°N) southward to the Northeast Newfoundland Shelf (50°N).

Roundnose grenadier are long-lived, slow-growing and late-maturing fish (Savvatimsky, 1972), but they probably do not attain ages as great as redfish. Females are apparently larger at age than males. As is the case for redfish, there are two schools of thought concerning ageing of grenadier by otoliths and scales, one method yielding very different results from the other (Fig. 2). Studies are being pursued in an attempt to resolve these differences and to arrive at more accurate age determinations.

Very little is known about the reproductive biology of this species. Although mature individuals have been commonly found in the Northeast Atlantic (Marshall, 1965; Savvatimsky, 1969; Pechenik and Trayanovsky, 1970; Zakharov and Mokanu, 1970 (cited by Podrazhanskaya, 1971); Grigor'ev, 1972; Geistdoerfer, 1979), very few sexually mature specimens have been taken in the Northwest Atlantic. Podrazhanskaya (1971) supported the opinion of Zakharov and Mokanu that roundnose grenadier spawn in Icelandic waters and that eggs and larvae are carried passively by the Irminger Current to waters south of Greenland where the West Greenland Current then transports the young fish to the Baffin Island area. From there, the Polar and Labrador Currents carry the young fish to the area off Labrador and eastern Newfoundland, where they attain lengths of 40–50 cm before beginning the return migration. Supporting this opinion was the evidence that the largest fish were found off Iceland both during the study of Podrazhanskaya (1971) and those of others (e.g. Savvatimsky, 1969). However, Grigor'ev (1972), Savvatimsky (1972) and Parsons (1976) discounted this theory for several reasons. They pointed out that grenadiers are unlikely to be good swimmers due to the shape of their body. Grigor'ev (1972) observed the presence of juveniles (about 8 cm long) along the entire Canadian coast from Baffin Island to the Grand Bank. Savvatimsky (1972) and Parsons (1976) both reported that the incidence of maturing and sexually mature individuals increased with increasing depth in the Northwest Atlantic. The three authors concluded that the Northwest Atlantic and Northeast Atlantic stocks are separate and that the spawning concentrations in the Northwest Atlantic occur at depths greater than those presently fished. This conclusion was supported by Geistdoerfer (1979) from his own observations.

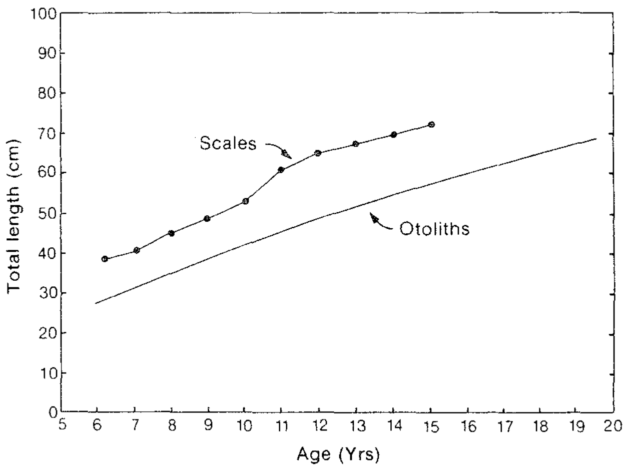

Fig. 2. Comparison of growth curves for roundnose grenadier in Subareas 0 and 1, based on ageing by scales (Kosswig, MS 1980) and by otoliths (von Bertalanffy curve from age-length data reported to NAFO by German Democratic Republic scientists).

The spawning time of roundnose grenadier is at present uncertain. Andriyashev (1954) suggested that they spawn in late autumn, and Savvatimsky (1969) noted the presence of spawning males and post-spawning females in October 1968. Podrazhanskaya (1971), on the other hand, noted that individuals in the area southeast of Iceland were in pre-spawning condition in May and in spawning and post-spawning conditions in August. Marshall (1965) concluded that spawning occurs both in spring and autumn, and this view was supported by Geistdoerfer (1979) based on recent observations. Phleger (1971), in discussing macrourids generally, suggested the presence of a specific spawning season. In contrast to the above, Grigor'ev (1972) concluded, on the basis of observations indicating the occurrence of individuals maturing at different times, that roundnose grenadier (at least in the Icelandic area) spawn intermittently throughout the year.

Feeding studies (Savvatimsky, 1969; Podrazhanskaya, 1971; Konstantinov and Podrazhanskaya, 1972; Geistdoerfer, 1976) indicate that roundnose grenadier are bathypelagic feeders, consuming a great variety of small crustaceans (copepods and euphausiids) as well as small fish, and often make significant vertical migrations from the bottom to feed. Such migrations are indicated by large midwater trawl catches in the commercial fishery (Savvatimsky, 1969). Roundnose grenadier appear to be heavily preyed upon at certain times by Greenland halibut (Konstantinov and Podrazhanskaya, 1972).

Savvatimsky (1969) reported that the sizes of roundnose grenadier in trawl catches sometimes showed a slight increase with increasing depth but never a decrease, and that the largest specimens were

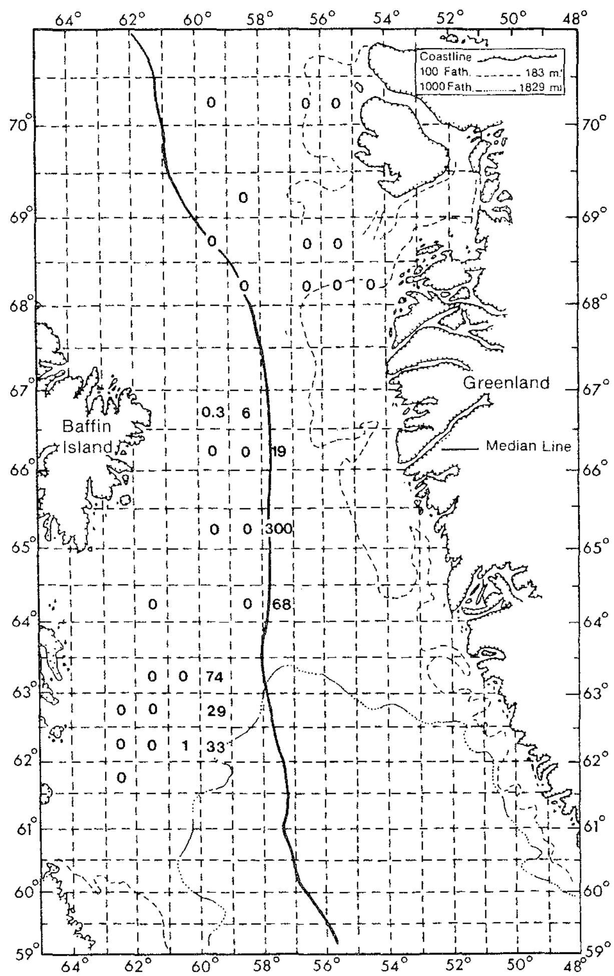

Fig. 3. Distribution of catches (kg per 30-min tow) of roundnose grenadier in Subareas 0 and 1 from *A. T. Cameron* cruises in 1958–73 (from Parsons, 1976).

taken at depths greater than 1000 m. Zilanov (MS 1976) suggested that they migrate to shallower depths from June to September for feeding and return to deeper areas later in the year. Recent Canadian data (unpublished) indicate that the larger fish are found at greater depths.

Distribution

Very little is known about the distribution of roundnose grenadier in Subareas 0 and 1, except that they inhabit depths from 350 to 2,500 m, and possibly deeper. Parsons (1976), in a review of roundnose grenadier catches by the Canadian research vessel *A. T. Cameron* in Subareas 0 and 1 during 1958–73, noted that the range of bottom temperatures was generally 3.5° to 4.5° C in areas were they were caught in quantity (Fig. 3). In 1977, the French research vessel *Cryos* conducted a stratified-random trawl survey in Subareas 0 and 1 (Minet *et al.*, MS 1978), and bottom temperatures at stations where roundnose grenadier were caught (Fig. 4) ranged from 3.0° to 4.4°C.

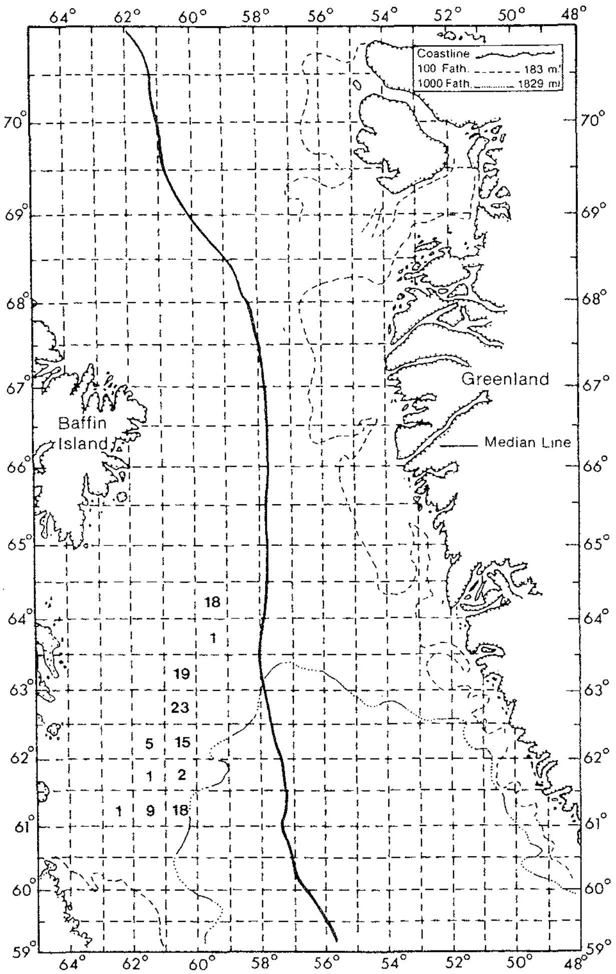

Fig. 4. Distribution of catches (kg per 30-min tow) of roundnose grenadier in Subarea 0 from the *Cryos* survey in October 1977.

There is no information available on spawning areas, distribution of eggs and larvae, and nursery areas for roundnose grenadier in the Northwest Atlantic.

Biomass estimates

Since no trawl survey has adequately covered all of Subareas 0 and 1, no realistic estimate of minimum trawlable biomass is presently available for roundnose grenadier in the whole area. However, Bormann (1977, MS 1978) carried out cohort analyses of the very limited data for the fishery in Subareas 0 and 1. Estimates of population numbers, derived from length and age compositions (1977 analysis) and age compositions (1978 analysis), ranged from 211 million fish with natural mortality (M) at 0.1 (1977 length analysis) to 1,052 million fish with M at 0.2 (1978 analysis). Application of a length-weight relationship for roundnose grenadier in Subareas 2 and 3 (Atkinson, MS 1980b) to the population length composition, derived by Bormann (1977) with M = 0.1, results in a biomass estimate of 36,500 tons. Because of the discrepancies in ageing, the conversion of number-at-age to weight-at-age is less reliable, but Bormann's (MS 1978) estimate of population numbers with M = 0.2 probably represents a biomass of about 86,000 tons. There is at present no basis for determining the relative distribution of these biomass estimates between Subareas 0 and 1.

TABLE 1. Nominal catch, standardized fishing effort and catch per unit effort for roundnose grenadier in Subareas 0 and 1.

Year	Catch (tons)	Effort (hours)	CPUE (t/hr)
1968	6,191	3,084	2.008
1969	2,710	1,390	1.949
1970	6,525	3,072	2.124
1971	8,304	7,639	1.087
1972	8,094	6,966	1.162
1973	4,884	4,687	1.043
1974	12,318	10,646	1.157
1975	4,953	7,056	0.702
1976	8,503	5,210	1.632
1977	2,935	2,003	1.465

Fishery trends

Historical catches and management strategy. A directed fishery for roundnose grenadier in Subareas 0 and 1 was first reported in 1968 when 6,000 tons were caught (Table 1). During 1968–77, nominal catches averaged about 6,500 tons annually, with a high of 12,000 tons in 1974 and lows of 3,000 tons in 1969 and 1977. Nominal catches for 1978 and 1979 have not been included, as Horsted (MS 1980) indicated that they are questionable due to misreporting.

A precautionary total allowable catch (TAC) of 10,000 tons was imposed in 1975, based on the upper limit of catches during 1968–73. The TAC was increased to 14,000 tons in 1976, based primarily on the high catch in 1974. The cohort analysis of Bormann (1977) indicated a yield of 8,000 tons at $F_{0.1}$, and the TAC was set at that level for 1977. More recent analyses (Bormann, MS 1978; Parsons *et al.*, MS 1978; Atkinson, MS 1979, MS 1980a) have consistently indicated a yield of about 8,000 tons, and the TAC has accordingly remained at that level up to 1981.

Fishing pattern and variability. Both catch and effort have fluctuated considerably since the commencement of the fishery (Table 1), due perhaps to variable environmental conditions (e.g. ice) and possibly to variable market conditions along with changing allocations and availability of other commercial species in recent years. Except in 1975, the catch rates, standardized by Atkinson (MS 1980a), were greater than 1.0 ton per hour trawling.

The breakdown of nominal catches by country and area (Table 2) is based on the original ICNAF boundary

TABLE 2. Nominal catches of roundnose grenadier in Subareas 0 and 1 (ICNAF boundary, 59°W) by country, 1968-77.

Sub-area	Country	Nominal catches (tons) by country 1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
0	German Dem. Rep.	—	—	—	—	206	—	—	—	—	47
	USSR	5,907	2,642	545	4,172	5,577	1,054	2,661	204	2,610	674
	Total	5,907	2,642	545	4,172	5,783	1,054	2,661	204	2,610	721
1	Denmark-G	—	—	—	—	—	11	5	6	1	10
	Fed. Rep. Germany	—	—	—	—	—	—	—	33	147	519
	German Dem. Rep.	168	—	—	14	—	1,835	2,804	186	181	14
	Poland	—	—	—	—	147	—	—	—	—	—
	USSR	116	68	5,980	4,118	2,164	1,984	6,848	4,524	5,564	1,671
	Total	284	68	5,980	4,132	2,311	3,830	9,657	4,749	5,893	2,214
0 + 1	Total	6,191	2,710	6,525	8,304	8,094	4,884	12,318	4,953	8,503	2,935
	% SA 1	4.5	2.5	91.6	49.8	28.6	78.4	78.4	95.9	69.3	75.4

line (59°W) between Subareas 0 and 1. USSR catches consistently accounted for more than 75% of the total nominal catches in Subareas 0 and 1 in all years except 1973 when the proportion was 62%. The relative percentages of the catches in Subareas 0 and 1 have varied considerably, particularly in the early years of the fishery, but the greater proportion of the catch was taken in Subarea 1 after 1972. The great variation in catches from Subarea 0 was probably due to variable ice conditions, as the trends in catch-per-unit-effort (CPUE) were quite similar for the two areas (Fig. 5).

In 1979, USSR scientists reassessed the distribution of their historical catches in Subareas 0 and 1, using 58°W as the boundary line which approximates more closely the new NAFO boundary than the original ICNAF boundary at 59°W (Table 3, Fig. 6). Both sets of data indicate a trend in recent years toward increased catches in Subarea 1, which does not appear to be related to CPUE trends (Fig. 5) but rather to a shift in directed fishing effort. The redistribution of catches to correspond approximately with the NAFO boundary indicated significant fishing activity in the area between 58°W and 59°W.

The percentage distribution of nominal catches, based on the 59°W boundary line, for Subarea 0 and the divisions of Subarea 1 are given in Table 4. In 1970-72, when USSR catches in Subareas 0 and 1 changed considerably upon adjustment from the 59°W boundary line to the 58°W line, relatively high percentages were taken in Div. 1D. This implies that the fishery in these years was concentrated in an area bounded by 62°30'-64°15'N and 58°00'W-59°00'W. In 1973 and later, there was an apparent shift in the fishery northward into Div. 1C and slightly eastward. The eastward movement may be postulated from the observation that during 1973-77 (except 1975) there was a reduced shift in USSR catch per area with changing boundary line (Table 3). Therefore, fishing was probably concentrated in the vicinity of, or just east of, the 58°W line. The probable location of the concentrated fishery for roundnose grenadier, as postulated above, is shown in Fig. 7.

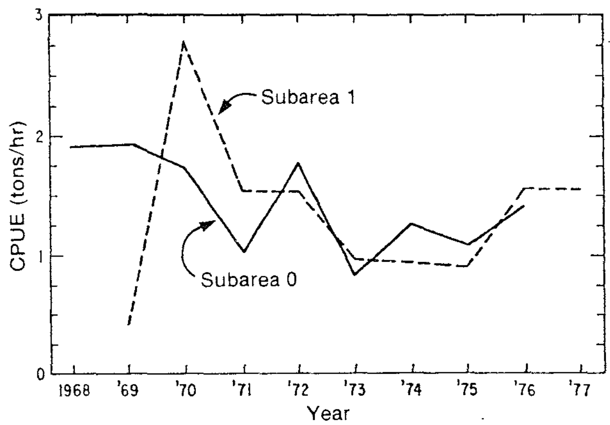

Fig. 5. Trends in catch-per-unit-effort in Subareas 0 and 1 during 1968-77, based on USSR otter-trawl catches (monthly for all tonnage classes) comprising more than 50% roundnose grenadier.

TABLE 3. Comparison of USSR catches of roundnose grenadier in Subareas 0 and 1, using 59°W and 58°W as the boundary between subareas.

Year	59°W boundary SA 0	SA 1	58°W boundary SA 0	SA 1	Total (0+1)
1968	5,907	116	6,007	16	6,023
1969	2,642	68	2,700	10	2,710
1970	545	5,980	6,525	—	6,525
1971	4,172	4,118	6,265	2,025	8,290
1972	5,577	2,164	7,371	370	7,741
1973	1,054	1,984	2,010	1,028	3,038
1974	2,661	6,848	2,808	6,701	9,509
1975	204	4,524	1,421	3,307	4,728
1976	2,610	5,564	3,942	4,232	8,174
1977	674	1,671	729	1,616	2,345
1968-72 (%)	60.2	39.8	92.3	7.7	—
1973-77 (%)	25.9	74.1	39.3	60.7	—

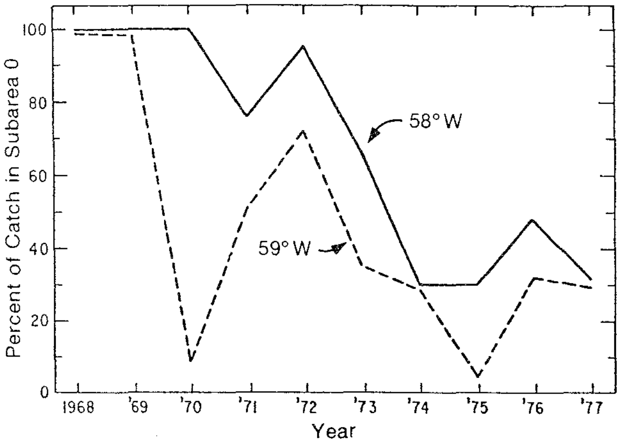

Fig. 6. Trends in percentage of USSR catches of roundnose grenadier in Subareas 0 and 1 that were taken in Subarea 0, based on the 58° W and 59° W boundary lines between these subareas.

TABLE 4. Percentage distribution of roundnose grenadier catches in Subarea 0 and by division in Subarea 0, using 59° W as the boundary line.

	Distribution of catches by area (%)						
Year	SA 0	1A	1B	1C	1D	1E	1F
1968	96.1	—	+	—	—	1.0	2.9
1969	97.5	—	—	0.5	2.0	—	—
1970	8.4	—	—	1.0	76.5	10.1	4.0
1971	50.2	—	1.3	3.4	45.1	—	—
1972	71.4	—	0.1	9.3	19.0	0.2	—
1973	21.6	+	1.5	72.0	0.7	4.2	—
1974	21.6	0.2	1.6	73.8	2.1	0.6	0.1
1975	4.1	0.1	1.3	87.2	6.8	0.5	—
1976	30.7	1.0	11.5	52.8	1.1	1.8	1.1
1977	24.6	0.4	0.9	58.3	9.8	1.6	4.4

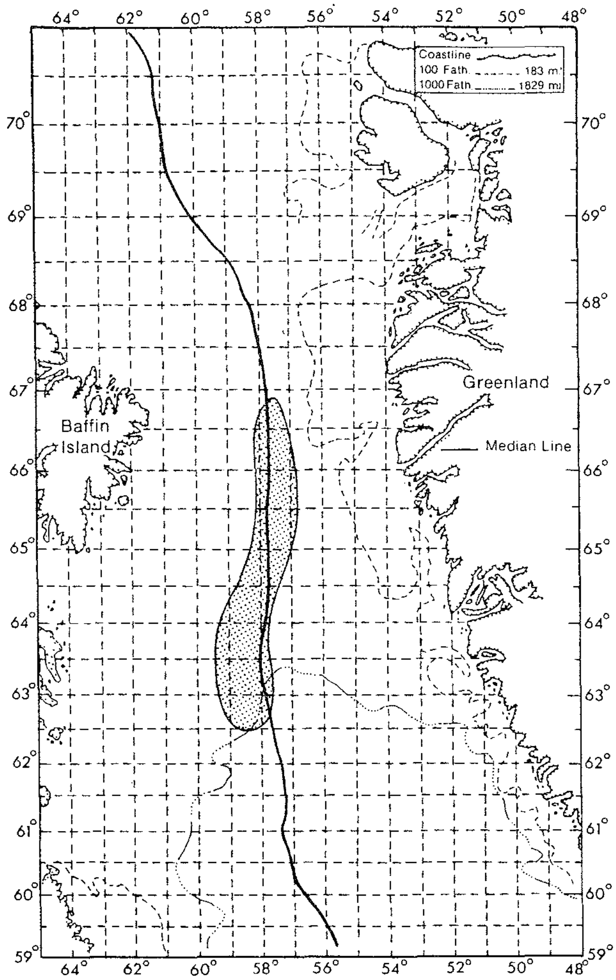

Fig. 7. Probable area of most concentrated fishery for roundnose grenadier in Subareas 0 and 1 during 1968-77.

Relation to other fisheries. Very little is known about the relationship of the grenadier fishery to other fisheries in the region. Because roundnose grenadier are found at greater depths than most other commercial fish, it may be postulated that the by-catch of other species is small with the exception of Greenland halibut. Studies conducted by USSR during 1967-74 in Subareas 0 and 1 at depths of 500-1,200 m (Zilanov, MS 1976) indicated that, in the directed fishery, roundnose grenadier consistently comprised more than 90% of the catches, with Greenland halibut being the major by-catch species. Konstantinov and Noskov (MS 1977) reported that more grenadier are caught when bottom temperatures are higher than the long-term average in Subarea 0, whereas the catch of Greenland halibut increases when temperatures are lower than the long-term mean.

Greenland Halibut

General biology

The Greenland halibut, *Reinhardtius hippoglossoides* Walbaum, exhibits amphiboreal distribution, being prevalent in the North Atlantic and North Pacific oceans but absent in Arctic waters which connect the two. Taxonomic studies, particularly by Hubbs and Wilimovsky (1964) based on meristic and morphometric characteristics, confirmed that the same species exists in both oceans, contrary to previous opinion (Andriyashev, 1954).

In the Northwest Atlantic, spawning seemingly takes place in spring in the warm deep water (to 675 m) between Baffin Island and West Greenland, south of Davis Strait Ridge at 67° N (Smidt, 1969). Eggs and small larvae are found at depths of 600-1,000 m, but the larvae later rise to the near-surface layer and are dispersed by currents which flow northward along West Greenland to the northern part of Davis Strait, from where some larvae are probably carried southward by the Polar Current to the banks off Baffin Island (Bowering, MS 1978).

Larvae 10-18 mm in length are usually bathypelagic and are typified by a yolk-sac which is about 25% of body length (Fig. 8). At this stage, an embryonic fin without rays extends from the top of the head dorsally

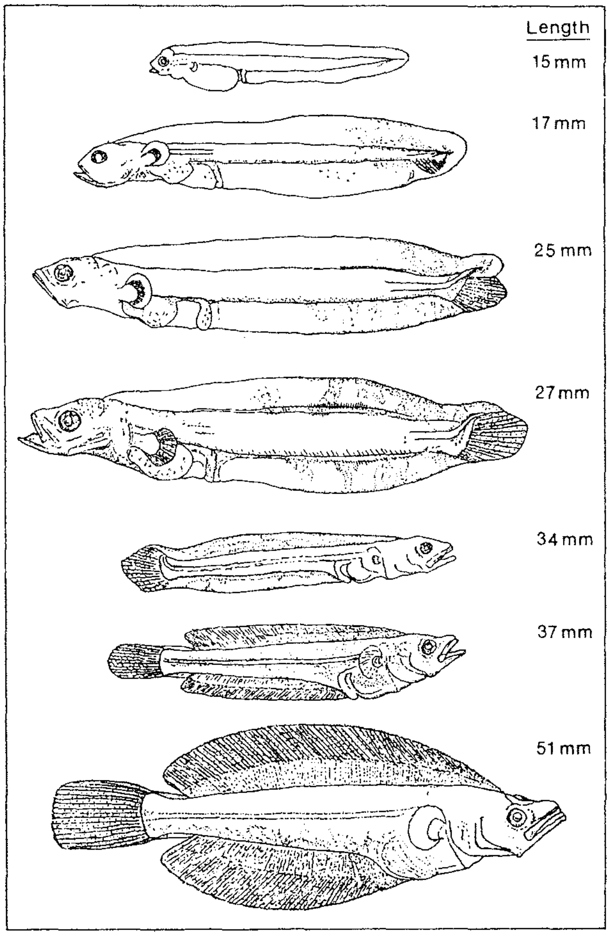

Fig. 8. Illustrations of various sizes of Greenland halibut larvae from Danish investigations in Davis Strait (from Schmidt, 1904).

and from the stomach ventrally to join in the caudal region. The bases of the pectoral fins are formed with embryonic fin rays present. When the yolk-sac is almost totally consumed, the hypural vertebra at the base of the caudal fin is formed and pigmentation occurs in the abdominal region as well as on the back (Jensen, 1935).

At 16-24 mm in length, the larvae become epipelagic. The body shape is still symmetrical but the left eye is noticeably higher than the right. Traces of the caudal fin are evident, but the pectoral fins have not developed more than was apparent in the bathypelagic stage and anal fins are not yet evident. In larger larvae (25-27 mm), the interspinous bones become noticeable and the dorsal and anal fins begin to develop. Pigmentation becomes more pronounced as the larva increases in size. In larvae larger than 30 mm, segmentation of muscles shows very clearly and pigmentation is distinct along the lines of the musculature. Pectoral fins are now fully developed from the bases to the outer margins. The number of vertebrae can almost be determined, but those at the extreme ends of the vertebral column are quite indistinct. The body is still symmetrical, but the left eye is slightly higher on the side of the head than in younger specimens.

In 70-75 mm larvae, the eye continues to move up the side of the head, and in one 79-mm specimen examined by Jensen (1935) it was situated at the top. Migration of the left eye appears to have been completed in 85-mm larvae, and the young of this size were found to have progressed from the pelagic to the bottom phase (Jensen, 1935). Also, the body is covered with scales, the teeth are completely formed, and pigmentation is evident on the well-formed fins. From this size until sexual maturity, pigmentation seems to be a major developmental process. Variation in pigmentation throughout the life of Greenland halibut is apparently associated with depth and light conditions of the habitat. Examples of seven different larval stages are illustrated in Fig. 8.

Greenland halibut, unlike other pleuronectiformes, have two specific features which can be attributed to their behavioral pattern: very distinctive pigmentation on the left side of the body gives them a very dark appearance, and the left eye does not "migrate" completely to the right side but stops at the top of the head providing a wide range of peripheral vision. The latter is considered to occur because the species is not as closely associated with the bottom as other flatfishes but spends considerable time in the upper water layers. Specific details on the behavior of Greenland halibut have been described by Schmidt (1904), Jensen (1935), Smidt (1969) and DeGroot (1970).

Length and age composition data for Greenland halibut in the Baffin Island-West Greenland area are very scanty. Some information is available from two stratified-random trawl surveys in Div. 0B off the southern part of Baffin Island, one by the French research vessel *Cryos* in October 1977 and the other by the German Democratic Republic research vessel *Ernst Haeckel* in October 1978. Age composition data from the 1977 survey (Fig. 9) indicated the dominance for both sexes of age-groups 3, 4 and 5 (1974, 1973 and 1972 year-classes respectively). Age-groups 1-19 were represented in the catches, but all fish older than 13 years were females. In the absence of age-composition data from commercial catches, it is not possible to know how these year-classes affect the commercial fishery. However, the same year-classes have recently been dominant in the Greenland halibut fishery off Labrador and eastern Newfoundland (Subarea 2 and Div. 3KL), where the TAC has been increased from 30,000 tons in 1979 to 35,000 tons in 1980 and to 55,000 tons in 1981 (Bowering, MS 1980).

The October 1978 survey in Div. 0B was primarily directed towards Greenland halibut and roundnose grenadier, and consequently depths less than 300 m

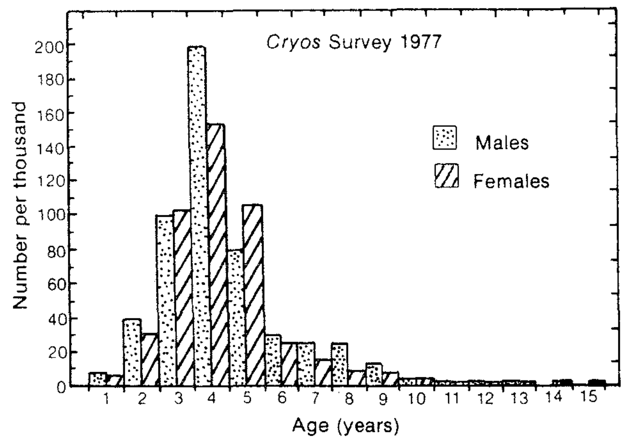

Fig. 9. Age compositions of Greenland halibut in Div. 0B from the *Cryos* survey in October 1977.

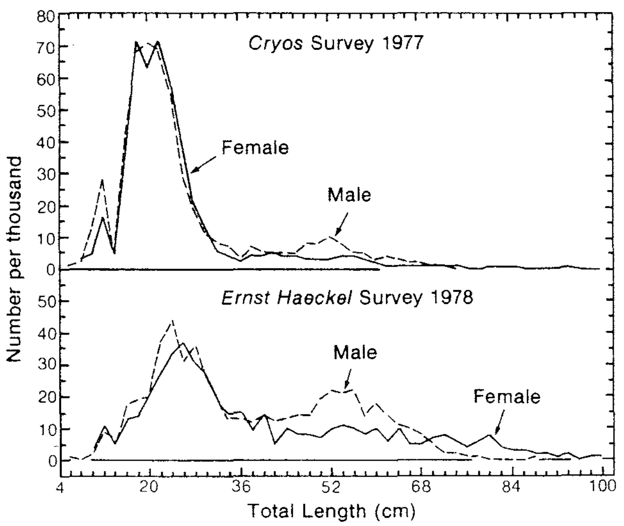

Fig. 10. Length compositions of Greenland halibut in Div. 0B from the *Cryos* survey in October 1977 and the *Ernst Haeckel* survey in October 1978.

were not fished. Age-composition data from this survey are not yet available, but the length compositions have the same general pattern as those from the October 1977 survey, taking into account a year's growth of the dominant age-groups between surveys (Fig. 10). The lower proportion of the dominant age-groups in the 1978 survey is probably due to the absence of sampling shallower depths where the younger fish are usually more plentiful. The dominance of males in the mid-range size groups from both surveys may indicate a spawning migration, as this area is near the spawning grounds.

Average length-at-age data for males and females from the October 1977 survey (Fig. 11) indicate similar growth up to age 9, after which females apparently grow faster than males. This divergence in growth after age 9 is probably the result of earlier maturation in

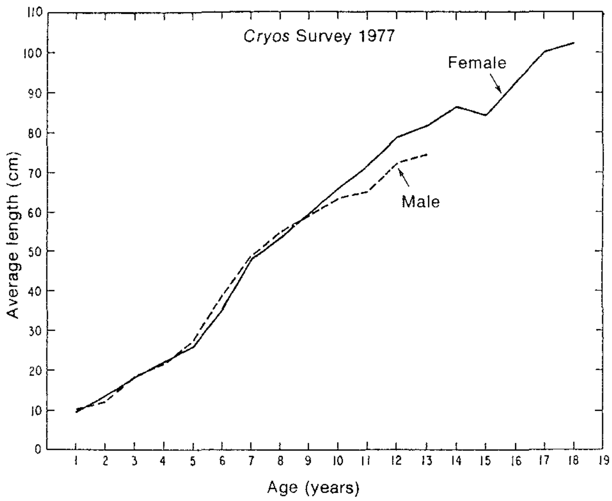

Fig. 11. Mean length at age for male and female Greenland halibut in Div. 0B from the *Cryos* survey in October 1977.

males than in females, whereby energy is diverted from growth to the formation of sexual products (Alm, 1959) at an earlier age in males. Comparison of mean length-at-age data from Div. 0B with linear growth patterns of Greenland halibut in Subareas 2-4 (Bowering, 1978) indicates a decline in growth from north to south, with the data for Div. 0B being similar to length-at-age values calculated from the regression lines for Subarea 2 and Div. 3K (Fig. 12).

As noted previously, Greenland halibut spawn in deep warm water in Davis Strait. Templeman (1973) suggested that higher temperatures aid ovarian and embryonic growth, which could explain why mature Greenland halibut close to spawning condition are extremely uncommon in the coastal bays and fjords and on the continental shelf off eastern Canada. Bowering (MS 1977), from observations in Subareas 2 and 3, noted that males become sexually mature at an earlier age than females but that it was difficult to determine precisely the average length or age at sexual maturity of the latter because mature females in spawning condition have not been observed, due possibly to the time of the year when the surveys were carried out. However, from a maturity ogive based on visual classification of ovaries in Greenland halibut caught during the *Cryos* survey in October 1977 in Div. 0B (Fig. 13A), the estimated length at 50% maturity is about 73 cm. From the average length-at-age data for females in Fig. 11, this length indicates an approximate age at 50% maturity of 11 years.

Because Greenland halibut in Subarea 2 appeared to be so large and old before becoming sexually mature, it was suspected that the visual classification of ovaries of large females as immature may be misleading if the residual eggs are absorbed very rapidly after spawning and the ovary assumes an immature

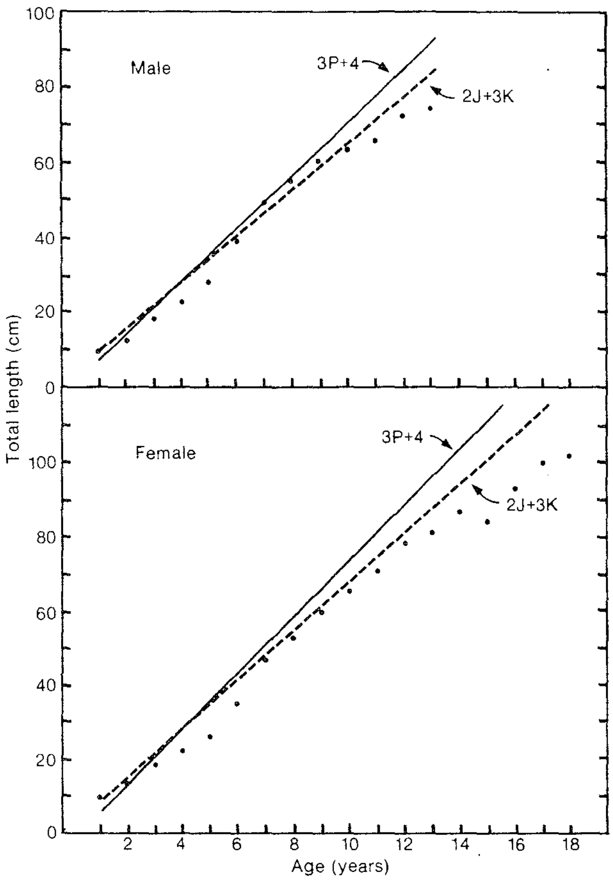

Fig. 12. Comparison of mean length-at-age data for males and females (from Fig. 11) with linear growth relationships for Greenland halibut in the Labrador-Newfoundland area (based on data from Bowering, 1978).

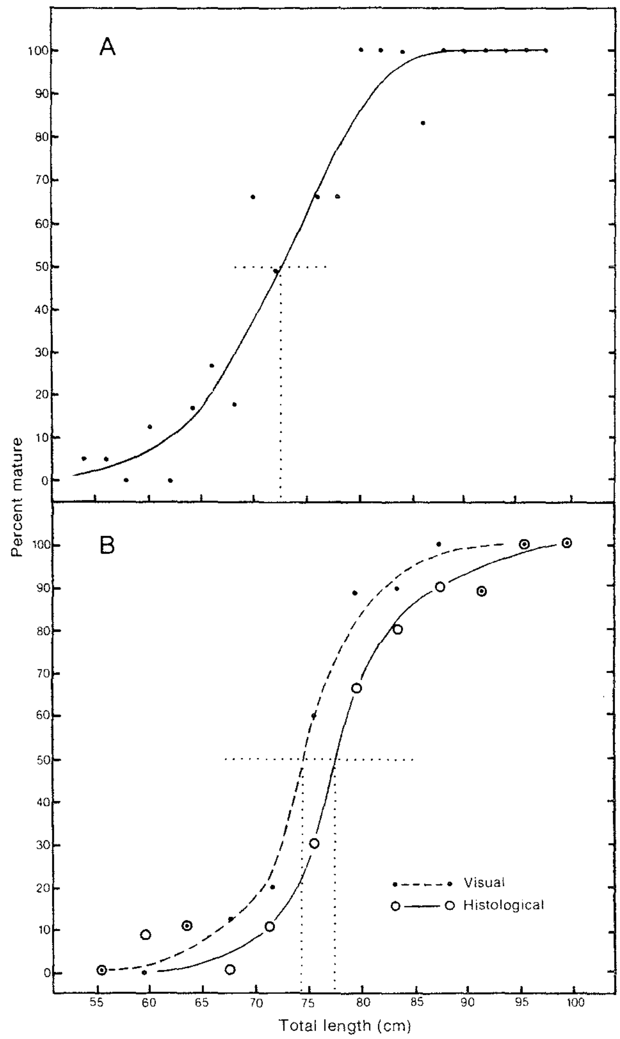

Fig. 13. Maturity ogives for female Greenland halibut from (**A**) the *Cryos* survey in Div. 0B in October 1977, and (**B**) study by Walsh and Bowering (1981) on specimens taken in Subarea 2 in August 1979.

appearance (Walsh and Bowering, 1981). However, a comparison of histological and visual observations on ovaries collected in August 1979 (Fig. 13B) indicated only a slight difference in the maturity ogives. An interesting feature of the maturity data from Div. 0B and Subarea 2 is the similarity of the maturity ogives derived from visual examination of ovaries.

The only information on the feeding of Greenland halibut in Subareas 0 and 1 is that reported by Smidt (1969), who observed that the northern shrimp, *Pandalus borealis*, was the most important food item in stomachs collected at various inshore locations of West Greenland during 1941-61 (Table 5). He also noted that the largest concentrations of Greenland halibut in Subarea 1 were located in the same areas (offshore and in the fjords) where shrimp concentrations were found. A variety of other crustaceans and fish was also commonly found in the stomachs. According to Lear (MS 1970), the primary food component of Greenland halibut in Subarea 3 is fish, mainly capelin. In general, the diet of Greenland halibut appears to be highly variable and dependent on the concentration of different prey species in different parts of its range.

Distribution

Exploitable stock. Recent information on the distribution of Greenland halibut in the Davis Strait region is based mainly on otter-trawl surveys by French research vessels. Data from a stratified-random survey in Div. 0B by the *Cryos* in October 1977 indicate widespread distribution of the species throughout the area (Fig. 14). Comparison of average catches per set, in numbers and weight, indicates that smaller fish were more prevalent at shallower depths along the western and particularly in the northern parts of the surveyed area, whereas the larger fish occurred at greater

TABLE 5. Incidence of various food items in the stomachs of Greenland halibut from Disko Bay and several fjords at West Greenland, 1946-61. Percentages relate to the numbers of stomachs with food (from Smidt, 1969).

Food items	Frequency of occurrence (%)					
	Julianehaab	Godthaab	Holsteinsborg	Disko Bay	Umanak	Total
Crustaceans	66	55	100	81	92	76
Pandalus borealis	44	39	59	64	46	51
Other prawns	4	6	2	1	13	4
Borcomysis	15	—	81	21	38	29
Euphausiids	17	—	20	4	—	10
Various Crustaceans	—	11	12	4	—	6
Other Invertebrates	3	2	—	5	—	2
Squids	3	2	—	5	—	2
Various	1	2	—	1	—	1
Fishes	41	47	3	23	12	28
Mallotus villosus	30	11	—	7	—	13
Lycodes sp.	4	14	—	3	—	5
Various	7	23	3	13	12	11
Stomachs examined	219	665	84	200	81	1,249
Stomachs with food	98	62	66	75	24	325
Fish length (cm)	20-94	31-118	30-80	20-60	50-98	20-118
Fishing depth (m)	240-620	300-580	330-350	260-400	115-700	115-700

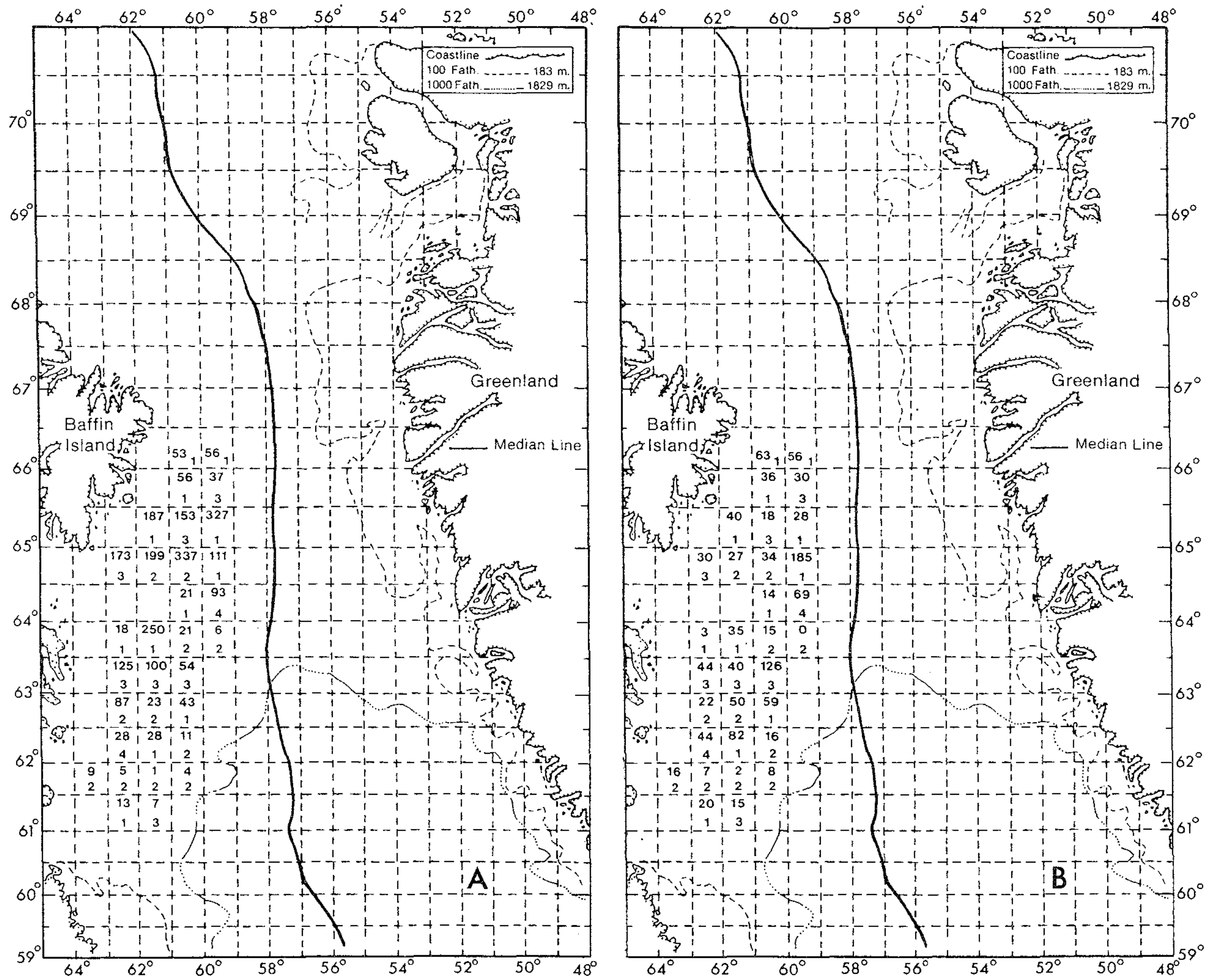

Fig. 14. Distribution of Greenland halibut in Subarea 0 from the *Cryos* survey in October 1977, as indicated by (**A**) number per 30-min tow, and (**B**) kg per 30-min tow. Values in each rectangle are average catch (above) and number of tows (below).

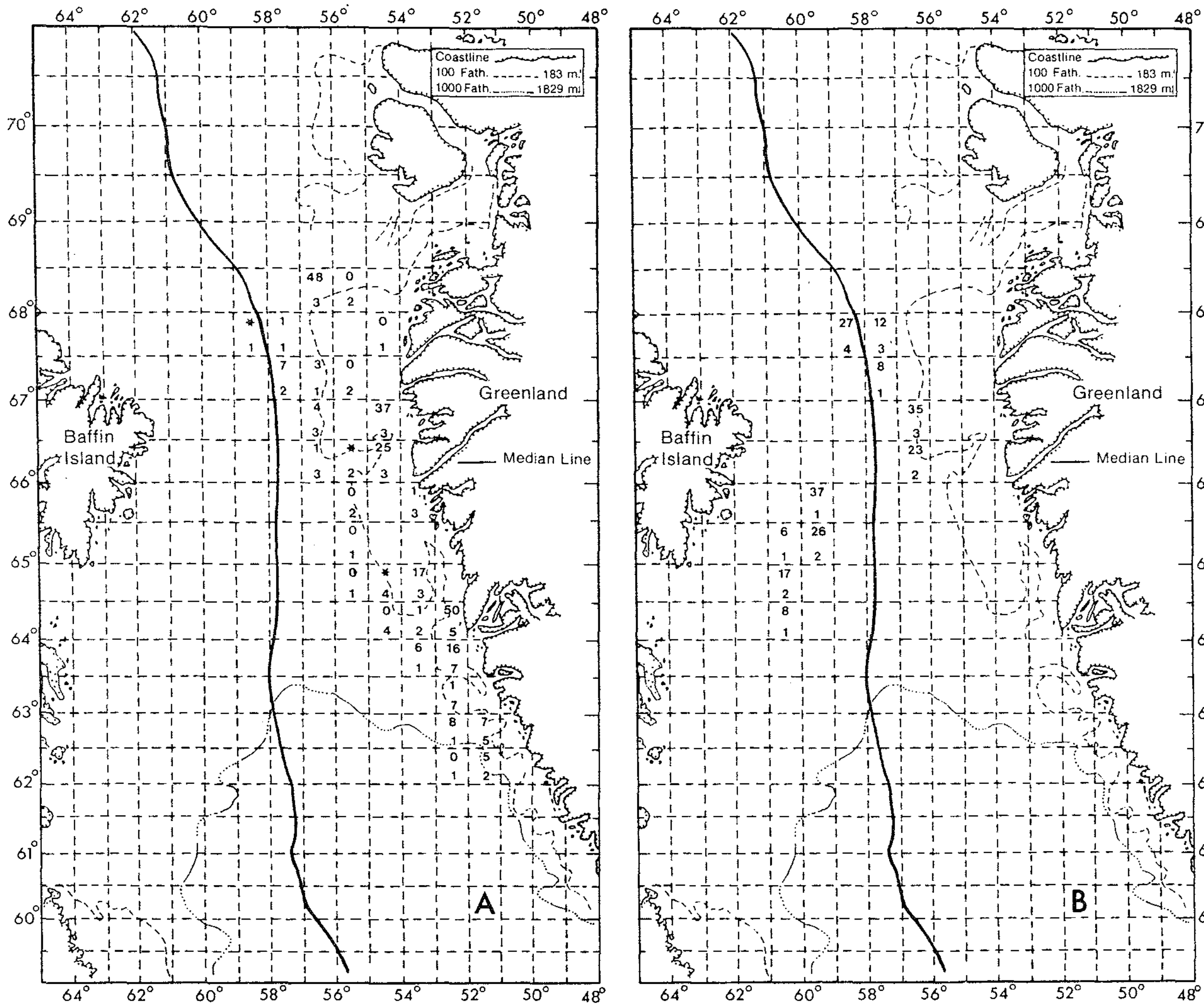

Fig. 15. Distribution of Greenland halibut in Subareas 0 and 1 (kg per 30-min tow) from the *Thalassa* surveys during (**A**) July-August 1970, and (**B**) September-October 1979. Values in each rectangle are average catch (above) and number of tows (below).

depths mainly in the southern part of the area. Bathymetric distribution of catches (mean number and weight per 30-min set) during the October 1977 survey was as follows:

	Mean catch per 30-min set by depth (m)					
	≤100	101–150	151–200	201–300	301–500	501–700
Number	18.0	135.9	163.4	47.6	17.2	31.4
Weight (kg)	3.0	35.6	33.2	45.4	36.6	47.0

A survey in Subarea 1 by the *Thalassa* in July-August 1970 (Fig. 15A) indicated that Greenland halibut were distributed widely off West Greenland, with the largest catches near the coast except for one on the northern slope of Store Hellefiske Bank. The prevalence of Greenland halibut near the coast at this time suggests that migration from the offshore spawning grounds to the fjords occurs as indicated by Smidt (1969). The distribution of Greenland halibut taken as by-catch in a shrimp survey by the *Thalassa* in September-October 1979 (Fig. 15B) indicated greater abundance along the western slope of Store Hellefiske Bank than in the 1970 survey. This may indicate a larger stock in recent years or more efficient operation of the larger shrimp trawl in catching Greenland halibut than the smaller otter-trawl used in the earlier groundfish survey or the formation of pre-spawning concentrations or a combination of all three factors.

There is a distinct change in the size composition of Greenland halibut by depth, as indicated in Fig. 16 and 17. Pre-recruit sizes (<40 cm) predominate at shallow depths (201-400 m) and the larger sizes are relatively more abundant at greater depths. Because of this, the commercial fishery usually takes place in the deepwater area between Baffin Island and West Greenland.

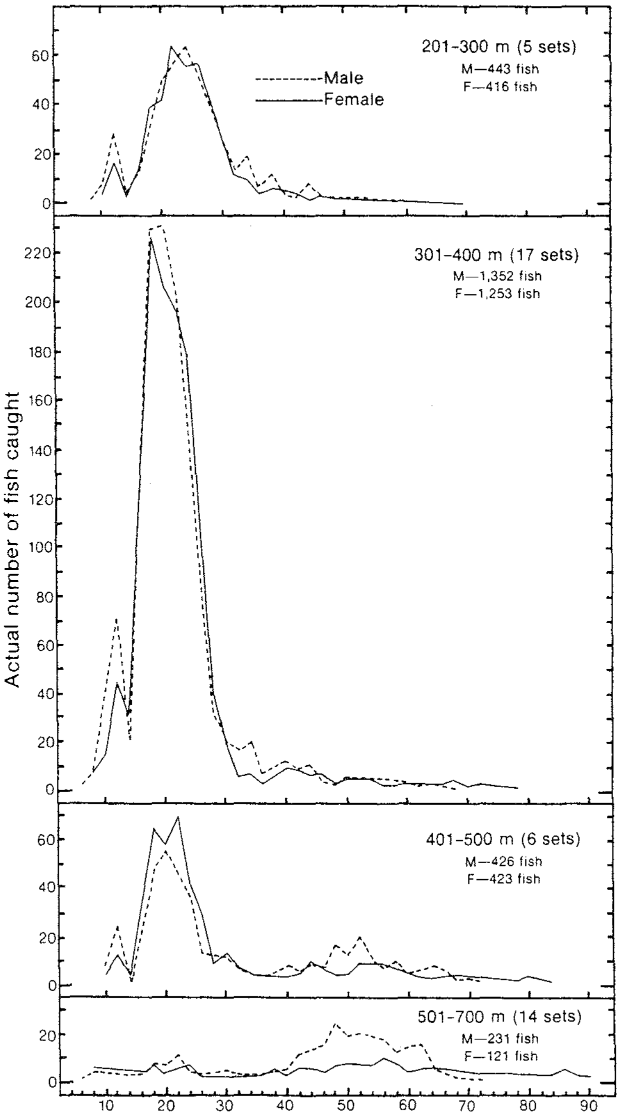

Fig. 16. Length composition of Greenland halibut by depth in Div. 0B from the *Cryos* survey in October 1977.

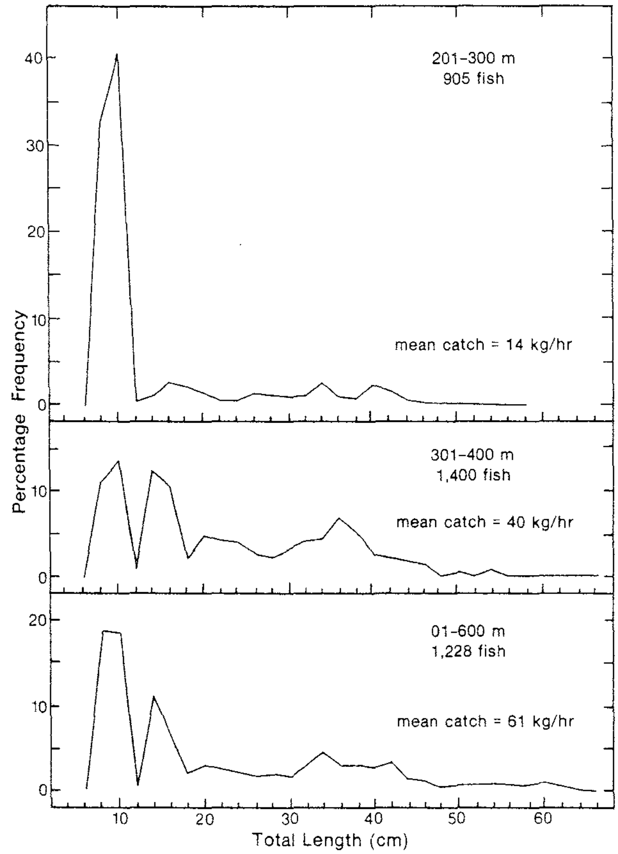

Fig. 17. Length frequencies of Greenland halibut by depth in Div. 1B from the *Thalassa* survey in September-October 1979.

Eggs and larvae. As indicated earlier, spawning and the hatching of eggs are believed to occur in the deep warm water south of the Davis Strait Ridge. Upon rising to the near-surface layer, the larvae are carried by currents and become distributed along the west coast of Greenland (Fig. 18) during the summer (Smidt, 1969). It is likely that there are several areas along the coast where the young settle to the bottom in the autumn and live for some time before migrating into deeper water and into the fjords. There is no information on the distribution of Greenland halibut eggs and larvae off Baffin Island.

Nursery areas. According to Smidt (1969), young (age 1) Greenland halibut are very abundant west of Disko Bay, and the vast shallow-water area (200-250 m) northwest, west and southwest of Disko Bay can be regarded as important nursery grounds from which Greenland halibut recruit to the fishery in Disko Bay, Umanak district and more northerly districts of West Greenland. It is also likely that large numbers of these young fish move southwestward toward Baffin Island and spend much of their early life in the northern part of Div. 0B. This was evident from the *Cryos* survey in October 1977 when many catches consisted of large numbers of fish less than 35 cm in length (Fig. 19). Another nursery ground is located in the coastal waters of Godthaab district (about 200 m deep), and it can be assumed that there are several nursery grounds along southwestern Greenland from which the fjord populations are recruited, but there is little concrete evidence to support this assumption. However, the size composition of Greenland halibut in shrimp-trawl catches from coastal and fjord areas at different depths tend to show a gradual migration from shallow coastal areas to the inner fjord areas and to deepwater areas offshore during their life cycle (Smidt, 1969).

Biomass estimates

Estimates of trawlable biomass of Greenland halibut are not available for the whole of Subareas 0 and 1.

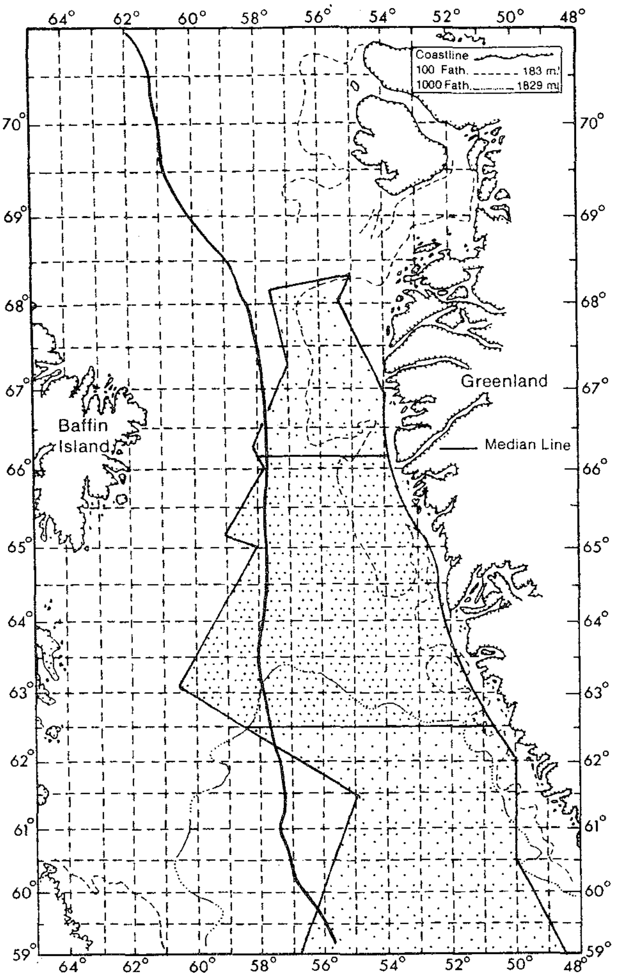

Fig. 18. Occurrence of Greenland halibut larvae from Danish investigations during 1908-64 (from Smidt, 1969).

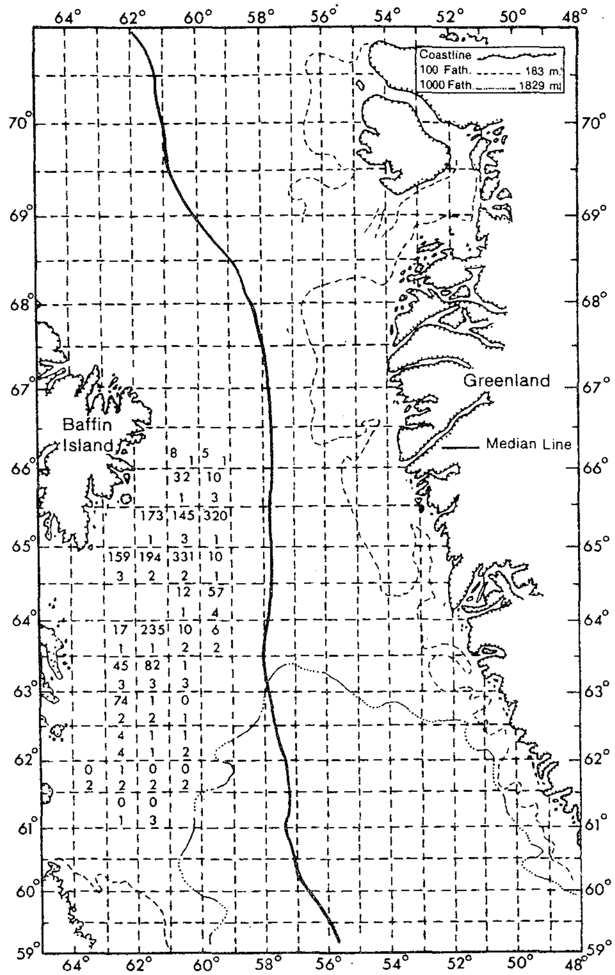

Fig. 19. Distribution of juvenile Greenland halibut (<35 cm long) in Div. 0B from the *Cryos* survey in October 1977. Values in each rectangle are average number per 30-min tow (above) and numbers of tows (below).

However, biomass estimates for Div. 0B have been calculated from data obtained during stratified-random trawl surveys by the *Cryos* in October 1977 and the *Ernst Haeckel* in October 1978. Biomass estimates by depth from the *Cryos* survey (Forest *et al.*, MS 1978) are as follows:

	Depth range (m)						
	≤100	101-150	151-200	201-300	301-500	501-700	Total
Area (sq. mi.)	630	6,314	7,728	7,648	5,930	2,054	30,304
Biomass (tons)	130	15,432	16,722	23,823	14,874	6,619	77,600

The estimate of 77,600 tons represents the minimum trawlable biomass for an area of about 30,300 square nautical miles in Div. 0B, with the greatest biomass in the depth range of 201-300 m. The *Ernst Haeckel* survey in 1978 was conducted in Div. 0B in depths greater than 300 m, and the data yielded a minimum trawlable biomass estimate of 90,000 ± 5,000 tons for an area covering 20,078 square nautical miles. These estimates were based on the old ICNAF boundary line between Subareas 0 and 1, and consequently they are underestimates of biomass in NAFO Div. 0B.

Fishery trends

Historical catches and management strategy. Nominal catches of Greenland halibut in Subareas 0 and 1 increased rapidly to about 14,000 tons in 1972 and, except for a decline to 9,600 tons in 1973, reached 25,000 tons in 1975 (Table 6). Subsequently, the total catch in both subareas declined to a level of about 12,000 tons in 1977 and 1978. Over the 1969-78 period, USSR vessels took 80% and 48% of the total catches in Subareas 0 and 1 and Danish vessels accounted for 20% and 40% respectively. Faroese vessels accounted for the largest share of the Danish catch in Subarea 0, whereas the Greenland inshore fishery accounted for most of the Danish catch in Subarea 1. There was considerable variation in the relative proportions of the annual catches taken in Subareas 0 and 1, but the

TABLE 6. Nominal catches of Greenland halibut in Subareas 0 and 1, 1969-78.

Sub-area	Country	Nominal catches (tons)										
		1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	Total
0	Denmark (F)	—	—	—	—	—	—	825	916	930	550	3,221
	Denmark (G)	—	—	—	—	912	4	288	—	—	—	1,204
	German Dem. Rep.	—	—	—	563	—	—	—	—	240	—	803
	Norway	—	—	—	—	—	24	—	—	—	146	170
	USSR	813	215	1,298	9,397	1,218	861	455	3,990	2,967	—	21,214
	Total	813	215	1,298	9,960	2,130	889	1,568	4,906	4,137	696	26,612
1	Denmark (F)	1	—	38	442	—	—	—	34	77	2	594
	Denmark (G)	1,477	1,212	1,159	2,950	3,655	4,054	3,436	3,546	6,110	5,985	33,584
	Denmark (M)	—	—	—	20	5	—	2	3	—	—	30
	Fed. Rep. Germany	68	13	16	128	65	2	24	93	590	4,965	5,964
	German Dem. Rep.	—	—	112	—	754	601	56	160	335	—	2,018
	Norway	19	—	1,168	12	35	12	37	7	11	5	1,306
	Poland	1	—	—	135	—	—	—	—	—	—	136
	Portugal	—	—	—	—	—	32	41	95	—	—	168
	United Kingdom	—	—	—	—	1	18	9	—	—	—	28
	USSR	123	444	545	245	2,913	8,650	19,775	6,944	1,389	—	41,028
	Total	1,689	1,669	3,038	3,932	7,428	13,369	23,380	10,882	8,512	10,957	84,856
0+1	Total	2,502	1,884	4,336	13,892	9,558	14,258	24,948	15,788	12,649	11,653	111,468
	Subarea 0 (%)	32.5	11.4	29.9	71.7	22.3	6.2	6.3	31.1	32.7	6.0	23.9

percentages of the total catch during 1969-78 were 24% and 76% respectively. However, the statistics given in Table 6 are based on the ICNAF boundary between Subareas 0 and 1. The establishment of the NAFO boundary line in 1979 to correspond to the median line separating the fishing zones of Canada and Greenland means that Subarea 0 is somewhat larger and Subarea 1 smaller by the same area than the sizes of these subareas under the ICNAF regime.

A management regime was established for Greenland halibut in Subareas 0 and 1, with a precautionary TAC of 20,000 tons in 1976 and 1977 (in the absence of adequate data for assessment). The TAC was increased to 25,000 tons in 1978, as a result of USSR biomass estimates from a reserch vessel survey which indicated a fairly large stock of Greenland halibut in the area. Although an analytical assessment of the stock was undertaken in 1978 (Chumakov *et al.*, MS 1978), there was little evidence to support the input parameters, and the TAC has remained at 25,000 tons for 1979, 1980 and 1981.

Fishing patterns and variability. In the absence of a time series of catch-per-unit-effort data, there is little information on variation in distribution and abundance of the exploitable stocks of Greenland halibut other than what can be seen from the time series of nominal catches (Table 6). Following the change in the boundary line between Subareas 0 and 1 in 1979, USSR scientists reassessed their historical catches in these subareas, using 58°W as the line which closely approximates the NAFO boundary in the area between Baffin Island and West Greenland where most of the fishing activity occurred. A comparison of USSR catches of Greenland halibut relative to the 59°W and 58°W lines is given in Table 7. The year-to-year variation in the relative proportions of the catches in the two areas and the 11% shift in the proportions of the catch between subareas implies that commercial concentrations occurred in the boundary area south of 69°N.

TABLE 7. Comparison of USSR catches of Greenland halibut in Subareas 0 and 1, using 59°W and 58°W as the boundary between subareas.

Year	59°W boundary		58°W boundary		Total
	SA 0	SA 1	SA 0	SA 1	(0+1)
1969	813	123	931	5	936
1970	215	444	655	4	659
1971	1,298	545	1,576	267	1,843
1972	9,397	245	9,453	189	9,642
1973	1,218	2,913	2,151	1,980	4,131
1974	861	8,650	910	8,601	9,511
1975	455	19,775	2,160	18,070	20,230
1976	3,990	6,944	6,972	3,962	10,934
1977	2,967	1,389	3,364	992	4,356
1978	—	—	—	—	—
Total	21,214	41,028	28,172	34,070	62,242
Percent	34.1	65.9	45.3	54.7	100

Northern Shrimp

General biology

The northern shrimp, *Pandalus borealis* Krøyer, first matures and functions as a male, then undergoes a short transitional phase, and subsequently spends the rest of its life as a female. This pattern of sex reversal is termed "protandric hermaphroditism". Spawning occurs from July to October, the duration varying from year to year. The egg-bearing period, when females are termed ovigerous or berried, lasts until April-May when hatching occurs. A first-time spawner produces approximately 1,300 eggs. The larvae are planktonic, and after 2-3 months the juveniles settle to the bottom in relatively shallow water. Males mature at age 3 years, and the transition to females occurs at age 4 or 5. Subtle variation in the life cycle of northern shrimp in different parts of West Greenland has been described by Horsted (1978b). Like other crustaceans, the northern shrimp undergoes stepwise growth which occurs in the short after ecdysis (shedding of the old shell) when the animal is termed "soft-shelled". Growth is affected by water temperature, being slower in the northern areas than for the same species living in warmer water of more southerly latitudes. Also, maturation tends to take longer and longevity is increased in the northern areas. Ecdysis cannot occur while the animal is ovigerous. Since females produce a new batch of eggs only a few months after the previous batch was hatched, little time is available for growth. This results in an accumulation of year-classes at the larger size-groups of the length-frequency distribution. Ageing of shrimp by conventional methods is not possible because ecdysis removes any structures that might indicate annual growth increments. The age-groups have been interpreted from modes in length frequencies (e.g. juveniles, males, and a composite of females).

Natural mortality is believed to be high for pandalids generally. Contributing to this for *P. borealis* in northern areas (Subareas 0 and 1) are several predators, mainly Greenland halibut and Atlantic cod, *Gadus morhua*. Although Atlantic redfish, *Sebastes* sp., frequently occur in the same habitat as northern shrimp, they are not considered to be as significant a predator as the two above-mentioned species.

The varied diet of *P. borealis* includes pelagic crustaceans, polychaetes, foraminifera, radiolarians and detritus. Their parasites include other crustaceans (mainly isopods) which may reduce their reproductive potential. Certain protozoans may also render the eggs to be non-viable and cause a breakdown of muscle fibers.

Distribution

Exploitable biomass. When considering the distribution of northern shrimp in Subareas 0 and 1 (Fig. 20), two stock complexes are recognized: (a) the traditionally-fished offshore and inshore stocks of West Greenland, and (b) the unexploited stocks off Baffin Island, described by Minet *et al.* (1978). The offshore grounds of the former overlap both subareas with the greater portion in Subarea 1, whereas the latter lie exclusively in Subarea 0 and have not been included in assessments or in management measures.

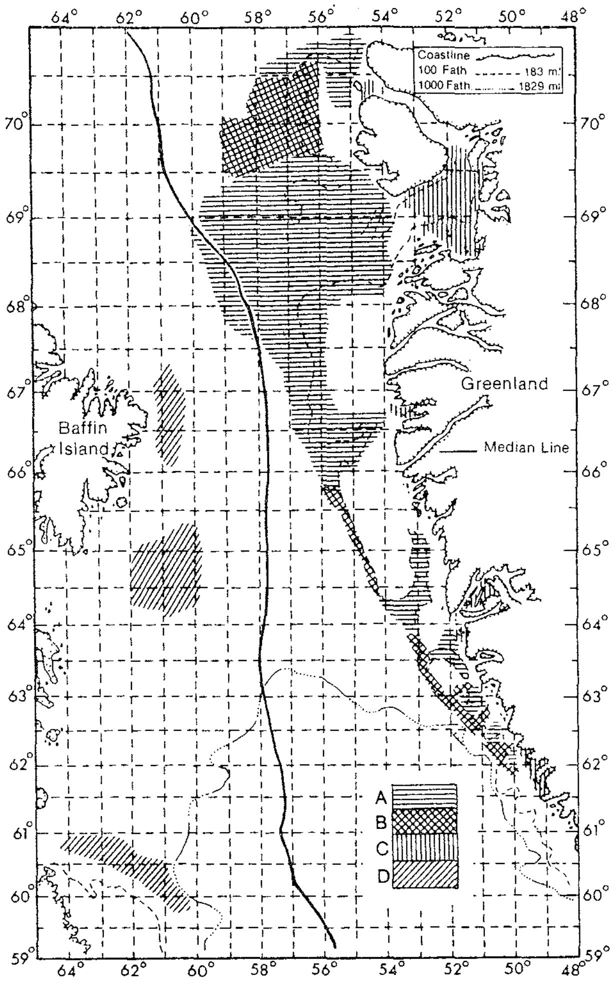

Fig. 20. Distribution of shrimp grounds in Subareas 0 and 1. (A = offshore grounds; B = potential grounds and nursery areas; C = major inshore grounds; D = areas where shimp have been found off Baffin Island.)

In the West Greenland offshore area, shrimp are generally distributed in depths of 150-500 m at temperatures from 1° to 4° C, the areas of greatest abundance being in Div. 1A, 1B and 0A. In 1979, shrimp were most abundant on the northwestern slope of Store Hellefiske Bank between 200 and 400 m (NAFO, 1980). Previous data for the offshore grounds in Div. 1A, except for the area immediately adjacent to Div. 1B, indicated low catch rates and small shrimp, but fishing in 1980 on previously unexploited grounds yielded catch rates as high as those in Div. 1B. Approximately 13% of the fishable shrimp grounds in the West Greenland area are located within 12 nautical miles of the coast.

Variation in size composition with depth seems to be characteristic of the shrimp populations in both the offshore and inshore areas. Trawl surveys of the offshore grounds in 1979 clearly showed a dominance of small shrimp (immature and male) in shallower depths (150-200 m), whereas males and large females predominated in greater depths (NAFO, 1980). Size compositions by depth of shrimp during a survey in Div. 1B

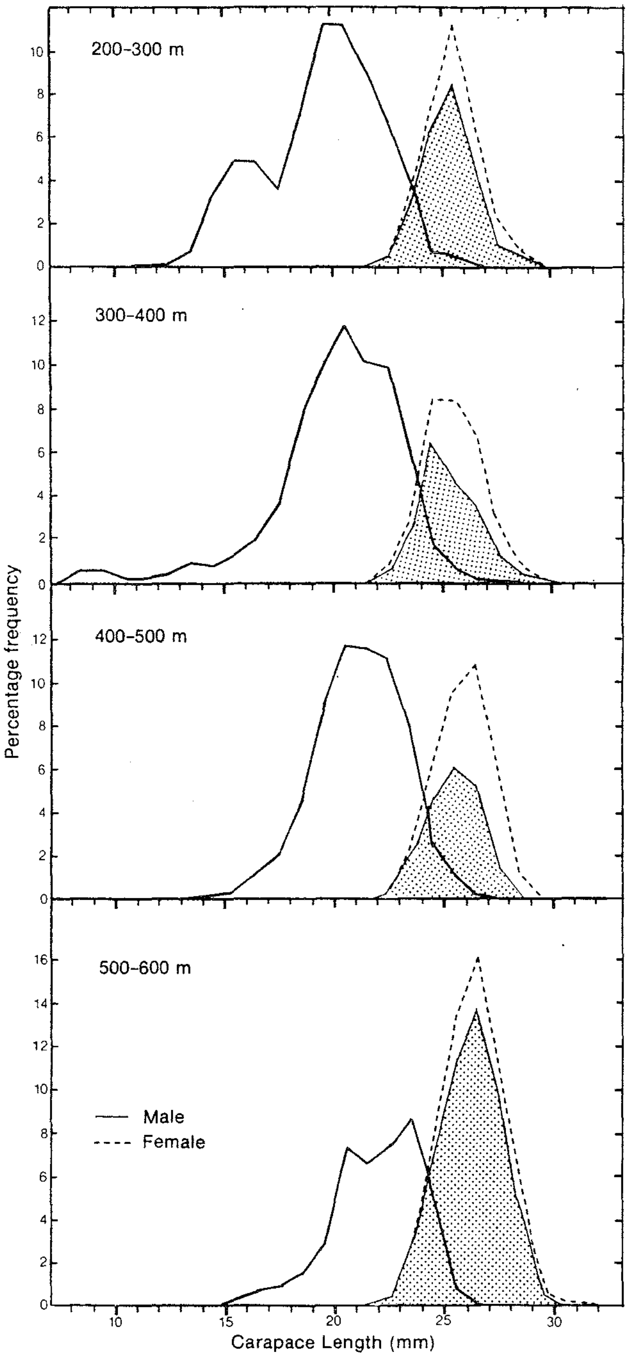

Fig. 21. Length composition of shrimp by sex and depth in Div. 1B in 1979 (from Fréchette and Dupouy, MS 1979).

in the autumn of 1979 (Fréchette and Dupouy, MS 1979) are shown in Fig. 21. The modes of these frequencies can be interpreted as age-classes.

Horizontal migration of shrimp has not been well studied. Considerable variation in daily catch rates indicates that movements may be extensive in a given area over a short period. However, these changes in abundance may be due to a variety of factors, such as fishing pressure, light intensity, currents, water temperature, etc. There is general concensus that females move to shallow areas prior to and during the period of hatching.

Shrimp are known to undertake diel vertical migrations, staying close to the bottom during daylight hours and rising vertically in the water column to considerable distances at night. This pattern of migration changes as the amount of sunlight varies on a seasonal basis. Figure 22 illustrates seasonal patterns of diel movement from commercial fishery statistics (Carlsson *et al.*, 1978). Vertical migration patterns are important when designing surveys to obtain biomass estimates, as such estimates have to be adjusted for diel variation.

Spawning and nursery areas. In other *P. borealis* stocks, egg-bearing females are believed to migrate to shallow areas where the larvae are released, but this behavior has not been elucidated for the offshore stock at West Greenland. Evidence of differential size distribution by depth, as noted above, indicates the existence of nursery grounds over most of the West Greenland area in relatively shallow water (150–200 m). Small shrimp were observed at some stations during recent exploratory surveys north of Store Hellefiske Bank in Div. 1A (Kanneworff, MS 1979), indicating that specific nursery grounds may be found in that area.

Failure of females to spawn seems to occur occasionally, thus providing an opportunity for some extra growth. However, failure to spawn seems to affect larval production much less significantly than egg mortality between spawning and hatching. Such mortality occurs not only in the fjords with cold bottom water but also on the offshore grounds. In the latter case, and probably also in the cold-water fjords, the phenomenon may be due to a parasitic dinoflagellate (Stickney, 1978).

Larvae. Davis Strait is an extremely dynamic area in relation to ocean currents (Fig. 23), and the circulation may significantly affect recruitment of shrimp to the inshore and offshore grounds. Northward drift of shrimp larvae over the West Greenland shelf from southern areas may provide recruitment to the stock in Div. 1B and 0A, but the spawning stock in Div. 1B is considered to supply a significant portion of recruitment to that area because the effect of currents is less pronounced. There may even be some drift of larvae southward in the western part of Davis Strait.

Some of the inshore grounds may be partly or fully dependent on recruitment from offshore areas. Partial

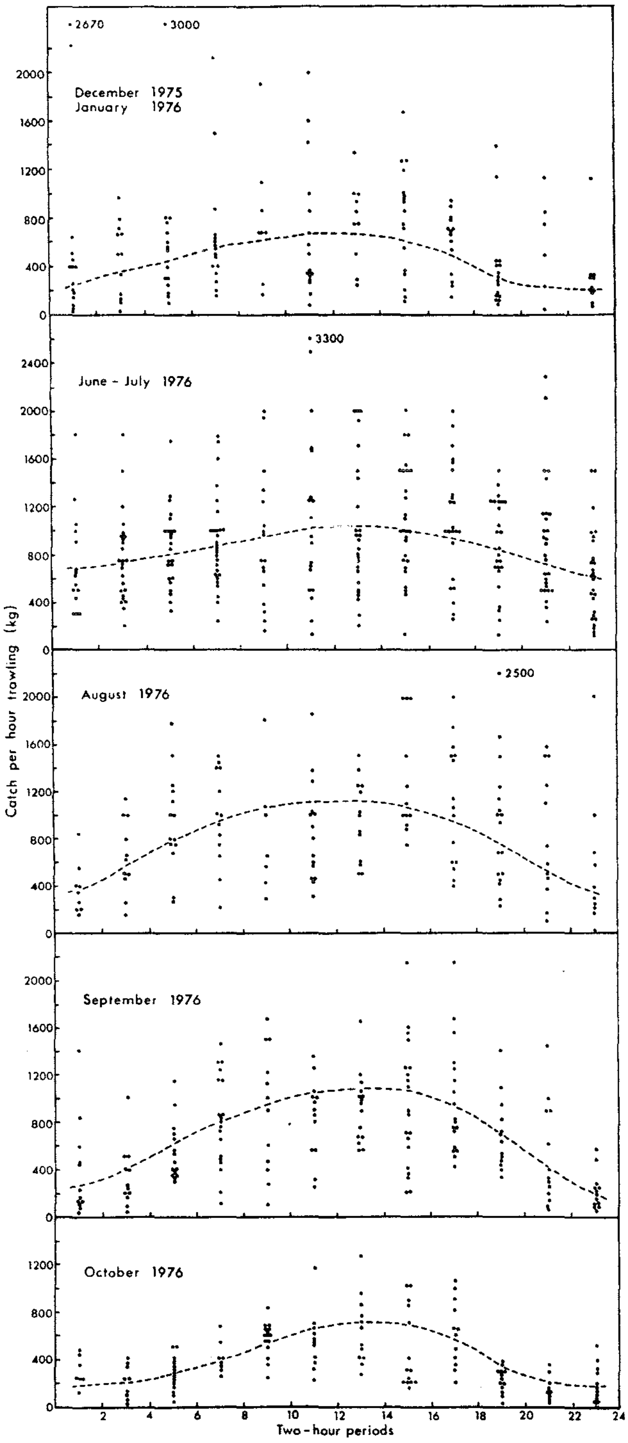

Fig. 22. Diurnal and seasonal variation in shrimp catches per hour trawling in Div. 1B from December 1975 to October 1976 (from Carlsson *et al.*, 1978).

dependency is considered to be the case for Disko Bay (Carlsson and Smidt, 1978), and appropriate conservation measures have been implemented in the offshore part of this area to prevent overfishing which might have a deleterious effect on the inshore portion of the

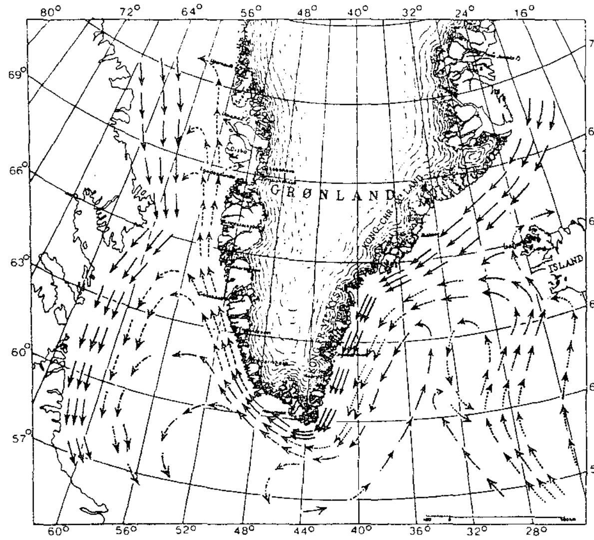

Fig. 23. The sea currents around Greenland (fig. 3 from Hermann *et al.*, 1975).

stock. Complete dependency on recruitment from offshore grounds exists for some inshore populations in threshold fjords where bottom temperatures are so low that spawned eggs never develop.

Biomass estimates

Estimates of biomass from both commercial and research-vessel survey data have been documented for the West Greenland area. The most commonly used technique is the swept-area method which leads to estimates of minimum trawlable biomass. However, the results obtained from surveys have been plagued by extreme variability in an assumed homogeneous situation, such variation being caused simply or collectively by such factors as vertical migration, light intensity, currents, seasonal migration, water temperature and predation. Some attempts have been made to adjust the biomass estimates to reflect maximum catch rates. The photographic technique has been used with some success to estimate biomass (Jørgensen and Kanneworff, MS 1980), but this method also involves high variance.

In 1979, surveys by Canadian and French research vessels were carried out on the shrimp resources in Davis Strait (Parsons, MS 1979; Dupouy *et al.*, MS 1979). With adjustments for differences in trawl opening, stratification scheme used, and diel variability, the data from both surveys led to an average biomass estimate of 45,000 tons in the Store Hellefiske Bank area from 66° N to 69° N (Table 8). This estimate is not very different from that (55,000 tons) reported by Horsted (1978a) based on a trawl survey of a similar area in 1976 or from those (46,000–52,000 tons) reported by Minet (MS 1979) based on commercial data from the French fishery in 1979. However, because the smaller-meshed trawls used in the 1979 surveys caught relatively more

TABLE 8. Estimates of shrimp biomass by subarea based on the average biomass estimates from the Canadian and French surveys in 1979.

French stratum number	Stratum area (km²)	Percent of stratum area		Average biomass (tons)	Biomass (tons)	
		SA 0	SA 1		SA 0	SA 1
02	8,427	16.3	83.7	12,505	2,038	10,467
03	3,355	2.8	97.2	5,958	167	5,791
04	3,032	35.9	64.1	8,140	2,922	5,218
05	637	100.0	—	1,540	1,540	—
06	3,665	14.6	85.4	5,633	822	4,811
07+08	2,298	—	100.0	2,006	—	2,006
09	1,565	—	100.0	5,798	—	5,798
10	1,420	52.0	48.0	44	23	21
11	1,200	4.3	95.7	2,308	99	2,209
12	1,135	—	100.0	452	—	452
13	610	—	100.0	314	—	314
14	4,000	—	100.0	191	—	191
15	1,385	—	100.0	482	—	482
Total	32,729			45,371	7,611	37,760
Percent				100	17	83

small and medium-sized shrimp than in the 1976 survey, the biomass in 1979 was probably less than in 1976.

Two independent estimates of the proportion of shrimp biomass in Subareas 0 and 1 were obtained from the 1979 survey data by assuming that shrimp are homogeneously distributed within each depth stratum. The proportions of the minimum trawlable biomass in Subareas 0 and 1 were estimated to be 16 and 84% respectively from the French survey, and 25 and 75% respectively from the Canadian survey, the latter for a smaller area (66° N to 68° 30'N). Combination of both sets of data, in order to reduce within-stratum variability, indicated 17% of the biomass in Subarea 0 and 83% in Subarea 1. Although some fishing for shrimp occurred outside the surveyed area (especially to the north and east in 1980), it is estimated that about 85% of the total offshore catch was taken within this area in 1980. It must be recognized that the breakdown by subareas applies only to the time of the surveys, because significant changes in distribution of shrimp may occur within and between years.

Fishery trends

Historical catches and management strategy. Nominal catches by country and subarea for 1972–80 are given in Table 9. Data for Subarea 0 are available only from 1976, and only the data for 1979 and 1980 comply with the new NAFO boundary line between Subareas 0 and 1. A significant observation is the precipitous rise in importance of the offshore fishery, with peak catches of 42,000 and 34,000 tons in 1976 and 1977 respectively. The inshore fishery has remained relatively stable during 1972–80 (7,000–8,000 tons), except for 10,000 tons in 1974.

The offshore fishery has been regulated by an annual total allowable catch since 1977. In that year, the TAC of 36,000 tons was almost fully utilized, but the 1978 catch was 13,000 tons less than the TAC of 40,000 tons. In 1979, the TAC was reduced to 29,500 tons and the catch was close to that level (27,100 tons), but provisional data for 1980 indicate that the catch substantially exceeded the TAC.

When quota regulations were introduced in 1977, no attention was given to a breakdown of the TAC between the Canadian and Greenland fishing zones, as almost no fishing activity was reported in Subarea 0. However, in 1978, the regulation specified an upper limit of catch that could be taken in the Greenland zone, and for 1979 and 1980 a breakdown of the TAC between the two zones was agreed to by Canada and the European Economic Community.

For the Greenland zone (Subarea 1), a breakdown into four management areas was made in 1977 in order to prevent overfishing of small but locally important grounds, should ice conditions restrict fishing on the major grounds for a longer period of the year than usual. Special attention was given to the likely interrelationship between shrimp on the offshore grounds adjacent to Disko Bay and those within the Bay where the inshore fishery is of great importance. Consequently, an offshore management zone was established between 68° N and 69° 30'N, in which no more than 3,000 tons were allowed to be taken. By 1979, this precautionary maximum allowable catch from the offshore grounds north of 68° N was allocated to Greenland vessels only. Apart from this, no specific breakdown of the TAC for the Greenland zone has been made since 1979.

TABLE 9. Nominal catches (tons) of northern prawn, *Pandalus borealis*, by country in Subareas 0 and 1, 1972-1980. (Statistics for 1972-78 pertain to ICNAF Statistical Area 0 and Subarea 1 and for 1979-80 to NAFO Subarea 0 and 1.)

Area		1972	1973	1974	1975	1976	1977	1978	1979	1980[a]
SA 0	Canada	—	—	—	—	—	—	—	—	59
	Denmark	—	—	—	—	—	68	86	67	—
	Faroes	—	—	—	—	—	239	—	115	—
	F. R. Germany	—	—	—	—	—	—	—	—	—
	France	—	—	—	—	—	—	21	7	—
	Greenland	—	—	—	—	—	—	—	149	815
	Norway	—	—	—	—	65	150	15	791	—
	Spain	—	—	—	—	327	—	—	—	—
	Total	—	—	—	—	392	457	122	1,129	874
SA 1	Canada	—	—	—	—	—	—	—	245	590
	Denmark	—	196	308	1,142	2,717	5,842	3,382	1,327	—
	Faroes	755	1,371	2,023	5,300	11,179	12,612	8,070	6,867	3,554
	F. R. Germany	—	—	—	—	—	31	—	—	247
	France	—	—	—	—	803	924	805	353	872
	Greenland (a)[b]	7,218	7,950	10,064	8,700	7,300	7,800	7,600	7,500	7,500
	" (b)	150	185	180	1,089	2,478	7,081	5,531	20,027	26,767
	Japan	—	—	—	—	146	—	—	—	—
	Norway	1,409	2,940	5,917	8,678	11,658	7,353	8,959	4,639	2,502
	Spain	—	—	—	6,948	6,925	—	—	—	—
	USSR	—	—	3,517	6,033	6,468	—	—	—	—
	Total	9,532	12,642	22,009	37,890	49,674	41,643	34,347	33,458	42,032
0+1	Offshore	2,314	4,692	11,945	29,190	42,766	34,300	26,869	27,087	35,406
	TAC (offshore)	—	—	—	—	—	36,000	40,000	29,500	29,500

[a]Provisional statistics.
[b]a = inshore and b = offshore catches.

Fishing patterns and variability. Monthly mean catch-per-unit-effort data for trawlers of the Royal Greenland Trade Department (Carlsson, MS 1980) indicate a general decline in catch rates from 1976 to 1978 and a relatively stable situation in 1979 and 1980 (Fig. 24). Seasonal variation in catch rates was very pronounced with the highest rates occurring in the first half of the year. Analysis of the data for July-September to reflect stock abundance indicates that catch rates declined from 1976 to 1978, leveled off in 1979 and increased somewhat in 1980. However, a portion of the observed increase for Greenland trawlers in 1980 may be due in part to more efficient gears than used previously and in part to the northward shift of the fishery.

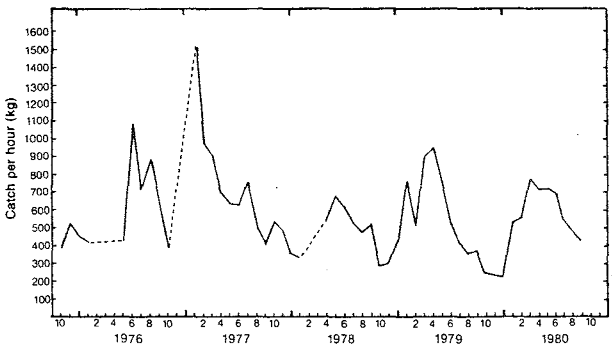

Fig. 24. Monthly mean catch (kg) per hour trawling in Div. 1A and 1B from October 1975 to September 1980, based on logbook data from six trawlers of the Royal Greenland Trade Department.

In reviewing the catch and effort statistics for the West Greenland offshore fishery, it must be recognized that ice conditions in Davis Strait are severe during certain months and variable from year to year, with consequent effects on catch rates and their use as an index of abundance. Also, there is evidence of a general northward displacement of fishing activity within the major shrimp ground west and northwest of Store Hellefiske Bank since 1976. Although this may reflect greater coverage of the shrimp grounds due to reduced severity of ice conditions, the annual variation in catch rates may also be interpreted as seasonal displacement of the stock itself. In 1979, most of the fishing activity took place south of 68° N, but Greenland trawlers in 1980 extended their coverage of the fishing grounds to a much greater extent than previously north of 68° N. Although the displacement of the fishery may indicate some displacement of the shrimp concentrations, comparison of the catch rates of some Greenland trawlers in the area between 67° N and 68° N and between 68° N and 68° 30′N does not support this interpretation. Elucidation of the reasons for the evident displacement of the fishery in recent years requires an in-depth analysis of the statistics by smaller unit areas in relation to enviromnmental factors.

Relative exploitation rates and their effect on biomass levels. In previous assessments of the size of the shrimp stock on the offshore grounds in Subareas 0 and 1 and how much of it should be harvested, certain biological assumptions were made. Natural mortality after first hatching was considered to be high (about 78%), and the time between recruitment to the fishery and hatching was estimated to be about 1.5 years. Consequently, Ulltang (1978) concluded that the mean annual removal of 40% of the exploitable biomass would lead to 50% reduction in the spawning stock biomass over several years if the level of fishing remains stable. The trend in mean catch rates for Greenland trawlers in the July-September period, indexed from the high level in 1976 which was considered representative of the virgin stock, is as follows:

Year	1976	1977	1978	1979	1980
Relative CPUE	1.00	0.73	0.67	0.50	0.64

If the trend in relative CPUE is considered to be representative of the changes in stock abundance during the period, a reduction of about 50% in stock biomass from the virgin level is indicated, as predicted by the model.

Relation to other fisheries. The major by-catch in the shrimp fishery continues to be redfish. Lesser quantities of other species include Greenland halibut, Atlantic halibut, wolffishes, Atlantic cod and Greenland shark. Most of the by-catches are discarded when fishing is conducted specifically for shrimp. By-catches have decreased in recent years, due mainly to reduced abundance of redfish, especially in Div. 1B. Although Atlantic cod at present pose no real problem to the shrimp stock in Div. 0A, 1A and 1B either as a predator or a competitor because of their low numbers, this has not always been the case, and any increase in the cod stock to levels previously experienced in Subarea 1 may have a significant effect on the abundance and distribution of shrimp.

References

ALM, G. 1959. Connection between maturity, size and age in fishes. *Rep. Inst. Freshwat. Res., Drottningholm*, **40**, 145 p.

ANDRIYASHEV, A. P. 1954. Fishes of the northern seas of the USSR. (Transl. from Russian by the Israel Program for Sci. Transl., Jerusalem, 1964, 617 p.)

ATKINSON, D. B. MS 1979. Roundnose grenadier stocks in ICNAF Subareas 0+1 and 2+3. *ICNAF Res. Doc.*, No. 57, Serial No. 5397.

MS 1980a. Assessment of the roundnose grenadier stocks in Subareas 0+1 and 2+3. *NAFO SCR Doc.*, No. 100, Serial No. N155.

MS 1980b. Weight-length relationships of roundnose grenadier in Subareas 0+1 and 2+3. *NAFO SCR Doc.*, No. 83, Serial No. N137.

BORMANN, H. 1977. Stock assessment of roundnose grenadier in the Northwest Atlantic. *ICNAF Sel. Papers*, **2**: 45–53.

MS 1978. Stock assessment of roundnose grenadier in the Northwest Atlantic. *ICNAF Res. Doc.*, No. 54, Serial No. 5220.

BOWERING, W. R. MS 1977. Trends in the Greenland halibut fishery in Subarea 2 and Div. 3K and 3L. *ICNAF Res. Doc.*, No. 11, Serial No. 5031.

MS 1978. The distribution of Greenland halibut in Statistical Area 0. *ICNAF Res. Doc.*, No. 38, Serial No. 5200.

1978. Age and growth of Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum), in ICNAF Subareas 2-4. *ICNAF Res. Bull.*, **13**: 5–10.

MS 1980. Stock assessment and abundance of Greenland halibut in the Canadian North Atlantic (Subarea 2 and Divisions 3K and 3L). *NAFO SCR Doc.*, No. 96, Serial No. N151.

CARLSSON, D. M. MS 1980. Data on the Greenland shrimp fishery in NAFO Subareas 0+1 in 1980 compared to earlier years. *NAFO SCR Doc.*, No. 174, Serial No. N261.

CARLSSON, D. M., and E. SMIDT. 1978. Shrimp, *Pandalus borealis* Krøyer, stocks off Greenland: biology, exploitation and possible protective measures. *ICNAF Sel. Papers*, **4**: 7–14.

CARLSSON, D. M., Sv. Aa. HORSTED, and P. KANNEWORFF. 1978. Danish trawl surveys on the offshore West Greenland shrimp grounds in 1977 and previous years. *ICNAF Sel. Papers*, **4**: 67–74.

CHUMAKOV, A. K., I. S. SHAFRAM, and V. L. TREJAK. MS 1978. Assessment of Greenland halibut abundance and biomass in Statistical Area 0 and Subarea 1 with application of the virtual population method. *ICNAF Res. Doc.*, No. 53, Serial No. 5219.

DE GROOT, S. J. 1970. Some notes on an ambivalent behaviour of the Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum) (Pisces: Pleuronectiformes). *J. Fish. Biol.*, **2**: 275–279.

DUPOUY, H., J. FRÉCHETTE, and C. LEROY. MS 1979. Biomass estimates of the northern deepwater shrimp, *Pandalus borealis*, in NAFO Divisions 1B and 0B — R/V *Thalassa* survey, September-October 1979. *NAFO SCR Doc.*, No. 6, Serial No. N017.

FOREST, A., J. P. MINET, and J. B. PERODOU. MS 1978. Results of groundfish survey on Baffin Island Shelf (ICNAF Statistical Division 0B). *ICNAF Res. Doc.*, No. 45, Serial No. 5207.

FRÉCHETTE, J., and H. DUPOUY. MS 1979. Preliminary biological data on the shrimp stocks of Davis Strait. *NAFO SCR Doc.*, No. 8, Serial No. N019.

GEISTDOERFER, P. 1976. Alimentation de deux Macrouridae de l'Atlantique nord: *Macrourus berglax* et *Coryphaenoides rupestris* (Teleostei, Gadiformes). *Rev. Trav. Inst. Peches Marit. Nantes*, **40**: 579–580.

1979. New data on the reproduction of macrourids (Teleostei, Gadiformes). *Sarsia*, **64**: 109–112.

GRIGOR'EV, G. V. 1972. Reproduction of *Macrourus rupestris* Gunnerus of the northern Atlantic. *Trudy PINRO*, **28**: 107–115. (Fish. Res. Bd. Canada, Transl. Ser. No. 2529).

HERMANN, F., P. M. HANSEN, and Sv. Aa. HORSTED. 1965. The effect of temperature and currents on the distribution and survival of cod larvae at West Greenland. *ICNAF Spec. Publ.*, **6**: 389–395.

HORSTED, Sv. Aa. 1978a. A trawl survey of the offshore shrimp grounds in ICNAF Division 1B and an estimate of the shrimp biomass. *ICNAF Sel. Papers*, **4**: 23–30.

1978b. The life cycle of shrimp, *Pandalus borealis* Kr., in Greenland waters in relation to the potential yield. *ICNAF Sel. Papers*, **4**: 51–60.

MS 1980. Subarea 1 cod: data for 1979 and early 1980, and estimates of stock and yield for 1980-82. *NAFO SCR Doc.*, No. 72, Serial No. N124.

HUBBS, C. L., and N. J. WILIMOVSKY. 1964. Distribution and synonymy in the Pacific Ocean and variation of the Greenland halibut *Reinhardtius hippoglossoides* (Walbaum). *J. Fish. Res. Bd. Canada*, **21**: 1129–1154.

JENSEN, A. S. 1935. The Greenland halibut, *Reinhardtius hippoglossoides* (Walb.), its development and migrations. *K. Danske Vidensk. Selsk. Skr.*, 9 Rk., **6**(4): 1-32.

JØRGENSEN, A. G., and P. KANNEWORFF. MS 1980. Biomass of shrimp (*Pandalus borealis*) in NAFO Subarea 1 in 1977–80 estimated by means of bottom photography. *NAFO SCR Doc.*, No. 169, Serial No. N256.

KANNEWORFF, P. MS 1979. Stock biomass in 1979 of shrimp (*Pandalus borealis*) in NAFO Subarea 1 estimated by means of bottom photography. *NAFO SCR Doc.*, No. 9, Serial No. N020.

KONSTANTINOV, K. G., and A. S. NOSKOV. MS 1977. USSR research report, 1976. *ICNAF Sum. Doc.*, No. 15, Serial No. 5071.

KONSTANTINOV, K. G., and S. G. PODRAZHANSKAYA. 1972. Nutrition and food interrelationships of grenadier and other deep-water fishes of the Northwest Atlantic. *Trudy PINRO*, **28**: 96–106. (Fish. Res. Bd. Canada Transl. Ser. No. 2537.)

KOSSWIG, K. MS 1980. A contribution on the age and growth of roundnose grenadier (*Coryphaenoides rupestris* Gunn.) at West Greenland (NAFO Subarea 1). *NAFO SCR Doc.*, No. 92, Serial No. N147.

LEAR, W. H. MS 1980. The biology and fishery of the Greenland halibut (*Reinhardtius hippoglossoides* (Walbaum)) in the Newfoundland area. M.Sc. Thesis, Dept. Biol., Memorial University of Newfoundland, St. John's, March 1980, 132 p.

LEIM, A. H., and W. B. SCOTT. 1966. Fishes of the Atlantic coast of Canada. *Bull. Fish. Res. Bd. Canada*, **155**: 485 p.

MARSHALL, N. B. 1965. Systematic and biological studies of the Macrourid fishes (Anacanthini, Teleostei). *Deep Sea. Res.*, **12**: 299–322.

MINET, J. P. MS 1979. Data on catches, CPUE and biomass of shrimp (*Pandalus borealis*) from the French fishery off West Greenland in 1979. *NAFO SCR Doc.*, No. 5, Serial No. N016.

MINET, J. P., A. FOREST, and J. B. PERODOU. MS 1978. Stratification scheme for ICNAF Statistical Division 0B. *ICNAF Res. Doc.*, No. 64, Serial No. 5232.

1978. Biological data on the northern deepwater prawn, *Pandalus borealis*, off Baffin Island. *ICNAF Sel. Papers*, **4**: 15–21.

NAFO. 1980. Report of Scientific Council, Special Meeting November 1979. *NAFO Sci. Coun. Rep.*, 1979–80: 23–33.

PARSONS, D. G. MS 1979. Canadian research efforts for shrimp (*Pandalus borealis*) in Division 0A and Subarea 1 in 1979. *NAFO SCR Doc.*, No. 7, Serial No. N018.

PARSONS, D. G., P. J. VEITCH, and W. E. LEGGE. MS 1978. Some characteristics of the roundnose grenadier fisheries in ICNAF Subareas 0+1 and 2+3. *ICNAF Res. Doc.*, No. 47, Serial No. 5209.

PARSONS, L. S. 1976. Distribution and relative abundance of roundnose, roughhead and common grenadiers in the Northwest Atlantic. *ICNAF Sel. Papers*, **1**: 73–88.

PECHENIK, L. N., and F. M. TROYANOVSKY. 1970. Trawling resources on the North American continental slope. (Transl. from Russian by the Israel Program for Sci. Transl., Jerusalem, 1971, 66 p.)

PHELEGER, C. F. 1971. Biology of the macrourid fishes. *Am. Zool.*, **11**: 419–423.

PODRAZHANSKAYA, S. G. 1971. Feeding and migrations of the roundnose grenadier, *Macrourus rupestris*, in the Northwest Atlantic and Iceland waters. *ICNAF Redbook* 1971, Part III: 115–123.

SAVVATIMSKY, P. I. 1969. The grenadier of the North Atlantic. *Trudy PINRO*, p. 3–72. (Fish. Res. Bd. Canada Transl. Ser. No. 2879.)

1972. The age of the rock grenadier in the Northwest Atlantic and a possible influence of fisheries on its population numbers. *Trudy PINRO*, **28**: 116–127. (Fish. Res. Bd. Canada Transl. Ser. No. 2491.)

SCHMIDT, J. 1904. On pelagic post-larval halibut (*Hippoglossoides vulgaris* and *H. hippoglossoides*). *Medd. Danm. Fisk.-og. Havunders. N. S.*, No. 1(3).

SMIDT, E. 1969. The Greenland halibut, *Reinhardtius hippoglossoides* (Walb.), biology and exploitation in Greenland waters. *Medd. Danm. Fisk.-og. Havunders. N.S.*, **6**: 79–148.

STICKNEY, A. P. 1978. A previously unreported Peridinian parasite in the eggs of the northern shrimp, *Pandalus borealis*. *J. Invertebr. Pathol.*, **32**: 212–215.

TEMPLEMAN, W. 1973. Distribution and abundance of Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum), in the Northwest Atlantic. *ICNAF Res. Bull.*, **10**: 83–98.

ULLTANG, Ø. 1978. A method for determining the total allowable catch of deep sea shrimp, *Pandalus borealis*, off West Greenland. *ICNAF Sel. Papers*, **4**: 43–44.

WALSH, S. J., and W. R. BOWERING. 1981. Histological and visual observations on oogenesis and sexual maturity in Greenland halibut off northern Labrador. *NAFO Sci. Coun. Studies*, **1**: 71–75.

ZILANOV, V. K. MS 1976. The problem of species composition and value of by-catch obtained in the course of a specialized grenadier (*Macrourus rupestris*) fishery in the Northwest Atlantic. *ICNAF Res. Doc.*, No. 112, Serial No. 3935.