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Observations of abundance, stock composition, body size and food of postsmolts of Atlantic salmon in the NE Atlantic during summer

by

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Abstract

Postsmolt Atlantic salmon were caught during pelagic trawl surveys in the Norwegian Sea in July-August, 1991 and 1995, and off the Hebrides in May-June 1995. Using the swept area technique abundance estimates of postmolts were produced for the three areas, giving estimates of 3.18 million postsmolts within the sampled area of the Norwegian Sea in 1991, 12.89 million postsmolts within the sampled area of the Norwegian Sea in 1995 and 3.26 million postsmolts within the sampled area off the Hebrides in 1995. These figures are rough estimates and should be regarded preliminary. The smolt age distribution of the postsmolts indicated a large component of postsmolts with a southern origin, both of those caught off the Hebrides and in the Norwegian Sea. Only a small fraction of the postsmolts had empty stomachs, indicating a favourable feeding regime in the sampled areas. *Parathemisto* spp. and 0-group of herring, redfish and blue whiting were the domination food items observed in the stomachs.

Introduction

There is only little knowledge on the distribution and biology of postsmolts of Atlantic salmon in the open ocean. Available information were reported by Dutil & Coutu (1988) from the northern Gulf of St. Lawrence, by Reddin & Short (1991) from the Labrador sea, and Holst et al. (1993) from the northern part of the Norwegian Sea. It has been suggested that the main mortality of salmon in the sea takes place at the postsmolt stage, a short time after the salmon have left their home rivers (e.g. Browne et al. 1982). This hypothesis is simply based on the assumption that small salmon are subjected to heavier predation than larger individuals, and that there are more predators inside the continental shelf than in oceanic areas.

Recent studies have indicated that survival of salmon at sea vary with changes in the environment such as e.g. temperature patterns (Friedland et al. 1993). However, the mechanisms underlying the varying survival are, however, unknown. Therefore, in order to further understand these variations it is of outmost importance to gain more knowledge about the distribution and biology of Atlantic salmon post smolts.

As part of an ecological research programme ("Mare Cognitum") in the north-east Atlantic, conducted by the Institute of Marine Research (IMR), Bergen, pelagic trawl surveys were carried out in the summers of 1991 and 1995. During these surveys Atlantic salmon postsmolts in the catches were identified and examined. This paper presents some results of these studies, such as salmon abundance, stock composition, size and age distribution and food.

Material and methods

Sampling

The Institute of Marine Research, Bergen, Norway, carried out pelagic trawl surveys in the Norwegian Sea during the summers of 1991, and 1995, and in the area between the Hebrides and Faroes in 1995 (Figures 1 and 2). In all years the trawls were fitted with buoys on the wings and headline to allow sampling from the surface down to about 20-25 meters (Valdemarsen & Misund, 1995). In 1991 the trawl was hauled by two vessels (pairtrawling) while in 1995 it was hauled by a single vessel. The trawling speed varied somewhat between years: it was 3.5 - 4 knots in 1991 and 3.6 - 3.8 knots in 1995. The duration of each haul was 45 minutes in 1991 and 30 minutes in 1995. For more detailed information about the sampling see Holm et al. (1996).

The main fish species identified in the trawl catches were herring, mackerel, lumpsucker and Atlantic salmon. Immediately after capture the postsmolts were placed on cooling elements (-18°C) to prevent autolysis of the stomach content. The postsmolts were measured (total length in 1991 and total length and fork length the other year), weighed (nearest gram) and sexed. In 1991, when only total lengths of the salmon postsmolts were available, we converted total lengths to fork lengths using the regression : Fork length = 0.96 total length - 5.34 (r^2= 0.997; n= 30), based on measurements carried out on the individuals collected in 1995. The stomachs were removed and immediately put into the freezer. Later, the stomach contents were identified to species if possible, and we recorded lengths and wet weights of the food items. Many of the postsmolts caught had lost most of their scales in the trawl, and in many cases scales were only available from areas of the fish not recommended for scale sampling (Shearer, 1992). Therefore we also sampled otholiths which were used for age determination.

Estimation of abundance

Estimation of abundance of postsmolts were carried out for the material collected during summer 1991 and 1995 in the Norwegian Sea and off the Hebrides in 1995 using the "swept area" technique. To estimate the abundance of postsmolts we did the following exercise.

Let:
a = estimated mean area sampled per trawl haul (km^2)
d = mean towing distance per trawl haul (km)
ew = estimated mean effective sampling width of the trawl (km)
ta = estimated total area swept by trawl within investigated area (km^2)
n = number of trawl hauls
N = estimated number of postsmolt salmon within the investigated area
TC = total number of postsmolt salmon caught within investigated area (= in n hauls)
A = total size of investigated area (km^2)

Then: $a = d * ew$,
and: $ta = n * a$,
and finally: $N = (TC / ta) * A$

The values applied for the abundance estimation are listed in Table 1. It should be noted that we based the estimated effective sampling width of the trawls (ew) on the measured wing spread of the trawls (Valdemarsen & Misund 1995).

Results

Postsmolts were captured in two main areas: off the Hebrides and in the Norwegian Sea. (Figs. 1 and 2). The fish were mainly caught in Atlantic water in an oceanic area covering a north/south belt from about 55° north to 73° north. It should be noted that only few postsmolts were caught along the Norwegian coast. The abundance of postsmolts within the area sampled in the Norwegian Sea was estimated to 3.18 million in 1991 while in 1995 the number was 12.89 millions (Table 2). Note that areas sampled in the Norwegian Sea differed between the two years. The estimated number of postsmolts in the area sampled off the Hebrides in May/June 1995 was 3.26 million individuals (Table 2).

The fork length distribution of the postsmolts caught in 1991 and 1995 in the Norwegian Sea and in 1995 off the Hebrides are shown in Figure 3. The fish were larger in the Norwegian Sea than off the Hebrides, and of the fish caught in the Norwegian Sea, those sampled in 1991 were on average larger than those sampled in 1995.

Smolt age distributions from all three areas are shown in Figure 4. There was a significant difference in smolt age distribution among the three groups ($X^2 = 40.05$; 6 df; P<

0.0001). In the material collected in 1995 postsmolts caught in the Norwegian Sea tended to be younger as smolts than those from off the Hebrides ($X^2 = 8.79$; 2 df; P=0.01), in fact, more than 30% of the postsmolts were 1+ in the Norwegian Sea in 1991. Off the Hebrides more than 80% of the postsmolts were 2+.

In the Norwegian Sea in 1991, off the Hebrides in 1995 and in the Norwegian Sea in 1995, 2.9, 8,7 and 14,5% respectively of the stomachs were found empty (Table 3). In the Norwegian Sea, the food organisms found most frequently in the postsmolt stomachs were *Themisto spp.*, krill (Euphausidae), herring and redfish larvae, whereas off the Hebrides blue whiting larvae/0-group were the only food item identified (Figure 5). Based on the wet weight percentage of the prey (Figure 6) it can be observed that the importance of fish is somewhat higher than can be observed from the frequency of occurrence. From the material collected in 1995 we found a significant relationship between the mean size of *Parahemisto spp.* in the stomachs and the length of postsmolts (n=19, $r^2=0.38$, p<0.005), suggesting that some size selective predation may have occurred.

Discussion

Salmon are distributed in large parts of the North East Atlantic Ocean, and commercial high seas fisheries took place in the Norwegian Sea in the 60ies and beginning of the 70ies (Anon., 1979). However, due to regulations the only legal fishery in this area at present are within the Faroese 200 mile EEZ. Sampling from these fisheries have generated significant knowledge on the biology of Atlantic salmon in these southern winter feeding areas (e.g. Anon 1990), but there is still very little knowledge about the biology of the Atlantic salmon in the summer feeding areas in the northern Norwegian Sea. This is in particular the case concerning postsmolt salmon and only recently observations of this agegroup of salmon have been obtained from these areas (Holst et al., 1993).

Based on the samples collected in 1991 and 1995 we made a first approach to estimate the abundance of postsmolt Atlantic salmon in different parts of the north east Atlantic. We are aware of the large numbers of potential pitfalls connected with such an exercise, and although we give absolute numbers, the presented figures should preferentially be regarded as indexes. The present sampling scheme is planned to be continued at least until year 2000 and the scientific value of these estimates will increase as the timeseries grow. Effort will therefore be put into standardising the sampling procedure in order to ease the interpretation of the timeseries in retrospect.

Amongst different sources of errors in the abundance estimates, we consider the low number of individuals caught as one of the most serious. We are also seriously concerned about the applied effective sampling width of the trawl and problems connected to salmon trawl avoidance behaviour. The fact that the survey started in the south and moved northwards may also have caused errors since presumably the postsmolts also moved northwards during that period (Jonsson et al. 1993), with a speed probably not far from that of the vessels mean northerly speed. At present we will not go deeper into these problems, but await the quantitative interpretation of these results until some more years of data become available.

Despite all unknown errors, where some would result in overestimation and others lead to underestimation, the estimated abundance of postsmolts seem to be within a realistic range. For example, the catch of salmon in the high seas and in European home waters is at present about 1,2 million fish, included estimates of unreported catch (Anon., 1996). If we assume that approximately the same number spawn, and take into consideration that the natural mortality of postsmolts is relatively high, the number of postsmolts estimated based on surface trawling might be relatively close to what could be expected. However, it is important to keep in mind that this attempt to estimate the abundance of salmon postsmolts in the ocean is provisional and crude, but might perhaps initiate efforts to improve the methods and so contribute to increased sample sizes in the future.

As expected, the postsmolts collected at the Hebrides in May-June were smaller than those caught in the Norwegian Sea July-August. The postsmolts caught in the Norwegian Sea in 1991 were on average larger than those caught in 1995, which we believe could partly be due to the somewhat later sampling period. However, the observed size difference between the two years may also be due to sampling in different stock compositions or be a result of variations in the general growth conditions of the postsmolts in the ocean.

One year old smolts are most common in southern Europe, e.g. Spain and France, and they are also common in Ireland and England. They also occur, but in very small numbers, in Scotland and SW Norway, but in these countries 2 and 3+ smolts are more common. In Norway also 4+ smolts are relatively abundant. The relatively high frequency of 1+ smolts in the samples taken in the Norwegian Sea surprised us somewhat. We expected postsmolts from more northern rivers along the eastern Atlantic to be present in this area in July. However, this does not seem to be the case, and we suggest, based on size and smolt age distribution that we mainly caught postsmolts from the more central and southern areas of Europe. This is supported by the fact that one microtagged fish was recaptured during the cruise in 1995. The fish, a wild postsmolt, was tagged on the River Test, near Southampton, southern England in April 1995, and was recaptured on 23 July 1995 at 70° 54'N; 2° 27'E. Fork length of the fish was 283mm and the total weight was 249g. We are somewhat confused about the apparent lack of fish with a high river age in the Norwegian Sea, but suspect that trawl selection may lead to underestimates of the postsmolts of northern origin. Due to a later sea migration, the northern postsmolts are smaller than their southern relatives at the time of sampling and may be underrepresented in the catches. They may also be found in areas outside the sampled regions.

There are some information about feeding of immature salmon in the ocean (reviewed by Reddin 1988; Hislop & Shelton 1993). In the north-west Atlantic, salmon feed mainly on capelin, sandeel, amphipods and euphasiids (Templeman 1968; Lear 1980; Reddin 1985). In the northeast Atlantic, salmon feed mainly on herring, lantern fish, sand eel, amphipods and euphausiides (e.g. Thurow 1973; Hislop & Youngson 1984; Hansen & Pethon 1985). A salmon research project carried out at Faroes in recent years (Jacobsen & Hansen 1996) showed that the most important prey items in the 1992/93 season were fish, whereas in the two following seasons crustaceans were most abundant. In total, crustaceans of the genus *Parathemisto (Themisto)* were the dominating group in the salmon stomachs. Other important food items were lantern fishes, krill, shrimps, barracudinas and silversides. The main prey items observed in the stomachs of <u>postsmolt</u> Atlantic salmon overlapped partly with what have been observed in larger salmon in oceanic waters. However, the fish observed in the diet of postsmolts consisted mainly of larvae/0-group (except from the Benthosema) and *Parahemisto* were by far the dominating item amongst the crustacean prey. The low number of empty stomachs indicate favourable feeding conditions in the sampled areas during the sampling period.

The total dominance of larvae/0-group of blue whiting observed in the stomachs of postsmolts taken off the Hebrides in 1995 caught our attention. Results from investigations on blue whiting have shown that the 1995 year-class of blue whiting originating from the spawning areas off Ireland/Porcupine bank and off the Hebrides is the strongest in many years (Anon. 1996). The postsmolt feeding off the Hebrides in May-June 1995 evidently took advantage of these abundant food resources. We also noted with some curiosity the finding of insects (Drosophilidae, Brachyeera, Gelechidae, Aphididae) in stomachs of postsmolts caught in the Norwegian Sea in 1995 some 350 kilometres from the nearest shore.

Moreover, it is interesting to note that given 0-group fish were available in the sampling area (as observed in the trawl catches), the postsmolt fed mainly on 0-group fish. From parallel plankton sampling we know that amphipods were available as prey in all areas sampled, indicating a selective feeding strategy of the postsmolt. It appears that 0-group fish is a preferred prey over crustaceans for postsmolt Atlantic salmon once available, at least in the sampled areas. There was also a tendency to a size selective feeding strategy as indicated by the positive relation between the size of *Parathemisto* spp.. in the stomachs and postsmolt size (this may alternatively be explained by a geographic or growth effect of the *Parathemisto)*. The size selective feeding strategy is also supported by the shift from dominating 0-group fish feeding in postsmolts to feeding on older and larger fish observed in 1 sea winter and older salmon.

The distribution, migration pattern and general biology of postsmolts of Atlantic salmon in the north-east Atlantic waters has, until recently, been an area of scarce knowledge. The present study shows that it is possible to catch these fishes, describe their distribution, migration, abundance, origin and feeding habits, provided we are able to sample over larger areas and more continuos time periods, and most of all, increase the sample sizes.

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Tables.

Table 1. Values applied for the estimation of abundance of postsmolts. ew = estimated mean sampling width of the trawl; d = mean towing distance per haul; a = estimated mean area sampled per trawl haul.

Year	ew (m)	d (km)	a (km^2)
1991	30.00	5.55	0.166
1995	25.00	3.52	0.088

Table 2. Abundance estimates of postsmolts of Atlantic salmon. Swept area is the area actually fished, and sampled area refers to the total area where postsmolts were captured (ref. figures 1 and 2).

Time	No. hauls	Swept area km^2 (ta)	No. fish caught (TC)	Sampled area km^2 (A)	Number per swept area nm^2 (TC/ta)	Abundance estimates (N)
1991	40	6.58	34	616,765	5.16	3,188,675
1995 (May/June)	26	2.23	46	158,274	20.64	3,267,088
1995 (July)	30	2.57	62	534,726	24.11	12,892,243

Table 3. Frequency of empty stomachs.

Location	Year	No. examined	No. Empty	% empty
Norwegian Sea	1991	34	1	2.9
Hebrides	1995	46	4	8.7
Norwegian Sea	1995	62	9	14.5

Figures.

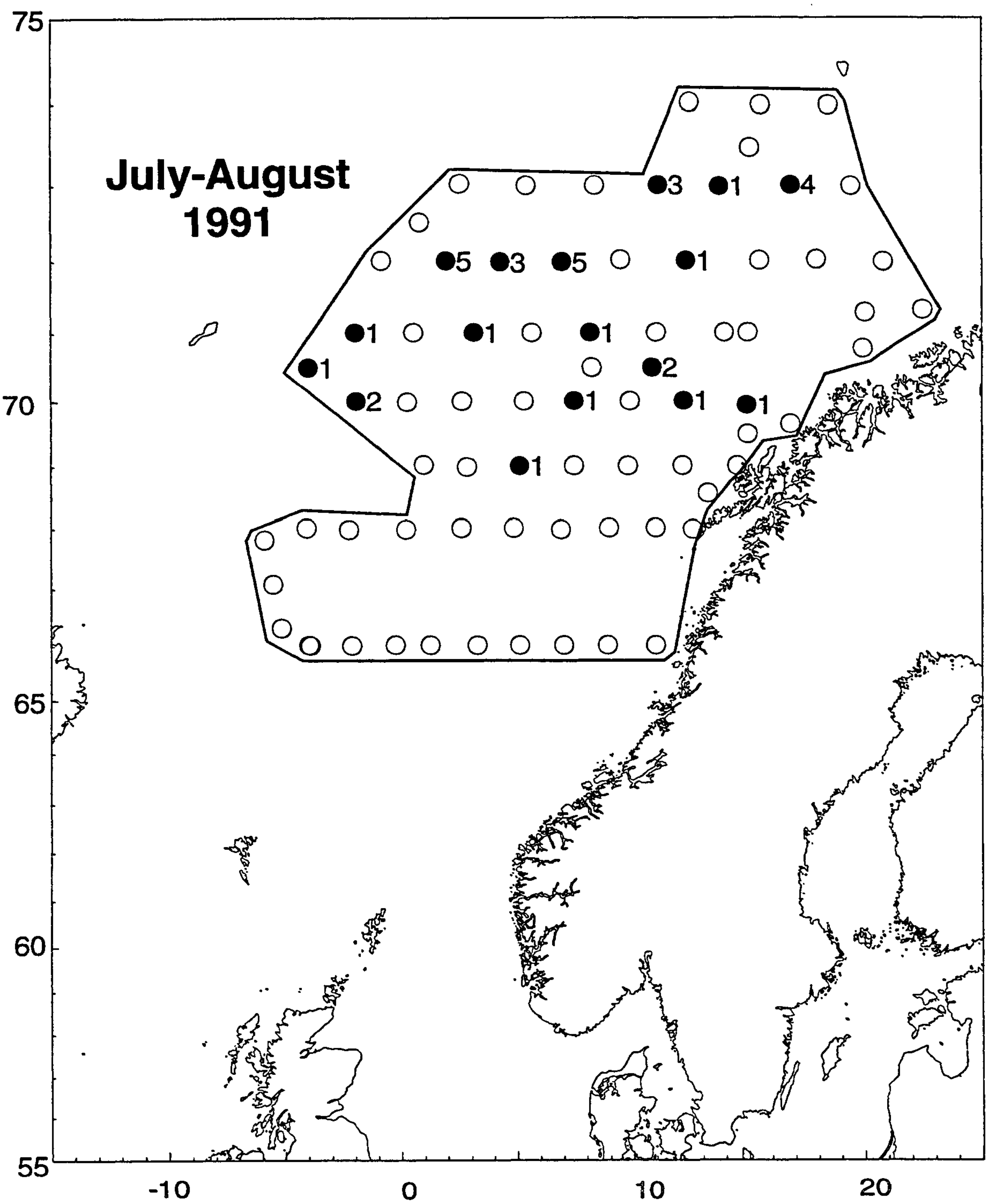

Figure 1. Geographic distribution of trawl stations in the Norwegian Sea in July/August 1991 with number of postsmolts caught. The encircled area was used for estimation of postsmolt abundance.

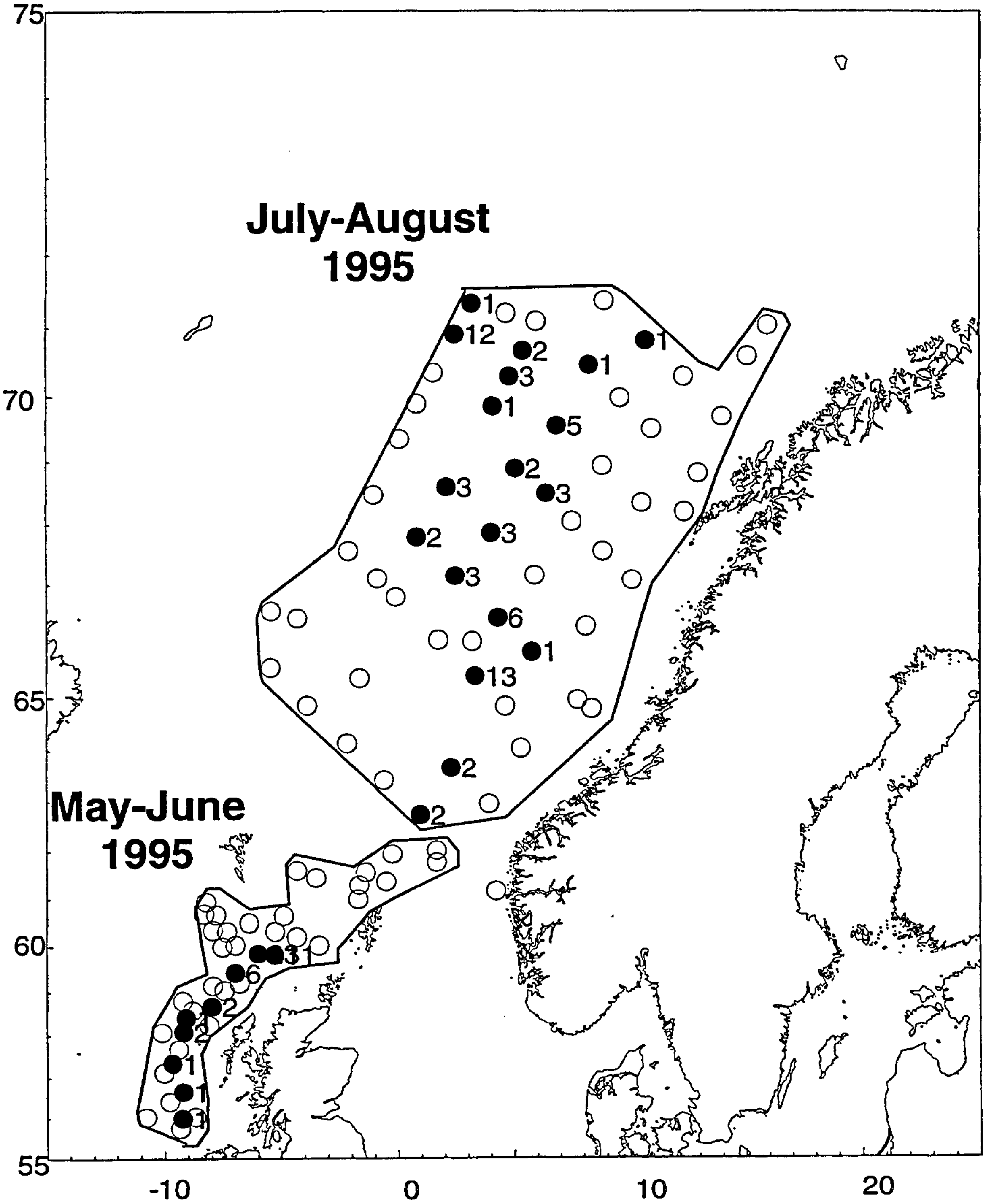

Figure 2. Geographic distribution of trawl stations off the Hebrides in May/June 1995 and in the Norwegian Sea in July/August1995 with number of postsmolts caught. The encircled area was used for estimation of postsmolt abundance

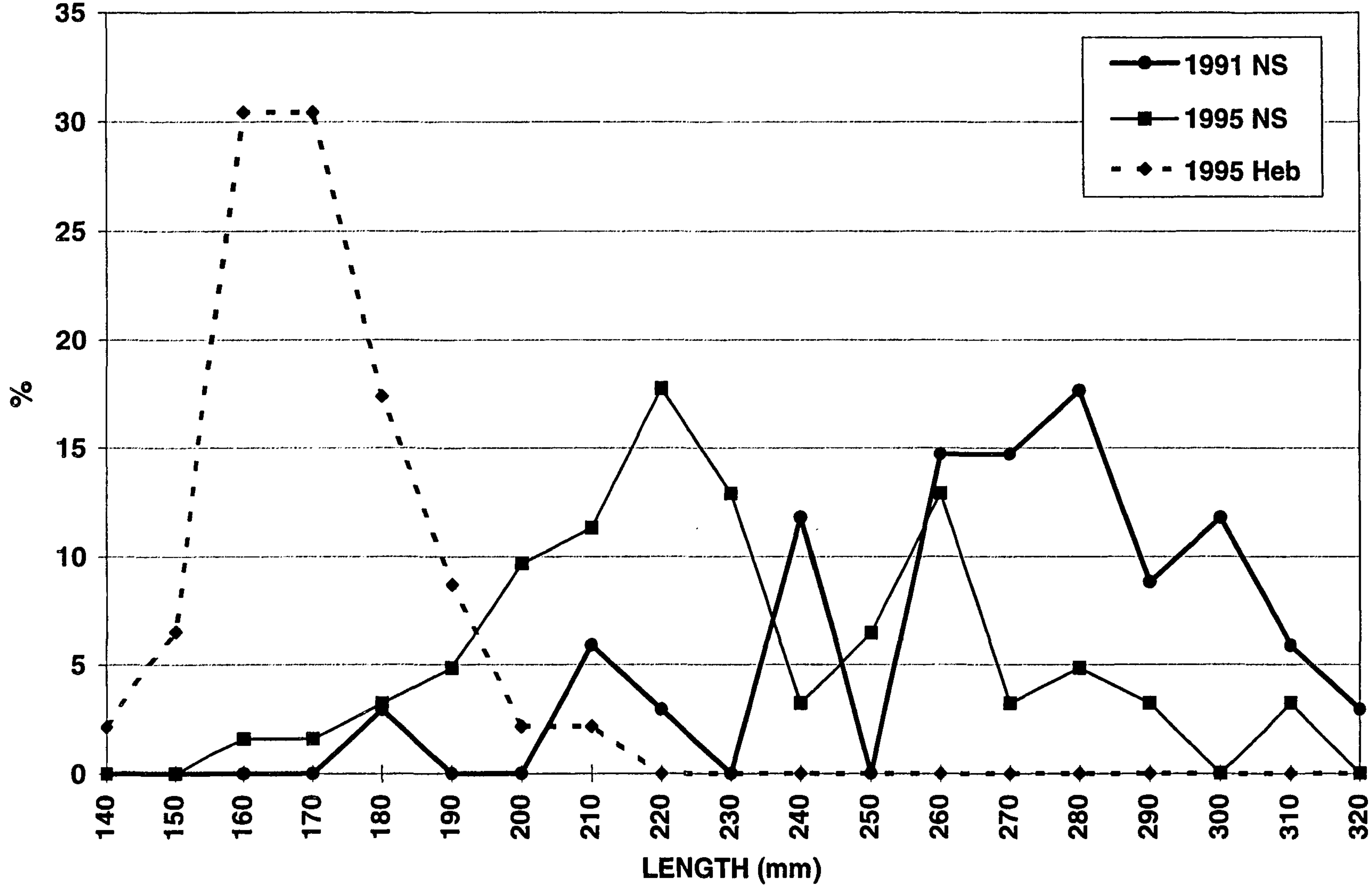

Figure 3. Length distribution of Atlantic salmon postsmolts caught in the Norwegian Sea (NS) 1991 and 1995, and off the Hebrides (Heb) in 1995.

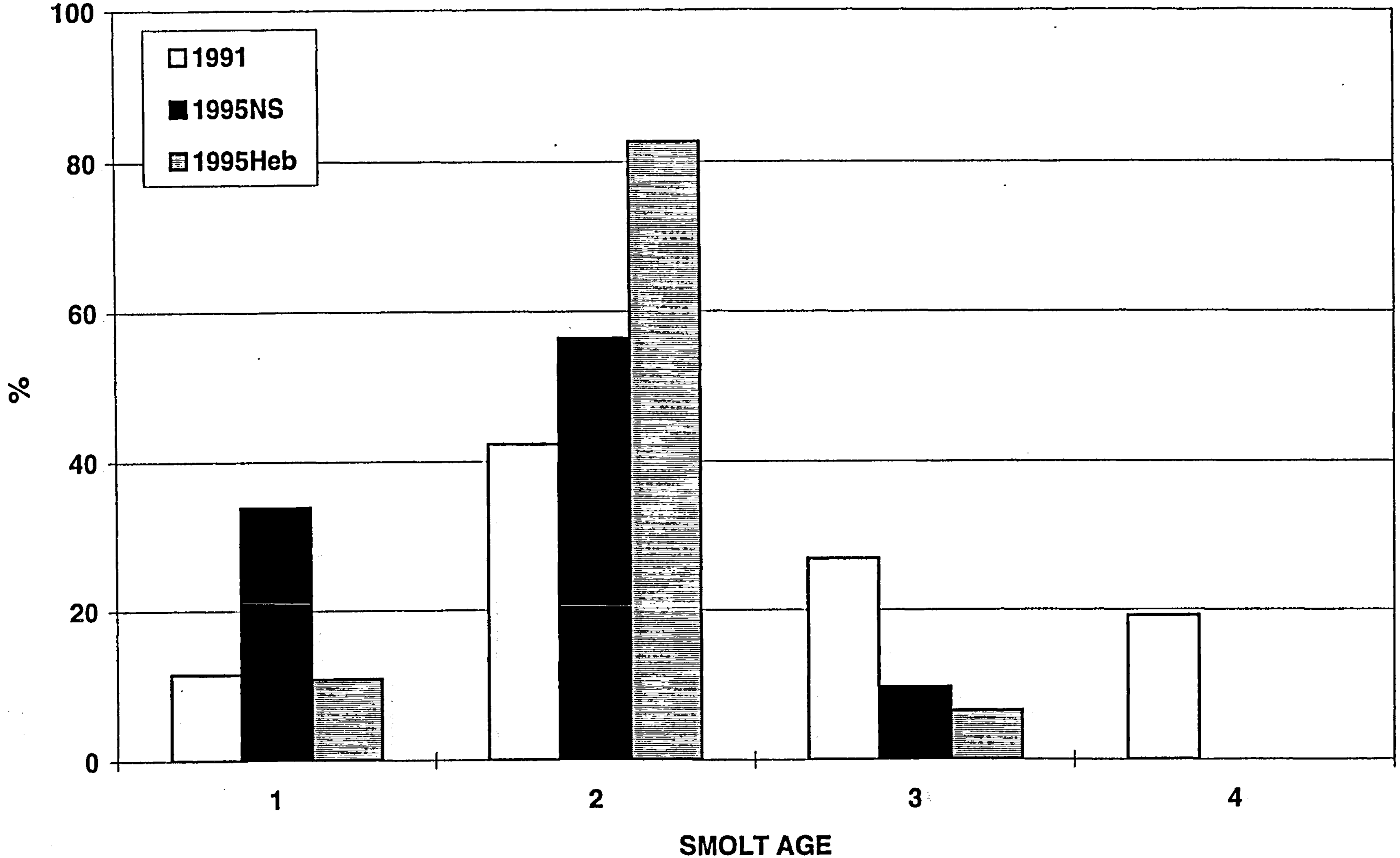

Figure 4. Smolt age distribution of postsmolts caught in the Norwegian Sea in 1991 and 1995 (NS) and off the Hebrides (Heb) in 1995.

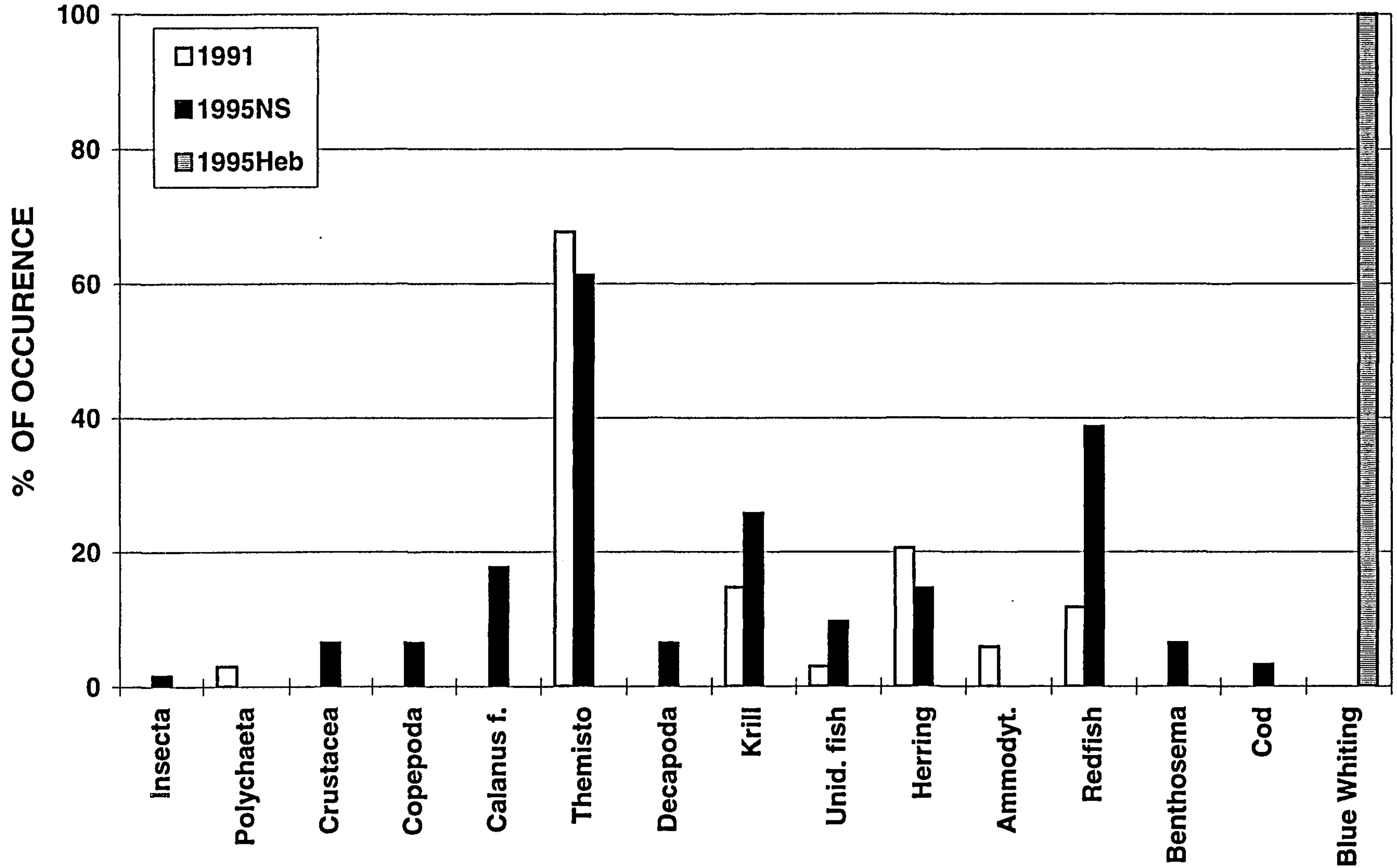

Figure 5. Percent of occurrence of the different food items observed in stomachs of salmon postsmolts in the Norwegian Sea in 1991 and 1995 (NS), and off the Hebrides (Heb) in 1995.

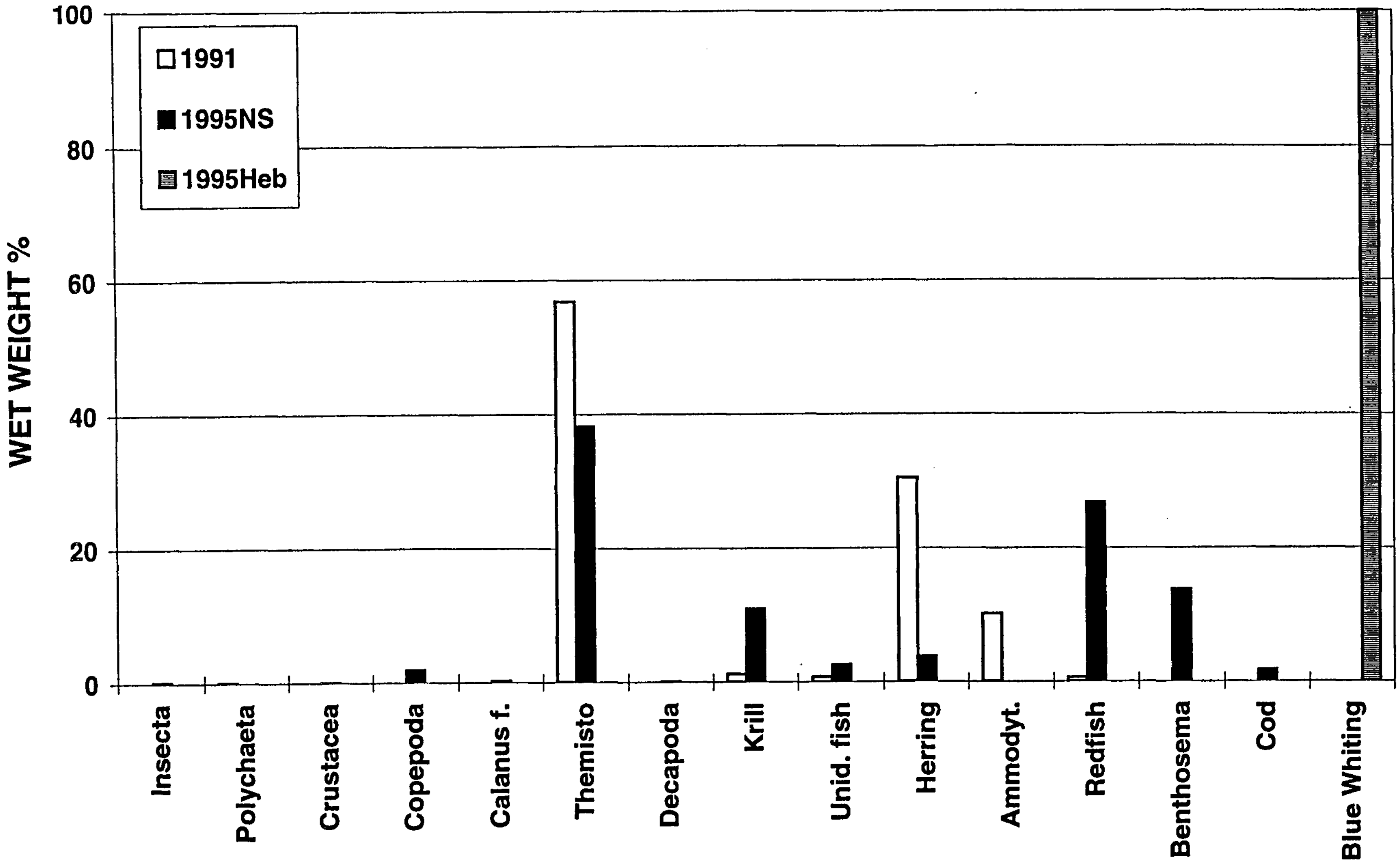

Figure 6. Wet weight percentage of different food items observed in stomachs of salmon postsmolts in the Norwegian Sea in 1991 and 1995 (NS), and off the Hebrides (Heb) in 1995.