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Pelagic Occurrence of Greenland Halibut, *Reinhardtius hippoglossoides* (Walbaum), in West Greenland Waters

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Abstract

The extent of pelagic occurrence of Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum), in Greenland waters was evaluated from four pelagic surveys, two conducted at deep water areas where the commercial fishery takes place and two in areas considered to be important nursery areas. The results from the pelagic surveys are compared to results from bottom trawl surveys conducted in the same areas and at the same time. Pelagic behaviour was further supported by investigations of stomach contents from Greenland halibut sampled during pelagic and bottom surveys, and by analysis of commercial bottom trawl data. One-year-old Greenland halibut were abundant and they undertook vertical feeding migrations at night. Older Greenland halibut were rarely encountered pelagically, and the analysis of commercial trawl data showed that the catchability of Greenland halibut did not vary diurnally.

Key words: abundance, distribution, food/feeding, G. halibut, pelagic, W. Greenland

Introduction

Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum), deviate from most other Pleuronectidae in several ways: almost identical coloration of both body sides; the positioning of the eyes, resulting bilateral vision; and the elongate shape. These morphologic characteristics all lead to the hypothesis that Greenland halibut are vigorous swimmers with a bathypelagic behaviour, more so than other Pleuronectidae. A number of investigations have advanced this hypothesis and have shown that horizontal migration, either as migration over long distances or as seasonal migration within a more limited area, is wide-spread among Greenland halibut (Riget and Boje, 1989; Jørgensen, 1997; Bowering, 1984).

Information about pelagic occurrence and vertical migrations of Greenland halibut is, however, scarce and is mainly based on indirect observations. Bowering and Lilly (1992) have reported that the stomach contents of small and medium sized Greenland halibut taken on the bottom were dominated by pelagic crustacea and capelin (*Mallotus villosus*), respectively. Furthermore, Bowering and Parsons (1986) and Chumakov (1970) have described changes in catch rates between day and night in a bottom trawl research fishery, which may also indicate vertical migration. The only direct observations of pelagic Greenland halibut, besides larvae, have been made by Smidt (1969) and Christensen and Lear (1977), who reported that Greenland halibut were occasionally caught at the surface in salmon nets off West Greenland.

Greenland halibut is an important resource in the Davis Strait area (NAFO Div. 0B, 1A–1D, Subarea 2 and Div. 3KLMNO), notably after the dramatic decline in the Div. 2J and 3KL and 1B–F cod fishery in the early-1990s. Apart from shrimp, Greenland halibut now sustains the most important fishery in West Greenland (Subarea 1). Pronounced bathypelagic behaviour and/or diurnal variation in the vertical distribution could have important implications for stock indices of abundance of Greenland halibut, and on stock assessments, if bottom trawl surveys is a major component of the assessments.

From 1990 to 1992, four pelagic surveys were conducted in conjunction with bottom trawl surveys, which were primarily aimed at estimating the trawlable biomass of Greenland halibut. Two of the surveys were carried out on the main offshore fishing grounds at West Greenland, and two at the northern slope of St. Hellefiske Bank (Northern part of NAFO Div. 1B) (Fig. 1), which is considered to be an important nursery area (Riget and Boje, 1988).

The purpose of the pelagic surveys was to investigate bathypelagic behaviour and possible diurnal variations in the vertical distribution of Greenland halibut in West Greenland waters. To support and differentiate the findings from the

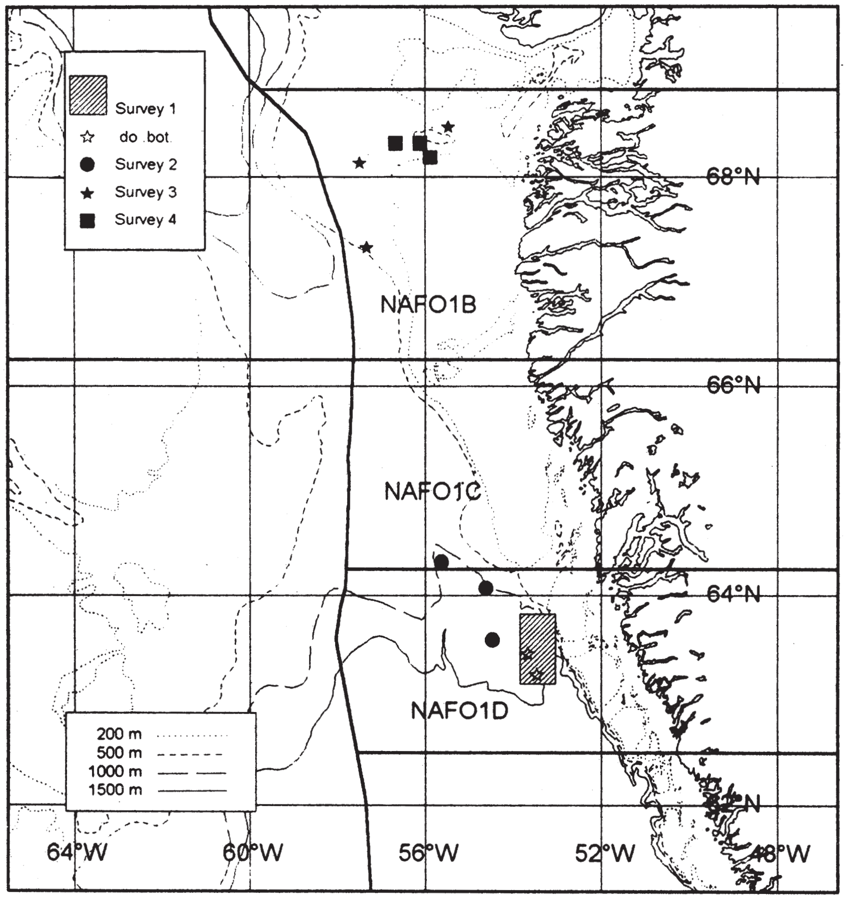

Fig. 1. Positions of four pelagic surveys and bottom trawl stations in corresponding bottom trawl surveys conducted at West Greenland in 1990–92.

surveys, analysis of diel variation in the commercial trawl catch rates of Greenland halibut, and comparisons between stomach contents of fish caught pelagically and on the bottom are given.

Materials and Methods

Each of the four pelagic surveys were preceded by a stratified random bottom trawl survey (Jørgensen and Akimoto, MS 1991; Yano and Jørgensen, MS 1992; Satani *et al.*, MS 1993). All surveys were conducted by the Japanese R/V Shinkai Maru, a 3 395 GRT 5 000 HP stern trawler.

The pelagic surveys were carried out in areas with good catches of Greenland halibut, although in some cases catches of roundnose grenadier (*Coryphaenoides rupestris*), redfish (*Sebastes* sp.) and northern shrimp (*Pandalus borealis*) were also taken into consideration in the selection of pelagic trawling locations. The outlines of the four surveys were changed slightly from survey to survey, based on results obtained. In the first pelagic survey, trawling took place within a defined area, while in each of the other three surveys trawling was carried out at three different locations (Fig. 1). In all of the pelagic surveys, the water column was divided in a number of depth strata, trawled around midnight, sunrise, noon and sunset in order to obtain a balanced survey design (Latin square design; Table 1).

In the first survey (Fig. 1), towing time varied between 30 and 90 min. Catches were standardized to catch/hour. In surveys two-four each stratum was divided into three substrata trawled for 20 min each (i.e. total fishing time per stratum of 60 min). Towing speed averaged 4.0 knots. The net opening was measured by net soundings and was approximately 30/70 m high and 40/80 m wide, respectively, in the two nets used (Table 1). Data were pooled by station irrespective of whether fishing took place over a period of up to five days at a single station.

Towing speed in the bottom trawl surveys was 3.5 knots, towing time was 30 min and wing spread 40 m. Fishing took place in day time only. In both types of surveys, mesh size was 140 mm in

TABLE 1. Outline of pelagic trawl surveys conducted at West Greenland, 1990–92.

	Period	Area	Bottom depth (m)	No. of hauls	Net opening (m)	Strata (m)
Survey 1	22.6–27.6 1990	63°09'N–63°49'N and 53°02'W–53°51'W	916–1 563	24	3 040	50[1]–150 b.s. 220–350 b.s. 420–550 b.s. 325–480 a.b. 380–150 a.b. 20 a.b.
Survey 2	14.9–19.9 1990	64°04'N 54°37'W		12		50[1]–300 b.s. 301–550 b.s.
		63°35'N 54°29'W	approx. 1 100	12	7 080	551–800 b.s. 801 b.s.–20 a.b.
		64°19'N 55°38'W		11		
Survey 3	31.8–5.9 1991	68°29'N 55°44'W		10		100[1]–190 b.s. 225–315 b.s.
		68°14'N 57°30'W	404–560	10	3 040	140–20 a.b.
		67°20'N 57°20'W		5		
Survey 4	29.8–12.9 1992	68°19'N 56°07'W		40		50[1]–140 b.s. 225–315 b.s.
		68°19'N 55°53'W	440–515	40	3 040	140–20 a.b.
		68°19'N 56°40'W		32		

[1] Position of head rope. All other positions are position of ground rope. b.s. below surface a.b. above sea bottom.

the codend, which was equipped with a 30 mm mesh liner. Catches were weighed to 0.1 kg and fish measured as total length to one cm below.

In 1992 (survey four) stomachs and whole fish were sampled from all three stations in the pelagic survey, covering all depth strata, and from the three bottom stations in the corresponding bottom trawl survey. Further, stomachs were sampled during a bottom trawl survey from 27 to 31 August 1993 in the area between 63°00'N and 65°00'N, and at depths ranging from 806 to 1 202 m (Ogawa *et al*., MS 1994). Stomachs and fish were frozen and stored at <-18°C. In the laboratory the stomach contents were identified to lowest possible taxon. Each food category was weighed to the nearest 0.1 g wet weight.

Results of stomach sampling are given as (1) Frequency of occurrence: The number of stomachs in which a prey taxon occurred, expressed as a percentage of the total number of stomachs examined; (2) Weight percentage: The weight of each prey item, or group of prey items, in the sample converted to a percentage of the total weight of stomach contents in the sample.

In 1992 (survey four) otoliths (n = 80) were sampled for age determination from fish taken both at pelagic and bottom stations. The otoliths were soaked in water and read in transparent light.

Logbook data from a commercial fishery conducted by the *Shinkai Maru* at West Greenland in the area between 62°30'N and 65°00'N and at depths >800 m were analyzed for differences in day and night catch rates (n =1 084 trawl hauls, mean trawling time 3 hr and 29 min). The data series covered the period April–November (no data from July) from 1988–94 (no data from 1993). All catch data were standardized to catch per hour and grouped into 4-hour intervals (22–02 and so on); the midpoint of each haul was used as the reference time.

Results

Surveys

A total of 59 pelagic hauls were carried out at the area where the main part of the offshore commercial fisheries for Greenland halibut take place (bottom depths exceed 900 m; surveys 1 and 2; Table 1, Fig. 1). Catches in these two surveys were very poor.

In areas hypothetical to be an important nursery area for Greenland halibut 137 hauls were made. (bottom depths between 404 and 560 m; survey 3 and 4) (Riget and Boje, 1988; Jørgensen, 1997). Catches ranged between 0 and 129.3 kg and were comprised almost exclusively of small specimens.

In pelagic survey 1, Greenland halibut were caught in 6 out of 24 hauls. The largest catch of seven specimens (5.6 kg total weight) was taken at midnight at the surface, while only one or two specimens were taken in each of the remaining five catches. Catches were distributed at the bottom, in midwater at the surface and were caught at different times of the day, except noon. Catches at two stations in the corresponding bottom trawl survey were 127.9 kg and 311.1 kg corresponding to 89 and 248 specimens, respectively.

Pelagic catches ranged from 25 to 52 cm in length. The majority were around 45 cm, while the lengths at the two bottom trawl stations ranged from 22 cm to 98 cm, dominated by fish between 44 and 54 cm (Fig. 2).

In pelagic survey 2, Greenland halibut were taken in 21 out of 35 hauls (Table 1, Fig 1). In 19 of these hauls, however, the catch comprised of 73 larvae from 6–8 cm, taken at all depths and at all times of the day without any clear distribution pattern, but with a tendency towards a greater concentration in the surface layer. However, the pelagic gear used had a large mesh size in most of the net except in the codend, and could not be considered efficient in catching fish larvae. Therefore no firm conclusions concerning concentrations or vertical distribution pattern of Greenland halibut larvae should be drawn.

Despite the increase in volume swept per tow in survey 2 compared with survey 1, large Greenland halibut were caught in only two hauls. The greatest catch, 8 specimens (5.0 kg), was taken in the depth stratum 301–500 m at noon and 1 specimen (0.7 kg) in the bottom stratum at sunset. Catches in the preceding bottom trawl survey at the same positions as the three pelagic stations were between 357.8 kg and 519.0 kg, corresponding to 203 and 460 specimens, respectively.

Fish length (excluding larvae) in pelagic survey 2 ranged from 29 to 48 cm and from 35 to 100 cm for the bottom survey, respectively, the bulk being between 44 cm and 54 cm (Fig. 2).

In pelagic survey 3, Greenland halibut were taken in 18 out of 25 hauls. The highest catch of 2 535 specimens (38.3 kg) was caught in the bottom stratum at sunset. Catch rates differed somewhat at the three stations (Table 2), reflecting differences in catches at bottom trawl stations (see below). Greenland halibut were taken in all hauls in the bottom stratum while fish were only caught in the upper stratum around midnight.

Catches increased by depth at all times of the day, except at midnight where catches were highest in the surface stratum when the pelagic stations

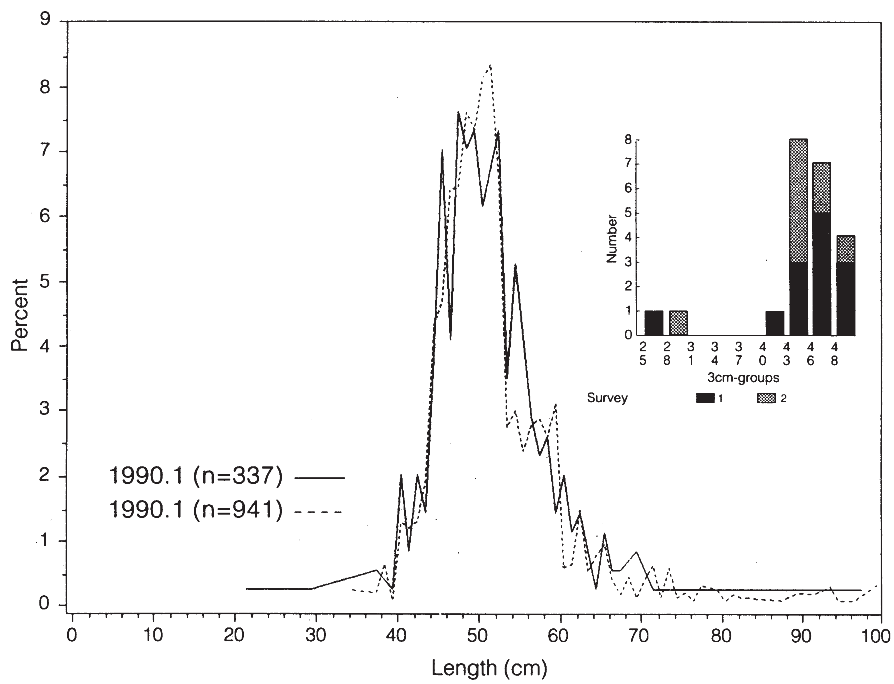

Fig. 2. Length distribution of Greenland halibut in two bottom trawl surveys and two pelagic surveys (insert) in the area where the commercial fishery takes place (Survey 1 and 2).

data are pooled (Table 3). Generally, catches in the two upper strata were very low. The low mean catches in the bottom stratum at noon were probably due to the lack of hauls at station 128, where catches were generally high. Catches at the three bottom trawl stations were 7.5, 144.9 and 213.6 kg (37, 445 and 1 029 specimens, respectively).

Length frequencies from the three pelagic stations were pooled, however, they were dominated by the large catches from station 128. While fish between 5 and 45 cm were caught in the water column, the length distribution was dominated by a very clear mode at 11 cm at all times of the day and at all depths (Fig. 3). Minor modes around 7 cm and 17 cm were also apparent. The mode around 7 cm was comprised of larvae originating from a single haul from the bottom stratum at sunrise. The length distribution of fish from the bottom ranged from 8 to 54 cm, with modes at 11, 19, 28, and 34 cm, where the first two modes presumably are representing ages 1 and 2 (Fig. 4, Table 4).

In pelagic survey 4, Greenland halibut were caught in 71 out of 112 hauls. The largest catch of 11 766 specimens (129.3 kg) was caught in the bottom stratum at noon. Catch rates were similar at the three trawl stations (Table 5), and the distribution patterns were very much alike. Greenland halibut were evenly distributed in the water column around midnight, while only very few fish were caught in the surface stratum during the rest of the day, based on combined data from the three stations. At noon, all fish were found near the bottom. Relatively few fish were observed in the midwater stratum around sunset and sunrise (Table 6). Catches at the three bottom trawl stations were 391.1, 246.9 and 344.1 kg (2 406, 1 021 and 8 63 specimens, respectively).

The length distributions at the three pelagic stations were very similar and data were pooled for further analysis. Total lengths ranged from 8 to 49 cm, with a pronounced mode at 11 cm found in all depth strata and at all times of the day. A small mode at 17 cm was seen at midnight for all depth strata and near the bottom at all times of the day (Fig. 5). The length distribution at the bottom ranged from 10 to 61 cm with at 12, 17, 27, and 35 cm, where the first two modes are representing ages 1 and 2 (Fig. 4, Table 4).

Stomach investigations

A total of 496 stomachs was sampled from Greenland halibut ranging from 22–102 cm (80% between 40 and 55 cm) from bottom trawl stations at depths >800 m in the area where the commercial fishery takes place. Most of these (88.5%) were empty. A total of 30 different species or species groups were identified in the stomachs, of which 11 were fish species. Macrouridae, Myctophidae and Greenland halibut were the most common fish

TABLE 2. Catches (kg/hour) in survey 3 distributed at stations, depth strata and time of day (MN = midnight, SR = sunrise, N = noon, SS = sunset).

	Station											
	80				93				128			
Time of day	MN	SR	N	SS	MN	SR	N	SS	MN	SR	N	SS
Surface	0.0	.	0.0	.	3.2	0.0	.	0.0	24.6[1]	0.0	0.0	.
Midwater	.	.	.	0.0	4.1[1]	0.0	0.0	.	9.8	.	0.0	6.2
Bottom	1.6	1.1	.	.	2.9	.	1.2	0.2	5.2	34.5	.	38.3

[1] Mean of two hauls, all other observations are based on one haul.

TABLE 3. Catches (kg/hour) (KG) in survey 3, Standard deviation (STD), number of hauls (n) distributed at depth stratum and time of day.

Depth	Midnight			Sunrise			Noon			Sunset		
Stratum	KG	STD	n	KG	STD	n	KG	STD	n	KG	STD	n
Surface	13.1	14.5	4	0.0	0.0	2	0.0	0.0	2	0.0	.	1
Midwater	6.0	3.3	3	0.0	.	1	0.0	0.0	2	3.1	4.4	2
Bottom	3.2	1.5	3	17.8	23.6	2	1.2	.	1	19.2	26.9	2

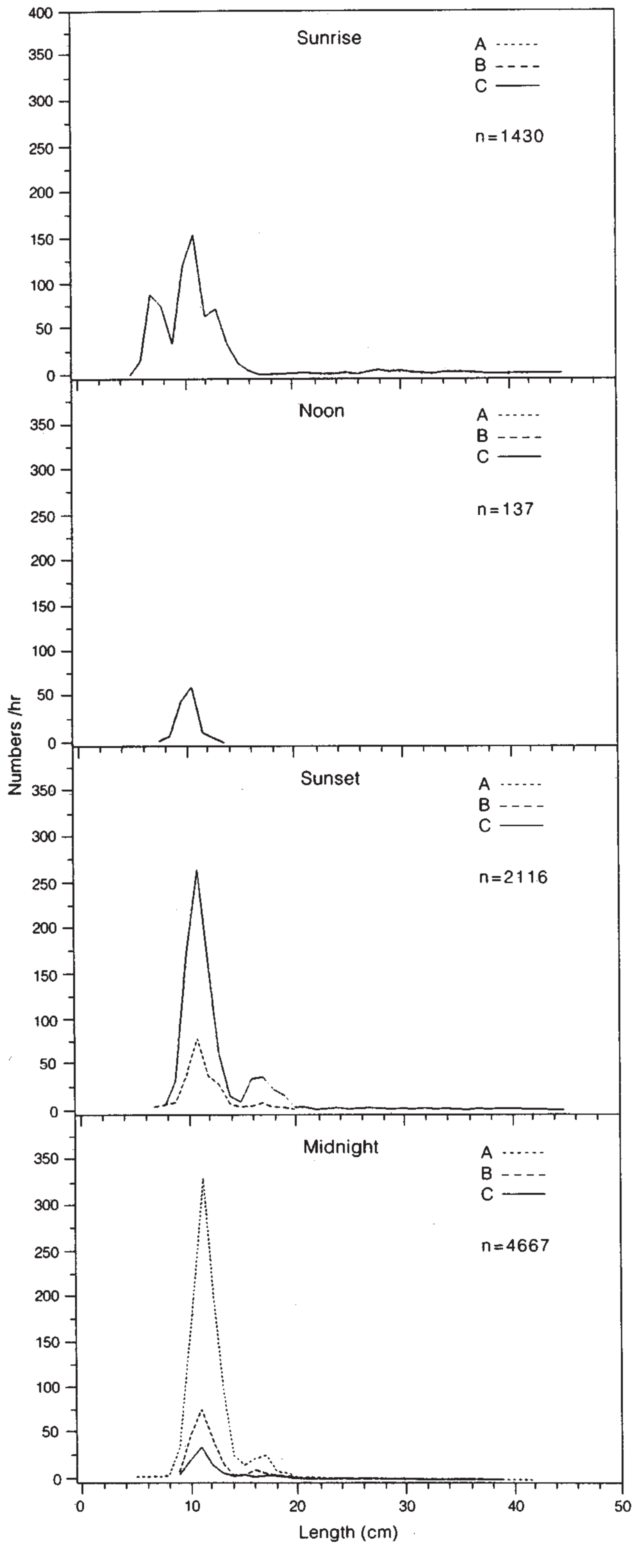

Fig. 3. Length distribution of Greenland halibut in pelagic survey 3, at midnight, sunrise, noon and sunset, at three depth strata: A = surface stratum, B = midwater stratum and C = bottom stratum.

species encountered. Fish were found in 5% of the stomachs and comprised 85.3% of the food by weight. Cephalopoda were the second most abundant prey, and were found in 3.4% of the stomachs, comprising 12.1% of the food by weight. Natantia, the third most frequent prey item encountered, comprised 1.8% of the food by weight (Table 7). Species strictly associated with the bottom, such as Bivalvia and Annelida, were found sporadically and comprised only about 0.5% of the food.

Of 205 stomachs sampled from fish in the water column in the nursery area, 13 (6.3%) were empty, whereas 46 out of 160 (28.8%) stomachs sampled from fish taken at the bottom at the same area were empty.

The diet of pelagic fish smaller than 15 cm was almost exclusively comprised of pelagic Crustacea, of which Hyperidae (*Parathemisto* sp.) was the most important, contributing nearly 60% or more of the stomach weight. Euphausiacea were the second most important prey for fish in the surface and midwater strata, while Euphausiacea were not found in fish caught from the bottom stratum (Tables 8 and 9).

Hyperidae were an important prey group for fish between 15 and 20 cm contributing more than 30% of the diet. Euphausiacea were present in significant quantities in the stomachs of fish caught at the surface stratum, but were replaced by Natantia (mainly *Pandalus borealis*) in the midwater and bottom strata. Fish contributed between 3–20% of the stomach weight in this length group, depending on depth (Tables 8 and 9).

Hyperidae and Euphausiacea almost completely disappeared from the diet of fish larger than 20 cm and were replaced by Natantia (*Pandalus borealis*) in the upper and midwater strata, and by fish and Natantia in the bottom stratum. Fish were present in 38.5% of the stomachs and contributed more than 70% of the total prey weight. Besides Greenland halibut and *Sebastes* sp., Liparidae, *Leptagonus decagonus* and *Myxocephalus scorpius* were identified in the stomach content.

There were no clear differences between the diets of fish caught in the water column and from the bottom. The fact that Crustacea were more important, and Hyperidae and Euphausiacea less important to fish caught at the bottom compared to those from the water column might reflect that stomach content was more difficult to identify because it was more digested in the stomachs sampled from fish caught on the bottom.

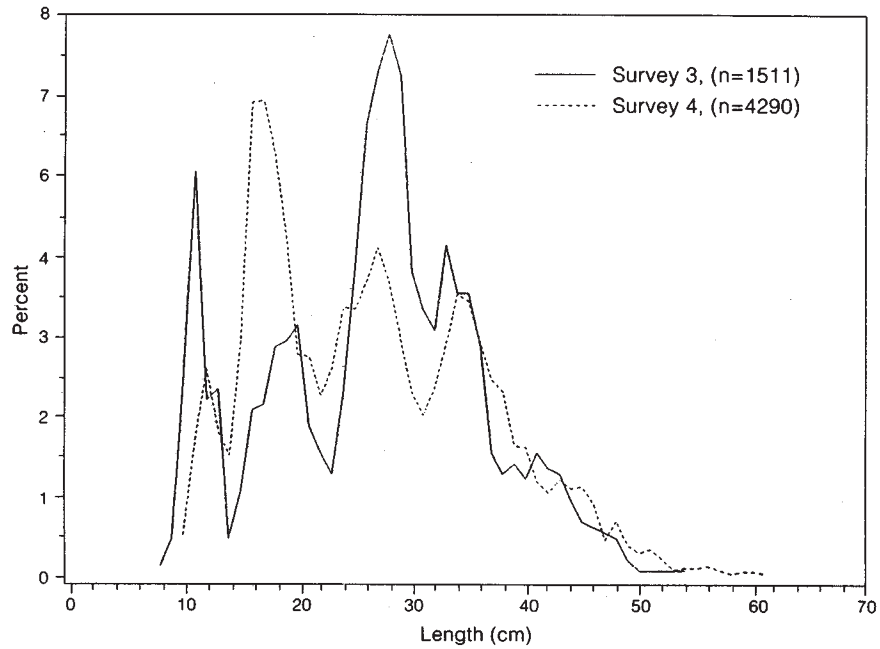

Fig. 4. Length distribution of Greenland halibut in at the bottom in survey 3 and 4, respectively.

TABLE 4. Mean length-at-age and standard deviation (STD) for Greenland halibut sampled (n) in 1992 (survey 4).

Age	Length	STD	n
1	11.97	1.44	37
2	17.65	1.37	34
3	25.14	2.04	7
4	29.50	2.12	2

TABLE 5. Catches (kg/hour) in survey 4 distributed at stations, depth strata and time of day (MN = midnight, SR = sunrise, N = noon, SS = sunset).

	Station											
	87				88				89			
Time of day	MN	SR	N	SS	MN	SR	N	SS	MN	SR	N	SS
Surface	0.7	0.0	0.0	0.0	4.6	0.1	0.0	0.0	1.0	0.1	0.0	0.1
Midwater	5.2	1.0	0.0	1.3	6.0	0.6	0.0	0.3	2.0	0.1	0.0	0.6
Bottom	3.3	10.7	20.0	9.2	7.4	15.3	39.7	19.3	2.2	12.3	3.8	13.4

Commercial bottom trawl data

As catch-per-unit-effort (CPUE) values are usually subject to multiplicative errors, catch-per-hour values were log transformed. Mean ln transformed CPUE data were grouped by cells defined by time of day, month and year and were analyzed by a three-way ANOVA (Gavaris, 1980; Anon., 1985), i.e.:

TABLE 6. Catches (kg/hour) (KG) in survey 4, standard deviation (STD), number of hauls (n) distributed at depth stratum and time of day.

Depth	Midnight			Sunrise			Noon			Sunset		
Stratum	KG	STD	n	KG	STD	n	KG	STD	n	KG	STD	n
Surface	2.1	3.4	9	0.1	0.1	9	0.0	0.0	8	0.0	0.1	11
Midwater	4.3	2.2	11	0.5	0.8	11	0.0	0.0	9	0.6	1.0	8
Bottom	4.5	2.6	8	13.0	8.3	8	21.3	37.1	11	14.5	13.6	9

$$Ln\,(catch\ per\ hour) = \alpha + \beta_1 T + \beta_2 M + \beta_3 Y + \beta_4 T\times M + \beta_5 T\times Y + \beta_6 M\times Y + \varepsilon,$$

where T is time of day,
M is month, and
Y is year.

The first order interaction effects time × month and time × year were not statistically significant and were excluded from the model. The resulting model was found to be highly significant (P<0.01) and explained 69% of the variation in the data. From Table 10 it can be seen that the variable 'time of day' is not statistically significant, indicating that there is little or no difference between catch rates during the various times of day. Although the variation in the data was considerable, there did not appear to be any clear diurnal variation in the vertical distribution of Greenland halibut at West Greenland at depths where the commercial trawl fisheries takes place.

There was a significant interaction effect between month and year due to a drop in catch rates from September to November in 1991 and from October to November in 1988, while catch rates were stable in the same period in 1989 and 1992. If data from these months in 1988 and 1991 are excluded from the analysis, the interaction effect is no longer statistically significant. However, a significant difference (P<0.01) was found in catch rates between years and between months and the variable 'time of day' was still not significant (P>0.10).

Discussions

Pelagic occurrence in shallow water

The results of the 137 pelagic trawl hauls in the putative nursery area showed that small Greenland halibut were common pelagically, and that the largest concentrations occurred in areas where there were also large concentrations at the bottom. During daylight hours Greenland halibut were found almost exclusively near the bottom, while they were evenly distributed in the water column around midnight. This, together with the vertical distribution observed around sunset and sunrise, indicates pronounced diel vertical migration (Tables 3 and 6). The length distribution showed that it was almost exclusively small, one year old, and to a lesser extent two year old fish that were pelagic (Fig. 3 and 5). Older fish were virtually absent in pelagic catches, even when they occurred in large numbers on the bottom (Fig. 4).

Analysis of the stomach contents indicated that small Greenland halibut feed almost exclusively on small pelagic crustacea such as *Paratemisto* sp. and Euphausiacea. There was no difference in the stomach contents of fish taken pelagically and on the bottom except that stomach contents from fish caught on the bottom seemed to be somewhat more digested. This observation suggests that there is an exchange between the stock components in the two habitats and that digestion takes place at the bottom (Tables 8 and 9). As fish increase in size, *Paratemisto* sp. and Euphausiacea disappeared from the stomach contents, while Natantia (mainly *Pandalus borealis*) and fish increased in importance, indicating that Greenland halibut become more associated with the bottom as they increase in size.

The main food items for Greenland halibut larger than 20 cm were fish (*Sebastes* sp. and Greenland halibut) and *Pandalus borealis*. This was also observed by Pedersen and Riget (1993), who, based on a larger sample from the same area, found that *Sebastes* sp. was the most abundant food item. Parsons *et al.* (MS 1991) reported that *P. borealis* migrate to some extent into the water column during the night, also observed in this investigation, while redfish stay close to or on the bottom at all times of the day (pers. obs, unpublished data). This is in good agreement with observed stomach contents and the few observations of larger Greenland halibut in the water column.

Smidt (1969), and Bowering and Lilly (1992) found a similar content of pelagic Crustacea in the stomachs of small Greenland halibut, <19 cm, at several localities at West Greenland and off Canada.

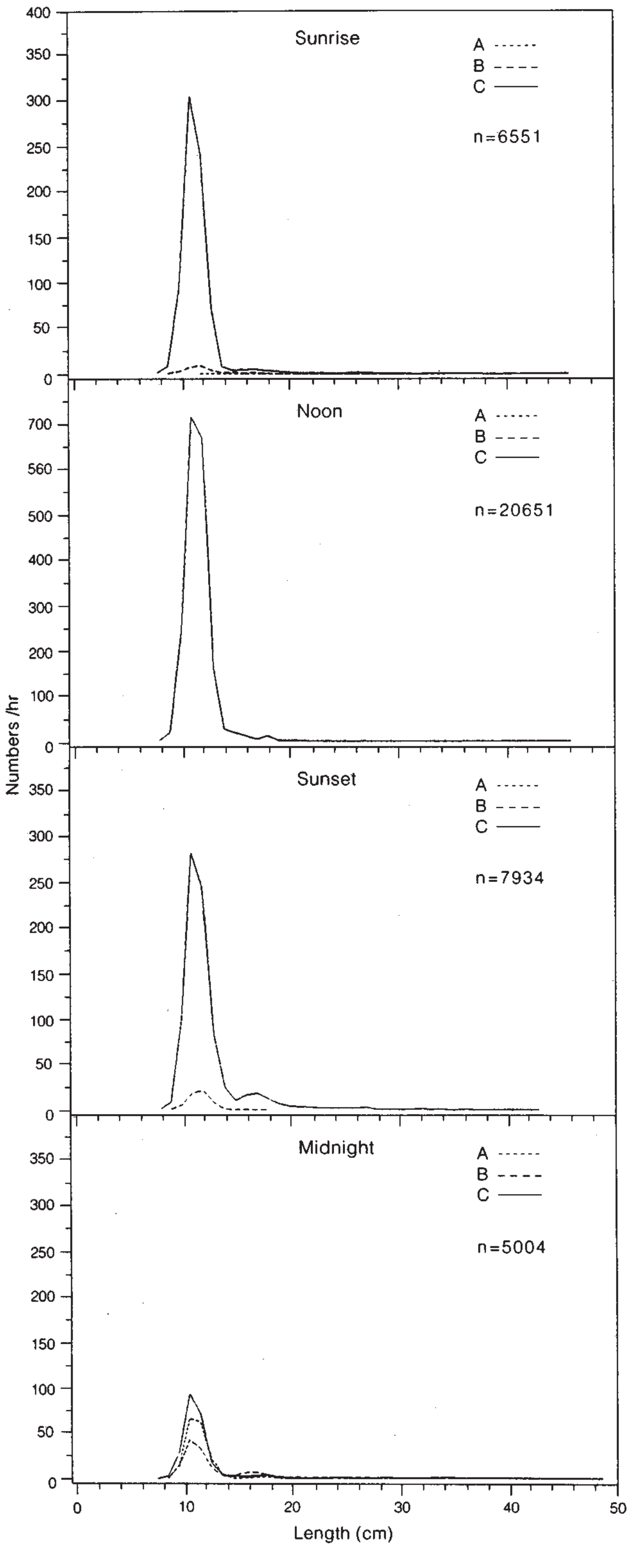

Fig. 5. Length distribution of Greenland halibut in pelagic survey 5, at midnight, sunrise, noon and sunset, at three depth strata: A = surface stratum, B = midwater stratum and C = bottom stratum. Notice different scale on y-axis.

They also reported that medium sized Greenland halibut (30–60 cm) feed mainly on capelin, which were neither observed in the stomachs nor in the trawl catches in this study. This indicates that the pelagic behaviour of medium sized Greenland halibut could be more pronounced than seen in this study, if capelin are available. Observations of 20–40 cm Greenland halibut in salmon drift nets (130–140 mm stretch mesh) in nursery areas at West Greenland (Smidt, 1969; Christensen and Lear, 1977) could be related to a feeding migration for capelin or sand-eel (*Ammodytes* spp.), although this is speculative.

Bowering and Parsons (1986) observed differences in catch rates of Greenland halibut between day and night in research bottom trawl fishery off Labrador. They reported that catches were generally lowest during the night. Analysis of length compositions showed that the proportion of small fish (mainly one year old) decreased in night catches, implying that they were not present at the bottom and that they had probably migrated into the water column. However, the finding of some small fish at the bottom during night shows that the small fish do not make vertical migrations every day. The diurnal differences in catch rates became smaller with increasing depth, which is probably due to a decreasing abundance of small fish with depth (Jørgensen, 1997).

Direct and indirect observations from both Canada and Greenland indicate that vertical migration, likely to be related to feeding, is a wide-spread phenomena for young Greenland halibut in shallow waters throughout the Davis Strait.

The fact that a large proportion of small fish were found off the bottom during daylight hours makes it difficult to interpret catch data from surveys and to estimate recruitment. If the surveys are conducted both during day and night, the interpretation of data becomes even more difficult, due to diel changes in vertical distribution. The extent of pelagic behaviour is likely to vary during the year as the vertical migration is related to feeding. This makes the comparison between surveys critical, if the surveys are not conducted at the same time of the year.

Pelagic occurrence in deep water

The pelagic hauls in deep water covered the entire water column except the 50 (100 m) closest to the surface and the 20 m closest to the bottom. Greenland halibut were caught in only 8 out of 59 hauls, and the catches were small, not exceeding 5.6 kg per hour fished. In the first survey the largest catch was taken from the surface layer at midnight.

TABLE 7. Percent occurrence and weight percent of food from Greenland halibut stomachs sampled at depths <800 m in a bottom trawl survey in 1993.

Prey	Percent Occurrence	Weight Percentage
Annelida	0.8	0.30
Bivalvia	0.2	0.23
Cephalopoda	3.4	12.09
Crustacea total	4.4	2.88
Gammaridae	0.2	0.04
Mysidae	1.2	0.16
Hyperidae	0.2	0.02
Natantia	1.8	1.57
Pandalus spp.	0.4	0.25
Crustacea (sp.)	0.8	0.03
Pisces (sp.)	5.0	85.28
UOM[1]	0.2	0.03
All		100.00

[1] Unidentified organic matter.

TABLE 8. Stomach content expressed as percentage occurrence from fish sampled (cm-group) from the water column and on the bottom in the nursery area, categorized into length groups. The water column is subdivided in three strata: A = surface stratum, B = midwater stratum and C = bottom stratum, n = number of stomachs investigated.

Type	Pelagic									Bottom		
cm-group	<15			15–20			>20			<15	15–20	>20
Species/depth stratum	A	B	C	A	B	C	A	B	C			
n	31	32	31	18	29	31	6	14	13	58	47	55
Bivalvia	6.5	0.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cephalopoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	0.0	0.0	0.0	1.8
Crustacea total	77.4	71.9	87.1	88.9	69.0	58.1	16.7	42.9	46.2	58.6	31.9	30.9
Calanoida	0.0	0.0	0.0	5.6	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0
Hyperidae	64.5	59.4	77.4	72.2	62.1	38.7	0.0	0.0	0.0	27.6	6.4	1.8
Euphausiacea	22.6	15.6	0.0	27.8	3.4	0.0	0.0	0.0	0.0	5.2	0.0	0.0
Natantia	0.0	0.0	0.0	0.0	3.4	6.5	0.0	14.3	15.4	0.0	2.1	5.5
Pandalus sp.	0.0	0.0	0.0	0.0	3.4	3.2	16.7	14.3	15.4	1.7	2.1	18.2
Crustacea (sp.)	9.7	12.5	16.1	27.8	10.3	16.1	0.0	14.3	15.4	27.6	21.3	5.5
Pisces total	0.0	3.1	0.0	27.8	6.9	19.4	0.0	0.0	38.5	1.7	12.8	16.4
Sebastes sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.0	2.1	5.5
Reinhardtius hippoglossoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.1	0.0	0.0	5.5
Pisces (sp.)	0.0	3.1	0.0	27.8	6.9	19.4	0.0	0.0	7.7	1.7	10.6	5.5
UOM[1]	54.8	53.1	58.1	83.3	75.9	71.0	66.7	78.6	53.8	27.6	23.4	38.2

[1] Unidentified organic matter.

The other catches were taken at different positions in the water column at different times of the day, except at noon. This indicates a migration into the water column during the night, however, this is not supported by the catch of 8 specimens (5.0 kg) in the midwater layer at noon in the second survey. The fact that the length distribution of fish found in the water column reflects the length distribution of fish found on the bottom, indicates that the fish likely migrated into the water column from great depths as opposed to from adjacent shallow waters.

Analyses of stomachs sampled from fish caught in deep water showed that the feeding rate was low; only 11.2 % of the stomachs contained food. The food was totally dominated by fish, and to a lesser

TABLE 9. Stomach content expressed as weight percentage from fish sampled (cm-group) in the water column and on the bottom in the nursery area, categorized into length groups. The water column is subdivided in three strata: A = surface stratum, B = midwater stratum and C = bottom stratum, n = number of stomachs investigated.

Type	Pelagic									Bottom		
cm-group	<15			15–20			>20			<15	15–20	>20
Species/depth stratum	A	B	C	A	B	C	A	B	C			
n	31	32	31	18	29	31	6	14	13	58	47	55
Bivalvia	2.6	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cephalopoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.8
Crustacea total	78.5	75.6	79.0	53.6	74.7	55.0	79.3	69.3	18.7	87.3	59.1	25.1
Calanoida	0.0	0.0	0.0	0.4	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Hyperidae	58.2	59.0	74.9	38.3	47.3	32.0	0.0	0.0	0.0	33.1	5.9	0.0
Euphausiacea	15.7	8.6	0.0	11.7	0.7	0.0	0.0	0.0	0.0	7.0	0.0	0.0
Natantia	0.0	0.0	0.0	0.0	1.4	6.4	0.0	16.5	3.5	0.0	0.6	5.6
Pandalus sp.	0.0	0.0	0.0	0.0	23.1	12.2	79.3	50.2	15.0	4.2	26.0	19.4
Crustacea (sp.)	4.6	8.0	4.1	3.2	2.2	4.1	0.0	2.6	0.2	43.0	26.6	0.1
Pisces total	0.0	5.3	0.0	19.5	2.9	15.7	0.0	0.0	76.5	5.6	27.8	72.6
Sebastes sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.8	0.0	2.4	3.5
Reinhardtius hippoglossoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.4	0.0	0.0	45.5
Pisces (sp.)	0.0	5.3	0.0	19.5	2.9	15.7	0.0	0.0	0.3	5.6	25.4	23.6
UOM[1]	19.0	19.2	21.1	26.6	22.4	29.4	20.8	30.0	4.8	7.0	13.0	1.8

[1] Unidentified organic matter.

TABLE 10. Statistically output of three-way ANOVA analysis of commercial trawl catch data.

	SS	df	F value	Pr > F	R^2
Model	5.693	21	8.29	0.0001	0.69
Year	1.159	5	7.09	0.0001	
Month	1.841	6	9.39	0.0001	
Time	0.186	5	1.14	0.3479	
Year Month	2.507	5	15.34	0.0001	
Error	2.615	101			

degree Cephalopoda. Most of the fish species found in stomachs (*Macrourus berglax*, *Lycodes* sp., *Synapobranchus kaupi*, *Triglops* sp., *Cottunculus* sp., *Onogadus* sp.) are considered to be benthic or benthopelagic. Fish species which are considered as bathypelagic or pelagic such as Myctophidae and *Boreogadus saidae* were also found in the stomachs, however, these species and Cephalopoda were all caught frequently in bottom trawls in the area (Jørgensen, 1995; Yano and Jørgensen, MS 1992; Satani *et al.*, MS 1993). Thus their occurrence in the stomachs can not be considered as evidence for extended pelagic feeding.

Analysis of diel variability in commercial trawl catches, covering an eight year period during most months of the year indicated that there was no difference in catch rates between night and day. This is in contradiction to what was noted by Chumakov (1970), who mentions that catches in Denmark Strait during the night were considerably lower than during the day, although no data or statistical analyses were presented. However, Chumakov stated that the catch rates could be increased by increasing the vertical span of the bottom trawl, implying that he considered the vertical migrations to be of limited extent.

The observations from the pelagic investigations, and to some extent stomach content analyses, reveal that Greenland halibut do occur pelagically in deep water, but that large Greenland halibut, >2 year old, are rarely found in the water column. Furthermore, the results of the pelagic investigations and analysis of the catch rates in the commercial fishery, suggest that is no diel variation in the pelagic occurrence of Greenland halibut. The pelagic occurrence of larger Greenland halibut may have been underestimated if there is no diel variation in the pelagic occurrence, as shown by the analysis of the commercial catch data, and fish are able to avoid a pelagic trawl towed at 4 knots.

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