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Diet composition of herring (*Clupea harengus* L.) and cod (*Gadus morhua* L.) in the southern Baltic Sea in 2007 and 2008

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Key words: diet composition; herring; cod; Crustacea; Baltic Sea

Abstract

Diet composition of two commercial fish species, herring and cod, were studied in some regions (mainly Gdańsk and Bornholm Basins, and the Polish coast) of the southern Baltic Sea in 2007 and 2008. Herring is the dominant zooplanktivorous species in the ecosystem of the Baltic Sea, but apart from mesoplanktonic organisms it also eats macroplanktonic and benthic species in considerable amount. The diet of cod consists of fish and crustaceans from pelagic, hyperbenthic and benthic habitats. The feeding preferences of fish indirectly reflect changes in the whole food chain in the Baltic Sea. This research focuses specifically on these invertebrate species, which are eliminated from the environment by most of the ichthyofauna of this region. The aim of this research is to examine the role of invertebrate organisms belonging to Crustacea in the diet of herring and adult cod to supply updated results about feeding of these fish as little data have been collected since the 1990s. The present study is a preliminary survey and results can not be considered conclusive. The restricted numbers of analyzed stomachs of fish and selected seasons of the year addressed in this paper are a starting point for further studies with a larger scope. In this study, 20 to 90% of herring had empty stomachs. Mesozooplankton dominated the diets of small and large herring. Mysidacea, which were historically important prey for herring, are now scarce and have been replaced by planktonic Amphipoda. In the case of cod, consumption of Mysidacea has never been as low as in this study. As for other invertebrate prey, the benthic isopod Saduria and Crangon shrimp achieved the highest amount by number and weight. These results show distinct changes in diet when compared to previous investigations and require verification at a larger spatial scale.

INTRODUCTION

The pelagic herring *Clupea harengus* L. and top-predator cod *Gadus morhua* L. are the most commercially important fish in the Baltic Sea (Möllmann et al. 2004). Fishery production in the southern Baltic Sea (central Baltic herring Subdivisions 25-27 and 32) is ten times higher than in the north. Spawning stock biomass (SSB) and harvest have systematically decreased in this region since the 1980s, related to a reduction in mean weights-at-age of herring. The decline was likely initiated by a change in the species composition of the zooplankton (prey) community and by an increased food competition between herring and sprat (Operation Programme 2008; ICESa 2010). Eastern Baltic cod stock (Subdivisions 25-32) is strongly driven by environmental factors. The high cod recruitment during the mid-1970s reflected a relatively high frequency of major inflows of high salinity water from the North Sea. The recruitment of this stock has diminished quite a bit since the mid-1980s. However, after a major inflow in 2003 the SSB of Eastern Baltic cod has been increasing according to BITS surveys (Baltic International Trawl Survey) (Andrulewicz 2009; ICESb 2010).

The diet composition of fish reflects changes in environment, which have consequences for maturation and growth of fish. Different prey species provide different energy source for fish, hence knowledge about food community is one link in the chain of understanding all processes that influence

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the condition of fish, with consequences for the fisheries.

Numerous studies on the diet composition of herring have been performed in different areas of the Baltic Sea (Popiel 1951; Załachowski et al. 1975; Hansson et al. 1990; Ostrowski, Mackiewicz 1992; Szypuła et al. 1997a,b; Flinkman et al. 1998; Möllmann, Köster 1999; Möllmann et al. 2003; Casini et al. 2004; Möllmann et al. 2004). Only a few of these recent articles are concerned with feeding of herring in the southern region of the Baltic Sea. Investigations of the food composition of cod were carried out as early as the 1950s and have continued irregularly since then (Reimann 1955; Chrzan 1962; Strzyżewska 1962; Załachowski et al. 1975; Załachowski 1977; Arntz 1978; Ostrowski, Mackiewicz 1992; Załachowski 1992; Uzars 1994; Uzars, Plikshs 2000). Since the 1990s no new data about cod diets from the southern Baltic Sea have been made available.

The aim of this study is to describe the diet and investigate the role of invertebrates of the subphylum Crustacea in the diet of herring and adult cod in the southern Baltic Sea. The size of the area under investigation comprises variable ecological niches from offshore to coastal waters, which are different habitats for the fish chosen in this study. The second basic objective of this research is to show the importance of macroplanktonic and nektobenthic crustaceans eaten by herring and adult cod. The share of these zooplankton groups in the diets of two chosen species of fish are compared with old data. In the southern Baltic Sea the significance of prey other than mesozooplankton in the diet of herring is greater due to its larger size in this area (Cardinale, Arrhenius 2000). The latest study of cod diets in the southern Baltic Sea concluded that Mysidacea was an important component of its food even for older one (Załachowski 1992). For this reason I especially focus on crustaceans in the diet of cod.

As this study is a preliminary survey carried out on a relatively small sample of fish, selected in the different seasons for herring and cod, the diet relationship between these species is difficult to assess. Decisive conclusions may be formulated through further studies of more comprehensive collections.

MATERIALS AND METHODS

Material for stomach analysis of fish was collected during cruises of the Sea Fisheries Institute's r/v 'Baltica' in the southern Baltic Sea. For better comparison with other data, ICES Subdivisions are marked on the map (Fig. 1).

Herring were caught in September 2008 in the Gdańsk and Bornholm Basins, Southern Middle Bank and Gotland Deep. These 10 hauls were carried

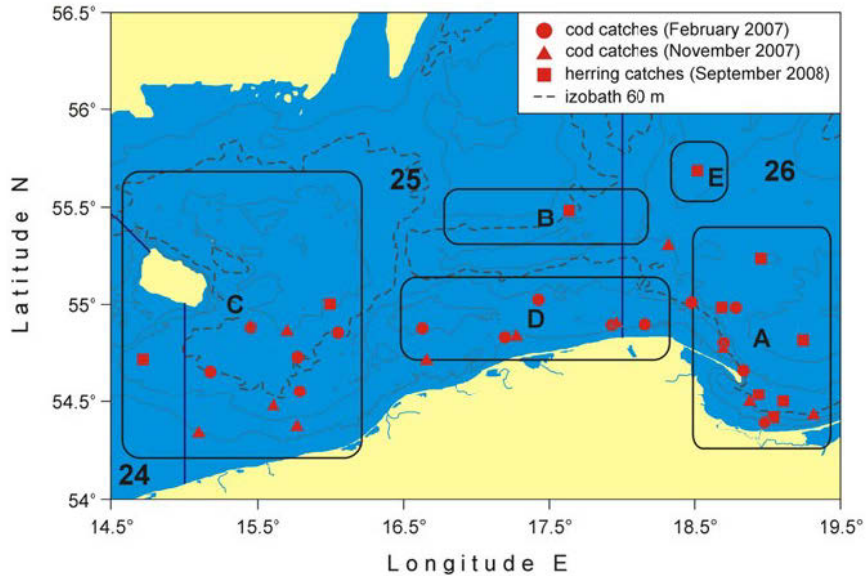

Fig. 1. Location of the fish catches on the bathymetric map (isobath every 20 m) of the southern Baltic Sea with regional division (A – Gdańsk Basin, B – Southern Middle Bank, C – Bornholm Basin, D – Polish coast, E – Gotland Deep) and identification of ICES Subdivsions (24, 25, 26).

out with WP 53/64x4 pelagic trawl at the depth of fish concentration, which ranged from 15 to 76 m as measured via echosounder during daytime. The standard time of fishing was 30 minutes. On board the vessel, herring were chosen randomly for total length (L_T) measurements (to the nearest 0.5 cm). Macroscopic examination of degree of stomach fullness was based on a 5 – grade scale (0 - empty; 1 - < half full; 2 - ~ half full; 3 - > half full; 4 - full) (Young, Davis 1992). Detailed diet analyses were conducted only from stomachs which were not empty. In the laboratory each stomach was removed from 4% buffered formaldehyde and dried for one minute on filtration paper. Food items were identified at the species level whenever possible (Sars 1903; Hayward, Ryland 1995) using an inverted microscope. All prey were counted, but only the biggest organisms, i.e. *Neomysis integer* and *Hyperia galba*, were measured to the nearest millimeter.

Cod samples were taken with tv3 – 930x80 bottom trawl in February (15 catches, ~ 20-99 m depth) and November 2007 (12 catches, ~ 19-75 m depth) during the daylight hours in the Gdańsk and Bornholm Basins and off the Polish coast. For a description of the differences in diet composition of cod caught from open sea versus coastal waters isobath 60 m was established as a border. All fish were measured to the nearest 1 cm (L_T). Stomachs of adult cod were preserved in 70% ethanol. Only the anterior part of the alimentary track (esophagus and stomach) was analysed macroscopically or under the inverted microscope. Each prey except for Pisces was determined to the lowest possible taxonomic level. Amorphous contents of digested food, which constituted a small percentage of the food in the stomach, were excluded from analysis. Identified items were counted and individually weighed to the nearest 0.01 g. Among these, size of planktonic crustaceans was determined with 1 mm precision and measured as length from the tip of the rostrum to the tip of the telson.

The content of a stomach was expressed as the percentage of different taxa, calculated from the number of identified items as well as, in the case of cod, from food biomass. From these percentages, means were calculated to represent the diet of fish in different regions of the southern Baltic Sea and on different dates. Differences in food composition were made also per length class of fish (width 2 cm for herring and 10 cm for cod) and grouping of planktonic organisms into several length classes depending on species.

RESULTS

Herring

A total of 1615 herring were analysed for determination of length distribution and degree of stomach fullness (Fig. 2). Herring varied in size between 10 to 28 cm with fish from 15.5 to 23.5 cm being most common. There were not marked

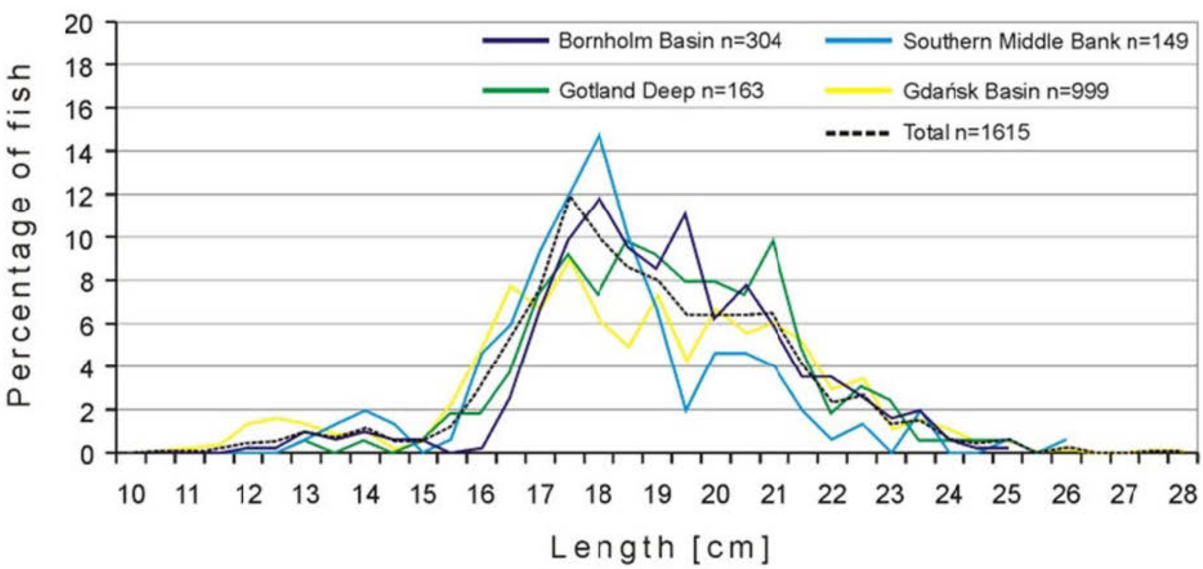

Fig. 2. Herring length distribution [%] in the southern Baltic Sea in September 2008.

differences in the number of herring from all length classes between regions of the southern Baltic Sea except for the Southern Middle Bank, where herring from the 17.5 cm length class constituted close to 20%. No herring stomach was full of food (4), and the majority of macroscopically analyzed stomachs were empty (0); 90% of stomachs from the Southern Middle Bank as well as 20% of stomachs from Gdańsk and Bornholm Basins, respectively, were empty. Nearly 60% of herring stomachs from Bornholm Basin had low food content (1). Stomachs around half full (2) were recorded in over 60% of herring stomachs from Gotland Deep. Less than 10% of all examined fish from four areas of the southern Baltic Sea had full stomachs (3) (Fig. 3).

Detailed analysis was conducted on 60 herring stomachs. Crustaceans dominated (95%) in the herring diet. Among these, cladocerans and copepods were most common, whereas organisms from the orders Mysidacea, Decapoda, Amphipoda and Cumacea were less abundant. The following species were found in herring stomachs: *Bosmina coregoni maritima* (Bosmina), *Podon intermedius*, *Podon leuckarti*, *Pleopsis polyphemoides* (Podon), *Evadne nordmanii* (Evadne), *Pseudocalanus minutus elongatus* (Pseudocalanus), *Temora longicornis* (Temora), *Centropages hamatus* (Centropages), *Acartia bifilosa*, *Acartia longiremis*, *Acartia tonsa* (Acartia), *Neomysis integer* (Neomysis), *Crangon crangon* (Crangon), *Hyperia galba* (Hyperia), and *Diastylis rathkei* (Diastylis). Besides Crustacea, some larvae of Bivalvia, Pisces and Polychaeta were also recognized. Names in parentheses were used in Figure 4 and food content was expressed as the average numeric composition of prey in the stomachs. Among copepods *P. minutus elongatus* dominated (40% of food content), in herring stomachs from Gdańsk Basin and Gotland Deep. Mysid *N. integer* and amphipod *H. galba* (14% respectively) were not of any significance in the diet of herring from Gdańsk Basin. *T. longicornis* (20%) and *C. hamatus* (10%) were also of little consequence in the diet of herring from Gotland Deep. Cladocerans, mainly *B. coregoni maritima*, were clearly prominent and exceeded 60% of the food in the stomachs of herring from the Middle Southern Bank. However, the proportions of food contents in herring stomachs from Bornholm Basin were mostly balanced between various species: *B. coregoni maritima*

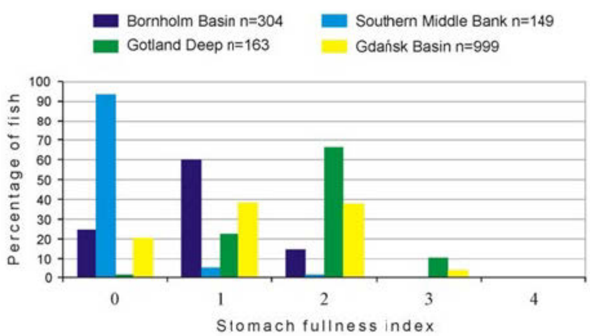

Fig. 3. Degree of herring stomach fullness on a scale of 0 to 4.

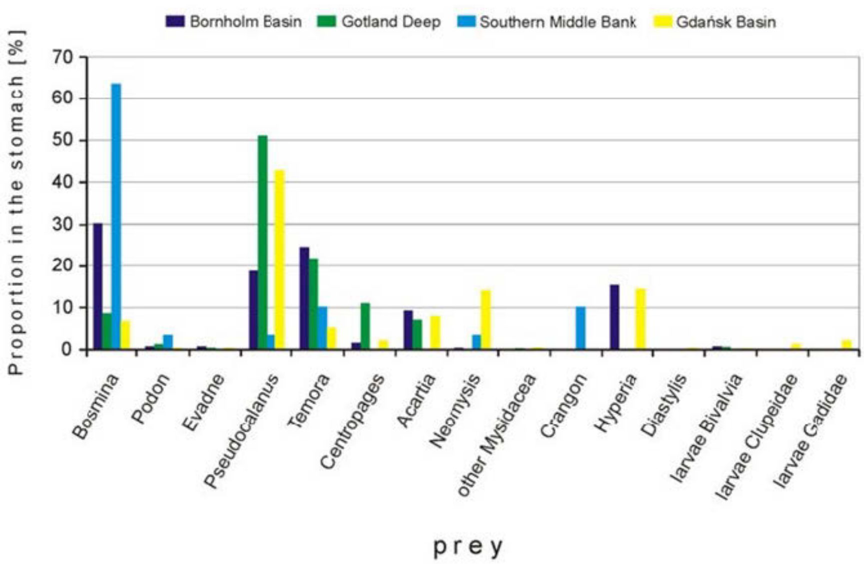

Fig. 4. Numeric composition [%] of prey in herring stomach from the different regions of the southern Baltic Sea in September 2008.

– 30%, *T. longicornis* – 25%, *P. minutus elongatus* – almost 20% and *H. galba* – 15%. Single prey of other groups (cumaceans, larvae of molluscs or fish and polychaetes) held an inconsequential share of the herring diet.

Due to the small number of fish analyzed in the Southern Middle Bank, results from this area were not used in calculating the frequency of occurrence of food components of the herring diet; only three areas of the southern Baltic Sea were taken into consideration for this calculation (Fig. 5). Cladocerans and copepods were included in all herring stomachs from Bornholm Basin and Gotland Deep. Larvae Bivalvia were noted in 65% of examined stomachs from Gotland Deep and individuals of Amphipoda were noted in 30% of stomachs from Bornholm Basin. Frequency of occurrence of the smallest zooplankton in herring stomachs from Gdańsk Basin was 70%, 30% for Amphipoda and 25% for Mysidacea. Parasites were observed in about 20% of the herring stomachs analyzed from Gdańsk Basin.

Prey selectivity by herring is shown in Figure 6. Small herring (<16 cm in length) selected only Copepoda and Cladocera. The fish from 16 to 17 cm in length fed on cladocerans and copepods (60%) and Amphipoda (40%). Preference for amphipods decreased for larger herring until fish reached the 24-25 cm length class, when the percentage of amphipods increased again to 40%. Mysidacea (10%

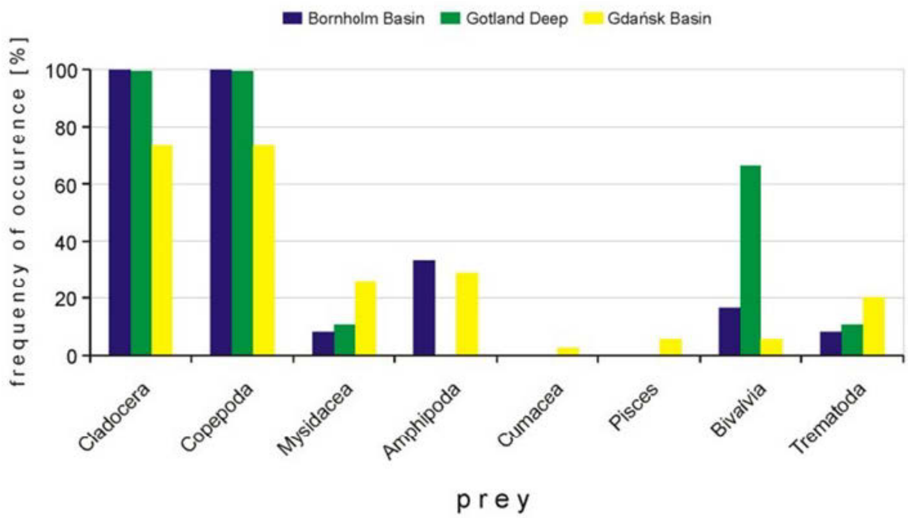

Fig. 5. Frequency of occurrence [%] of food and parasites in herring stomach from the southern Baltic Sea in September 2008.

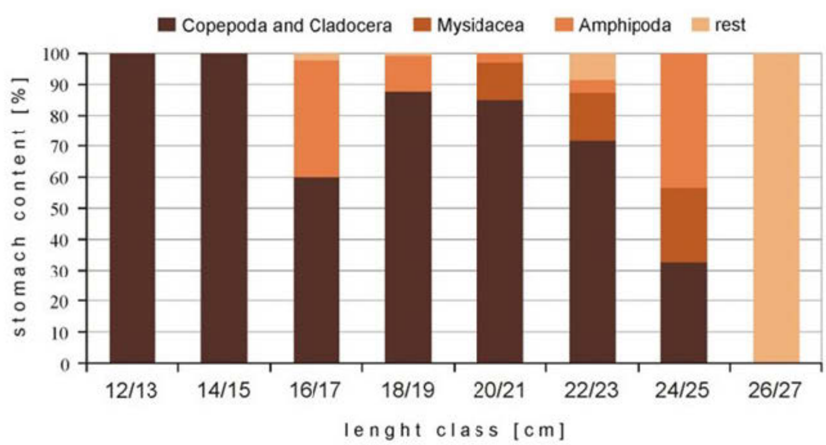

Fig. 6. Diet composition [%] of herring per length class (rest: Decapoda, Cumacea, larvae of Bivalvia and Pisces; southern Baltic Sea; September 2008).

of food content) appeared first in the stomachs of herring 20 cm in length. Positive selection for Mysidacea was observed with increasing body size of herring to 25 cm. The largest analysed fish (26-27 cm length class) had stomachs full of larvae of Pisces of size ranging from 20 to 50 mm. Differences in the prey size distribution in relation to length class of herring was analysed only for two stomach components: *N. integer* and *H. galba* (Fig. 7). Individuals of fish from 20 to 23 cm length class fed

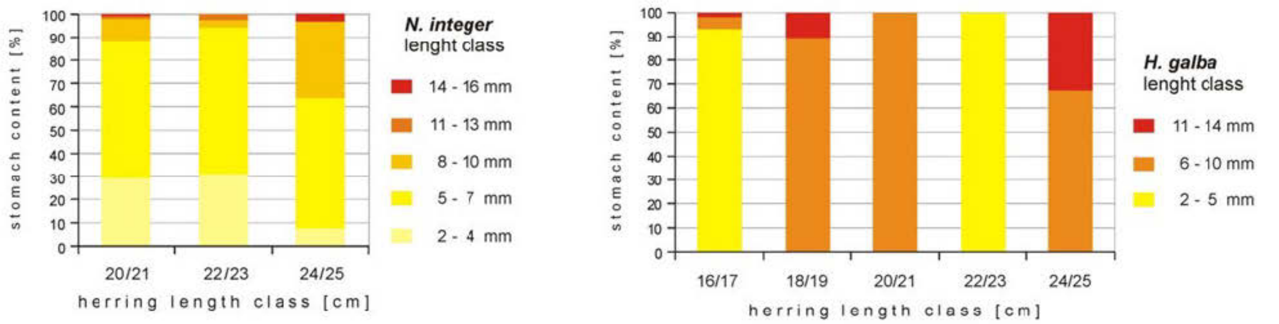

Fig. 7. Size distribution of herring and its stomach components (*Neomysis integer*, *Hyperia galba*).

mostly on smaller mysids from 2 to 7 mm. Larger mysids (5-10 mm in length) were found in the stomachs of larger herring (24-25 cm length class). In fact, larger mysids comprised almost 90% of the contents. The maximum size of mysids in these stomachs was 16 mm in length. The smallest size class of *H. galba* (2-5 mm) was found in stomachs of both smaller (16-17 cm) and larger (22-23 cm) herring. Nearly 40% of the largest (11-14 mm) and 60% of smaller (6-10 mm) amphipods were recognized in stomachs of herring from the 24-25 cm length class.

Cod

Food analysis was performed on the stomachs of 78 adult cod caught during winter and on the stomachs of 93 cod caught during the autumn of 2007. The fish were from 25 to 56 cm in length. The most abundant and important prey items were Pisces, mainly from the families Clupeidae, Ammodytidae and Gobiidae. The rest of the cod diet included crustaceans and organisms from class Bivalvia and Polychaeta, which were disregarded on the graph of diet composition of cod because they were eaten in such small numbers. Five orders and 12 species of Crustacea were identified, constituting 26% (mean for the whole study area based on wet weight biomass) of cod diet in November and only 11% in February. *Mysis mixta* (Mysis), *Neomysis integer* (Neomysis), *Crangon crangon* (Crangon), *Gammarus zaddachi*, *Gammarus salinus*, *Gammarus oceanicus*, *Gammarus locusta* (Gammarus), *Hyperia galba* (Hyperia), *Pontoporeia femorata* (Pontoporeia), *Diastylis rathkei* (Diastylis) and *Saduria entomon* (Saduria) were eaten by cod in both seasons. See figures 8 and 9 for a complete list of prey items, using the names in parentheses above. Mysids, decapods and isopods made quite significant contribution to the cod diet when looking at the numeric composition of prey (Fig. 8). The contents of cod stomachs from the coastal waters of Gdańsk Basin contained approximately 40% *M. mixta* in November and 20% of this species in February. Differences in *M. mixta* consumption in relation to the depth of catch were easy to see. As depth increased, the share of *M. mixta* declined. Below 60 m in Gdańsk Basin the proportion of this species in cod stomachs reached 5% in February. In other analysed regions of the southern Baltic Sea *M. mixta* constituted an inconsequential share among prey items of cod except for fish from the coastal waters of Bornholm Basin (17% - November; 8% - February). *N. integer* accounted for about 22% of the total number of prey in cod stomachs from the Polish coast in February. In this period the latter fish also fed on *C. crangon* (30%) and *S. entomon* (22%), whereas in November they fed less intensively on these prey. In the autumn *C. crangon* dominated in cod stomachs from coastal waters of the Gdańsk (16%) and Bornholm (33%) basins. *S. entomon* held a prominent role in diet composition for winter cod from coastal waters of Bornholm Basin and the Polish coast (each 20%). They were the most common prey consumed in November for cod from the open sea of Gdańsk Basin (over 50%). Among the remaining Crustacean

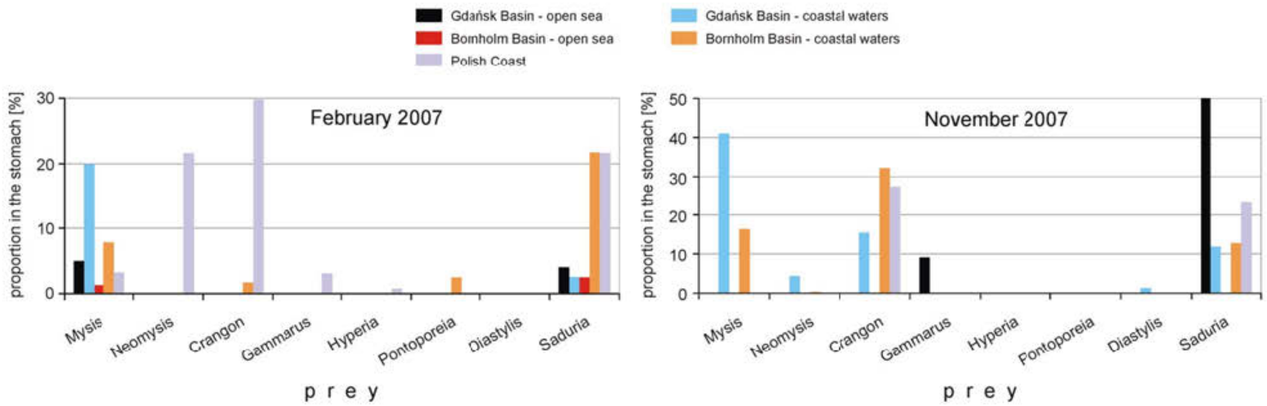

Fig. 8. Numeric composition [%] of prey (Crustacea) in cod stomach from the different regions of the southern Baltic Sea in February and November 2007.

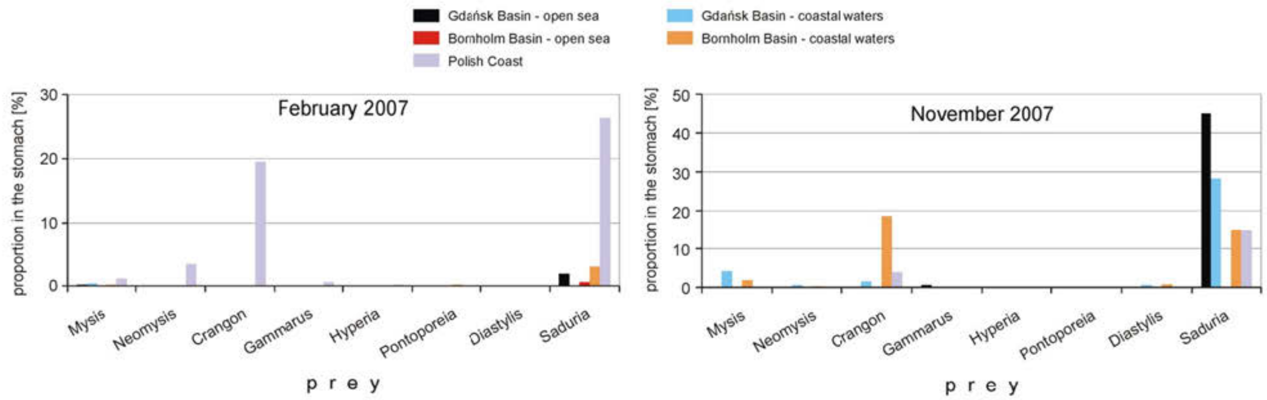

Fig. 9. Weight composition [%] of prey (Crustacea) in cod stomach from the different regions of the southern Baltic Sea in February and November 2007.

species only *Gammarus* sp. appeared in cod stomachs. It was found in relatively small but noticeable numbers. Pisces were predominant in the diet composition based on weight of prey items. That is why Crustacea as measured by weight (Fig. 9) showed less importance in the diet than it did when measured by number of individuals. Decapods and isopods were the only crustaceans consumed in considerable amounts. It was recorded that *C. crangon* gained importance with 20% of the total weight of prey items for cod from the Polish coast in February, but only 4% in November. In the last period *C. crangon* was dominant (close to 19%) among crustacean for cod from the coastal waters of Bornholm Basin. In autumn *S. entomon* was most common in cod diets when data from the open sea of Bornholm Basin were removed. Cod caught in November at deeper stations of Gdańsk Basin had a large percentage (over 40%) of *S. entomon* in the stomach. In contrast, the share of this isopod in cod diets was very small in February in this part of the southern Baltic Sea. In winter a large share of *S. entomon* (26%) was observed only in shallow area between 20 and 33 m depth (Polish coast). The weight share of mysids was low, e. g. *M. mixta* did not exceeded 4% of the diet of adult cod from coastal waters of Gdańsk Basin in November. Fish from the Polish coast held a recognizable share of *N. integer* (4%) in winter.

Pisces were observed in almost all cod stomachs from the southern Baltic Sea in both study periods and it was the only food found in the stomachs of cod from the open sea of Bornholm Basin in November (Fig. 10). In a deeper subarea of Gdańsk Basin the frequency of occurrence of fish in cod diets was only 50%. Gdańsk Basin cod preyed upon Isopoda 33%. Frequency of occurrence of Mysidacea in cod stomachs was higher in November (about

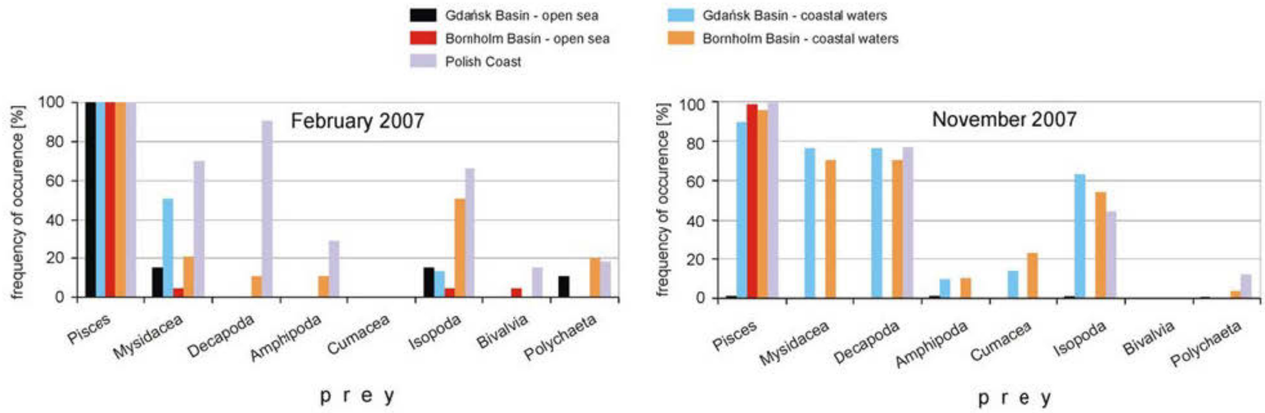

Fig. 10. Frequency of occurrence [%] of food in cod stomach from different regions of the southern Baltic Sea in February and November 2007.

75%) than in February, but unlike in winter, mysids were recognized in autumn only in cod stomachs from the coastal waters of Gdańsk and Bornholm Basins. Decapoda from all coastal waters were observed in November (in 75% of stomachs), but in February only for cod caught along Polish coast. Isopoda were frequent in stomachs of autumn cod (average 40%) as well as winter cod (average 29%), but the percentage of isopods was lower for cod from Gdańsk Basin in February.

Data indicate size selection of main food groups by cod (Fig. 11). Differences between seasons concerned fish from the 30 – 39 cm length class, which consumed more decapods in February (30%) than in November (17%). Smaller cod individuals (25 – 29 cm) significantly selected decapods (68%) and mysids (23%), while larger cod primarily ate fish. Medium size cod (30 – 49 cm) selected mainly isopods and decapods as well as mysids in small amounts (up to 4%). Generally isopods were only eaten by cod longer than 50 cm.

To show the size distribution of cod corresponding to its planktonic stomach contents the author has chosen only those species which were of great importance to the cod diet (Fig. 12). *C. crangon* eaten by autumn and winter cod were from 9 to 50 mm in length. Medium size shrimps (21 – 30 mm) prevailed in the diet of medium size cod (30 – 49 cm), comprising half of the total share in November. *N. integer* of 14 – 18 mm were found in great amounts in the diet of winter cod, while the smallest *N. integer* (10 – 13 mm) did not exceed 33% of food composition for cod from the 30 - 39 cm length class. Minimal size of *M. mixta* identified in autumn cod stomachs was 15 mm and the biggest was 25 mm. Larger mysids (20 – 25 mm) were more common and reached 73% of the diet for cod between 30 and 39 cm long.

DISCUSSION

In the present study trends in the feeding ecology of herring and cod, with an emphasis on the share of crustaceans in their diet, were investigated. Thus, despite lack of data about the structure of the zooplankton assemblage in the environment of the southern Baltic Sea, the observed diet composition of these two fish indirectly reflects indirectly the changes in the Baltic plankton community in 2007 and 2008. For herring, autumn was chosen for the collection period, because it corresponds to the time of most intensive feeding by this pelagic fish (Hansson et al. 1990). Certain macroplanktonic and nektobenthic crustaceans may be more intensively consumed by cod in autumn than at other times of the year (Załachowski 1992), thus autumn was chosen to compare with winter.

The feeding success of fish can be characterized by the proportion of empty stomachs. Unfortunately, in the case of herring, a huge number of fish with empty or nearly empty stomachs were caught, mainly in the area of Bornholm Basin and the Southern Middle Bank. Popiel (1951) suggested that stomachs of herring caught in the morning had low food content in contrast to fish from catches in the middle of the day. Moreover, Cardinale et al. (2003) pointed out that herring in the southern Baltic Sea fed upon zooplankton mainly at twilight. However, the degree of fullness of stomachs in this paper was calculated based on the mean from all catches in a particular regions, which were conducted at different times of the day. Total stomach fullness of herring has

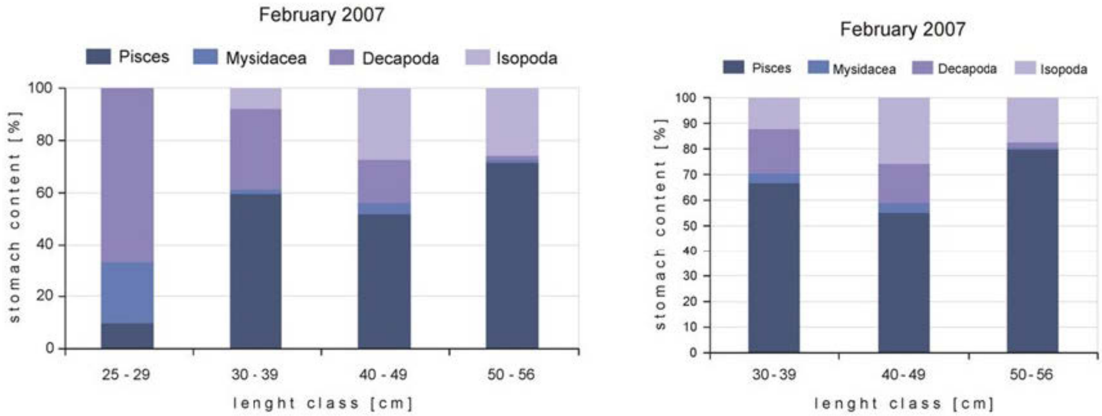

Fig. 11. Weight composition of main prey items [%] of cod per length class in the southern Baltic Sea in February and November 2007.

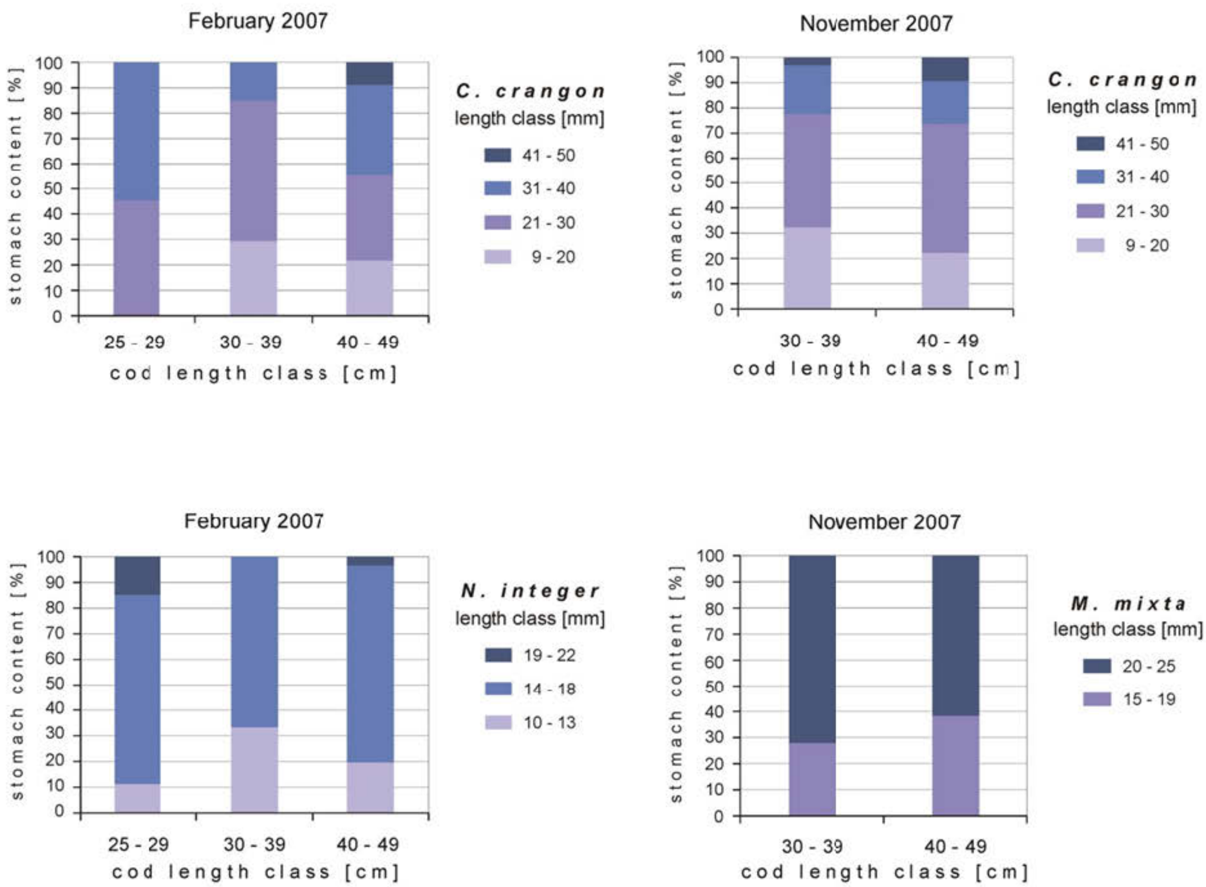

Fig. 12. Size distribution of cod and its stomach components (*Crangon crangon*, *Neomysis integer*, *Mysis mixta*) in February and November 2007.

decreased since the late 1970s with maximum percentages of empty stomachs during the late 1990s (Möllmann et al. 2000). Those data mean about 30% of stomachs were empty, which is only slightly lower than the mean number of empty stomachs in this research (35%), when all regions are averaged together. The average stomach fullness of herring from the northern Baltic in 1991 was 1,9 (on a scale of 0 to 5) (Flinkman et al. 1998). Additionally, means and medians of stomach fullness slightly decreased in autumn (Möllmann et al. 2004). This observation may be supported by the current study. Nevertheless, the great number of empty stomachs strengthens evidence for a low food supply.

In the food composition of herring given by Popiel (1951) three species were dominants: *Pseudocalanus minutus elongatus*, *Temora longicornis* and *Mysis mixta*, which concurred with the results of Załachowski (1975). In this study mesozooplankton (Copepoda and Cladocera) were generally predominant, as represented by *P. minutus elongatus*, *T. longicornis* and *Bosmina coregoni maritime*. The latter species occurred clearly in the shallow area of the Southern Middle Bank. Numeric composition of herring stomach contents in this article could overestimate the role of cladocerans. It is worth mentioning that in the 1990s *B. coregoni maritima* was the most important food item, followed by *T. longicornis* and *Acartia* spp. in the Central Baltic Sea (Kornilovs et al. 2001). Szypuła et al. (1997b) also stated that in September, as in this research, the role of Cladocera was more than twice as large as Copepoda. Similarly to current study in 1986-1990 among the Copepoda, *T. longicornis* and *P. minutus elongatus* were dominant in the southern region of the Baltic, whereas in 1995-1996 *Acartia* spp. also played a relatively important role for herring (Szypuła et al. 1997a). What is more, Möllmann and Köster (1999) suggested that *Acartia* spp. was observed in herring stomachs mostly in spring and early summer. Nevertheless, according to my data *Acartia* sp. was eaten rarely. Only in the northern Baltic proper were a considerable proportion of herring stomach contents composed of *Eurytemora* spp. and *Temora* spp. in the summer (Hansson et al. 1990). The food spectrum of herring has significantly changed since the mid-1980s. The shares of *P. minutus elongatus* and Mysidacea have considerably diminished (Kornilovs et al. 2001). The decrease of *P. minutus elongatus* abundance was reflected in the amount of this copepod found in herring diets and resulted in a decrease of total average stomach content (Möllmann et al. 2003). *Pseudocalanus* spp. seemed to be the most energetically valuable copepod eaten in spring (Möllmann et al. 2004). Thus clupeid fed early in the season in the region of the permanent halocline in the Baltic deep basins (Köster, Schnack 1994), where *Pseudocalanus* spp. reproduced (Möllmann et al. 2004). In this investigation herring fed mostly between 15 and 76 m according to acoustic measurements of the biggest stock distribution. It shows that the prey found in this depth interval could reliably represent the available prey and *P. minutus elongatus* is a prominent item except in the Southern Middle Bank. On the other hand, as in earlier studies (Popiel 1951; Załachowski 1975; Ostrowski, Mackiewicz 1992; Szypuła et al 1997b; Möllman et al. 2004), the fact that Mysidacea played a significant role in the diet composition of herring was not confirmed. Only in Gdańsk Basin (mainly from catches at 60 m depth) *Neomysis integer* was recognized in a noticeable amount (10% of food content) for herring of at least 20 cm long, whereas *M. mixta* had an inconsequential share in the herring diet. Previously Mysidacea were common components in the Baltic herrings' stomachs over the whole year with multiple peaks between July and December. It is interesting to note that *M. mixta* was the primary food content for spring-spawning herring in September (Popiel 1951). The stock of spring-spawning herring is now the basis for fisheries, because autumn spawning herring have virtually become extinct (Skóra 2010). According to Ostrowski and Mackiewicz (1992) *M. mixta* was the most predominant and frequently consumed crustacean in the autumn (it was found in 68% of the herring stomachs examined). Hence Horbowy (1997) modeled growth of herring in relation to the biomass of *M. mixta* as basic food resource. Similarly Szypuła et al. (1997a) stressed the importance of the macrozooplanktonic fraction in the diet of planktivores. This study found quite similar data regarding the diet composition of herring as did Casini et al. (2004) in the Bornholm Basin, also in autumn. While in 2008 herring favored the zooplankton *B. coregoni maritima* (30%), *T. longicornis* (25%), *P. minutus elongatus* (19%) and *Hyperia galba* (15%), stomachs analyzed in the same method in 1999 (Casini et al. 2004) were full of *T. longicornis* (65%), *B. coregoni maritima* (25%) and *M. mixta* (10%). First of all, the share of cladocerans could be considered comparable. On the other hand, high food content of one species of copepod decreased at the cost of two species. Besides, even though the proportion of Mysidacea in the stomach had been markedly low in 1999, the food composition of herring has undergone certain changes as a shortage of Mysidacea was replaced with Amphipoda (only *H. galba*) in the diet of herring in 2008. Maybe it is a substantial reflection of the zooplankton structure prevailing in the sea. Regarding macroplanktonic and benthic food in the diet of larger herring, Amphipoda played an important role. In earlier research other species within Amphipoda were present: *Monoporeia affinis* (Załachowski et al. 1975) or *Bathyporeia pilosa* (Ostrowski, Mackiewicz 1992). Worthy of notice is the fact that in this investigation Polychaeta was found in only a few stomachs in minimal quantities in comparison with previous results, where it comprised a marked portion of the herring diet in autumn (Załachowski et al. 1975; Ostrowski, Mackiewicz 1992; Szypuła et al. 1997b).

I quantify the frequency of occurrence of various food sources only for herring stomachs which contained food, and include lower feeding intensity on organisms different from Copepoda and Cladocera. Also parasites (Trematoda) occurred in some stomachs of herring quite frequently, which was previously noted in only a few stomachs by Popiel (1951).

The above-presented results with respect to the selectivity of herring are very similar to the data given by Casini et al. (2004), which demonstrated that small herring (≤15 cm) are strictly zooplanktivorous. Casini et al. (2004) were also investigating whether larger fish were essentially nektobenthos feeders, preying on *M. mixta* during the autumn, as was found with the current study under some circumstances. However, in this study only herring larger than 20 cm fed more on Mysidacea (*N. integer*), although individuals larger than 24 cm mainly preferred Amphipoda, and the largest ones (26-27 cm) ate only the larvae of Pisces.

This positive correlation of herring body size and food types consumed was also analyzed with respect to prey size. Here, I took into consideration only makroplanktonic species from Mysidacea and Amphipoda. As regards *N. integer*, increase of prey size was predicted to be positively selected by larger fish. This prediction did not explain the selection for *H. galba*, perhaps because too small a number of fish ate this type of food. Therefore, further studies of larger herring are needed for more precise assessment.

So far, very few investigations of the diet composition of cod in the southern Baltic Sea have been carried out. Those that have been done were primarily executed during the 1960s (Chrzan 1962, Strzyżewska 1962) and 1970s (Załachowski et al. 1975, Załachowski 1977). Since it has been proven that Pisces are a common food item for adult cod of medium to large size, this paper investigates more intensively the significance of invertebrates in the cod diet.

Forty percent of the individuals found in November in the stomachs of medium sized cod (30-50 cm) from the coastal waters of Gdańsk Basin were *M. mixta*. On average 16 individuals of *M. mixta* were found per cod stomach. Research by Chrzan (1962) showed an average of 40 individuals for the same cod size, the same period and the same study area. *M. mixta* was not only a main prey item for young cod, but for adults too (Strzyżewska 1962, Załachowski 1992), especially in autumn (Załachowski 1977). The latter author did not note differences in the proportion of *M. mixta* in the stomach between cod caught in Gdańsk and Bornholm Basin. This is not supported by the current results because twice as many individuals of *M. mixta* were found in the stomachs of cod from Gdańsk than from Bornholm Basin, regardless of study period. Additionally, *N. integer* was recorded in considerable numbers in the stomachs of cod caught along the Polish coast in February. On the other hand, it is important to remember that Mysidacea constitute only a slight share of the cod's diet when measured by weight. The observed downward trend in the consumption of Mysidacea is at an all time low (less than 4% by weight). Załachowski (1992) wrote that *M. mixta* replaced Polychaeta, Amphipoda and Isopoda. Because of this, *M. mixta* was the most important component of the diet for older cod from the southern Baltic Sea in summer and autumn. Załachowski (1992) explained this phenomenon by the great availability of this crustacean, which has never been observed before. In the late 1980s the abundance of juvenile and adult cod was reduced (Uzars 2000), but adult cod adhered to their pelagic life style and did not change the components of their food supply which were easily accessible, i.e. *M. mixta* (Załachowski 1992). According to Uzars (1994), in the late 1980s, mysids constituted more than 40% (by weight) of the diet of adult cod over 30 cm in length for the second half of the year in the Central Baltic.

In this analysis, despite the fact that it is based on two seasons, when data from all study areas are merged, within invertebrates only *Saduria entomon* (Isopoda) constituted the largest portion of the diet by number and weight for cod, mainly in autumn. *Crangon crangon* was the second most important crustacean in the diet, especially for cod from the coastal waters of Bornholm Basin in autumn and the Polish coast in winter, whereas Amphipoda or Cumacea occured only in small quantities. Strzyżewska (1962) observed that while *S. entomon* was the most important crustacean in the cod diet, *C. crangon* was also present in much smaller numbers.

Strzyżewska (1962) also reported that *Gammarus* spp. and *Pontoporeia* spp. were common in the stomachs of cod from the southern Bornholm Basin in February. In this study a similar tendency was noted for *Gammarus* spp. in the same area and season. Even though it was recorded in small amounts, in comparison to the rest of the material this result is noteworthy. Załachowski (1977) also found that *S. entomon* outnumbered and outweighed *C. crangon*, but the former was consumed more in winter. Based on an analysis of the 2007 data, this trend is not obvious in the current study although once *C. crangon* achieved almost 30% by number and 20% by weight of the cod diet along the Polish coast in February, in contrast with a much smaller amount in November. Furthermore, *C. crangon* has decisively the largest share in the diet of small sized cod (25 – 29 cm), which concurs with data presented by Ostrowski and Mackiewicz (1992). On the other hand, *C. crangon* was never as important as *M. mixta* or *S. entomon* in the cod diet, as presented by all authors quoted above. It is also probable that the sharp decline in principal food items is the reason for the shift to alternate food in some areas. In 1963-1985 *S. entomon* constituted about 40-50% of the adult cod diet. In the late 1980s its presence in the cod diet declined (Uzars 1994). According to this author, on the feeding ground of the Central Baltic, cod of more than 30 cm in length switched to a macroplanktonic diet with mysids prevailing, whereas *S. entomon* was less intensively utilized during the second half of the year (23% of cod food content). The weight share of *S. entomon* in the cod food content in this study was in the 15 - 45% range. The highest measurement was noted for cod from the open waters of Gdańsk Basin and is an exception. Considering isopods are the main crustacean food resource in this investigation, their share in the total food budget of cod decreased in comparison to previous observations, though now and then they are second only to fish in their importance in the diet of cod in the southern Baltic Sea.

Invertebrate fauna made up about 40-50% (mean for all seasons) of the total weight of the food consumed by middle-sized (25 – 55 cm long) cod individuals in the 1970s (Załachowski et al. 1977) and in the late 1980s (Uzars 1994). Current observations are at least twofold lower, but invertebrate fauna continue to be a part of the cod diet.

Załachowski et al. (1977) found that Polychaeta (predominantly *Bylgides sarsi*) was chiefly eaten in large quantities by adult cod from deeper waters, especially in winter. In this study it was noted only sporadically as single individuals in the stomach, and therefore it was disregarded from calculation of the diet composition of cod.

There are dissimilarities in the amounts of crustaceans eaten by cod caught in shallow and deep waters. At depths greater than 60 m, *M. mixta*, *N. integer* and *C. crangon* all decreased or disappeared from the total invertebrate cod food. A large percentage of *S. entomon* and a considerable amount of *Gammarus* spp. in comparison to the others' results were only noted in November in the open and deeper waters of Gdańsk Basin. Similar variations were also recorded by Załachowski (1977), who did not observe a particular reduction in the consumption of *S. entomon*, *Gammarus* spp. or *Pontoporeia* spp. by cod with increasing depth, unlike with *N. integer* and *C. crangon.* Załachowski (1977) did not notice a reduction in the consumption of *M. mixta* with increasing depth.

Over and above that the frequency of occurrence of Pisces in cod stomachs from the open sea of Gdańsk Basin in November was substantially low. The cod diet favored Isopoda and Amphipoda which seems to coincident with their high ratio in the total weight budget of cod at that time. Generally, frequency of occurrence of Mysidacea and Decpoda (almost 80%) as well as Isopoda (close to 60%) are quite high, but despite this they contribute only a small amount of weight to the adult cod diet. Crustaceans could take second place in the feeding ecology of adult cod from Kiel Bay (western Baltic) after molluscs and then crustaceans followed by fish as showed by Arntz (1978).

Size of prey items is a factor in their importance as a food source for cod from different length classes. *Mysis* spp. was the most common food source for cod of 20 to 30 cm (Chrzan 1962). The same correlation is observed in this study and the consumption of mysids decreased for larger cod. *C. crangon* and *S. entomon*, as prey items from the medium-sized class of Crustacea, were eaten most often by cod of medium size (30 – 50 cm) (Załachowski 1977). These findings are very close to the results of this study, but I found some differences in the feeding preferences of cod in the 10-cm length class. *S. entomon* was first found in the stomachs of cod 30 cm in length. Its consumption increased for cod up to 50 cm, and then seemed to decrease for the largest cod. The share of *C. crangon* in the diet composition of cod was twofold higher for cod smaller than 30 cm. For cod 30 cm and larger the number of decapods consumed gradually declined.

In conclusion, this study adds some new results of feeding preferences of fish, whose condition and growth have consequences for the fishing industry. The results indirectly suggest changes in the abundance and availability of meso- and macroplankton over the years. Numeric diet composition in this research overestimates the role of Copepoda and Cladocera in the diet of larger herring. Mysidacea, Amphipoda and Decapoda were not numerous, but were an important food source for herring based on the amount of energy they provide. On the other hand, the results provide evidence that Mysidacea, which were historically important prey for herring, have become scarce. It seems that this food was replaced by more available prey of comparable size, i.e. Amphipoda. The same holds true for cod, though isopods and decapods have always constituted a significant portion of the invertebrate prey consumed by cod. Nevertheless, the share of *S. entomon* in the total food budget of cod decreased in comparison to previous observations and *C. crangon* was never as important as *M. mixta* and *S. entomon*. This paper suggests one of the many avenues of research which could provide a better understanding of the dynamics of the food chain in the Baltic Sea. This study requires verification at a larger spatial scale.

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