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Aspects of the feeding of capelin (*Mallotus villosus*) during autumn and early winter in the waters north of Iceland

Th. Sigurdsson and O.S. Astthorsson,
Marine Research Institute,
Skúlagata 4, P.O. Box 1390,
IS-121 Reykjavík, Iceland.

Abstract

The feeding of capelin (*Mallotus villosus*) caught in August, November and December 1989 in the waters north of Iceland was investigated. A total of 1240 stomachs of capelin ranging in length from 3-19 cm were examined. Of these 504 or 41% were found to be with food. Empty stomachs were more frequent amongst the smaller length classes and within a given size class the percentage of empty stomachs further increased from August to December, e.g. for 5-7 and 15-17 cm fish from c. 60 to 98% and from 25 to 82%, respectively. In August the stomach content of the smallest capelin (3-9 cm) was dominated (c. 75%) by the small copepod *Oithona* spp. while in December *Calanus finmarchicus* (c. 60%) and unidentified calanoid copepods (c. 40%) were most abundant in this size class. On the three sampling occasions *C. finmarchicus* was most numerous (c. 60-90%) in the stomachs of capelin of intermediate size (9-13 cm). Calanoid copepods were most numerous in the stomachs of the largest (13-19 cm) capelin during August (*C. finmarchicus*, *Metridia* spp., unidentified calanoid copepods) and November (*C. finmarchicus*, *C. hyperboreus*, unidentified calanoid copepods). In December, however, euphausiids (mainly *Thysanoessa inermis*) dominated (70-100%) by number in the largest size classes. Clearly there was a shift from smaller to larger food items and also the stomach content became more diverse as the capelin became larger. An investigation of the diel change in stomach fullness demonstrated two main peaks, one at 08-12 hr and another one at 16-20 hr. Further, during these two periods the state of digestion of the food was also lowest.

Introduction

Capelin, *Mallotus villosus*, is by far the most important pelagic fish stock in the waters around Iceland. Further, the capelin is also the most important prey of the cod in Icelandic waters, which in turn is the most important benthic stock in the area (Magnússon and Pálsson 1989). Intensive fishing for capelin began in the late sixties and during the period of its exploitation the capelin has undergone major changes in stock size (Vilhjálmsson 1983, 1984a, 1984b). The changes in adult stock size have partly been attributed to heavy fishing but environmental factors seem also to have played an important role in the annual recruitment. The changes in the stock size of the capelin have been reflected in the growth of the Icelandic cod stock (Magnússon and Pálsson 1989) and thus demonstrating its key role in the trophic relations in the waters around Iceland.

Many aspects of the fisheries biology of the Icelandic capelin have been studied in considerable detail (see Vilhjálmsson 1983, 1984a). However, very limited information is available on the food and feeding of the capelin around Iceland. Saemundsson (1926) mentioned important prey items but provided no quantitative data. More recently Pálsson (1973, 1974, 1977) and Jónsson and Fridgeirsson (1986), respectively, presented quantitative information on the food of the 0-group and larvae, while no quantitative studies have hitherto been made on the food of the older year classes. Similarly, only a limited information is available on the food and feeding of capelin in other boreal and arctic ecosystems. The food of the capelin in the Barents Sea was investigated by Panasenko (1981, 1984), Panasenko and Nestrova (1983), and Ellertsen et al. (1982) while Vesin et al. (1981) reported on the food of the capelin in Canadian waters.

Detailed information on the food of the capelin in Icelandic waters is a prerequisite for understanding its dynamics and role in the marine ecosystem around Iceland. The present study was undertaken as an initial step in this direction.

Material and methods

The capelin was sampled by a pelagic Harstad trawl at 17 stations near and off the shelf edge north of Iceland (c. 67–68° N) during August, November and December 1989 (Fig. 1). The trawl had an opening of approximately 20m x 20m and the mesh size in the cod end was 10 mm. The trawling speed was approximately 2.5 knots while trawling time and depth varied from several minutes to one hr and from the near surface to approximately 200 m depth, respectively.

At each station an attempt was made to sample a random subsample of c. 50 fish from each of the three age classes (0, I, II-group) which constitute the bulk of the Icelandic capelin stock. However, this was not always possible and sometimes only one age class (limited part of the size range) could be sampled. After sampling the ventral side of the capelin was cut open and the fish preserved in 5% formalin-seawater solution for later stomach content analysis. In the laboratory the capelin was length measured, the stomach cut free and its fullness index estimated using the following subjective scale:

0 = empty stomach to approximately 5% full,
1 = stomach fullness 5–25%,
2 = stomach fullness 25–50%,
3 = stomach fullness 50–75%,
4 = stomach 75–100% full.

After evaluation of fullness, the stomach was cut open and digestion index for the food estimated using the following scale:

1 = food fresh and completely undigested,
2 = food virtually undigested,
3 = limited digestion and food items could still be identified to species or groups,
4 = food highly digested and difficult to recognize to species or groups,

5 = stomach content unrecognizable.

Finally the stomach content was emptied into a petri dish for identification to the lowest taxonomic level possible and counting. When possible *Calanus finmarchicus* was further grouped into developmental stages and the length of the largest planktonic groups (e. g. euphausiids) measured. Below the results from the stomach content analyses are presented for 2 cm length classes.

Results

The length distribution of the capelin from which stomachs were sampled during the present study is summarized in Figure 2. A total of 1240 stomachs were examined and of those only 504 or 41 % were found to have food of some kind. Empty stomachs were particularly evident amongst the smallest length classes (3-5, 5-7, 7-9 cm) and only in August were these found to have food to a marked extent. For each length class the proportion of empty stomachs increased from August to December. Thus, in the 5-7 cm length class, 60% were empty in August while in 98% were empty in this size class in December. Similarly, in the 15-17 cm length class, the percentage of empty stomach increased from 25% in August to 82% in December. Further, the estimated stomach fullness did decrease as the autumn progressed, being on the average 1.3, 1.4 and 0.3 in August, November and December, respectively.

In August the stomach content of the smallest length groups (3-5, 5-7, 7-9 cm) was dominated (c. 70-80%) by the small copepod *Oithona* spp., while other small copepods (*Oncaea borealis*, *Pseudocalanus elongatus*) and unidentified calanoid copepods were also found in the stomachs (Fig 3). It should, however, be noted that in August the observations on the smallest length classes are only based on material from one station and therefore they may only partly reflect the food of this group. *C. finmarchicus* was the most numerous food item in the 9-11 and 11-13 cm length classes (c. 50-60%) along with

Metridia spp. and unidentified calanoid copepods. The majority of the unidentified calanoid copepods were probably *C. finmarchicus* and therefore its importance as a part of the food is even greater than demonstrated in Fig. 3. The numerical dominance of *C. finmarchicus* was reduced to 15-30% amongst the largest length classes (13-15, 15-17 cm) in August while *Metridia* spp. and unidentified calanoid copepods remained c. 20% of the food items. The larger zooplankton groups, such as *Thysanoessa inermis* and unidentified euphausiids, were only found in the stomachs of the largest length classes and they became more numerous at the same time as the numbers of *C. finmarchicus* did decrease (Fig. 3).

In November (Fig. 3) the food composition of the different length classes was mainly similar to that observed in August. *C. finmarchicus* dominated (c. 90%) in the 7-9, 9-11 and 11-13 cm length classes. *Calanus hyperboreus* was relatively abundant in the 13-15 cm length class (43%) while the abundance of *C. finmarchicus* had decreased. As in August, the food of the very largest capelin (15-17, 17-19 cm) in November was not dominated by one or two food groups but *C. finmarchicus*, unidentified calanoid copepods and euphausiids were most numerous. The euphausiids (unidentified, *T. inermis*, *Meganyctiphanes norvegica*) constituted <1% of the food of the 9-11 cm length class while they made up c. 35 and 44% respectively of the animals in the 15-17 and 17-19 cm length classes.

In December (Fig. 3) the composition of the food was again largely similar to that observed in August and November, except that euphausiids were more numerous than previously in the largest size classes. Thus *C. finmarchicus* dominated in the 5-7, 9-11, 11-13 cm length classes (c. 70-100%) while unidentified calanoid copepods were most numerous (c. 80%) in the 7-9 cm length class. *T. inermis* and unidentified euphausiids were equally numerous (40% each) in the 13-15 cm length class while in the 15–17 and 17–19 cm length classes *T. inermis* dominated. Most of the unidentified euphausiids probably belonged to *T. inermis* which further emphasizes the importance of this species as the food for the largest capelin north of Iceland. Pelagic amphipods (*Parathemisto* spp.) constituted 20% of the animals in the 13–15 cm length class while they were not recorded from other length classes. A single 0-group capelin was recorded from the stomach of 7 cm capelin collected in December.

In Figure 3 the results of the analysis of the food of the capelin were presented on the basis of numbers. However, due to the different size of the different prey groups this may give a somewhat misleading picture of their actual importance as a food. Thus, in order to get a better idea of the relative importance of the of the different planktonic groups as a food for the capelin, Fig. 4 shows its constitution for 4 major categories (copepods, euphausiids, amphipods and others) both in terms of number and weight. The conversion from number to weight was based on own measurements (Sigurdsson, unpublished data) and information from the litterature (Bogorov 1959). When the food is considered in terms of weight the transition in its composition (from copepods and to euphausiids) as the capelin grow beyond c. 11–13 cm is clearly demonstrated (Fig. 4).

Diel changes in the stomach fullness of capelin were investigated by grouping the data into 4 hr periods according to the time of sampling and calculating for each period the mean fullness index for the capelin examined. The data are limited for certain periods, but nevertheless some changes are indicated (Fig. 5). Thus, as judged from the stomach fullness, there appeared to be two periods of main feeding activity, the first one in the morning (08–12 hr) and the second one in the afternoon (16–20 hr). The two main peaks coincided with the sunrise and sunset in November at 66° N.

In a similar manner the mean digestion index was also calculated for each four hr period (Fig. 5). Apparently the digestion was lowest at 08–12 hr and at 16–20 hr, or at approximately the same time as when the stomach fullness was at a maximum. A secondary low in the digestion was also observed during 00–04 hr when similarly a slight increase occurred in the stomach content. The generally low state of digestion at the time when the food occurred in largest quantities in the stomachs reflects that then it had only recently been consumed. Further, this also suggests that the observed diurnal change in stomach fullness is reflecting a true pattern in the feeding activity of the capelin.

Discussion

The present material was sampled north of Iceland at about the time when the juvenile and adult capelin return from their summer feeding migration into the southern Greenland Sea. The relatively high proportion of empty stomachs (Fig. 2) indicates that at the time of sampling the summer feeding period was already coming to an end and that the zooplankton stocks were probably being depleted. Further, amongst the maturing capelin the low food consumption could also been related to the development of the ovaries and preparation for the spawning (Vesin et al. 1981). Similar to the present findings Vesin et al. (1981) reported that 69–85% of the stomachs of >14 cm capelin sampled in October–November in the Gulf of St. Lawrence were empty and in the Barent Sea capelin does not feed during the period November–January (Prokhorov (1965) as referred to by Winters 1970). Almost all of the smallest individuals (0-group, 3–9 cm) found to have food in their stomachs were caught in August. Possibly, this reflects that their seasonal feeding period is shorter than that of the larger length classes which kept on feeding at a low level also in November and December. This may be attributed to the seasonal dynamics of the small copepods such as *Oithona* spp. on which the smallest capelin appear to depend for food. Further studies involving concurrent stomach and zooplankton sampling are, however, needed to answear questions such as this. Pálsson (1973), who similarly examined the stomach content of 0-group capelin sampled northwest of Iceland in August, noted relatively high percentage of empty stomachs (40%).

The food of the capelin north of Iceland was similar during the three sampling periods (Fig. 3). Thus, the smallest capelin (3-9 cm, 0-group) fed mainly on small copepods (*Oithona spp.* dominating), capelin of intermediate size (9-13 cm, I-group) consumed largely *C. finmarchicus*. The largest size classes (>13 cm) fed on *C. finmarchicus*, euphausiids and amphipods. Numerically, the euphausiids dominated only in the largest size groups (13-15, 15-17, 17-19 cm) in December. When the food was considered in terms of weight the importance of euphausiids for the largest size classes in general became more evident (Fig. 4). From both the Gulf of St. Lawrence and the Barents Sea, Vesin et al. (1981) and Panasenko (1984), respectively, observed the same general pattern of a shift from copepods to euphausiids as the capelin length increased.

In terms of weight Ellertsen et al. (1982) reported calanoid copepods (47%), euphausiids (33%), *Sagitta elegans* (10%) and *Parathemisto abyssorum* (6%) to be the most important constituents of the food of 14-16 cm capelin from the Barents Sea. Except for *S. elegans*, these are the same food groups as observed to be most important in the stomachs of capelin of similar size (13-15) from the waters north of Iceland, however, their relative importance is somewhat different. Thus, euphausiids constituted 74% of the weight of the food of capelin north of Iceland, while copepods and amphipods (*Parathemisto* spp.) made up 15 and 11%, respectively (Fig. 4). The two studies were conducted at different times and therefore differences in the food composition may be expected. Further, due the to patchy distribution of the major prey organisms considerable variation in their quantities in the capelin stomachs is likely to be observed.

Pálsson (1973) found *Acartia* spp. to be the most numerous (60%) food item in the stomachs of 4-6 cm capelin larvae he examined from the waters north of Iceland. In the present material, however, only a single *Acartia* spp. was recorded from stomach of a capelin in the 11-13 cm length class. Probably this is related to the fact that *Acartia* spp. is a neritic species and most of Pálssons (1973) stations were taken in relatively shallow water compaired to the present more offshore sampling.

Two peaks, at 08-12 and 16-20 hr and which approximately coincided with sunrise and sunset, were evident in the autumn and winter feeding activity of the capelin north of Iceland (Fig. 5). During the period May to August Vesin et al. (1981) similarly observed morning and evening peaks in the feeding activity of capelin in the Gulf of St. Lawrence, while samples from October and November suggested only one feeding peak at midday. Vesin et al. (1981) postulated that the shift to a single feeding peak was possibly related to the combined effect of colder temperatures and shortened day length. On the other hand, Panasenko´s (1981) studies on the feeding rhythm of capelin in the Barents Sea in August demonstrated a single feeding maximum in the morning. Apparently, much more detailed studies involving intensive stomach sampling of the capelin and simultaneous monitoring of zooplankton desities and distribution are needed in order to understand its feeding dynamics in arctic and subarctic waters.

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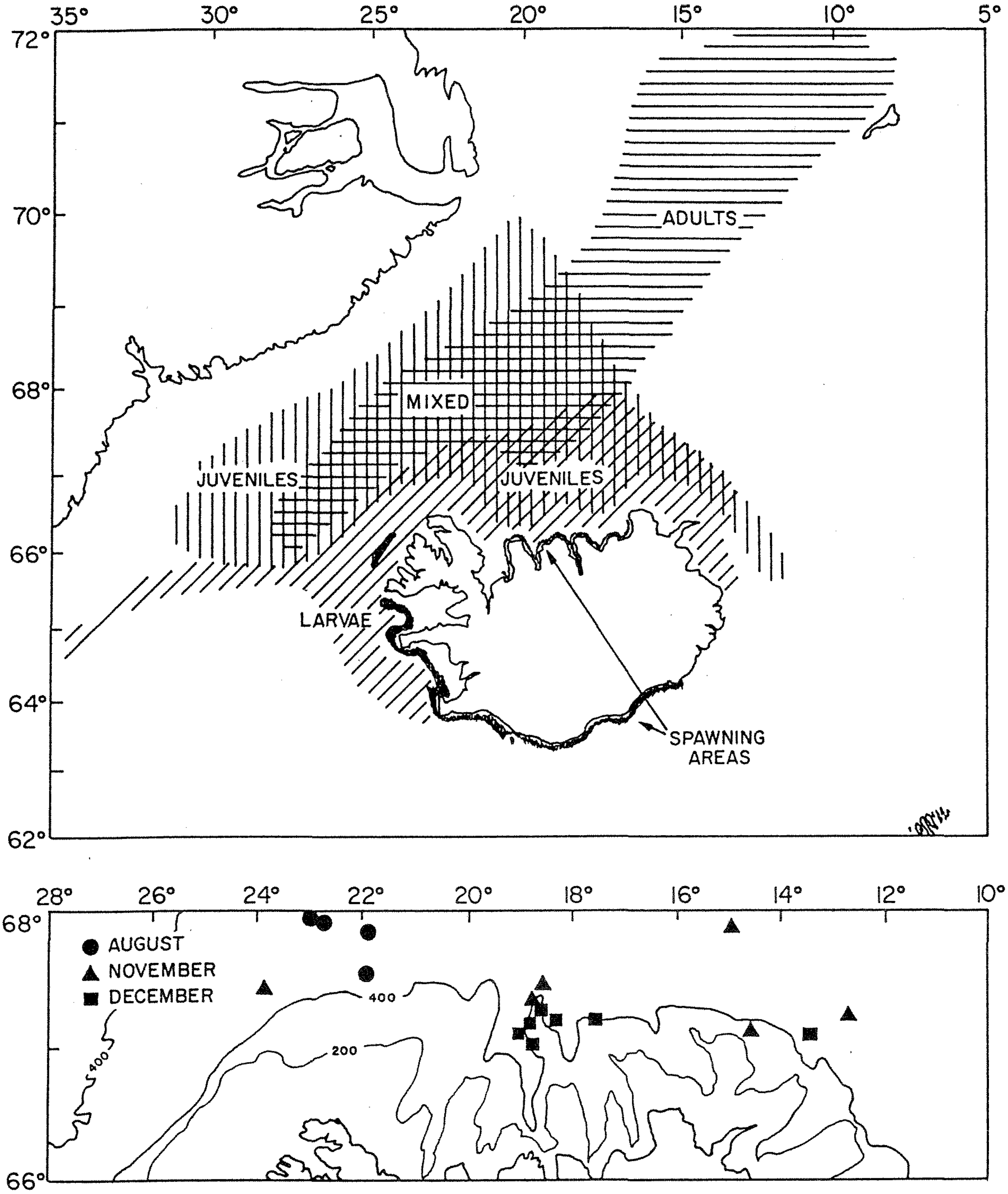

Fig. 1. Spawning grounds and general distribution of larvae, juvenile and adult stock of Icelandic capelin (adapted from Vilhjalmsson 1983) and the location of trawling stations for stomach samples north of Iceland in August, November and December 1989.

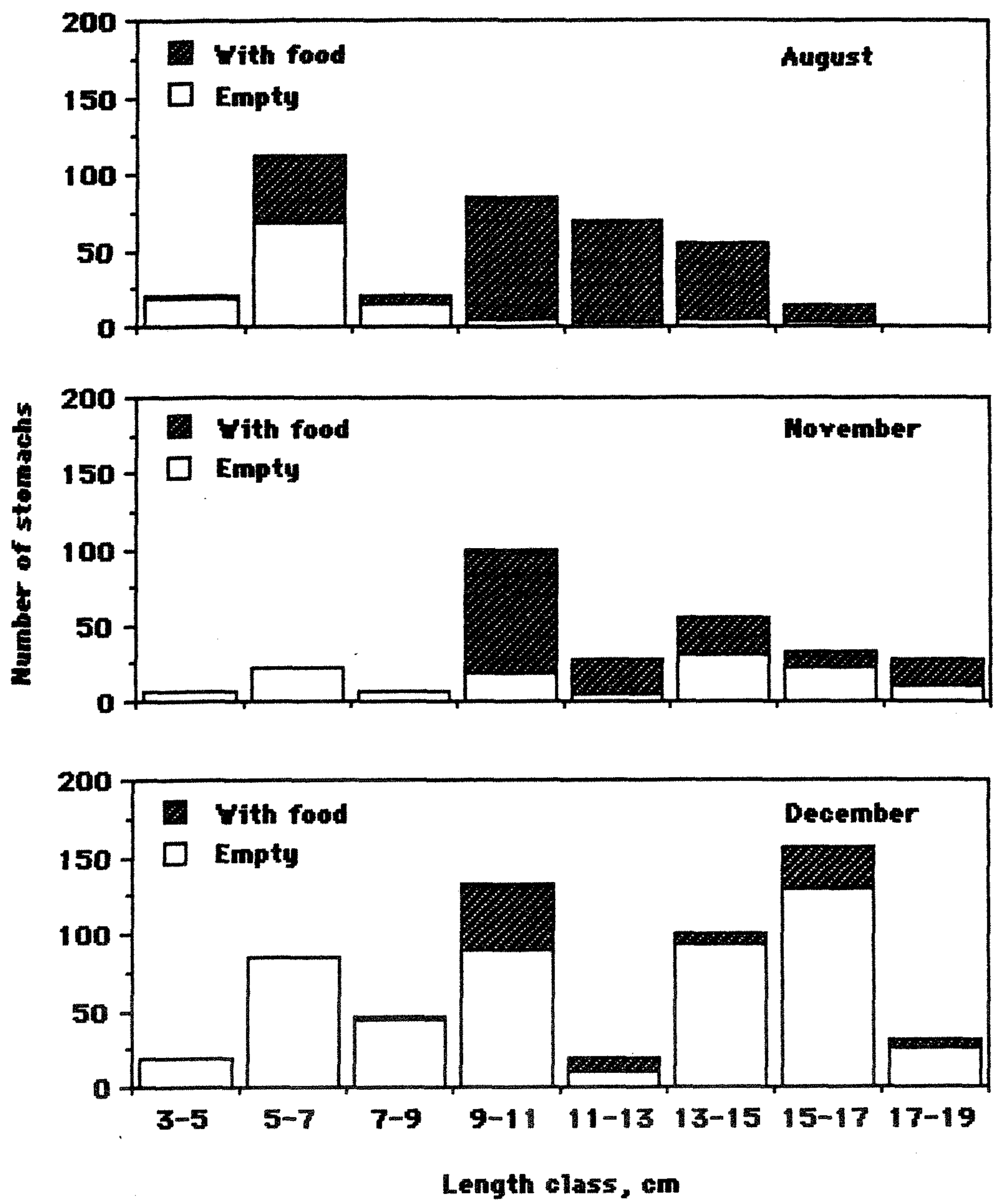

Fig. 2. Length frequency histograms of capelin sampled for stomach analysis in August, November and December 1989. The shaded parts of the bars denote the capelin which had food in their stomachs.

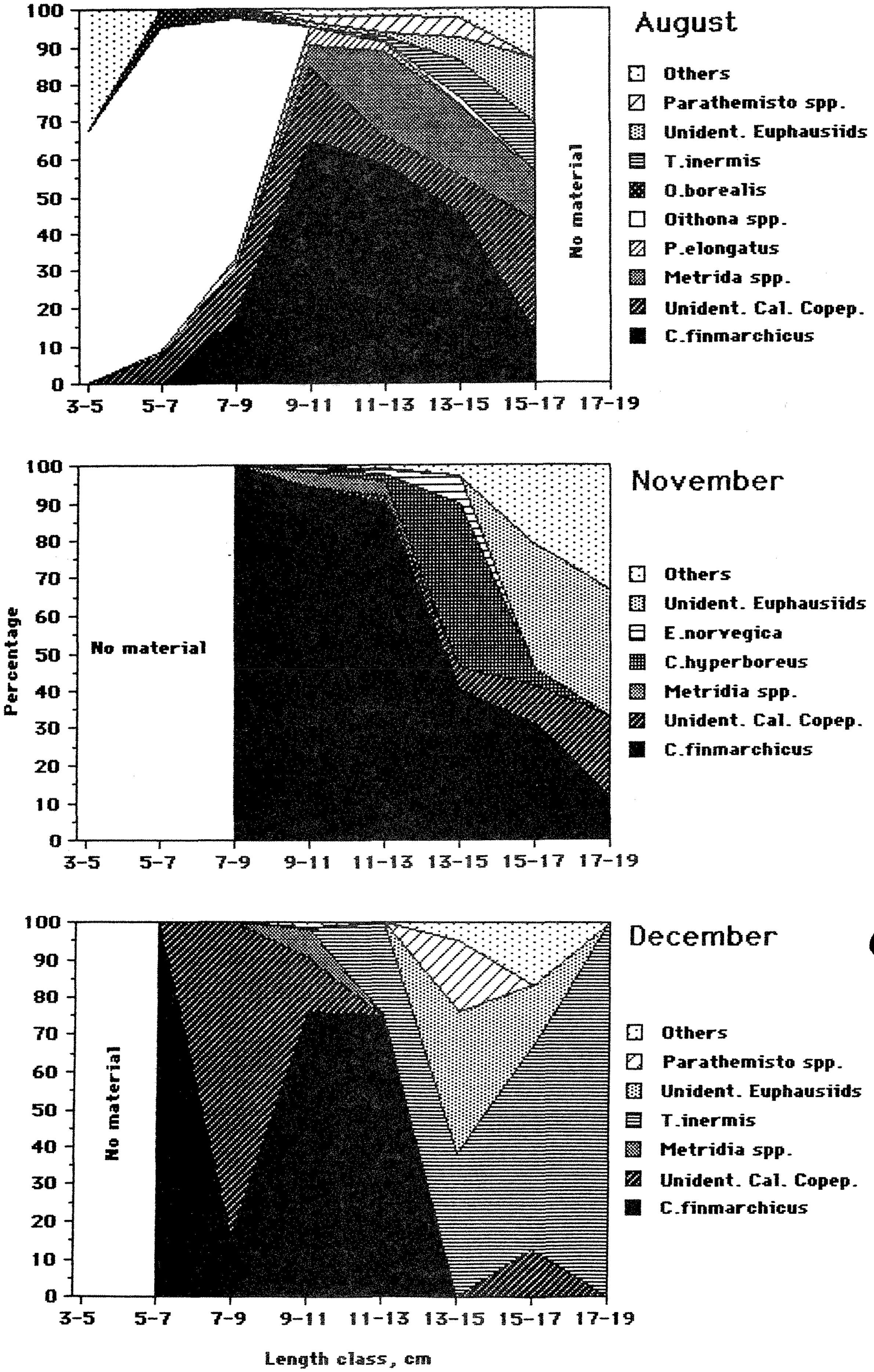

Fig. 3. Food composition (percentage by number) of capelin north of Iceland in August, November and December 1989.

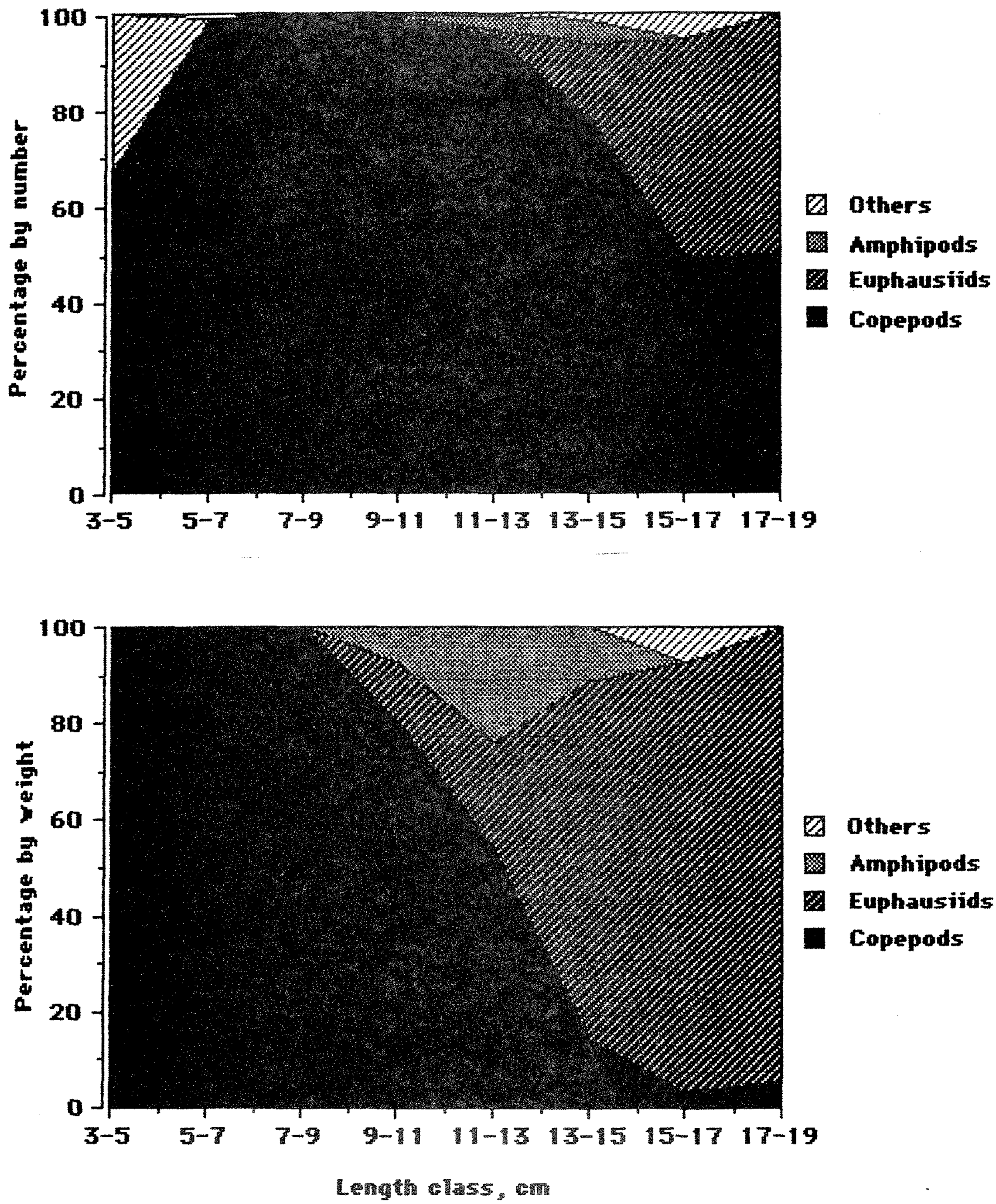

Fig. 4. A summary of the food composition of capelin north of Iceland in autumn and early winter (all samples from August, November and December 1989 combined) in terms of numbers and weight.

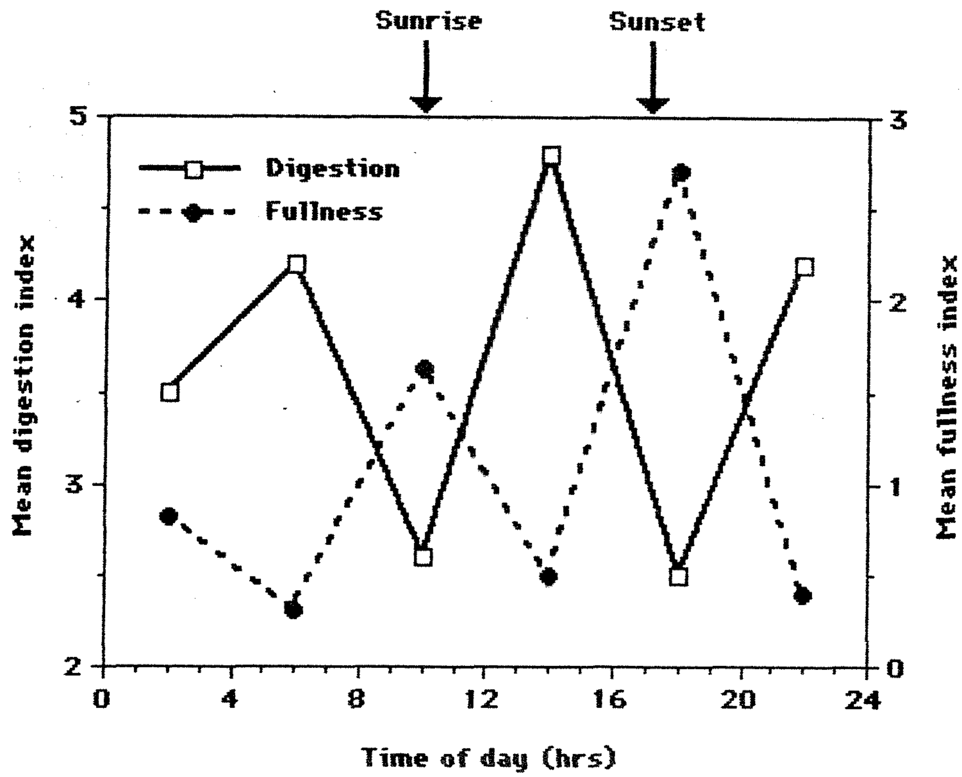

Fig. 5. Digestion and fullness indices at different times of the day for capelin north of Iceland in autumn and early winter 1989 (all stations and length classes combined).