PAPER

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Feeding Habits of Greenland halibut, *Reinhardtius hippoglossoides*, in West Greenland Waters with special emphasis on Predation on Shrimp and juvenile Redfish

by

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ABSTRACT

A total of 3,030 Greenland halibut stomachs were collected in summer and autumn 1990-91 and in winter and spring 1992. The composition of Greenland halibut stomach content shows strong similarity among sampling periods. Redfish, *Sebastes sp.*, was by far the most dominating fish species contributing 17 to 48% of the total prey weight. Northern shrimp, *Pandalus borealis*, was the dominating crustacean in the stomachs and was found in all sampling periods. Shrimp contributed 21 to 43% of the total prey weight. No influence of prey size preference of Greenland halibut for shrimp and redfish was found. There was no influence of predator size and sampling period on the average degree of stomach fullness. The daily ration (% of body weight per day) of Greenland halibut was calculated to 0.92 (%BWD) for the autumn-winter period and to 0.54 (%BWD) for the spring-summer period using an exponential gastric evacuation rate model. The annual consumption of redfish was calculated to 2,900 tons and 5,100 tons for 1990 and 1991, respectively and the consumption of shrimp to 1,300 tons for 1990 and 1,100 tons for 1991. We conclude that the estimated annual consumption of shrimp and redfish seems to have a minor impact on the shrimp stock, but a significant impact on the redfish stock.

INTRODUCTION

During the last two decades the offshore fishery for northern shrimp, *Pandalus borealis*, in the Davis Strait has been one of the largest fisheries for this species in the world. In 1991, the nominal catch of shrimp in the offshore area of West Greenland south of 71° N increased to about 57,000 tons – the highest level in the history of this fishery (Anon., 1992). The distribution area for shrimp coincide with important nursery areas for Greenland halibut and redfish mainly, and large quantities of these two fish species are caught and discarded in the shrimp fishery (Smidt, 1969; Jensen, 1979; Riget et al., 1988;Pedersen and Lehmann, 1989; Parsons and Veitch, 1992).

Little is known about trophic interactions between shrimps and fish and between the key fish species in the marine ecosystem off West Greenland, and little is known about the effects of the shrimp fishery on the ecosystem. Investigations of selective shrimp trawls which reduce the by-catch and discards of small shrimp and fish were started in Greenland waters in 1990. These investigations have raised the question whether increased survival rates of fish will reduce the yield from the shrimp fishery due to increased predation mortality on the shrimp stock.

In order to study the importance and level of predation on the shrimp stock by fish a sampling program for fish stomachs from the key fish species was started in 1990 (Pedersen and Riget, 1991) and continued in 1991 and 1992. The purpose of this paper is to provide a description of the food and feeding habits of Greenland halibut in West Greenland waters, including seasonal and spatial variations in the stomach content; influence of predator size; prey size preference; and estimated annual consumption of shrimps and juvenile redfish.

MATERIALS AND METHODS

The study area was the continental shelf between 61°52'5N and 69°30'N in the Davis Strait from the 3-n.mile limit off the Greenland coast in depths of 150–600 m (Fig. 1). A total of 3,030 Greenland halibut stomachs were analyzed. The stomachs were collected from catches at 132 trawl locations off West Greenland during seven research surveys in summer and autumn 1990 and 1991 and during two commercial trips in winter and spring 1992. The research surveys were not designed to this study. The sampling gear was bottom trawl – commercial shrimp trawl or small meshed research trawls for fish. Except from a few trawl hauls the stomachs were sampled during day-time only. All sampling stations have been divided by year and sampling season (Table 1 and Fig. 1). During winter the sea ice (Westice) forces the commercial shrimp fishing fleet from its main fishing areas off West Greenland to fishing grounds in southwest Greenland. Therefore, in February 1992, fish stomachs were collected from southwest Greenland only. Similarly, the ice situation in April 1992 restricted the area from where fish stomachs could be collected.

When possible the sampling strategy was to collect stomachs stratified by length from the catch in each haul at different locations and seasons within the study area. Stomachs from fish with no signs of regurgitation were individually tagged and frozen (<–18°C) for later examination (in most cases whole fish). In the laboratory the stomachs were thawed in water and examined. The weight-length equation for the investigated fish was estimated from least-squares regression of individual weight and length measurements on 1746 fish after logarithmic transformation (r^2=0.98):

$$W(g)=0.005087 \times L(cm)^{3.1297}$$

The stomach content was identified to the lowest possible taxon within a reasonable time consume. The degree of digestion of fish prey was judged by a six point scale and of invertebrate prey by a four point scale as proposed by Bromley and Last (1990). Each food category was counted and weighed to nearest 0.1 g. Excess liquid was removed only mechanically. When possible fish prey was measured to the nearest mm total length and/or the length of the vertebral column was measured. Carapace and pleuron length of *Pandalus borealis* were measured with an accuracy of 0.1 mm.

For redfish found in the stomachs it was in many cases possible to measure the length of the vertebral column but not the total length. A relationship between the length of the vertebral column and the total fish length was established from 123 redfish found in the stomachs. After logarithmic transformation of the two variables least-squares regression of total length (TTL) and length of vertebral column (VCL) was calculated (r^2=0.88). Using the equation from the regression, the total length was calculated in cases when only the vertebral column could be measured:

$$TTL(cm)=1.7279 \times VCL(cm)^{0.9192}$$

For shrimps found in the stomachs it was in many cases possible to measure the length of the pleuron but not the length of the carapace. A relationship between the length of the pleuron and the length of the carapace was established from 216 fresh shrimp sampled from a commercial catch. After logarithmic transformation of the two variables least-squares regression of carapace length (CPL) on pleuron length (PL) was calculated (r^2=0.91). Using the equation from the regression, the carapace length was calculated in cases when only the pleuron could be measured:

$$CPL(mm) = 0.8100 \times PL(mm)^{1.2739}$$

The relative importance of individual prey taxa was assessed with indices of frequency of occurrence, number and weight (Clark, 1985) and a stomach fullness index (Lilly, 1991):

Frequency of occurrence: The number of stomachs in which a food item occurred was expressed as a percentage of the total number of stomachs investigated.

Number: The number of each prey item was expressed as a percentage of the total number of food items in all stomachs.

Weight: The weight of each prey item was converted to a percentage of the weight of the total stomach contents.

The mean partial fullness index of prey was calculated as:

$$PFI_i = \frac{1}{n}\sum_{j=1}^{n} \frac{W_{ij}}{L_j^3} \times 10^4 \quad .$$

where W_{ij} is the weight of prey i in fish j, L_j is the length of fish j, and n is the number of fish in the sample. Mean total fullness index (TFI) was calculated by adding values of mean partial fullness index.

The stomach content data were seasonally combined and the prey was compared among season. Within each season the data were divided by fish length into 10 cm size groups and the mean PFI of each prey category was calculated.

RESULTS

Seasonal and spatial variations in prey and stomach fullness

The proportion of empty stomachs regardless of fish length ranged from only 8% in spring 1992 to 55% in summer 1990. In general, the proportion of empty stomachs was larger in summer (55% and 35% in 1990 and 1991, respectively) than in autumn (48% and 29% in 1990 and 1991, respectively). In winter 1992 it was found to be 40% (Table 1).

The composition of Greenland halibut stomach contents show strong similarity among sampling periods (Table 2). Fish was the most important prey, occurring in 21–53% of the stomachs but contributed 53–72% of the total prey weight. Redfish, *Sebastes sp.*, was by far the most dominating fish species contributing 17–48% of the total prey weight. Other fish species such as *Mallotus villosus*, *Reinhardtius hippoglossoides*, *Boreogadus saida*, *Arctogadus glacialis* and *Leptoclinus maculatus* were found in minor quantities.

Crustaceans occurred in 17–33% of the stomachs and contributed 22–47% of the total prey weight. Northern shrimp, *Pandalus borealis*, was the dominating crustacean in the stomachs and was found in all sampling periods. Shrimp contributed 21–43% of the total prey weight and these values are minimum values since shrimp probably contribute significantly to the part of unidentified crustaceans found in the stomachs. The hyperiid, *Parathemisto sp.*, was present in relative high number of the stomachs but constituted little by weight.

Other prey items such as polychaetes, molluscs and cephalopods occurred only rarely.

The mean total fullness index (TFI) was about 1.0 in all the investigated sampling periods, and no clear effects of predator size on the mean TFI can be seen (Fig. 2). The mean partial fullness index (PFI) of fish and especially redfish is dominating in most length groups and sampling periods. PFI of crustaceans is dominated by the hyperiid, *Parathemisto sp.* for the smallest size group (5–14 cm). Northern shrimp, *Pandalus borealis*, shows a tendency to increase with increasing predator size.

To study the variation in total stomach content between sampling periods and depths, fish between 15 and 44 cm were selected and the mean total fullness index (TFI) was calculated for each sampling station. Only stations with at least 10 fish investigated were selected. A one-way ANOVA with sampling period as class variable shows no significant (F=0.44, p=0.82) effect on TFI of sampling period. A one-way ANOVA with depth (100 m depth zones) as class variable shows a significant (F=2.95, p=0.03) trend in TFI from shallow to deep water, TFI of stomachs from 200-300 m (TFI=1.5) being nearly twice the TFI at 500-600 m (TFI=0.77), however, the total variance explained by the model was only 13%.

Prey size preference

The relationship between carapace length and predator length based on both actual measured carapace length and pleuron back-calculated carapace length are shown in Fig. 3. Shrimp size and predator size are weakly correlated (R^2=0.09), and show only a weak trend of increasing prey size preference with increasing predator size (Fig. 5).

A combined carapace length frequency distribution of all measured northern shrimps found in the stomachs shows that shrimp size range from 6 to 34 mm with the highest frequencies between 18 and 28 mm (Fig. 4). Size distributions of northern shrimps in stomachs by sampling year and season are shown in Fig. 6. The shrimp size distributions in summer and autumn 1990 are similar with a dominant mode at 20 mm CPL in both seasons. The shrimp size distributions in summer and autumn 1991 are also similar but with a dominant mode at 23-24 mm CPL. Size distributions of northern shrimps by sampling year and depth are shown in Fig. 7. In 1990, there seems to be a relationship between shrimp size in the stomachs and depth strata but not in 1991.

The relationship between total length of redfish and predator length based on both actual measured total length and vertebral column back-calculated total length is shown in Fig. 8. Redfish size and predator size are weakly correlated (R^2=0.13).

A combined total length frequency distribution of all measured redfish found in the investigated stomachs shows that redfish size range from 3.5 to 14.0 cm with the highest frequencies between 5.5 and 8.0 cm (Fig. 9). Size distributions of redfish in stomachs by sampling year and season are shown in Fig. 10. The redfish size distributions in summer and autumn 1990 are clearly different as are the size distributions in summer and autumn 1991. There is similarities between the distributions in summer 1990 and 1991 with a clear mode of 7.5 cm, and between the distributions in autumn 1990 and 1991, winter 1992 and spring 1992 all with a clear mode of 6.0 cm. Size distributions of redfish in redfish stomachs by depth strata shows that redfish smaller than 6.0 cm in length are found above 400 m. In the 400-600 m depth strata there is two modes in the size distribution of redfish at 7.5 cm and at 10 cm (Fig. 11).

Weight of shrimp and redfish in stomachs of Greenland halibut

The mean weight of shrimp (*Pandalus borealis*) and redfish (*Sebastes sp.*) in the stomachs of Greenland halibut by 10 cm groups was calculated from the total material in average for two half-year periods, autumn-winter and spring-summer, respectively. Unidentified crustaceans were allocated to the shrimp category in proportion to the weight of identified shrimp (*Pandalus borealis*) relative to other crustaceans. Likewise, unidentified fish were allocated to redfish in proportion to the weight of identified redfish to other fish species. (Table 3).

By assuming a constant abundance of Greenland halibut throughout the year the total weight of shrimp and redfish in stomachs of the Greenland halibut population at the time of sampling in average for the two periods autumn-winter and spring-summer was estimated (Table 3). The abundance of Greenland halibut by 10 cm length groups in the study area was estimated from the catches of Greenland halibut during the Greenland research survey for shrimp in summer 1990 and 1991 (Kanneworff and Pedersen, 1992). The weight of redfish in stomachs of the population is generally much higher during the autumn-winter period (21 and 42 tons) than in the spring-summer period (7-8 tons) caused by increased abundance of 0-group redfish at West Greenland due to recruitment from East Greenland during the autumn and winter months (Wieland, 1992). The weight of shrimp in stomachs of the population show much less variability between year and half year period (5-7 tons) (Table 3).

Annual consumption of shrimp and redfish by Greenland halibut

In order to give a rough estimate of the annual consumption of shrimp and redfish we use the model of Elliott and Persson (1978) to calculate daily ration (D.R.). This model assumes that the rate of gastric evacuation (R) is exponential and temperature dependent:

$$R = a \times e^{bT}$$

Information on gastric evacuation rates in Greenland halibut is lacking. It was, therefore, necessary to make assumptions based on the literature. Durbin et al. (1983) concluded that the slope (b) is fairly constant for different prey types and fish species (b=0.115) whereas the constant (a) changes with prey type. We use the value of a=0.0143 found by Dwyer et al. (1987) for fish prey in gastric evacuation experiments on walleye pollock. These experiments were also used by Yang and Livingston (1988) when calculating daily ration of Greenland halibut in the eastern Bering Sea. Although gastric evacuation rate (R) changes with prey type there seems not to be significant difference in R between shrimp, herring and capelin as prey in feeding experiments with cod judged from the data presented by Dos Santos and Jobling (1991). Therefore, we have used the same value of the constant (a=0.0143) for the prey types shrimp and redfish. A general observation of temperature in the study area is a higher bottom water temperature during the autumn-winter period than in the spring-summer period (Buch, 1982). Based on bottom temperature distributions in Buch (1982) we have assumed an average bottom water temperature during the autumn-winter period of 4.5°C for the whole study area and an average bottom water temperature during the spring-summer period of 3.0°C.

Using the above assumptions and stomach content data the daily rations for each period can be calculated as:

$$D.R. = 24 \times S \times R$$

where S is the mean stomach content weight (% of body weight) calculated for all stomachs in each 10 cm length group (Table 4). Since there is no clear pattern between length group and mean stomach content (Table 4) an overall mean value of S used was S=1.60 (%BW) for the autumn-winter period and S=1.12 (%BW) for the spring-summer period. Furthermore, we assume no diel pattern in the stomach content and feeding, as found for Greenland halibut in the northwest Atlantic by Bowering and Lilly (1992) and in the eastern Bering Sea by Yang and Livingston (1988). The daily ration regardless of fish size was calculated to 0.92 (%BW) for the autumn-winter period and to 0.54 (%BW) for the spring-summer period.

To convert the mean stomach content of shrimp and redfish to daily consumption we simply multiplied the calculated daily rate of evacuation (24 x R) with the estimated total weight of shrimp and redfish in stomachs of the population at the time of sampling. The annual consumption was calculated by multiplying daily consumption by each half-year period (182 days) and summation of the two. The annual consumption of redfish was calculated to 2,900 tons and 5,100 tons for 1990 and 1991, respectively and the consumption of shrimp to 1,300 tons for 1990 and 1,100 tons for 1991.

DISCUSSION

The proportion of empty stomachs found in our investigation ranged between 8% in spring 1992 to 55% in summer 1990. Except for the unusually low proportion of empty stomachs found in spring 1992, our findings are comparable to findings by Bowering and Lilly (1992) in the area of Southern Labrador and Northeastern Newfoundland and by Skúladóttir and Jónsson (1991) in North and East Island, but lower than found by Chumakov and Podrazhanskaya (1986) in the Northwest Atlantic (63-82%). In the eastern Bering Sea Yang and Livingston (1988) found a lower proportion of empty stomachs in summer (28-38%) than in autumn (55%), which is opposite to our findings.

The most important prey of Greenland halibut in the area around St. Hellefiske Bank were redfish and shrimp.

This is in accordance with investigations made in September 1955 and July 1964 in the same area (Smidt, 1969). Our investigation has been concentrated on the shrimp grounds off West Greenland and may not be representative for the feeding of Greenland halibut in the whole distribution area. Chumakov and Podrazhanskaya (1986) made an intensive study of feeding of Greenland halibut in the Northwest Atlantic, covering NAFO Subarea 1 with a greater range both geographically and by depth. They also found shrimp and redfish as important prey but not as frequently in the stomachs as in our investigation. Another important prey in their investigation was grenadiers.

The importance of shrimp measured as the weight percent of the total stomach content ranged between 21 and 43% and this is equal to the findings on the shrimp grounds in Hopedale and Cartwright Channels off Labrador (Bowering et al., 1984) and on shrimp ground in North-East Iceland (Skúladóttir and Jónsson, 1991). Also on the shrimp grounds in the fjords of West Greenland shrimp is the most important food component (Smidt, 1969).

The area around St. Hellefiske Bank is an important nursery ground for redfish, especially *Sebastes mentella*, and these small redfish constitute a major part of the fish found in the stomachs. In other areas where redfish are not abundant other fish species dominate the stomach content. In an area off southern Labrador/Northeastern Newfoundland capelin is the most important fish prey (Bowering and Lilly, 1992), like in North and East Iceland (Skúladóttir and Jónsson, 1991), in the Norwegian-Barents Sea (Shvagzhdis, 1990) and in the fjords of West Greenland (Smidt, 1969). In the coastal waters of western Spitzbergen in summer the polar cod, *Boreogadus saida*, is the most important food item for Greenland halibut (Haug and Gulliksen, 1982). In the eastern Bering Sea walleye pollock is the dominant prey of Greenland halibut (Yang and Livingstone, 1988).

The diet composition varied with fish size. Shrimp was found in the stomachs from length group 15–24 cm and upward with a weak tendency of increasing importance with predator size. Bowering et al. (1984) also found an increasing importance of shrimp up to a predator size of 60–69 cm in their investigation on the shrimp grounds in Cartwright Channels off Labrador. It was not possible to demonstrate size-dependent prey preference for shrimp or redfish by Greenland halibut. However, Fig. 8 shows that although all sizes of Greenland halibut feed on small redfish the upper size limit of redfish taken by Greenland halibut increase with predator size.

Chumakov and Podrazhanskaya (1986) found an increase in feeding activity with depth with a higher activity on the slope than on the shelf. In the Barents Sea, the trend in feeding activity was opposite with the highest activity in shallower water (Nizovtsev, 1977). We found a decreasing stomach fullness with increasing depth zones, however, our sampling has a much narrower depth range than the above mentioned studies.The average degree of stomach fullness was lesser than found by Bowering and Lilly (1992).

We found no seasonal difference in average degree of stomach fullness. We therefore assume that Greenland halibut is feeding throughout the year. This is in contradiction to Chumakov and Podrazhanskaya (1986), who found increased feeding activity during summer and autumn and a sharp decline to very low levels during winter and spring, and also from the assumptions made by Bowering and Lilly (1992) in their estimation of annual consumption of capelin.

Comparing the shrimp size distributions found in the Greenland halibut stomachs with shrimp size distributions in the catches from the Greenland random-stratified trawl survey for shrimp off West Greenland in 1990 and 1991 there are some similarities (Carlsson and Kanneworff, 1992). The shrimp size distributions from the 1990 trawl survey show a clear and dominating mode at about 20 mm CPL estimated to be a strong 1985 year class. The shrimp size distributions from the 1991 trawl survey show a decreased but still dominating mode of the 1985 year class at about 22–23 mm CPL. In the 1990 and 1991 trawl survey practically no shrimps were found in shallow water (150-200 m) and there was no indication of new recruitment to the fishery (Carlsson and Kanneworff, 1992). These similarities between the dominating modes in size distributions obtained from the trawl surveys and from the stomach investigations might reflect that Greenland halibut feed on the most abundant shrimp sizes within its habitat and that size-dependent prey preference is of less importance. Acting as "a natural sampling gear" investigations of Greenland halibut stomachs might be used to predict new and strong shrimp year classes before they are caught in the commercial fishery and during the research surveys.

The calculated weight of shrimp in stomachs of the Greenland halibut population at the time of sampling was very similar in 1990 and 1991, mainly because of a rather similar abundance of Greenland halibut in shrimp eating sizes between the two years. The calculated weight of redfish in stomachs of the population at the time of sampling was much higher in 1991 than in 1990. This difference between years is due to a much higher abundance of small Greenland halibut (5–14 cm) in 1991 than in 1990. This size group was found to feed on the small 0-group redfish in the autumn-winter period.

The estimated annual consumption of shrimp and redfish presented in this paper is based on many assumptions and may be improved in several ways. First of all the information on gastric evacuation rate in Greenland halibut is needed together with the influence of different natural food types. Also more stomach content data from the winter and spring seasons are required. The abundance of Greenland halibut in the study area is estimated with great uncertainties from bottom trawl surveys and in the summer period only. These estimates should be verified by a better knowledge of trawl catchability together with information on seasonal variability and vertical distribution in the water column.

The annual consumption of northern shrimp by Greenland halibut was estimated to 1,300 tons for 1990 and 1,100 tons for 1991. These values should be compared with an estimated biomass of the shrimp stock in the study area of 132,200 tons and 95,400 tons for 1990 and 1991 (Carlsson and Kanneworff, 1992). The estimated annual consumption of shrimp by Greenland halibut seems to have a minor impact on the shrimp stock. The biomass of redfish in the study area was estimated to 8,810 tons for 1990 and to 23,800 tons for 1991 (Pedersen and Kanneworff, 1992), therefore the estimated annual consumption of 2,900 tons and 5,100 tons of redfish for 1990 and 1991, respectively, is likely to have significant impact on the redfish stock. We have estimated the annual consumption of shrimp by redfish to be a significant part of the shrimp stock (Pedersen and Riget, 1992), and, therefore, conclude that the food links between shrimp, redfish and Greenland halibut are of major importance for the dynamics between these resources and the shrimp fishery, and that they should be considered in the management of the fishery in the area.

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Table 1 Number of Greenland halibut stomachs analysed for food by predator length groups, year and seasons of sampling (**Seasons: Summer**=June–August 90/91, **Autumn**=September and November 90, November 91, **Winter**=February 92, **Spring**=April 92).

Total number of stomachs investigated		LENGTH (CM) 5-14	15-24	25-34	35-44	45-54	55-	ALL	Percent empty
		n	n	n	n	n	n	n	
YEAR	SEASON								
1990	SUMMER	22	142	199	67	21	2	453	55
	AUTUMN	.	9	106	82	17	.	214	48
1991	SUMMER	279	225	275	154	48	8	989	35
	AUTUMN	303	223	252	197	59	1	1035	29
1992	WINTER	46	112	69	23	6	.	256	40
	SPRING	1	44	30	7	1	.	83	8
ALL		651	755	931	530	152	11	3030	37

Table 2 Percentages of occurrence (O), numbers (N), and weight (W) and mean partial fullness indices (PFI) of prey items in the stomach contents of Greenland halibut at West Greenland by year and seasons of sampling.

	YEAR=90 SEASON=SUMMER			
	O(%)	N(%)	W(%)	PFI
Polychaeta	0.6	0.7	0.1	0.00
Cephalopoda	0.6	0.7	0.2	0.00
Crustacea(total)	27.3	51.3	46.6	0.43
Copepoda	0.3	0.3	0.0	0.00
Hyperiida				
Parathemisto sp.	4.8	6.2	0.3	0.01
Unid. Hyperiida	0.0	0.0	0.0	0.00
Gammaridea				
Mysidacea	1.5	1.6	0.1	0.00
Euphausiacea	1.5	4.3	0.3	0.01
Natantia				
Pandalus borealis	13.2	22.6	34.2	0.29
Pandalus montagui	0.6	0.7	0.4	0.01
Pandalus sp.	4.5	6.2	8.4	0.08
Others and unid.	3.0	5.2	2.3	0.02
Unidenti.Crustacea	2.4	4.3	0.7	0.01
Pisces(total)	28.4	47.1	52.9	0.59
Arctogadus glacia.	0.6	0.7	0.4	0.01
Boreogadus saida	0.3	0.3	0.4	0.00
Mallotus villosus	1.2	1.3	3.1	0.10
Reinhardtius hipp.	0.3	0.3	3.6	0.01
Sebastes sp.	17.1	30.7	34.5	0.34
Others and unid.	10.4	13.8	10.8	0.13
Unidentified and POM	0.3		0.3	0.00
TOTAL				1.04

	YEAR=90 SEASON=AUTUMN			
	O(%)	N(%)	W(%)	PFI
Polychaeta	1.4	0.9	0.0	0.00
Cephalopoda				
Crustacea(total)	31.4	27.2	39.9	0.38
Copepoda	0.3	0.3	0.0	0.00
Hyperiida				
Parathemisto sp.	4.2	3.7	0.3	0.00
Unid. Hyperiida	0.7	0.5	0.0	0.00
Gammaridea				
Mysidacea	1.4	0.9	0.0	0.00
Euphausiacea				
Natantia				
Pandalus borealis	15.7	14.3	24.3	0.21
Pandalus montagui				
Pandalus sp.	7.9	6.5	11.2	0.12
Others and unid.	2.1	1.4	3.3	0.03
Unidenti.Crustacea	0.7		0.7	0.01
Pisces(total)	49.1	70.1	60.1	0.73
Arctogadus glacia.	0.7	0.5	1.0	0.02
Boreogadus saida	0.7	0.5	1.0	0.01
Mallotus villosus				
Reinhardtius hipp.	1.4	0.9	5.9	0.05
Sebastes sp.	30.0	57.1	43.6	0.57
Others and unid.	10.7	11.1	8.6	0.08
Unidentified and POM	0.7	0.5	0.0	0.00
TOTAL				1.12

Table 2 (continued) Percentages of occurrence (O), numbers (N), and weight (W) and mean partial fullness indices (PFI) of prey items in the stomach contents of Greenland halibut at West Greenland by year and seasons of sampling.

	YEAR=91 SEASON=SUMMER			
	O(%)	N(%)	W(%)	PFI
Polychaeta	0.2	2.9	0.0	0.00
Cephalopoda	0.9	1.6	0.9	0.02
Crustacea(total)	23.7	61.6	34.0	0.28
Copepoda	0.6	2.4	0.0	0.00
Hyperiida				
Parathemisto sp.	7.1	15.4	0.5	0.08
Unid. Hyperiida	1.4	5.3	0.2	0.04
Gammaridea	0.2	2.9	0.1	0.00
Mysidacea	1.9	4.4	0.2	0.01
Euphausiacea	1.1	2.6	0.1	0.01
Natantia				
Pandalus borealis	6.7	13.6	23.5	0.09
Pandalus montagui				
Pandalus sp.	2.4	4.0	4.0	0.02
Others and unid.	2.0	3.4	2.0	0.01
Unidenti.Crustacea	1.2	2.6	0.2	0.02
Pisces(total)	21.1	46.9	71.9	0.39
Arctogadus glacia.				
Boreogadus saida	3.0	6.4	8.5	0.09
Mallotus villosus	0.2	0.4	0.6	0.01
Reinhardtius hipp.	1.8	3.4	18.6	0.04
Sebastes sp.	13.9	29.1	26.1	0.18
Others and unid.	3.2	4.9	14.4	0.07
Unidentified and POM	0			
TOTAL				0.69

	YEAR=91 SEASON=AUTUMN			
	O(%)	N(%)	W(%)	PFI
Polychaeta	0.1	0.1	0.0	0.00
Cephalopoda	3.8	4.2	3.5	0.09
Crustacea(total)	22.8	36.0	22.1	0.57
Copepoda	0.1	0.1	0.0	0.00
Hyperiida				
Parathemisto sp.	7.1	11.5	0.9	0.15
Unid. Hyperiida	5.0	6.3	0.7	0.12
Gammaridea	1.3	1.2	0.3	0.00
Mysidacea	2.3	3.1	0.5	0.02
Euphausiacea	4.9	8.8	0.4	0.14
Natantia				
Pandalus borealis	4.7	6.3	15.8	0.07
Pandalus montagui	0.5	0.5	0.7	0.00
Pandalus sp.	1.6	1.8	4.1	0.02
Others and unid.	0.7	0.6	0.9	0.02
Unidenti.Crustacea	0.3	0.7	0.2	0.03
Pisces(total)	26.8	35.5	68.9	0.57
Arctogadus glacia.	0.2	0.4	1.4	0.01
Boreogadus saida	2.2	2.3	7.7	0.06
Mallotus villosus	1.6	2.6	9.1	0.06
Reinhardtius hipp.	1.5	1.4	3.8	0.04
Sebastes sp.	12.9	16.6	16.6	0.17
Others and unid.	13.3	14.0	33.2	0.23
Unidentified and POM	0.4	17.8	0.4	0.00
TOTAL				1.25

	YEAR=92 SEASON=WINTER			
	O(%)	N(%)	W(%)	PFI
Polychaeta	0.4	0.4	0.2	0.00
Cephalopoda	0.4	0.4	3.7	0.01
Crustacea(total)	16.8	23.8	26.8	0.26
Copepoda	1.2	2.2	0.0	0.02
Hyperiida				
Parathemisto sp.	0.4	0.4	0.0	0.01
Unid. Hyperiida	0.4	0.4	0.0	0.00
Gammaridea	0.4	0.4	0.0	0.00
Mysidacea	0.4	0.9	0.0	0.00
Euphausiacea	2.7	3.5	0.5	0.02
Natantia				
Pandalus borealis	5.1	7.9	19.2	0.16
Pandalus montagui	0.8	0.9	0.6	0.00
Pandalus sp.	2.3	3.1	5.0	0.02
Others and unid.	2.4	2.6	1.2	0.02
Unidenti.Crustacea	0.8	0.9	0.2	0.01
Pisces(total)	40.2	75.3	69.4	0.60
Arctogadus glacia.				
Boreogadus saida				
Mallotus villosus				
Reinhardtius hipp.	0.8	0.9	17.8	0.03
Sebastes sp.	37.5	68.3	47.8	0.51
Others and unid.	5.2	6.1	3.8	0.06
Unidentified and POM	0			
TOTAL				0.88

	YEAR=92 SEASON=SPRING			
	O(%)	N(%)	W(%)	PFI
Polychaeta				
Cephalopoda				
Crustacea(total)	32.5	53.0	40.2	0.39
Copepoda				
Hyperiida				
Parathemisto sp.	1.2	0.9	0.0	0.00
Unid. Hyperiida				
Gammaridea				
Mysidacea				
Euphausiacea	9.6	21.4	3.3	0.13
Natantia				
Pandalus borealis	16.9	17.1	29.4	0.20
Pandalus montagui				
Pandalus sp.	8.4	10.3	5.8	0.04
Others and unid.	1.2	0.9	1.1	0.01
Unidenti.Crustacea	1.2	2.6	0.4	0.01
Pisces(total)	53.0	46.2	59.8	0.81
Arctogadus glacia.				
Boreogadus saida				
Mallotus villosus	1.2	0.9	4.2	0.05
Reinhardtius hipp.	1.2	0.9	20.3	0.09
Sebastes sp.	47.0	41.0	33.4	0.62
Others and unid.	3.6	3.5	1.9	0.05
Unidentified and POM	0			
TOTAL				1.20

Table 3 Weight of shrimp (Pandalus borealis) and redfish in stomachs of the population of Greenland halibut by half year period, length and year.

Spring-summer:

Length (cm)	Mean content of red (g)	Mean content of shr (g)	Abundance ('000) 1990	Abundance ('000) 1991	Tot. wgt of redfish (kg) 1990	Tot. wgt of redfish (kg) 1991	Tot. wgt of shr (kg) 1990	Tot. wgt of shr (kg) 1991
5-14	0	0	10650	38696	0	0	0	0
15-24	0.35	0.12	14037	12264	4912	4292	1684	1472
25-34	0.54	0.65	3323	4368	1794	2359	2160	2839
35-44	1.01	2.98	884	616	893	622	2634	1836
45-	0.67	3.63	192	56	129	38	697	203
SUM					7,728	7,310	7,175	6,350

Autumn-winter:

Length (cm)	Mean content of red (g)	Mean content of shr (g)	Abundance ('000) 1990	Abundance ('000) 1991	Tot. wgt of redfish (kg) 1990	Tot. wgt of redfish (kg) 1991	Tot. wgt of shr (kg) 1990	Tot. wgt of shr (kg) 1991
5-14	0.79	0	10650	38696	8413	30569	0	0
15-24	0.57	0.17	14037	12264	8001	6990	2386	2085
25-34	0.88	0.4	3323	4368	2924	3844	1329	1747
35-44	1.11	1.85	884	616	981	684	1635	1140
45-	2.95	3.97	192	56	566	165	762	222
SUM					20,886	42,253	6,113	5,194

Table 4 The mean stomach content weight of Greenland halibut, expressed as a percentage of body weight (% BW±SE). Data from autumn-winter and spring-summer and all times of the day were combined. N=number of stomachs.

	Autumn-winter		Spring-summer	
Length (cm)	N	% BW±SE	N	% BW±SE
5-14	343	2.51± 0.116	275	0.82± 0.117
15-24	337	1.13± 0.118	337	1.10± 0.106
25-34	379	1.33± 0.110	373	1.17± 0.101
35-44	277	1.47± 0.130	175	1.45± 0.147
45-54	80	1.34± 0.241	53	1.04± 0.267
55-	1	0.00± 2.157	9	3.90± 0.649

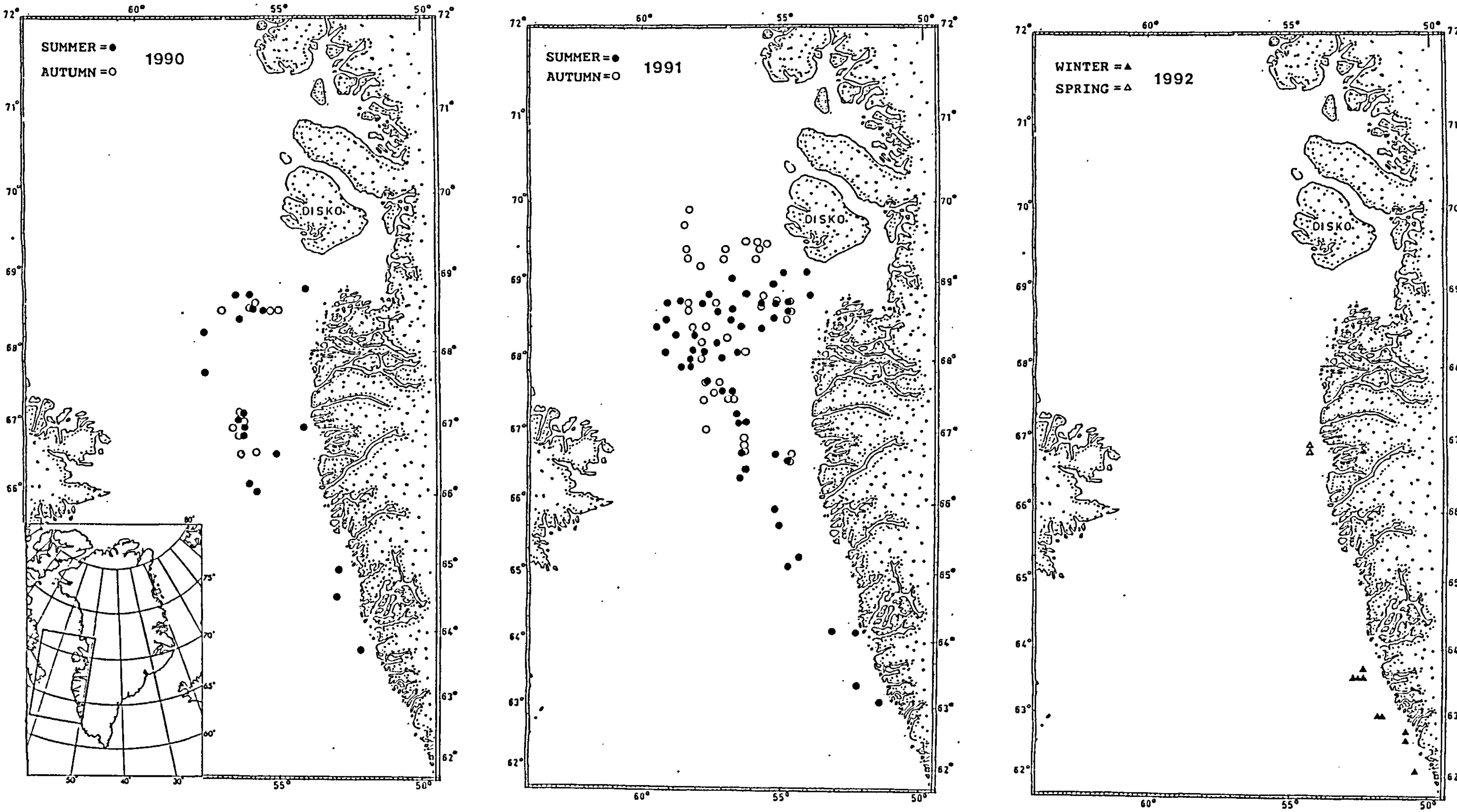

Fig. 1 Sampling stations on the West Greenland continental shelf at depths between 150-600 m by year and seasons of sampling (Seasons: **Summer**=June–August 90/91, **Autumn**=September and November 90, November 91, **Winter**=February 92, **Spring**=April 92).

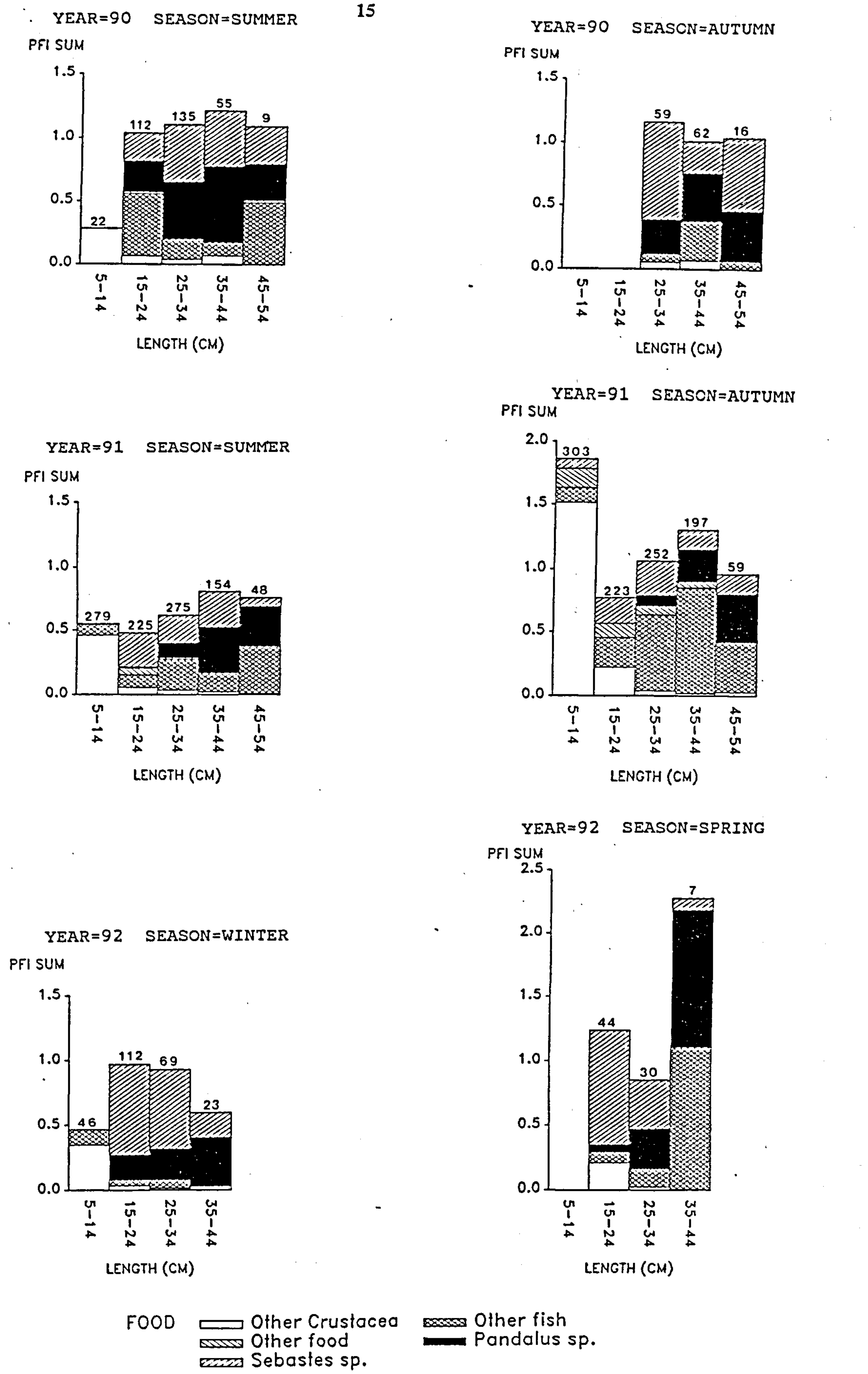

Fig. 2 Stomach contents (expressed as partial fullness indices) in relation to predator length, year and seasons of sampling. Sample sizes are given at the top, only length groups with sample sizes larger than five are presented.

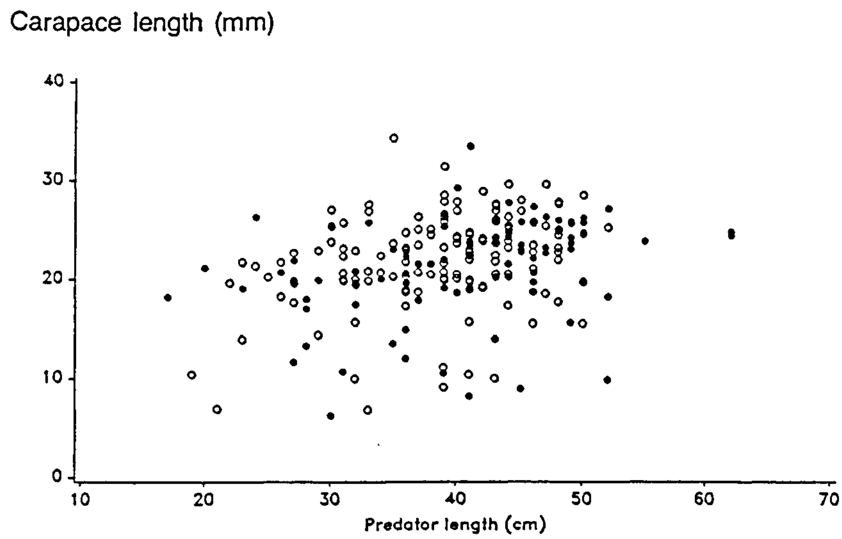

Fig. 3 Plot of carapace length of shrimps found in Greenland halibut stomachs versus predator length. (Dots=actual measured carapace length, Circle=pleuron calculated carapace length).

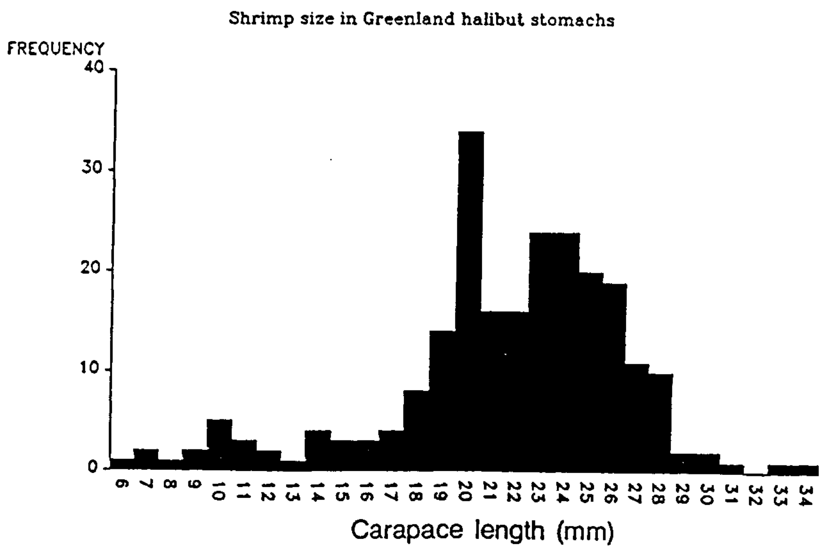

Fig. 4 Combined size distibution of northern shrimp found in the Greenland halibut stomachs 1990–1992.

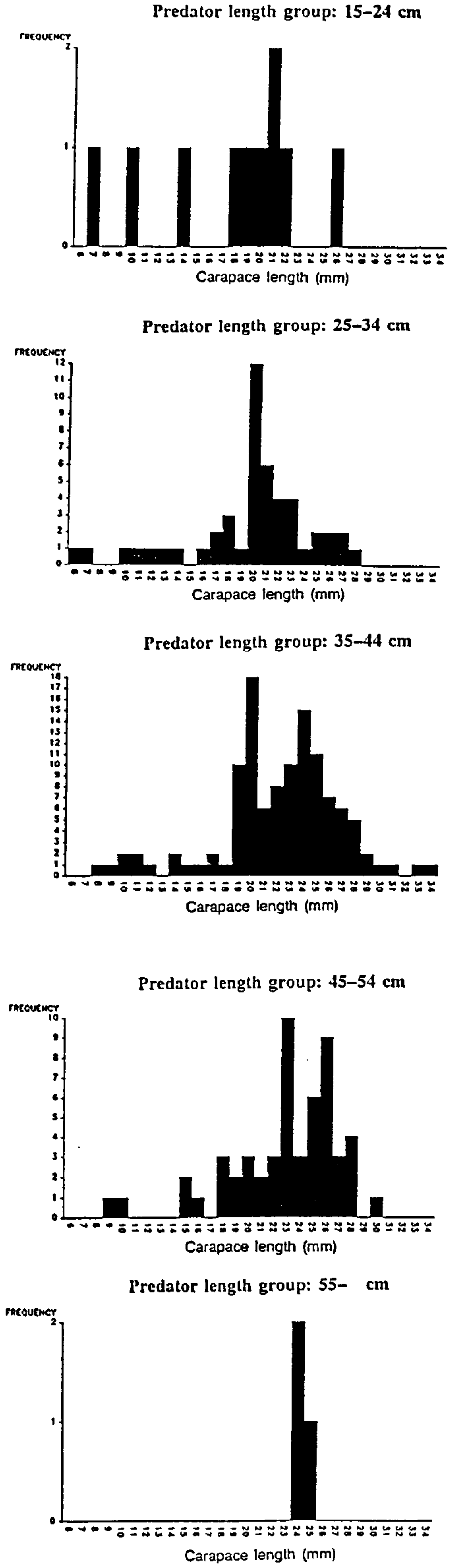

Fig. 5 Size distributions of northern shrimp found in Greenland halibut stomachs 1990-1992 by predator length groups.

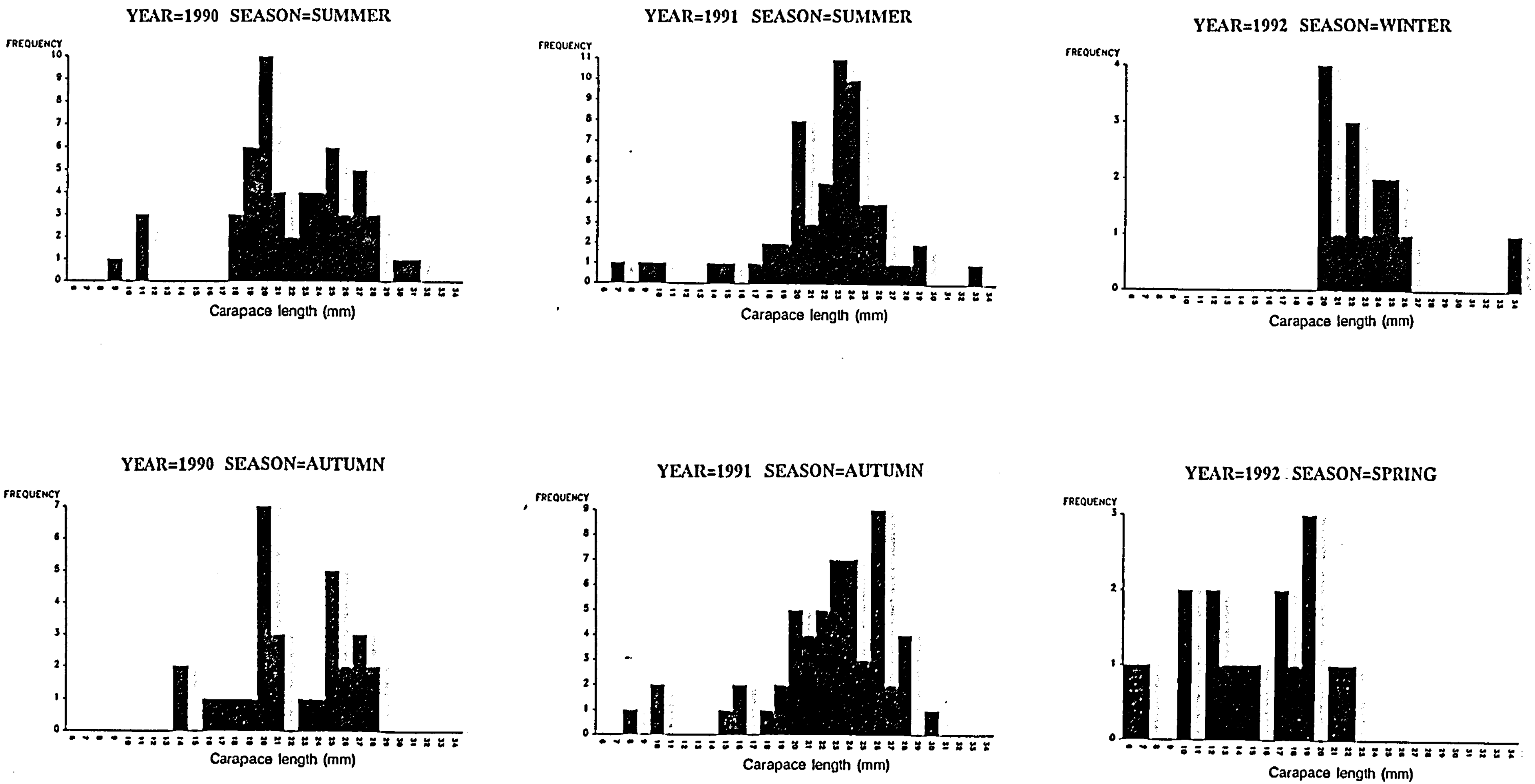

Fig. 6 Size distributions of northern shrimp found in Greenland halibut stomachs by sampling year and season.

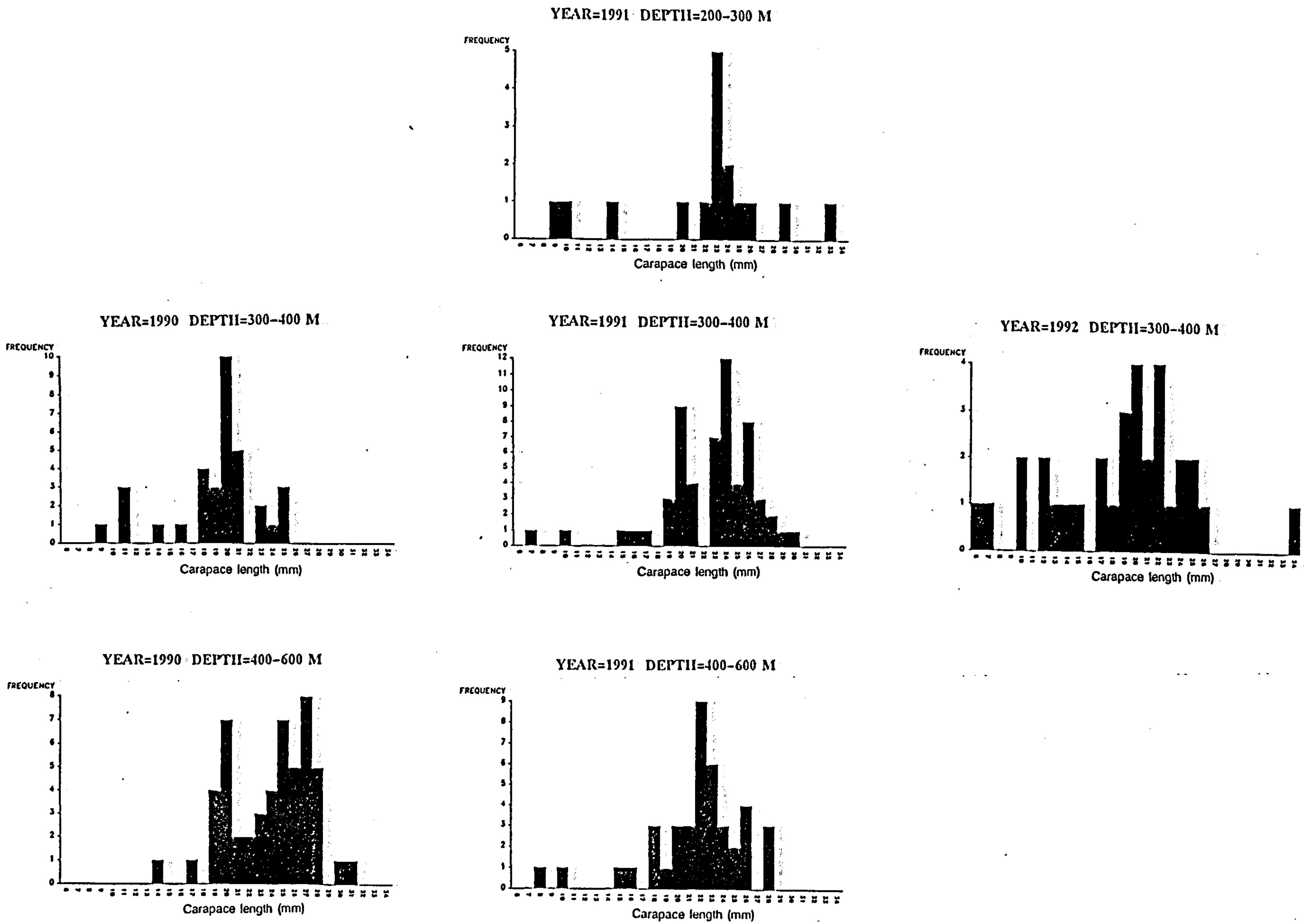

Fig. 7 Size distributions of northern shrimp found in Greenland halibut stomachs by sampling year and depth strata.

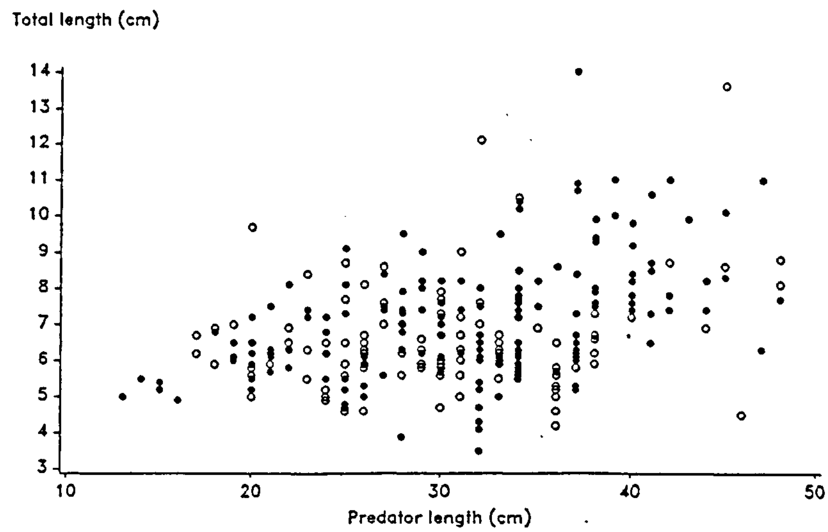

Fig. 8 Plot of total length of redfish found in Greenland halibut stomachs versus predator length. (Dots=ac tual measured total length, Circle=vertebral column calculated total length).

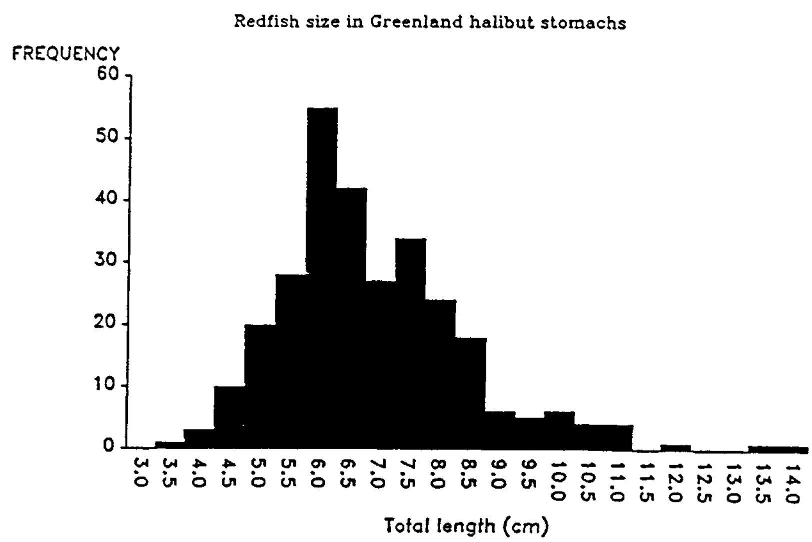

Fig. 9 Combined size distibution of redfish found in the Greenland halibut stomachs 1990-1992.

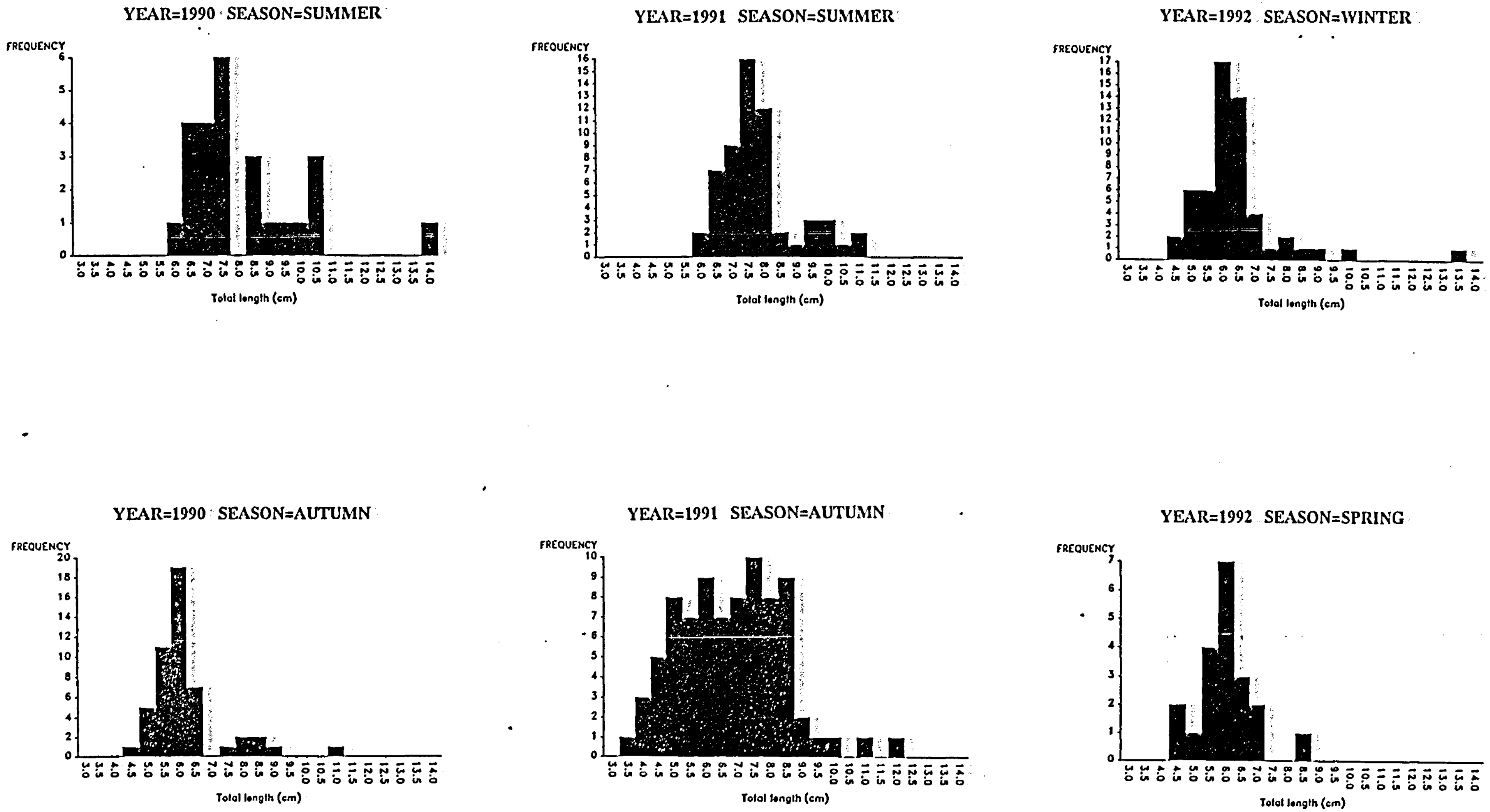

Fig. 10 Size distributions of redfish found in Greenland halibut stomachs by sampling year and season.

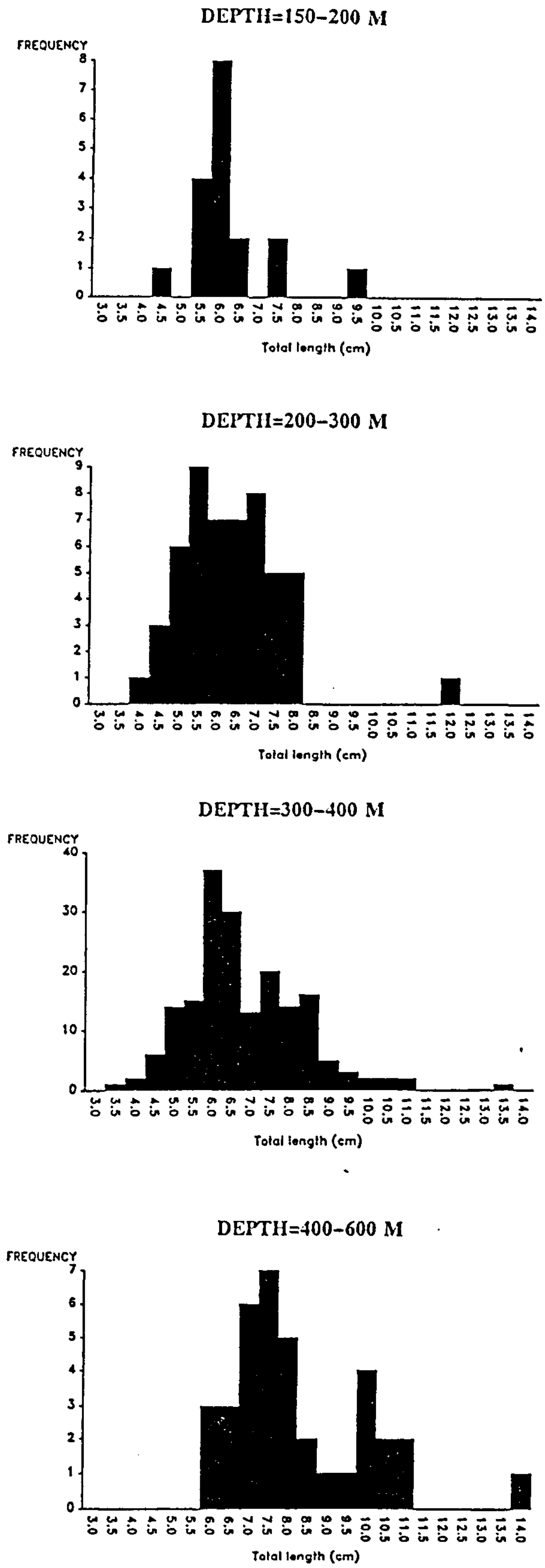

Fig. 11 Size distributions of redfish found in Greenland halibut stomachs by sampling depth strata.