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Food and Feeding conditions of herring *Clupea harengus* in the Norwegian Sea

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Abstract

The feeding ecology of herring was studied using samples collected during cruises in 1994 and 1995. Investigations were carried out in the Møre shelf region off western Norway where the major spawning of herring occurs, and in the off shelf area of the eastern Norwegian Sea, where herring migrate after spawning.

Our study shows low feeding activity of herring during their main spawning season with the peak feeding period occurring in June and July. After spawning in February - March herring fed upon euphausiids, mainly *Thysanoessa inermis* and *Meganyctiphanes norvegica* on the shelf and at the shelf edge. In late spring and summer herring which had migrated to the Norwegian Sea fed mainly on *Calanus finmarchicus*, copepodite stages IV and older. In colder waters e.g., waters influenced by East Icelandic Current, *C. hyperboreus* was important in the diet. In the western part of the Norwegian Sea the zooplankton biomass was dominated by amphipods, *Themisto* spp., which is also a major prey of herring in that region. Herring were found to feed on fish at only a few stations.

The herring showed size selective feeding of copepodite stages of *C. finmarchicus* and *C. hyperboreous*. There seem to be no selection between *C. finmarchicus* and *C. hyperboreous* when the species were of similar size. Larger prey such as krill were preyed upon regardless of their size. The amount of food ingested by herring in April 1995 was comparatively higher in the Arctic water than in the Atlantic water. The zooplankton biomass showed a similar distribution pattern. The herring seem to be less selective in their feeding behavior in situations with low prey concentrations such as in the warmer Atlantic waters.

Introduction

The feeding and spawning migration patterns of the Norwegian spring spawning herring (*Clupea harengus*) has changed during and after the collapse of the stock around 1970 (Røttingen 1992). At present, herring spawn at several locations along the Norwegian coast with the main spawning occurring on the Møre coast, off western Norway and northwards. The spawning stock size in 1995 was estimated to be around 5 million tonnes (Anon. 1996).

The main feeding grounds of herring before the collapse of the stock were located in the Norwegian Sea between Jan Mayen and Iceland, and in the late 1960 s, also in the area between Jan Mayen and the Bear Island (Dragesund 1980; Røttingen 1989). During a period when the stock size was very low, the feeding area of the herring was restricted to the coastal waters of northern Norway (Røttingen 1990, 1992). With the increase in the stock since the mid 1980 s, herring have migrated to their previous feeding grounds covering large areas of the Norwegian Sea. Investigations carried out in 1994 showed that the herring did not cross the Arctic Front into the Arctic waters of the northwestern Norwegian Sea in spite of higher zooplankton biomass and thus better feeding conditions in that region (Melle *et al.* 1994).

Previous studies demonstrated that the copepod *Calanus spp.*, especially *C. finmarchicus* , krill *Thysanoessa inermis, Meganyctiphanes norvegica* and amphipods *Themisto* spp. are the major prey of herring (Østvedt 1965; Harding and Nichols 1987; Last 1989; Dalpadado 1993; Melle *et al.* 1994). Pelagic fish such as herring are also important predators of fish eggs and larvae (Harding and Nichols 1987; Holst 1992). Holst (1992) reported cannibalism to occur in coastal waters of northern Norway where the distribution of 0-group and adult herring overlapped during the period when the stock was very low.

The dominant copepods *C. finmarchicus* and *C. hyperboreus* have wide distributions in the Norwegian, Icelandic and Greenland Seas, but the latter species tend to be most abundant in the colder water masses of the Greenland Sea (Wiborg 1955; Pavshtiks and Timokhina 1972; Melle *et al*, 1993; Hirche *et al.* 1994; Astthorson and Gislason 1995). The dominant krill species *T. inermis, T. longicaudata* and *M. norvegica* also are widely distributed with high abundances of *M. norvegica* restricted to the warmer Atlantic waters (Einarsson 1945; Ellertsen *et al.* 1995). Hyperid amphipods *Themisto* spp. are abundant and are available as prey for herring especially in the northwestern part of the Norwegian Sea (Dunbar 1957; Ellertsen *et al.* 1995).

The primary aims of the surveys carried out in the Norwegian Sea in 1994 and 1995 are to; 1) determine the major prey of herring in different regions/water masses e.g., Atlantic, Arctic, Arctic Front, Coastal, 2) examine the spatial distribution of herring in relation to its prey organisms, and 3) describe the stomach contents of herring in relation to prey availability (selective feeding).

Materials and Method

Herring stomachs were collected during 5 surveys undertaken in the Norwegian Sea in 1994 and 1995 (Figs. 1-3). Samples were obtained from one cruise with R/V "G. O. Sars"(30 May - 27 June) in 1994, 3 cruises aboard the R/V "G. O. Sars" in 1995 (1-21 March, 18-27 April, 26 May - 22 June) and one cruise aboard the R/V "Johan Hjort" in 1995 (7 July-1 August).

The herring were located acoustically using a 38 KHz echosounder connected to the Bergen Echo Integrator (BEI). A pelagic trawl (Åkra) with a 30 x 30 m mouth opening and a cod end with mesh size of approximately 16 mm (stretched) was used for sampling the herring. The trawl was fitted with a Scanmar depth sensor. The towing speed was 3 - 4 knots.

A random sample consisting of ca. 100 fish from the trawl catch were taken when possible. The length, weight, age and maturity of the herring were recorded according to the instructions given in Fotland *et al.*, (1995). Twenty herring stomachs were preserved in formalin while 30 stomachs were frozen immediately. Only frozen stomachs were analyzed except for the cruise in April 1994. Two fish in each one cm length group were used for stomach content analyses.

Herring stomachs were analyzed at the Institute of Marine Research (IMR), Norway. Stomach fullness and the state of digestion of the stomach contents were classified using the scales given by Fotland *et al.*, (1995) for all specimens. The stomach content was carefully teased apart. All identifiable prey, were identified to the lowest taxonomic group and enumerated. The length of prey organisms was measured to the nearest 0.1 mm using an ocular micrometer. For copepods the cephalothorax length or the developmental stages (copepodite I-VI) were determined. For all other organisms, the carapax or total length was recorded. Dry weights of all major prey categories were taken separately and the rest of the stomach contents were weighed together. Dry weight of the stomach content was obtained by keeping the samples in a drying oven at 80 °C for 24 hours or until a constant weight was obtained.

Plankton samples were obtained by using the MOCNESS (Multiple Opening Closing Net and Environmental Sensing System) plankton net (Wiebe *et al.*, 1985). The MOCNESS was equipped with 8 nets of 180 µm mesh size. At most stations the nets were towed in oblique hauls from 700-500, 500-400, 400-300, 300-200, 200-100, 100-50, 50-25, and 25-0 meter depths close to the herring trawling location. At some stations, only the upper 200 meters were sampled with the MOCNESS. In addition to the combined trawl and MOCNESS sampling stations, the MOCNESS was regularly used separately.

The zooplankton samples were usually separated into two halves. One half was preserved in formaldehyde and the second half was size fractionated into three categories; 180 to 1000 µm, 1000 to 2000 µm and above 2000 µm. These categories were dried at 70° C for 24 hours before weighing. Large organisms e.g.,

euphausiids were treated separately. Lengths were measured on these specimens before taking the dry weight.

Analyses concerning prey size selectivity in the herring have been performed, based upon MOCNESS data and herring stomach contents from "G.O.Sars"-cruises in March and April 1995. During the March and April cruises the zooplankton data were used from the upper four MOCNESS nets (i.e. 200-0 meter depth). In addition, data from 400 to 200 m was also used for the April cruise. During the July and August 1995 cruise MOCNESS data from 200 to 0 m as well as 700-0 meter were used.

Results and Discussion

March 1995

Stomach samples collected in March 1995 from the Møre coast and shelf and shelf edge northwards had 33% empty stomachs. Studies by Dalpadado (1993) and Melle *et al.* (1994) showed quite low feeding activity of herring during their main spawning season in February and March. In March 1995, however, majority of the herring (64%) had already spawned and these seem to have started to feed.

Herring fed almost exclusively on krill in March, comprising more than 95% of the total prey weight (Fig. 4). The dominant krill species were *Thysanoessa inermis* and *Meganyctiphanes norvegica*. Previous investigations in February/March 1991 and March 1993 also showed krill to be the most dominant prey of herring along the Møre coast (Dalpadado, 1993, Melle *et al.*, 1994).

Figure 5a shows the length distribution of *Meganyctiphanes norvegica* consumed by herring during March 1995. The total krill lengths varied from 9 - 43 mm with the length frequency distribution showing two peaks; one at 20 - 23 mm, the second at 34 - 37 mm. The length frequency distribution of *M. norvegica* from MOCNESS samples was similar showing with a peak at 21 - 24 mm and another at 32 - 34 mm.

The length frequency distributions of *Thysanoessa inermis* from the stomach content (Fig. 6a) and MOCNESS (Fig. 6b) also revealed similar patterns, i.e. the two distributions are almost identical. Both distributions gave one peak at 20 - 24 mm length.

Since euphausiids are fast swimmers and may to some extent avoid the MOCNESS sampler, the MOCNESS data used in Figs. 5b and 6b are based on night samples only. In March there is a pronounced change in light between day and night, and the avoidance at night time is supposed to be minor. However, in the stomach content 12 % of the *M. norvegica* were equal to or larger than 37 mm, versus 2 % in the MOCNESS samples. This may be due to an avoidance of the plankton sampler by the largest specimens, even at night. The data from this study indicate that herring fed on krill regardless of their size.

April 1995

The cruise with R/V "G.O. Sars" in April 1995 was designed to cover the migration of the herring from the spawning grounds to their early feeding grounds in the eastern and central parts of the Norwegian Sea (Fig. 7). At this time the herring was found along the Arctic front between Atlantic water and the water masses of the East Icelandic current. At 100 m depth the front was observed as a reduction in temperature from more than 5°C in Atlantic water to less than 3.2 °C in Arctic water (Fig. 8a). At 300 m the Arctic front was less distinct, however, the cold and fresher Arctic water could still be distinguished from the Atlantic water in the south and northeastern regions (Fig. 8a and 8c). Based on hydrography, the trawl stations were classified as Arctic or Atlantic stations.

In the Arctic waters as well as in the Atlantic waters copepods dominated the diet comprising 51% and 59% by weight, respectively (Fig. 9). However, dietary differences were observed in these waters. *C. hyperboreous* was the most abundant of the copepods in the Arctic waters whereas in the Atlantic waters only C. *finmarchicus* was present. In addition to copepods, the fish *Maurolicus muelleri* was abundant prey of herring in the Arctic waters, and in the largest size classes (>35 cm) krill *M. norvegica* and arrow worms *Sagitta* spp. were also important constituents. *M. norvegica* is widely distributed in the Norwegian Sea though mostly restricted to the warmer Atlantic waters (Dunbar, 1964; Ellertsen *et al.* 1995)

Figure 10 shows the distributions of developmental stages of *C. finmarchicus* in MOCNESS samples 200-0 m and herring stomach content from trawl stations 258 and 259 located in Atlantic water masses. In the MOCNESS samples we observed the ontogenetical stages CIII to adults with adult females dominating (44%) and CIV being the second most important (31%). However, in the stomach content stages CIII was absent, stages CIV and CV constituted a minor part (2 and 5 %, respectively), while adults dominated.

Similar comparisons were made with the material from MOCNESS stations 267, 268, 269 and 279 and trawl stations 252, 253, 254, 261 located in water masses influenced by cold Arctic water (Fig. 11). In the herring stomachs the youngest copepodite stages (CI-CIII) of *C. finmarchicus* were absent while CIV, which was dominating in the MOCNESS samples, constituted only 4 % of the stomach content. However, the adult *C. finmarchicus* was estimated to 26% of the *in situ* *C. finmarchicus* stock while in the herring stomachs the amount was very high (78%). The herring seemed to omit feeding on the small copepodites when larger ones are accessible.

In the Arctic water masses a substantial number of *C. hyperboreus*, both *in situ* and in the herring stomachs was observed (Fig. 12). Copepodite stages CI and CIII were observed in small quantities *in situ*, while these were totally absent from the identified stomach contents. Figure 12 shows that the CIV stage constitute 70% of the total *C. hyperboreus* in the MOCNESS samples from 200-0 meter. In the herring stomachs only 5.4% belonged to CIV stage while CV and adults

dominated. As mentioned above, at the same time the adult *C. finmarchicus* was proportionally richer in the stomach content than *in situ*. These results indicate that small copepodite stages, CI-CIII of *C. hyperboreus* is not eaten by the herring.

C. hyperboreus larger than CIV, i.e. CV and adults, is poorly represented in the MOCNESS samples. At the four stations in question the average number of these stages was ca. 390 ind. per m^2, or 28 % of the total stock. However, in the stomach content these stages constituted 94.6% of the total *C. hyperboreus* preyed, which indicate that a selection takes place towards larger copepods. Arrhenius (1995) stated that adult herring selected adult stages of copepods, while young fish preferred intermediate sized copepods.

C. hyperboreus CIV and adults of *C. finmarchicus* are of similar size (ca. 3 mm cephalothorax length). The following numbers of *C. hyperboreus* and *C. finmarchicus* were observed *in situ* and in the stomach contents:

	in situ (MOCNESS) average per station	in herring stomach
C. finmarchicus adults	24998 ind per m^2	502
C. hyperboreus CIV	989 "	24
C.f./C.h. relationship	25:1	21:1

A similar relationship between adult *C. finmarchicus* and stage CIV of *C. hyperboreus in situ* and in the stomach content suggests that no selection between species takes place when the herring is offered copepods of similar size.

Preliminary analyses indicate herring to select the larger copepods despite the presence of smaller copepodite stages in large numbers *in situ*. This type of feeding behavior may be energetically beneficial for the herring, which may spend the same energy feeding upon a small or large copepod, provided the concentration of the larger specimens is above a certain threshold. Arrhenius (1995) stated that herring switched between particulate-feeding at low prey densities to filter-feeding at higher prey densities. Our data indicate that the herring in question perform particulate-feeding, since the smallest copepodites were not observed in the herring stomach contents even in areas where they occurred *in situ*.

The lack of young copepodite stages in the stomach contents could indicate a fast digestion due to their small size, thereby being underestimated. However, since they were not observed at all, even in stomachs showing minor digestion, they are probably not eaten by the herring.

C. hyperboreus is regularly observed in the cold water masses in the western part of the Norwegian Sea, though their concentrations are almost always far exceeded

by *C. finmarchicus*. The fact that a proportionally higher number of *C. hyperboreus* is found in the stomach content, may be due to the selection towards larger organisms.

Biomass of zooplankton (MOCNESS) versus stomach contents

The prey items most commonly found in the herring stomachs are contained in the zooplankton size fractions 1000-2000 µm and above 2000 µm. The depth at which the herring feeds in the spring is not known. However, observations of vertical distribution of the herring during the cruise in April 1995, indicate that feeding may have taken place near the surface at night and between 200 and 400 m depth at daytime (Misund *et al.* 1996). Biomass distributions are therefore shown as g m^{-2} integrated over the upper 200 m and between 200 and 400 m. Highest biomasses of both size fractions in both depth strata were found in the cold water (Fig. 13).

The dominance of larger species such as *C. hyperboreus* and chaetognaths in the herring stomachs taken in the Arctic water masses as opposed to smaller calanoid copepods as *C. finmarchicus* in the stomachs from Atlantic water masses, may be understood if the apparent size selectivity in the herring feeding behavior is taken into consideration. Biomasses of both size fractions were high in cold water and low in warm water. Thus, in cold water the herring can feed on an abundant supply of both large and small prey items. In this situation one would expect the herring to feed on the larger prey items. This is confirmed by the stomach samples from the cold region where C. *hyperboreus* and chaetognaths dominated. In warm water where both small and large prey items were less abundant, feeding seemed to be less selective. These stomachs mainly contained smaller calanoid copepods (*C. finmarchicus*). A possible reason for this may have been that food supply in the warm water was insufficient, and the herring was forced to eat smaller prey than otherwise preferred. This view is supported by the smaller amount of stomach contents found in the warm compared to the colder region (Fig. 9).

May and June 1994

A total of 125 herring stomachs from 9 stations were analyzed from a cruise with "G. O. Sars" in June 1994 (Fig. 2). Most of the herring caught in June were of 1983, 1992 and 1993 year classes and ranged between 23 and 39 cm.

The percentage of empty stomachs in all stations except station 264 was quite low (7%), indicating high feeding activity during this period by herring which were in immature and maturing stages. In station 264, 50% of the stomachs examined were empty. It could be that these herring caught at ca. 17.45 hrs had not started to feed. Seventy percent of the herring caught at night (St. 268) had full stomachs with little or partly digested food.

Copepods (*Calanus* spp.) were the major prey of herring in May and June varying from 50-90% of the total prey weight (Fig. 14). In stations taken in Atlantic and mixed waters, more than 90% of the dry weight of the stomach contents were

copepods. At most stations *Calanus* spp. consisted of overwintering stages (IV-VI). In addition, in coastal waters krill comprised 33 % of herring stomachs by weight. *M. norvegica* (20-45 mm) were the dominant krill species present in herring stomachs in the coastal waters. In station 250 *C. hyperboreus* dominated the diet (32%). These were mostly in copepodite stages IV to VI (Cephalothorax length 5-6.5 mm). *C. hyperboreus* is most abundant in the cold waters (Hirche *et al.*, 1994; Astthorsson *et al.*, 1995). Station 250 is influence by the cold east Icelandic current, which might explain the dominance of *C. hyperboreus* . Only at one station (St. 264), we found herring to feed on fish.

May and June 1995

Analysis of stomach contents in May - June 1995 in the coastal waters off Lofoten/Vesterålen showed that 80% of the prey weight in herring stomachs consisted of larvaceans (Fig. 15). In the same region Dalpadado (1993) also found larvaceans to dominate the diet of herring. In the Atlantic waters herring have fed almost exclusively on *C. finmarchicus* which is the most abundant zooplankton by weight in the warmer Atlantic waters of the Norwegian Sea (Wiborg, 1955; Pavshtiks and Timokhina 1972; Melle *et al.*, 1993). As in May-June cruise in 1994, *C. finmarchicus* consisted mainly of overwintering stages (IV-VI).

July and August 1995

Figure 3 shows the location of the pelagic trawl stations from a cruise with "Johan Hjort" in July and August 1995. A total of 336 herring stomachs from 24 stations were analyzed. All stations were taken in the Atlantic and mixed waters in the central Norwegian Sea and on the Norwegian continental shelf. The percentage of empty stomachs observed in our study in July was quite low (16.6%), indicating that herring is probably in its peak feeding period. The largest herring (above 34 cm) were found in the north west of the study region (Fig. 16). These mostly belonged to the 1983 year class and were in maturity stage 8 (resting stage). Most of the young herring (3-4 years) were in maturity stages 1-4 (immature/maturing).

Copepods (*C. finmarchicus*) were the dominant prey species in herring stomachs in July and August (Fig. 17a, Table 1). In 12 out of the 24 stations examined, copepods comprised more than 50% of herring stomachs by weight. At most stations *C. finmarchicus* consisted of stages IV-VI. In addition to copepods, amphipods were also important in the diet of herring caught in the north western part of the study area (Fig. 17b). *Themisto abyssorum* (3-7 mm) were the dominant amphipod species and constituted over 60% of the prey weight in herring stomachs (stations 336, 344, 348, 355 and 377). Investigations on the large scale distributions of amphipods in the Nordic Seas show them to be highly abundant in the western region (Ellertsen *et al.*, 1995). Krill were not found in 10 out of the 24 stations examined and comprised a lower percentage of the prey

weight compared to copepods and amphipods except for three stations (351, 363 and 372) (Fig. 17c). Herring fed on fish (juvenile *Sebastes* spp.) at only two stations (St.355 and 372).

Biomass of zooplankton (MOCNESS) versus stomach contents

In the upper 200 m the average zooplankton biomass from the MOCNESS samples, all size fractions included, was estimated to be 12.5 g/m^2, with the highest contribution from the 1000-2000 µm fraction (8.3 g/m^2). As seen from figure 18 the highest biomasses were observed in the western part of the area investigated. The horizontal distribution of zooplankton from 700 to 0 m was somewhat similar (Fig. 19). Higher concentrations, above 30 g/m^2, were found in the western part of the study area, while the average abundance was 25.5 g/m^2.

The higher biomasses in the western area is partly due to high numbers of late ontogenetical stages of the dominating copepod, *Calanus finmarchicus* and higher concentrations of amphipods, mainly *Themisto abyssorum*. The large copepod *Calanus hyperboreus* is also rather common in these water masses. In the Norwegian Coastal Current and eastern part of the Norwegian Sea the biomasses were low. The main reason for this could be the dominance of copepod *C. finmarchicus* which consisted mainly of early developmental stages, CI-CIII.

The distribution of herring is rather contrary to that of the zooplankton. The highest concentrations of herring were observed in the eastern part of the area, i.e. along the Norwegian shelf stretching westward to about E 4°00 (Anon. 1966) (Fig. 20) , where the lowest concentrations of zooplankton were found.

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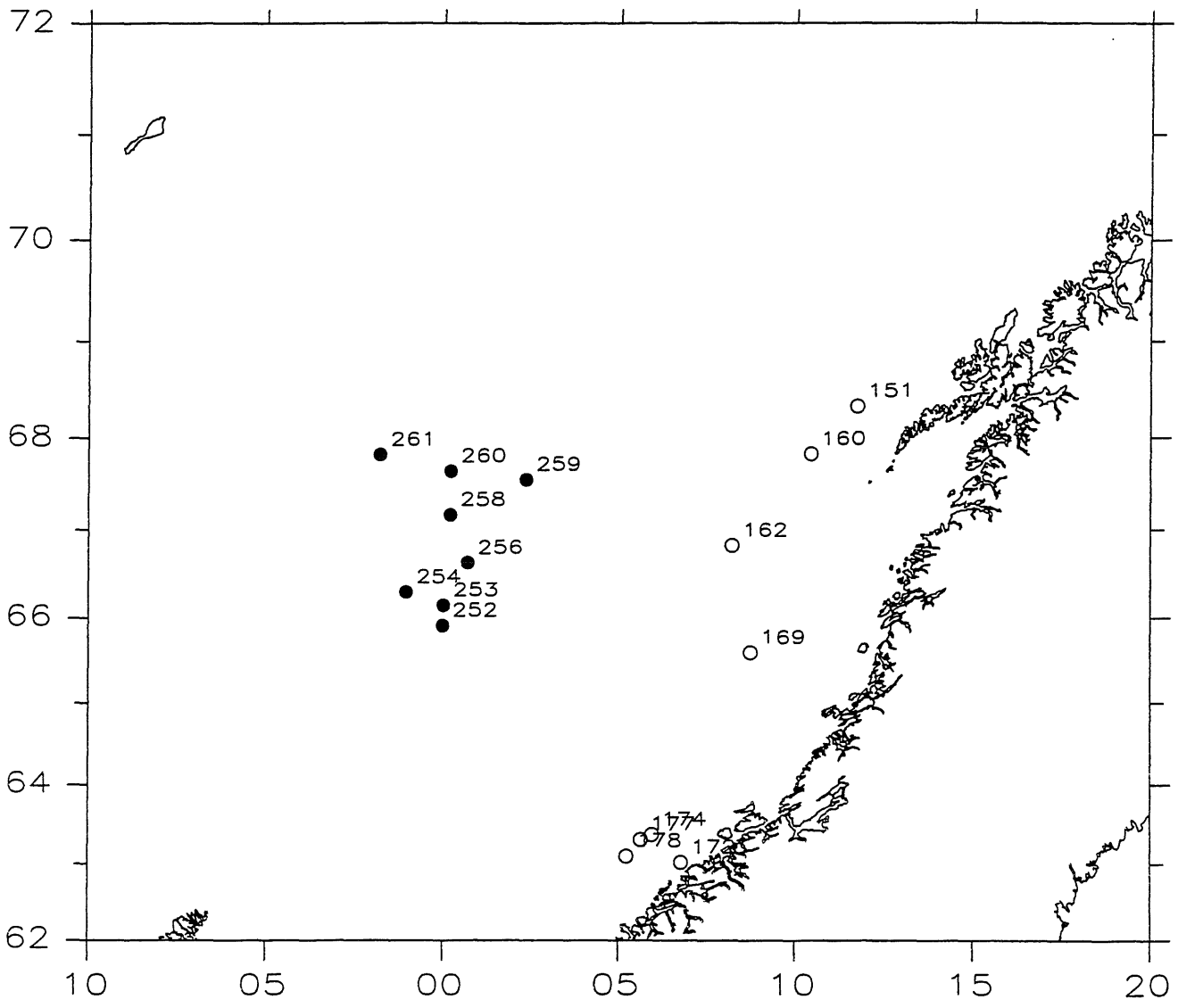
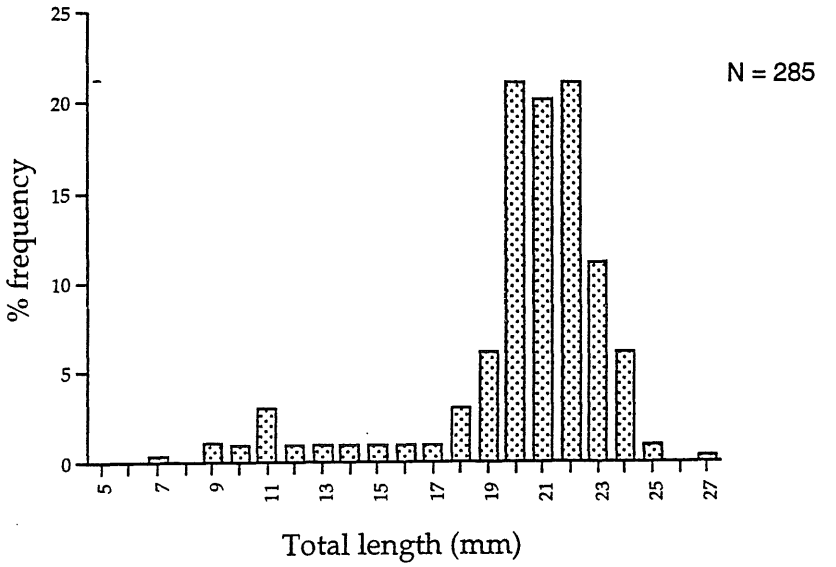


Figure 1. Locations of pelagic trawl stations where herring stomachs were analyzed, from 1- 21 March (open circles), and 18- 27 April (filled circles) 1995.

a) *Thysanoessa inermis*



Herring length groups (cm)	24-30	30 - 35	35 -40
Number of herring in each length group	4	7	9
Mean length of *T. inermis* preyed	12.4	20.9	21.1
Range in length of *T. inermis* preyed	(7-22)	(17-24)	(13-27)

b)

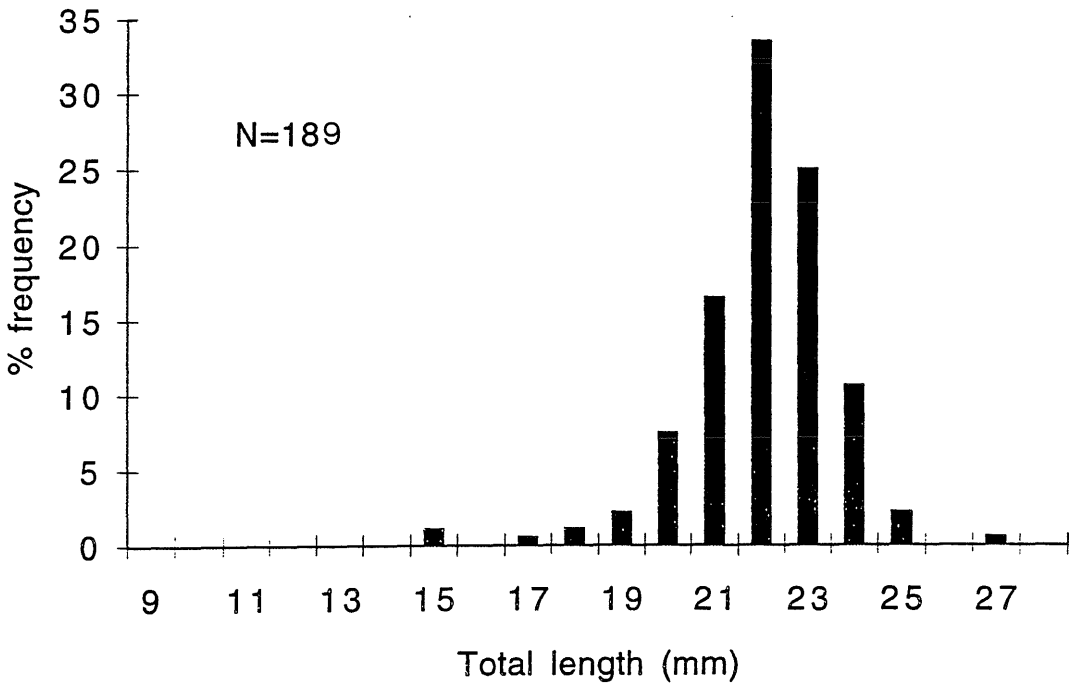


Figure 6. Length distribution of *Thysanoessa inermis* in herring stomachs (a), and in MOCNESS samples (b), in March 1995.

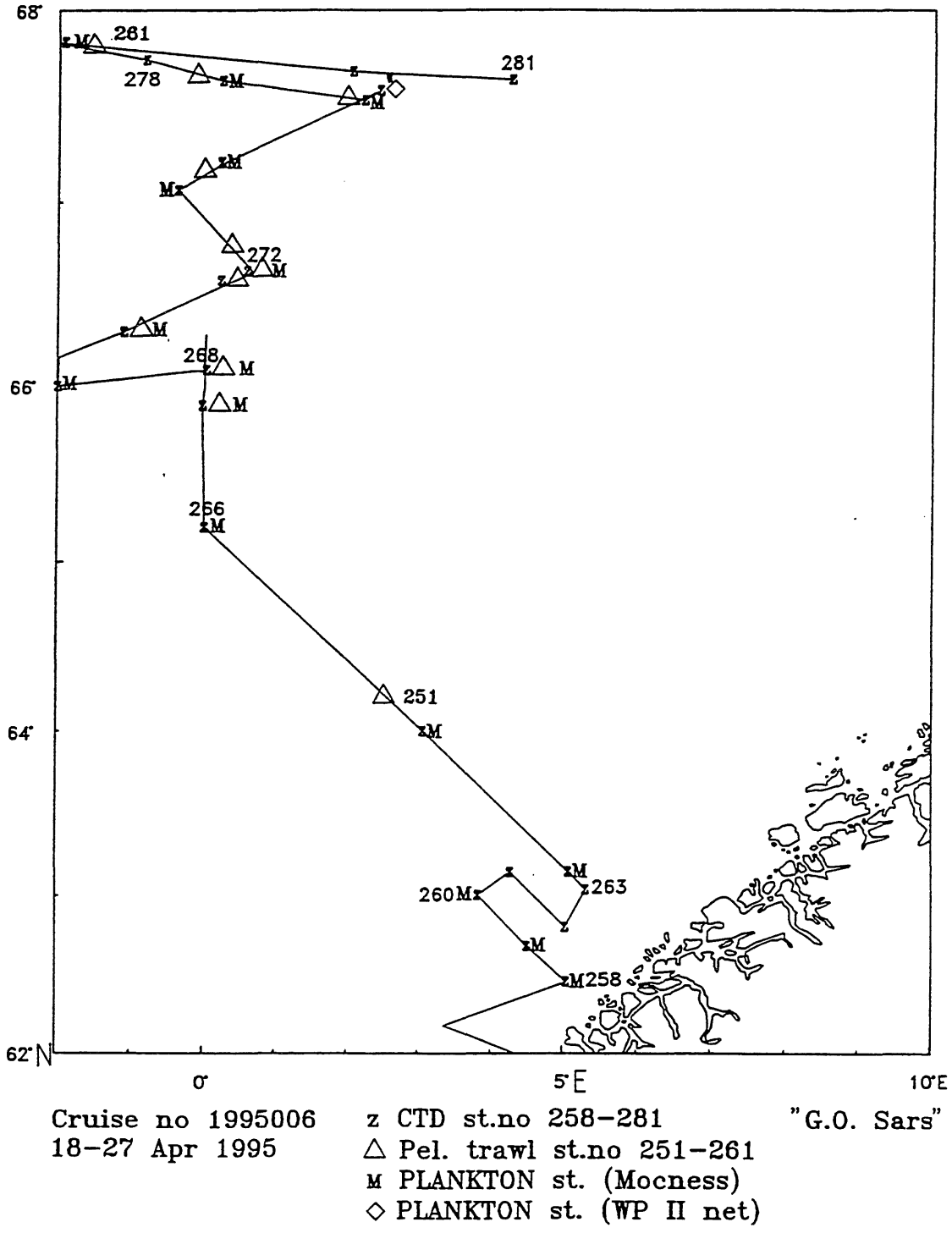


Figure 7. Cruise tracks and sampling stations in April 1995.

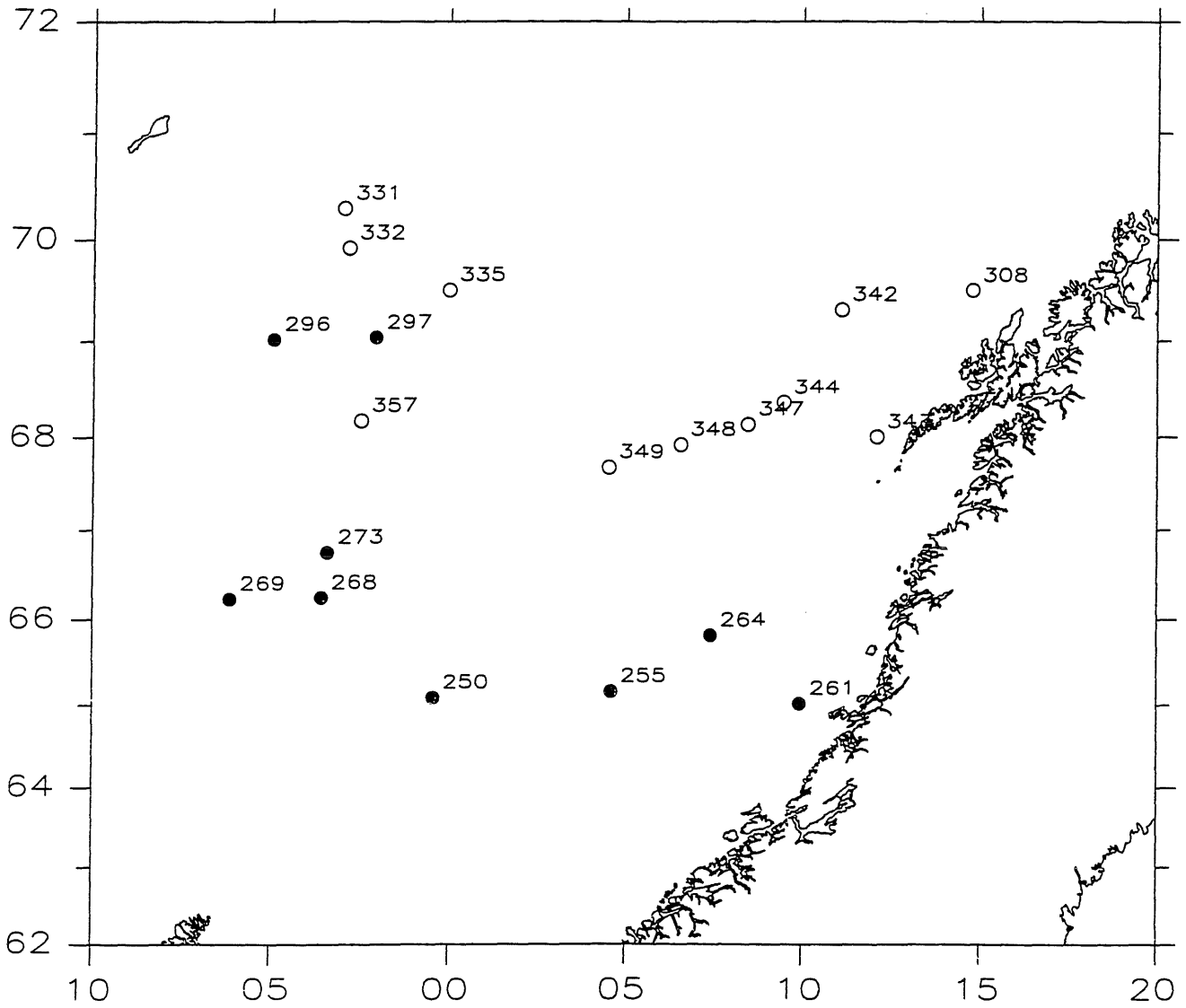


Figure 2. Locations of pelagic trawl stations where herring stomachs were analyzed, from 30 May- 27 June 1994 (open circles), and 26 May - 22 June 1995 (filled circles).

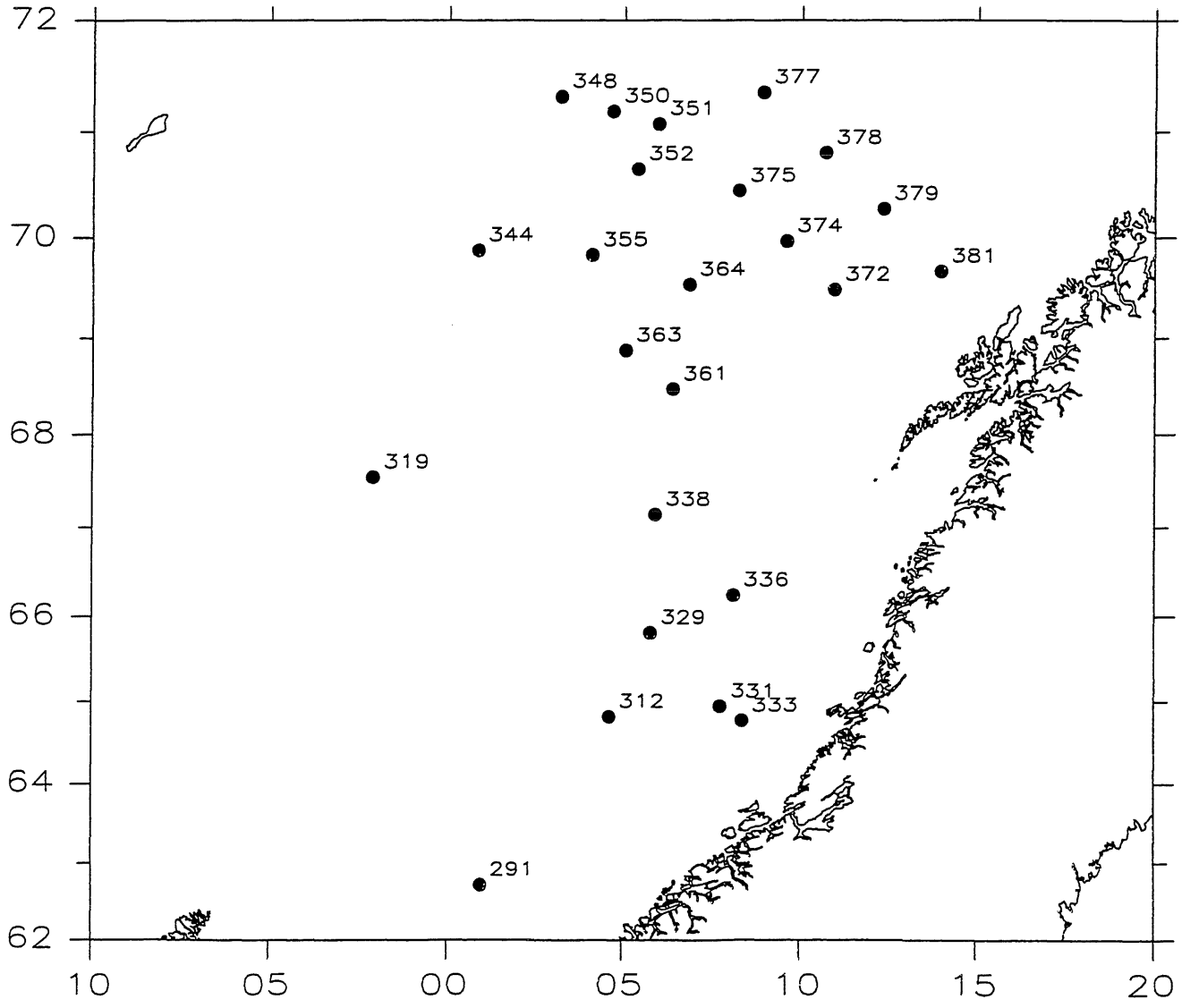
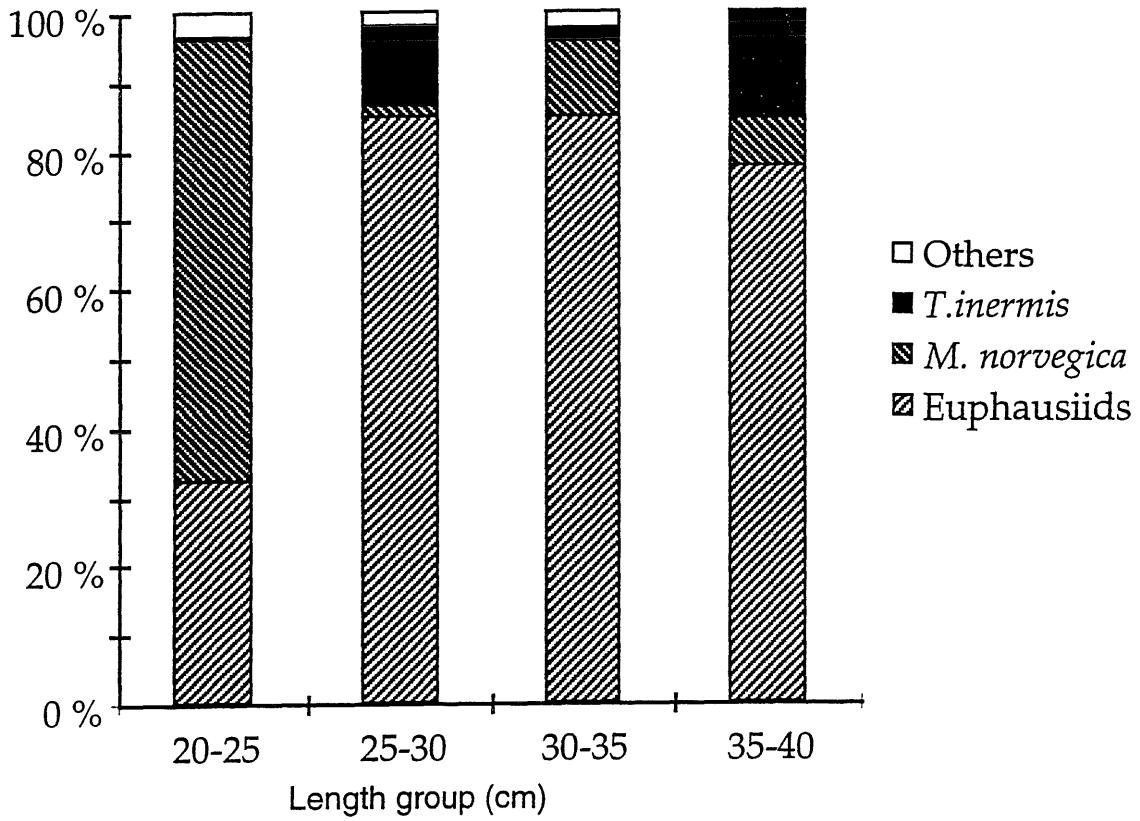


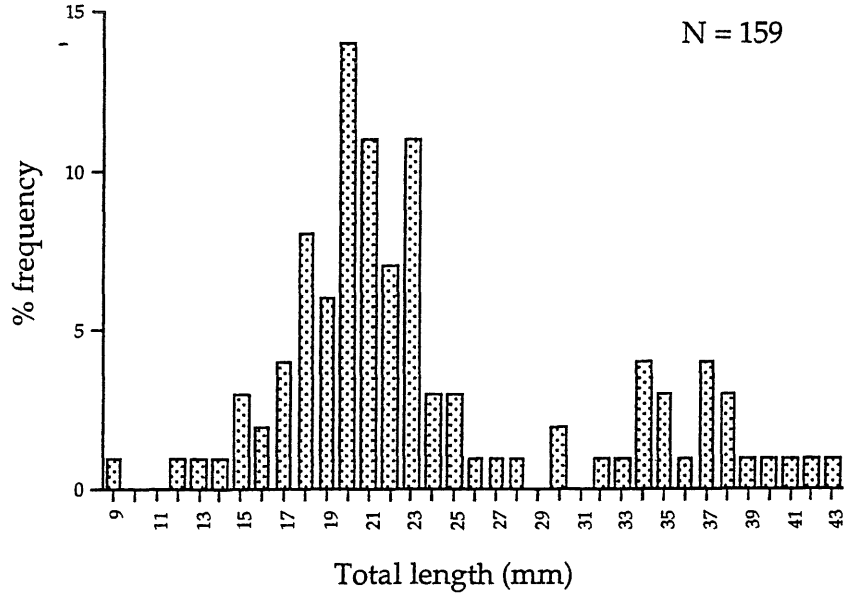
Figure 3. Locations of pelagic trawl stations where herring stomachs were analyzed, from 7 July - 1 August 1995.



8	23	60	21	No. of herring
65.75	129.1	264.3	1295.2	Mean prey weight in mg
71.2	420.2	534.2	1513.6	Standard deviation

Figure 4. Major prey of herring as percentage of the total dry weight in March 1995.

a) *Meganyctiphanes norvegica*



Herring length groups (cm)	24-30	30 - 35	35 -40
Number of herring in each length group	6	7	9
Mean length of *M. norvegica* preyed	29.6	25.2	22.5
Range in length of M. norvegica preyed	(9-41)	(16-40)	(18-43)

b)

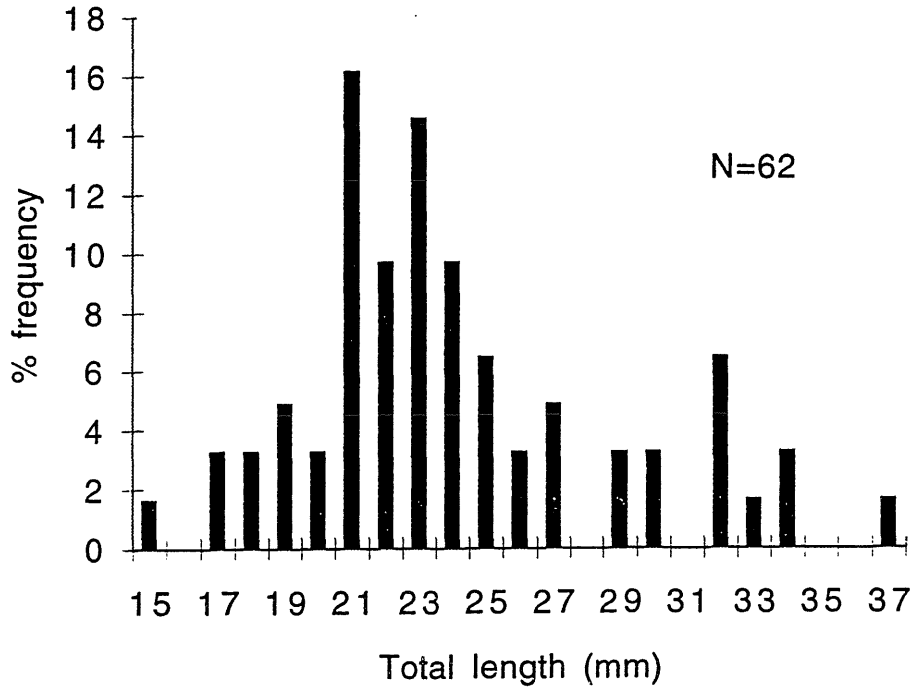


Figure 5. Length distribution of *Meganyctiphanes norvegica* in herring stomachs (a), and in MOCNESS samples (b), in March 1995.

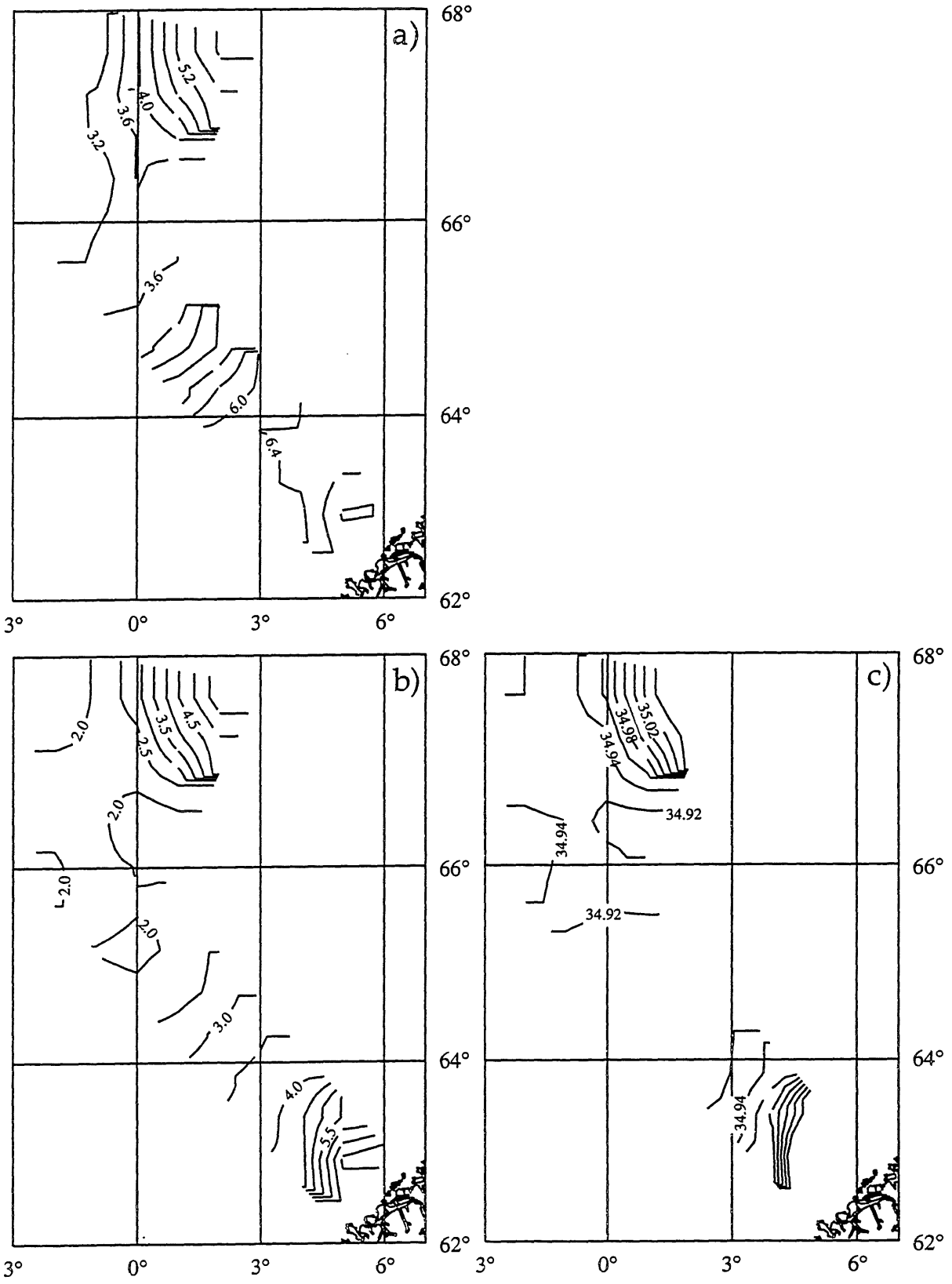
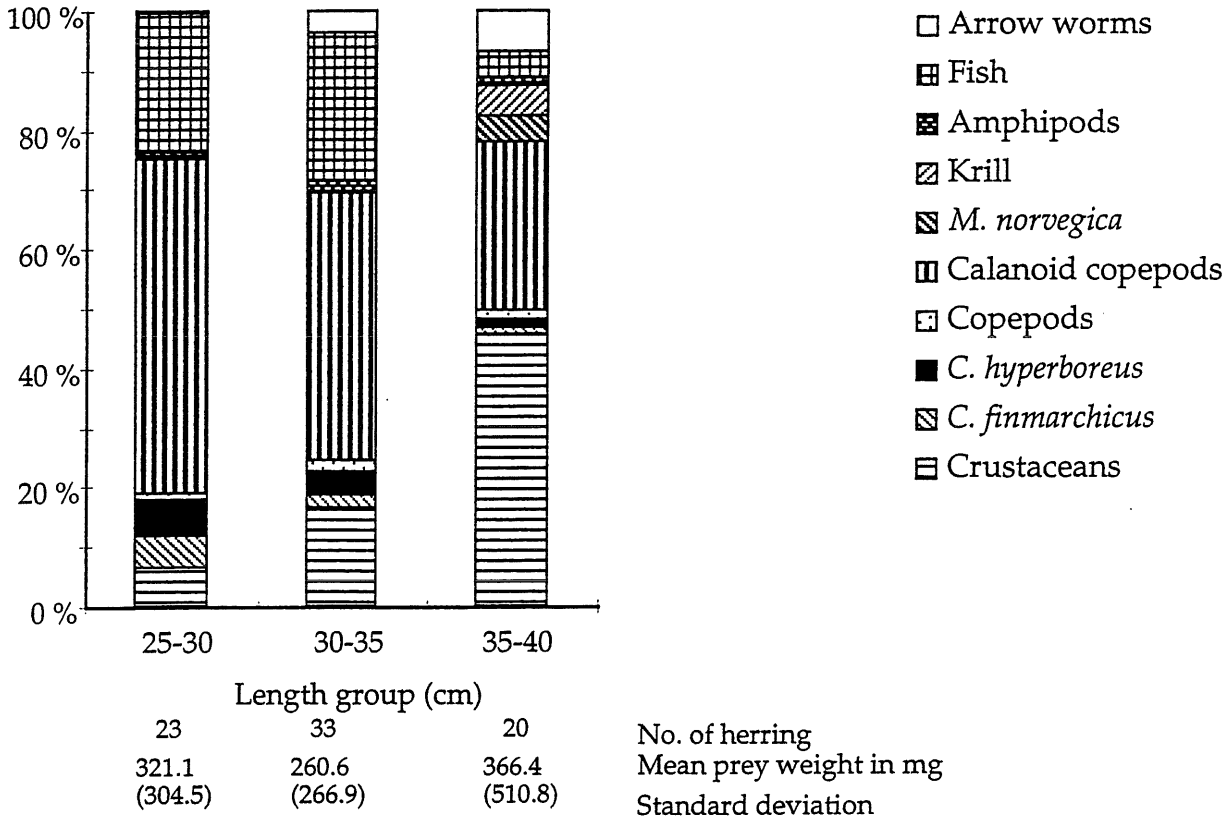


Figure 8. Hydrography in April 1995. Temperature °C at 100 m (a), temperature °C at 300 m (b) and salinity at 300 m (c).

Arctic waters- St. 252, 253, 254, 256 and 261



Atlantic waters - St. 258, 259 and 260

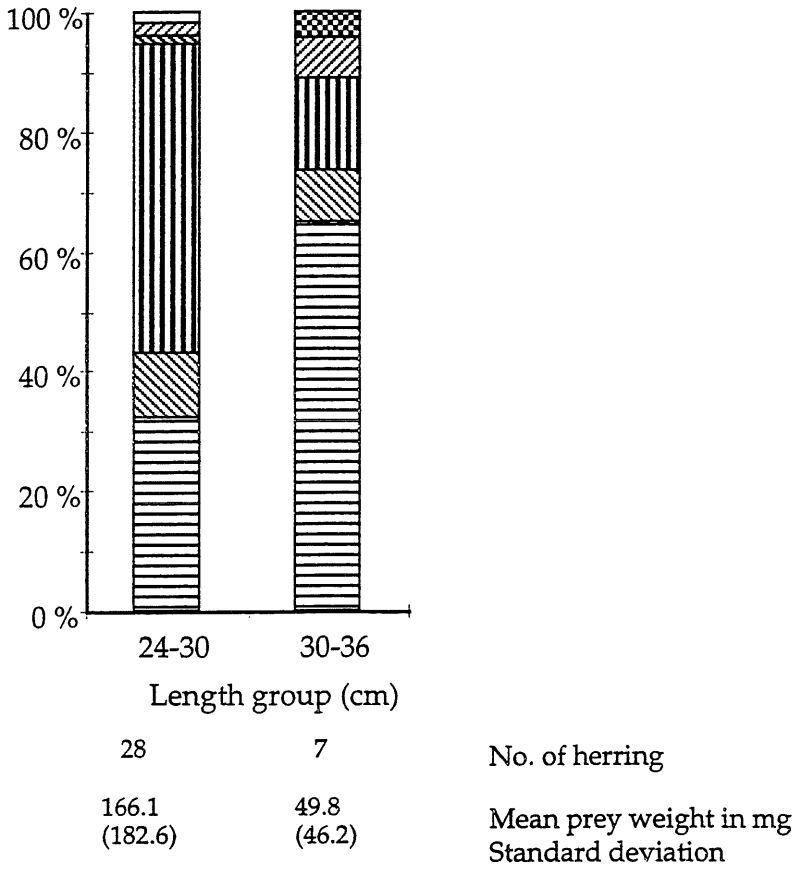


Figure 9. Major prey of herring as percentage of the total dry weight in April 1995.

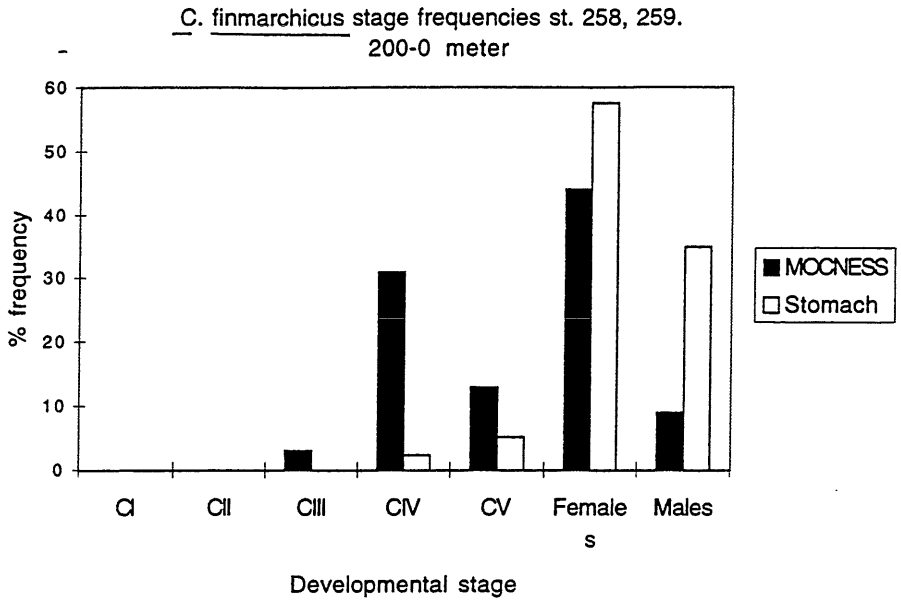


Figure 10. Frequency distribution of developmental stages of *Calanus finmarchicus* in MOCNESS samples and herring stomachs in warm (Atlantic) water in April 1995.

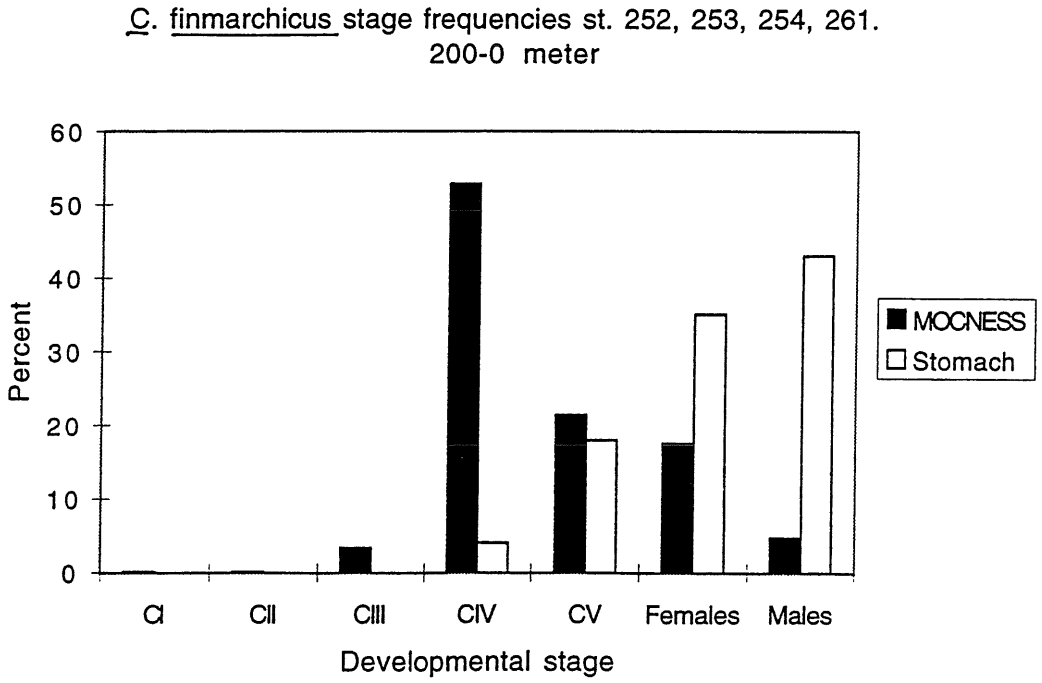


Figure 11. Frequency distribution of developmental stages of *Calanus finmarchicus* in MOCNESS samples and herring stomachs in cold (Arctic) water in April 1995.

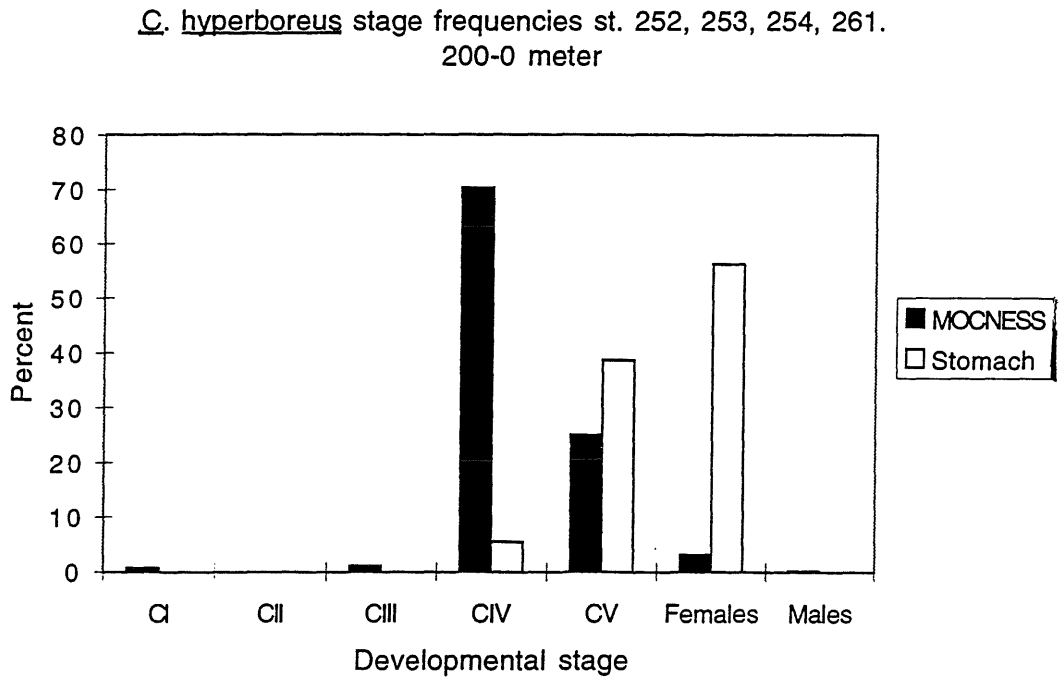


Figure 12. Frequency distribution of developmental stages of *Calanus hyperboreus* in MOCNESS samples and herring stomachs in cold (Arctic) water in April 1995.

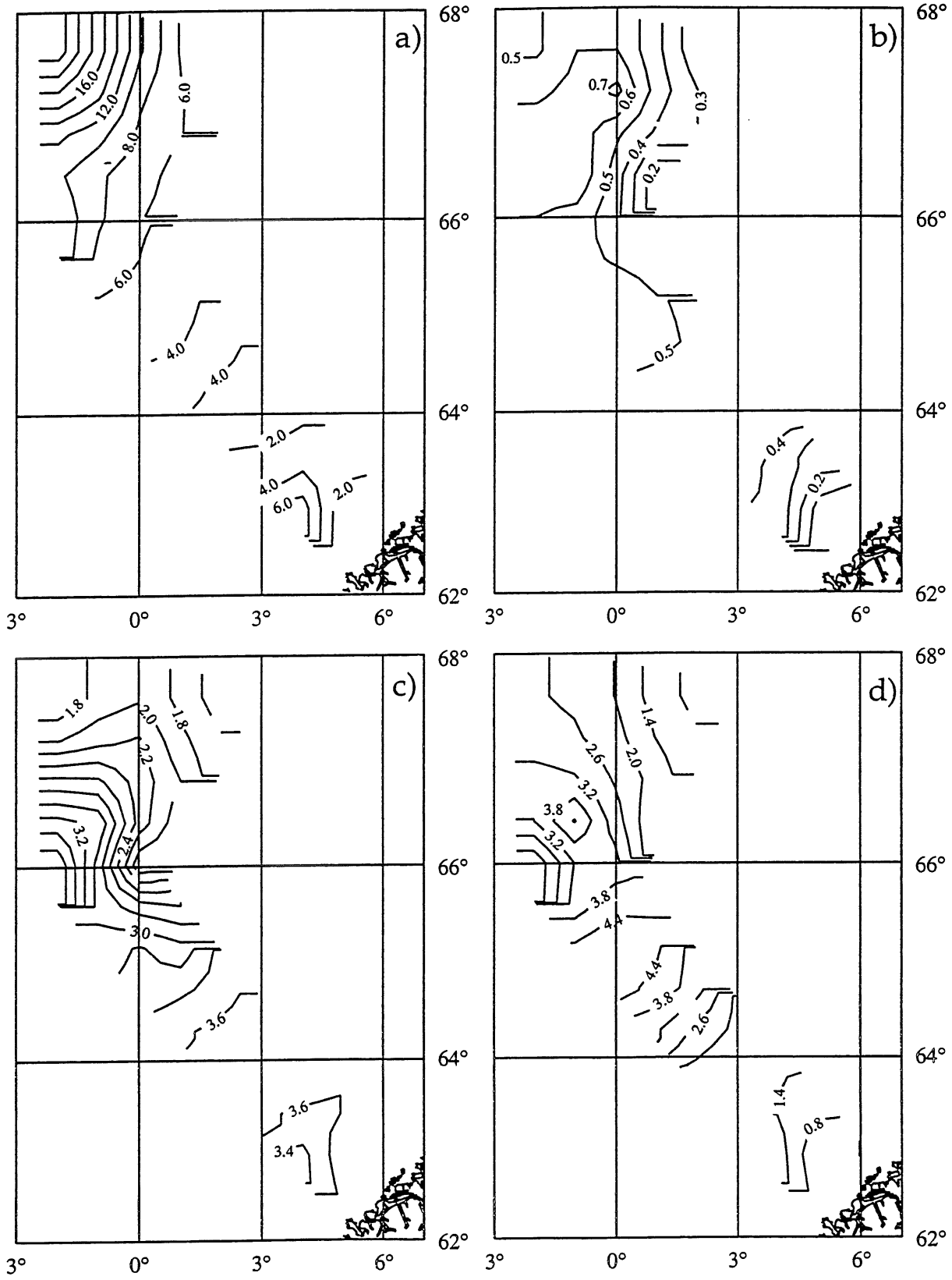


Figure 13. Zooplankton biomass distributions in April 1995. Integrated dry weight (g m^{-2}) between 0 and 200 m of size fraction 1000 to 2000 µm (a) and size fraction >2000 µm (b). Integrated dry weight (g m^{-2}) between 200 and 400 m of size fraction 1000 to 2000 µm (c) and size fraction >2000 µm (d).

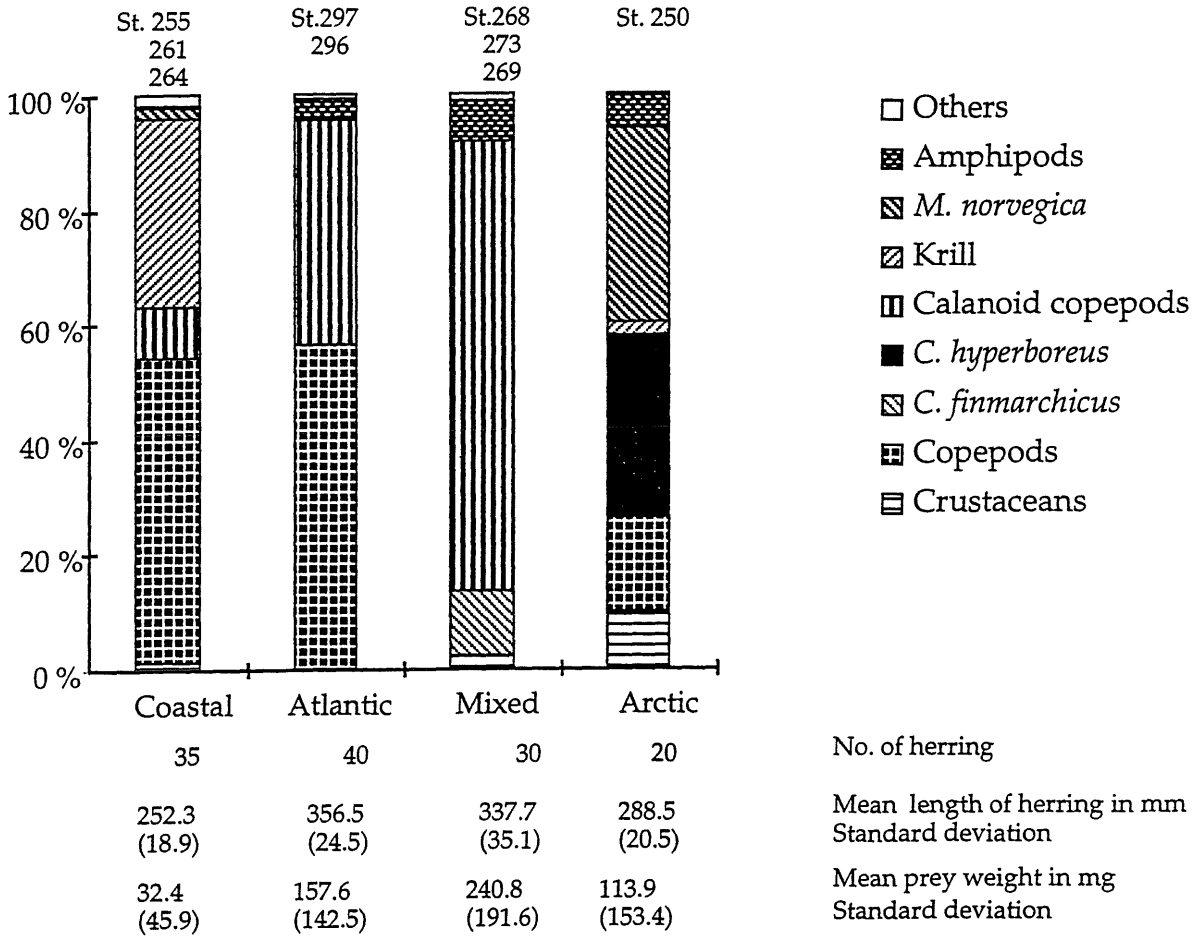


Figure 14. Major prey of herring as percentage of the total dry weight in May and June 1994.

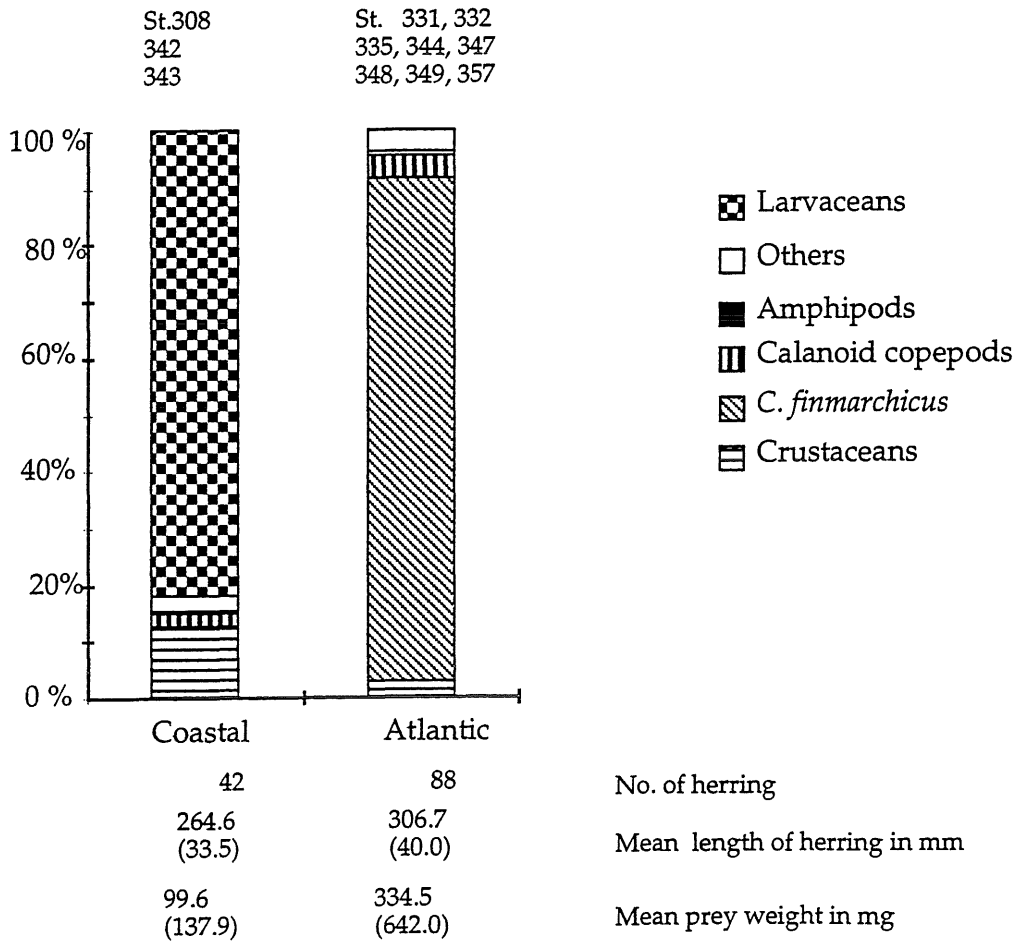


Figure 15. Major prey of herring as percentage of the total dry weight in May and June 1995.

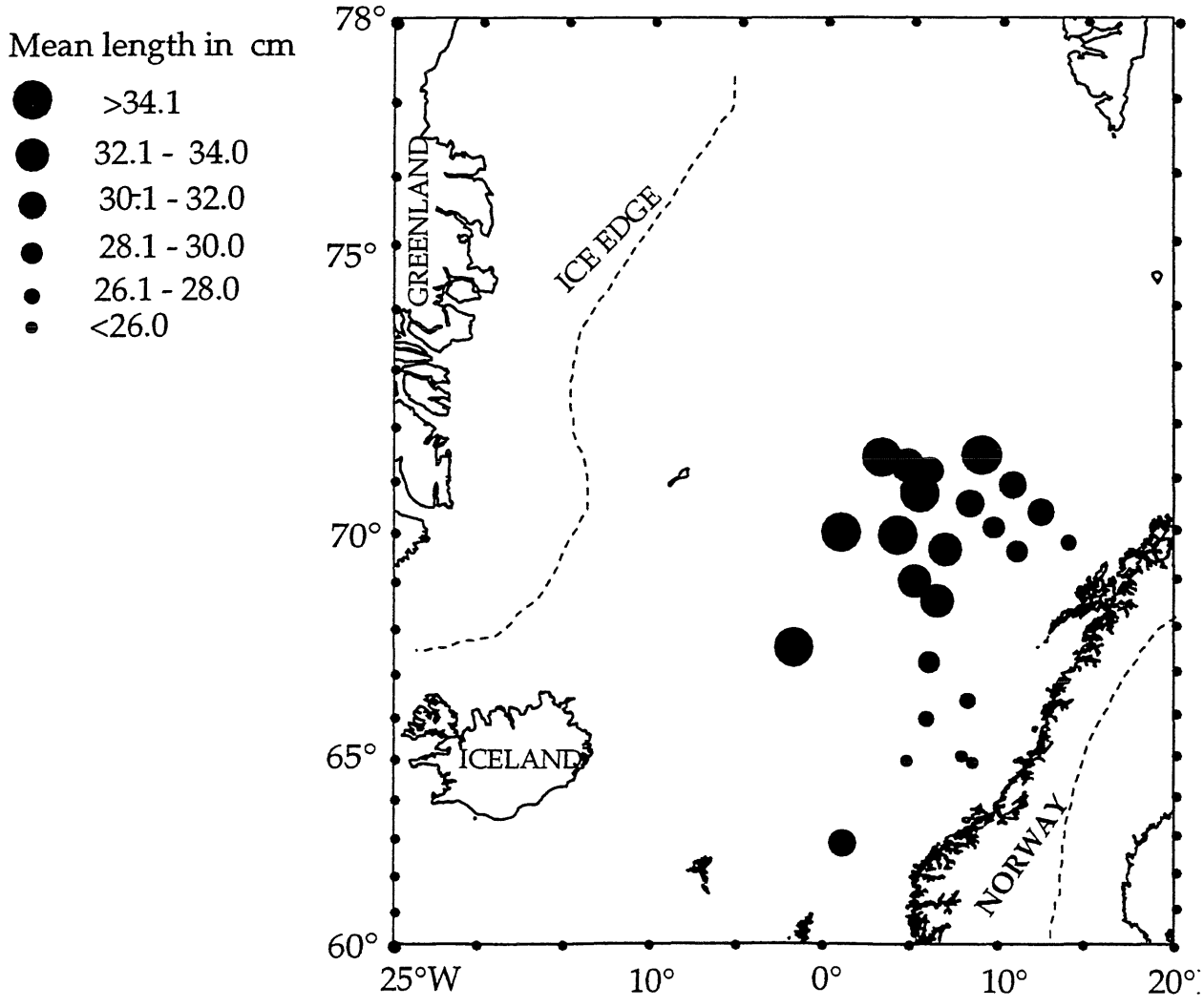


Figure 16. Mean length of herring in July and August 1995.

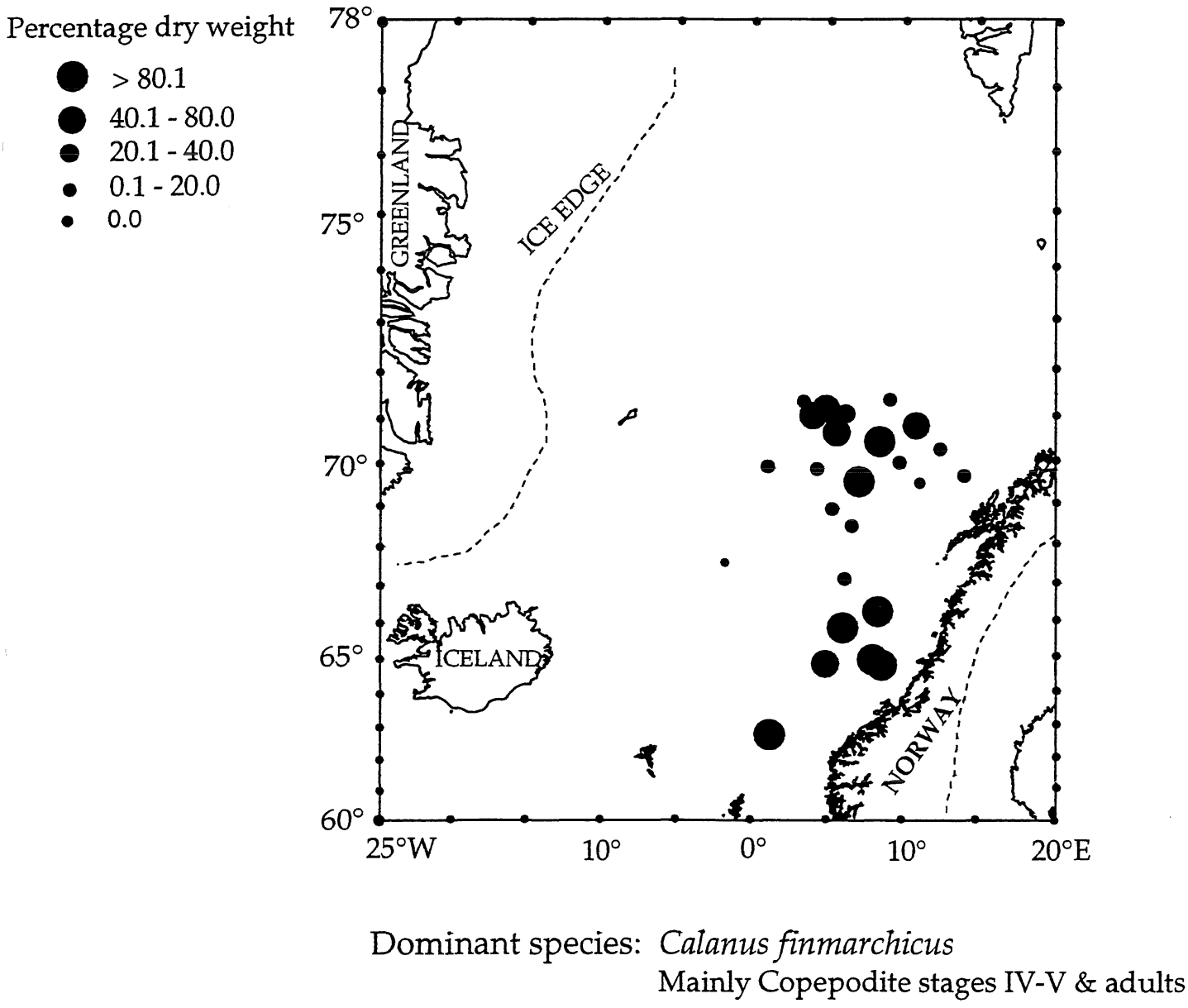
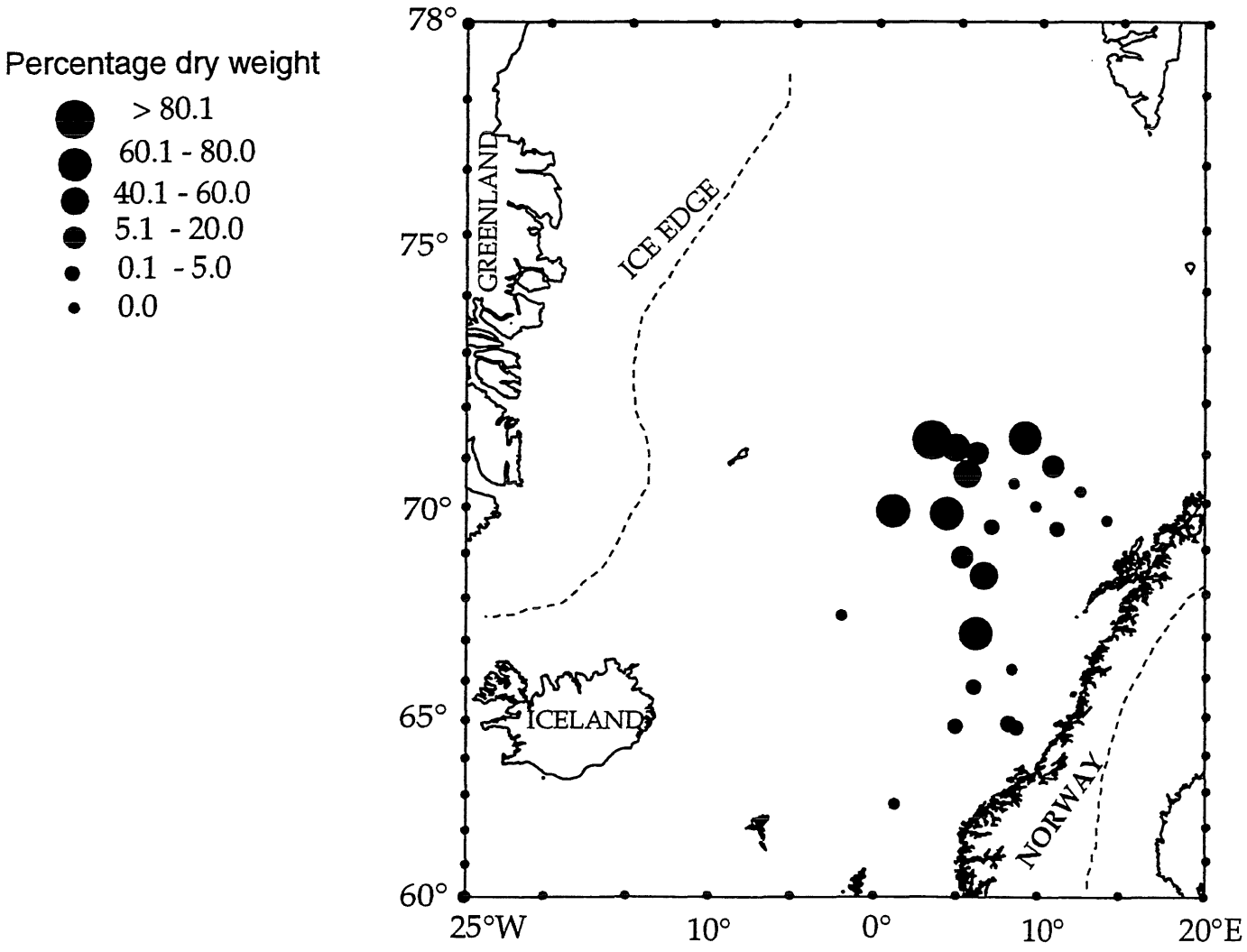


Figure 17a. Stomach content of herring in July and August 1995.
Copepods as percentage of total prey weight.



Dominant species: *Themisto abyssorum* (3-7mm)

Figure 17b. Stomach content of herring in July and August 1995. Amphipods as percentage of total prey weight.

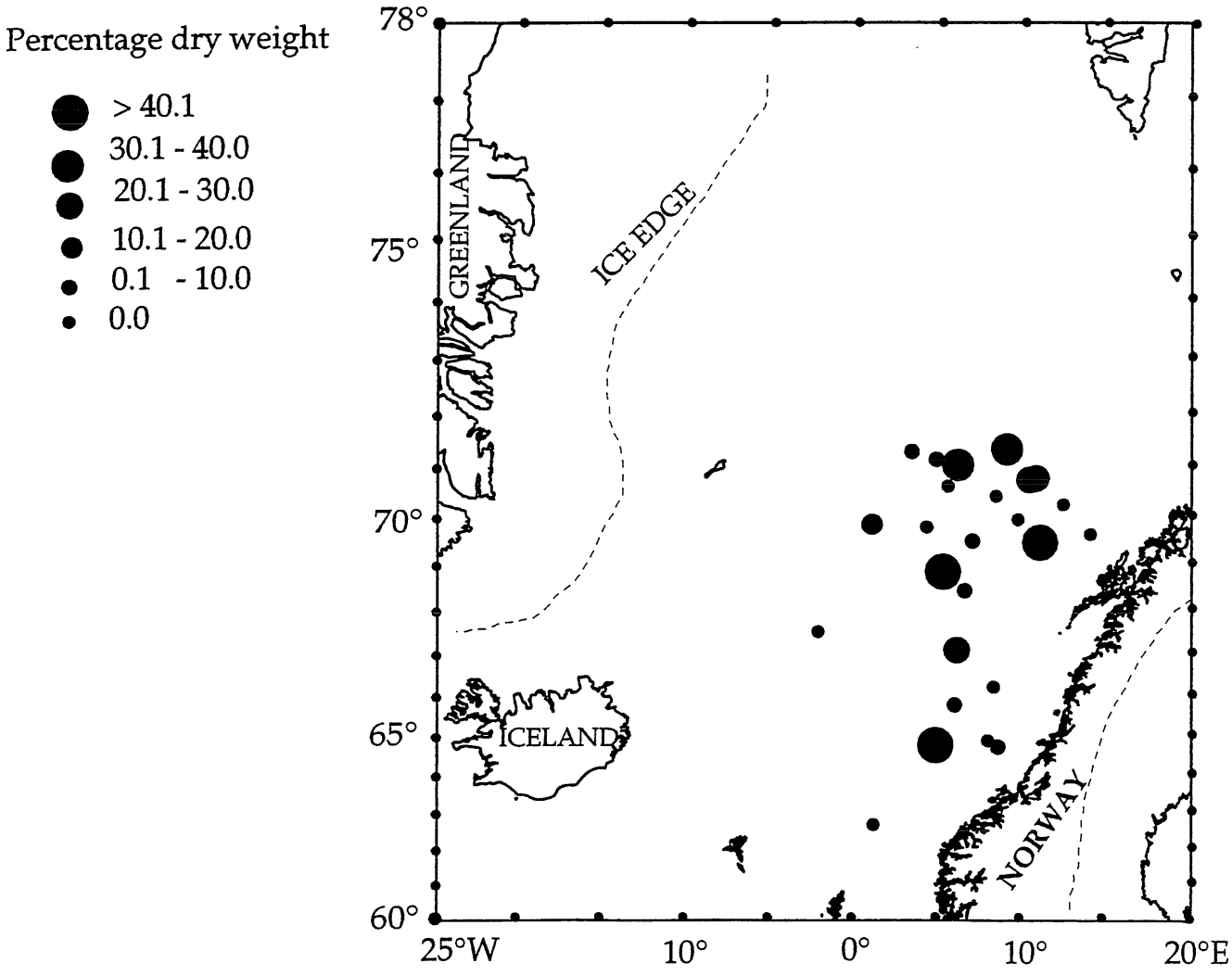


Figure 17c. Stomach content of herring in July and August 1995. Krill as percentage of total prey weight.

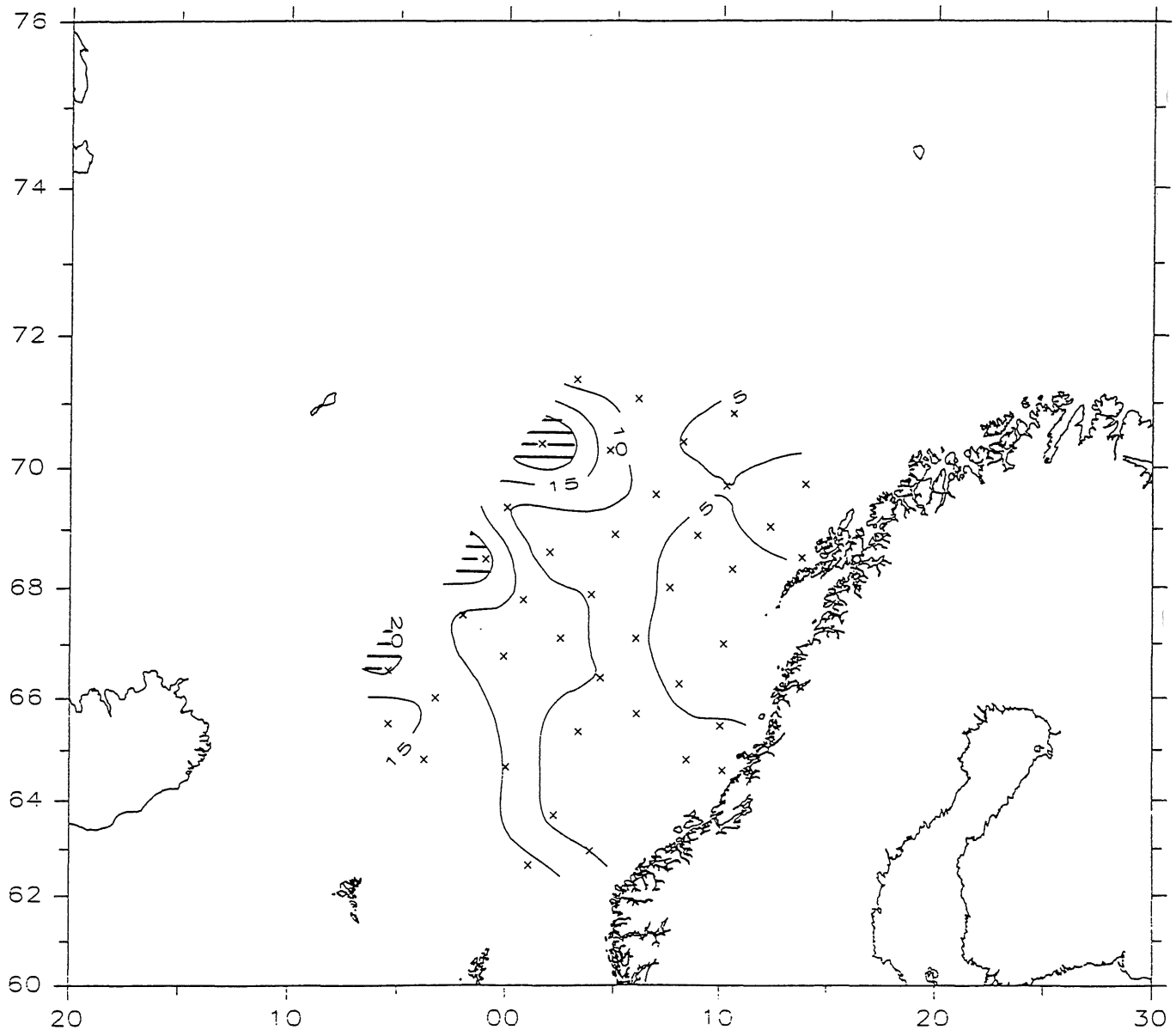


Figure 18. Total zooplankton biomass (g m^{-2}) distribution in 0 to 200 m in July and August 1995.

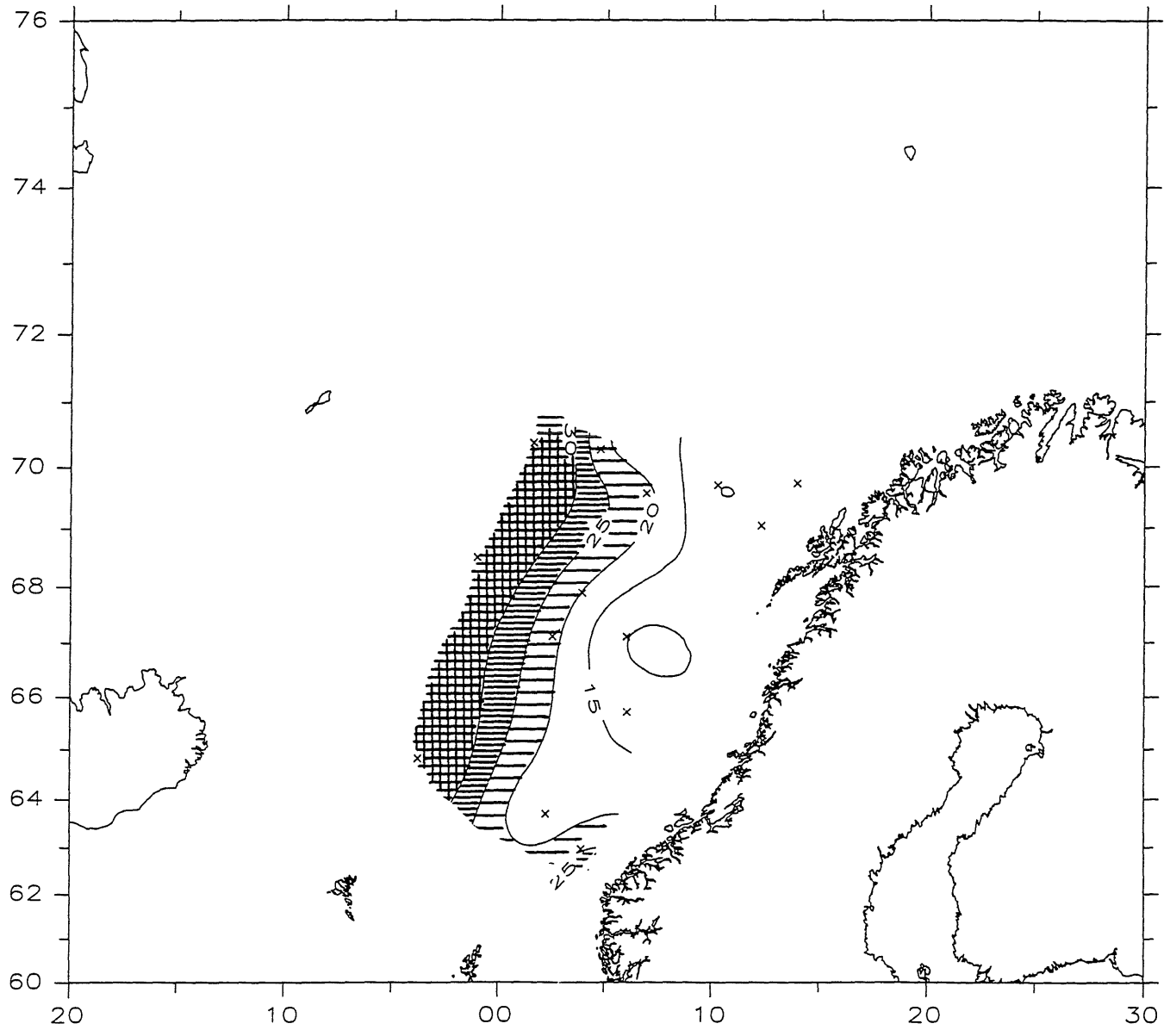


Figure 19. Total zooplankton biomass (g m^{-2}) distribution in 0 to 700 m in July and August 1995.

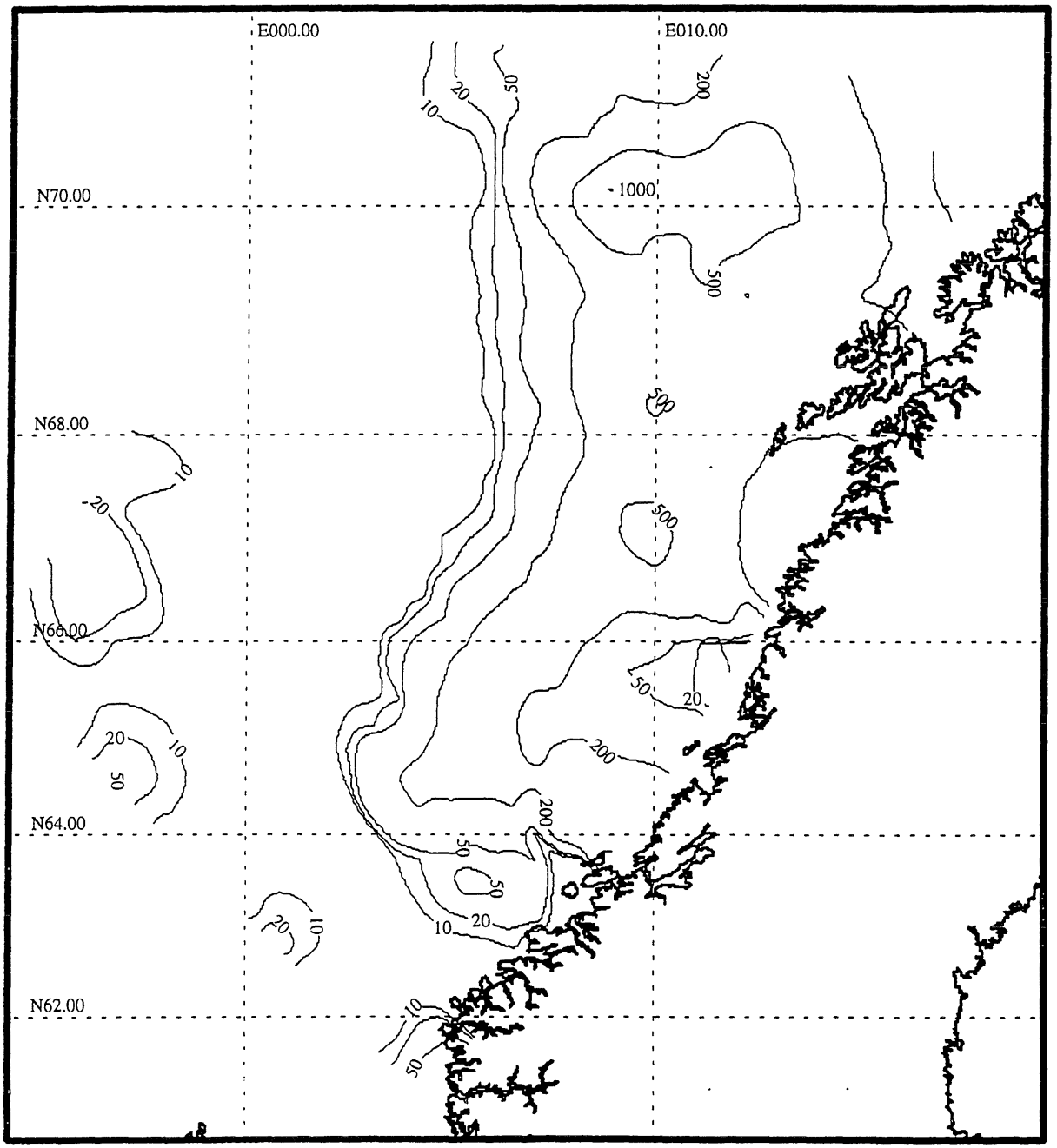


Figure 20. Distribution of herring, Sa (area backscattering)-values. July and August 1995.

Table 1. Diet composition of herring, July 1995; prey items in numbers

St. No	Lat.	Lon.	Number	Empty	Mean len.	KRILL				COPEPODS						AMPHIP.				Crus	FISH	Limci	OTHERS	TOTAL
			herring	stomachs	(CM)	T. inermis	M. norveg	T.longi	krill	C. fin	Calanus	Euchaeta	Metridia	others	T. abys	T. libell	Them.	other					prey
291	62.72	0.97	11	8	31.8	0	0	0	0	43	0	0	0	0	0	0	0	0	0	0	0	0	43
312	64.82	4.62	20	0	25.3	2	0	0	0	4386	0	0	0	0	8	0	6	0	0	0	1	0	4403
319	67.55	2.08	3	1	37.5	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	30
329	65.82	5.78	11	0	26.5	0	0	0	4	1446	0	0	0	0	20	0	0	0	0	0	20	0	1490
331	64.93	7.77	7	0	24.6	0	0	0	0	915	0	0	0	0	0	0	1	0		0	45	0	961
333	64.77	8.38	12	0	25.5	0	0	0	25	115	0	0	0	0	1	0	1	0	0	0	426	0	568
336	66.25	8.12	16	10	27.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
338	67.13	5.92	10	6	28.4	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0	19
344	69.88	0.85	11	1	34.6	0	0	0	0	0	0	1	0	0	2	0	1	1	0	0	0	0	5
348	71.32	3.20	9	0	35.8	1	0	0	0	0	0	0	0	0	9499	0	0	0	0	0	0	0	9500
350	71.18	4.68	22	1	32.9	0	0	0	1	464	0	98	0	0	479	0	0	18	0	0	0	0	1060
351	71.07	5.97	12	0	30.1	0	0	0	19	93	1	60	0	0	66	0	0	0	0	0	21	0	260
352	70.65	5.38	14	1	35.3	0	0	0	0	13	0	484	0	0	260	0	0	0	0	0	0	0	757
355	69.83	4.10	16	3	34.8	0	0	0	0	328	0	6	0	0	87	4	0	5	0	21	0	1	452
361	68.47	6.38	12	1	33.8	0	0	0	0	119	0	26	0	0	75	0	2	0	0	0	0	385	607
363	68.88	5.07	17	6	33.1	8	0	0	0	14	0	0	0	0	11	0	0	0	0	0	0	0	33
364	69.53	6.85	29	2	32.3	0	0	0	0	4	0	0	0	0	12	0	3	0	0	0	0	0	19
372	69.50	10.93	17	3	29.6	0	0	0	17	0	0	0	0	0	4	0	0	0	0	0	0	0	21
374	69.97	9.57	16	4	29.0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	16
375	70.45	8.25	10	0	30.3	0	0	0	0	193	0	0	0	0	0	0	0	0	0	0	0	0	193
377	71.37	8.92	15	1	34.2	0	0	19	65	0	0	0	49	0	342	1	21	0	0	0	0	0	497
378	70.80	10.67	16	4	30.1	0	0	0	39	129	0	0	0	0	28	0	1	0	0	0	0	0	197
379	70.28	12.32	14	0	30.7	0	0	0	0	136	0	0	0	0	0	0	0	0	0	0	0	0	136
381	69.67	13.97	16	4	26.6	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0	18