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FIELD STUDIES OF HARP SEAL *PHOCA GROENLANDICA* DISTRIBUTION AND FEEDING ECOLOGY IN THE BARENTS SEA IN SEPTEMBER 1990

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ABSTRACT

The harp seal *Phoca groenlandica* is the most abundant seal species in the Barents Sea, and it may be a significant predator on other marine resources in this area. In order to evaluate the ecological role of harp seals, field studies, including both analysis of harp seal stomach contents and concurrent estimates of prey abundance, were carried out in the Barents Sea during August/September 1990. It appeared that, at this time of the year, the harp seals were confined to the northmost areas of this sea, either close to or within the pack ice belt.
Trawl surveys revealed that the most abundant food resources in sea surface layers in areas close to the pack ice belt were the amphipod *Parathemisto libellula* and krill *Thysanoessa* spp. The fish fauna is poor, and occurs mainly near the bottom. Numerically, capelin *Mallotus villosus* and polar cod *Boreogadus saida* dominated, but also long rough dab *Hippoglossoides platessoides*, Greenland halibut *Reinhardtius hippoglossoides*, snailfish *Liparis fabricii* and Atlantic poacher *Leptagonus decagonus* occured quite frequently.
The amphipod *P. libellula* is the prey item found most often in seal stomachs and it also contributed most to the biomass of the seal diet. A few fish, in particular polar cod and Greenland halibut, were also found in the seal stomachs.

INTRODUCTION

The harp seal *Phoca groenlandica* is the most abundant seal species in the Barents Sea. Traditionally, Barents Sea harp seals have been exploited by Soviet and Norwegian sealers in the East Ice, i.e., the pack ice areas in the White Sea and southeastern Barents Sea (Iversen 1927, Yakovenko 1967, Benjaminsen 1979). Despite the controversies connected with sealing operations in recent years, sealing in the East Ice has been maintained, both because the harp seal is a valuable renewable resource, and because it may be a significant predator of other marine resources in the Barents sea area. Annual invasions of harp seals in coastal waters of North Norway since 1978 have caused particularly large problems for coastal fisheries in this area (Bjørge et al. 1981, Wiig 1988, Nilssen et al. 1991, Haug et al. 1991).

This has encouraged the evaluation of the ecological role of harp seals in the Barents Sea. This is also important when these and other top predators are to be included in multi-species models which may form the basis for a more rational management of marine resources in the area. Field studies of Barents Sea harp seals are thus now in progress, aimed primarily to gather information about the feeding habits and general condition of the animals in the area throughout the year. The sampling design for these studies are based on existing knowledge about the migratory patterns of harp seals in the Barents Sea (see Smirnov 1924, Chapskii 1938, 1961, Sivertsen 1941, Popov 1970, Benjaminsen 1979, Wiig 1988).

The sampling effort in the harp seal ecology studies is concentrated on areas of abundance in the open waters along the pack ice belt in the Barents Sea in summer and autumn, in coastal waters of Norway in winter, and in the breeding and moulting areas in the spring. Pilot autumn studies of offshore harp seal feeding in the Barents Sea were carried out by the Institute of Marine Research, Bergen, in 1981-1983 (unpublished data) and continued in 1987 (Lydersen et al. 1991). This report presents preliminary results from further studies carried out along the drift ice belt using the research vessel "Johan Ruud" in September 1990. The studies included the sampling of stomach contents and condition parameters from seals as well as concurrent estimates of possible prey abundance using trawl gear.

AREA SURVEYED

The survey route followed by "Johan Ruud" during the cruise is shown in Fig. 1. The vessel left the coast of Norway on 29 August, and reached the pack ice belt in the areas between Spitsbergen and Kong Karls Land (N 78° 37', E 23° 20') on 1 September. "Johan Ruud" then operated in the pack ice belt as far east as to the Zemlja Franca Iosifa (N 79° 43', E 47° 53') until 17 September when it returned southwards and arrived at the Murman coast in northern Soviet on September 20. Because "Johan Ruud" is not an ice strengthened vessel, both the observation and hunting activities had to be confined to the ice edge areas, although two fast moving Zodiac inflatable boats (15' and fitted with 40 hp outboard motors) were in some cases used to penetrate some distance into the pack ice belt.

Almost simultaneously with the "Johan Ruud" cruise (16 August - 5 September) the annual international 0-group fish survey was carried out in the Barents Sea and adjacent waters. On this cruise, which included 3 Norwegian and 2 Soviet research vessels operating in the whole Barents Sea as far north as N 77° and on the coastal banks to the west of Spitsbergen (Anon. 1990), lookout was kept for seals by all wheelhouse crews.

MATERIAL AND METHODS

Estimation of prey abundance

The abundance of harp seal prey was examined by trawling in the same areas where seals were observed and captured. Bottom trawling was carried out using a REFA Gisund Super 1280 mesh shrimp trawl with rubber bobbins, 45 m sweep wires, 43.2 m fishing line length, and a cod end mesh size of 35 mm. Trawling just above (10-15 m) the bottom, in distinct echo-layers (at 20 m depth) and in the surface layers were carried out using a pelagic trawl (made by Fiskernes Redskapsfabrikk, Tromsø, Norway) fitted with a Simrad trawl eye to monitor trawl depths, and with a fine (10 mm) 'tobis' net in the cod end. All trawl hauls lasted 1 hour. Approximate volumes of fish (which were also identified and counted, in some cases also length measured), crustaceans (which were classified to the lowest possible taxons) and squid were recorded in all trawl hauls. Temperatures were recorded using Nansen water bottles.

Capture of seals

In general, harp seals do not haul out on the ice during autumn. Attempts were therefore made to capture the seals in the water by the use of specially designed nets. The net units applied were 55 m long and 9.5 m deep and were either of 8 or 12 inches mesh size. 10 units were used in each net setting which was kept floating 2-3 m below the surface. No seals were, however, captured in the nets which could only be used as passive gear. It proved impossible to chase the seals towards the nets or in any other predetermined direction. Use of underwater sound producing device (e.g., asdic) were observed to cause panic in the seal herds, and may prove applicable in combination with nets in future pelagic harp seal hunting.

With the failed net fisheries, seals had to be shot in the water, either from the bow of "Johan Ruud", from the Zodiac inflatable boats, or from ice floes. Under the circumstances the latter method proved most applicable, for one thing due to the lacking ability of "Johan Ruud" to penetrate into the calmer areas within the pack ice. The inflatable boats were used to pick up the shot animals from the sea. Killed seals were immediately transported to the vessel for weighing, body measurements, and dissection on deck. Lower jaws with teeth were collected and salted for age determination as described by Bowen et al. (1983).The seal stomachs were collected and frozen for later laboratory examination of contents, whereas the contents from the intestines were washed out immediately and fixed in 70% ethanol.

Stomach contents analyses

In the laboratory the stomachs were cut open after thawing. The total weight of the stomach contents was recorded. All fresh specimens of fish and crustaceans were identified by gross morphological characteristics. The fish material were separated from the crustaceans, and the weights of each group was recorded.

For crustaceans, a random subsample from each seal stomach was weighed and analyzed with respect to species composition. Total weight and number of individuals was recorded for each species in the subsample, and this was used to obtain crude estimates of the numerical contribution of each prey species to the total seal diet. Mean weights of fresh crustaceans, as obtained from random samples taken from the trawl catches, were used to obtain crude estimates of the original biomass of the crustaceans eaten by the seals.

The material of fish and the remaining crustaceans were placed in a tray and washed repeatedly in cold water in order to "pan out" fish otoliths (see Treacy & Crawford 1981, Murie & Lavigne 1985). The otoliths were identified to the lowest possible taxon, preferably to species (see Breiby 1985, Härkönen 1986). The total number of each fish species was determined by adding the number of fresh specimens, the number of intact sculls and half the number of free otoliths. All otoloiths were measured, and otolith length - fish weight correlations (Härkönen 1986) were used to estimate the original fish weight.

The otoliths found in the intestines were only identified to species (see Härkönen 1986) in order to control if all the fish species found in the stomachs could also be identified qualitatively after passage through the rest of the digestive tract.

Feeding indices were used to estimate the dietary contribution of different prey items (Berg 1979, Hyslop 1980, Eliassen & Jobling 1985). Since no feeding index gives a complete or realistic picture of dietary composition, the data were recorded as: 1) The percentage occurrence of a given dietary component, defined as the percentage of stomachs which contained one or more individuals of this component. 2) Relative frequency of occurrence was calculated as the numerical fraction each prey item constituted of all prey categories. 3) Relative frequency of occurrence was also determined by estimating the relative contribution of each prey species to the total diet expressed in terms of calculated fresh weight (i.e., biomass).

RESULTS AND DISCUSSION

General ice conditions and observations of harp seals

No harp seals were observed along the survey track south of Hopen Island (Fig. 1). Between Hopen and the pack ice belt, where capelin *Mallotus villosus* seemed to be plentiful (as indicated from registrations on the echo sounder and from the presence of large amounts of seabirds, minke whales *Balaenoptera acutorostrata* and humpback whales *Megaptera novaeangliae*), only a few harp seals were observed. Considerable numbers of harp seals - both in smaller (4-5 individuals) and larger (20-30 animals) groups - were, however, seen as soon as the vessel reached the pack ice belt in Olgastredet (see Fig. 1) between Spitsbergen and Kong Karls Land (N 78° 37', E 23° 20'). "Johan Ruud" operated along the pack ice in Olgastredet and Erik Eriksenstredet (trawl stations 1 and 2, respectively, in Fig. 1) during the period 1-9 September, and the abundance of seals appeared to be considerable in the whole area. It is worth noting, however, that the herds of seals were generally distributed in relatively small groups which never seemed to exceed 30 animals. The whole first period of the cruise was characterized by very calm and good weather, although fog restricted observations and hunting on some days.

During the period 10-14 September, the ice edge between Spitsbergen and Zemlja Franca Iosifa was surveyed along an eastgoing and a westgoing transect (Fig. 1). Harp seals seemed to be scattered along most of the edge with more animals being present in the areas near Zemlja Franca Iosifa than in the open waters further west. Harp seals observed during the eastgoing survey seemed to be somewhat less abundant and to occur in smaller groups (seldom more than 4-5 animals) than in the Spitsbergen areas. Due to the limited ice penetrating abilities of "Johan Ruud", the sounds and straits of the Zemlja Franca Iosifa archipelago were not surveyed, although it is known from Soviet observations that harp seals occur here (V. Potelov, unpublished material). This was also verified during a research cruise with Soviet research vessel "Pomor" in these areas in September 1990 where several groups of 10-15 animals were observed (Øystein Wiig, Norwegian Polar Research Institute, Oslo, Norway, pers. comm.).

As seen from Fig. 1, the westgoing survey route from Zemlja Franca Iosifa was further north than the eastgoing route. This was due to a period of moderately strong southerly and southwesterly winds which caused a northward ice drift and also a packing of the ice. Thus, upon return to the Spitsbergen areas on 14 September, the ice conditions had changed completely. The whole ice belt had been packed northeastwards to the east side of Nordaustlandet north of Erik Eriksenstredet (Fig. 1). "Johan Ruud" operated in these areas until 17 September, and harp seals were still abundant in considerable numbers along the ice edge. The packing of the ice hampered both the observation and hunting activities due to the unability of "Johan Ruud" to penetrate into the ice belt. In the now open water areas in Erik Eriksenstredet, which were covered with pack ice one week previously, no harp seals were observed. Likewise, no harp seals were observed along "Johan Ruud"'s route southwards towards the Soviet coast.

Except for a few stragglers around Hopen, no harp seals were recorded from any of the research vessels participating in the international 0-group fish survey (see Anon. 1990) in the Barents Sea and adjacent waters. It seems that the autumn distribution of harp seals in the Barents Sea is confined only to the northmost areas of this ocean, and always close to - possibly also to some extent within - the pack ice belt. This was also the impression gained during the harp seal 1987 autumn survey (Lydersen et al. 1991). Combined with the summer (May-August) observations of Chapskii (1938, 1961), the present observations seems to confirm quite clearly that after breeding and moulting in spring, the harp seals leave the White Sea area and follow the drift ice belt northwards in the Barents Sea as the ice cover recede and disintegrate throughout the summer and autumn.

Prey abundance - results from the trawl surveys

Provided gelatinous plankton is disregarded as harp seal food, the most abundant food resource in the upper layers (surface and 20 m depth) in both Olgastredet and Erik Eriksenstredet is the amphipod *Parathemisto libellula* (Fig. 2), a species known to be dominant in cold water plankton communities (Dunbar 1957). In Olgastredet and on the shallowest trawl station in Erik Eriksenstredet the largest abundances of this amphipod were registered in the surface layer, while it was most numerous at the 20 m layer on the deeper Erik Eriksenstredet trawl station. *Parathemisto* species are typically patchy distributed (Kurt Tande, Norwegian College of Fisheries Science, University of Tromsø, Norway, pers. comm.), and this may have contributed to the low abundance observed in the surface layers in the 350 m Erik Eriksenstredet trawl station. Such patchy distribution is also evident from very large variations in the mean *P. libellula* catch volume in hauls taken during the day and night (Table 1).

P. libellula was abundant in considerable quantities also in the water layers 10-20 m above the bottom (Fig. 2). In both Erik Eriksenstredet stations, these layers were also characterized by the presence of krill *Thysanoessa* spp. which were abundant in amounts similar to *P. libellula*. The bottom layers, which were surveyed with bottom trawl and thus should not be compared quantitatively with the pelagic trawl data, contained almost exclusively fish.

As seen from Fig. 2, the volumetric contribution of fish to the catches in all layers except the bottom is very low. In the upper layers, the fish observed were 0-group polar cod *Boreogadus saida*, capelin and snailfish (probably *Liparis fabricii*). Fish observed in the 20 m layer were always polar cod and capelin except for one sculpin (*Triglops pingelii*) which occurred on the Erik Eriksenstredet 250 m station. *T. pingelii* also occurred in some of the hauls 10-20 m above the bottom where, in addition to the most commonly occurring polar cod and capelin, *L. fabricii* and the lumpsucker *Eumicrotremus derjugeni* were also caught.

The invertebrates found in the bottom trawl included *P. libellula*, small numbers of the decapods *Pandalus borealis* and *Sclerocrangon boreas*, and a few squid *Gonathus fabricii*. Numerically, capelin and polar cod dominated the fishes caught in the bottom trawl hauls (Fig. 3). In Erik Eriksenstredet, where the largest bottom trawl fish catches were obtained (see Fig. 2), the flatfishes long rough dab

Hippoglossoides platessoides and Greenland halibut *Reinhardtius hippoglossoides*, the snailfish *L. fabricii*, and the Atlantic poacher *Leptagonus decagonus* occurred quite frequently (Fig. 3). Other fish species that occurred more fragmentarily in the bottom trawl catches included *Raja radiata, Anisarchus medius, Lycodes* sp., *Sebastes mentella, Artediellus atlanticus, T. pingelii, Cottunculus microps, E. derjugeni* and *Careproctus reinhardtii.*

In general, the fish fauna observed during these trawl surveys on the eastern side of Spitsbergen included fewer species and individuals than in similar trawl surveys on the western side of Spitsbergen in 1987 (Falk-Petersen et al. in prep.). Falk-Petersen et al. (loc. cit.) also observed vertical migrations of several species (e.g., *S. mentella* and the Greenland halibut), but in the present survey they were recorded only in the bottom hauls.

Water temperatures measured in the four survey depths on the Erik Eriksenstredet 350 m station were: Surface, 1.35°C; 20 m, -0.55°C; 20 m above bottom and bottom, -0.10°C.

Capture of the harp seals

A total of 22 harp seals (Table 2) were captured during the cruise: 4 were shot from the bow of the research vessel, 2 were shot from inflatable boats and the remaining 16 were shot from ice floes. Twenty one of the animals were taken in Olgastredet and Erik Eriksenstredet during the first period (1-9 September) of the cruise. No harp seals were taken on the survey eastwards to Zemlja Franca Iosifa, whereas only one animal was shot during the second period of operation (14-17 September) in Erik Eriksenstredet. More difficult weather and ice conditions during the last part of the cruise clearly hampered the hunting operations which always had to be carried out along the ice edge, out of reach of the calmer areas within the pack ice. The use of an ice-going vessel would most probably have resulted in a larger catch of seals (see, e.g., Lydersen et al. 1991). The captured seals ranged in age between 1.5 and 21.5 years (Table 2).

Harp seal stomach contents

From examinations of the collected stomach samples, it is apparent that the amphipod *P. libellula* is the prey item occurring in most stomachs (Table 2). Krill *Thysanoessa* spp., prawns *P. borealis* and various fish species such as Greenland halibut and polar cod were also found, although by no means as frequently as *P. libellula*. Evidently, *P. libellula* contributed most to the total seal food both numerically (Fig. 4A) and when the biomass of the prey organisms is considered (Fig. 4B). The contribution of krill and fish seems to be of rather little importance as prey for the harp seals in the area and period of investigation. The present study, thus, seems to confirm the impressions gained during similar investigations in the same areas in 1987 (Lydersen et al. 1991). A possible importance of *P. libellula* as prey species has also been pointed out for harp seals inhabiting the Arctic areas of Greenland and Canada (Sergeant 1973, Davis et al. 1980, Kapel & Angantyr 1989, Finley et al. 1990). The otoliths found in the intestines confirm a similar fish composition as found in the stomach (Table 4).

SOME PRELIMINARY CONCLUSIONS

1. It seems that the Barents Sea harp seals are mainly confined to the pack ice belt in the north during autumn. This view is supported both by the lack of harp seal observations in the Barents Sea south of 77°N and to the west of Spitsbergen by the vessels participating in the international 0-group fish survey, and by the simultaneous observations on the "Johan Ruud" cruise of harp seals in most of the pack ice area between Spitsbergen and Zemlja Franca Iosifa. Apparently, harp seals belonging to the White Sea breeding stock follow the drift ice belt northwards in the Barents Sea as the ice cover recede and disintegrate

throughout the summer and autumn.

2. The observed areas of harp seal abundance is clearly to the north of the usual distributional area of capelin (see Anon. 1991) in the Barents Sea during September. This is also confirmed by the results from the trawl surveys which revealed a major abundance dominance of the amphipod *P. libellula* in most water layers. Some fish, particularly polar cod and capelin, were observed in the bottom hauls.

3. Gill nets used as passive gear in surface layers do not seem suitable to catch harp seals in open waters at this time of the year. However, it is possible that fast moving vessels fitted with some underwater sound-producing device may succeed in driving the seals towards the nets. The most successful capture method applied during the present cruise was the shooting of seals in the water from ice floes.

4. Examinations of the stomachs of the harp seals confirms their opportunistic feeding nature in that the diet was dominated by the most abundant prey species *P. libellula*. Thus, the present investigation supports the findings of Lydersen et al. (1991) made in the same areas in 1987. These findings in the northeast Atlantic are consistent with observations made in the northwest Atlantic where *P. libellula* has been suggested to be the most important link in the food chain between copepods and other smaller planktonic forms on the one hand, and the vertebrates on the other (Dunbar 1957). The lack of seals in the more southerly Barents Sea areas, where large amounts of capelin were observed this autumn (Anon. 1991), may indicate that this pelagic fish is not an important food resource for the harp seals at this time of the year.

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Table 1. Mean catch volume (in l) of *Parathemisto libellula* captured in day and night one hour hauls using pelagic trawl at the surface and at 20 m depth. Data from Olgastredet and Erik Eriksenstredet are pooled. N = number of hauls.

WATER LAYER	DAY (0600-1800)			NIGHT (1800-0600)		
	N	Mean	S.D.	N	Mean	S.D.
Surface	1	1.5		5	22.0	33.3
20 m depth	2	50.0	7.1	6	9.3	7.3

Table 2. List of harp seals taken for scientific purposes during the "Johan Ruud" cruise in the northern Barents Sea in September 1990.

DATE OF CAPTURE	POSITION	SEX	LENGTH (cm)	WEIGHT (kg)	AGE (years)
1 Sep	N78°49'/E22°46'	Female	127	46	1.5
1 Sep	"	Male	125	44	1.5
2 Sep	N78°51'/E22°50'	Male	139	74	5.5
2 Sep	N78°48'/E22°48'	Female	156	112	9.5
3 Sep	N78°41'/E23°30'	Male	162	93	6.5
3 Sep	"	Male	179	156	18.5
4 Sep	N79°03'/E26°10'	Female	159	117	13.5
4 Sep	"	Female	176	131	14.5
4 Sep	"	Female	187	145	13.5
4 Sep	"	Female	165	137	14.5
5 Sep	N79°13'/E26°30'	Male	179	172	14.5
5 Sep	"	Female	168	128	11.5
5 Sep	"	Female	167	158	-
5 Sep	"	Male	126	50	1.5
6 Sep	N79°28'/E28°32'	Male	175	156	21.5
6 Sep	"	Female	174	146	11.5
6 Sep	"	Male	182	151	19.5
8 Sep	N79°33'/E28°15'	Female	156	126	12.5
8 Sep	"	Male	177	138	19.5
9 Sep	N79°40'/E28°38'	Female	154	111	6.5
9 Sep	"	Male	162	116	10.5
15 Sep	N79°39'/E26°57'	Female	180	148	20.5

Table 3. Frequencies of occurrence of empty stomachs and identified taxa of prey in stomachs of 22 harp seals captured in the pack ice belt in the Barents Sea in September 1990.

PREY ITEM	PERCENTAGE OCCURRENCE
Empty stomachs	9.1
Mollusca	
Gastropoda	4.5
Crustacea	
Amphipoda	
Parathemisto libellula	90.9
Euphausiacea	
Thysanoessa spp.	45.5
Decapoda	
Pandalus borealis	9.1
Pisces	
Osmeridae	
Mallotus villosus	4.5
Gadidae	
Boreogadus saida	36.4
Lumpenidae	
Leptoclinus maculatus	4.5
Liparididae	
Liparis fabricii	9.1
Cottidae	
Gymnocanthus tricuspis	4.5
Triglops pingelii	22.7
Agonidae	
Leptagonus decagonus	4.5
Cyclopteridae	
Eumicrotremus derjugeni	9.1
Pleuronectidae	
Reinhardtius hippoglossoides	13.6
Unident. fish remains	22.7

Table 4. Number of otoliths found in the intestines of 10 harp seals captured in the pack ice belt in the Barnts Sea in September 1990.

FISH SPECIES	NO. OF OTOLITHS
Boreogadus saida	35
Reinhardtius hippoglossoides	10
Liparis fabricii	7
Lycodes sp.	6
Mallotus villosus	3
Gymnocanthus tricuspis	2
Leptoclinus maculatus	1
Hippoglossoides platessoides	1
Unidentified otoliths	12

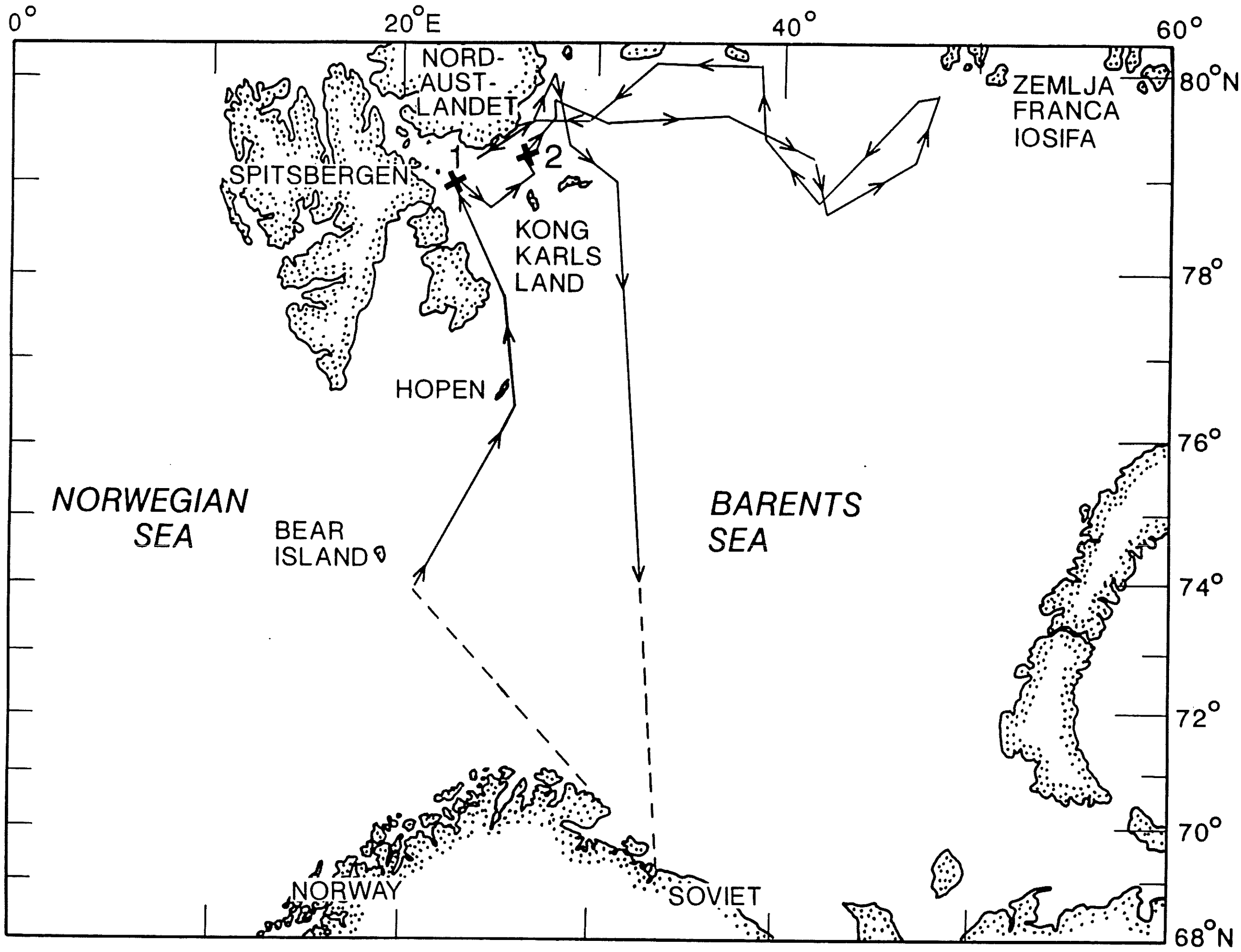

Fig. 1. The route of "Johan Ruud" during the 1990 September harp seal cruise in the Barents Sea. The two crosses indicate areas of trawling in 1) Olgastredet, and 2) Erik Eriksenstredet.

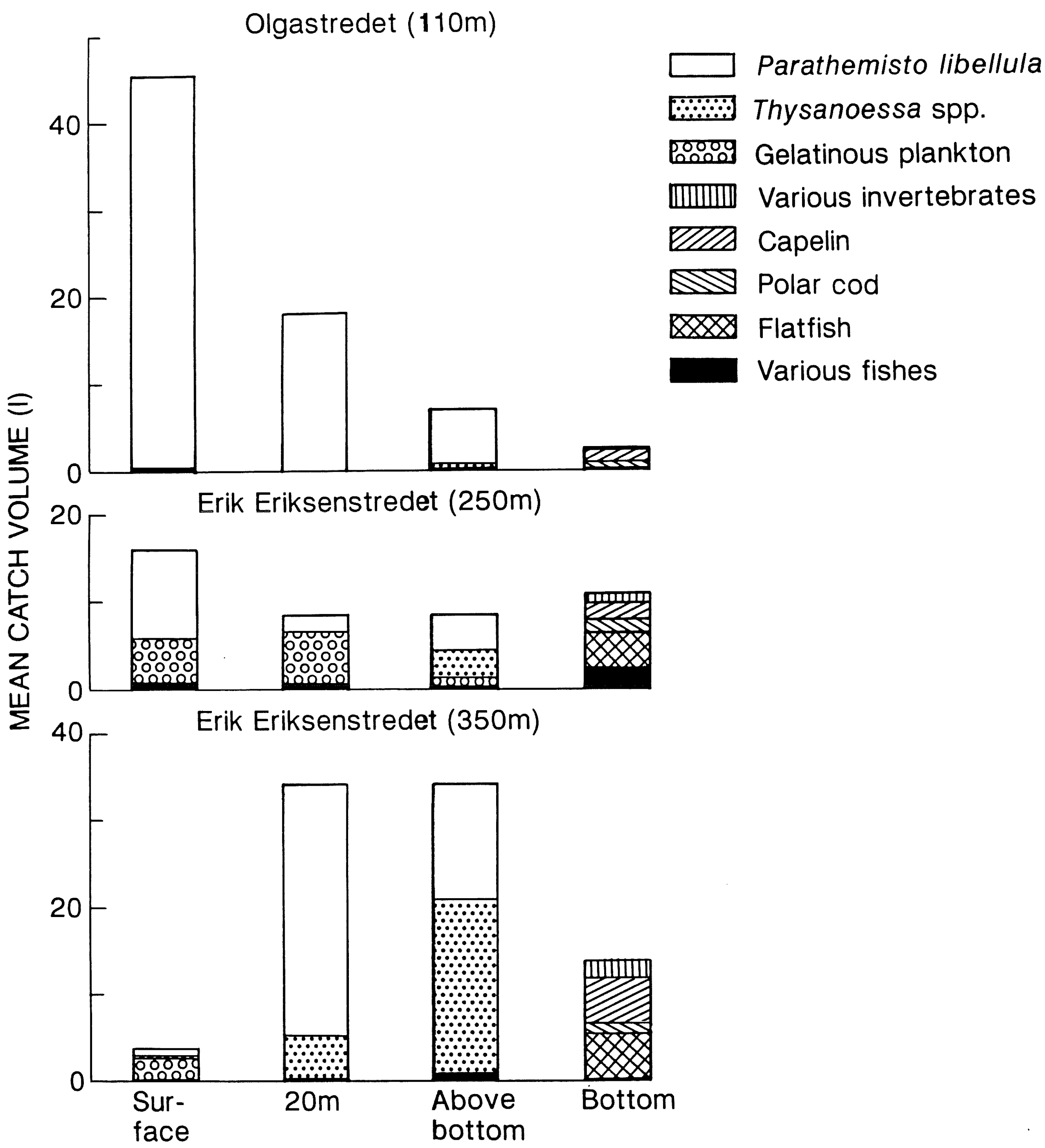

Fig. 2. Mean total contribution (in volume) of various organisms to the catches obtained in standard one hour hauls performed with pelagic trawl at the surface, at 20 m depth and 10-20 m above the bottom, and with bottom trawl at three different trawl stations. Echo-depth at each station is given in parentheses.

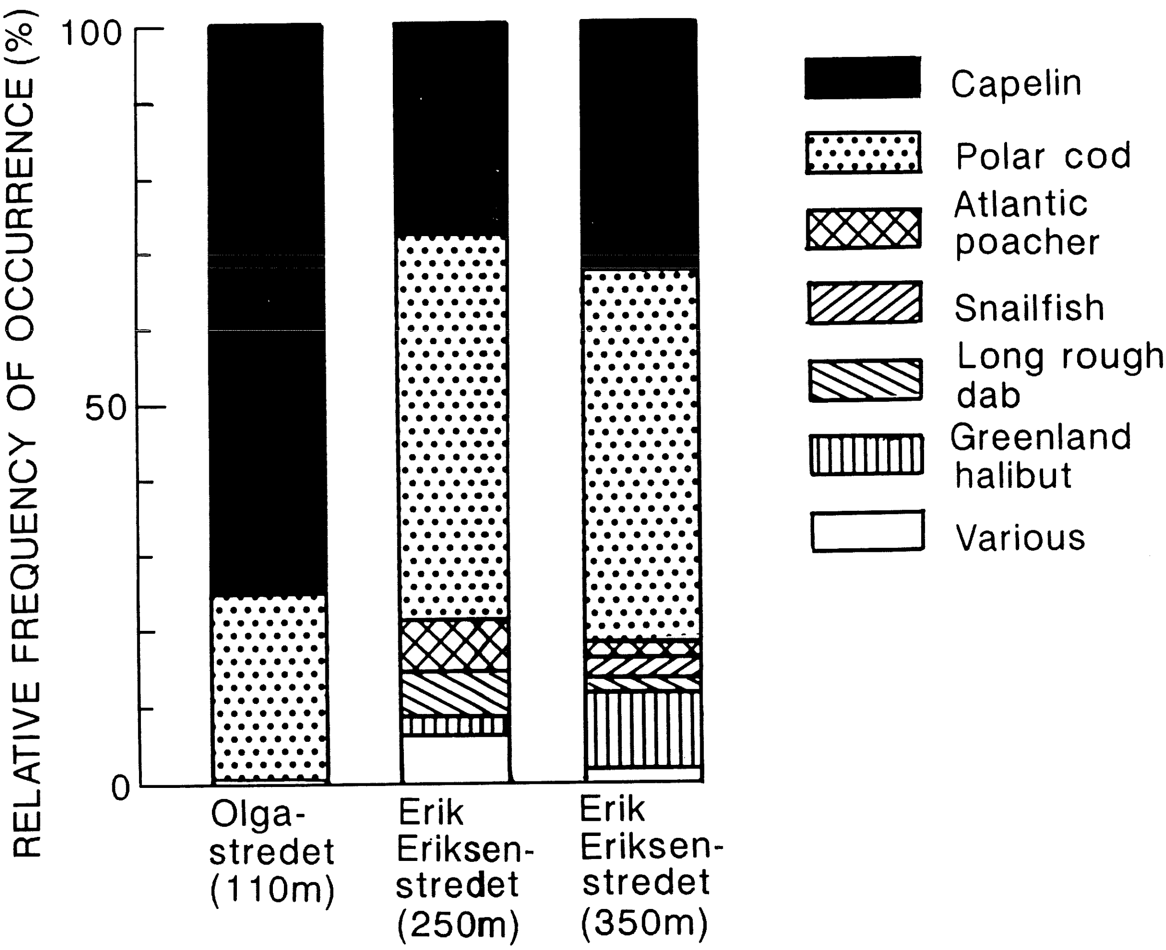

Fig. 3. Relative frequency of occurrence (by numbers) of the various fish species captured in bottom trawl hauls at three different trawl stations.

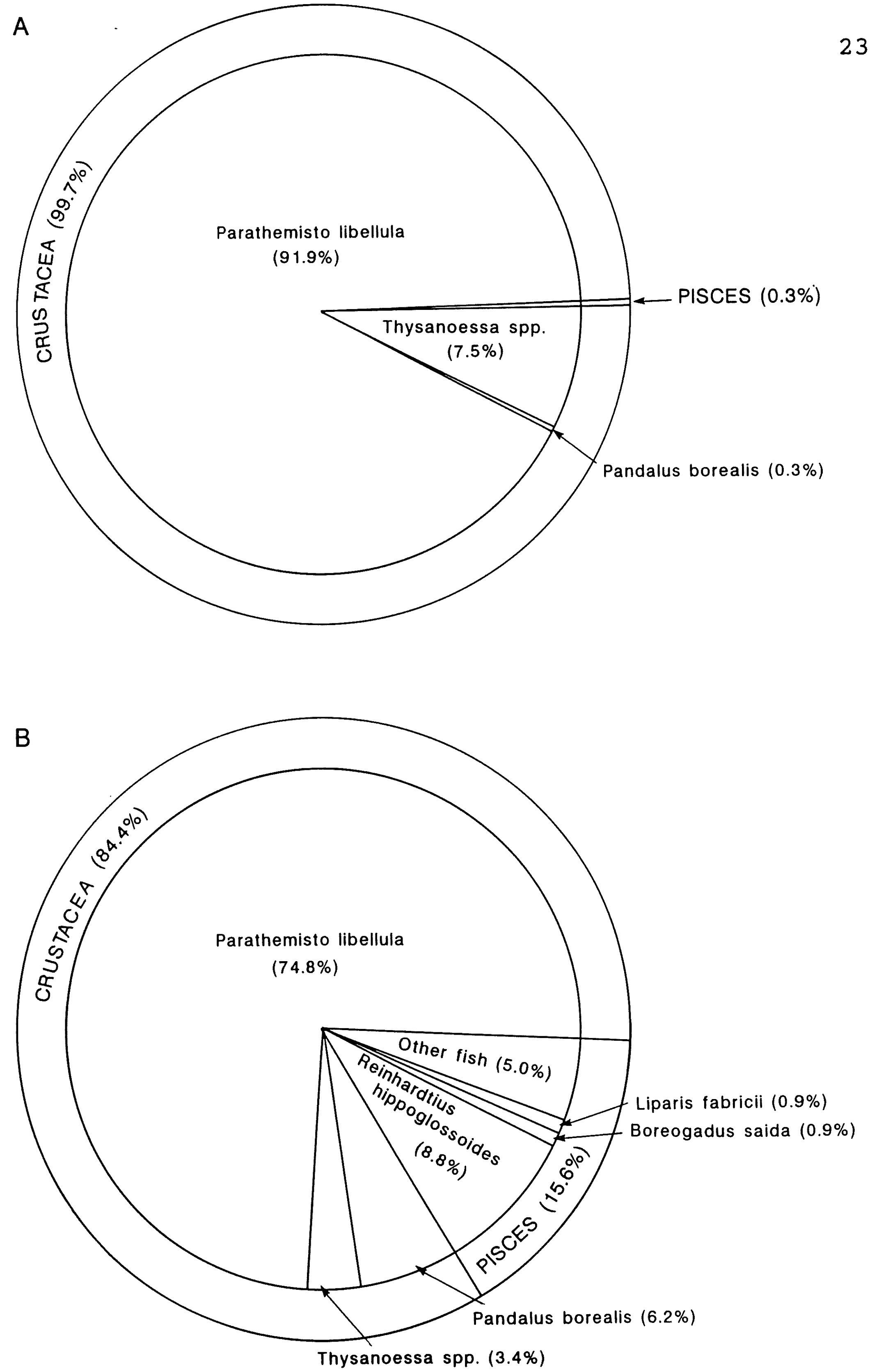

Fig. 4. Food composition of harp seals based on: A) Relative frequency of occurrence of each prey item given as numerical fractions of all prey specimens. B) Relative frequency of occurrence of each prey item in terms of calculated biomass.