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Observations on Diet Composition of *Neogobius melanostomus* Pallas 1811 (Gobiidae, Pisces) in the Gulf of Gdansk (Baltic Sea)

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ABSTRACT. *This study documents the diet of *Neogobius melanostomus* (round goby) from three different habitats within the Gulf of Gdansk. Diet composition of the round goby in the Gulf of Gdansk appears similar to that in its natural environment within the Ponto-Caspian Basin. In its native habitat, the round goby feeds mainly on epibenthic organisms and opportunistically forages on seasonally abundant components of the benthic community. A natural mollusk-feeder, the round goby feeds mainly on the mussel *Mytilus trossulus* in the Gulf of Gdansk. This food preference most likely is due to the fact that *M. trossulus* is commonly distributed throughout most of the gulf and dominates the benthic biomass. The adult round goby prefers an environment full of hiding places that also can be used for nests. Thus, submerged stones or concrete structures covered with colonies of *M. trossulus* are its preferred habitat. Younger gobies are more abundant in the frontal areas of underwater concrete structures where the substrate is characterized by loose stones and the presence of *Mya arenaria*. These habitats have different faunal structures and, therefore, different trophic relations. The round goby, which is well suited for ecological expansion, has great potential to dominate the majority of the coastal zone of the Baltic Sea. Puck Lagoon, devoid of predatory fish and rich in mussel beds, is an ideal habitat for this gobiid species.*

INDEX WORDS: *Neogobius melanostomus*, round goby, Baltic Sea, Gulf of Gdansk, diet.

INTRODUCTION

Neogobius melanostomus, the round goby, is a non-indigenous, demersal fish species that has recently been introduced into the ichthyofauna of the Baltic Sea. It was first observed in 1990 (Skora and Stolarski 1993), and since has spread quite significantly (Kuczynski 1995, Skora and Stolarski 1995, Skora 1996a, Borowski 1999). Until now, publications describing the range of occurrence of the round goby in the Gulf of Gdansk did not address the diet of this species, mainly because such data were very scarce. In recent years, however, the abundance of the round goby has become sufficient to allow collection of preliminary data on diet composition. This study documents the diet of the round goby from three different habitats within the Gulf of Gdansk, including some considered novel for this species. Results from this study may serve as a basis for evaluation of the development of feeding strategies that the round goby may employ under conditions that it might encounter in the Baltic Sea.

It should be mentioned that the Gulf of Gdansk is not the only area of the world to which this Ponto-Caspian species has been accidentally introduced. In recent years, the Moscow River in Asia (Sokolov *et al.* 1989) and the Great Lakes in North America (Jude *et al.* 1992) have also become colonized by the round goby. These accidental introductions underline the problem of introductions of non-indigenous species into the Baltic Sea and around the world. The proliferation of organisms into aquatic ecosystems beyond their endemic range has been caused, in part, by insufficient control of ballast water carried by marine ships and river boats, irresponsible introductions by aquaculturists and ornamental fish traders, and, historically, the construction of canals interconnecting previously-separated watersheds.

MATERIALS AND METHODS

Round gobies were collected in the summer of 1995 and 1996 within the Gulf of Gdansk with gill nets (mesh size = 35 mm), fyke nets (mesh size =

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TABLE 1. Number of round goby collected and stomachs analyzed.

Collection site	Fishing gear	Month, Year	Number of Stomachs			Percentage of full stomachs
			Empty	Full	Total	
Gdynia	fyke nets	July, 1995	56	23	79	29.1
	fyke nets	August, 1995	81	33	114	28.9
	gill nets	July, 1996	8	12	20	60.0
	fyke nets	October, 1995	9	6	15	40.0
Puck Lagoon	fyke nets	July, 1996	3	27	30	90.0
	fyke nets	August, 1996	3	27	30	90.0
Hel Peninsula	fyke nets	October, 1995	27	7	34	20.6
	bottom trawl	October, 1996	0	8	8	100.0
	fishing rod	July, 1996	1	9	10	90.0
Total			188	152	340	44.7

15–20 mm), bottom trawls (wing and codend mesh size = 5 mm), and by angling. Fish were caught in three different types of habitats within the Gulf of Gdansk: in the vicinity of Gdynia at the foothills of post-glacial cliffs where the substrate is stone-sand, in the vicinity of Rewa in Puck Lagoon where a peat bottom is overgrown with vegetation, and near hydrotechnical constructions on the Hel Peninsula. Collection dates, types of fishing gear, and the number of specimens captured are given in Table 1.

Fish were killed immediately upon collection and preserved in a formaldehyde solution. Fish were identified by sex, wet weighed (nearest 0.01 g), and measured to total length (mm). Stomach contents were analyzed qualitatively and quantitatively. The frequency of occurrence, relative numerical abundance and weight of each food item were computed and then combined into the Index of Relative Importance (IRI). The IRI signifies which prey items are important in the diet (Pinkas *et al.* 1971). Digestive tracts were weighed with a precision of 0.01 g. The number and size of heavily digested organisms were estimated based on characteristic structural elements such as mandibles of Polychaeta, and telsons and legs of Crustacea. The weight of digested organisms was estimated by using biometric conversion factors of Rumohr *et al.* (1987). Results of these analyses were expressed as dry weights of food components.

RESULTS

Round gobies collected for this study measured from 29 to 215 mm in total length. Approximately 75% of the fish captured belonged to the 110–160

mm length-class (mean length = 145 mm; Fig. 1). Males dominated the sex ratio at all three collection sites (Fig. 2). Females constituted from 21% to 25% of all analyzed fish. Males and females had similar weight to length correlation coefficients, which equaled 2.96 and 3.0, respectively (Fig. 3).

Ten food items were observed in the diet of the round goby from the Gulf of Gdansk. The most important were mollusks, mainly bivalves such as *Mytilus trossulus* and *Macoma balthica*, with the minimal component being *Cardium* sp.. Fish also fed on small snails from the genus *Hydrobia*. Among Crustaceans, *Idotea balthica* was most common while other organisms from this group (Gammaridae and *Balanus improvisus*) were found incidentally. Polychaetes were more important than Crustacea and were almost exclusively represented by *Nereis diversicolor*. Remnants of algae and fish scales were also found inside the digestive tracts.

The size of food items ingested by the round goby was difficult to evaluate. The round goby crushes mollusk shells, making it impossible to reconstruct the precise size of the prey item. In some cases, intact *M. trossulus* shells (10 to 15 mm long) were found in the stomachs of the round goby. These were likely the biggest mollusks swallowed whole by the round goby. The shells of *M. balthica* and *Cardium* sp. were usually intact, probably due to their small size; their length was not larger than 4 mm and most of the shells were approximately 1 mm long. On rare occasions, these two genera were found in large numbers (up to 500 in one stomach). Algae and *B. improvisus* were found only when *M. trossulus* was present in the stomach. *M. trossulus* is frequently overgrown with barnacles (Wiktor

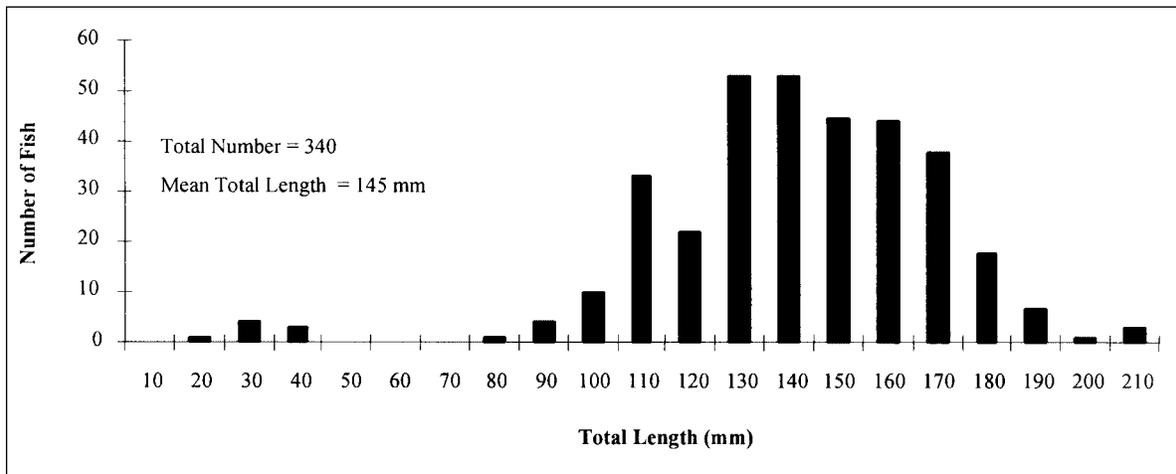


FIG. 1. Length-frequency distribution of round goby.

1990), which probably implies how the cirriped was consumed by round goby.

The importance of specific food items in the diet of round goby from the Gulf of Gdansk is shown in Figure 4. The highest values of IRI were obtained for *M. trossulus* (2,464) and *I. balthica* (1,461), while the values for the remaining prey items did not exceed 300. The food composition of individual fish differed with fish size and type of habitat. After analyzing 24 fish of various body sizes from the same type of habitat, it was found that the importance of bivalves in the diet increased and the role of crustaceans and polychaetes decreased with increasing fish size.

The main food items for small round gobies (29 to 45 mm) were the crustaceans *Idotea* sp. and Gammaridae (IRI = 3,671), as well as Polychaeta (IRI = 3,987). An additional prey item for fish in this size group was small *Cardium* sp. (1 to 2 mm, IRI = 795). The most common food items were Polychaeta (50% frequency of occurrence and 59% wet weight of the diet) and Crustacea (63% fre-

quency of occurrence and 36% wet weight of the diet). Older fish in the 13 to 15 cm length-classes fed mainly on Mollusca (*M. trossulus*, IRI = 4,746; *M. balthica*, IRI = 24; *Hydrobia* sp., IRI = 2,310). *M. trossulus* constituted the largest weight component of food (90%), while *Hydrobia* sp. (1 mm in size) comprised only 4% of food weight, although they were numerically most abundant (81%). Polychaeta were less common than Crustacea (found in 9% and 36% of fish, respectively), and both food types constituted only a small weight component of diet (Polychaeta = 1%, Crustacea = 4%). The largest fish (16 to 18 cm length-class) fed almost exclusively on Bivalvia (*M. trossulus*, IRI = 10,843; *M. balthica*, IRI = 1,904; *Cardium* sp., IRI = 507) and *B. improvisus* (IRI = 83). The mollusk that occurred most frequently was *M. trossulus*, which was found in 80% of fish and comprised 81% of the diet (Fig. 5).

Differences in diet composition were noted between round gobies collected from the three different sample sites. Fish dwelling in the vicinity of

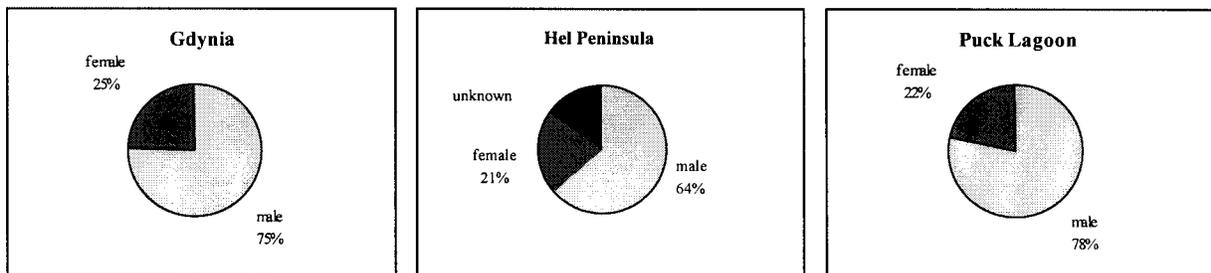


FIG. 2. Sex ratio of round goby by location.

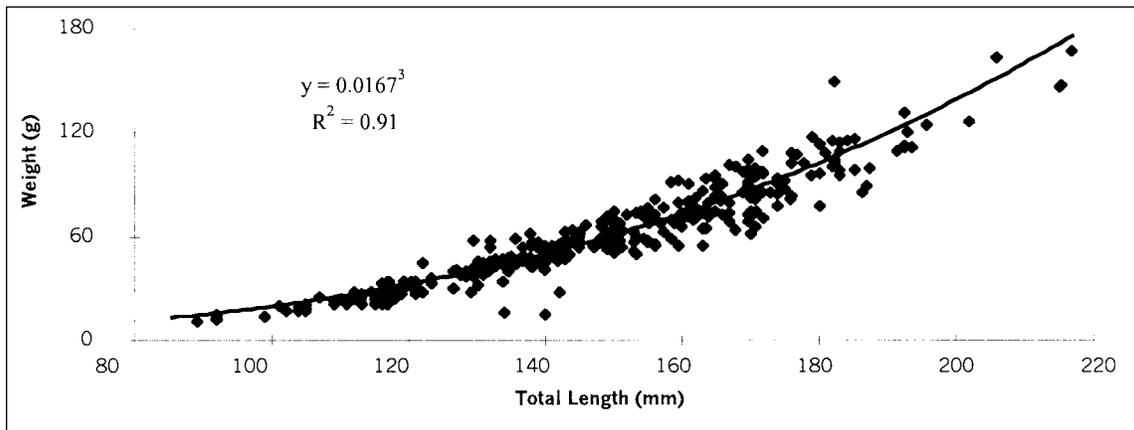


FIG. 3. Length-weight relationship of round goby.

Rewa, feeding among benthic macrophytes, had the highest value of IRI (16,636) for *I. balthica*, an organism characteristic of this area. *I. balthica* was found in 90% of the fish collected from this area, and constituted over 90% of the weight of stomach contents. Polychaeta were an additional food item, found only in 15% of fish and comprising a mere 3% of the diet by weight. The highest IRI values for fish collected from Gdynia and Hel Peninsula were for *M. trossulus*, with values of 3,694 and 4,910, respectively. This species was found in 44.6% and 62.5% of fish from the respective areas.

In the vicinity of Gdynia, other food components

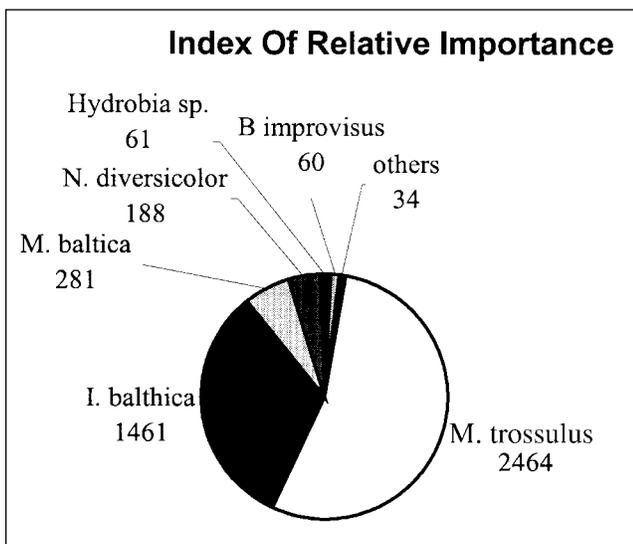


FIG. 4. Index of Relative Importance (IRI) for specific food items of round goby collected from the Gulf of Gdansk.

were less significant (i.e., *I. balthica* in 0.0% and *Cardium* sp. in 1.4%) while some were observed quite frequently (i.e., *B. improvisus* in 31.1% and Polychaeta in 20.3% of fish). Young *M. balthica* (1 mm) rarely were found in large numbers in the stomachs of fish from this area, but occurred in only 6.8% of individuals examined (Table 2). In the area of Hel Peninsula, large *M. balthica* (5 to 6 mm) were observed in the stomachs rather frequently, comprising an average of 26.8% of the weight of stomach contents. *Hydrobia* was an important mollusk in the diet (IRI = 1,488), and was found in 18.8% of fish collected. Though it constituted only 5.3% of diet biomass, it comprised 74% of counted food items. *Hydrobia* was primarily consumed by small round gobies. Other food items (Gammaridae, *Cardium* sp., algae, and fish) were less important in the diets of fish collected from each of the three collection sites.

Specific observations were made in reference to changes in diet composition during the summer season. Samples were chosen from two areas: from the vicinity of Gdynia in July and August 1995, and from the Rewa area in July and August 1996. Samples collected from Rewa exhibited no differences in diet composition from July to August, while some variation became apparent for the Gdynia area samples. In the Gdynia samples from July, *M. trossulus* was most frequent, occurring in 65.2% of fish and comprising 55.8% and 84.4% of total stomach contents by number and weight, respectively (IRI = 9,173). A considerable number of *B. improvisus* also were found in samples containing *Mytilus* specimens (IRI = 910). In the Gdynia samples from August, the diet of the round goby was

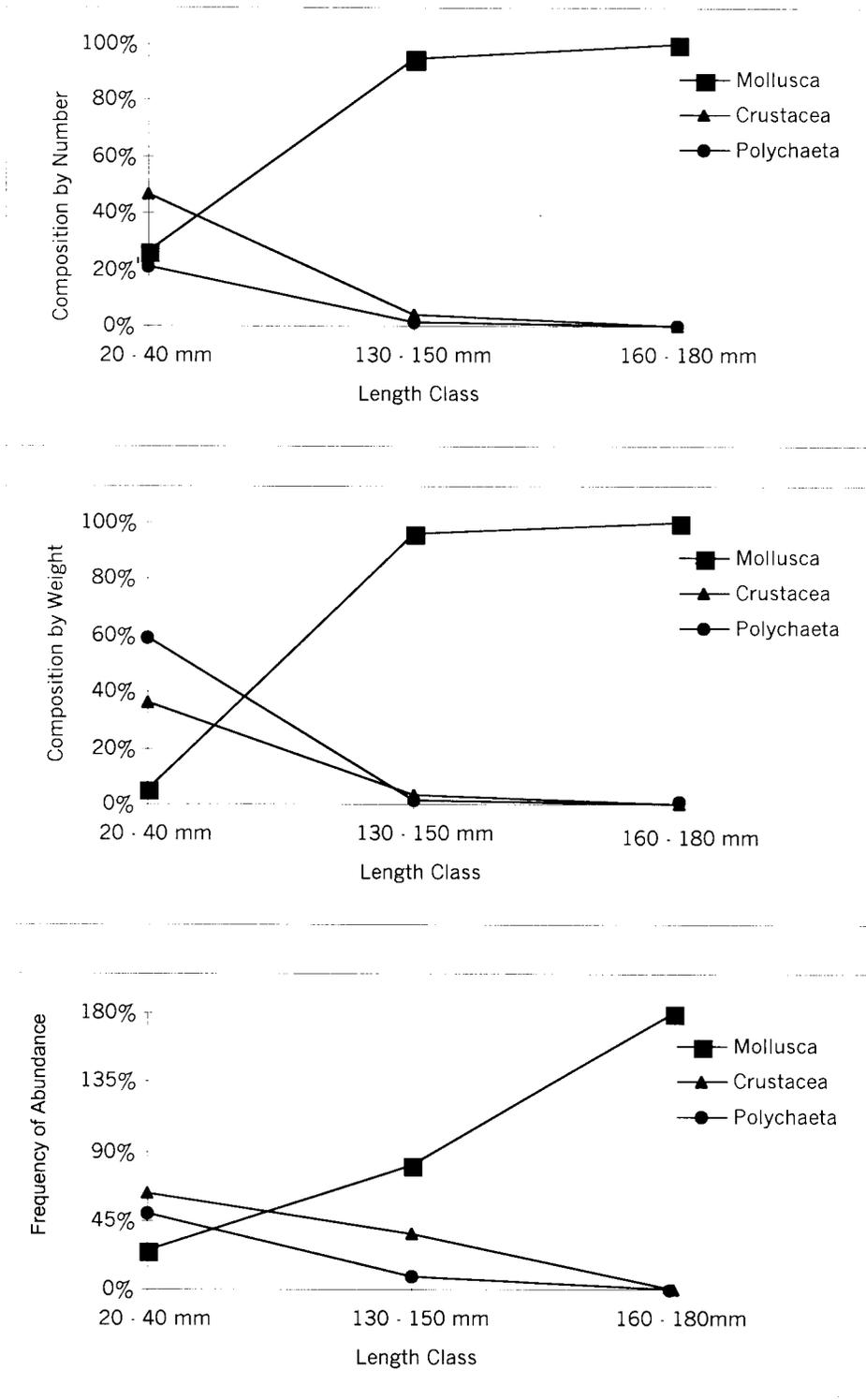


FIG. 5. Feeding of round goby of various size groups, expressed as frequency of abundance and food composition by number and weight.

TABLE 2. Percent composition of diet of round goby by collection site. Abbreviation used: f—frequency of abundance, n—composition by number, w—composition by weight, I.R.I.—index of relative importance.

Food composition	Gdynia			Puck Lagoon			Hel Peninsula			Total						
	f.	n.	w.	I.R.I.	f.	n.	w.	I.R.I.	f.	n.	w.	I.R.I.				
<i>Polychaeta</i>	20.3	5.8	11.4	348	15	7	3	139	6.3	0.4	1.0	9	17.2	4.8	6.1	188
<i>M. trossulus</i>	44.6	14.2	68.6	3,694	0.0	0.0	0.0	0.0	62.5	18.7	59.9	4,910	32.1	13.2	63.6	2,464
<i>B. improvisus</i>	31.1	5.0	0.0	155	0.0	0.0	0.0	0.0	6.3	0.4	0.0	2	17.9	3.3	0.0	60
<i>M. baltica</i>	6.8	69.2	10.9	541	0.0	0.0	0.0	0.0	18.8	3.1	26.8	559	6.0	45.9	1.2	281
<i>Cardium</i> sp.	1.4	0.1	0.0	0	0.0	0.0	0.0	0.0	12.5	0.8	0.2	12	2.2	0.2	0.0	1
<i>Gammaridae</i>	8.1	3.6	8.9	101	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	2.4	3.2	25
<i>Hydrobia</i> sp.	2.7	0.7	0.2	2	0.0	0.0	0.0	0.0	18.8	74.0	5.3	1,488	3.7	15.9	0.5	61
<i>I. balthica</i>	0.0	0.0	0.0	0.0	89	90	97	16,636	18.8	2.7	6.8	179	38.1	13.0	25.4	1,461
Algae	14.9	1.3	0.0	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.2	0.9	0.0	7
Fish scales	0.0	0.0	0.0	0.0	7	3	0	25	0.0	0.0	0.0	0.0	3.0	0.3	0.0	1

TABLE 3. Comparison of diet composition of round goby collected from different locations (% total weight).

Area (Source)	Mollusca	Polychaeta	Crustacea	Pisces
Sea of Azov (Svietovidov 1964 after Ilin 1949)	51	30	18	—
Sea of Azov in 1956–57 (Kovtun <i>et al.</i> 1974 after Kostjuchenko 1960)	87.4	2.5	6.3	1.6
Sea of Azov in 1968–72 (Kovtun <i>et al.</i> 1974)	85.3	2.5	6.9	4.8
Black Sea (Svietovidov 1964)	60	?	?	?
Caspian Sea (Nevelov, pers.comm. after Pischuk unpubl.)	43.6	?	?	?
Gulf of Gdansk	65.3	6.1	28.6	—

enriched with two new components, the mussels *M. balthica* and *Cardium* sp. The amount of *M. trossulus* in the diet was reduced, increasing the importance of Polychaeta (*N. diversicolor*). The fish also fed less frequently on *M. trossulus* (18.2%), resulting in a reduction in its percent of total gut content biomass (31.5%) in comparison with the value for July. At the same time, Polychaeta were observed in 36% of fish, and comprised 30.8% of the food weight (compared to 10.8% in July); the IRI value for Polychaeta increased from 175 to 1,353. Young *M. balthica* (0.5 to 1 mm) were not observed in July but were frequently found (12.1% of the analyzed fish stomachs) in August, comprising 86.6% and 29% of the total food by number and weight, respectively. The IRI for *M. balthica* in August was 1,402, representing the highest value from among the other food components.

DISCUSSION

In general, the diet composition of the round goby collected from the Gulf of Gdansk appears similar to that of the round goby in its natural environment in the Ponto-Caspian Basin. Diet composition did suggest that round goby will feed opportunistically on the most available prey and associated habitat. The round goby, a natural mollusk-feeder, mainly feeds on the mussel *M. trossulus* in the Gulf of Gdansk. This food preference most likely is due to the fact that *M. trossulus* is commonly distributed throughout the gulf and domi-

nates the benthic biomass (Legezynska and Wiktor 1981, Wiktor 1993). Similarly, in the St. Clair River and in the Great Lakes Basin, Mollusca are the most important food component for larger round gobies, particularly the abundant non-indigenous species, *Dreissena polymorph* (Jude *et al.* 1995). In the Sea of Azov, where stomach content analyses were systematically conducted, the dominance of Mollusca in the diet of the round goby had been established after the regulation of the Don River and a decrease in stock size of benthophagous fish species, such as *Acipenseridae*, bream, and roach (Table 3; Skazina and Kostjuchenko 1968). In the northern part of the Caspian Sea, mollusks also constitute 43.6% of the diet, with *Dreissena rostriformis* comprising approximately one half of this component. In the southern Caspian Sea, *Mytilaster lineatus* is the dominant food item of the diet, which is supplemented by fish and *D. rostriformis* (A.V. Nevelov, personal communication, November 1990).

The frequency and percent composition of other food items, including Polychaeta and Crustacea, in the diet of the round goby from the Gulf of Gdansk were comparable with values published by Svetovidov (1964) and Kowtun *et al.* (1974) for the round goby populations from the Sea of Azov. The round goby feeds mainly on epibenthic organisms (Kowtun *et al.* 1974) and opportunistically forages on seasonally abundant components of the benthic community. In the vicinity of Gdynia, *M. balthica*

attains adulthood in August. Its shell reaches a size of 1 to 2 mm and it covers the substrate, including submerged vegetation and debris, in large numbers (Wenne 1993). When it reaches adulthood, *M. balthica* becomes a food item for round goby. It is unclear whether such small bivalves are ingested by fish as a result of by-catch, such as while foraging on Polychaeta, or are actively preyed upon by round gobies burrowing in the substrate while deepening their sandy hiding places.

Available data suggest that gobiids change their feeding habits with age. Opuszynski (1979) stated that fish generally switch from small and poorly mobile food items to larger and often more mobile organisms with increasing age. In the case of the round goby, an opposite trend was observed due to the fact that older, and therefore bigger fishes fed less on crustaceans and polychaetes while sedentary bivalves were becoming more and more important in their diets.

The food composition of the biggest and oldest fishes was the least variable, consisting of bivalves and cirripeds only. These findings were consistent with the observations of Svietovidov (1964) and Kowtun *et al.* (1974) for the Black Sea and the Sea of Azov where young fish feed mainly on crustaceans, and adults consume mostly bivalves. Similar observations were reported for the Great Lakes (Jude *et al.* 1995). Such feeding preferences are due to the increased ability of older fish to pick and crush mollusk shells, and to the more stationary behavior of adults as observed through underwater surveillance. Adult round gobies prefer an environment full of hiding places that also can be used for nests. Therefore, submerged stone or concrete structures covered with colonies of *M. trossulus* are their preferred habitat. Younger gobies are more abundant in the frontal areas of underwater concrete structures where the substrate is characterized by loose stones and the presence of *Mya arenaria*. These habitats have different faunal structures and, therefore, different trophic relations.

Partially digested fish scales, sporadically found in the analyzed stomachs, all belonged to the same fish species. It is difficult to explain this phenomenon, as there were no remnants found within the stomach contents that would indicate ingestion of fish by gobies. However, in earlier investigations conducted by Svietovidov (1964), Jude *et al.* (1995), and Kasymov (1987), it was observed that the round goby attacked and ate other fishes. In the Sea of Azov, the goby feeds on the relatively small fish *Mullus barbatus* (Svietovidov 1964). Jude *et*

al. (1995) observed 100 mm gobies preying on slightly smaller perch (*Perca flavescens*), and regularly eating dead fish (*Osmerus mordax*) under laboratory conditions. In this study, the gobies caught in fyke nets (where food was scarce inside the trap) could probably feed on the carcasses of dead fish, as well as attack weaker individuals.

Marsden and Chotkowski (1995) pointed out that round goby feeds on the eggs of other fish species and, in this particular case, the observation was made in reference to a laboratory experiment with lake trout (*Salvelinus namaycush*) eggs. Some eggs were occasionally found in round goby stomachs in Lake Erie where, in most incidences, data suggest that round gobies will consume their own eggs (Carey Knight, ODNR Division of Wildlife, 11 November 2000). In the stomachs of gobies from the Gulf of Gdansk, no fish eggs were found. However, it should be noted that fish eggs are easily digested and might not have been detected during the analyses. The season of sample collection also could have affected the occurrence of fish eggs in the diet. In July and August, the following families of fish spawn in the Gulf of Gdansk: gasterosteidae, gobiidae, ammodytidae, and sygnathidae. The first two fish families deposit their eggs in places that could be potential feeding grounds for the round goby. However, the availability of eggs may be limited because these particular spawning species protect their nests against intruders. The spawning grounds of the latter two fish families did not coincide with the location of the round goby feeding grounds. Feeding on the eggs of other fishes can be a concern when the predator is present in large numbers (Jude 1997). In that respect, the ever increasing population of the round goby in the Gulf of Gdansk implies that egg predation should be carefully examined as it may become a concern in the future (Skora 1996b).

In the northern part of the Caspian Sea, gobies also are very abundant and compete for food with commercially valuable fish species, including sturgeon, pikeperch, and roach (Nikolski 1970). In the Gulf of Gdansk, the round goby may become a competitor with plaice (*Pleuronectes platessa*), which feeds primarily on *M. trossulus*, *M. baltica*, *Cardium* sp., and Crustacea (Mulicki 1947). By feeding on crustaceans and polychaetes, the round goby also may become a competitor with *Gobius niger*, a species whose main diet consists of *Cardium* sp., *Idotea* sp., *Gammarus* sp., and *Nereis diversicolor* (Morawski 1978). The competition for food between flounder and the round goby may

occur in early life stages due to the fact that the fry of both species feed mainly on crustaceans and polychaetes (Szypula and Zalachowski 1978, Malorny 1990). Additionally, the round goby diet may overlap with some demersal Baltic fish species such as eelpout (*Zoarces viviparus*), eel (*Anguilla anguilla*), perch (*Perca fluviatilis*), roach (*Rutilus rutilus*), and vimba (*Vimba vimba*). Currently, resources for these fishes (food, nesting sites, space) in the Baltic do not appear to be limited. Nevertheless, the round goby is rapidly expanding its population size and range, and potential for competition seems an issue worth raising.

The round goby probably appeared in the Gulf of Gdansk in the late 1980s (Skora and Stolarski 1995), with its first appearance in the North American Great Lakes Basin occurring in 1990 (Jude *et al.* 1992, Crossman *et al.* 1992). Similar to other non-indigenous species unintentionally introduced into North American waters in recent years, the round goby has become an integral component in its new environment (Jude *et al.* 1995, Crossman *et al.* 1992). The Gulf of Gdansk, in general, and its coastal area, in particular, are facing a similar situation. The round goby, which is so well suited for ecological expansion, has great potential to dominate the majority of the coastal zone of the Baltic Sea. Puck Lagoon, devoid of predatory fish and rich in mussel beds, is an ideal habitat for this gobiid species. In the Black Sea and the Sea of Azov, predatory pressure of pikeperch and fishing pressure of humans controlled the gobiid population. In the years of high abundance of pikeperch, a significant decrease in the round goby population was observed (Svietovidov 1964). In the Gulf of Gdansk, there currently are no predatory fishes in high enough numbers to control the growth of the round goby population. However, birds are consuming the round goby, and have benefited from the increase in its population. Cormorants (*Phalacrocorax carbo*), which are becoming more numerous in the area of Puck Bay, have adopted the round goby as the mainstay of their diet. At times, the round goby represents up to 90% by number of the fish eaten by cormorants (Bzoma 1998). In the area of Hel Peninsula, herons (*Ardea cinerea*) have become more and more numerous. In summer, they feed primarily on round gobies dwelling in shallow waters (20 to 30 cm depth). The round goby, as prey for diving and wading birds, is important to the highest levels of the food web of the Puck Bay ecosystem.

Currently, the round goby is not commercially exploited in Poland. However, sport anglers have

regularly fished this species. From 1996–97, round gobies were being caught near Gdynia at rates ranging up to several individuals per hour. Round gobies also are an increasingly frequent component of by-catch in fyke nets, attaining 20 to 30 kg for one setting of nets (2 to 3 days). At this time, however, there is no round goby-targeted fishery or sufficient angling pressure that would help reduce the goby population. The commercial value of the round goby is minimal, amounting to approximately \$0.50/kg of fresh whole fish. The most important role of this species is in connection with its ecological impact in the gulf and in the future of the entire Baltic Sea Basin.

Presently, the increasing abundance of round goby may lead to a gradual reduction in the population size of benthic filter-feeders in the Gulf of Gdansk and possibly change the energy flow in the ecosystem, especially at the highest trophic levels. Moreover, if the round goby becomes a forage base for predators at the higher trophic levels within the fish community, the natural trophic relationships historically found within this basin may be disrupted.

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