Oceanological and Hydrobiological Studies
Vol. XXXIV, No. 3

Institute of Oceanography (39-55) University of Gdańsk
2005

Research Article

DOES FOOD QUALITY AFFECT THE CONDITIONS OF THE SAND AND COMMON GOBIES FROM THE GULF OF GDAŃSK, POLAND?

KATARZYNA WALIGÓRA BOREK , ILONA ZŁOCH, MARIUSZ R. SAPOTA[1], MONIKA FIJAŁKOWSKA, KAROLINA FORYCKA

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

e-mail:[1] ocems@univ.gda.pl

Key words: sand goby, common goby, Gulf of Gdańsk, fish condition, feeding

Abstract

Sand and common goby specimens were collected from the costal waters in the vicinity of Sopot and Chałupy (Gulf of Gdańsk) from August to October. The relationship between the food consumed and the fish condition was investigated for both species using the Fulton and Clark factors, HSI, feeding intensity, and the index of relative importance. The results indicated that the mean values of the common goby condition factors (20 – 29 mm) were higher in September, the last month of reproduction. The sand gobies (30 – 39 mm) were characterized by lower condition factor values in September, one month after spawning. It was concluded that there is a direct link between diet composition and goby condition during spawning and in the months following it.

INTRODUCTION

The sand goby, *Pomatoschistus minutus* (Pallas 1770), and the common goby, *Pomatoschistus microps* (Kröyer 1840), are two of the most abundant fish species in the estuaries, lagoons, and shore waters of Europe (Salgado et al. 2004). The geographical distribution of the common goby ranges from the coast of Norway to the Gulf of Lion in the Mediterranean Sea (Boucherereau and Goulorget 1997), while that of the sand goby ranges from the coast of Norway to the west coast of the Black Sea (Boucherereau et al. 1989). These species prefer exposed sandy, exceptionally muddy, or bottom habitats overgrown with marine plants (Żmudziński 1990). Shallow costal waters are environments with highly variable biotic and abiotic conditions. While physical parameters like temperature, salinity, and pH have an impact on fish life functions, so does the diversity of their food. The sandy bottom ecosystem is an important habitat for many fish species, and it provides suitable conditions for developing young and small fishes away from larger predators. The sand goby reaches very high densities in the littoral zone, so it can be an important object of prey (Hesthagen 1977).

It has been observed that the sand and common gobies coexist in some shallow waters on the Polish coast. These species are closely related and morphologically similar; moreover, they consume approximately the same food (Edlund and Magnhagen 1981). Several studies on Gobiidae feeding have been published, but they were either conducted in other regions of occurrence or as laboratory experiments (Edlund and Magnhangen 1981, Magnhagen and Wiederholm 1982, Aarnio and Bondorff 1993).

The aim of the present study was to determine whether there is a relationship between the diet and condition of *P. minutus* and *P. microps* in the Gulf of Gdańsk.

MATERIAL AND METHODS

The study was conducted in the costal waters of the Gulf of Gdańsk. The sand goby specimens were collected in August 2002 (last month of spawning) and in September 2002 (first month following spawning). Specimens of common goby were collected from September 2002 (last month of spawning) to October 2003 (first month following spawning). *P. microps* specimens were caught in Sopot (in September) and Chałupy (in October), while all of the *P. minutus* individuals were collected in Sopot. The material was collected at a depth of 1 m using a towing-net with a 2 m opening. The distance of the hauls was approximately 100 m. Following capture, the gobies were preserved in a

4% buffered formaldehyde solution. In the laboratory, the total length of the fish was measured to the nearest 1 mm. The fish were also weighed, with and without viscera, to the nearest 0.0001 g. The livers and stomachs were weighed to the nearest 0.0001 g. The stage of stomach fullness was determined using the following formula:

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

The stomach contents were identified to the lowest possible taxonomic level. The stomach contents were counted and measured under a stereomicroscope. Prey wet weight was determined using the length-weight relationship (Berestovsky et al. 1989, Witek 1995). These data were analyzed in terms of frequency of occurrence, quantity, and weight in fish stomachs, and were presented as the index of relative importance (IRI) (Pinkas et al. 1971). Individual data categories were expressed as percentages:

$$IRI = (\%N + \%W) \cdot \%O$$

where:
%N – numerical percentage of a food item in the stomachs;
%W – percentage by volume of a food item in the stomachs;
%O – frequency of occurrence of a food item.

The relationship between the relative importance of a given prey item and its energetic value was assessed and considered in light of the research by Witek (1995).

The following indexes were calculated: Clark condition factor (relationship between weight without viscera and total length); Fulton condition factor (relationship between total weight and total length); hepatosomatic index (HSI) (dependence between liver weight and total fish weight) (Ricker 1975). The factors and indexes are not presented in the same fish length classes for both species in each month because individuals were scarce in the investigated area.

RESULTS

Fulton factor

The highest Fulton factor values were attained by the common goby from the 30-39 mm length class in October. This is the first month following spawning. The sand goby attained the highest values in the 40-49 mm length class during the last month of spawning. The condition factor usually increased with fish length. The opposite trend was observed only in the case of the common goby during the last month of spawning, and only for these same fish did the Fulton factor decrease with fish length (fig. 1).

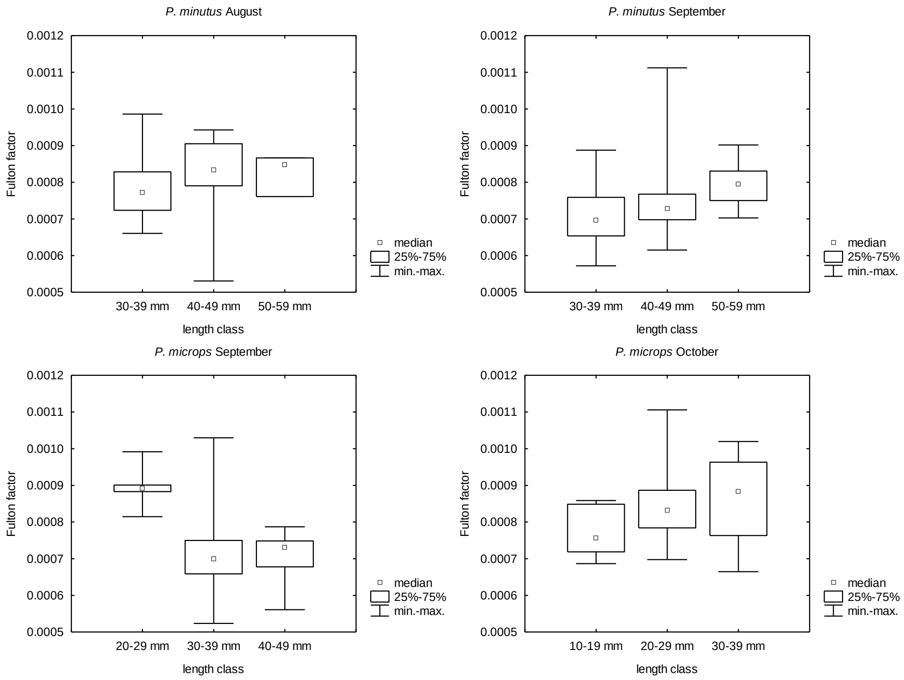

Fig. 1. Changes of Fulton factor values in fish length classes

Clark factor

The values of the Clark factor usually increased with fish length. September is the only exception; the condition factor for *P. microps* decreased with fish length. The highest values were achieved by both the common goby (20-29 mm length class) and the sand goby (50-59 mm length class) in September (Fig. 2).

Hepatosomatic index (HSI)

The HSI increased in all months with fish length for the sand goby, while for the common goby it only did so in October. *P. microps* achieved the highest HIS in October in the 30-39 mm length class. The lowest values were in September for the common goby in the 30-39 mm and 40-49 mm length classes (Fig. 3).

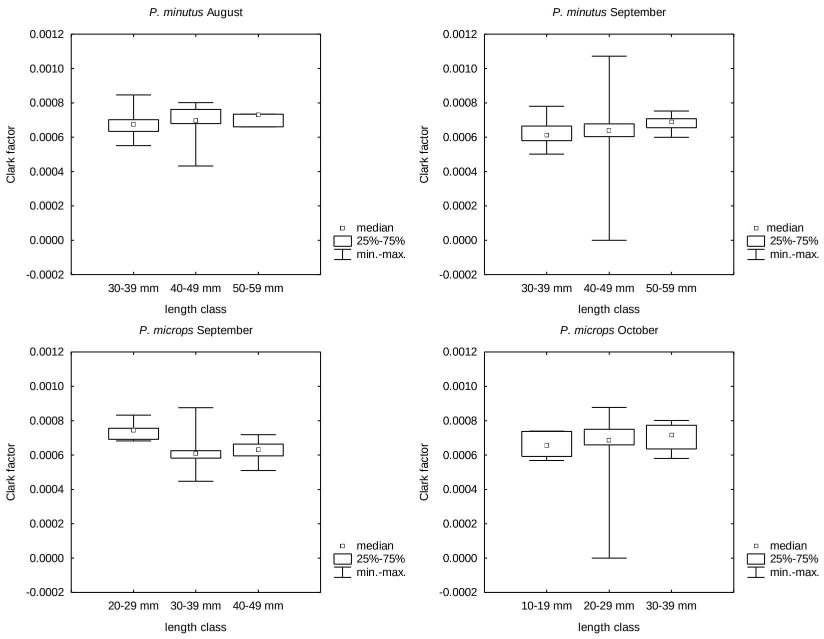

Fig. 2. Changes of Clark factor values in fish length classes

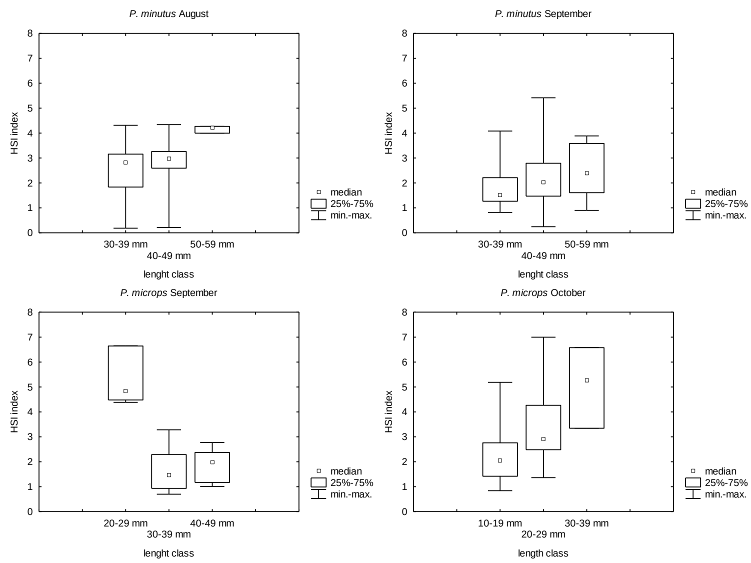

Fig. 3. Changes of HSI values in fish length classes

Feeding intensity

In August 2001, the largest food intake was exhibited by the sand gobies from the 40 – 49 mm length class. In the following month, the youngest individuals of *P. minutus* fed the most intensively. In the case of *P. microps*, the highest rate of food intake was observed for individuals from the 20 – 39 mm length classes. In October 2003, at Chałupy station, the longest common goby individuals had the highest value of stomach fullness index (Fig. 4).

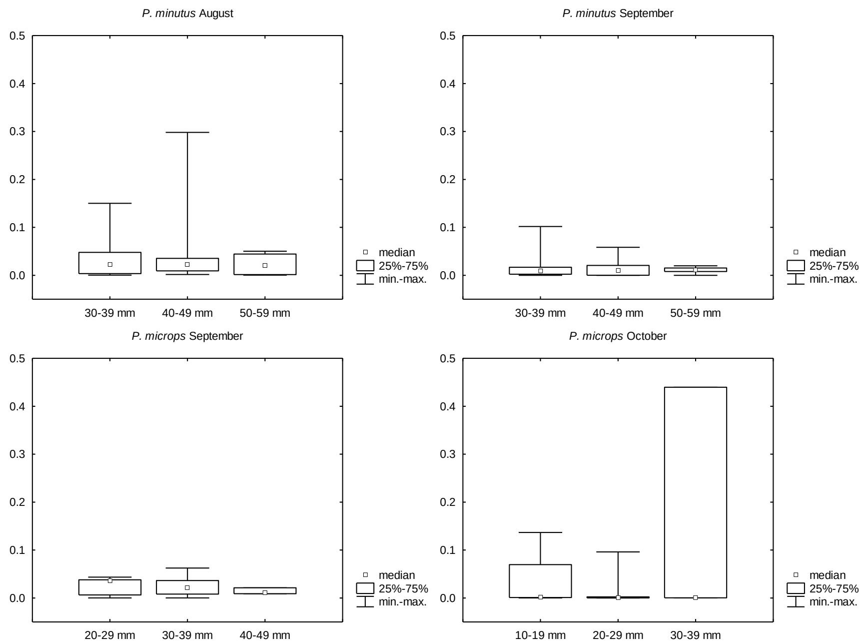

Fig. 4. Changes of seasonal feeding intensity in gobies by length classes

Food composition of P. minutus

Numerically, calanoids dominated the sand goby diet in all fish length classes in August 2001. Copepod eggs, chironomids, and sand goby young were the most frequently found prey items in the food of all the investigated fish length classes of *P. minutus*. In the diet of the sand goby from the 30 – 49 mm length class, amphipods were the dominants in terms of biomass, but in the stomachs of the longest specimens, the prey included young individuals of its own species. For smaller *P. minutus* (from the 30 - 39 and 40 - 49 mm length classes), the most important prey (%IRI) were calanoids, whereas for the largest ones (exceeding 50 mm) the most significant prey object was *P. minutus* (Table 1).

Food composition in different length classes of *P. minutus* in August 2001

	Sand goby length classes											
	30-39 mm				40-49 mm				50-59 mm			
Prey item	%O	%N	%W	%IRI	%O	%N	%W	%IRI	%O	%N	%W	%IRI
Amphipoda	20.00%	0.88%	0.48%	0.29%	5.00%	0.30%	24.28%	2.97%	-	-	-	-
Bathyporeia pilosa	24.00%	1.06%	94.56%	24.33%	5.00%	1.50%	68.85%	8.51%	-	-	-	-
Calanoida	84.00%	76.81%	0.33%	68.71%	60.00%	33.83%	0.07%	49.23%	50.00%	25.00%	0.32%	9.85%
Copepoda	28.00%	4.60%	0.014%	1.37%	30.00%	3.59%	0.01%	2.62%	-	-	-	-
***Gammarus* sp**	-	-	-	-	10.00%	0.60%	0.21%	0.20%	-	-	-	-
Harpacticoida	8.00%	0.35%	0.00012%	0.03%	15.00%	9.28%	0.0012%	3.37%	25.00%	4.17%	0.0029%	0.81%
Insecta	-	-	-	-	15.00%	0.90%	0.23%	0.41%	-	-	-	-
Eggs	4.00%	0.18%	0.000035%	0.01%	10.00%	0.60%	0.00026%	0.14%	25.00%	8.33%	0.014%	1.62%
Copepoda eggs	24.00%	7.61%	0.00014%	1.94%	25.00%	39.22%	0.00024%	23.73%	25.00%	4.17%	0.00045%	0.81%
Mysidacea	-	-	-	-	5.00%	0.30%	0.02%	0.04%	25.00%	4.17%	1.53%	1.11%
Nematoda	4.00%	0.18%	0.00005%	0.01%	5.00%	0.60%	0.00006%	0.07%	-	-	-	-
Neomysis integer	4.00%	0.35%	0.63%	0.04%	-	-	-	-	-	-	-	-
Pomatoschistus minutus	20.00%	1.59%	2.86%	0.95%	30.00%	2.40%	1.43%	2.78%	75.00%	20.83%	90.38%	64.91%
Mysis mixta	4.00%	0.18%	0.29%	0.02%	-	-	-	-	-	-	-	-
Balanus improvisus	4.00%	0.18%	0.00008%	0.01%	-	-	-	-	-	-	-	-
Chironomidae	40.00%	4.96%	0.015%	2.11%	30.00%	3.59%	0.0043%	2.61%	75.00%	25.00%	0.17%	14.69%
Cladocera	8.00%	0.35%	0.00036%	0.03%	-	-	-	-	-	-	-	-
Pisces	12.00%	0.53%	0.63%	0.15%	-	-	-	-	-	-	-	-
***Pomatoschistus* sp.**	4.00%	0.18%	0.19%	0.02%	25.00%	1.80%	2.21%	2.42%	50.00%	8.33%	7.59%	6.20%
***Bosmina* sp.**	-	-	-	-	5.00%	0.30%	0.00011%	0.04%	-	-	-	-
Cestoda	-	-	-	-	5.00%	0.30%	0.00003%	0.04%	-	-	-	-
Polychaeta	-	-	-	-	10.00%	0.60%	2.6484%	0.79%	-	-	-	-
Pontoporeia affinis	-	-	-	-	5.00%	0.30%	0.0466%	0.04%	-	-	-	-
Number of stomachs	25				20				4			

Table 2

Food composition in different length classes of *P. minutus* in September 2001.

	Sand goby length classes											
	30-39 mm				40-49 mm				50-59 mm			
Prey item	%O	%N	%W	%IRI	%O	%N	%W	%IRI	%O	%N	%W	%IRI
Amphipoda	27.59%	3.50%	34.14%	23.56%	16.00%	0.90%	16.88%	4.45%	37.50%	1.09%	28.67%	13.87%
Annelida	-	-	-	-	2.00%	0.11%	0.00%	0.00%	-	-	-	-
Bathyporeia pilosa	31.03%	3.85%	30.41%	24.13%	40.00%	3.95%	46.41%	31.54%	25.00%	1.45%	26.27%	8.62%
Calanoida	17.24%	4.90%	0.45%	2.09%	14.00%	1.13%	0.14%	0.28%	-	-	-	-
Copepoda	-	-	-	-	20.00%	2.15%	0.07%	0.69%	37.50%	22.10%	0.41%	10.50%
***Gammarus* sp**	-	-	-	-	4.00%	0.23%	5.12%	0.33%	-	-	-	-
Harpacticoida	34.48%	25.87%	0.14%	20.36%	32.00%	9.72%	0.09%	4.91%	25.00%	0.72%	0.01%	0.23%
Heterotanais oerstedti	-	-	-	-	2.00%	0.11%	1.07%	0.04%	-	-	-	-
***Hydrobia* sp.**	-	-	-	-	2.00%	0.11%	0.56%	0.02%	-	-	-	-
Insecta	-	-	-	-	2.00%	0.11%	1.77%	0.06%	-	-	-	-
Eggs	-	-	-	-	2.00%	0.23%	0.02%	0.01%	-	-	-	-
Copepoda eggs	13.79%	55.94%	0.01%	17.51%	42.00%	78.42%	0.09%	51.62%	62.50%	72.46%	0.05%	56.34%
Mysidacea	10.34%	1.05%	3.15%	0.99%	10.00%	0.56%	2.37%	0.46%	-	-	-	-
Nematoda	10.34%	1.75%	0.01%	0.41%	4.00%	0.68%	0.00%	0.04%	-	-	-	-
Neomysis integer	17.24%	1.75%	22.94%	9.66%	16.00%	1.13%	20.10%	5.32%	25.00%	1.09%	19.41%	6.37%
Pomatoschistus minutus	-	-	-	-	2.00%	0.11%	2.62%	0.09%	-	-	-	-
Pontoporeia femorata	-	-	-	-	4.00%	0.23%	0.83%	0.07%	-	-	-	-
Praunus flexuosus	-	-	-	-	2.00%	0.11%	1.84%	0.06%	-	-	-	-
Gastropoda	3.45%	0.35%	0.17%	0.04%	-	-	-	-	12.50%	0.36%	0.87%	0.19%
Macoma balthica	3.45%	0.35%	2.95%	0.26%	-	-	-	-	-	-	-	-
Mysis mixta	6.90%	0.70%	5.62%	0.99%	-	-	-	-	-	-	-	-
Mesopodopsis slabberi	-	-	-	-	-	-	-	-	12.50%	0.36%	8.84%	1.43%
Pygospio elegans	-	-	-	-	-	-	-	-	12.50%	0.36%	15.46%	2.46%
Number of stomachs	29				59				8			

In September 2001, the most abundant food objects in the diet of the sand goby from all length classes were Copepoda eggs. These food items were also found more often than not in the stomachs of individuals longer than 40 mm. The exceptions were fish from the 30 - 39 mm length class, because their diet consisted of numerous harpacticoids. Taking into account the prey biomass, the diet of all sand goby individuals contained a high percentage of amphipods (mainly *Bathyporeia pilosa*). The highest values of the relative importance index were noted for *B. pilosa* (sand goby under 39 mm) and for Copepoda eggs (sand goby exceeding 40 mm) (Table 2).

Table 3

Food composition of *P. microps* in different length classes in September 2001.

	Common goby length classes											
	20-29 mm				30-39 mm				40-49 mm			
Prey item	%O	%N	%W	%IRI	%O	%N	%W	%IRI	%O	%N	%W	%IRI
Amphipoda	7.69%	0.88%	30.81%	7.41%	5.56%	0.54%	9.09%	1.68%	-	-	-	-
Bathyporeia pilosa	15.38%	1.77%	61.62%	29.65%	22.22%	2.69%	45.46%	33.60%	22.22%	1.60%	49.34%	28.60%
Calanoida	7.69%	1.77%	0.25%	0.47%	5.56%	5.91%	1.22%	1.24%	11.11%	6.40%	0.91%	2.05%
Harpacticoida	38.46%	23.01%	0.33%	27.29%	27.78%	17.20%	0.12%	15.11%	33.33%	14.40%	0.21%	12.31%
Copepoda eggs	15.38%	70.80%	0.07%	33.14%	11.11%	69.89%	0.01%	24.39%	22.22%	76.00%	0.06%	42.70%
Mysidacea	7.69%	0.88%	6.90%	1.82%	5.56%	0.54%	2.04%	0.45%	-	-	-	-
Nematoda	-	-	-	-	5.56%	0.54%	0.003%	0.09%			-	-
Neomysis integer	-	-	-	-	16.67%	2.69%	42.06%	23.42%	11.11%	1.60%	49.48%	14.34%
Balanus improvisus	7.69%	0.88%	0.02%	0.21%	-	-	-	-	-	-	-	-
Number of stomachs	5				9				3			

Food composition of P. microps

In September 2001, Copepoda eggs were the most important prey in terms of quantity in the dietary composition of the common goby. However, the most frequently found food items in the common goby stomachs were harpacticoids. The weight of *B. pilosa* and the undetermined Amphipoda was significant in the food of the smallest common goby individuals. Hence, the bulk of the food biomass of common goby longer than 30 mm not only consisted of *B. pilosa*, but also of *N. integer*. Copepoda eggs were the most important food items (%IRI) for the common goby from the 20 – 29 mm and 40 – 49 mm length classes (Table 3).

The food composition at the Chałupy station was dominated quantitatively by Harpacticoida in every common goby length class (20 - 29, 30 - 39, 40 - 49 mm). In the *P. microps* diet from all length classes, *B. coregoni maritima* and Harpacticoida often occurred. Additionally, chironomids were common prey items in the food composition of common goby longer than 30 mm. Polychaeta dominated in the food biomass compared to the weight of other prey in the stomachs of the common goby between the 30 – 49 mm length classes. Comparable prey biomass values in the smallest *P. microps* individuals were noted for *B. pilosa*. The highest values of the relative importance index were noted for Harpacticoida in every common goby length class (Table 4).

Table 4

Food composition of *P. microps* in different length classes in October 2003.

	Common goby length classes											
	20-29 mm				30-39 mm				40-49 mm			
Prey item	%O	%N	%W	%IRI	%O	%N	%W	%IRI	%O	%N	%W	%IRI
Amphipoda	-	-	-	-	9.09%	0.66%	4.00%	0.46%	-	-	-	-
Bathyporeia pilosa	25.00%	1.27%	95.20%	19.20%	15.15%	1.10%	9.10%	1.68%	-	-	-	-
Bosmina coregoni maritima	100.00%	25.32%	2.38%	22.05%	69.70%	13.63%	0.15%	10.46%	66.67%	13.79%	0.03%	7.42%
Calanoida	-	-	-	-	9.09%	0.66%	0.04%	0.07%	-	-	-	-
Cestoda	25.00%	1.27%	0.03%	0.26%	3.03%	0.22%	0.0007%	0.01%	-	-	-	-
Chironomidae	25.00%	1.27%	0.17%	0.29%	57.58%	8.35%	0.26%	5.40%	100.00%	17.24%	0.15%	13.99%
Copepoda	-	-	-	-	3.03%	0.22%	0.0008%	0.01%	-	-	-	-
Cyclopoida	-	-	-	-	3.03%	0.22%	0.0238%	0.01%	-	-	-	-
Harpacticoida	100.00%	70.89%	2.22%	58.21%	93.94%	71.21%	0.26%	73.11%	100.00%	62.07%	0.04%	49.98%
Eggs	-	-	-	-	6.06%	0.44%	0.0072%	0.03%	-	-	-	-
Copepoda eggs	-	-	-	-	6.06%	2.64%	0.0006%	0.17%	-	-	-	-
Polychaeta	-	-	-	-	9.09%	0.66%	86.15%	8.59%	33.33%	3.45%	86.38%	24.10%
Gammarus locusta	-	-	-	-	-	-	-	-	33.33%	3.45%	13.40%	4.52%
Number of stomachs	4				33				3			

Calorific value of prey

The present paper uses the calorific prey values from the research by Witek (1995) (Table 5).

Table 5

Calorific values of prey items

Prey items	*Organic carbon content [gC/g m.m.]*	*Calorific value [kJ/g m.m.][a]*
Nereis diversicolor	0.068	3.4
Pygospio elegans	0.064	3.2
Balanus improvisus	0.020	1
Bathyporeia pilosa	0.065	3.25
***Gammarus* sp.**	0.063	3.15
Pontoporeia affinis	0.080	4
Pontoporeia femorata	0.084	4.2
Hydrobiidae	0.068	3.4
Macoma balthica	0.035	1.75
Nematoda	0.083	4.15
Harpacticoida	0.065	3.25
Mysis mixta	0.040	2
Neomysis integer	0.038	1.9
Gobiidae	0.077	3.85
Mesozooplankton crustaceans	0.064	3.2

[a] based on the estimation that 1 g C equals 50 kJ

DISCUSSION

Optimalization is an important aspect of fish feeding. How can an animal adapt its feeding to achieve the maximum energy gain, which is then used for maintenance, growth, and reproduction? Most animals can consume a wider range of prey than they actually do (Viherluoto 2001). An organism has to maximize its overall energy gain. Accordingly, it has to considered whether to invest energy in foraging for the most profitable prey or to feed on every potential organism unconditionally and expend minimum energy on searching and catching. The best feeding strategy would be to strike a balance between these alternatives, and, depending on the availability of different prey, select the best one (Landry 1981). Although large prey are energetically the best choice, they are also difficult to catch or to ingest; thus, selecting the best feeding techniques and foraging locations are also very important (Viherluoto 2001).

As regards foraging, fitness is understood as the rate of net energy gain. Foraging is closely correlated with fitness because a high rate of energy gain can decrease the amount of time spent on foraging and increase growth rate or energy stores. It is clear that fish behave so as to maximize their rate of net energy gain. This should lead to improved fitness; however, under some circumstances, maximizing the rate of net energy gain will not maximize fitness. Most fish energy resources are available for fast growth, the maintenance of life functions, and reproduction; thus, the additional cost of foraging directly influences survival rather than energy storage.

The food intake of fish is usually limited by food availability. After a period of restricted feeding, fish may increase their feeding rate due to increased food supply. These fish are often hyperphagic with higher food consumption than those which feed continuously at the same rate (Ali and Wootton 2001). After a prey depletion period, the fish first try to re-fill the gut. The time of re-filling depends on gut size as its capacity changes during fish growth and may vary as a consequence of an ontogenic shift in diet composition. In the case of the Gulf of Gdańsk, it seems that its shallow waters provide quite a good prey supply (Łukasiewicz 2002, Złoch 2004) and fish do not suffer from starvation. The sand goby strategy for energy compensation appears to differ from the pattern described above. After a limited feeding period during spawning, the sand goby chooses high-energetic food items, such as Copepoda eggs, rather than larger prey. Even the largest individuals of sand goby that could have preyed on larger prey objects chose this strategy, and their condition improved continuously in September. Contrary to increasing condition index values, the intensity of feeding decreased. This is because the food intake index is based on food weight. Copepoda eggs did not comprise the bulk of the sand goby food biomass, but they were still the most important (%IRI) food item. In the first months of the study (August and September), the mean value of food intake of both gobies in all length classes was higher than in the following months. This decline in feeding rate could have been caused by lower water temperatures since exothermic fishes decrease their metabolism and level of activity as temperatures decrease (Nikolsky 1967), and this entails a lower food intake.

The food composition of both gobies suggests that they fed on organisms whose distribution in the environment is patchy, *e.g.*, *Neomysis integer*. A patch is understood as any group of organisms that is higher in density than the environmental average. The utilization of a patch can be energetically beneficial because of the greater average food intake rate (gain) and limited foraging time. However, the advantage of this strategy for the fish is rather short-term when considering a single patch. The rate of gain while foraging in a patch declines because of prey depletion. In general, the foraging decision to move to another patch is affected both by the environment and the body condition of the fish.

The observed range of goby food is broad, which means they are well adapted to biotic changes in the environment, and they freely switch to suitable food items. Even if they do not starve, they have a limited time in which to obtain rich food sources that allow them to spawn. Their risk of falling prey to larger predators may be higher than that of long-lived species. There are also other potential costs of plasticity, such as reduced breeding, reduced growth, and errors in appropriate behavioral responses. When food supplies are highly variable, as in the case of coastal waters, fish may be forced to store fat for later use. Therefore, feeding plasticity is expected to increase with environmental variability (Komers 1997).

Male-male competition and parental care (nest preparation and guarding offspring) are energetically costly and require good condition (Lindström 1998). Due to this, food affects the distribution of breeding gobies. In the field, most non-breeding gobies are in poorer body condition than nesting individuals (Kangas 2000). Female mating costs may change over the spawning season, and they become more choosy later in the breeding season (Forsgren 1997), which, in the present study, was in August or September. This fact can affect the body condition of males and females. Males are in good condition at the beginning of the spawning season, so most of them are not rejected by females. The search for a mate can be more costly in terms of predation risk early in the spawning season. Hence, older goby individuals use more of their accumulated energy for courtship. This is reflected in a decline in the hepatosomatic index of older individuals in August. The energy budget even seems to control female choice between dominant and non-dominant males. Sometimes, the cost of choosing a dominant male can outweigh the benefits (Qvarnström and Forsgren 1998).

Highly competitive males pay direct energy costs for aggressiveness that are related to increased metabolic rates, and they could be more liable to starve. They can compensate for these costs through the filial cannibalism of their eggs. This was not noted in the present study because, other than those of Copepoda, eggs were not an important food item for either goby species.

Throughout the spawning period the gobies tended to feed continuously but with variable intensity (Złoch 2004). As the spawning season progresses, body energy resources decline and guarding males may compensate for this by cannibalizing their own eggs (Lindström 1998). In the present study, the gobies did not exhibit such behavior. Both of the investigated niches probably provided alternative high-energy food sources to help gobies survive until the end of breeding. This can be seen in the example of the consumption of Copepoda eggs by the common goby. This food item constituted most of the *P. microps* diet in the last month of spawning (September) and its importance declined considerably in the following month as it was no longer needed to such an extent. However, this also could have been the result of decreased Copepoda egg abundance in the environment due to the completion of spawning. The decline of this goby food component requires further investigation.

In October 2004, immature common goby individuals were observed. Their energy costs and benefits are considerably different from those of older individuals. Due to their small size, their prey is also small and consists mainly of *Bosmina coregoni maritima* and Harpacticoida. As young gobies grow, they also feed quite frequently on Chironomidae. The choice of food by the youngest gobies cannot be considered in terms of spawning. Their aims are different from those of adult individuals. Larval mortality can be caused by predation and starvation, so parts of the body needed for swimming and feeding must develop as rapidly as possible and preferably in balance. The importance of *Bathyporeia pilosa* for newly-hatched individuals of the common goby is very high, as is that of meiofauna. However, such a high relative importance index value is influenced by the individual biomass of larger prey. *B. pilosa* is not abundant in the common goby food in all length classes, which reflects its low availability in the environment (Kotwicki 1997).

For such short-lived species like the sand and common gobies, fast growth seems to be a priority in the early stage of development. They need to reach the required length to spawn in a short period as they die soon after reproduction. (Wheeler 1969). The mean weight of common gobies in particular length classes is almost twice that of sand gobies (Wendt 2004). Additionally, the common goby can be considered to be better adapted to more effective growth than the sand goby. Protection through lipid reserve levels and good body condition are more important for the older individuals.

The Fulton and Clark condition factors for the 20 – 29 mm common goby were very similar in September and October. This may indicate that these individuals were too small to spawn. The significant decline in the hepatosomatic index value in October shows that they used their energy stores for fast growth and development rather than for spawning. Moreover, decreased somatic condition in adult common gobies during warm months was not only caused by courtship. High water temperature in the summer resulted in an increased metabolic rate. Furthermore, food intake was lower than average during spawning so decreased prey energy gain was insufficient to maintain metabolic needs. This was probably the reason that the sand gobies were even forced to feed on their own newly-hatched young in August to cover all energy costs.

As regards the occurrence of *N. integer* in the food of gobies, it is clear that this prey item is important only for larger fish individuals. Furthermore, due to the low abundance of *N. integer* in the environment at the Chałupy station (Kotwicki 1997), only the gobies from the Sopot station fed on this species. In September, the high biomass of *N. integer* in the food of both gobies indicated that, for some reason, the fish chose this prey in that particular month. It seems that the energy value of one prey organism is insufficient to explain fish food choice. Even if *N. integer* individuals do not attain a high energy value in September, the quantity of the accumulated energy in the population per water volume unit reaches its maximum level in that particular month (Szaniawska et al. 1986). The *N. integer* biomass per water volume unit is the highest in September.

In September 2001, the feeding intensity of the common goby decreased, which was reflected in its lower condition. What is more, the older the common goby were, the less important were amphipods in their food. The largest amphipod biomass decline was observed in the food mass of the common goby in the 20 to 39 mm length range. This resulted in the lower condition of this fish species. This observation concurs with the findings of Jackson et al. (2002), who concluded that the depletion of macrofaunal prey resources leads to a loss of fitness. This is partially caused by the increased length of the search for meiofaunal prey and a lower energetic return. Indeed, feeding on large prey decreases foraging time, and there is also a lower risk of being predated. On the other hand, most of the considered prey species have a patchy distribution in the environment so the time spent searching for them should not differ considerably. The energetic value of mesozooplankton and macrofaunal prey also did not differ significantly. It is possible that feeding on zooplankton does not lower fish fitness, and it may be energetically beneficial since a higher number of small prey is available.

The sand goby choice of food was partially different from that of the common goby. In contrast to *P. microps*, the sand goby food composition consisted of typically planktonic Calanoida. This indicates that they utilized the water column differently from the common goby, which prefers rather shallower waters (Wiederholm 1987). Furthermore, the *B. pilosa* biomass in *P. minutus* food was at a rather constant value in all length classes (with the exception of 50 mm fish in August) as was the feeding rate, but the condition of the sand goby varied. So, again it can be concluded that prey other than macrofaunal organisms influenced the fitness of fish. Planktonic prey is also a good source of food because it accumulates lipids first as opposed to benthic prey, which store carbohydrates first and then lipids (Szaniawska 1993).

In future environmental studies, the sex of gobies should be considered separately as food abundance affects females and males differently. Males increase their potential reproductive rate when there is a food shortage, while females reproduce more slowly (Kvarnemo 1997).

CONCLUSION

Gobies spend their available energy stores with varying priority for particular needs at different stages of development. Therefore, their choice of prey items depends on food availability in the environment and fish energy requirements. Apart from trophic niche richness, spawning period also directly affects goby dietary composition. Goby feeding exhibits a high degree of plasticity adjusted to current energy costs and benefits. The energy content of prey is partially responsible for the condition of both gobies. Regardless of this, the condition pattern of the common goby in all investigated lengths differed from that of the sand goby.

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

Ali M., Wootton R.J., 2001, *Capacity for growth compensation in juvenile three-spined sticklebacks experiencing cycles of food deprivation*, J. Fish Biol., 58, 1531-1544

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

Bouchereau J.-L., Guelorget O., 1997, *Comparison of three Gobidae (Teleostei) life story strategies over their geographical range*, Oceanol. Acta, Vol. 21, No 3, 503-517

Bouchereau J.-L., Quignard J.P., Joyeux J.Ch., Tomasimi J.A., 1989, *La population de Pomatoschistus minutus (Pallas, 1770) de la lagune de Mauguio, France, Paramétres démographiques et croissance individuelle*, Cah. Biol. Mar., 30, 487-514

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

Forsgren E., 1997, *Mate sampling in a population of sand gobies*, Anim. Behav., 53, 267-276

Hesthangen I. H., 1977, *Migrations, breeding, and growth in Pomatoschistus minutus (Pallas) (pisces, Gobiidae) in Oslofjorden*, Sarsia, 63 (1), 17 – 26

Jackson A.C., Rundle S.D., Attrill M.J., 2002, *Fitness consequences of prey depletion for the common goby Pomatoschistus microps*, Mar. Ecol. Prog. Ser., 242, 229-235

Kangas N., 2000, *Mechanisms of sexual selection in the sand goby, Pomatoschistus minutus,* Academic manuscript, 1-24

Kangas N., Lindström K., 2001, *Male interactions and female mate choice in the sand goby, Pomatoschistus minutus*, Anim. Behav., 61, 425-430

Komers P.E., 1997, *Behavioural plasticity in variable environments*, Can. J. Zool., 75, 161-169

Kotwicki L., 1997, *Macrozoobenthos of the sandy littoral zone of the Gulf of Gdańsk*, Oceanologia, 39 (4), 447-460

Kvarnemo C., 1997, *Food affects the potential reproductive rates of sand goby but not of males*, Behav. Ecol., 8 (6), 605-611

Landry M.R., 1981, *Switching between herbivory and carnivory by the planktonic marine copepod Calanus pacificus*, Mar.Biol., 65, 77-82

Lindtröm K., 1998, *Effects of costs and benefits of brood care on filial cannibalism in the sand goby*, Behav. Ecol. Sociobiol., 42, 101-106

Łukasiewicz A., 2002, *Odżywianie się ryb w strefie piasczystego eulitoralu (0-1 m głębokości) w rejonie kąpieliska Sopot*, Msc. Th., University of Gdańsk, 33 pp.

Magnhagen C., Wiederholm A. M., 1982, *Habitat and food preferences of Pomatoschistus minutus and P. microps (Gobidae) when alone and together: an experimental study*, Oikos, 39, 152-156

Nikolsky G.V., 1963, *The ecology of fishes*, Academic Press, London and New York, 17-25

Qvarnström A., Forsgren E., 1998, *Should females prefer dominant males?*, Tree, 13 (12), 498-501

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

Ricker W. E., 1975, *Computation and interpretation of biological statistic of fish populations*, Department of the Environment Fisheries and Marine Service, 209-210

Selgado J. P., Cabral H. N., Costa M. J., 2004, *Feeding ecology of the gobies Pomatoschistus minutus (Pallas, 1770) and Pomatoschistus microps (Kröyer, 1838) in the upper Tagus estuary*, Sci. Mar., 68 (3), 425-434

Szaniawska A., 1993, *Wartości energetyczne bezkręgowców [w:] Zatoka Pucka*. Fundacja Rozwoju Uniwersytetu Gdańskiego, Gdańsk, 494 – 509.

Szaniawska A., Wiktor K., Jaruszewska-Nasińska G., 1986, Sezonowe zmiany wartości energetycznych Neomysis integer (Leach) w Zatoce Gdańskiej, Zeszyty Naukowe Wydziału BiNoZ UG, Oceanografia, 11, 75-97.

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

Wendt D., 2004, *Biological characteristic of common goby (Pomatoschistus microps) from the Gulf of Gdańsk*, Msc. Th., University of Gdańsk, 33-34 (in Polish)

Wheeler A., 1969, *The Fishes of British Isles and North-West Europe*, Macmillan, London-Melbourne-Toronto, 425-426

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

Witek Z., 1995, *Produkcja biologiczna i jej wykorzystanie w ekosystemie morskim w zachodniej części Basenu Gdańskiego*, Morski Instytut Rybacki, Gdynia, 14 pp.

Złoch I., 2004, *Feeding interactions between sand goby, common goby and flounder living in inshore waters of the Gulf of Gdańsk*, Msc. Th., University of Gdańsk, 63 pp. (in Polish)

Żmudziński L., 1990, *Świat zwierzęcy Bałtyku*, WSiP, Warszawa, 154 pp.

English revision: Jennifer Zielińska