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A Review of the Biology and Fisheries of Roundnose Grenadier (*Macrourus rupestris*), Greenland Halibut (*Reinhardtius hippoglossoides*) and Shrimp (*Pandalus borealis*) in Davis Strait (NAFO Subareas 0 and 1)

by

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Introduction

During the mid 1970's when ICNAF began monitoring stocks more closely and imposing Total Allowable Catches (TACs), species found on both sides of the 59°W line between Baffin Island and Greenland were considered as one stock and 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 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 for stocks within these zones at the request of the coastal states concerned. In 1979, the boundary between what was ICNAF Subareas 0 and 1 was changed to represent the equidistant line between Canada and Greenland (Fig. 1). This new boundary south of Div. 1A falls much closer to the 58°W line. Control of the stocks overlapping NAFO Subareas 0 and 1 is to be shared by Canada and the European Economic Community (EEC) based on management advice provided through NAFO's Scientific Council.

Among the species present on both sides of the new boundary only three

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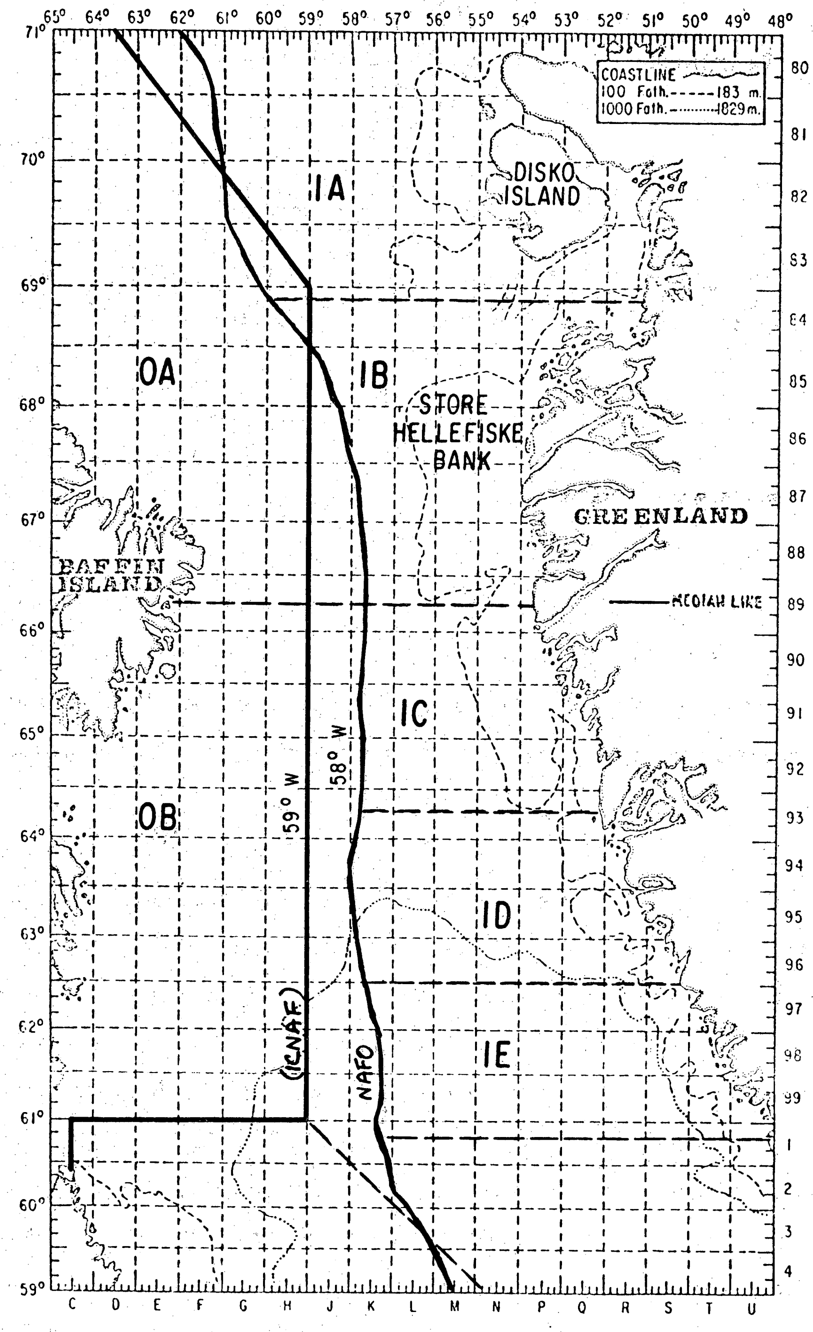


Fig. 1. Map of area showing subareas, divisions, etc. referred to in the text.

are at present considered of commercial interest, viz. roundnose grenadier (Macrourus rupestris), Greenland halibut (Reinhardtius hippoglossoides) and shrimp (Pandalus borealis) and in early 1980, Canada and the EEC agreed on the principle that objective scientific criteria be made available to aid in allocating the TAC's for these joint stocks. Consequently a working group consisting of Canadian and EEC scientists was established to review the existing data.

This paper is a review of the biology of fisheries of these species and represents the current state of knowledge concerning these three species in Subareas 0 and 1.

Roundnose Grenadier

1. General Biology

At least seven species of grenadier have been reported to occur in the Northwest Atlantic but at present only one, the roundnose grenadier (Macrourus rupestris Gunn.) is considered to be available in significant commercial quantities and is fished under NAFO regulation. It is distributed on both sides of the Atlantic Ocean in depths of 350-2500 + m. In the western Atlantic the greatest concentrations are found from 50°N northward to the area between Baffin Island and Greenland south of the ridge between the two islands.

Roundnose grenadier appear to be relatively long lived, slow growing and late maturing fish (Savvatimskii 1972) although they probably do not attain ages as great as do redfish. Females are apparently larger at age than males. As with redfish, there are two schools of thought concerning the ageing with the otolith method yielding results different from those by the scale method (Fig. 2). Investigations are on-going in an attempt to resolve these differences and to arrive at more accurate age determinations.

Very little is known concerning the reproductive biology of this species. Although mature individuals have been found commonly in the Northeast Atlantic (Marshall 1965, Savvatimskii 1969, Pechenik and Trayanovskii 1970, Zakharov and Mokanu 1970 (as cited by Podrazhanskaya 1971), Grigor'ev 1972, Geistdoerfer 1979), very few sexually mature specimens have been encountered in the Northwest Atlantic (references as above). These findings led Zakharov and Mokanu (1970, cited and supported by Podrazhanskaya 1971) to suggest that roundnose grenadier spawn in Icelandic waters, the eggs and larvae being carried passively by the Irminger current to the waters south of Greenland where the West Greenland current carries the young fish to the Baffin Island area. From there the Canadian and Labrador currents carry the fish to the Labrador-north Newfoundland area where they remain until attaining lengths of 40-50 cm at which time they begin a return migration. Supporting this proposal was the evidence that

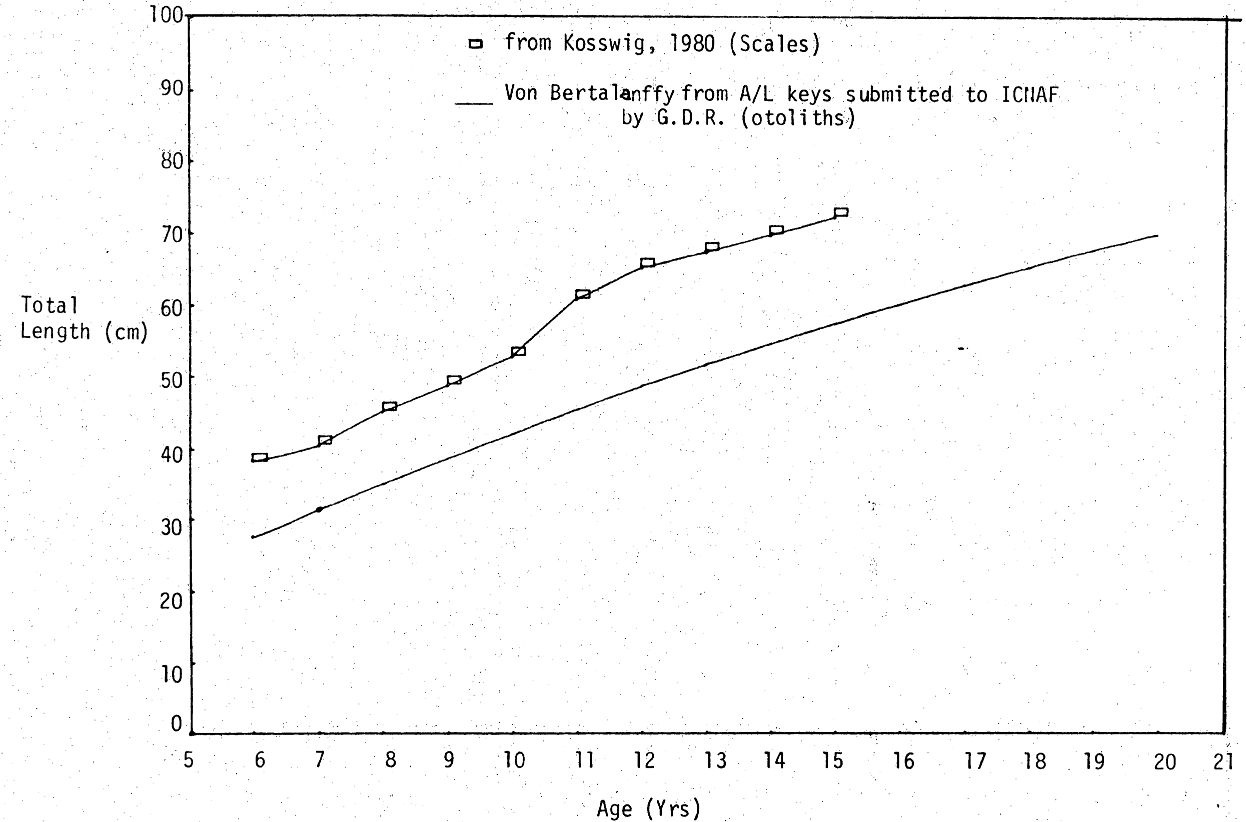


Fig. 2 Comparison of Roundnose Grenadier Length at age in SA 0+1 using scales and otoliths.

larger fish were found off Iceland, both during Podrazhanskaya's (1971) study and those of others (Savvatimskii 1969). Grigor'ev (1972), Savvatimskii (1972), and Parsons (1975) discounted this theory for a number of reasons. They pointed out that due to their body shape it is highly unlikely that grenadiers are good swimmers. Grigor'ev's (1972) observations indicated that juveniles approximately 8 cm long were encountered along the entire Canadian coast from Baffin Island to the Grand Banks. Savvatimskii (1972) and Parsons (1975) both reported that the incidence of sexually mature and maturing individuals increased with increasing depth in the West Atlantic. The three authors concluded that the West Atlantic and East Atlantic stocks are separate and that in the West Atlantic spawning concentrations occur at depths greater than those presently fished. This conclusion is supported by Geistdoerfer (1979) based on his own studies.

The spawning time of grenadier is at present poorly understood. Andriashev (1954) suggested that they spawn at the end of autumn and Savvatimskii (1969) noted the presence of spawning males and post spawning females in October 1968. Podrazhanskaya (1971) on the other hand noted that in the area southeast of Iceland individuals were in pre-spawning condition in May and spawning and post-spawning condition in August. Marshall (1965) concluded that spawning occurs both in spring and fall and this belief is supported by Geistdoerfer (1979) based upon his own recent observations. Phleger (1971) in a discussion of macrourids in general suggested the presence of a specific spawning season. In contrast to the above, Grigor'ev (1972) concluded that roundnose grenadier (at least in the region of Iceland) spawn intermittently all year round based on observations indicating the maturation of different individuals at different times. To date the differences noted have not been resolved.

Feeding studies (Savvatimskii 1969, Podrazhanskaya 1971, Konstantinov and Podrazhanskaya 1972, Geistdoerfer 1976) suggest that roundnose grenadier are bathypelagic feeders consuming a wide variety of small invertebrates-crustaceans e.g., copepods, euphasids; as well as small fish and squid and often make significant vertical migrations from the bottom to feed. These migrations are discussed in length by Savvatimskii (1969) and are supported by the large midwater trawl catches of the commercial fishery. Indications are that roundnose grenadier are heavily preyed upon at certain times by greenland halibut (Konstantinov and Podrazhanskaya 1972).

Savvatimskii (1969) reported that with increasing depth the length of roundnose grenadier caught sometimes showed a slight increase but never a decrease and at considerably greater depths (>1000 m) larger specimens were caught. Zilanov (1976) suggested that the fish migrated to shallower depths from June to September in order to feed then back to deeper waters later in the year implying a seasonal stratification. Preliminary Canadian data (unpublished) suggest a separation of large and small fish by depth.

2. Distribution

(a) General distribution and migration of exploitable stocks

Very little is known concerning the distribution of roundnose grenadier in Subareas 0 + 1. As stated previously, the species is generally found from 350-2500 + m but in this area little work has been done to more exactly define the range and area(s) of greatest concentration. Parsons (1975) in a review of roundnose grenadier catches by the Canadian research vessel A. T. Cameron from 1958-73 noted that in areas where they were taken in quantity the temperature range was quite narrow, generally 3.5C-4.5C. The catches (kg/30 min tow) by the A. T. Cameron in Subareas 0 + 1 are shown in Fig. 3.

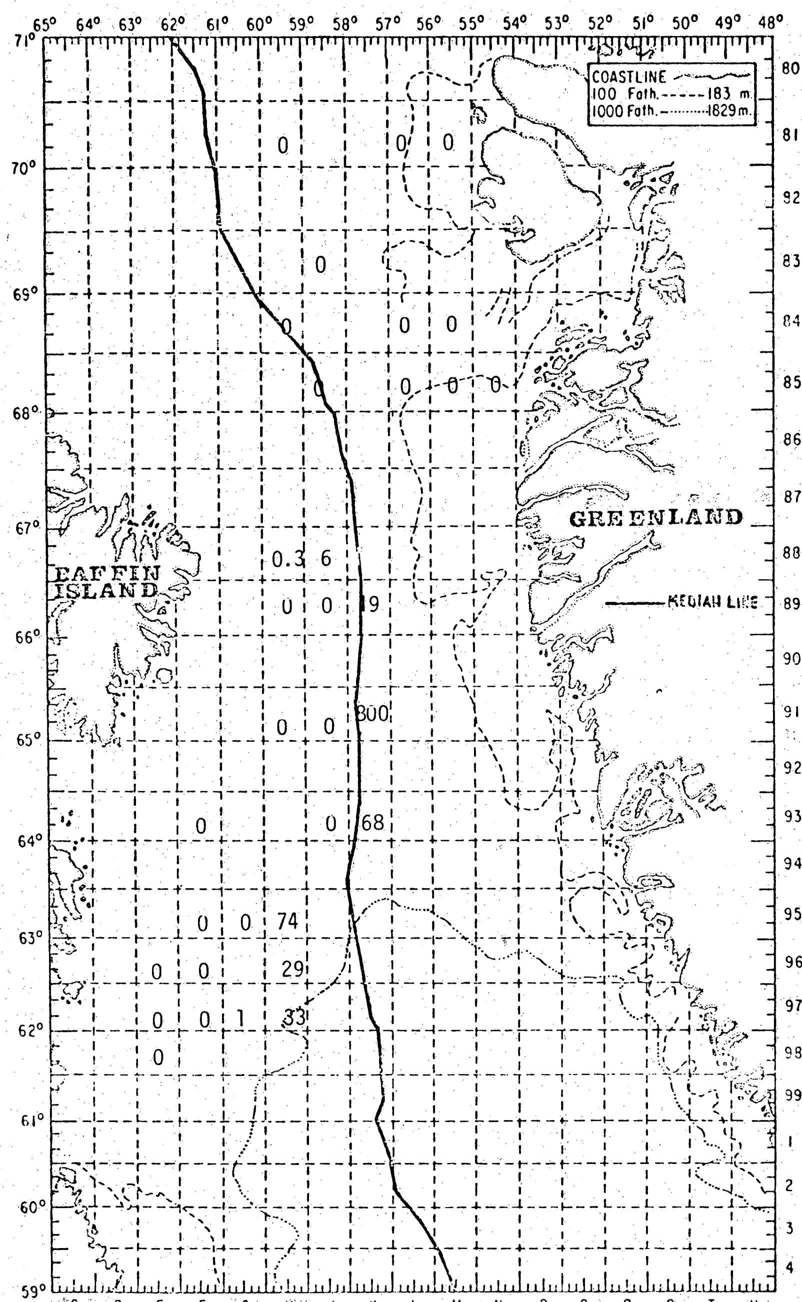


Fig. 3. Distribution of catches (kg./30 min. tow) of roundnose grenadier by the A.T. Cameron 1958-1973 (from Parsons, 1975).

In 1977 the French research vessel <u>Cryos</u> conducted a random stratified groundfish survey in Subarea 0 (Minet et al. 1978a). The grenadier catches can be seen in Fig. 4. Where these catches occurred, bottom temperatures ranged from 3.0C-4.4C.

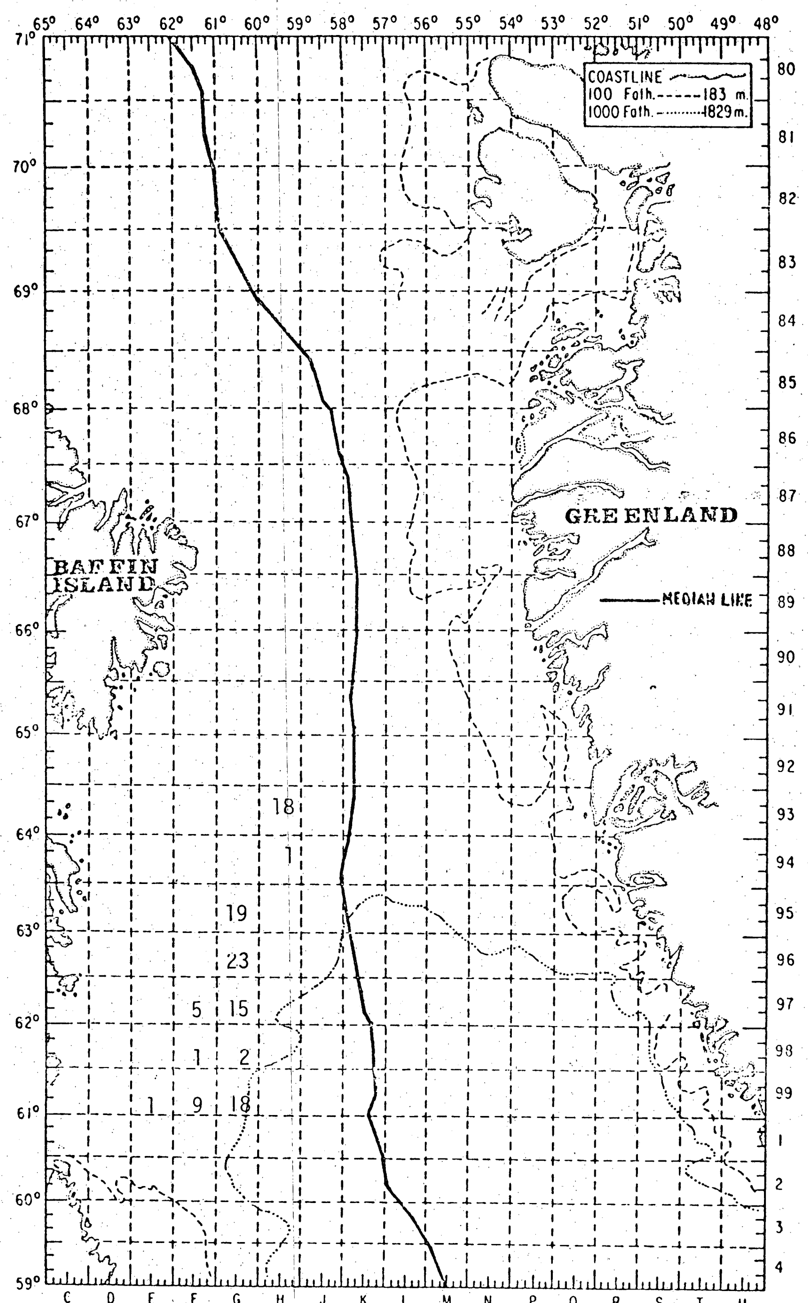


Fig. 4. Distribution of catches (kg./30 min. tow) of roundnose grenadier by the <u>Cryos</u>, 1977.

(b) Spawning areas (No information available)

(c) Egg and larval distribution (No information available)

(d) Nursery areas (No information available)

3. Biomass

Since no survey has adequately covered all of Subareas 0 + 1 no estimate of minimum trawlable biomass is presently available. In 1976 and again in 1978 Borrmann presented cohort analyses of the Subareas 0 + 1 fishery to ICNAF. From the estimates of population numbers derived from cohort runs based upon both age and lengths (1976) and age (1978) the population ranged from 211 million fish (length, 1976) at $M = 0.1$ to 1052 million individuals (age, 1978) at $M = 0.2$. Based upon the weight/length relationship for Subareas 2 + 3 (Atkinson 1980b), the 1976 minimum estimate at $M = 0.1$ based upon length converts to 36,500 t. Because of the present discrepancies in ageing, the conversion of numbers at age to weights is less reliable. However, the 1978 estimate at $M = 0.2$ probably represents approximately 86,000 t. There is at present no way of determining the relative distribution of this biomass between Subareas 0 and 1.

4. Fishery

(a) Historical catch and effort

A directed fishery for roundnose grenadier in Subareas 0 + 1 was first reported in 1968 when 6000 t were landed. Since then catches have averaged 6500 t with a high of 12,000 t in 1974 and lows of 3000 t in 1969 and 1977. A precautionary TAC of 10,000 t was first imposed in 1975 based on average catches in previous years. This was raised to 14,000 t in 1976 based primarily upon the high catch in 1974. A preliminary cohort assessment presented by Borrmann (1976) suggested a TAC at $F_{0.1}$ of 8000 t and the 1977 TAC was set at this level. More recent assessments (Borrmann 1978; Parsons et al., 1978; Atkinson 1979, 1980a) have continually suggested a catch of 8000 t and the TAC has accordingly remained at this level and will do so through 1981.

Table 1 and Fig. 5 show the total catches, effort (standardized, Atkinson 1980a) and catch per unit effort (CPUE) for all of Subareas 0 + 1. It should be noted that due to the possibility of a great deal of misreporting (Horsted 1980), the data for 1978 and 1979 are questionable and have therefore been omitted.

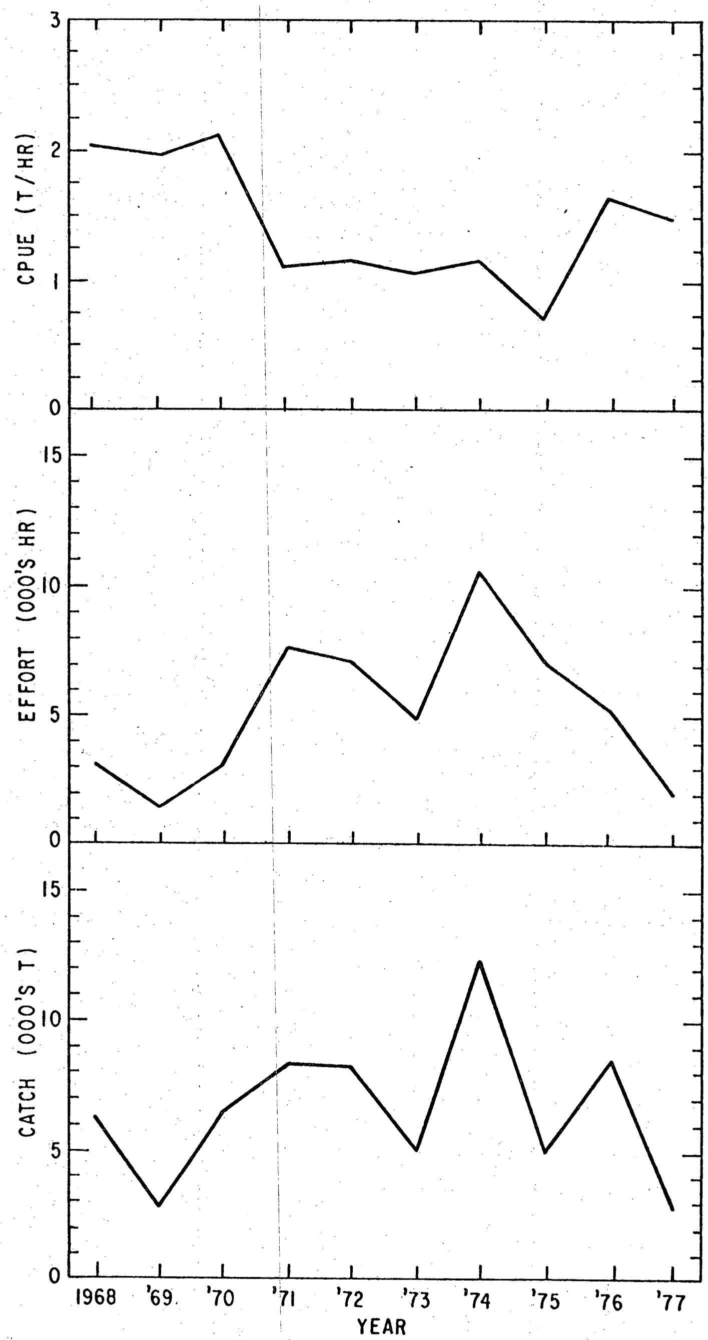


Fig. 5. Catch, effort and CPUE for Roundnose Grenadier from 0+1.

Table 1. Catch, effort (standardized) and CPUE for roundnose grenadier in SA 0+1.

Year	Catch (t)	Effort (hr)	CPUE (t/hr)
1968	6239	3084	2.023
1969	2710	1390	1.949
1970	6525	3072	2.124
1971	8304	7639	1.087
1972	8101	6966	1.163
1973	4884	4687	1.042
1974	12,318	10,646	1.157
1975	4953	7056	0.702
1976	8503	5210	1.632
1977	2935	2003	1.465

(b) Fishing patterns and variability

Both catch and effort have fluctuated considerably since the commencement of this fishery perhaps due to the variable environmental conditions in the area (e.g. ice) and possibly variable market conditions along with changing allocations and availability of other commercial species.

Table 2 shows a breakdown of the catches by country and area (using the 59°W line as the boundary between Subareas 0 and 1 according to the original ICNAF scheme). It can be seen that up to and including 1977 the USSR catches consistently accounted for greater than 60% of the total reported landings and except for one year (1973) they represented greater than 75% of the totals.

Figure 6 illustrates the percentage of Subareas 0 + 1 landings of roundnose grenadier that were reportedly caught in Subarea 0 (59°W). It can be seen that with time there has been a shift in the catches out of Subarea 0 into Subarea 1. The reason for this is possibly environmental (ice cover) as it can be seen in Fig. 7 that the trends in CPUE in the two areas have remained quite similar.

Table 2. Breakdown of grenadier catches (t) in SA 0+1 by country and area (using 59°W as dividing line).

COUNTRY	AREA	1968	1969	1970	1971	YEAR 1972	1973	1974	1975	1976	1977
USSR	0	5996	2642	545	4172	5577	1054	2661	204	2610	674
	1	128	68	5980	4118	2171	1984	6848	4524	5564	1671
Poland	0	-	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	147	-	-	-	-	-
GDR	0	-	-	-	-	206	-	-	-	-	47
	1	115	-	-	14	-	1835	2804	186	181	14
FRG	0	-	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	33	147	519
Den-G	0	-	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	11	5	6	1	10
Total	0	5996	2642	545	4172	5783	1054	2661	204	2610	721
	1	128	68	5980	4132	2318	3830	9657	4749	5893	2214
%USSR (0+1)		98.2%	100.0%	100.0%	99.8%	95.6%	62.2%	77.2%	95.5%	96.1%	79.9%

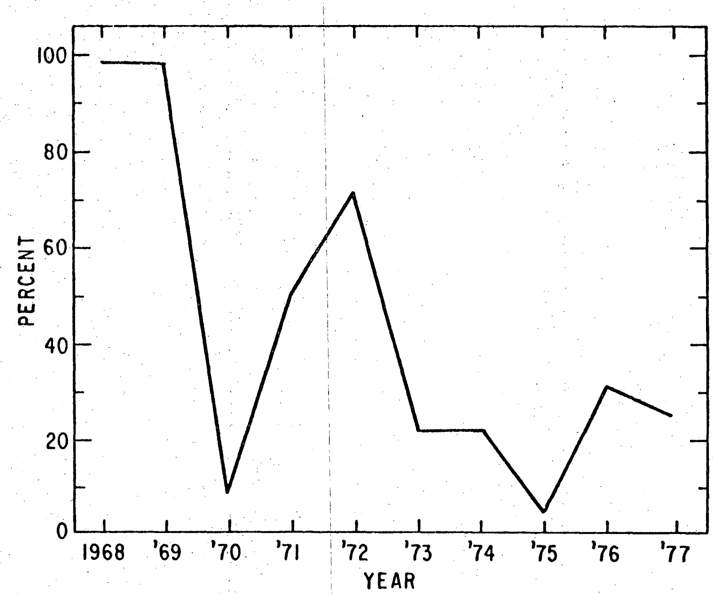


Fig. 6. Percent of total Roundnose Grenadier landings from SA 0+1 reported caught in SA 0 (59°W).

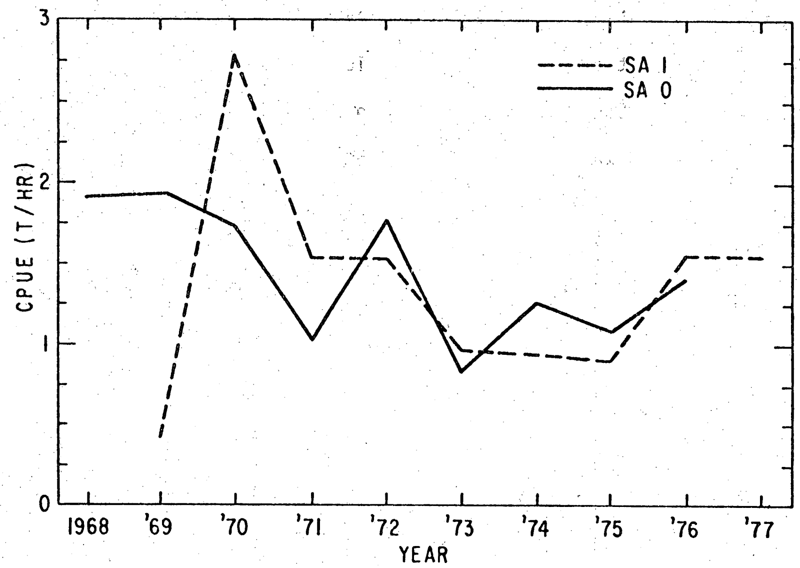


Fig. 7. Trends in CPUE in SA 0 and SA 1 based upon USSR (catches >50% RNG, all gears and tonnage classes).

In 1979 the USSR reassessed their historical catches in Subareas 0 + 1 using the 58°W line as the border between the two Subareas. A comparison of their catches in the two areas using the traditional boundary (59°W) and the 58°W line boundary (approximate to the new boundary) can be seen in Table 3 and is illustrated graphically on a percentage basis in Figure 8. As with Fig. 6, this shows, in recent years, a trend toward increased catches in Subarea 1 using either the 59°W line or the 58°W line but as noted earlier this does not appear to be related to shifts in the CPUE in the two areas and thus represents a shift in the area of directed effort. It can be seen from Table 3 that for USSR catches from 1973-1977 there is a 40:60 split from Subarea 0 and Subarea 1 respectively based upon the 58°W line as boundary.

Table 4 gives a breakdown (based on the 59°W line) of the annual total landings from Subareas 0 + 1 caught in Subarea 0 and each division of Subarea 1. It can be seen that in 1970, 1971 and 1972 (the years when the USSR landings from Subarea 0 and Subarea 1 shifted considerably when the 58°W line was used instead of the 59°W line) relatively high percentages were caught in 1D. This would imply that during this period the fishery was concentrated in an area between 62°30'N-64°15'N and 58°00'W-59°00'W.

Table 3. Comparison of USSR catches of Roundnose Grenadier in SA 0 and 1 using the 59°W and 58°W lines as the boundary between areas, 1968-77.

	USSR Catches (000's t) 59°W											
	68	69	70	71	72	73	74	75	76	77	% 68-72	% 73-77
SA 0	6	3	1	4	6	1	3	+	3	1	60%	26%
SA 1	+	+	6	4	2	2	7	5	6	2	40%	74%
Total	6	3	7	8	8*	3	10	5*	9*	3	100	100
	USSR Catches (000's t) 58°W											
	68	69	70	71	72	73	74	75	76	77	% 68-72	% 73-77
SA 0	6	3	7	6	7	2	3	1	4	1	92%	39%
SA 1	+	+	-	2	+	1	7	3	4	2	8%	61%
Total	6	3	7	8	7*	3	10	4*	8*	3	100	100

* Difference between tables due to rounding

Table 4. Percent of total Roundnose Grenadier landings from SA0+1 reported caught in each division (59°W line).

	% Total Catch									
	68	69	70	71	72	73	74	75	76	77
0	96.1	97.5	8.4	50.2	71.4	21.6	21.6	4.1	30.7	24.6
1A	-	-	-	-	-	+	0.2	0.1	1.0	0.4
1B	+	-	-	1.3	0.1	1.5	1.6	1.3	11.5	0.9
1C	-	0.5	1.0	3.4	9.3	72.0	73.8	87.2	52.8	58.3
1D	-	2.0	76.5	45.1	19.0	0.7	2.1	6.8	1.1	9.8
1E	1.0	-	10.1	-	0.2	4.2	0.6	0.5	1.8	1.6
1F	2.9	-	4.0	-	-	-	0.1	-	1.1	4.4
TOTAL	100	100	100	100	100	100	100	100	100	100

In 1973 and later there was an apparent shift in the fishery northward into 1C and slightly eastward. The eastward movement may be postulated from the observation that during this time period (except 1975) there is a reduced shift in the USSR catch per area with changing boundary line (Table 3). Thus fishing was probably concentrated in the region of, or

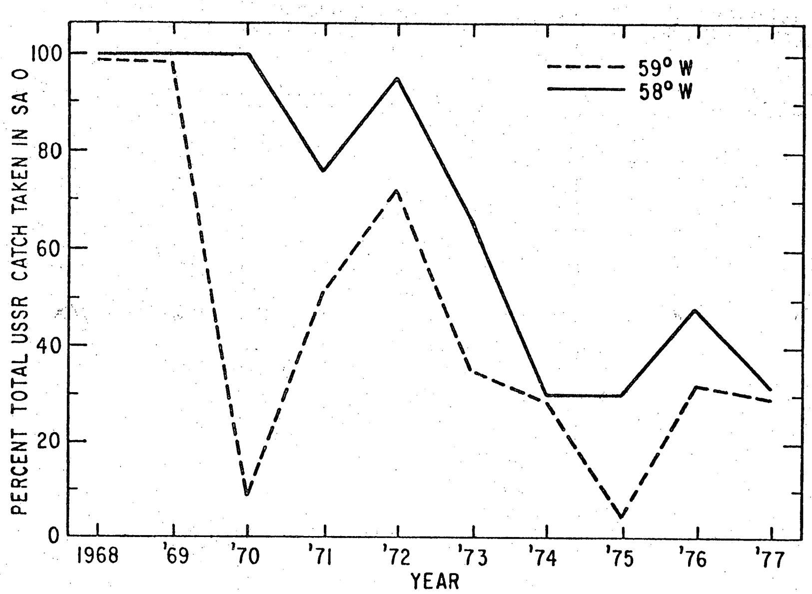


Fig. 8. Percent of total USSR catch from SA 0+1 taken in SA 0.

just east of the 58°W line. Fig. 9 indicates the probable location of the most concentrated grenadier fishery as determined from above.

(c) Relative exploitation rates and their effects on current biomass levels

No information is available.

(d) Relation to other fisheries

Very little is known concerning the relationship of the grenadier fishery to other fisheries. Because this species is found in relatively deep waters in comparison to other commerical fish it may be postulated that relatively little by-catch is encountered with the exception of Greenland halibut. Studies conducted by the USSR from 1967-1974 in Subareas 0 + 1 in depths of 500-1200 m (Zilanov 1976) indicated that in the directed fishery, roundnose grenadier consistently accounted for greater than 90% of the catch with Greenland halibut being the major by-catch. Konstantinov and Noskov (1977) reported that in Subarea 0 when the temperature is higher than the long-range average more grenadier are caught but if the temperature is lower than this average the catches of Greenland halibut increase.

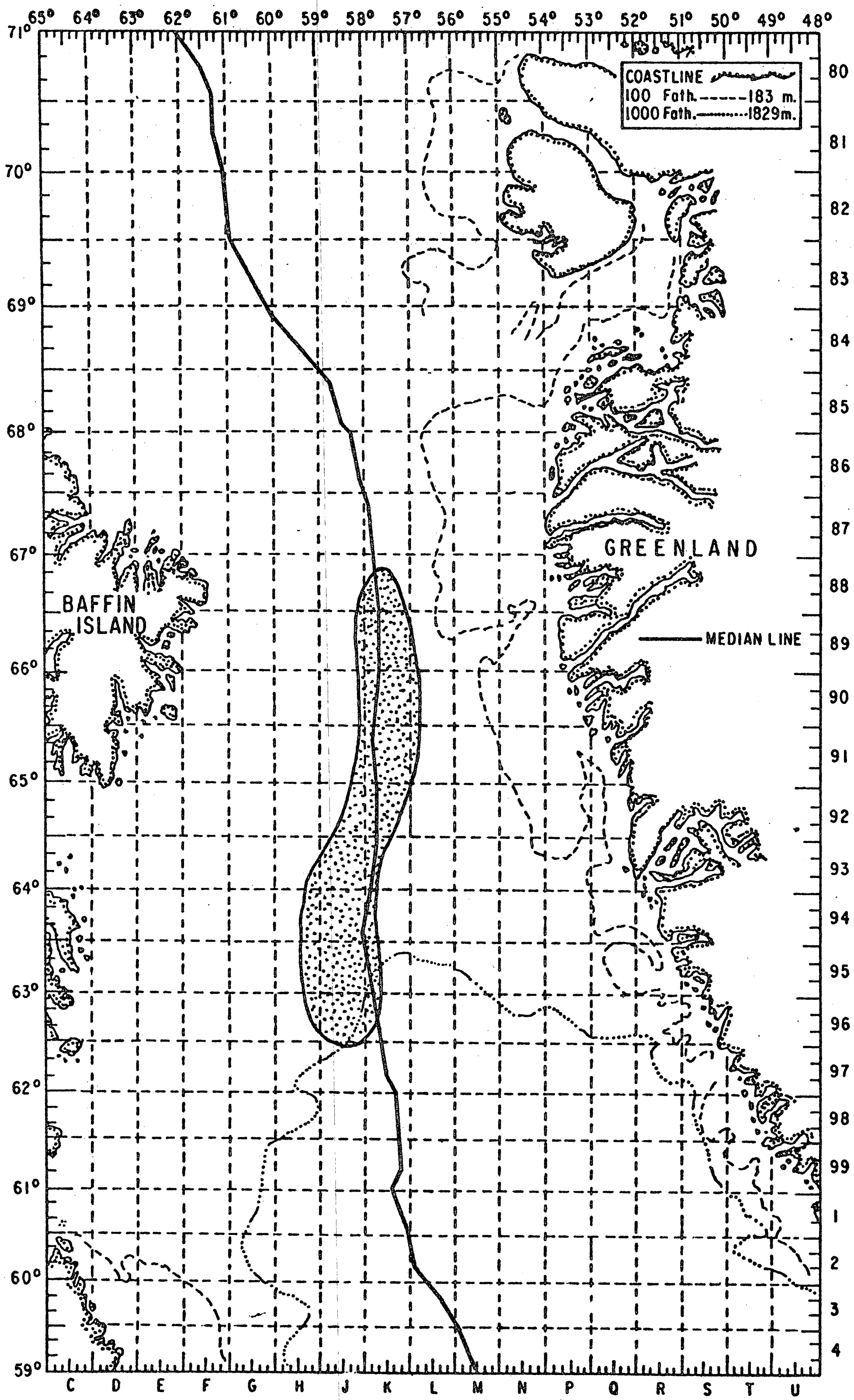


Fig. 9. Probable location of most concentrated grenadier fishery 1968-1977.

Greenland Halibut

1. General Biology

The Greenland halibut exhibits an amphiboreal distribution pattern meaning it is prevalent in both North Atlantic and North Pacific Oceans but absent in the Arctic waters which separate the two. Taxonomic studies particularly by Hubbs and Wilimovsky (1964) concerned with meristic and morphometric characteristics of the Greenland halibut have concluded that it is in fact the same species in both oceans contrary to previous opinion (Andriyashev 1954).

Spawning seemingly takes place in spring in Davis Strait in warm deep water to the south of the Greenland-Canadian Cascade between Greenland and Baffin Island at about 67°N latitude (depths down to 675 m) (Smidt 1969). The eggs and small larvae are found in depths of 600-1000 metres, however, the larvae later rise to the surface waters where they are taken by currents to and along the west coast of Greenland to the northern part of Davis Strait where the current turns and some larvae are likely taken southward to the Banks of Baffin Island (Bowering 1978a).

Larvae of 10-18 mm are usually bathypelagic and are typified by a yolk-sac which occupies about 25% of the body length. At this stage, the body is surrounded by an embryonic fin without rays from the top of the head to the posterior portion of the stomach. The base of the pectorals are formed with embryonic fin rays present. As the yolk-sac is almost totally consumed, the hypural vertebra at the base of the caudal fin is formed and pigmentation occurs on the abdominal region as well as the back (Jenson 1935).

At a length of 16-24 mm the larvae become epipelagic with the body shape still symmetrical, however, the left eye is noticibly higher than the right. Traces of the caudal fin are detected with pectoral fins no further developed than in the bathypelagic phase. Anal fins cannot be detected at this stage. In older pelagic larvae (25-57 mm) the interspinous bones become noticable and the dorsal and anal fins begin to show. Pigmentation becomes even more pronounced. In the later part of this stage (over 30 mm) the segmentation of muscles shows very clearly and the pigmentation is very definitely arranged along the lines of the musculature. As well, the pectoral fins are now fully developed from the base to the outer margin of the fin. The number of vertebrae can almost be determined, however the extreme ends of the vertebral column are still relatively indistinct. The body is still perfectly symmetrical with the left eye slowly moving upwards.

In specimens of 70-75 mm the eye is still advancing up the side of the head and in one specimen of 79 mm examined by Jensen (1935) it is situated at the edge. At 85 mm the migration of the left eye appears to have been completed and specimens this size were found to have moved from the pelagic to the bottom phase (Jensen 1935). Also, in specimens of this size the body is covered with scales, the teeth are formed completely and pigment grains are becoming apparent on the various well formed fins. From here pigmentation seems to be the final developmental process up to sexual maturity. Pigmentation will show variation throughout the life of this species apparently depending upon the depth and light conditions of the habitat. Examples of 7 different size larvae are shown in Fig. 10. The Greenland halibut, unlike other pleuronectiformes, have two specific distinctions which can be attributed to their specific behaviour patterns. Firstly, the pigmentation on the left side is very prevalent giving them a very dark appearance; secondly, the left eye does not "migrate" fully to the right side but stops at the edge of the body which gives it a wide range of peripheral vision. This is considered to be due to the fact that they are not a markedly bottom fish like other flatfishes but spend considerable time in the upper water layers. Specific details on the behaviour of Greenland halibut can be found in Schmidt, (1904), Jensen (1935), Smidt (1969) and de Groot (1970).

Very little age data from recent years is available from the Baffin Island-Greeland area. However, a stratified-random groundfish survey by the French research vessel <u>Cryos</u> during October 1977 was conducted in NAFO Div. OB. Data on age composition of male and female Greenland halibut caught are presented in Fig. 11. A full range of ages was present in the catches from 1-19, however, from ages 14-19 inclusive were all females. The age composition consisted primarily of 3-5 year-olds for both sexes, i.e. the 1972, 1973, and 1974 year-classes, however, since age composition of Greenland halibut in the commercial fishery in SAC+1 is not available it is impossible to know how these year-classes affect the fishery. It should be pointed out that these particular year-classes have dominated the Greenland halibut fishery in SA2 and 3KL recently where TAC's have gone from 30,000 t in 1979 to 35,000 t in 1980 and will be increased to 55,000 MT in 1981 (Bowering 1980). Since age composition of the commercial fishery in SA0+1 is not available, it is impossible to know how these year-classes affect this fishery.

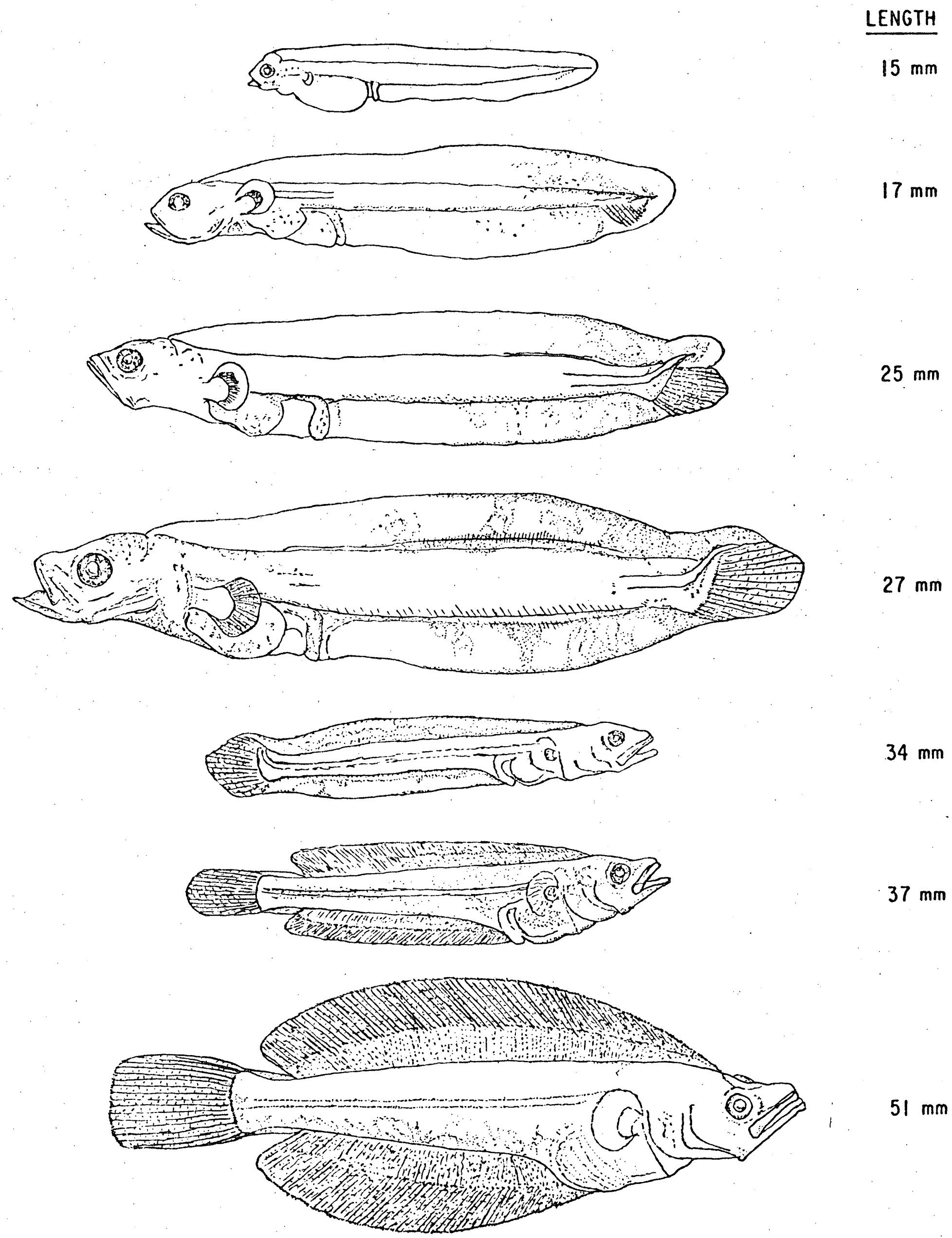


Fig. 10. Seven (7) different stages of Greenland halibut larvae taken during various Danish investigations in Davis Strait.

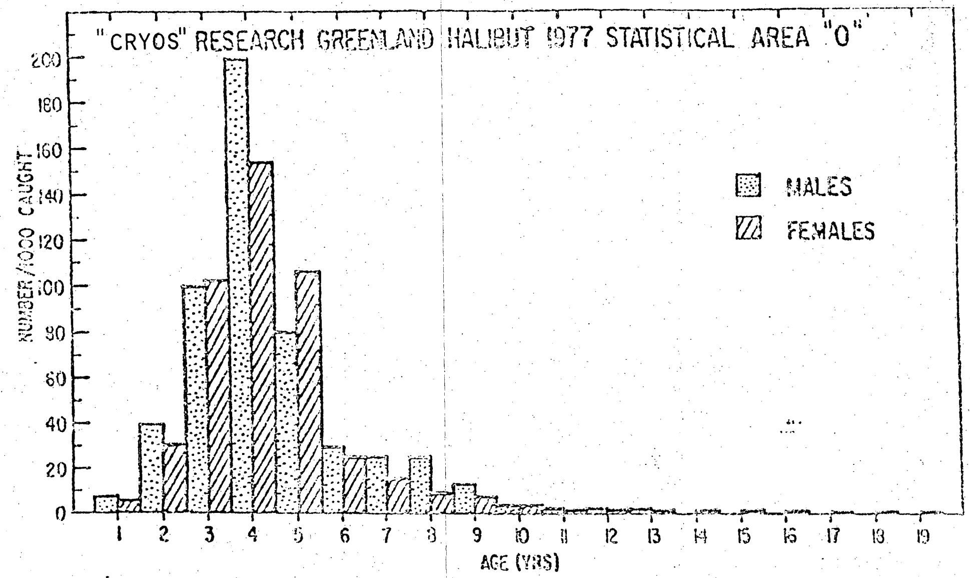


Fig. 11. Age composition of male and female Greenland halibut from the French research vessel cruise in Subarea "0" during October, 1977.

During October, 1978 a stratified-random groundfish abundance survey was conducted in Div. 0B by the German Democratic Republic research vessel Ernst Haeckel. Since the survey was primarily directed towards Greenland halibut and roundnose grenadier, depths less than 300 meters were not surveyd. The age composition was not readily available from this area, however, the length composition of the catches are presented in Fig. 12 as well as that of the Cryos, 1977 for comparison. The size composition is basically the same for the two surveys taking into account the year's growth of the predominant year classes in the 1978 survey. The lower percentages of the predominant year classes in the 1978 survey can be explained by:

a) natural mortality from October 1977 to October 1978 and

b) the 1978 survey did not include the shallower depths where the younger, smaller fish are more plentiful (see distribution by depth). The clear predominance of males in the mid-range size groups may indicate a spawning migration since this area is near the spawning grounds and most males in this size range are probably sexually mature. On the other hand, females in this size range are probably immature (see section on sexual maturity).

The average length at age was plotted for males and females separately for the 1977 data only since the 1978 age data were not available (Fig. 13).

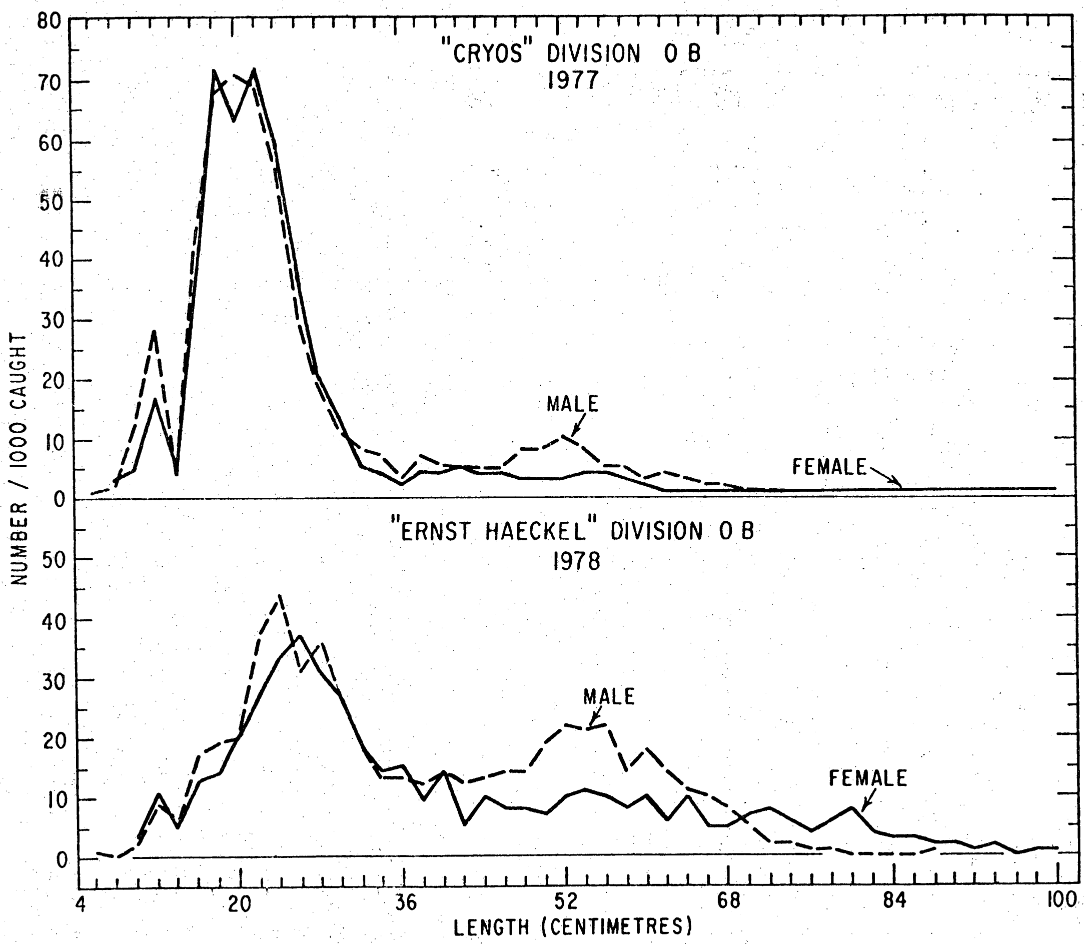


Fig. 12. Length compositions of male and female Greenland habibut from two separate research surveys in NAFO Subarea "0".

The average length at age was relatively similar for males and females up to age 9 where the females began to show faster growth. This diversity of growth rate at this point is probably due to the influence of more sexually mature males as opposed to more immature females where the energy normally used for growth is diverted to the formation of sexual products (Alm 1959).

In Subarea 2-4, Bowering (1978) has expressed the growth of Greenland halibut in terms of linear regression (Fig. 14), since the older age groups were not present in the catches and consequently the more linear section of the Von Bertalanffy growth curve below the inflection point was all that could be considered. It was pointed out that the growth rate essentially decreased going from north to south and in looking at the average lengths at age in Div. 0B it appears that the growth rate in this area is amongst the slowest for similar portions of the age range as would be expected.

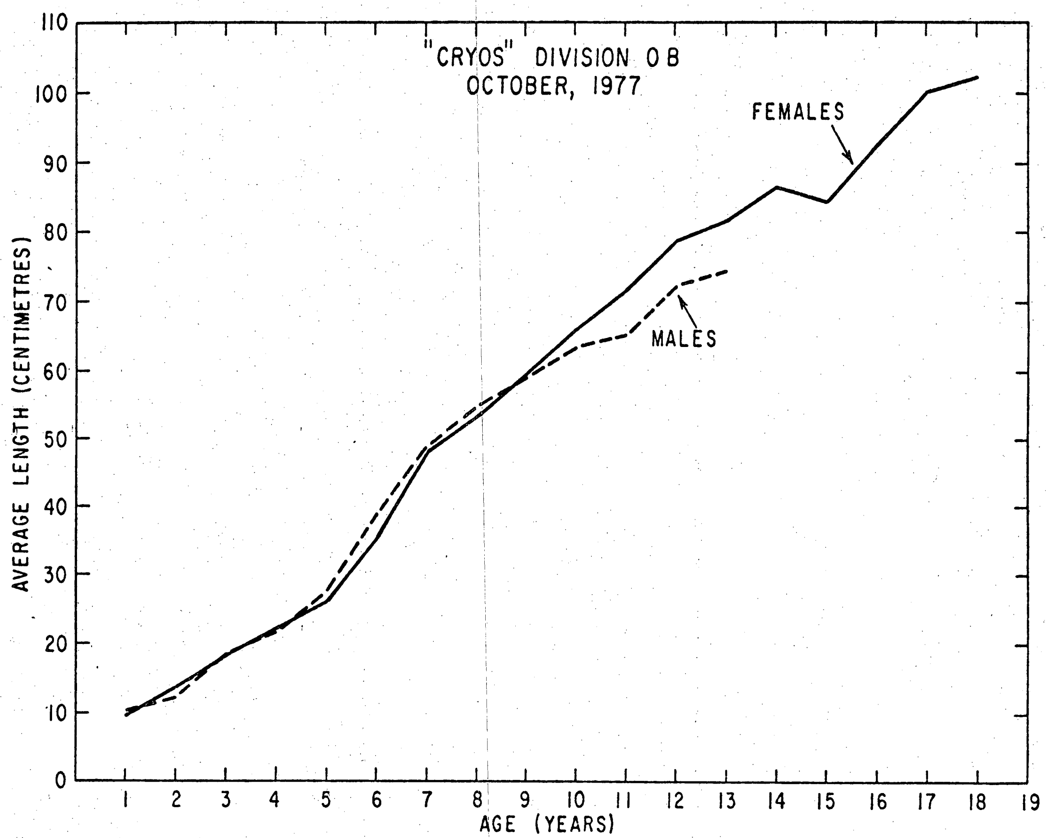


Fig. 13. Average length at age for female Greenland halibut in Subarea 0 as taken by the research survey in 1977 by the French research vessel "Cryos".

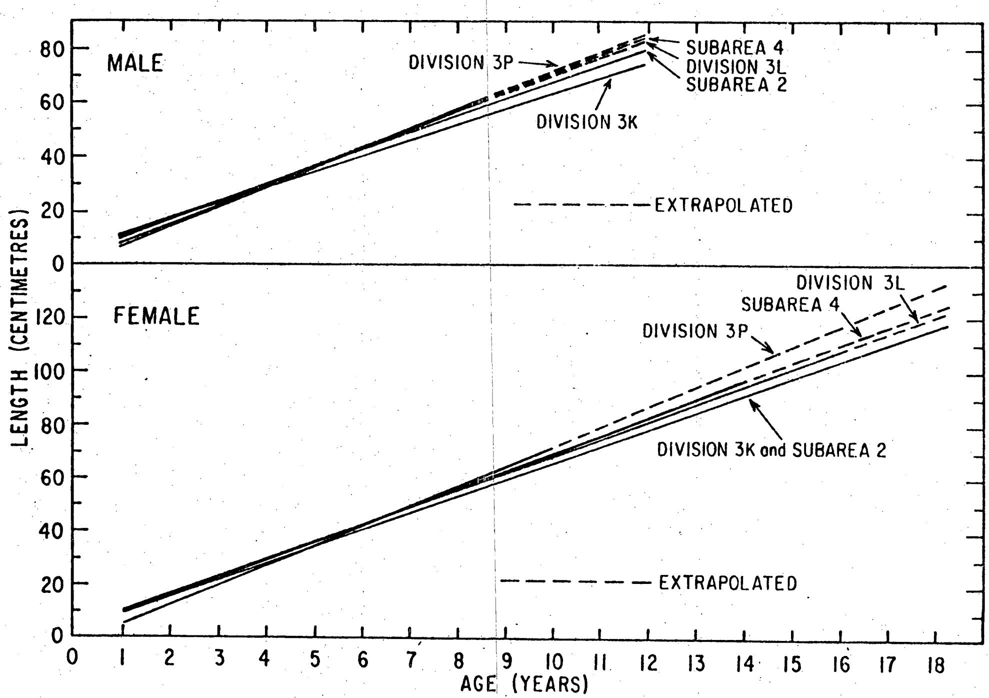


Fig. 14. Regression of length on age for male and female Greenland halibut for ICNAF Divisions 3P, 3L and 3K and Subareas 2 and 4 (from Bowering, 1978).

The Greenland halibut spawns in deep warm waters during winter in Davis Strait as previously mentioned. Templeman (1973) suggested that higher temperatures aid Ovarian and embryonic growth which could explain why Greenland halibut with large eggs close to spawning condition are extremely uncommon in the bays or fiords and on the continential shelves of the Northwest Atlantic. Observations on males have shown that they probably reach sexual maturity much earlier in the life cycle than females (Bowering 1977), however they have not been observed in "running condition" (fully ripe) therefore, it is difficult to determine an accurate point of sexual maturity. This problem could be due to time in the year when surveys have been carried out.

Research data on sexual maturity of females from the research vessel <u>Cryos</u> data in Div. 0B in 1977 are presented as percent mature at length and a maturity ogive is drawn by eye through the points (Fig. 15). The length at 50%

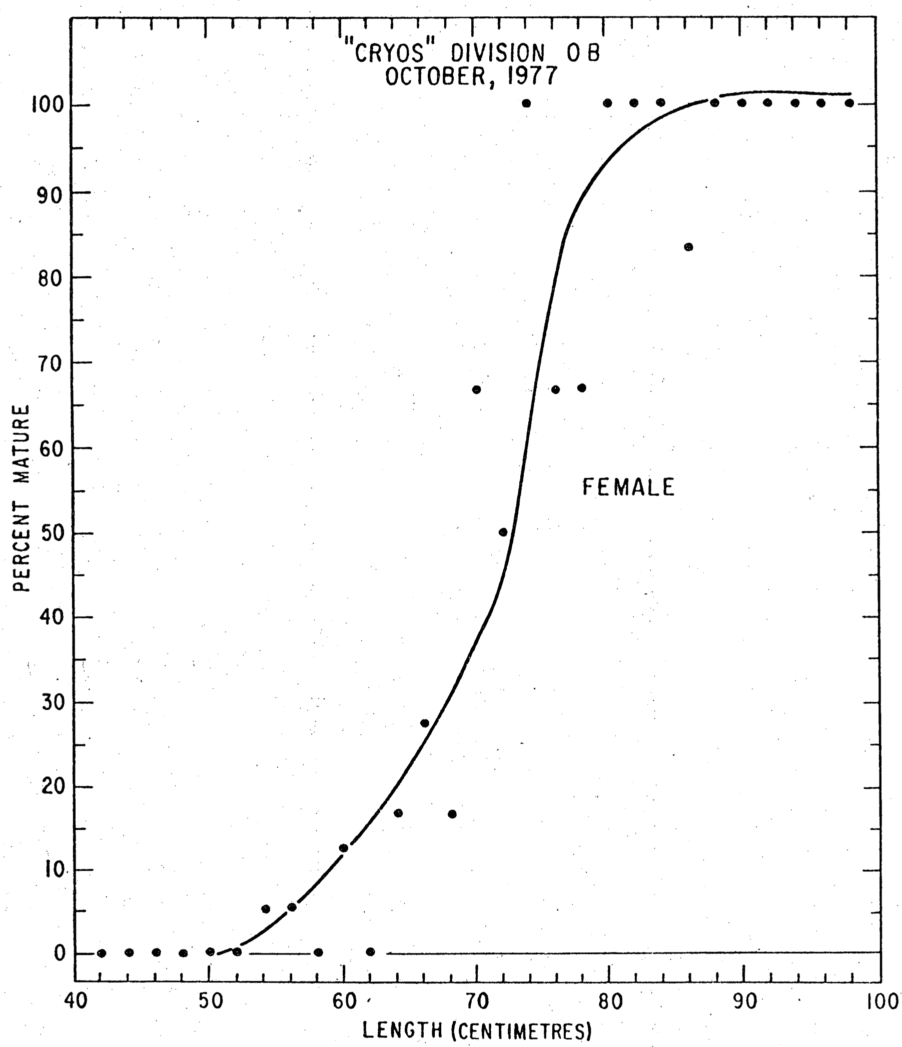


Fig. 15. Maturity ogive of female Greenland halibut in Div. 0B from the "Cryos" survey in October, 1977.

maturity level is estimated to be about 73 cm. This length applied to the average length at age in Fig. 13 would suggest an approximate age of 50% maturity at age 11.

In Subarea 2 it was recently suspected that since female Greenland halibut appear to be so old when maturing that they may in fact resorb remaining eggs so quickly that the visual appearance of immature condition may in fact be misleading (Walsh & Bowering 1980). To elucidate this problem a comparison of histological and visual observations was carried out and found to show little difference (Fig. 16, from Walsh & Bowering 1980). In fact the visually observed maturity ogive was almost exactly the same as that for Div. 0B with the histologically observed maturity ogive slightly greater.

Recent data are not available for Greenland halibut, however, Smidt (1969) published some data on the feeding of Greenland halibut in Subarea 1 (Fig. 17 Table 1). It was evident from his analysis that the pink shrimp (Pandalus borealis) is by far the most important food item in the diet of the Greenland halibut in Greenland waters. As a result of this he found that the largest

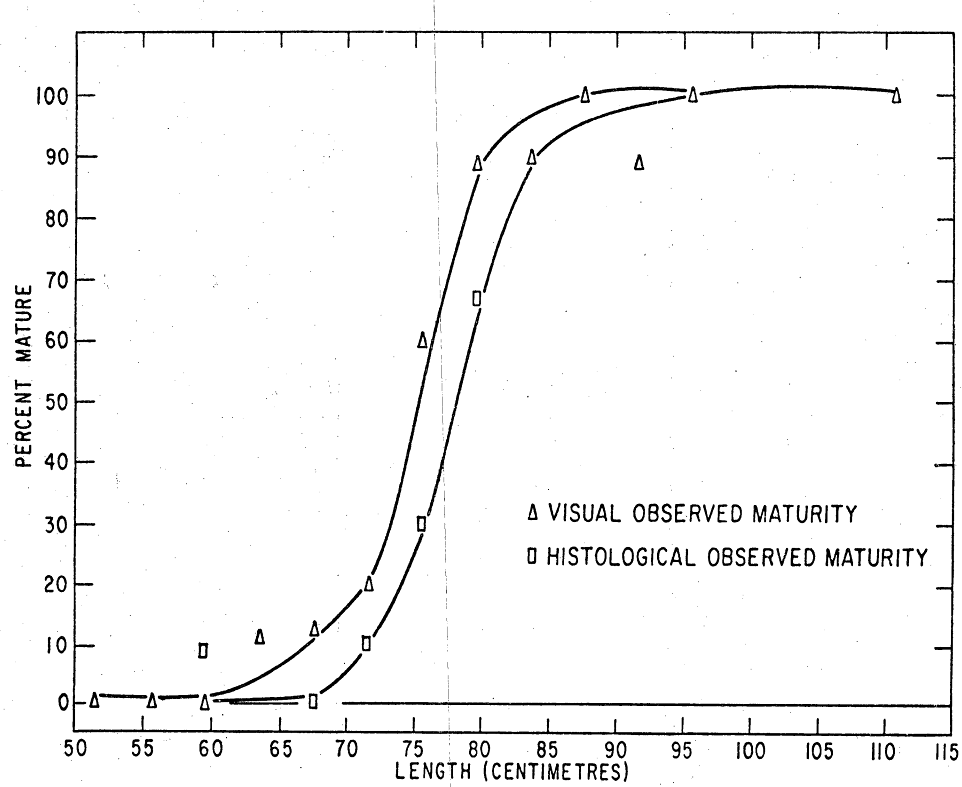


Fig. 16. Maturity ogives for visual and historical stages of maturity of female Greenland halibut in northern Labrador (from Walsh & Bowering, 1980).

Table 5. Stomach contents sampled in 1946-61 in fjords in different districts and in Disko Bay. One sample from March, the others from July-December. Frequency-% of different food components. Numbers of stomachs in which the food components are found are given as % of stomachs with food content. (From Smidt, 1969).

District	Julianehab	Godthab	Holsteinsborg	Disko Bay	Umanak	Total
No. of stomachs						
examined	219	665	84	200	81	1249
with content	98	62	66	75	24	325
Crustacea total	66	55	100	81	92	76
Prawns total	47	43	61	64	58	54
Pandalus borealis	44	39	59	64	46	51
Other prawns	4	6	2	1	13	4
Borcomysis	15	-	81	21	38	29
Euphausids	17	-	20	4	-	10
Crustacea varia	-	11	12	4	-	6
Squids	3	2	-	5	-	2
Other invertebrates	1	2	-	1	-	1
Fish total	41	47	3	23	12	28
Mallotus villosus	30	11	-	7	-	13
Lycodes	4	14	-	3	-	5
Fish varia	7	23	3	13	12	11
Fish lengths in cm .	20-94	31-118	30-80	20-60	50-98	20-118
Fishing depth in m .	240-620	300-580	330-350	260-400	115-700	115-700

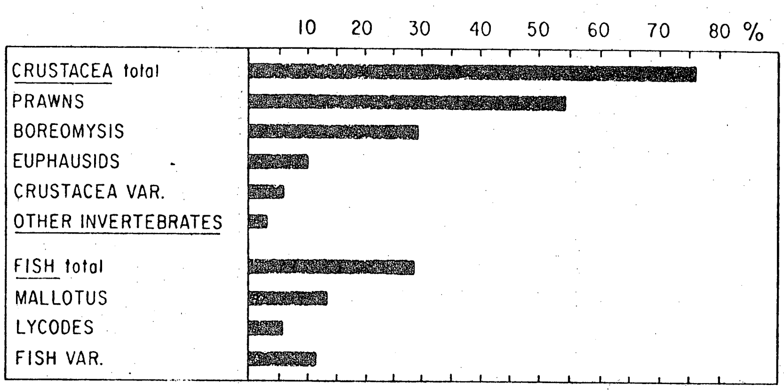


Fig. 17. Frequencies of various food components in stomachs of Greenland halibut fished in inshore West Greenland waters in 1946-61. The numbers of stomachs in which the food components are found are given as % of stomachs with food content (from Smidt, 1969).

concentrations of Greenland halibut in Subarea 1 were located in exactly the same localities where the richest shrimp stocks were found. This applied to both the offshore and the fiords. Other crustacea were commonly found in the stomachs of Greenland halibut such as various types of euphausids gammarids and crab. Fish were also found at about 30% incidence primarily Arctic Cod (Boreogadus saida).

In other areas such as Subarea 3, the food composition was the opposite according to Lear (Ms, 1970) in that the prime food component being fish mainly capelin. In general, Greenland halibut appears to be highly variable in its diet depending upon the concentration of food species in a particular area of its range.

2. Distribution

(a+b) General distribution, migration of exploitable stock and spawning areas.

Recent information on distribution of Greenland halibut in the Davis Strait region is limited mainly to the surveys of France.

The average numbers and average weights per set from the RV Cryos survey in October 1977 in Div. 0B are presented in Fig. 18 and 19 respectively. It is evident from these figures that Greenland halibut are generally distributed throughout the survey area of Div. 0B. The average weights per set (Fig. 19) indicate the larger catches by weight are in the deeper waters towards the mid-range area. The larger average numbers per set on the other hand were found in the shallower waters (Fig.18) and were much more abundance in the northern part of Div. 0B).

A survey by the French research vessel RV Thalassa in 1970 in Subarea 1 indicates Greenland halibut distributed along the coast of southwest Greenland with the larger average catches appearing nearer the coastline of west Greenland for the area surveyed (Fig. 20). Since this survey was conducted in July-August it would suggest that the migration from the spawning grounds to the fiords occurs as indicated in Smidt (1969).

A more recent shrimp survey by the RV Thalassa in September-October 1979 (Fig. 21) shows larger average catches on the western slop of Store Hellefiske Bank between 66°-68° north latitude in Subarea 1 than the 1970 Survey (Fig. 20). This could indicate a larger stock size in recent years or a prespawning concentration forming in the area as might be expected this time of year or a combination of both.

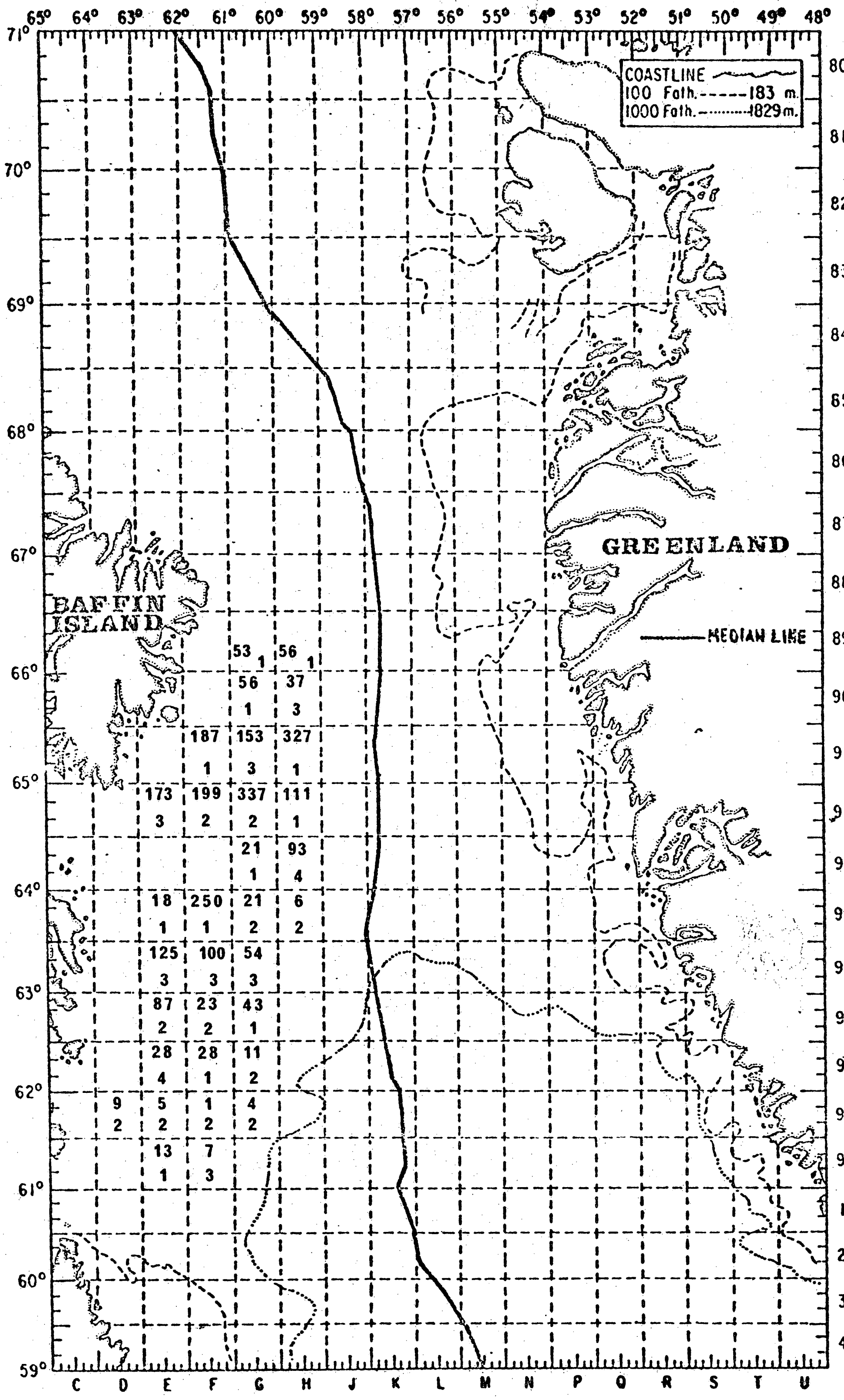


Fig. 18. Distribution of Greenland Halibut, R/V Cryos - Sept-Oct 1977. [Numbers per 30 minutes (upper); Number of hauls (lower).]

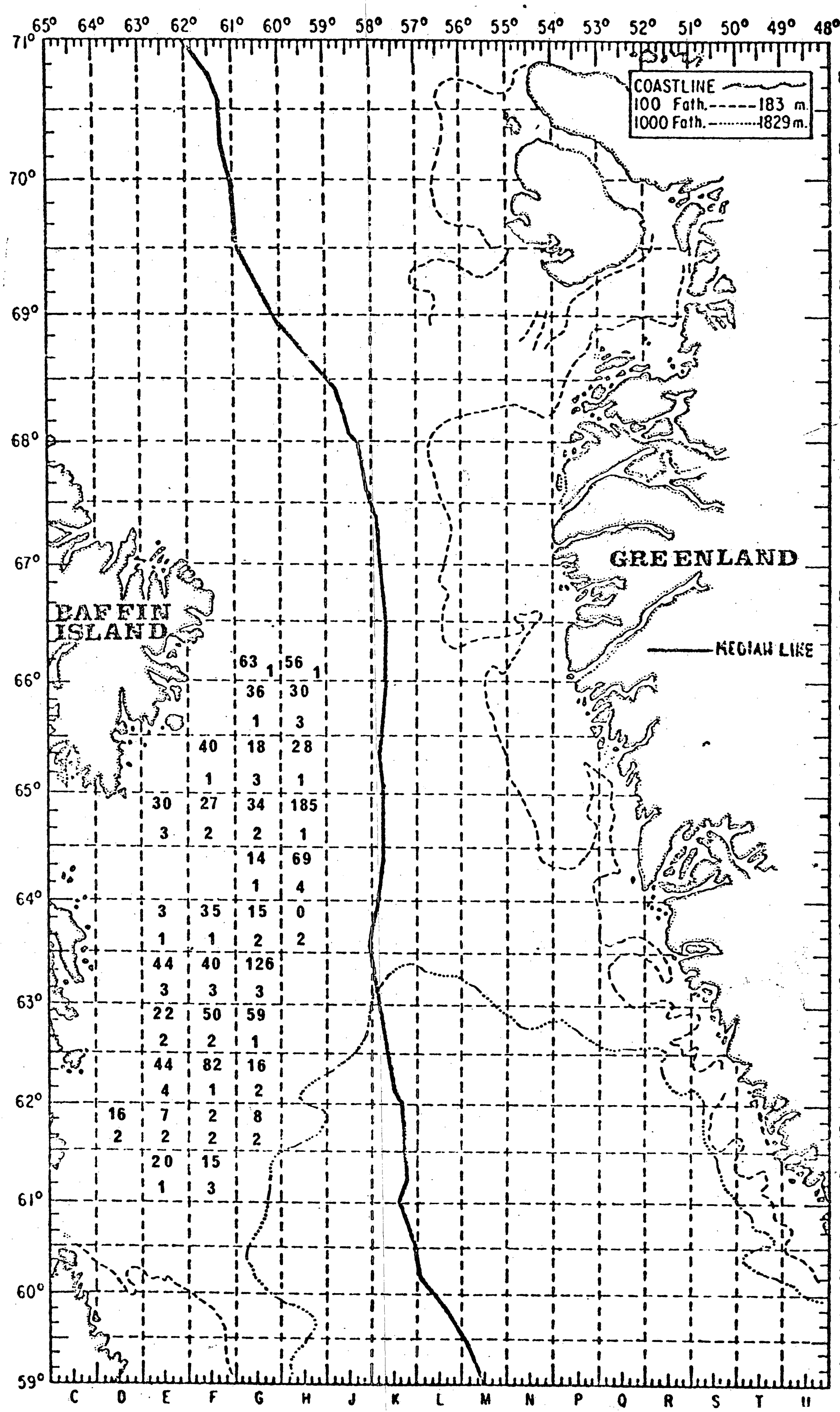
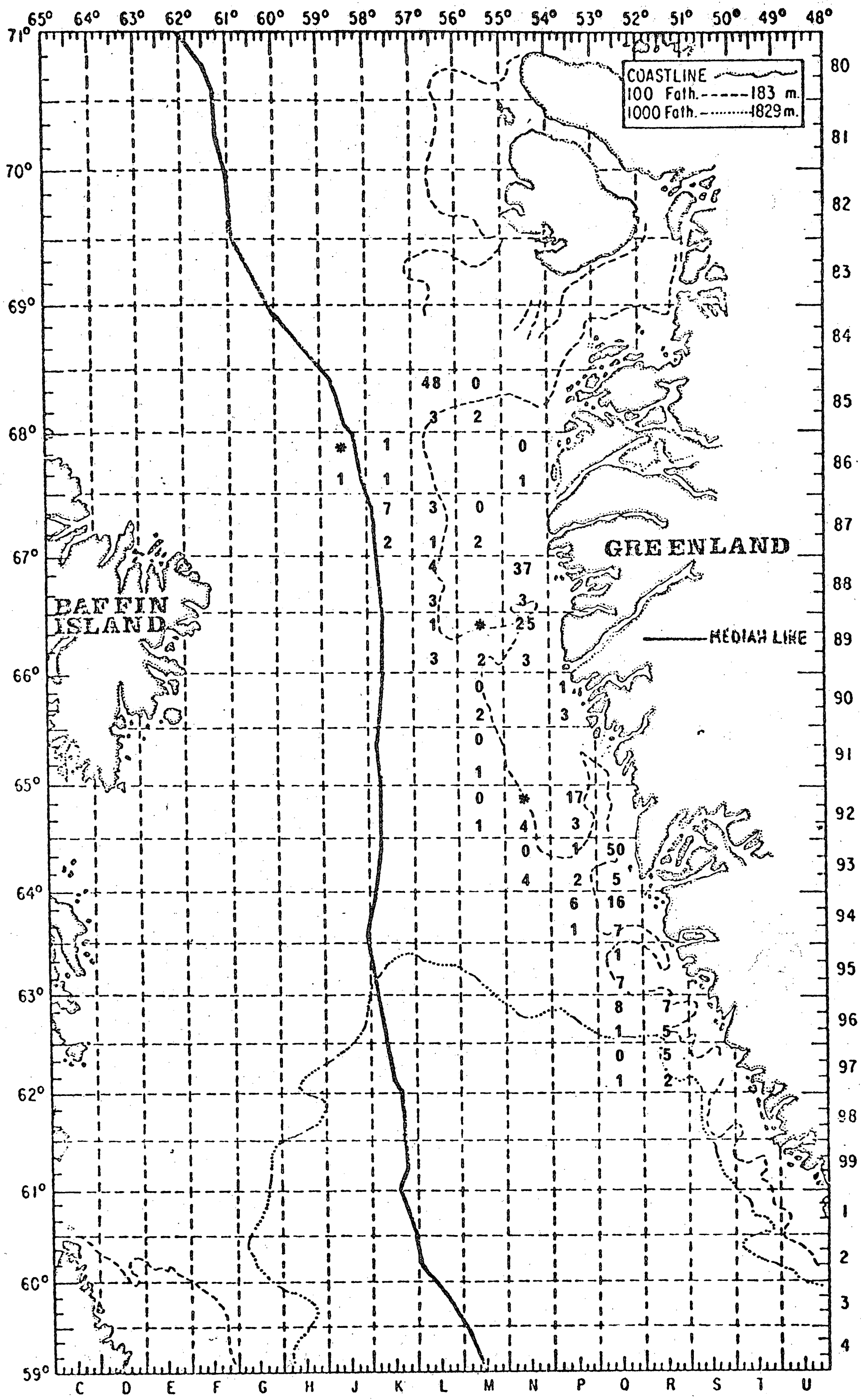


Fig. 19. Distribution of Greenland halibut, R/V Cryos- Sep-Oct 1977.
[Weight per 30 minutes (upper) in kg; number of hauls (lower).]



✱: presence

Fig. 20. Distribution of Greenland halibut, R/V Thalassa - July-Aug 1970.
[Weight per 30 minutes (upper) in kg; number of hauls (lower).]

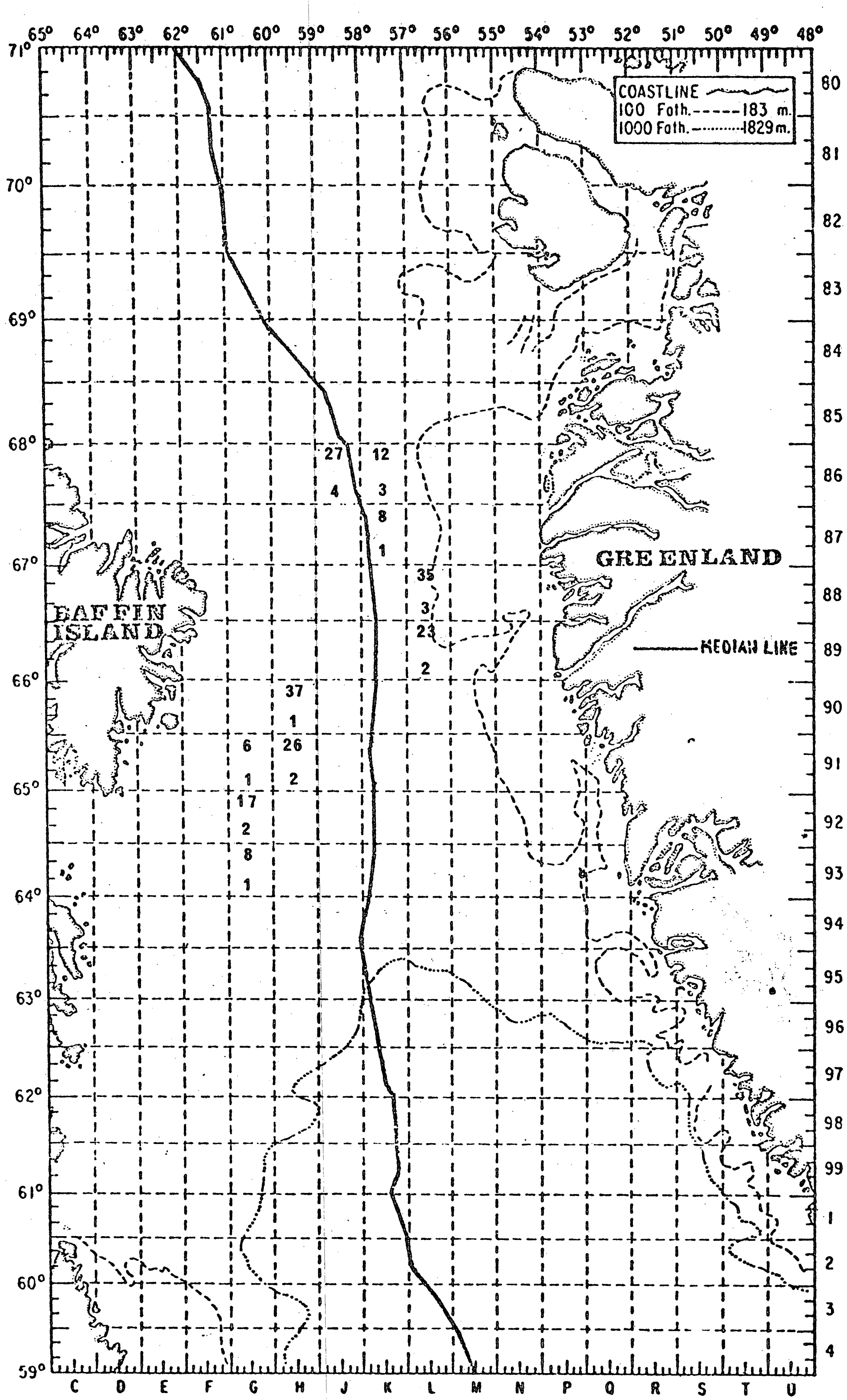


Fig. 21. Distribution of Greenland halibut, R/V Thalassa - Sep-Oct 1979.
[Weight per 30 minutes (upper) in kig; number of hauls (lower).]

There is a distinct change in distribution of size according to depth. This is evident in Fig. 22, 23 and 24 and Table 6. The smaller sizes are predominent in the shallower depth ranges up to 400 m whereas beyond 400 m, prerecruits become less abundant and the larger fish become more abundant. Because of this, the mobile fishery on commercial size groups would be expected to be in mid-range between the two countries.

(c) Eggs and larval distribution

The pelagic larvae of Greenland halibut generally drift from the spawning site at the Greenland-Canadian cascade in the Davis Strait area (Fig. 25) along the west coast of Greenland during the summer months and in the autumn the bottom stages become more abundant. It is evident that along the west Greenland coast there may be several areas where newly settled bottom stages live before migrating to deeper waters and into the fiords.

(d) Nursery areas

According to Smidt (1969) the I-group of Greenland halibut is very abundant west of Disko, and the vast shallow areas (about 200-250 m) northwest, west and southwest of Disko Bay can be regarded as very important nursery grounds from where the stocks in Disko Bay, Umanak district and more northern Greenland districts are recruited. Accordingly, large numbers of these young fish probably move south and spend much of their early life in the northern part of Div. 0B. This is evident from the RV Cryos survey where most of the catches consisted of very large numbers of fish less than 35 cm (Fig. 26). Another nursery ground is found in the coastal area of Godthaab district (250 m) and it is assumed that there are several nursery grounds along the southwest coast of Greenland from where the different fiord stocks are recruited. Unfortunately, there is little concrete evidence to support this. The length compositions of Greenland halibut from shrimp trawl catches taken in the coastal areas, the outer and inner fiord areas and at different depths do however illustrate the gradual migration from shallow coastal areas to the inner fiord areas and to deeper water during the life span of the fish (Smidt 1969).

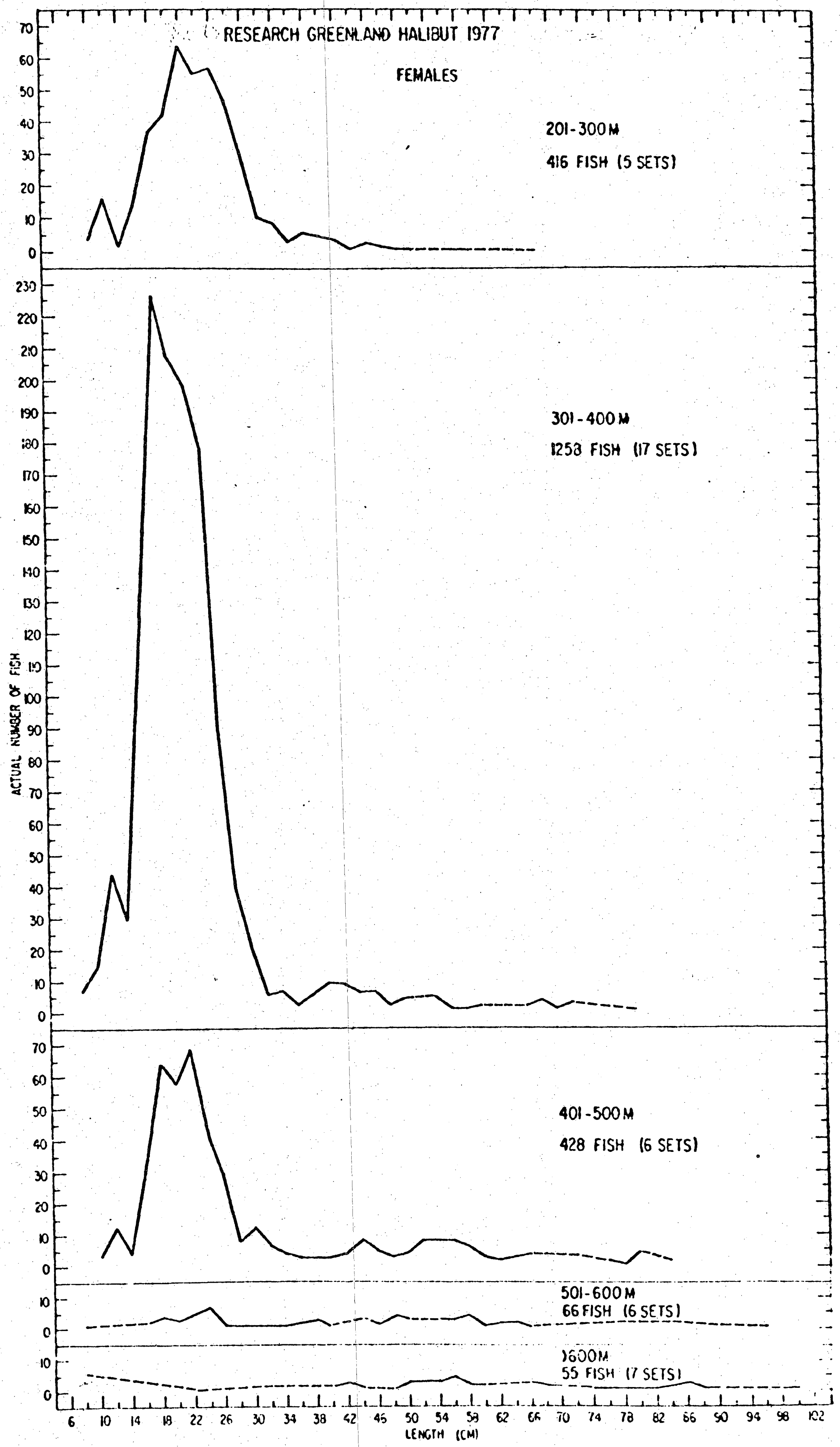


Fig. 22. Depth distribution by size of female Greenland halibut in Division OB from the French research vessel *Cryos*, October, 1977.

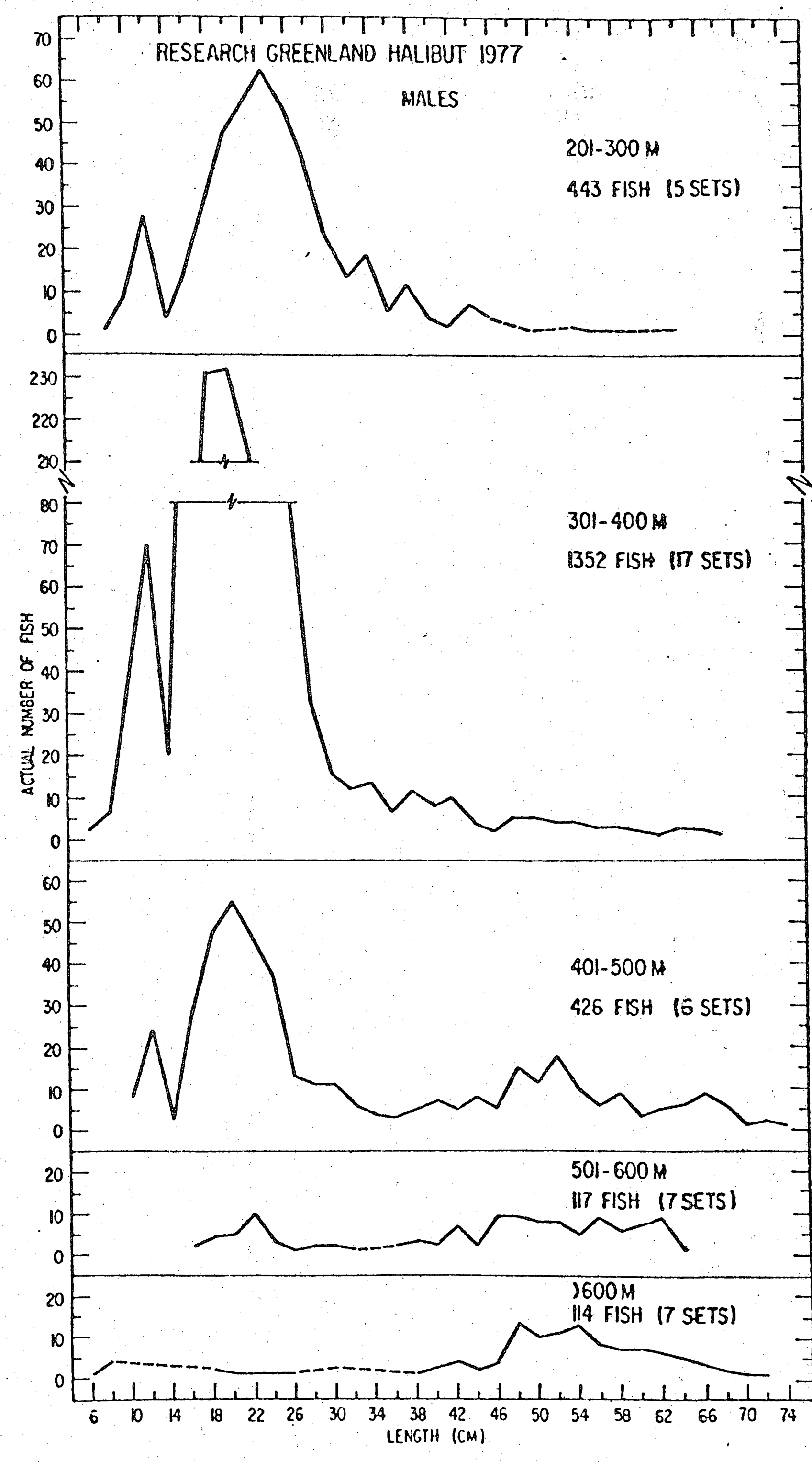


Fig. 23 . Depth distribution by size of male Greenland halibut in Division 0B from the French research vessel Cryos , October, 1977.

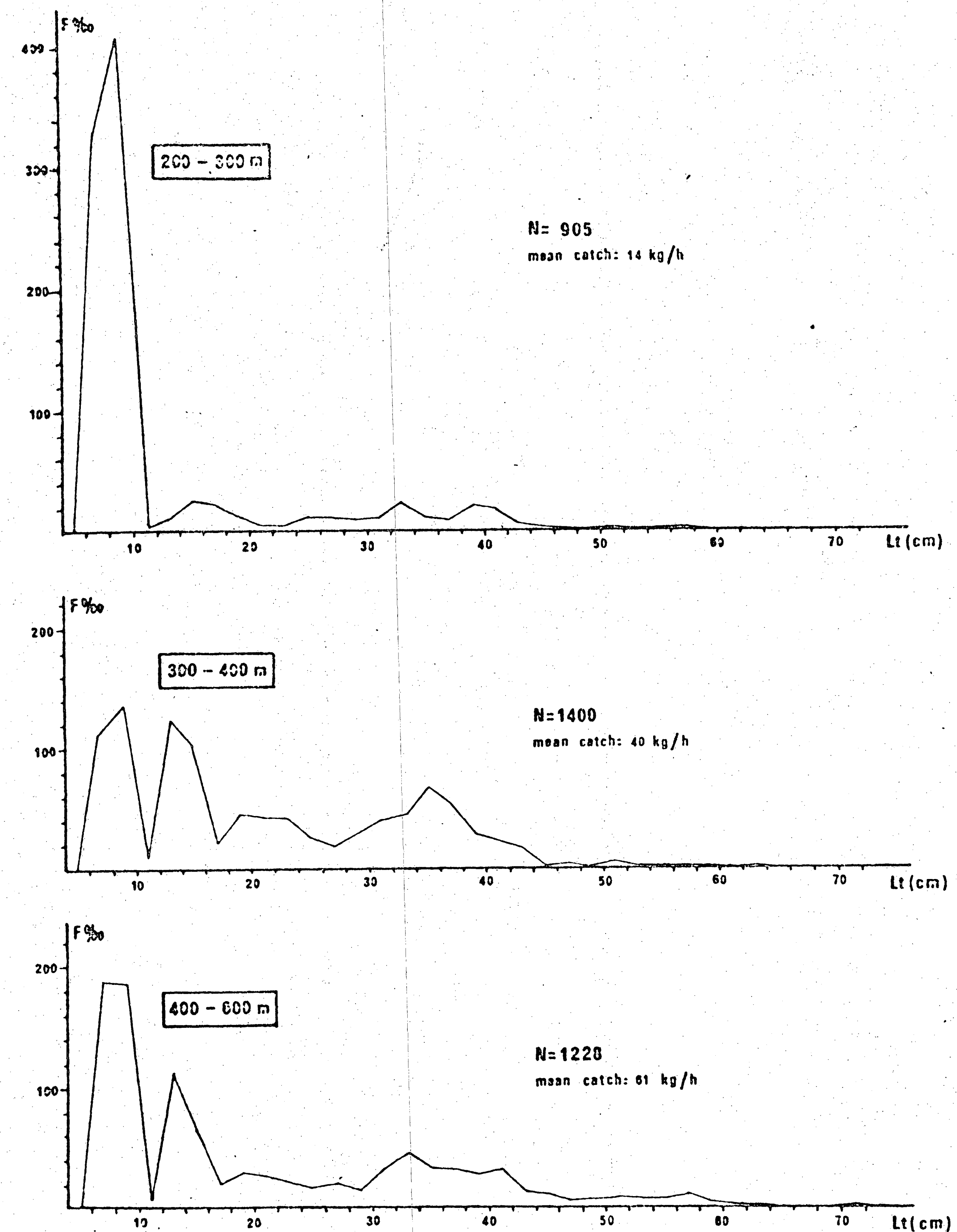


Fig. 24. Length frequencies of Greenland halibut and abundance index by depth in Subarea 1B - Thalassa survey September-October, 1979.

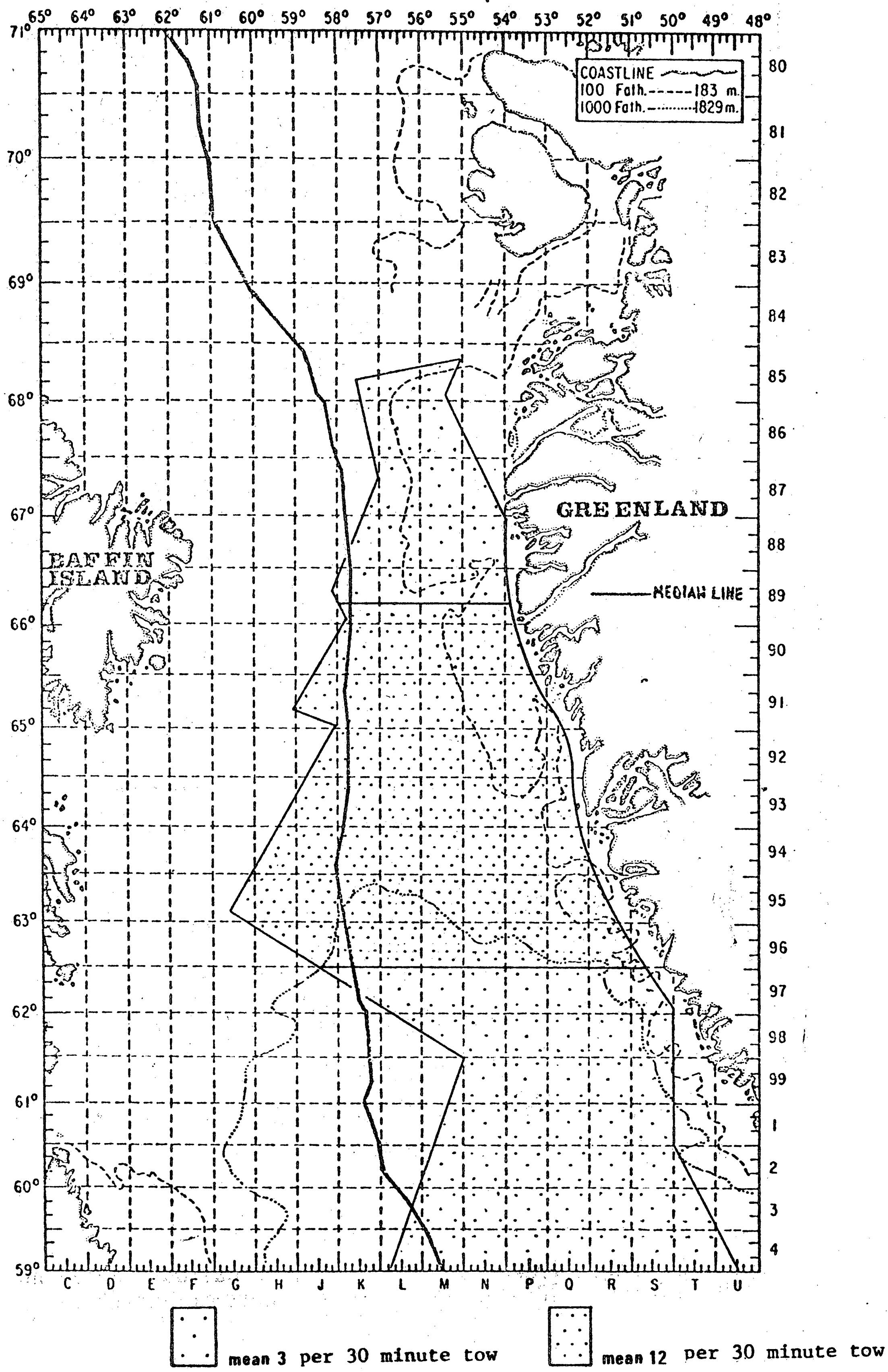


Fig. 25. Occurence of pelagic Greenland Halibut larvae from Danish investigations 1908-1964 (from Smidt,1969).

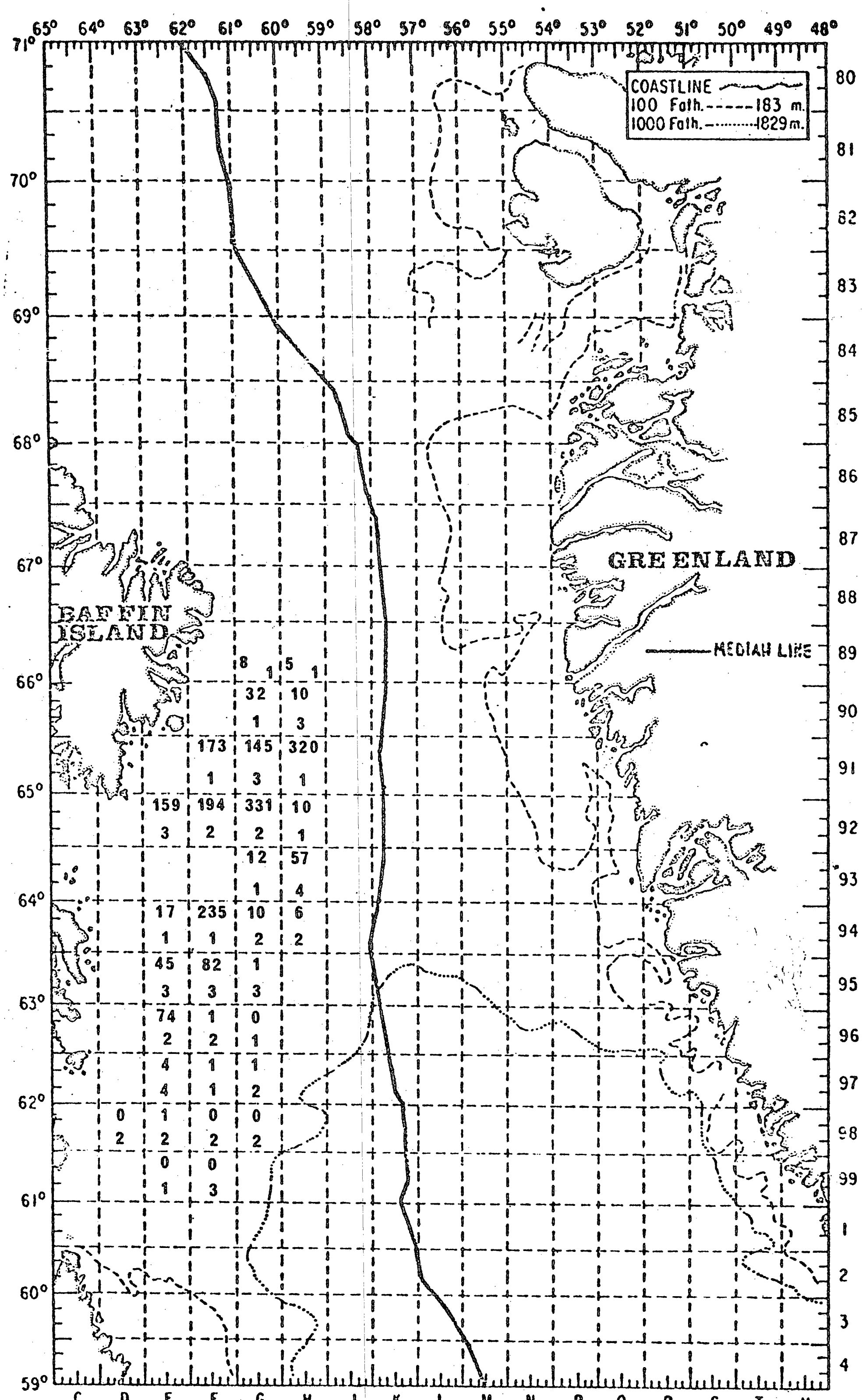


Fig. 26. Distribution of Greenland halibut, R/V Cryos - Sep-Oct 1977.
[Numbers ≤35 cm LT per 30 minutes (upper); number of hauls (lower).]

Table 6. Bathymetric distribution in number and weight of Greenland halibut in Subarea 0. R.V. "Cryos" - September-October 1977.

Depth (m)	<100	100-150	150-200	200-300	300-500	500-700
$\bar{N}$/30 mn	18.0	135.9	163.4	47.6	17.2	31.4
$\bar{N}$/30 mn (kg)	3.0	35.6	33.2	45.4	36.6	47.0

3. Biomass estimates

Estimates of trawlable biomass for Subareas 0 + 1 are not available for the area as a whole, however, estimates of biomass in Div. 0B are available from the RV Cryos and the German Democratic Republic RV Ernst Haeckel from 1977 and 1978 respectively. Biomass estimates by depth from the Cryos survey are presented in the following table.

	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 (t)	130	15,432	16,722	23,823	14,874	6,619	77,600

The estimate of minimum trawlable biomass in 0B from this survey yields a value of 77,600 + 7606 t (Forest et al. 1978). This biomass estimate covers the total area of Div. 0B at 30,304 square nautical miles. It also suggests that the greatest biomass of Greenland halibut can be found between 200-300 m.

The survey of the RV Ernst Haeckel in 1978 was conducted in the accessible deep water region of Div. 0B and yielded a biomass estimate of 90,000 ± 5000 t covering an area of 20,078 square nautical miles.

It must be noted that these biomass estimates refer to the old boundary between Subareas 0 and 1 and consequently are underestimates of biomass in the new Div. 0B.

4. The Fishery

(a) Historical catches, catch and effort and present management strategy

Nominal catches of Greenland halibut in Subareas 0 + 1 increased from 9000 t in 1973 to over 25,000 t in 1975. The landings declined to a level of 16,000 t in 1976 then further declined to a level of 13,000 t in 1977 and 12,000 t in 1978. Catches by country for Subarea 1 from 1969-78 are presented in Table 7. Catches for Subarea 0 are presented in Table 8 from 1973-78. For both areas the main prosecutors of the Greenland halibut fishery have been historically the Soviet Union and Denmark. In Subarea 0 the Faroese are the main Danish component whereas in Subarea 1, the inshore Greenland fishery by Greenlanders is the main Danish component. Since 1969, the USSR has accounted for more than 48% of the total Greenland halibut landings in Subarea 1 and more than 60% in Subarea 0. In Subarea 1, Denmark has accounted for 40% since 1969 and in Subarea 0, almost 31% of the total landings since 1973.

Table 7. Nominal catches of Greenland halibut in Subarea 1, 1969-78.

					YEAR						
Country	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	Total
Denmark (F)	1	-	38	442	-	-	-	34	77	2	594
Denmark (G)	1477	1212	1159	2950	3655	4054	3436	3546	6110	5985	33,584
Denmark (M)	-	-	-	20	5	-	2	3	-	-	30
FRG	68	13	16	128	65	2	24	93	590	4965	5964
GDR	-	-	-	-	754	601	56	160	335	-	1906
Norway	19	-	1168	12	35	12	37	7	11	5	1306
Poland	1	-	-	135	-	-	-	-	-	-	136
USSR	123	444	545	245	2913	8650	19,775	6944	1389	-	41,028
UK	-	-	-	-	1	18	9	-	-	-	28
Portugal	-	-	-	-	-	32	41	95	-	-	168
Non-members	-	-	112	-	-	-	-	-	-	-	112
Total	1689	1669	3038	3932	7428	13,369	23,380	10,882	8512	10,957	84,856

Table 8. Nominal catches of Greenland halibut in Subarea 0 1973-78.

Country	1973	1974	1975	1976	1977	1978	Total
Canada	-	-	-	-	-	-	-
Den (F)	-	-	825	916	930	550	3221
Den (G)	912	4	288	-	-	-	1204
Den (M)	-	-	-	-	-	-	-
FRG	-	-	-	-	-	-	-
GDR	-	-	-	-	240	-	240
Norway	-	24	-	-	-	146	170
Poland	-	-	-	-	-	-	-
Portugal	-	-	-	-	-	-	-
Romania	-	-	-	-	-	-	-
USSR	1218	861	455	3990	2967	-	9491
Non. Mem.	-	-	-	-	-	-	-
Total	2130	889	1568	4906	4137	696	14,326

Total catches of Greenland halibut by Subarea since 1973 are as follows:

Catches ('000's t)

	1973	1974	1975	1976	1977	1978	Total	%1973-78
SA0	2	1	2	5	4	1	15	17%
SA1	7	13	23	11	9	11	74	83%
Total	9	14	25	16	13	12	89	100%

It must be noted that these statistics refer to the boundary line between Subareas 0 and 1 before the change in boundary corresponding to the midline of the economic zones between the two counteries which means Subarea 1 is now smaller and Subarea 0 larger by the same area. From this table it shows that the landings from Subarea 1 have averaged about 83% of the total from 1973-78. This large percentage is mainly due to the Greenlanders fishing for Greenland halibut in the fiords which accounts for more than 40% of the total fishery. No effort data are available for Greenland halibut.

Because of inadequate data, a precautionary TAC of 20,000 t was placed on this stock in 1976 and 1977. It was subsequently increased to 25,000 t in

1978 as a result of Soviet biomass estimates from a research survey which indicated a fairly large stock of Greenland halibut in the area. An analytical assessment was presented to ICNAF during 1978 by the Soviet Union, however, there was very little evidence to support the input parameters. Consequently, the 25,000 t TAC remained for 1979. The TAC has remained at 25,000 t for 1980 and will remain again for 1981.

(b) Fishing patterns and variability

During 1979, information on catch breakdown of Greenland halibut by the Soviet Union for east of 58°W longitude and west of 58°W longitude became available to Canada from 1969-77. These data are used since they fit closely to the new boundary line and are presented as follows:

	Catches ('000's t)										
	1969	1970	1971	1972	1973	1974	1975	1976	1977	% 1969-77	% 1973-77
W of 58°W	0.9	0.7	1.6	5.5	2.2	0.9	2.2	7.0	3.4	42	31
E of 58°W	0	0	0.3	0.2	2.0	8.6	18.1	4.0	0.9	58	69

A breakdown of the Soviet landings over the same period based upon the 59°W longitude line (the old boundary line) is as follows:

	Catches ('000's t)										
	1969	1970	1971	1972	1973	1974	1975	1976	1977	% 1969-77	% 1973-77
W of 59oW	0.8	0.2	1.3	5.4	1.2	0.9	0.5	4.0	3.0	30	19
E of 59oW	0.1	0.4	0.5	0.2	2.9	8.7	19.8	6.9	1.4	70	81

Statistics reported to ICNAF do not cover both areas prior to 1973 although data presented to Canada in 1979 covered the period 1969-77. Thus, landings from Subarea 0 prior to 1973 had to be inferred from total landings as reported to Canada and landings from Subarea 1 as reported to ICNAF, however, from 1973 to 1977 the two sets of data could be compared and cross-checked. Therefore two sets of percentages are presented, 1969-77 and 1973-77. It should be noted that prior to 1972 the Soviet catches of Greenland halibut were low.

Regardless of what time period is used to compare the two sets of data there is a 12% shift in the proportion of these catches between the two areas from one data set to the other. This suggests that in between 58°W and 59°W a corresponding proportion of these catches has occurred. If this is so, then it is likely that Greenland halibut may be concentrated in commercial quantities in this area.

Shrimp (Pandalus borealis)

1. General Biology

Pandalus borealis (the pink shrimp or northern deepwater prawn) first matures and functions as male, then undergoes a relatively short transitional phase and, subsequently, spends the rest of its life as a female. This pattern of sex reversal is termed protandric hermaphroditism. Relatively subtle differences in life history occur in areas off West Greenland (Horsted 1978b) but for the purposes of this introduction, generalizations can be made.

Spawning occurs from as early as July up to October, the duration being variable among years. The egg-bearing period when females are termed ovigerous or berried lasts until April-May, when hatching occurs. The average number of eggs is approximately 1300 for a first-time spawner. The larvae are at first planktonic but after two to three months settle as juveniles in relatively shallow water. Males mature at three years with the transition to females occurring at 4 to 5 years.

Like other crustaceans shrimp have step-wise growth which takes place in the relatively short period after ecdysis (shedding of the old shell) when the animal is soft-shelled. Growth is affected by temperature. In northern areas the colder water results in slower growth than for conspecifics of more southern and/or warmer latitudes. Maturation (of either sex) tends to take longer and longevity is increased. Ecdysis cannot occur while the animal is ovigerous, otherwise eggs would be lost. Since females lay new eggs only a few months after the previous clutch has hatched, little time is available for growth. This results in an accumulation of year-classes at the upper end of the length frequency distribution. Ageing of shrimp by conventional methods is not possible since ecdysis removes any material which might otherwise indicate annual growth increments. Three age classes of juveniles and males and a composite group of females have been interpreted from modes in the length frequency data.

Natural mortality is believed to be high for pandalids generally. Contributing to this for P. borealis are main predators such as Greenland halibut (Reinhardtius hippoglossoides) and cod (Gadus morhua). Although redfish (Sebastes spp.) often occur in the same habitat, they are not considered as important a predator as the former two.

Shrimp reveal a varied diet including pelagic crustacea, polychaeta, foraminifera, radiolaria and detritus. They also support parasites including other crustaceans (mainly isopods) which, in a number of ways, can reduce reproductive potential. Certain protozoans may also render eggs non-viable and cause the breakdown of muscle fibres.

2. Distribution (Geographic, bathymetric and seasonal)

When considering shrimp distribution in Subareas 0 and 1, it should be recognized that there are two stock complexes. These are:

1. the traditionally fished West Greenland offshore and inshore stocks, and
2. unexploited shrimp stocks east of Baffin Island described by Minet et al. 1978b (Fig. 27).

The offshore grounds of the former overlap both subareas, the greater portion occurring in Subarea 1 and the latter lies exclusively in Subarea 0, and has not been included in the assessment of the overlapping stock, nor in the present TAC management.

(a) General distribution and migration of exploitable stock

Shrimp in the West Greenland offshore area are found in the whole of Subarea 1 with some overlap into Div. 0A. They are generally distributed from 150 to 500 m in temperatures of 1C to 4C with areas of greatest abundance occurring in Div. 1A, 1B and 0A. In 1979 shrimp were most abundant in these divisions on the northwest slopes of Store Hellefiske Bank between 200 and 400 m (NAFO, 1979). Previous data from Div. 1A offshore areas, except for areas immediately adjacent to Div. 1B, showed relatively low catch rates and smaller shrimp, but fishing in 1980 on previously unexploited parts of the grounds show catch rates as good as those in Div. 1B. Approximately 13% of the fishable part of the grounds east of 59°W may be located within the 12 nautical mile limit.

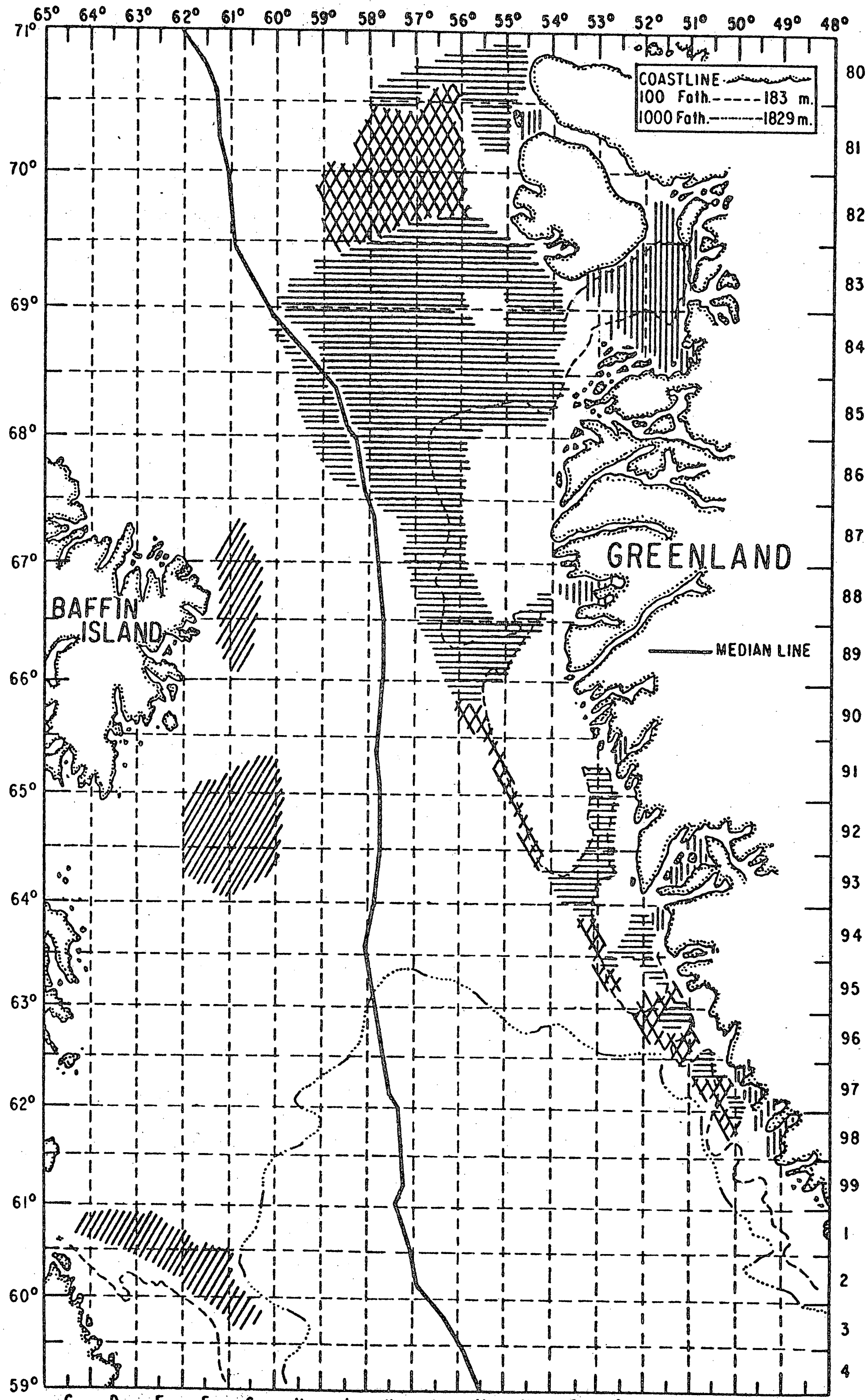


Fig. 27.
Offshore Greenland shrimp grounds.
Possible potential shrimp grounds, possibly nursery areas.
Major Greenland inshore grounds.
Areas where shrimp have been found off Baffin Island.

Although size distribution by depth is not so evident as in the inshore area, immature animals and males are usually found in relatively shallow water between 150 and 300 m. In depths greater than 300 m larger males and females predominate. Fig. 28 (Fréchette and Dupouy, 1979) shows size distribution by depth for the west Greenland offshore area in 1979. Modes in these length frequencies can be interpreted as age-classes.

Horizontal migrations of shrimp are not well-studied. Considerable variation in daily catch rates indicates that movements may be extensive in a given area over a short time. These changes in abundance may not only reflect horizontal migrations but fishing pressure, light intensity, currents, tides, changes in water temperature or any combination of these as well. Seasonal trends in water temperature may cause more extensive migrations (McLaren Marex Inc., 1979). There is also general consensus that females tend to move into more shallow water towards hatching time.

Shrimp are known to undertake a diel vertical migration usually associated with high and low sun periods. During the day, shrimp stay close to or on the bottom but at night rise vertically in the water column to considerable distances. As the amount of daylight varies on a seasonal basis so does the pattern of diel distribution. Fig. 29 (from Carlsson et al., 1978) indicates patterns of diel movement from commercial catch statistics.

The vertical migration is important when considering survey design to obtain biomass estimates, and the estimates have to be adjusted for the diel variation to reflect periods of maximum density.

(b) Spawning and nursery areas

Hatching females in other areas are believed to migrate into shallower waters where the larvae are released but this behaviour has not been elucidated for the offshore stock at west Greenland. Evidence of the differential size distribution by depth (as discussed earlier) suggests that nursery grounds occur over the whole area in relatively shallow water (150-200 m). An exploratory trip to Div. 1A also located shrimp of smaller average size than other areas indicating that specific nursery areas may be found in this region.

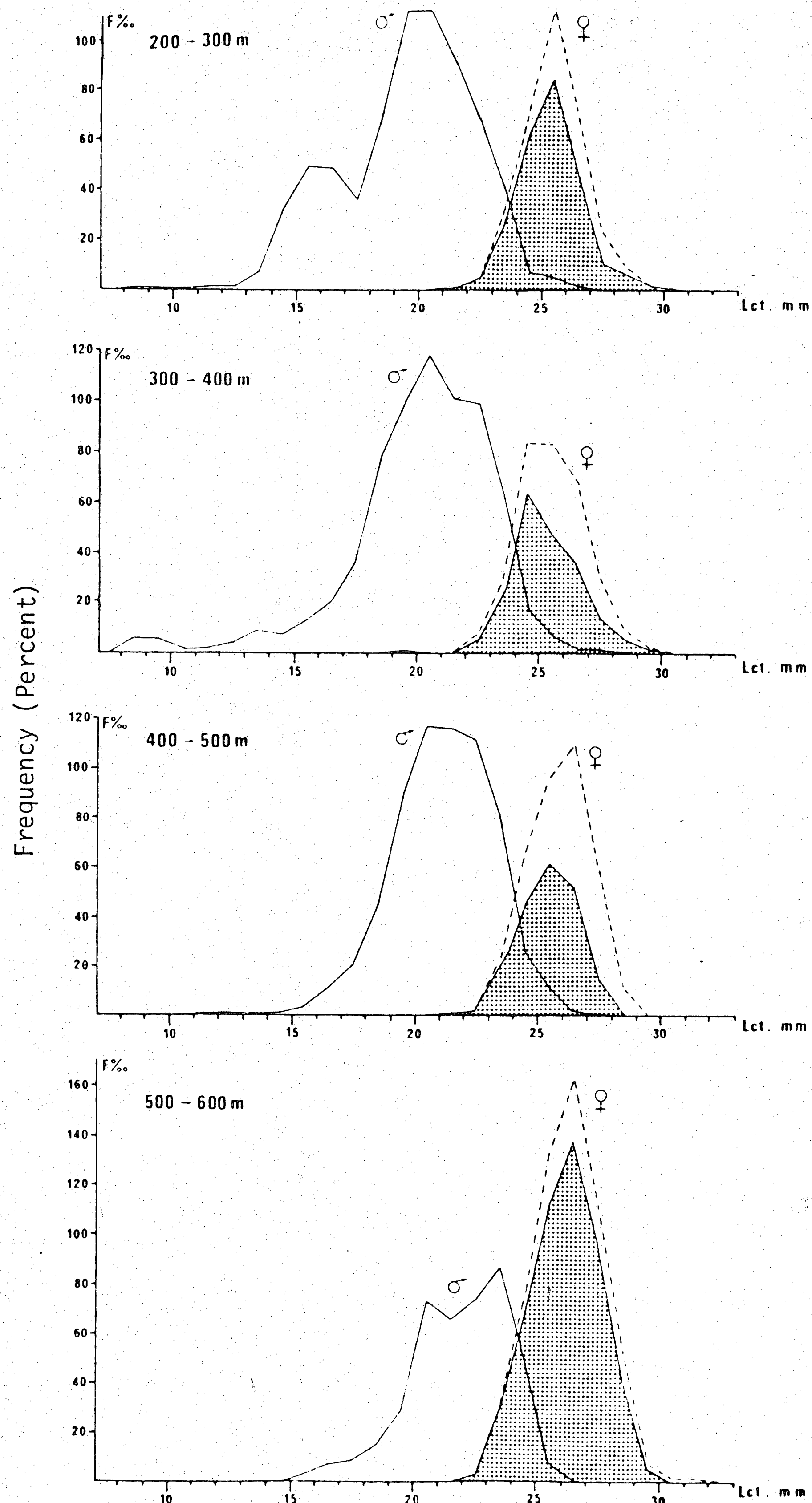


Fig. 28. Length distribution of shrimp (*Pandalus borealis*) in Division 1B according to depth (stippled area represents ovigerous females).

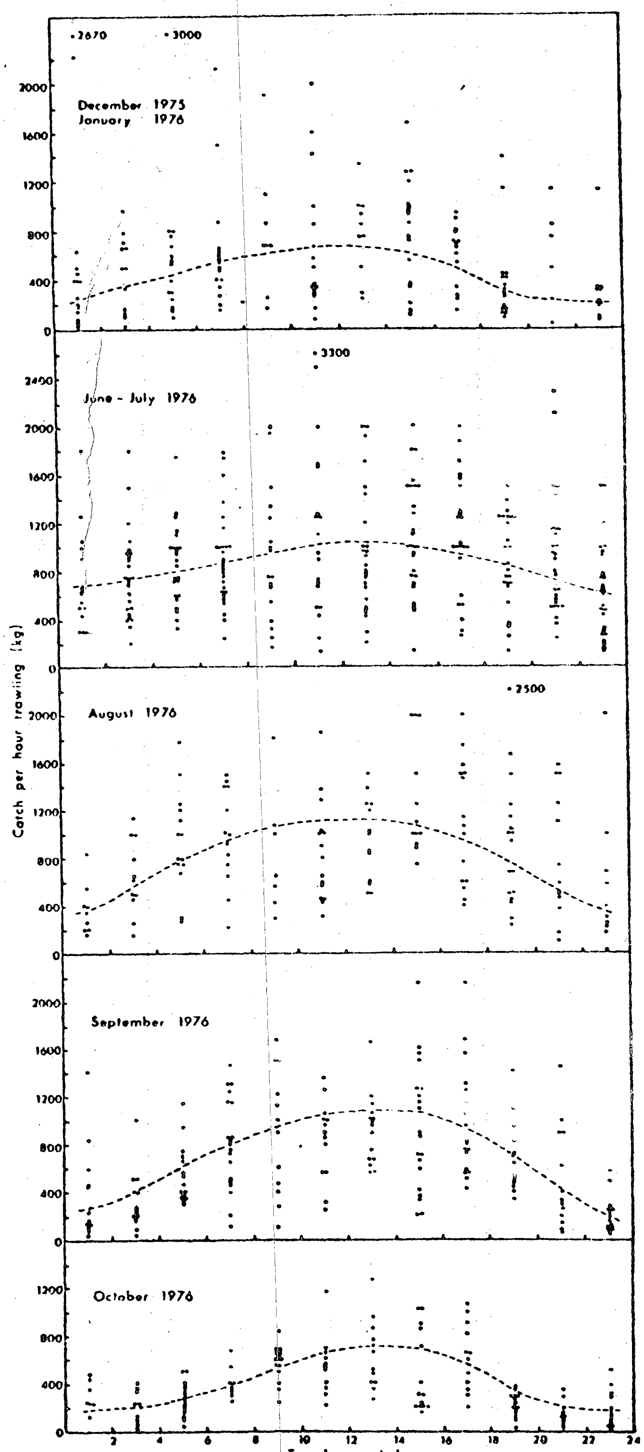
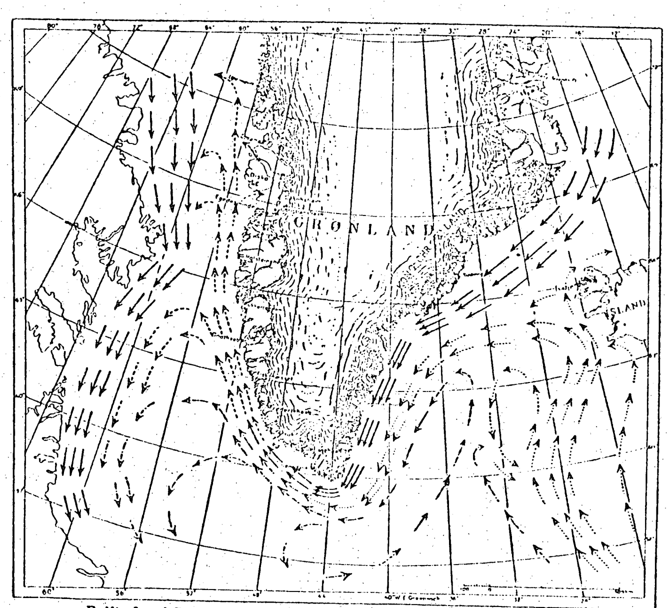


Fig. 29. Shrimp catches per hour trawling by the *Sisimlut* in Div. 1B from December 1975 to October 1976, arranged to show diurnal and seasonal variation. Each dot represents a haul plotted at the mid-point of a 2-hr period. The median lines are fitted by eye.

Failure for females to spawn seems to occur occasionally and may give female shrimp an opportunity for some extra growth. However, for the Subareas 0 and 1 stocks failure to spawn seems a minor limiting factor for the larvae production compared to egg mortality between spawning and hatching. Such mortality does occur not only in fiords with cold bottom water (see below), but also in the offshore stocks. In the latter case (and probably also in the cold fiords) the phenomenon may to be caused by a parasite dinoflagellate (Stickney 1978).

(c) Larvae

The Davis Strait is extremely dynamic in relation to ocean currents (Fig. 30). The circulation of these waters may have a significant effect on recruitment to inshore and offshore areas. A northward drift of shrimp larvae over the west Greenland Shelf may supply recruitment to the 1B-0A stock from southern areas. However, the spawning stock in 1B is also considered significant in that area because the effect of the currents is not so pronounced. There may even be some drift of larvae back southwards in the more westerly sections of the grounds.



Baffin Land Current and Labrador Current. West Greenland Current.
Irminger Current. Subartic Mixed Currents.

Fig. 30 The sea current round Greenland. (Simplified after Kiilerich, 1939, Hermann and Thomson 1946).

Some of the inshore grounds may be partly or fully dependent on recruitment from offshore areas. A partial dependency is thought to be the case for the Disko Bay area (Carlsson and Smidt 1978) and appropriate management has been implemented in the offshore area to prevent overfishing which might have deleterious effects inshore. A complete dependency on recruitment from offshore areas exists for some minor inshore stocks in the threshold fiords, where bottom water temperature seems to be so cold that spawned eggs gradually all die before hatching.

3. Biomass

Estimates of biomass, both from commercial and research data, have been documented for the west Greenland zone. The swept area (volume) methods is most commonly employed which leads to minimum trawlable estimates. Results obtained from such surveys have been plagued by extreme variability in an assumed homogeneous situation. Factors such as vertical migration, light intensity, tides, seasonal migration, water temperature and predators may singly or collectively cause some of this variation. Some attempts have been made to adjust biomass figures to reflect maximum catch levels.

Photographic techniques (Jørgensen and Kanneworff, 1980) have also been used with some success to estimate biomass but this method also involves high variance.

In 1979 Canadian and French research surveys on shrimp resources were carried out in the Davis Strait (Dupouy et al., 1979; Parsons 1979). Information from both provide estimates of biomass in an area from 66°N to 69°N in the Store Hellefiske Bank area. Differences exist in stratification schemes and estimates of trawl opening but standardization of the data lead to a combined estimate of 45,000 t (Table 9). This is not very different from the trawl survey, estimates of 55,000 t for a similar area in 1976 (Horsted 1978a) and from the 1979 French commercial data (Minet 1979) which led to estimates between 46,000 and 52,000 t. However, the 1979 surveys used trawls with smaller meshes which caught relatively more small and medium - sized shrimp than in 1976. Therefore, biomass in this area may be somewhat lower in 1979 than in 1976.

Table 9. Shrimp biomass by Subarea from French and Canadian combined data, 1979.

French Stratum Number	Area (km2)	% Area Subarea 1	Subarea 0	Average Canadian -French Biomass (t)	Biomass (t) Subarea 1	Subarea 0
02	8427	83.7	16.3	12,505	10,467	2038
03	3355	97.2	2.8	5958	5791	167
04	3032	64.1	35.9	8140	5218	2922
05	637	-	100.0	1540	-	1540
06	3665	85.4	14.6	5633	4811	822
07+08	2298	100.0	0	2006	2006	-
09	1565	100.0	0	5798	5798	-
10	1420	48.0	52.0	44	21	23
11	1200	95.7	4.3	2308	2209	99
12	1135	100.0	0	452	452	-
13	610	100.0	0	314	314	-
14	4000	100.0	0	191	191	-
15	1385	100.0	0	482	482	-
Total	32,729 km2			45,371	37,760	7611
%				100	83	17

Two independent estimates of the proportion of biomass by Subarea are available from the 1979 survey areas. Both assume that within each depth stratum shrimp are homogeneously distributed (the same assumption used with swept area biomass estimates). The French survey indicated 16% and 84% of the trawlable biomass in Subareas 0 and 1, respectively. The Canadian estimates are 25% and 75%, respectively, but for a smaller area (66°N to 68°30°oN).

Data from both surveys were standardized and used together to give better estimates by reducing variability within each stratum. The results of the combined data indicated 17% of the biomass in Subarea 0 and 83% in Subarea 1. Catches used in this exercise have been adjusted to reflect diel variability in abundance (Carlsson et al., 1978). Although fishing takes place outside the zone surveyed (especially in 1980 in areas to the north and east) it is estimated that around 85% of the total offshore catch occurred within this area so far in 1980 based on preliminary catch data.

Although an areal breakdown can be given it must be recognized that the results apply only to the period of the survey and that significant changes may take place both within and between years.

4. Fishery

(a) Historical catches and effort and present management strategy

Historical catches from 1972 to October 1980 are given in Table 10. Data for Subarea 0 are only available after 1975 and only the data for 1979 and 1980 comply with the new boundary. An immediate observation is the preciptous rise in importance of the offshore fishery. Peak catches occurred in 1976 and 1977 at 42,000 and 34,000 t respectively.

The TAC of 36,000 t in 1977 was nearly taken whereas the catch in 1978 was 12,000 t less than the TAC of 40,000 t. In 1979 the TAC was reduced to 29,500 t and the catch came close to that level (26,400 t), and in 1980 preliminary catch statistics indicate the TAC (29,500 t) was taken by October. The inshore fishery has remained relatively stable from 1972 at 7000 to 8000 t, except for 1974 (10,000 t).

Effort figures are available for various fleets, and the catch per unit effort pattern is shown in Fig.31 based on data reported by trawlers of the Royal Greenland Trade Department (Carlsson 1980). Catch rates generally declined from 1976 to 1978 but have levelled off in 1979-1980.

Seasonal changes in catch rates are very pronounced with highest catch rates in the first half of the year. Catch-per-unit-effort figures for the months of July to September in recent years, have been used to reflect stock abundance. Catch rates during this period also declined from 1976 through 1978 but levelled off by 1979 and increased somewhat in 1980. However, some of the observed increase for the Greenland trawlers may in part be due to more efficient gears than used previously and in part to northward shift of their fishery.

When a quota regulation was first introduced for the year 1977 no attention was paid to a breakdown of the TAC between the Canadian and Greenland zones since almost no fishing had been reported in Subarea 0. In 1978, however, the regulation specified an upper limit which could be taken in the Greenland zone. For 1979 and 1980 some breakdown arrangements were agreed upon by Canada and the EEC.

Table 10. Nominal catches and total allowable catches (t) of shrimp (Pandalus borealis) in Subareas 0 and 1[1].

Area	Country	1972	1973	1974	1975	1976	1977	1978	1979	1980[2]
SA 0	CAN									175[3]
	DEN-F						239			
	DEN-G								149	1175
	DEN-M						68	86	67	
	FRA-M							21	7	122
	NOR					65	150	15	738	
	SPA					327				
	TOTAL					392	457	122	961	1454
SA 1	CAN								245	2079[3]
	DEN-F	755	1371	2023	5300	11,179	12,612	8070	6982	2000
	DEN-G(a)[4]	7342	7950	10,064	8700	7300	7800	7600	7500	7500
	(b)	150	185	180	1089	2478	7081	5531	12,527	21,313
	DEN-M		196	308	1142	2717	5842	3382	1062	871
	FRA-M					803	924	805	352	126
	FRG						31			
	JAP					146				
	NOR	1409	2940	5917	8678	11,658	7353	8959	4251	2494
	SPA				6948	6925				
	USSR			3517	6033	6468				
	TOTAL	9656	12,642	22,009	37,890	49,674	41,643	34,347	32,919	36,383
	OFFSHORE	2314	4692	11,945	29,190	42,374	33,843	26,747	25,419	28,883
	TAC (0+1 offshore)						36,000	40,000	29,500	29,500

[1] Statistics for 1972-1978 pertain to ICNAF Statistical Area 0 and Subarea 1, and for 1979 and 1980 to the new NAFO Subareas 0 and 1.
[2] Preliminary to the end of October.
[3] Canadian data for 1979 include catches from cooperative arrangements with other countries.
[4] a = inshore, b = offshore catches.

In the Greenland zone a breakdown into four management areas was made in 1977 in order to prevent local overfishing of relatively small but locally important grounds if, for instance, ice would prevent fishing in the major area over a longer period of the year than usual. Special attention was paid to the likely interrelationship between shrimp on the offshore ground adjacent to Disko Bay and those in the bay itself where the inshore fishery is of very great importance. An offshore management zone was established between 68°N and 69°30'N inside which no more than 3000 t were allowed to be taken.

By 1979 the breakdown of the TAC allocated to the Greenland zone was changed to an arrangement whereby fishing north of 68°N was allowed for Greenland vessels only. Locally, a precautionary area with a maximum allowable catch of 3000 t was maintained off Disko Bay between 68° and 69°30'N, but apart from this no specific breakdown of the offshore Greenland zone has been made since 1979.

(b) Fishing patterns and variability

In reviewing the catch and effort statistics for the west Greenland offshore shrimp resource it must be recognized that the ice conditions in Davis Strait are severe during certain months and variable from year to year. Effort data could easily be affected for certain years and consequently affect CPUE calcuations. This is extremely important when considering CPUE as an index of abundance.

Throughout the years since 1976 and annual seasonal northward displacement of the fishing activity has been observed inside the major shrimp ground west and northwest of the Store Hellefiske Bank. Although this could reflect simple availability to the grounds determined by drift ice, the annual variation CPUE figures in the area may also be interpreted as some seasonal displacement of the stock itself.

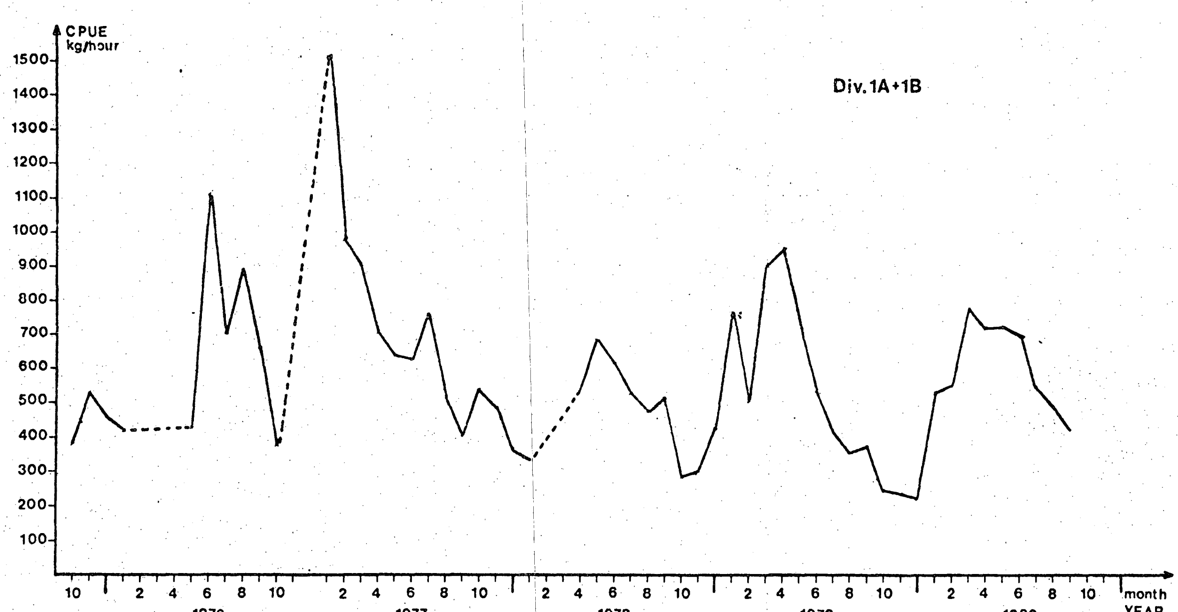


Fig. 31. Monthly mean catch per unit effort (kg/hour) in Div. 1A+B from Oct 1975 to Sep 1980 based on logbook information from six trawlers (722 GRT) of the Royal Greenland Trade Department.

Between years there is also a clear picture of a northward displacement of the area where fishing activity is most concentrated. Thus, in 1979 a great part of the activity took place just south of 68°N, but in 1980 the Greenland trawlers, to a much greater extent than previously, extended fishing grounds north of 68°N (see Distribution). Although the displacement of the fishery between years may be interpreted as some displacement of the stock concentrations, a comparison between CPUE figures for some of the Greenland trawlers summarized for the area between 67° and 68°N, and between 68° and 68°50'N does not lend support to this suggestion. An in-depth analysis, including breakdown of statistics on smaller areas and analyses of environmental factors, may elucidate the reasons behind the evident displacement of the fishery. However, such analysis has not yet been presented.

(c) Relative exploitation rates and their effects on current 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 (around 78%) and the time between recruitment to the fishery and first hatching was estimated at 1.5 years. Under these assumptions, mean annual removal of 40% would lead to 50% reduction in the spawning stock biomass over several years if the level of fishing remained stable (Ulltang, 1978). CPUE data from July to September for Greenland trawlers were indexed from a high level in 1976 which was considered as representative of a virgin stock. Figures for other years in the following table are ratios of catch rates to the 1976 level.

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

Provided recruitment has remained relatively constant a reduction of around 50% is indicated in the spawning stock from the virgin level as predicted by the model.

(d) Relation to other fisheries

The major by-catch in the shrimp fishery continues to be small redfish (Sebastes mentella). Lesser quantities of other species occur including Greenland halibut, Atlantic halibut, wolffishes, Greenland shark and cod. Most of the by-catch is discarded. A decrease in by-catch, due mainly to a reduction in catches of redfish, has been indicated in recent years especially in Div. 1B.

Although cod at this time poses no real problem to the shrimp stock in Div. 0A, 1A and 1B either as a predator or competitor because of their relatively low numbers, it must be pointed out that this has not always been the case and any increase in the cod stock to levels once experienced in these areas may have a significant effect on the abundance and distribution of shrimp.

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