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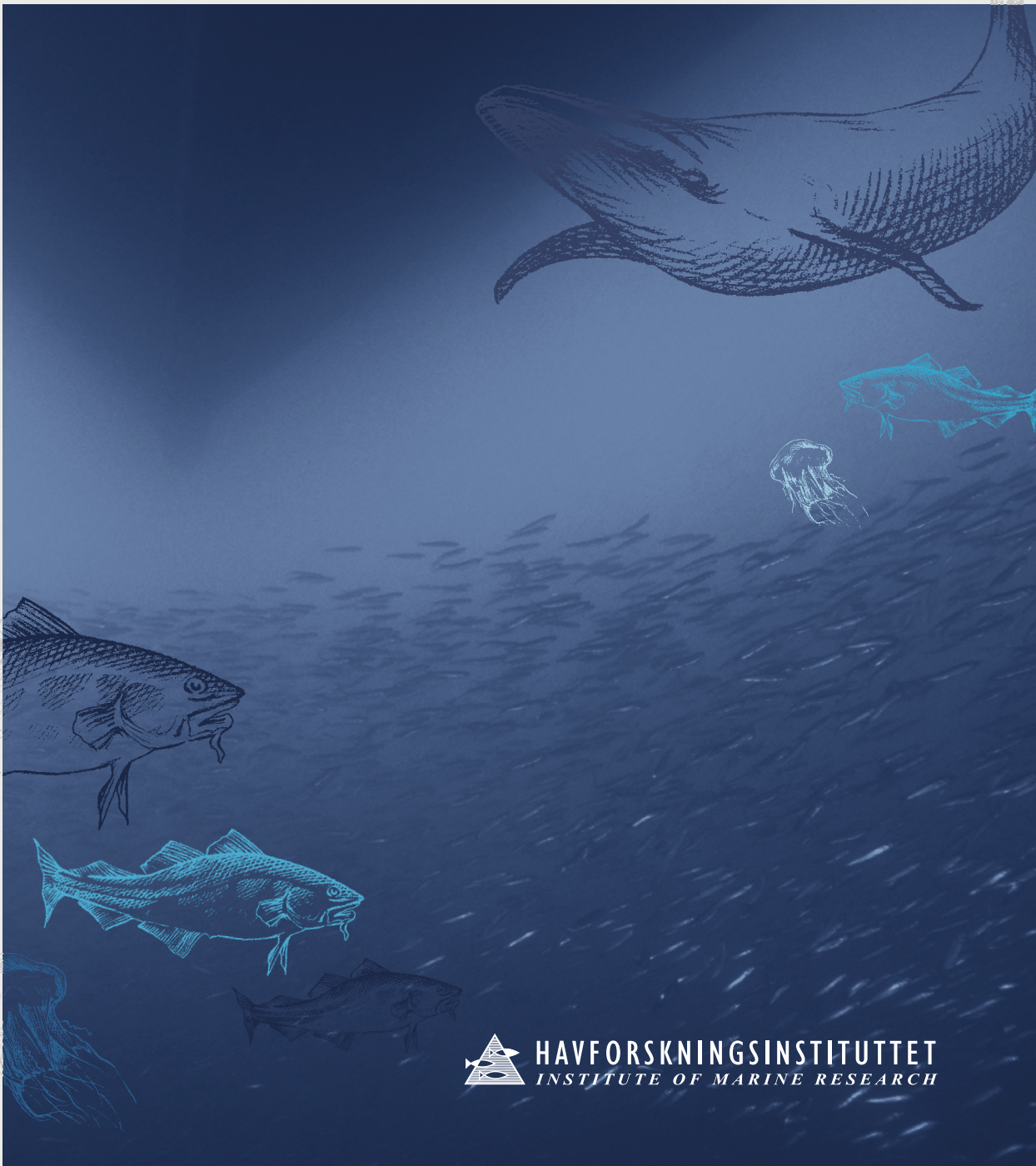
Report on the diet of the blue whiting in the Barents Sea in the summer 2005 and in the winters of 2002 and 2006

Inger Marie Beck, Kirsti Børve Eriksen, Mikko Heino, Edda Johannesen and Erik Olsen



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Forfatter(e): Inger Marie Beck, Kirsti Børve Eriksen, Mikko Heino, Edda Johannesen, Erik Olsen	

Sammendrag (norsk):
Vi undersøkte dietten til kolmule i Barentshavet i februar-ma2002 og 2006, og i august og september 2005. Krill var det viktigeste byttet til kolmula i Barentshavet, og utgjorde ca 90% av diett om vinteren og ca 50% om sommeren. Kolmula spiste også amfipoder og fisk, inkludert kolmule. Hoppekreps, som er viktig for kolmula i Norskehavet, utgjorde en ubetydelig andel av dietten.

Summary (English):
We analysed stomach content of blue whiting in the Barents Sea in February-March 2002 and 2006, and in August-September 2005. Krill was the most important prey for blue whiting in the Barents Sea, and constituted about 90% of diet in winter and 50% in summer. Blue whiting also fed on amphipods and fish, including blue whiting. Copepods, an important group of prey for blue whiting in the Norwegian Sea, was unimportant in the diet in the Barents Sea.

Emneord (norsk):	Subject heading (English):
1. Kolmule	1. Blue Whithing
2. Trofiske interaksjoner	2. Trophic interactions
3. Magedata	3. Stomach data

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Report on the diet of the blue whiting in the Barents Sea in the summer 2005 and in the winters of 2002 and 2006

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Background

Blue whiting (*Micromesistius poutasso*u) is a mesopelagic gadoid that is common and widespread in the north-east Atlantic. The Barents Sea is the northeastern fringe of the distribution of the blue whiting. There has been a marked increase in the abundance and distribution of blue whiting in the Barents Sea over the ten last years or so. This can be seen both from survey data and from the diet and estimated blue whiting consumption by cod in the Barents Sea (Figures 1 and 2). Fluctuations in blue whiting abundance in the Barents Sea is caused by variation both in recruitment in the Atlantic blue whiting stock and in inflow of Atlantic water in the Barents Sea (Heino et al. 2006). In years with strong inflow of warm Atlantic water, there is higher abundance and wider distribution of blue whiting in the Barents Sea (Heino et al. 2006).

Climate induced changes in distribution and abundance of some species influence other species in the ecosystems through ecological interactions, that is, competition and predator-prey interactions. In the case of blue whiting in the Barents Sea, this is demonstrated by the increase in importance of blue whiting as prey for cod, with a ten-fold increase in the proportion of blue whiting in cod diet the last ten years (0.4%, average 1984-2000; 4%, average 2001-2005, adapted from ICES 2006a). We wanted to further explore the ecological interactions of blue whiting in the Barents Sea. We therefore analysed blue whiting diet as a basis for evaluating the role of blue whiting as a predator and a food competitor in the Barents Sea ecosystem.

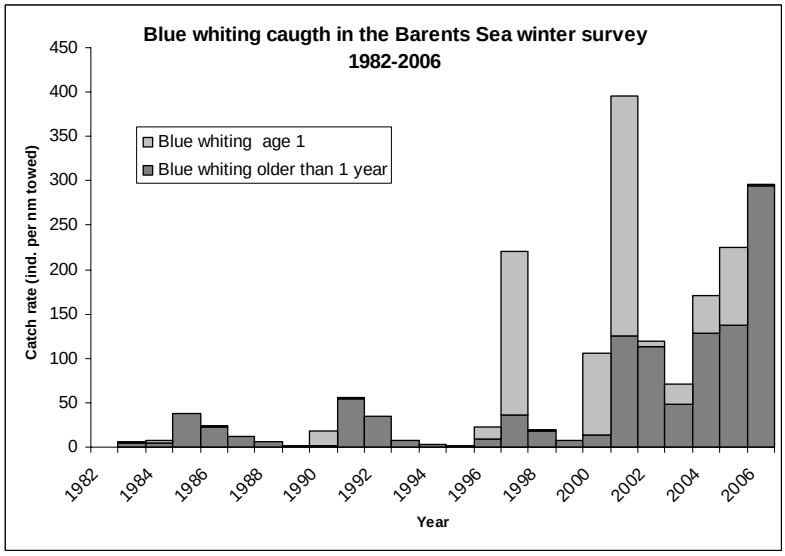

Figure 1. Catch rate (individuals per towed nautical mile, demersal trawls) in the Barents Sea in February 1982-2006. The light and dark part of the columns are the catch rate of one-year old (≤ 18 cm) individuals, and 2+ individuals, respectively. The data is taken from ICES (2006b).

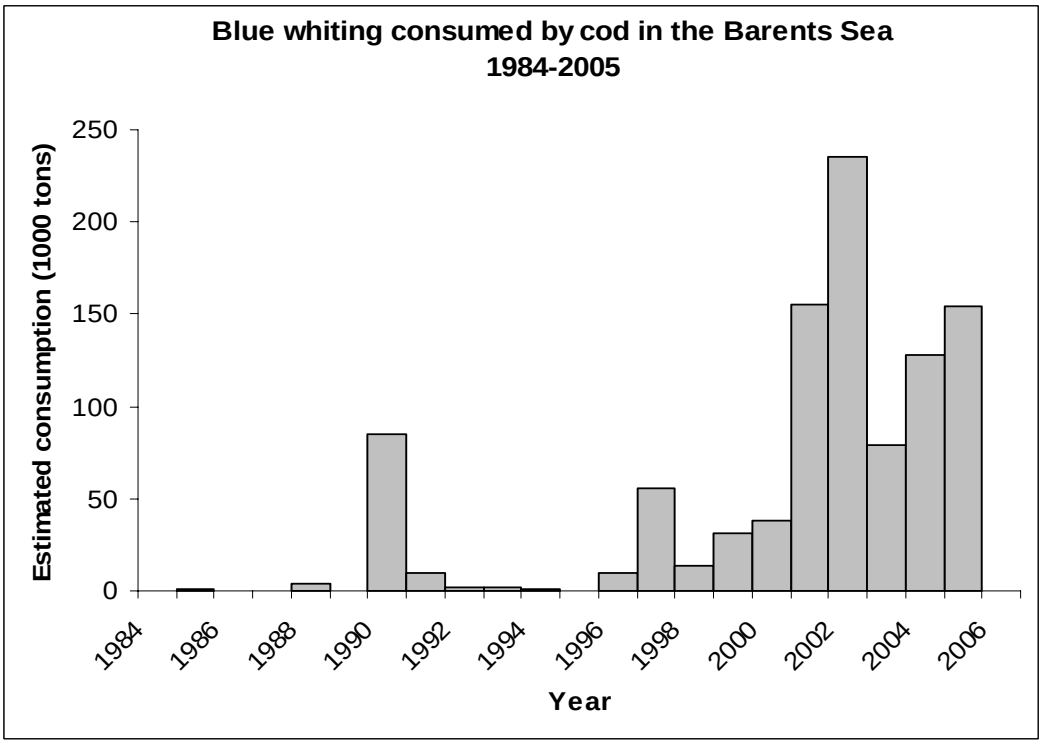

Figure 2. Consumption of blue whiting (in 1000 tons) by cod in the Barents Sea. The data are adapted from ICES (2006a). Consumption is estimated with the method described in Bogstad and Mehl (1996).

Material and methods

SAMPLING

The stomachs were collected at the "winter survey" (Jakobsen et al. 1997) in the Barents Sea in February-March 2002 and 2006, and at the joint IMR-PINRO ecosystem survey (Anon 2005) in the Barents Sea in August-September in 2005.

Table 1. Number of blue whiting stomachs and average lengths of blue whiting for which stomachs were sampled by month and year. The number of stations where blue whiting stomach samples were taken is given together with the gear used: P is pelagic trawl and D is demersal trawl.

Year	Sampling month	Average length (cm)	Number of stations/ Gear	Number of stomachs
2002	February	24.4	10 D	33
2005	August-September	25.7	78 D 4 P	266
2006	February-March	26.8	15 D	46

The stomachs samples were length stratified with one stomach taken per 5 cm length group of blue whiting in each station. At the Joint IMR-PINRO Ecosystem survey in August and September 2005, samples were collected in the western Barents Sea on board the R/V “G. O. Sars” and R/V “Johan Hjort”. Stomachs were collected at all stations where blue whiting were found with these boats (Figure 3). In the winter surveys in 2002 and 2006, stomachs were sampled only on some of stations where the blue whiting were found (Figure 4 and 5). Whole, individual, stomachs were frozen onboard.

LABORATORY ANALYSES

The diet analyses were done in the laboratory at IMR in 2006 and were conducted according to IMR’s standard procedures (Mjanger et al., 2005). At the lab the stomachs were thawed and opened carefully with small scissors. The contents were removed and placed in a petri dish, and water was added. The contents were studied under a binocular microscope and the species were identified, weighed and if possible counted and length measured. Photographs were taken of well-preserved prey specimens. All the trawl data and biological measurements were stored in IMR’s software system Regfisk 3.15.

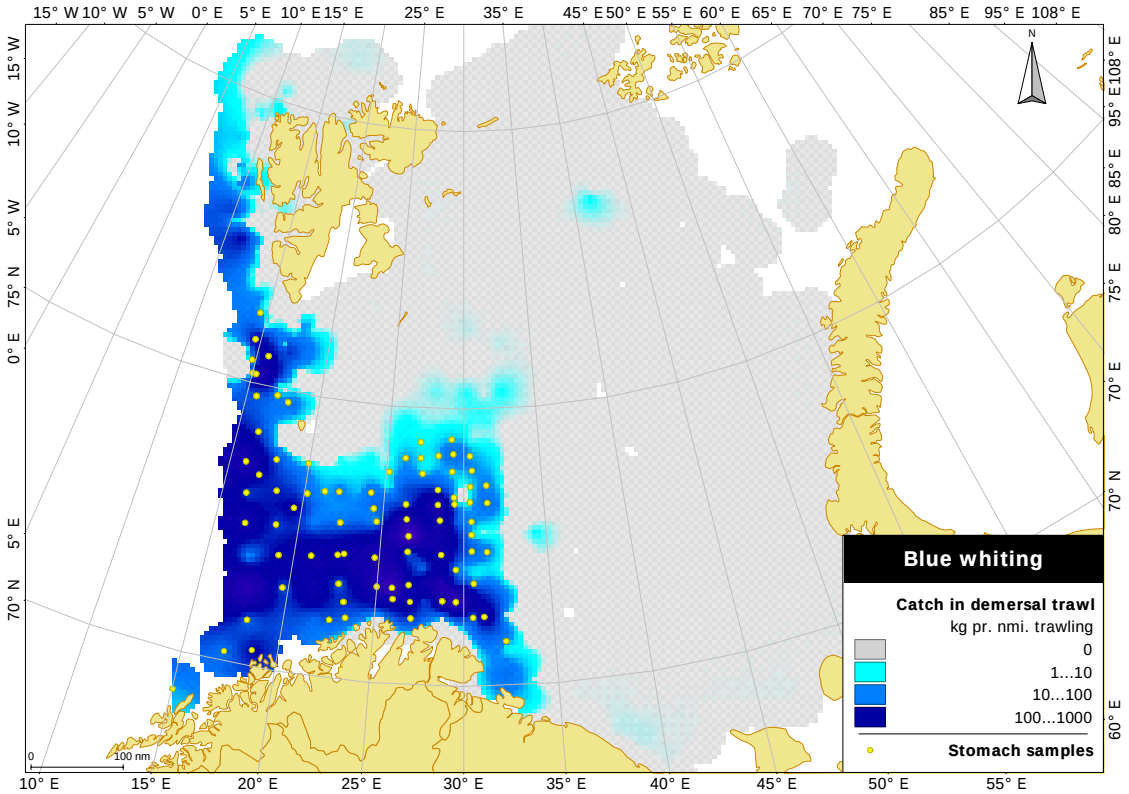

Figure 3. Distribution of blue whiting (blue) interpolated from trawl catches and stomach samples (yellow dots) in the Barents Sea in August – September 2005.

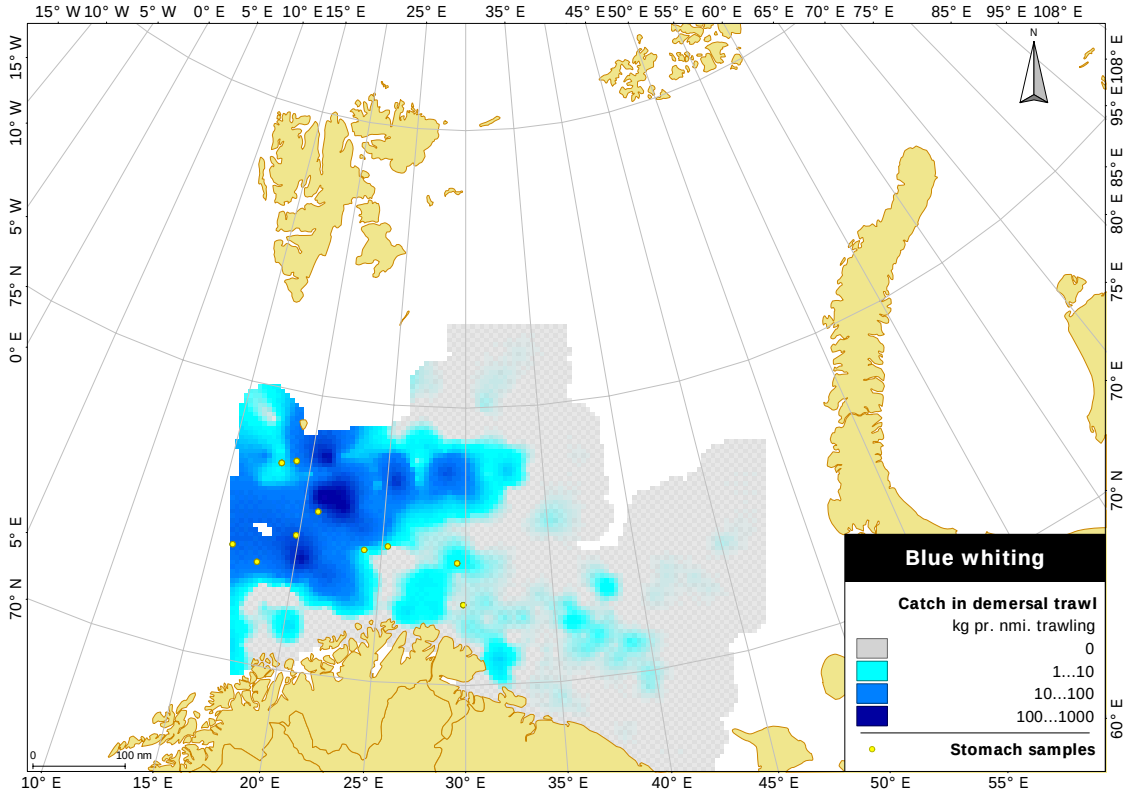

Figure 4. Distribution of blue whiting (blue) interpolated from trawl catches and stomach samples (yellow) in the Barents Sea February 2002.

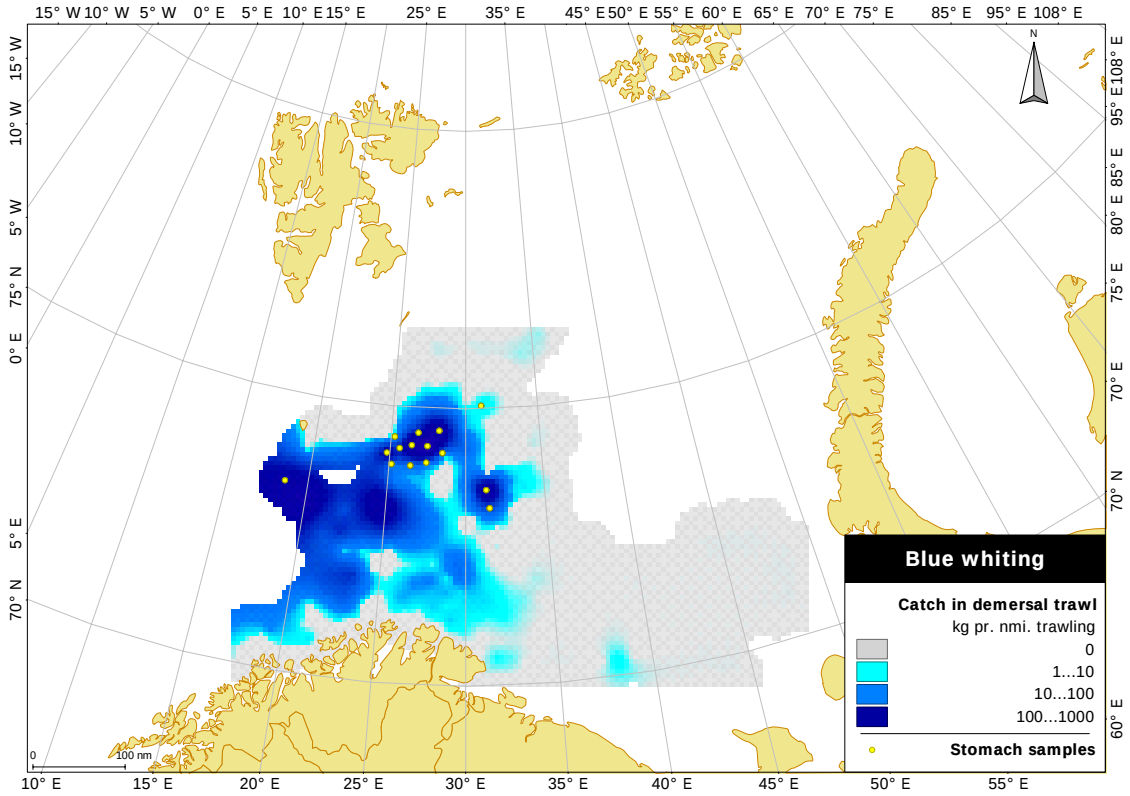

Figure 5. Distribution of blue whiting (blue) interpolated from trawl and stomach samples (yellow) in the Barents Sea February-March 2006.

Results

BLUE WHITING DISTRIBUTION

The distribution of blue whiting in the Barents Sea in the north and north-west seems to follow the polar front, with few blue whiting being encountered in the arctic water masses. Of the three years studied here, distribution of blue whiting in the Barents Sea was greatest in the summer of 2005. Comparing the winter seasons 2002 and 2006, we found that the distribution was broader in 2006 (Figure 4 and 5). The area coverage of the winter survey is smaller than the coverage in summer, but it seems like the distribution of blue whiting is much more southerly in winter than in summer.

DIET COMPOSITION

In winter 2002, 18% of stomachs were empty (6/33), whereas in winter 2006, 35% of stomachs were empty (16/46). In summer 2005, 18% of stomachs were empty (47/266).

Diet in summer was more diverse than in winter (Table 2, Figs 6-8). However, more stations were sampled in summer 2005 and both pelagic and demersal trawl was used (Table 1). Planktonic crustaceans dominated the diet, but to a lesser extent in summer than in winter.

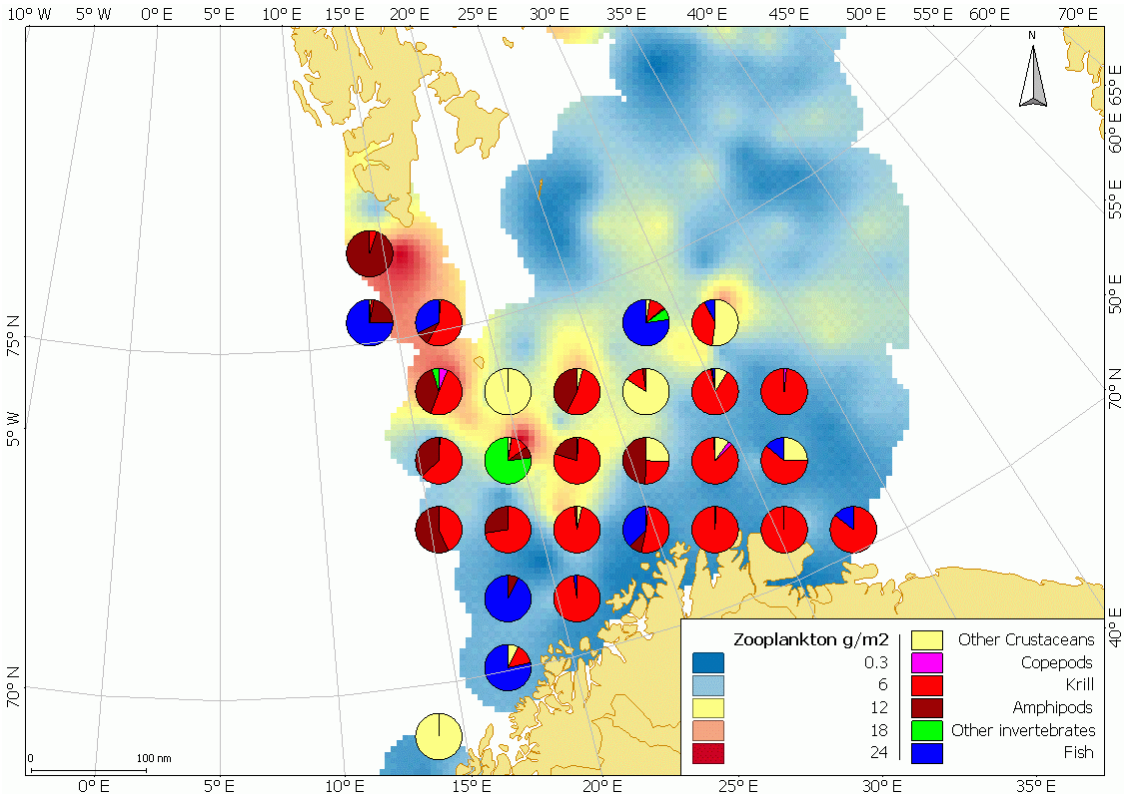

Figure 6. Pie charts of blue whiting diet in August-September 2005 for 60 by 60 nautical mile grid cells, seen in comparison of zooplankton distribution interpolated from zooplankton nets. The category "Other crustaceans" includes unclassified crustaceans (Table 2).

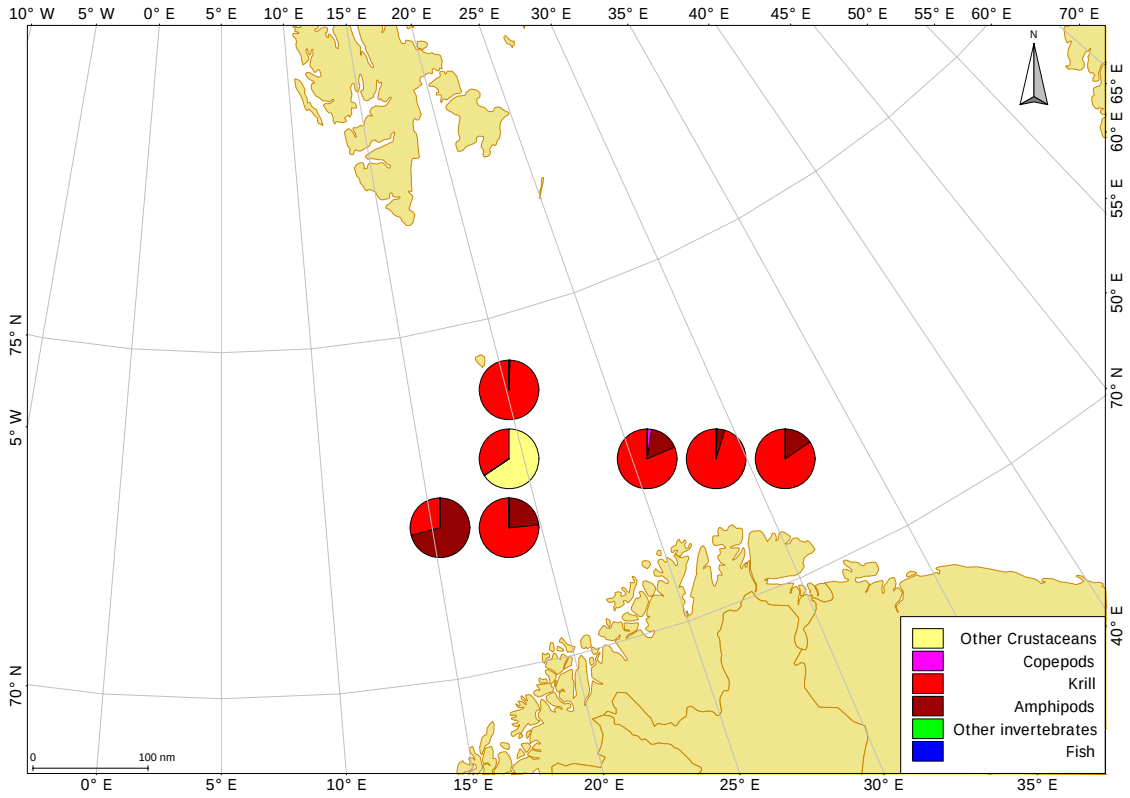

Figure 7. Pie charts of blue whiting diet in February 2002 for 60 by 60 nautical mile grid cells.

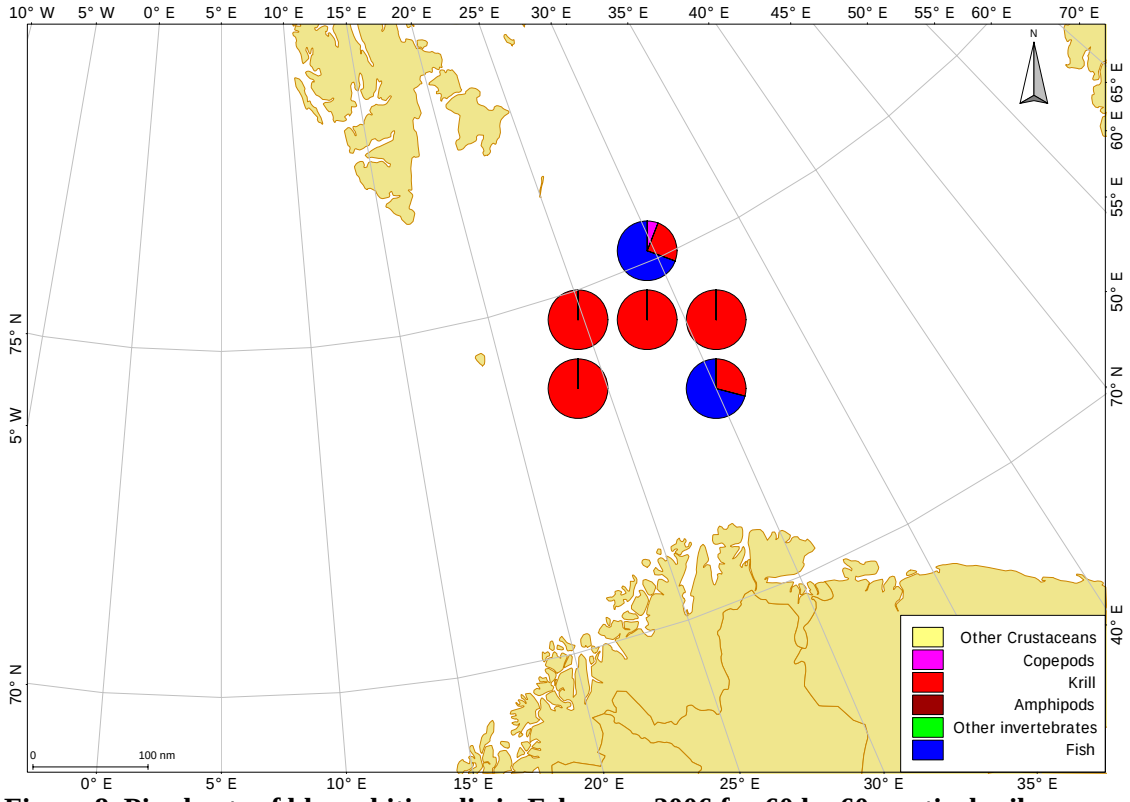

Figure 8. Pie charts of blue whiting die in February 2006 for 60 by 60 nautical mile grid cells.

Krill was important in both summer and winter. In most cases it was impossible to identify the krill to species level, because the specific characteristics needed for identification were destroyed. In some stomachs we nevertheless could identify both *Meganyctiphanes norvegica* and *Thyssanoessa inermis*, of which the former was the more important prey species (Table 2). Diet in winter was dominated by krill that represented almost 90% of the stomach content by weight (Table 2). In summer, 47% of diet was krill (Table 2).

Table 2. List of prey items with the number of stomachs in which they were present and weight %.

	Number of stomachs			Weight percentage		
Prey category	Winter 2002 n=33	Winter 2006 n=46	Summer 2005 n=266	Winter 2002	Winter 2006	Summer 2005
Copepoda	2	2	2	0.06	0.7	0.02
Calanus finmarchicus	0	0	2	0	0	0.03
Gaidius tenuispinus	0	0	1	0	0	0.01
Euchaedae	0	0	3	0	0	0.1
Sum copepods				**0.06**	**0.7**	**0.2**
Amphipoda	1	0	1	0.1	0	0.01
Themisto	1	0	0	0.2	0	0
Themisto libellula	2	2	33	0.1	0.07	3.3
Themisto abyssorum	5	0	43	1.0	0	5.7
Themisto compressa	1	0	0	0.3	0	0
Sum amphipods				**1.7**	**0.07**	**9.0**
Euphausiacea	9	15	105	63.3	41.8	25.8
Euphausiidae	0	0	13	0	0	18.8
Meganyctiphanes norvegica	10	13	5	24.2	45.1	2.6
Thysanoessa inermis	0	0	3	0	0	0.2
Sum krill				**87.5**	**87.0**	**47.3**
Crustacea (unidentified)	1	0	19	7.5	0	0.8
Mysida	0	0	7	0	0	1.1
Caridea	0	0	3	0	0	0.4
Pandalus	0	0	4	0	0	8.9
Pandalus borealis	0	0	7	0	0	4.3
Sum other crustaceans				**7.5**	**0**	**15.5**
Cephalopoda	0	0	1	0	0	0.03
Coleoida	0	0	1	0	0	0.03
Gonatus fabricii	0	0	2	0	0	6.1
Sum other invertebrates				**0**	**0**	**6.2**
Teleostei	1	1	7	0.01	4.4	2.2
Capelin	0	1	0	0	7.8	0
Pearlside	0	0	1	0	0	0.3
Gadidae	0	0	1	0	0	4.3
Cod	0	0	1	0	0	0.3
Blue whiting	0	0	4	0	0	11.6
Wolffish	0	0	1	0	0	0.5
Spotted snake blenny	0	0	2	0	0	2.3
Sum fish				**0.01**	**12.3**	**21. 6**
Indeterminatus	5	0	21	**3.2**	**0**	**0.3**

Amphipods constituted 9% of stomach contents by weight in summer and were present in ~29% of the stomachs (Table 2). Amphipods were found in ~30% of the stomachs in winter 2002, and in ~4% of the stomachs in the winter of 2006. Three different amphipod species were found: *Themisto libellula*, *T. abyssorum* and *T. compressa*, the first two being the most important (Table 2).

Copepods were unimportant as prey for blue whiting in both summer and winter in the Barents Sea (Table 2).

Shrimp were found in the stomachs only in summer and constituted ~13% of stomach contents by weight and were found in ~5% of the stomachs. Also cephalopods were found only in summer. They constituted 6% of stomach contents by weight, but were found in only 1.5% of the stomachs.

Fish constituted ~12 % of the diet by weight in the winter of 2006, and ~22% of diet by weight in summer 2005. Fish was found in ~3% of the stomachs in winter 2002 (in highly digested state), in ~4% of the stomachs in winter 2006, and in 6% of the stomachs in summer 2005. Findings of blue whiting otoliths in the stomachs indicate that blue whiting exhibit cannibalistic behaviour. Otoliths too digested for species identification were found in 10 stomachs. One wolffish was observed in one stomach and was identifiable by its skin and otoliths. We also found several snake blennies (*Leptoclinus maculatus*); these were less digested and easily identified by their general appearance. Cod, pearlside (*Maurolicus muelleri*) and capelin were also found in one instance each

DIET BY LENGTH

The proportions of empty stomachs by 5 cm length groups are depicted in Figure 8. The proportion of empty stomachs did not vary by blue whiting length (p=0.32).

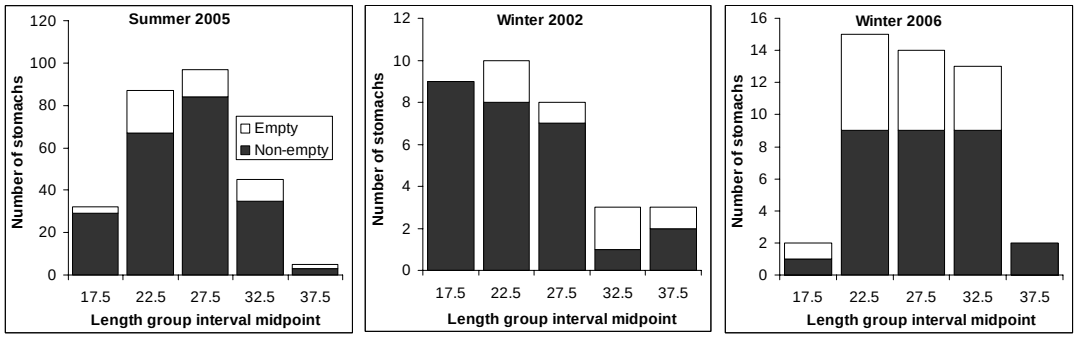

Figure 9. Proportion of empty stomachs according to 5 cm length intervals of blue whiting.

Diet composition (weight percentage) according to 5 cm length groups are shown in Figure 10. The probability of finding fish in the stomach did not increase with blue whiting length (p=0.84). This was an unexpected result. However, samples of large blue whiting were relatively few.

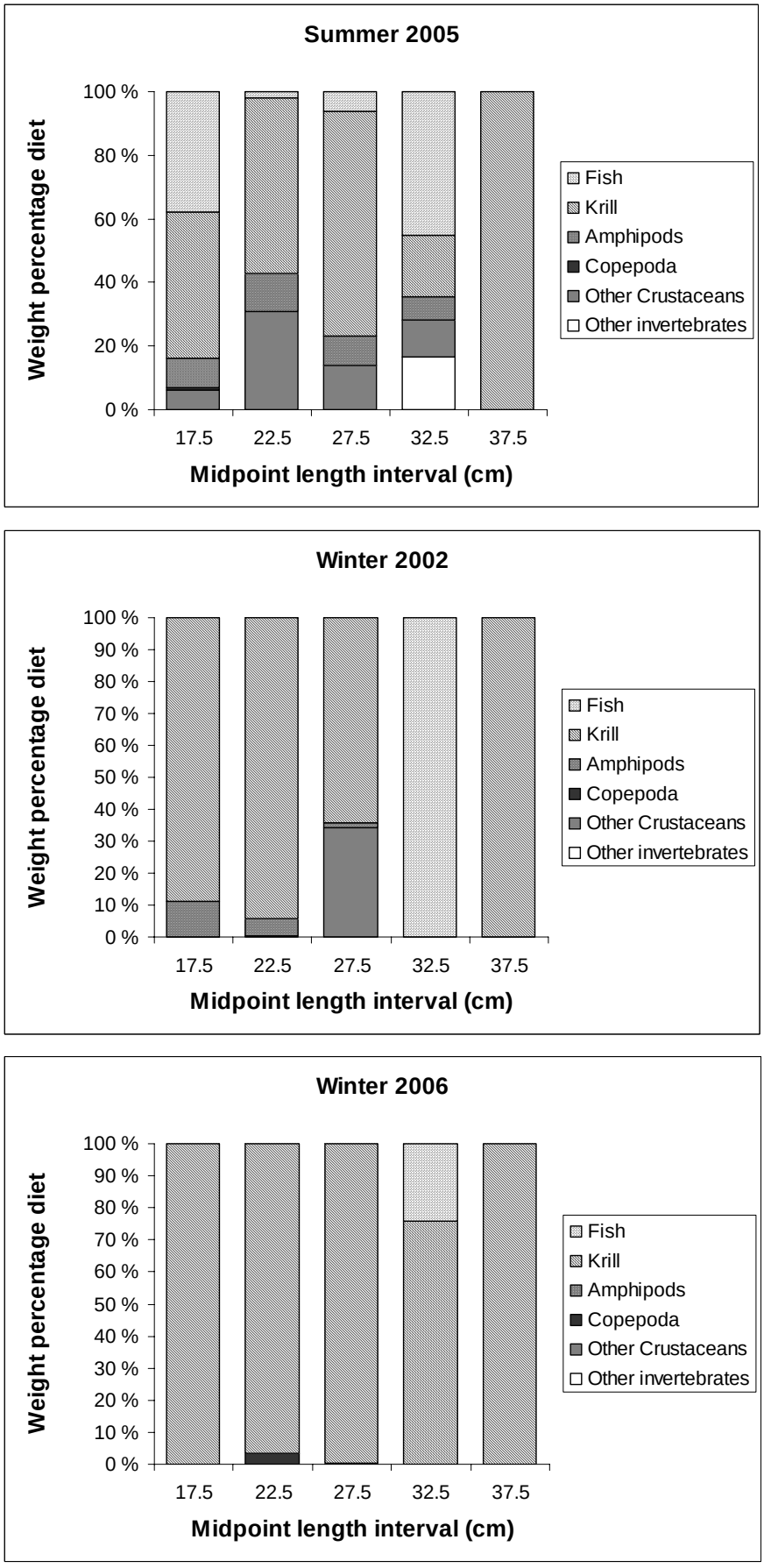

Figure 10. Diet composition (weight percentage) by 5 cm length groups of blue whiting in the Barents Sea.

Discussion and comparison with results from other areas

We have shown that the diet of blue whiting in the Barents Sea is dominated by krill. Blue whiting are feeding throughout the year, but the diet is more varied in summer than in winter. Especially in summer, there are significant spatial variations in the dominant diet components. However, the diet of blue whiting did not show consistent changes with individual body size.

Zilanov (1968, 1982) analysed the diet of blue whiting in the 1960's and 1970's in the Barents Sea. These are the only published studies on blue whiting diet in the Barents Sea to our knowledge. The result of Zilanov's investigations are similar to our findings: he found that krill was the most important prey of blue whiting in the Barents Sea, followed by small fish of various species and amphipods, mainly *Themisto* sp.

Zilanov (1968, 1982) also studied blue whiting diet in the Norwegian Sea, the areas around Iceland, Greenland, Ireland and at the Porcupine, Rockall and Flemish Cap banks. He found that krill was the most important prey in all areas. Krill (*Meganyctiphanes norvegica*) was reported as the most important prey of blue whiting in Skagerrak by Degnbol and Munch-Petersen (1985) and in the Norwegian Deep by Bergstad (1991a,b). Krill (*M. norvegica*) was also found to be the most important prey in winter off Portugal (Cabral and Murta 2002), and in southern parts of the Norwegian Sea in August by Dumke (1981). Dumke (1981) found that amphipods were more important than krill in the northern part of the Norwegian Sea around Jan Mayen and Spitsbergen in August.

Seasonal differences in diet were reported by Monstad (2004) in the Norwegian Sea. He reported that *Calanus finmarchicus* was important for small blue whiting in spring/early summer, but towards the end of the year, diet of small blue whiting was similar to that of older fish that mainly fed on krill but also on fish. In the Norwegian Sea and around the Porcupine, Rockall and Irelands shoals, Zilanov (1968, 1982) found that copepods, mainly *C. finmarchicus* were very important especially in spring. The importance of *C. finmarchicus* in spring/early summer in the Norwegain Sea was underlined by Prokopchuk and Sentyabov (2006) and by Plekhanova and Soboleva (1983) who found that blue whiting were distributed in areas with mass concentrations of *C. finmarchicus*.

We classified Norwegian Sea blue whiting stomach data from the Norwegian fish database and the joint IMR-PINRO stomach content database by season (Figure 11).

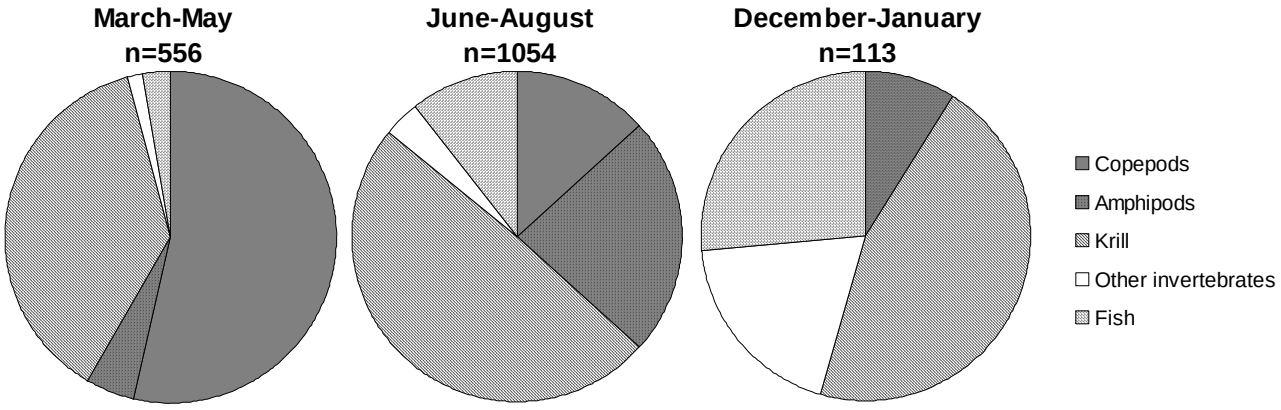

Figure 11. Diet composition (weight) in the Norwegian Sea 1985-1987 and 1995-1997. Data were sampled between 60.3°N and 71.5°N between 9.9°W and 15.2°E.

We found that copepods (mainly C*alanus finmarchicus*) were most important in spring,

Launch Internet Explorer Browser.lnk whereas amphipods, fish and other invertebrates (e.g. appendicularians, arrow worms, molluscs) became more important in diet in summer and in winter. Krill was important throughout the year.

To conclude, the diet of blue whiting in the Barents Sea did not differ dramatically from the diet in other areas, and in all areas and studies, krill, especially *Meganyctiphanes norvegica*, were important prey.

Seasonal variation in diet was found in all areas where sampling had been conducted in different months. We also found seasonal variation blue whiting diet in the Barents Sea, where krill dominated more in winter than in summer.

The main difference in blue whiting diet between Barents Sea and the Norwegian Sea was the importance of copepods, especially *C. finmarchicus* in the Norwegian Sea, a prey that was almost absent from the diet in the Barents Sea. The apparent lack of importance might be caused by the time of sampling, with no stomach sampling in spring/early summer in the Barents Sea.

The cannibalistic feeding of blue whiting has earlier been recorded by Dumke (1981), Zilanov (1982) and Cabral and Murta (2000) (see also the review by Bailey 1982).

We conclude that blue whiting is an important predator of krill, mainly *Meganyctiphanes norvegica*, and also of amphipods *Themisto sp*. in the western parts of the Barents Sea, where blue whiting has its core distribution area in the Barents Sea. Blue whiting is a competitor to other predators preying upon krill and amphipods. This as yet unquantified competitive interaction will be determined by spatial overlap between blue whiting and potential competitors.

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