Size structure and feeding ecology of fish communities in the surf zone of the Eastern Baltic

D. Uzars¹, D. Ustups¹, B. Müller – Karulis², E. Urtans¹

¹Latvian Fisheries Research Institute, Daugavgrivas Str. 8, LV-1048, Riga, Latvia. Tel:+371 7610766, dana@latfri.lv
²Institute of Aquatic Ecology, University of Latvia, Daugavgrivas Str. 8, LV-1048, Riga, Latvia. Tel: + 371 7610851, baerbel@latnet.lv

Abstract

Benthic and pelagic fishes of the nearshore area of the Eastern Baltic were sampled by beach seine in 1998-2002. During the summer-autumn seasons the shallow waters were inhabited by marine juveniles and small-sized fish species. Juvenile diadromous or freshwater fishes stay nearshore for a shorter time period and were recognized as migrants. Trophic interrelations among more abundant and frequently occurring juveniles in the early years of life prior to maturity were studied. Multivariate analysis of the diet similarities between fish species resulted in determination of six trophic guilds: copepod feeders, bathyporeia feeders, mysidae feeders, mysid – copepod feeders, mysid – bathyporeia feeders and piscivores. Food composition of different size classes of juvenile flounder (Platichthys flesus) showed high variety in prey taxa. Ontogenetic shifts from copepods and small amphipods to macrofauna in flounder and from mysids to fish food in turbot (Scophthalmus maximus) occurred as fish grew. The majority of fish diets (7 out of 9 species) included mysids, and turbot was the main consumer of this prey. Besides, juveniles of turbot and perch (Perca fluviatilis) as well as adult greater sandeel (Hyperoplus lanceolatus) were found to be also piscivores. However, for several species, mysids occurred less frequently in their diet. Diets of smelt (Osmerus eperlanus), lesser sandeel (Ammodytes tobianus), juvenile flounder and 0-group turbot were dominated by amphipods and zooplankton. Altogether, the coexistence of the different fish species at the nursery grounds suggests high trophic flexibility and ability of species or size classes of species to partition the available food sources.

Key words: surf zone, juvenile flatfish, diadromous, freshwater fish, diet, feeding guilds
Introduction
Along the coastline brackish water masses of intermediate salinity between sea and freshwater are formed (Barnes, 1999). Because of connections to both fresh water and marine systems, brackish waters contain a number of freshwater and marine species. The environment of coastal waters, also that of shallow sandy beaches, is variable and greatly influenced by short-term fluctuations in physical factors such as wind, wave height, temperature and light. However, the coastal waters provide important nursery grounds for numerous fish and invertebrate species. The fish species inhabiting the surf zone of Belgium can be grouped according to their appearances for a short time or during prolonged periods into resident species and migrant or sporadic species (Beyst et al., 2001). In the Baltic Sea, the fish fauna of the Curonian Lagoon (South Eastern Baltic) is composed of freshwater migratory fish species as well as marine species (Ziliukienė, 2002).

Among the marine demersal species, juvenile flounder and turbot appear in the coastal area after metamorphosis and spend part – the first 2 years - of their life cycle there (Vitinsh, 1989, Beyst et al., 1999). Pelagic juvenile herring migrate to the nearshore areas in spring where warmer waters provide better feeding and growth conditions (Urho and Hilden, 1990). The diadromous juvenile smelt appear in the coastal area in the middle of summer (Ziliukienė, 2002). The better temperature conditions (Urho, 1996) also explain why 0-group perch stay in the littoral area of the Northern Baltic.

The coastal area is inhabited also by important fish prey, such as hyperbenthic and epibenthic crustaceans and worms. From the family Mysidae, Neomyis integer inhabits brackish waters and is more abundant in summer and early autumn, while the freshwater species Mysis relicta is abundant in the coastal zone in autumn (Rundstam and Hannson, 1990). Because demersal fishes forage mainly in the epibenthic water layers, mysids and amphipods, which perform vertical migrations, are an important component in the diet of several fish species, as Hostens and Mees (1999) found in the Westerschilde estuary.

Diet studies of flatfishes in the northern Baltic showed that flounder < 4.5 cm mainly consumes meiofauna (Harpacticoida, Copepoda), while the larger fish eat macrofaunal prey (Oligochaeta, Amphipoda and Chironomidae). Turbot less than 3 cm consumes amphipods, while larger conspecifics prey on mysids, amphipods and fish (Aarnio et al., 1996). Fishes inhabiting bottom areas on the Swedish west coast formed five major feeding guilds (Wennhage and Pihl, 2002). Within species, ontogenetic temporal and spatial differences in resources use were found.

The present study was designed to assess size structure and densities of fish species inhabiting the nearshore area of the Eastern Baltic. The aim was to assess the feeding ecology of juvenile flatfish during the first years of their life. Additionally, the diet of other fish species which utilized the same habitat were analysed. The partitioning of food resources between fish species and size-classes was studied because of their similarity in size and preference for benthic prey.

Material and Methods
The study area was located in the Latvian coastal waters of the Eastern part of the Baltic Proper near Pape and Jurmalciems (Fig. 1). Fishes within the depth strata 0 – 2 m were sampled with a beach seine (meshsize 10 and 5 mm in wings and codend, respectively). Samples were taken at 5 stations per site during daylight in May and July 1998 - 2002 and in September 2001. The fishes were preserved in 80 % alcohol for later otolith and stomach analyses. The stomachs of juvenile flounder, turbot,
perch and adult smelt, sand goby (Pomatoschistus sp.), greater and lesser sandeel were examined individually and food items were determined to species level. The number of stomachs analysed for flounder did not exceeded 20 per sample. For rare species like turbot and perch all available stomachs were analysed. All other fish species were included into the stomach analysis if at least five stomachs contained food. Food composition of juvenile herring and smelt were derived from literature sources (Arrhenius and Hansson, 1993; Ziliukiene, 2002). Juvenile flounder were divided into the size classes ≤ 5; 5.1 - 9; 9.1 - 15 cm. Turbot was grouped into size classes ≤ 5 cm, 5 - 12; 14 - 19; and > 19 cm. Food composition was expressed as frequency of occurrence, defined as the percentage of stomachs in which a certain prey item occurred.

For statistical analysis, stomach content data were examined at species level for perch, greater sandeel, lesser sandeel, sand goby and perch. For flounder and turbot, the diets were studied in each length-group separately. Prey items were aggregated into nine categories (zooplankton, Amphipoda (excluding Bathyporeia pilosa), Decapoda, Bathyporeia, Polychaeta, Mysidae, Isopoda, fish and others). Further analysis was based on average frequency of occurrence for the nine prey types within each of the 14 predator categories.

Cluster analysis (STATISTICA software), based on Euclidean distances and unweighted pair-group averages as linkage rule, was used to identify predator groups with similar diet composition. Differences in the average food composition of the clusters were tested for significance by Kruskal-Wallis ANOVA (STATISTICA) and by the mediantest (STATISTICA) for each of the nine food-items separately. To further explore the diet characteristics of the 14 species and length groups, the nine different food items were aggregated into two vectors (dimensions) by multidimensional scaling (STATISTICA). Dimensions were subsequently interpreted with respect to the nine food items using non-parametric regression techniques (Kendall Tau, Spearmann Rank Order Correlations, STATISTICA).

**Results**

**Size structure and density of the main fish species**

Nearly all individuals caught during the warmer season were juvenile and small sized adults in the size range 1 - 17 cm (Fig. 2, 3). Among adult fishes, Ammodytidae (lesser and greater sandeel), sand goby, three-spined stickleback (Gasterosteus aculeatus), and in part also smelt, belonged to the size class less than 15 cm. Flounder, turbot, herring and smelt at lengths between 15 cm and 25 cm were rare. In the length group larger than 25 cm mainly flatfish were recorded. Mean density of the main fish species ranged on average from 1 to 600 individuals per station (Fig. 4).

Larvae and juveniles at the size range 1 - 2 cm were the smallest individuals that occurred in the beach seine catches (Fig. 3). These were demersal early juveniles of marine fishes that had settled out from the water column. Juvenile sand goby was about 1 - 2 cm long, 0-group flounder and turbot measured around 2 - 3 cm. The most abundant inhabitants of the warm shallow waters were juvenile fishes between 3 - 4 cm and 5 - 6 cm length. Larval and juvenile smelt, which occurred in these length groups, dominated the beach seine catches and made up 50 – 60 % of the individuals caught. Juvenile herring, belonging mainly to the length group 3 – 4 cm, contributed about 25 % of the catch. Juvenile herring at length 3 – 4 cm was abundant at 60 individuals per station in May, whereas juvenile smelt 3 - 4 cm and 5 – 6 cm long was
characterized by high density (600 individuals per station) in July (Fig. 4). 1-year old flounder and turbot were less abundant.

Demersal fish species were dominated by lesser sandeel and adult smelt. Juvenile lesser sandeel between 7 - 8 cm and 9 - 10 cm length was relatively abundant, contributing on average 40 % and 60 % of the respective length groups. Occurrence of adult smelt at both size groups 7 - 8 cm and 9 - 10 cm was by 15 – 20 % lower than the very high occurrence of juvenile smelt at lengths 3 - 4 cm and 5 – 6 cm. At larger length-groups the proportion of juvenile flatfish increased to about 8 %.

The size classes 11 - 12 cm and 13 – 14 cm were characterized by the dominance of adult lesser sandeel (60 %). Lesser sandeel was equally abundant (mean density about 50 individuals per station) during both spring and summer (Fig. 4). Within these length groups, also adult smelt occurred frequently. However, the average abundance of adult smelt in all length groups was highest in May. At the length group 13 – 15 cm the occurrence of juvenile flounder increased to about 15 %. In general, juvenile flounder and turbot occurred at similar densities (18 and 3 individuals per station respectively) during the warm season (Fig. 4). In September the occurrence of flatfish slightly increased, while the density of other fishes was reduced.

Juveniles of other fish species such as perch, three-spined stickleback and others were recorded at low average densities (< 1 individual per station).

**Length distribution and age of flatfish**

Length and age distribution of flounder and turbot was analysed for beach seine catches from May, July and September (Fig. 5).

From May to September, juvenile flounder was present at nearly 95 % of the sampling stations and was therefore considered as a resident of the coastal zone (Ustups, et al, 2003). Most abundant in the beach seine catches was flounder in age groups 1 and 2, at size approximately between 3 - 9 cm and 10 – 16 cm, respectively. The number of flounder in age group 3 and higher was low.

Flounder caught in July was in the size range 2 – 20 cm, with peak abundance at 4 – 9 cm length . The first settlement of flatfish was observed at the earliest in the end of July. 0-group newly settled flounder was about 2 - 3 cm long. Flounders at age 1 and 2 were 4 - 9 cm and 10 – 16 cm long, respectively. Abundance of flounder in the elder age-groups was lower in July than in May.

In September, 0-group flounder ranged in size from 2 – 6 cm. 1-group flounder measured 6 – 12 cm. Juvenile flounder (14 – 18 cm) belonged mainly to age group 2. Juvenile turbot constantly inhabited coastal nursery grounds in numbers varying between 2 to 3 individuals per sampling at all seasons (Fig. 4). In May, the dominating lengths of turbot were 5 - 12 cm and 15 – 19 cm which corresponded to the age groups 1 and 2.

Length frequency distribution of juvenile turbot in July clearly demonstrated that size classes 1 - 3 cm and 7 – 13 cm dominated in the catches. The 0-group settled turbot, which was observed only in 2001, were less than 3 cm long. Most of 1 group juveniles were between 7 cm and 13 cm long.

The occurrence of 0-group turbot at nearshore areas was highest in September, when 0-group turbot settled to the benthic layers was 3 to 9 cm long. Abundance of 1 and 2-group turbot at lengths 13 – 17 cm and over 20 cm, respectively, was low.
Diet composition of flatfish

**Flounder**

The diet of juvenile flounder included organisms of different size and utilized prey from different habitats. Figure 6 illustrates the food choice of different flounder size groups (≤ 5 cm, 5.1 - 9 cm, 9.1 - 15 cm) and the seasonal variation of the diet.

In May, juvenile flounder immigrated to the nearshore waters (length ≤ 5 cm and 5.1 – 9 cm), mostly consumed *B. pilosa* (58 % and 65 % occurrence in stomachs, respectively). Juvenile flounder ≤ 5 cm also fed on planktonic copepods, a small prey which occurred in about 30 % of stomachs. In larger fish (9.1 – 15 cm), the occurrence of *B. pilosa* decreased to 30 % and was gradually replaced by larger preys (*Crangon sp, Idotea balthica, N. integer, Gammarus sp.*). The average number of empty stomachs constituted 27 % for flounder and was higher at larger size classes.

In July *B. pilosa* remained the major prey for flounder, which made up about 45 % of the diet in each size class. Zooplankton (25 %) was again important in the diet of small flounder ≤ 5 cm. Medium-sized (5 – 9 cm) flounder showed a diet shift from zooplankton to juveniles of the polychaeta *Marenzelleria viridis*, which occurred in 26 % of stomachs. Larger conspecifics preyed upon *Pontoporeia sp.*, *M. viridis*, and juvenile fish. However, the occurrence of macrofauna organisms in the diet of large juvenile flounder was lower in summer than in spring. The high share (48 %) of non-feeding large juveniles may indicate limited food.

In September the main food component for flounder in all size classes were juvenile mysids (*M. relicta*, occurrence 50 - 60 %). *N. integer* was the secondary prey, occurring in about 15 - 20 % of stomachs. Occurrence of *Gammarrus sp.* was high for the larger juveniles.

**Turbot**

The length distribution and food choice of turbot was differed from that of flounder during all seasons (Fig. 6).

In May, the length–frequency distribution of turbot indicated a clear size separation (Fig. 5). Turbot in length between 5 and 13 cm dominated in the nearshore environment, where the number of larger (14 - 20 cm) turbot was significantly lower. Both 5 - 3 cm and 14 - 20 cm long turbot preyed on *N. integer* which occurred in 80 % of stomachs (Fig. 6). Only 8 % of turbots were non-feeding.

Juveniles from the July settlement were between 1 cm and 3 cm long. The small newly settled turbot consumed both *N. integer* (50 %) and *B. pilosa* (44 %). Zooplankton occurred only in 6 % of fishes. Turbot at length 5 – 14 cm and larger (14 - 20 cm) consumed mainly *N. integer* (about 50 %) and juvenile fishes. In particular, the occurrence of juvenile smelt increased in the diet of medium and larger turbot to 40 – 50 %.

In September, recently settled turbot (0-group) were well represented in the seine catches. Individuals between 3 cm and 9 cm length fed to a higher degree on mysids - *N. integer* (50 %) and juvenile *M. relicta* (45 %). Larger (14 – 16 cm) turbot also preyed upon larger *N. integer* while they supplemented their diet with decapods and juvenile fishes.
**Dietary guilds**

Frequency of occurrence of the nine prey categories studied (zooplankton, amphipods, decapods, bathyporeia, polychaetes, fish, mysidae, isopods and other) differed widely between predator species and length groups (Fig. 7 A). Juvenile smelt and herring were highly specialized and solely preyed on zooplankton, while large juvenile flounder was found to be a generalist, which consumed all available different types of prey items. All other fish species were also associated with a more or less high number of different food resources.

Cluster analysis was employed to identify groups of species with similar diet composition. The level of aggregation, at which clusters were thought to represent dietary guilds, was chosen to retain small, homogeneous groups that differed significantly from each other. At a linkage distance of 40 (Fig. 7 B) six groups remained in the clustering scheme and differences in food composition between these six groups were significant (Kruskall-Wallis ANOVA, p < 0.01). Varying proportions of zooplankton, *B. pilosa*, mysids, polychaetes and fishes distinguished the diet of each of the six groups (Mediantest, p < 0.02), while differences were not significant with respect to amphipods, isopods, decapods and other species.

The largest within-group similarity and at the same time the largest difference to all other groups (linkage distance 113), was found for juvenile smelt and herring, whose diet consisted solely of zooplankton. Smelt and herring accordingly formed the guild of copepod feeders.

Cluster analysis also grouped together the three larger size classes of juvenile turbot at high linkage distance from all other species (linkage distance 75), forming the guild of mysidae feeders, which consumed mainly mysids and fish, but were separated from all other species by the absence of zooplankton and *B. pilosa* in their diet.

Food choice was very similar (linkage distance 21) for the two smaller groups of juvenile flounder. Together with the larger juvenile flounder they formed the dietary guild of bathyporeia feeders, who consumed a combined diet dominated by *B. pilosa* and supplemented by mysids, amphipods, polychaetes and zooplankton.

The occurrence of zooplankton decreased with flounder size. Instead, large juvenile flounder added larger prey types such as decapods (*Crangon sp*), amphipods (*Gammarus sp*), isopods (*I. balthica*), fish, and other preys to their diet. These changes in food composition with size were well reflected in the higher linkage distance (40) for the largest flounder size group.

Cluster analysis also revealed high similarities in the food composition of juvenile perch and adult greater sandeel (linkage distance 24). Both showed relatively high proportion of fish in their stomachs (about 35 %), and could be termed piscivores. However, compared to turbot, which also preyed on mysids and fish, the diet of juvenile perch and greater sandeel included zooplankton and amphipods. Sandgoby, adult smelt, and the smallest size class of juvenile turbot formed a guild that consumed mainly mysids. *B. pilosa* as supplementary food distinguished this group from the mysidae feeders. This group could therefore be termed mysid – bathyporeia feeders.
Based on the cluster analysis, lesser sandeel formed a dietary guild on its own based on its simple food composition, made up of equal proportions of zooplankton and mysids. This type of food selection could therefore be termed mysid – copepod guild.

Multidimensional scaling showed, that the food composition for all groups could already be well represented by two dimensions (stress 0.06, Fig. 8), suggesting that only two variables were needed to represent the differences in food composition. Both Kendall Tau as well as Spearman Rank Order Correlation found a significant (p < 0.05) positive correlation between dimension 1 and zooplankton, while mysidae and fish correlated inversely with dimension 1 (p < 0.05). Dimension 2 was negatively correlated (p < 0.05) with the occurrence of B. pilosa, polychaetes, amphipods and others in the diet of the species investigated. No other significant (p < 0.05) correlations were found. Multidimensional scaling confirmed the highly different diet composition of the copepod feeders juvenile smelt and herring, since they were placed far from all other species with high values for dimension 1, identifying them as zooplankton consumers, and high values for dimension 1 which agrees well with their specialized diet, that did not contain B. pilosa, polychaetes amphipods or other species correlated with dimension 2.

All other species, except lesser sandeel, were placed on a line connecting mysidae feeders (turbot) to bathyporeia feeders (flounder). According to their diet composition, which consisted almost entirely of mysids and fish, all juvenile turbot except the smallest size group was characterized by low values for dimension 1 and high values for dimension 2. On the other hand, the diet of flounder was most diverse, containing both zooplankton and mysids, leading to intermediate values for dimension 1, as well as B. pilosa, polychaetes, and amphipods, causing the low values for dimension 2. Mysid – bathyporeia feeders and piscivores marked transitions in the food characteristics between mysidae and bathyporeia feeders. Both groups had a wider food spectrum than the mysidae feeder turbot, but not as diverse as for the bathyporeia feeder flounder. Mysid - bathyporeia feeders replaced fish and part of the mysids in the food of turbot by B. pilosa and a higher proportion of amphipods, leading to lower values for dimension 1. At the same time, their dependence on Mysidae was lower than for turbot, but higher than for flounder. In addition, group 6 did not – in contrast to flounder - prey on zooplankton. Also the piscivores juvenile perch and greater sandeel preyed on a diet intermediate between turbot and flounder. In contrast to mysid - bathyporeia feeders, their consumption of fish was similar to turbot, but mysids were partially replaced by zooplankton, amphipods or B. pilosa. Similar to cluster analysis, also multidimensional scaling indicated a different feeding strategy for lesser sandeel as lesser sandeel did not fit into the transition between bathyporeia and mysid feeders.

Discussion
From the 31 fish species belonging to 19 families caught at shallow depth (0 to 2m) only several species were abundant (Ustups et al. 2003). These were marine species that spawn and undergo larval development at sea, but as juveniles utilize the shallow coastal zone. In spring and summer, the very nearshore waters are warmer than the mid-water or bottom layers of the offshore (unpublished data, Yula 2003). Water temperature in shallow water (depth < 2 m) rises to 7 – 11 °C by the middle of May. Juveniles of demersal flounder and turbot as well as pelagic herring and sprat, occur constantly in the surf zone during the warm period of the year. This change from
offshore to nearshore occurrence takes place in relation to both temperature increase and development of food resources. The coastal waters are therefore considered to be a nursery of marine fishes at juvenile stages. However, densities and seasonal distribution patterns were different for pelagic and demersal species. For juvenile clupeids, especially for herring, the coastal zone was characterized by a higher density than for flatfish. In general, juvenile herring were more abundant in the shallow zone in spring. However, the distribution of juvenile herring aggregations in nearshore areas was often uneven, maybe due to the shallowness and frequent mixing of the water mass.

Similar to herring, juveniles of the demersal species flounder and turbot appeared close to the shoreline in May. Most of the juvenile flounder approaching the nursery grounds were between 4 and 17 cm long. Thus, 1 to 2 group flounder entered the shallow waters to extend their feeding area. Juvenile turbot (5 - 11 cm and 13 – 19 cm) inhabited shallow waters similar to those occupied by flounder. Densities of juvenile flatfish, particularly of turbot were relatively low. However, flatfish were important at all stations and distributed in similar densities during the spring and summer periods.

Even though flatfish exhibit year-to-year variations in recruitment, mean densities of each species were rather similar in spring and summer with a slight increase only in autumn. However, the size distribution of juvenile flounder and turbot differed between seasons. The flatfish caught in May were larger in size with peak abundance of 1-group flounder and turbot. In July and especially in September, 0-group flounder and turbot settled in the shallow nursery grounds and as a result the occurrence of fishes in the smaller size classes increased. The other demersal fish investigated, lesser sandeel, occurred in equal numbers in spring and summer. Diadromous fishes were abundant at depth < 2 m only during the migration of adult smelt in spring. Temperature increase to about 19 – 20 °C in July caused changes in fish species composition, density and population structure. Adult smelt and larger size juvenile herring left the shallow areas and were distributed at greater depth (Urho and Hilden, 1990). The peak of juvenile smelt (between 3 – 6 cm lengths) occurred during a short period in summer. They entered the surf zone in July and in high densities distributed in patches.

Juveniles of freshwater species immigrated also mainly during summer to the coastal zone from adjacent inshore basins. However, the abundance of freshwater juveniles was low. Mainly juveniles of perch, vimba (Vimba vimba), bleak (Alburnus alburnus), roach (Rutilus rutilus) and bream (Abramis brama) utilized feeding habitats in shallow waters. Both juveniles of diadromous and freshwater fishes inhabited shallow waters only for short time periods and were therefore considered as migrants. All other marine fishes investigated (adult and juvenile lesser sandeel, greater sandeel and sandgoby) do not occur outside the coastal zone and were considered therefore as residents with the exception of sandgoby, which was found in stomachs of marine fishes offshore (Uzars, 1994).

In September densities of all fish species with exception of flatfishes decreased to low numbers in the nearshore area. Contrary, at the same time the occurrence juvenile flounder and turbot was highest, probably due to the appearance of 0-group newly settled flatfish.

Feeding was investigated for 9 dominant adult and juvenile fish species mainly at length up to 17 cm. Diet of juvenile and adult fish species included small size meio-
and macrofaunal food items. Because diet includes food items different in size and abundance (from zooplankton to fishes), frequency of occurrence was used in this study to indicate how prey was selected by different fish species.

Ontogenetic changes in diet composition were investigated only for juvenile flounder and turbot. Within these species clear differences in resource utilization, caused by differences in size, were observed. Diet of juvenile fish included numerically abundant zooplankton and less abundant larger size crustaceans, worms and fishes. A shift in prey utilization from meiofauna to macrofauna occurred as fishes grew (Aarnio et al. 1996; Burke, 1995). Furthermore, considerable intraspecific differences in food composition were detected between flounder and turbot.

Demersal small-sized flounder had a positive selection for the planktonic copepods *Eurytemora hirundoides*, *Bosmina coregoni* and Harpacticoida sp. with E. hirundoides the most preferred. Macrofauna in the diet of small fishes ≤ 5 cm were represented by the small sized benthic amphipod *B. pilosa*. The change from the smaller planktonic food to the larger epibenthic B. pilosa and hyperbenthic N. integer occurred at size-class 5 - 9 cm. At size class 9 – 15 cm prey selection again shifted to large amphipods, decapods and fishes. The relatively high number of non-feeding larger juvenile flounder may be related to the mobility and distribution of large crustaceans in this variable environment. Also the polychaete *M. viridis*, an invader from North-America (Bick and Burckhardt, 1989), became an element of the flounder diet recently. In autumn, juvenile flounder diet was dominated by juvenile M. relicta, likely due to their high abundance. The diverse diet of flounder in the shallow waters exhibited a broad food spectrum and high trophic flexibility.

The diet of larger size (5 - 12 cm and 14 – 20 cm) and small (≤ 5 cm) turbot consisted mainly of mysids. Besides, larger turbot supplemented their diet with fishes, whereas 0-group turbot ate B. pilosa. Thus, diet of juvenile turbot was restricted to two main prey groups, Bathyporeia and mysids, and mysids and fishes. Apart from the potential intra- and interspecific competition, juvenile turbot, particularly the newsettlers, might depend upon the availability of mysids as suitable food.

The multivariate analysis in the present study was based on the occurrence of food taxa in the diet of different fish species and size classes and determined six major trophic guilds: copepod feeders, mysidae feeders, bathyporeia feeders, mysid – copepod feeders, mysid – bathyporeia feeders, and piscivores. The fish community dwelling in the nearshore waters included fish species that consumed preferably mysids, a fast-moving hyperbenthic prey. The diet of the majority of fish (7 out of 9 species) included mysids. Mysidae feeders included larger turbot juveniles feeding preferably on N. integer. Several of the species whose main food were mysids changed their foraging behaviour, shifting to other, possibly more abundant prey items. For example, the juveniles of the piscivores greater sandeel and juvenile perch ate small fishes in nearly equal proportion as mysids at several time periods. For adult smelt, sandgoby and small turbot, clustered together in the mysid – bathyporeia feeders group, alternative preys were B. pilosa and larger size amphipods, decapods and juvenile fishes.

**Conclusion**

The study showed that shallow coastal nursery areas are important feeding grounds of marine, diadromous and freshwater fishes. During summer, nine more abundant fish species were caught in the nursery ground. Juvenile smelt, herring as well as adult
smelt and lesser sandeel seasonally occurred in high abundance. Juvenile flatfish were relatively stationary in the surf zone. Feeding studies showed highly different food composition of the copepod, mysidae and bathyporeia dietary guilds. In the mysid-copepod guild prey taxa prevailed. The dominance of different prey taxa in their diet distinguished piscivores and mysid-bathyporeia from mysidae and bathyporeia guilds. This suggests that interspecific competition for food was minimized by specialization of each size class and species on a different combination of prey types and sizes. The coexistence of the different fish species at the nursery grounds implied high trophic flexibility of the most abundant fish species and the ability to partition available food resources.

References


Fig. 1 Study area with location of sampling stations
Fig. 2. Length distribution (in % by numbers) of smelt and other fishes found in different size-classes.

Fig. 3. Percentage (by numbers) of fish species found in different size-classes.
Fig. 4 Density (individuals per station) of the main fish species by months in 1998 - 2002.
Fig. 5. Length distribution (for age 0-2) of flounder and turbot by months
Fig. 6. Occurrence (%) of food items in flounder and turbot stomachs by months.
Fig. 7. Dietary relationship between fish species found in the nearshore area
A- percentage occurrence of food items in stomachs of different fish species
B - similarity dendrogram - presence or absence of different food items for individual fish
Abbreviations: SME - juvenile smelt; HER - juvenile herring; TB1 - turbot < 5cm; TB2 - turbot 5-9cm;
TB3 - turbot 9-15 cm; TB4 - turbot 15 -20 cm; FL1 - flounder <5 cm; FL2 - flounder 5-9 cm; FL3 -
flounder 9-15 cm; LSA - lesser sandeel; PER - perch; GSA - greater sandeel; SGA - sand goby; SMA -
smelt.
Fig. 8. Dietary guilds in relationship to food dimensions identified by multidimensional scaling. Abbreviations: SME - juvenile smelt; HER - juvenile herring; TB1 - turbot < 5cm; TB2 - turbot 5-9cm; TB3 - turbot 9-15 cm; TB4 - turbot 15-20 cm; FL1 - flounder <5 cm; FL2 - flounder 5-9 cm; FL3 - flounder 9-15 cm; LSA - lesser sandeel; PER - perch; GSA - greater sandeel; SGA - sand goby; SMA - smelt.