Oceanological and Hydrobiological Studies
Vol. XXXIV, No. 3

Institute of Oceanography (69-84) University of Gdańsk
2005

Research Article

DIEL FOOD COMPOSITION AND CHANGES IN THE DIEL AND SEASONAL FEEDING ACTIVITY OF COMMON GOBY, SAND GOBY AND YOUNG FLOUNDER INHABITING THE INSHORE WATERS OF THE GULF OF GDAŃSK, POLAND

ILONA ZŁOCH, MARIUSZ SAPOTA[1], MONIKA FIJAŁKOWSKA

Department of Marine Biology and Ecology, Institute of Oceanography
University of Gdańsk, al. Marszałka Piłsudskiego 46
81-378 Gdynia, Poland

e-mail: [2]ocems@univ.gda.pl

Key words: inshore waters, diel feeding, goby, flounder.

Abstract

A study was conducted from 2001 to 2003 in the Gulf of Gdańsk (Poland) on the diel food composition and diel and seasonal changes in the feeding activity of *Pomatoschistus minutus*, *Pomatoschistus microps*, and *Platichthys flesus*. During the three-year study, no empty fish stomachs were noted, and the fish food was comprised exclusively of prey species that inhabit the shallow water zone (*e.g.*, *Bathyporeia pilosa*). It can also be stated that the shallow waters of the Gulf of Gdańsk are an important feeding ground for *Pomatoschistus* sp. and *P. flesus*. The food intake of all three investigated fish was lower at night than during the day, which led to the conclusion that these fish are day feeders. The seasonal feeding intensity of the sand and common gobies was approximately the same throughout the investigation but was higher in April, June, and August, and lower in September. The flounder fed most intensively in August and March, while feeding intensity was lower in May and June. In September 2001, the most important prey items for *P. minutus* were Amphipoda undet. and Mysidacea undet. in the morning, *N. integer* and Mysidacea undet. at noon, and Harpacticoida and Copepoda undet. in the evening. In the same month, *P. microps* fed mainly on *B. pilosa* at 08:00, *N. integer* at 00:00, and Harpacticoida at 20:00. From 2001 to 2003, *P. flesus* preyed mainly on Polychaeta in the morning hours, while in the evening it targeted *N. integer* according to the prey frequency of occurrence and quantity in the fish stomachs.

INTRODUCTION

The shallow sandy bottom of the Gulf of Gdańsk (southern Baltic Sea) is mainly inhabited by gobies (*Pomatoschistus* sp.) and juvenile flatfish, especially *Platichthys flesus* (Sapota 2001, Lizińska 2002). These species can attain high abundance in this zone during the summer and early fall when juvenile recruitment peaks.

One of the most common species is the sand goby, *P. minutus*, with a maximum size of about 74 mm (Ławacz 1965) and a spawning period that stretches from April to September (Waligóra-Borek 2004). The common goby, *P. microps*, is morphologically similar to the sand goby although it only reaches a total length of about 52 mm (Ławacz 1965) and reproduces in batches from April to October (Wendt 2004). As the water temperature rises in spring, the adult individuals of both gobies migrate to shallow waters to spawn. In late fall they migrate to deeper areas where they winter (Aarnio and Bonsdorff 1993). In addition to seasonal changes in activity, gobies also exhibit diurnal rhythms (Wiederholm 1987). Previous papers have indicated that the sand and the common gobies prey on approximately the same taxa of crustaceans, copepods, and polychetes (Evans 1983, Aarnio and Bonsdorff 1993, Hampel and Cattrijsse 2004)

The flounder, *Platichthys flesus*, is larger than the two goby species, and adult specimens can attain 40 cm in the Baltic Sea (Gąsowska 1962). The average length of young individuals from the 0 and 1 year age groups that inhabit the shallow waters of the Gulf of Gdańsk is 83 mm (Sapota and Mudrak 1998). Flounder spawning in the Gdańsk Deep occurs from March to June (Gąsowska 1962). In eulittoral waters, the densities of young flounder and goby individuals varies during the day (Lizińska 2002). Additionally, light is an important environmental factor that clearly influences foraging behaviour since all three of the investigated species are visual predators (De Groot 1971, Edlund and Magnhagen 1981). Flounder feeds mainly on crustaceans, bivalves, polychetes, and chironomids (Mulicki 1947, Ostrowski 1997).

Information about diel changes in the feeding habits of *Pomatoschistus* sp. and *P. flesus* is lacking in the Polish literature and the issue of the seasonal intensity of fish feeding in the inshore waters of the Gulf of Gdańsk has been focused on infrequently (Malorny 1990, Ostrowski 1997).

The objectives of the present study were to describe and compare the diel and seasonal feeding activity patterns of three fish species living in the shallow, inshore waters of the Gulf of Gdańsk as well as to examine diel changes in dietary composition. The datasets obtained facilitated investigating if this zone is an important feeding ground for the fish in question.

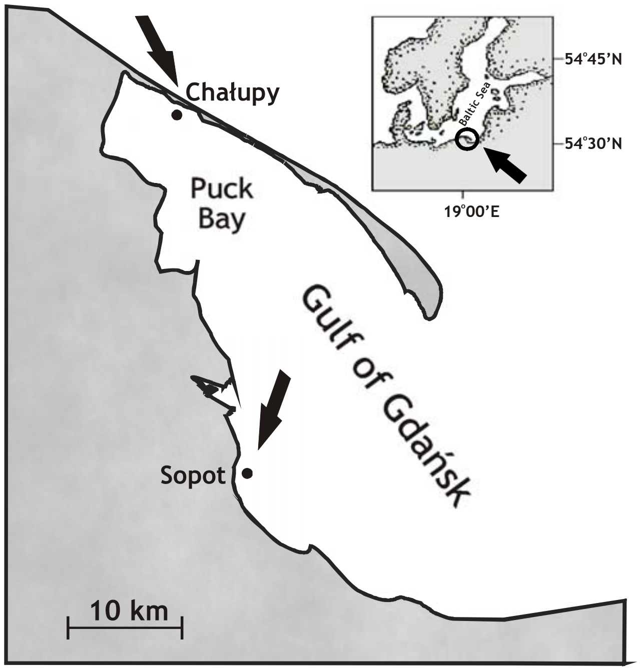

Fig. 1. Study area and sampling sites

MATERIAL AND METHODS

This work focuses on the following three species: *Pomatoschistus minutus*, *Pomatoschistus microps*, and *Platichthys flesus* from the Gulf of Gdańsk. The samples were collected in inshore waters at two sites: Sopot and Chałupy (Fig. 1). Sampling was done during a 24-hour cycle (at two- or four-hour intervals), monthly, during the period from July 2001 to November 2003. Catches were conducted using a hand trawl (mesh size – 6 mm; codend mesh size – 1 mm) with a horizontal opening of approximately 2 m. Trawling was done in the 1 m isobath parallel to the coast line. After sampling, the fish were preserved in a

4% formaldehyde solution. In the laboratory, the total length of the fish was measured rounding down to the nearest mm, and they were weighed to the nearest 0.0001 g. The stomachs were resected from the fish and the degree of stomach fullness was determined on a five-degree scale, ranging from empty stomach (‘0’) to full stomach (‘4’ or more than 75%). Stomach content was identified under a stereomicroscope to the lowest possible taxon, and the prey items were counted and measured. The weight of the prey items was estimated using length-weight conversion coefficients (Berestovsky 1989, Witek 1995). Monthly feeding intensity was assessed with the following formula:

$$\text{stomach fullness index} = \frac{\text{weight of ingested food}}{\text{weight of fish}} \times 100\%$$

Stomach fullness (based on a five-degree scale) and the stomach-fullness index are both considered in the present paper as a measure of the intensity of fish feeding.

Different diurnal food compositions were estimated from the “index of relative importance” formula (IRI) in Pinkas et al. (1971), which includes numerical, frequency of occurrence and weight percentages. Seasonal dietary changes were estimated from the frequency of occurrence and quantity of prey in the fish stomachs.

To show the relationship in diel food composition between the two closely-related gobies, the IRI values were estimated for one day in September to avoid the influence of abiotic factors.

RESULTS

The sand goby individuals included specimens with a total length range from 30 mm to 65 mm (average 43.5 mm ± 7.06 SD). Among common goby individuals, total length ranged from 19 mm to 60 mm (average 31 mm ± 10.7 SD). The average total length derived from the measurement of all flounder specimens was 56.5 mm ± 16.6 SD; the largest specimen was 150 mm and the smallest was 18 mm.

Diel feeding activity (stomach fullness)

In August 2001, a relatively high proportion of at least half full stomachs (third and forth degree) in *P. minutus* was noted in the afternoon hours. A large number of full stomachs were noted at 00:00 and full or almost full at 08:00. In September 2001, many of the sand goby stomachs were 25% filled, which was

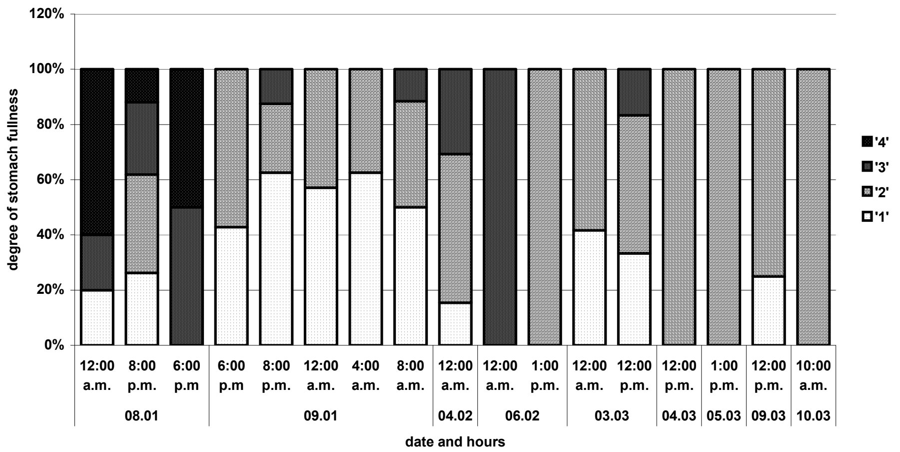

Fig. 2. Changes in diel and seasonal feeding activity (stomach fullness) in *P. minutus.*

common in stomach samples collected at all investigation times during that month. For the rest of September, stomach content rarely exceeded 50% fullness (Fig. 2). The degree of *P. microps* stomach fullness was generally lower than that of *P. minutus* throughout the study. Similarly to the sand goby, in September 2001, common goby stomachs were only filled to 25% capacity, and in August 2001 many stomachs were almost full (75%). At 00:00 in March 2002, April 2002, and March 2003, stomachs that were full to the second and third degree were noted frequently in *P. microps*. Throughout the investigation period (2001 – 2003), the stomach samples from 00:00 were highly variable, so it was impossible to distinguish a dominant fullness level (Fig. 3). Contrary to the gobies, the stomachs of flounder were not filled with food in August 2001, but in September 2001 they were. The degree of flounder stomach fullness from the same month but different years at the Sopot station is highly varied; thus the most common stomach fullness cannot be distinguished. The stomachs of flounder from the Chałupy station were characterized by first degree fullness. The same stomach fullness was noted in the common goby from the same station. In months when there were more flounder catches (April, June 2002, March and July 2003), there was a tendency for the fish to have higher stomach fullness during dusk and the early evening hours and lower fullness degrees at night. Generally, it can be said that a relatively high number of full or nearly full flounder stomachs were recorded in the evening hours, while more stomachs with a small amount of food were recorded in the morning throughout the three-year investigation (Fig. 4).

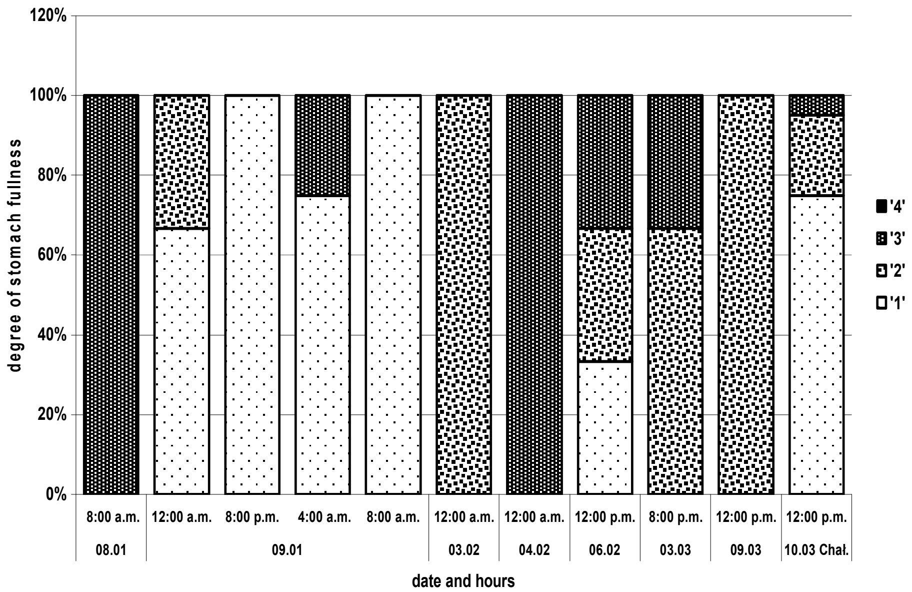

Fig. 3. Changes in diel and seasonal feeding activity (stomach fullness) in *P. microps*

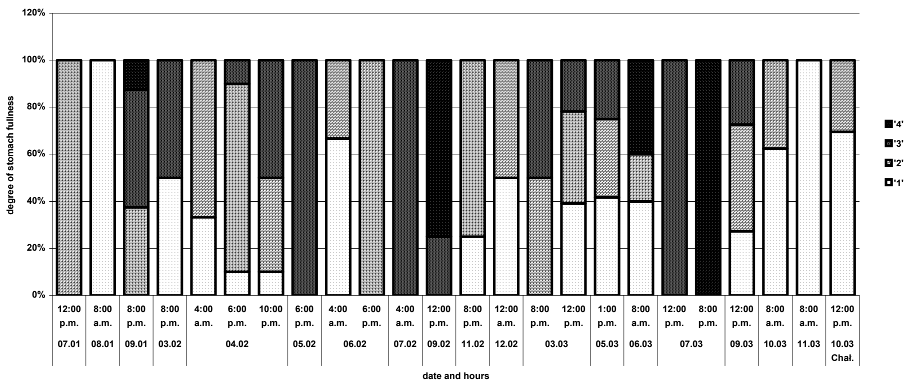

Fig. 4. Changes in diel and seasonal feeding activity (stomach fullness) in *P. flesus*

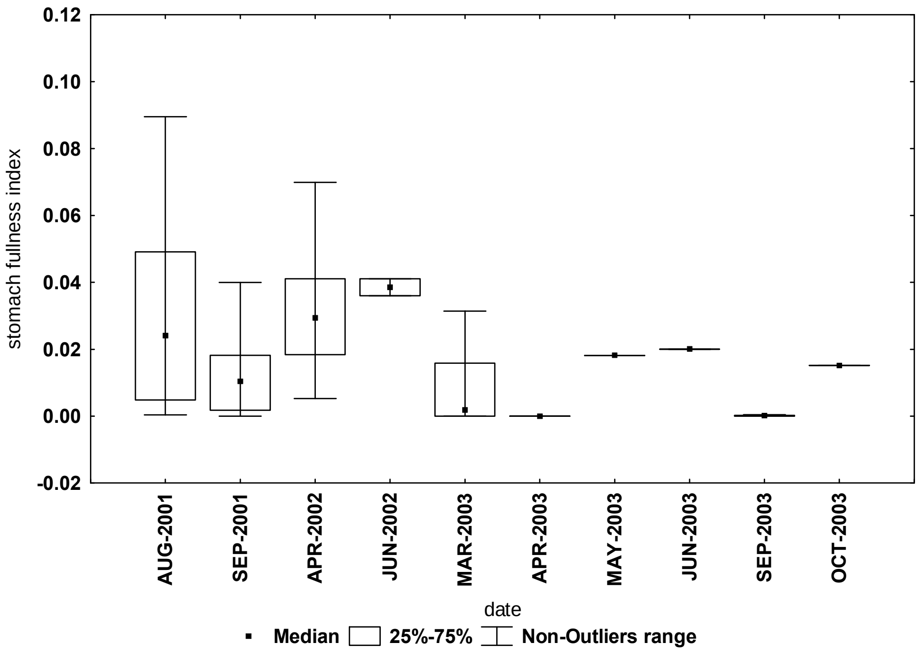

Fig. 5. Changes in seasonal feeding activity in *P. minutus*.

Seasonal feeding activity

P. minutus exhibited the highest feeding activity in August 2001 and June 2002. The lowest was recorded in April 2003 and September 2003. There was also a tendency of increasing feeding activity in August, followed by a decreasing tendency in September. Another increase was recorded in April and June (Fig. 5). Similarly to *P. minutus,* the stomach fullness index of *P. microps* was higher in August 2001 as well as in October 2003 (Fig. 6). During the investigation period, the average feeding activity index value was lower for the common goby than for the sand goby. Seasonal fluctuations of this index were approximately the same for both gobies. *P. flesus* exhibited the highest food intake intensity of all three of the investigated species. The flounder pattern noted was quite different from that of the gobies; it had three periods with different degrees of feeding intensity. The highest food intake occurred in August and March, medium intake was in September, and the lowest was in May and June (Fig. 7).

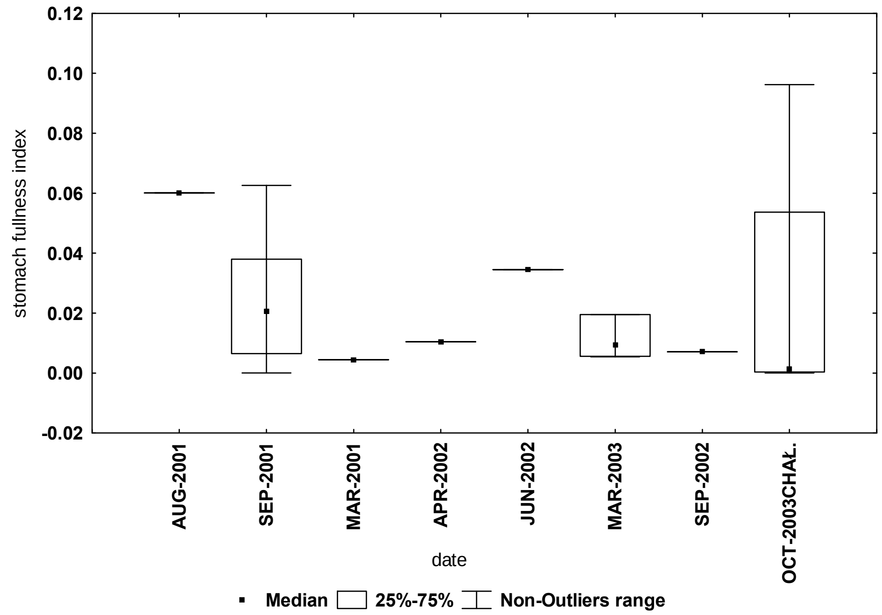

Fig. 6. Changes in seasonal feeding activity in *P. microps*.

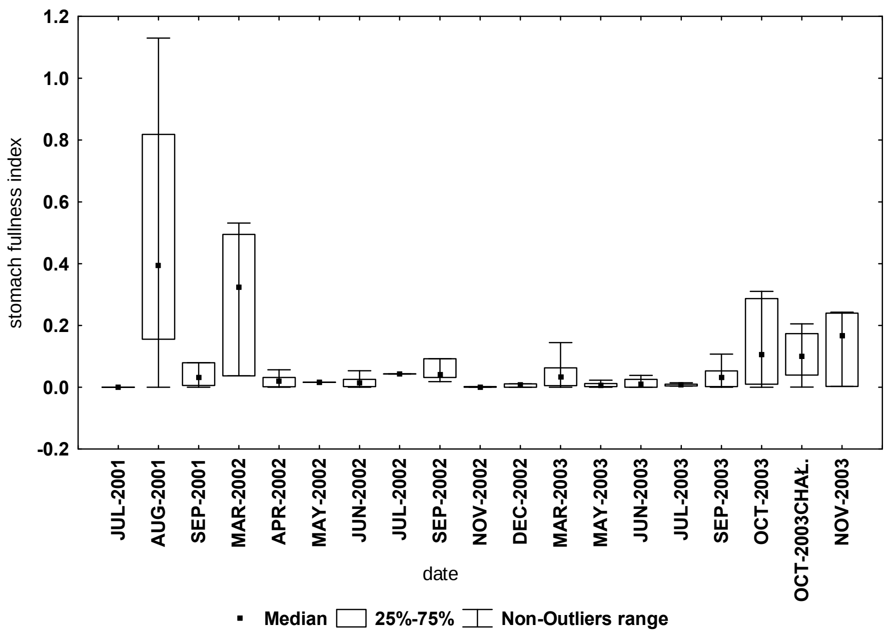

Fig. 7. Changes in seasonal feeding activity in *P. flesus*.

Diel food composition changes

During the study period (2001-2003), the most frequent and numerous prey in the diet of *P. minutus* at 08:00 included Amphipoda, Copepoda, Harpacticoida, and Calanoida, while the most abundant at 20:00 only included Copepoda and Harpacticoida. At 12:00, the dietary composition of this species was completely different and consisted of *Bathyporeia pilosa*, Mysidacea, and *Neomysis integer* (Table 1). In the evening hours, *P. flesus* frequently fed on *B. pilosa* and *N. integer* individuals, but between 01:00 and 05:00 *B. pilosa*, in contrast to *N. integer*, was present in *P. flesus* stomachs in high amounts. Polychaeta were noted very often in flounder stomachs in the morning. With the exception of the period from 08:00 to 00:00, Harpacticoida occurred quite often in the stomachs throughout the 24-hour period although they were important quantitatively only during the night (Table 2).

Table 1

Changes in diel food composition of *P. minutus* from 2001 to 2003 (%N – prey quantity; %O – prey frequency of occurrence).

Hour	Number of stomachs	Prey items													
		Amphipoda Undet.		*B. pilosa*		Mysidacea undet.		*N. integer*		Copepoda undet.		Harpacticoida		Calanoida	
		%N	%O	%N	%O	%N	%O	%N	%O	%N	%O	%N	%O	%N	%O
00:00	45	13.33	14.29	59.66	39.22	60.00	60.00	52.78	54.84	4.07	9.68	6.50	16.67	15.74	6.25
04:00	16	6.67	7.14	5.04	11.76	6.67	6.67	5.56	6.45	4.07	3.23	14.50	13.89	2.08	10.42
08:00	68	63.33	60.71	21.01	29.41	26.67	26.67	11.11	9.68	41.46	58.06	32.00	33.33	77.85	72.92
12:00	12	0.00	0.00	0.00	0.00	6.67	6.67	5.56	6.45	2.44	9.68	1.50	2.78	3.46	2.08
18:00	8	3.33	3.57	0.84	1.96	0.00	0.00	11.11	9.68	3.25	6.45	1.50	5.56	0.00	0.00
20:00	24	13.33	14.29	13.45	17.65	0.00	0.00	13.89	12.90	44.72	12.90	44.00	27.78	0.87	8.33

Table 2

Changes in diel food composition of *P. flesus* from 2001 to 2003 (%N – prey quantity; %O – prey frequency of occurrence).

Hour	Number of stomachs	Prey items							
		B. pilosa		*N. integer*		Harpacticoida		Polychaeta	
		%N	%O	%N	%O	%N	%O	%N	%O
20:00 - 00:00	48	40.19	44.00	60.17	50.00	10.60	29.73	9.09	9.09
01:00 - 05:00	19	44.98	12.00	1.69	5.88	52.28	27.03	13.64	13.64
08:00 -12:00	54	8.61	24.00	34.75	38.24	12.72	10.81	77.27	77.27
13:00 - 18:00	13	6.22	20.00	3.39	5.88	24.41	32.43	0.00	0.00

The dataset of diel food composition in September 2001 indicated that the importance of Amphipoda undet., *B. pilosa*, and Mysidacea undet. for the sand goby diet was the highest at 08:00. At 00:00, this species ingested mainly *N. integer* and slightly fewer Mysidacea undet. The smaller food items of Harpacticoida and Copepoda undet. comprised the diet at 20:00. Calanoida were the only significant prey at night (Fig. 8). *P. microps* exhibited similar diel dietary composition patterns to those of *P. minutus* as regards *B. pilosa* and *N. integer*. Harpacticoida was the most important food item for the common goby at 08:00 (Fig. 9).

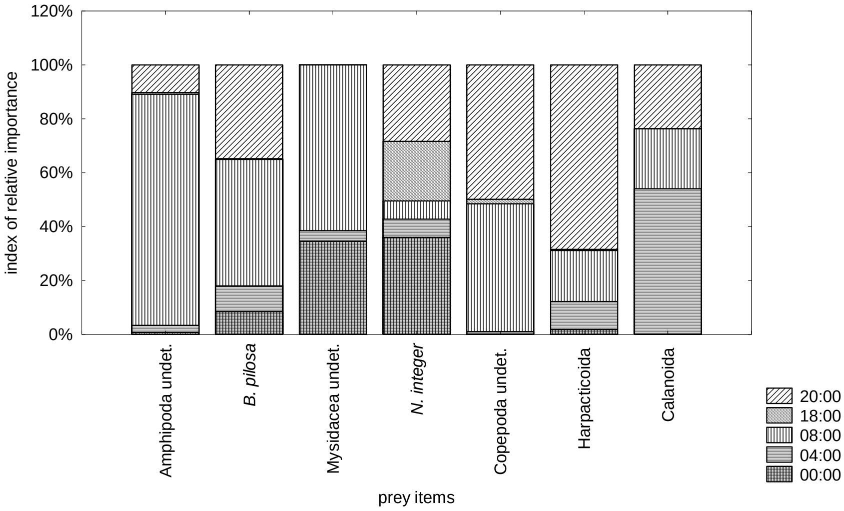

Fig. 8. Diel importance of prey items in the diet of *P. minutus* in September 2001.

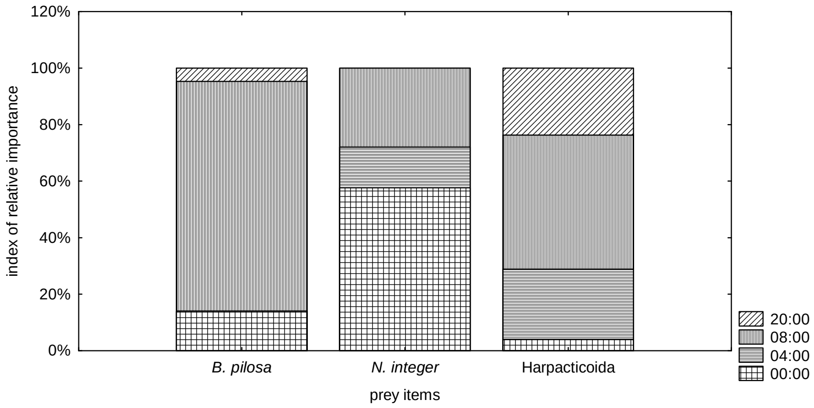

Fig. 9. Diel importance of prey items in the diet of *P. microps* in September 2001.

DISCUSSION

The feeding intensity of the sand goby, common goby, and flounder inhabiting the inshore waters of the Gulf of Gdańsk varies seasonally. It is the most intense during the summer months until November and in March before goby spawning, while it is the weakest during the winter. This might be related to changes in the fat content of the fish bodies in different seasons; it is highest during fall and the lowest during spring (Ostrowski 1997). The fish investigated in the current study presumably migrate in winter to deeper waters to decrease metabolic costs while not feeding. Some inconsistencies in the general trend of food intake rate in some months are due to the small number of individuals examined in months when the fish samples were taken.

The biomass range of the investigated species from shallow waters varies widely during the day and reached the maximum value at night (Lizińska 2002). One of the reasons fish migrate is to optimize feeding. This is understood as taking the most profitable prey, which is defined as the dependence of energy value, prey handling time, and catch effort. This strategy is associated with increased food availability, for example, the diel vertical migration of zooplankton, but also with predator avoidance (Gliwicz and Jachner 1992). Furthermore, observations of higher feeding activity linked to diel onshore-offshore migrations is a consequence of optimal foraging strategy enhanced by energetic advantages.

In a laboratory experiment by Wiederholm (1987), no differences in activity were measured in September for *Pomatoschistus minutus* and *P. microps*. Both goby species showed clear diel rhythms with the highest activity during daytime from 08:00 to 18:00. Additionally, higher *P. minutus* activity can be related to higher feeding frequency as is indicated by the lower number of stomachs with small amounts of food than were noted at other times. The intensity of *P. microps* feeding was higher at 00:00 and 04:00 and was not followed by hours of higher fish activity.

When frightened, *P. microps* is more apt to hide than *P. minutus* (Wiederholm 1987), so it loses foraging time. Shallow waters are used intensely by humans, and there is predation from birds. Based on dietary composition, which included prey organisms that inhabit deeper waters, it was assumed that fish predation also occurred outside of the sampling zone. All of these factors may have affected the intensity of *P. microps* feeding and rendered it lower in comparison with that of *P. minutus*.

Variation in the percentage of importance within the range of prey types depended on the timetable. In the Baltic Sea, Mysidacea are a good source of food due to their high abundance (Wiktor 1993) and energy value (Szaniawska

1993). On the other hand, their patchy distribution (Salemaa et al. 1986) influences their availability. Mysidacea, a zooplankton component that was especially dominant in the *N. integer* that fish consumed, perform diurnal vertical migrations. These are connected strictly with similar migrations undertaken by other zooplankton organisms and are mainly regulated by the intensity of solar radiation. The feeding migration of zooplankters, which consist of mysid food, also affects mysids (Viherluoto 2001). This fact may be connected with the higher intensity of fish feeding during the evening as they forage for one of their preferred prey types. At night, the intensity of feeding decreases because all three investigated fish are visual predators. On the other hand, littoral mysids feed at a constant rate despite light conditions (Viherluoto 2001), and the way they feed is not affected by the light factor. Consequently, this also does not affect fish in their choice of mysids as food only when their feeding grounds are confined to shallow waters.

Although there were significantly fewer typically planktonic than benthic organisms in the diet of the three investigated fish, the former were relatively important prey especially for *P. minutus*. The energetic value of the plankton in the Baltic Sea increases from April to November (Renk 1985). The seasonal changes in the energetic values of zooplankton may be due to alternations in species composition during the year, as well as to variation in the fat content of individual plankton species (Renk 1985). The zooplankton which consist of older development stages and mature Copepoda have a higher energetic value (Williams and Robins 1979). There are also diel fluctuations in the calorific value of plankton with increases during the night and decreases during the day, which are probably related to the diel feeding rhythm of plankton (Renk 1985). Therefore, feeding during evening and morning hours is more favorable for fish. This is confirmed by the high frequency of occurrence of plankton organisms in the fish diet during the 20:00-00:00 period and at 08:00. Seasonal fluctuations in energetic values also occur in other prey objects. However, there are more high- than low-calorific food items in the fish diets. The choice of high-calorific prey is not always determined by the preferences of the fish for such organisms, but often depends on many biotic and abiotic factors.

Diel feeding activity is a complex process influenced by environmental, behavioral, and physiological features (Cortés 1997). Activity choices made by fish may be influenced by hunger or the risk of predation but also by other demands such as reproduction and territorial defense (Magnhagen 1988). The trophic niches that were investigated in the current study were rich in food and no empty stomachs were noted; thus, the fish did not have to take the risk of increased foraging to find prey. Hence, they were not detected by larger visual predators. On the other hand, shallow coastal waters are considered to be relatively free of predators (Lenanton 1982), so the avoidance of larger predators probably does not explain decreased prey encounters and lower food intake. Feeding activity is rather more negatively affected by abiotic factors such as low temperature or salinity changes. (Thorman and Wiederholm 1983). These factors are strongly unpredictable and may either increase or decrease fish feeding intensity in the littoral zone.

Since vision is key for prey detection, fish food intake is dependant on the light-dark cycle. Accordingly, the investigated fish forage only during daylight. The fish may be forced into continuous activity during the day which resulted in the lack of empty stomachs in the present study. This behavior may be related to the high abundance of organisms with low-energetic values which forces fish to forage continuously in order to meet their energy needs. This is observed in the less energetically important *N. integer,* which was consumed to some extent throughout the day. There were clear peaks of importance in the more calorific prey the diet composition in September 2001 over the course of just a few hours (Fig. 8, 9). Undoubtedly, since *B. pilosa* is an actively swimming species, it is easier for predators to notice and is more energetically advantageous. Probably due to this, it is a very important prey item for all the studied fish.

Flounder stomach fullness during the summer months in the current study was significantly higher than that during the same period in a study by Malorny conducted in the Gulf of Gdańsk in 1990, when a high percentage of empty or almost empty stomachs was recorded. In the present study, no empty stomachs were noted and those with first degree fullness were rarely noted. The majority of stomachs were filled with food at least in 50% which confirms that the sandy bottom of the eulittoral provides a good food base for the fish inhabiting it.

It should be kept in mind that fish feeding activity is also related to length because dietary composition changes during development. Since the current research was confined to adult goby and juvenile flounder, the results are valid only for a narrow range of length classes. It is likely that, after migrating to deeper waters, each species would exhibit different feeding patterns.

Feeding activity chronology cannot be assessed fully based only on stomach content weight; data on dietary composition and stage of digestion of each prey individual in each stomach at each sampling time are essential to do this.

CONCLUSION

Generally, it can be stated that all three investigated species are day feeders and that food intake decreases at night. However, their behavior indicates that the timetable is flexible and depends on the type of prey and their seasonal and daily accessibility.

Since no empty stomachs were noted and the food items present throughout the investigation period (2001 – 2003) were characteristic of the shallow inshore water zone (*e.g.*, *B. pilosa*), it can be concluded that the shallow inshore waters of the Gulf of Gdańsk are a good source of food for fish inhabiting these areas.

REFERENCES

Aarnio K., Bonsdorff E., 1993, *Seasonal variation in abundance and diet of the sand goby Pomatoschistus minutus (Pallas) in a northern Baltic archipelago*, Ophelia, 37 (1), 19-30.

Berestovsky E.G., Anysymova, N.A., Denysenko S.G., Luppova, E.N., Savynov, V.M., Tymofeev, S.F., 1989, *Zavysymost mezdu razmeramy y massoj tela nokotoryh bespozvonochnyh y ryb severovostochnoj atlantyky*, Akademya Nauk CCCP, 1-24.

Cortés E., 1997, *A critical review of methods of studying fish feeding based on analysis of stomach contents: application to elasmobranch fishes*, Can. J. Fish. Aquat. Sci., 54, 726-738.

De Groot S.J., 1971, *On the interrelationships between morphology of the alimentary tract, food and feeding behaviour in flatfishes (Pisces: Pleuronectiformes)*, Neth. J. Sea Res., 5, 121-196.

Edlund A.-M., Magnhagen C., 1981, *Food segregation and consumption suppression in two coexisting fishes, Pomatoschistus minutus and P. microps: an experimental demonstration of competition*, Oikos, 36, 23-27.

Evans S., 1983, *Production, predation and food niche segregation in a marine shallow soft-bottom community*, Mar. Ecol. Prog. Ser., 10, 147-157.

Gąsowska M., 1962, *Kręgouste i ryby, Klucze do oznaczania Kręgowców Polski*, cz. I, PWN, Kraków.

Gliwicz Z.M., Jachner A., 1992, *Diel migrations of juvenile fish: a ghost of predation past or present?*, Arch. Hydrobiol., 124, 385-410.

Hampel H., Cattrijsse A., 2004, *Temporal variation in feeding rhythms in a tidal marsh population of the common goby Pomatoschistus microps (Kroyer, 1838)*, Aquat. Sci., 66, 315-326.

Lenanton R.C.J., 1982, *Alternative non-estuarine nursery habitats for some commercially and recreationally important fish species of south-western Australia*, Aust. J. Mar. Freshwat. Res., 33, 881-900.

Lizińska A., 2002, *Seasonal and daily distribution of commercial and non-commercial fish in shallow inshore waters of the Gulf of Gdańsk*, Oceanol. Hydrobiol. Stud., 31(1-2), 31-42.

Ławacz W., 1965, *An analysis of variations in two populations of Gobius microps Kr. Depending on the salinity of the habitat*, Ekologia Polska – Seria A, Tom XIII, Nr 10, 1-18.

Magnhagen C., 1988, *Changes in foraging as a response to predation risk in two gobiid fish species, Pomatoschistus minutus and Gobius niger*, Mar. Biol., 49, 21-26.

Malorny K., 1990, *Obserwacje narybku storni (P. flesus L.) występującego w strefie przybrzeżnej Zatoki Gdańskiej w latach 1982-1983*, Zeszyty Naukowe Wydziału BiNoZ UG, Oceanografia, 12, 43-58.

Mulicki Z., 1947, *Odżywianie się storni w Zatoce Gdańskiej*. Arch. Hydrobiol. Ryb., 13, 221-259.

Ostrowski J., 1997, *Odżywianie się storni (Platichthys flesus) w południowym Bałtyku w 1996 i 1997 r.*, Raporty MIR-u 1996, 237-247.

Pinkas L., Oliphant M. S., Iverson I. L. K., 1971, *Food habits of albacore, blue fin tuna, and bonito in California waters*, Fish. Bull. Calif., 152, 1-105.

Renk H., Filarski J., Ochocki S., Piechowska B., 1985, *Energetic value and lipid content of the Baltic zooplankton*, Oceanol., 21, 99-108.

Salemaa H., Tyystjärvi-Muuronen K., Aro E., 1986, *Life histories, distribution and abundance of Mysis mixta and Mysis relicta in the northern Baltic Sea*, Ophelia Suppl., 4, 239-247.

Sapota M. R., 2001, *Spatial (depth dependent) and temporal distribution of fish in sandy eulitoral of the tip of the Hel Peninsula (The Gulf of Gdańsk-Baltic)*, Oceanol. Stud., 3-4, 77-89.

Sapota M. R., Mudrak S., 1998, *Growth of the young flounder (Platichthys flesus) in inshore shallow waters of the Gulf of Gdańsk*, Oceanol. Stud., 3, 19-29.

Szaniawska A., 1993, *Energetic values of invertebrates* [in:] *Puck Bay*, K. Korzeniewski (ed.), Fundacja Rozwoju Uniwersytetu Gdańskiego, Gdańsk, 494 – 509. (in Polish)

Thorman S., Wiederholm A.-M., 1983, *Seasonal occurrence and food resource use of an assemblage of nearshore fish species in the Bothnian Sea, Sweden*, Mar. Ecol. Prog. Ser., 10, 223-229.

Viherluoto M., 2001, *Food selection and feeding behaviour of Baltic Sea mysid shrimps*, W. & A. de Nottbeck Foundation Sci. Rep., 23, 1-35.

Waligóra Borek K., 2004, *Biological characteristic of Pomatoschistus minutus from the Gulf of Gdańsk*, Msc. Th., University of Gdańsk, 34 pp. (in Polish)

Wendt D., 2004, *Biological characteristic of common goby (Pomatoschistus microps) from the Gulf of Gdańsk*, Msc. Th., University of Gdańsk, 42 pp. (in Polish)

Wiederholm A.-M., 1987, *Habitat selection and interactions between three marine fish species (Gobiidae)*, Oikos, 48, 28-32.

Wiktor K., 1993, *Zooplankton, Macrozoobenthos,* [in:] *Puck Bay*, K. Korzeniewski (ed.), Fundacja Rozwoju Uniwersytetu Gdańskiego, Gdańsk, 388 – 394, 442 – 454. (in Polish)

Williams R., Robins D., 1979, *Calorific, ash, carbon and nitrogen in relation to length and dry weight of Parathemisto gaudichaudi in the North East Atlantic Ocean*, Mar. Biol., 52, 247-252.

Witek Z., 1995, *Produkcja biologiczna i jej wykorzystanie w ekosystemie morskim w zachodniej części Basenu Gdańskiego*, MIR, Gdynia, 15 pp.

English revision: Jennifer Zielińska