

Metazoa parasites of the invasive round goby *Apollonia melanostoma* (*Neogobius melanostomus*) (Pallas) (Gobiidae: Osteichthyes) in the Gulf of Gdańsk, Baltic Sea, Poland: a comparison with the Black Sea

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Abstract The known metazoa parasite fauna of the invasive round goby *Apollonia melanostoma* (formerly *Neogobius melanostomus*) consists of 12 species. The core of the parasite fauna comprises two species: *Cryptocotyle concavum* and *Diplostomum spathaceum*; secondary species are absent; satellite species include *Cercariae* gen. sp. and *Ergasilus sieboldi*; rare species are *Acanthocephalus lucii*, *Anguillicola crassus*, *Bothriocephalus* sp., *Dichelyne minutus*, *Hysterothylacium aduncum*, *Pomphorhynchus laevis*, *Piscicola geometra*, and *Tylodelphys clavata*. Fifty percent of metazoa parasites that occurred in the invasive round goby in the Gulf of Gdańsk (an invasion that was first detected in 1990) are also typically found in the native Gulf of Gdańsk gobiids. The round goby hosts common fish parasite species: *C. concavum* and *D. minutus*, but none that are unique to the species and no Ponto–Caspian parasites. Notably, the parasite species of the invasive round goby in the Gulf of Gdańsk includes species that are atypical for this species in its native habitat. In its new habitat, the round goby variously serves the roles of definitive, second intermediate, and paratenic host for different parasite species. The fish species is involved in a parasitic system that includes fish-eating birds, fishes of

different ecological groups (predatory, planktivorous, and benthivorous), and invertebrates.

Introduction

The round goby *Apollonia melanostoma* (formerly *Neogobius melanostomus*; see Stepien and Tumeo 2006) is a bottom dwelling Ponto–Caspian gobiid fish species. Its native habitats include the coastal zones of the Black and Caspian Seas, the Seas of Azov and Marmora, and their basins (Smirnov 1986). The species first was reported in the Baltic Sea off Hel, Poland, in 1990 (Skóra and Stolarski 1993) and was also observed in the basins of the North Sea (van Beek 2006), the Danube River (Simonović et al. 1998), and now is widely distributed in the North-American Great Lakes (Charlebois et al. 1997).

The colonization of invasive gobies presents several problems. In addition to the obvious problem of competition with the native fauna as parasite hosts, they may also be responsible for spreading diseases to economically valuable fishes and birds. In the Sea of Azov the round goby is a host to the nematodes *Tetrameres fissispina* and *Streptocara crassicauda* that lead to poultry epizootics (Kovalenko 1960) and, therefore, can have commercial impacts. Also, the round goby is an intermediate host of *Pygidiopsis genata* (Kvach 2005) that can infect humans (Youssef et al. 1987).

In the Baltic Sea the investigations of the invasive round goby parasites began in the Gulf of Gdańsk (near Gdynia and Rewa) in 1994 (Rokicki and Rolbiecki 2002). In total, five metazoa parasite species were found: *Bothriocephalus* sp. (noted as *Bothriocephalus scorpii*), *Diplostomum* spp., *Echinorhynchus gadi*, *Hysterothylacium aduncum*, and

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Pomphorhynchus laevis. According to our previous data the invasive round goby in the Gulf of Gdańsk is infected by four parasite species: *Acanthocephalus lucii*, *Diplostomum spathaceum* (partly noted as *Diplostomum* spp.), *Ergasilus sieboldi*, and *H. aduncum* (Kvach 2002). Recently, the round goby was also found to be a new paratenic host of the invasive nematode *Anguillicola crassus* (Kvach 2004a; Rolbiecki and Kvach 2005). Taking into account the ecological plasticity of the round goby, current studies of its parasite fauna in places of invasion are necessary. Specifically, a study examining the colonization of the invasive host by parasites in new areas and the changes during the period of assimilation is needed.

Therefore, the goals of the present work were to describe the current condition of the metazoa parasite fauna of the invasive round goby and to evaluate its role in the parasitic systems of the Gulf of Gdańsk.

Materials and methods

The fish were sampled using trawl, sweep, and fyke nets and were angled on six sites of the Gulf of Gdańsk (nearshore off Hel, Jastarnia, Chałupy, Puck, Sopot, and Gdańsk) during June 2001, April 2003, and October–December 2003 (Fig. 1). The standard length (SL) in centimeters of each individual fish was measured. In total, 232 individual round gobies were examined for parasites and all possible microhabitats were carefully examined for parasites. Metacercariae were isolated from cysts and

stained with lactic or acetic carmine. Cestodes and adult trematodes were fixed in 70% ethanol and then stained with carmine. Later, the stained helminths were dehydrated in ethanol and mounted in Canada balsam. Acanthocephalans, nematodes, and crustaceans were fixed in 70% ethanol and mounted in glycerol for identification.

To compare the parasite faunas, the Czekanowski–Sørensen index was used: $Ics = \frac{2c}{a+b} \times 100\%$ where a is the number of parasite species found in host A, b is the number of parasite species found in host B, and c is the number of parasite species common for both host species.

Parasitological indices were calculated according to Bush et al. (1997): including percent prevalence (P), intensity (presented as the intensity range, IR), mean intensity (MI), and abundance (A). The significance of separate species in the parasite fauna was evaluated by the concept of Zander et al. (1999) according to the abundance index: >2, core species; 0.6–2, secondary species; 0.2–0.6, satellite species; and <0.2, rare species.

The standard deviation (SD) for mean parameters (M) is given.

Results

The mean SL of examined fishes was 11.3 ± 4.3 ($n=232$). Three individuals caught off Gdańsk ($SL=7.7 \pm 2.1$) were found to be free from parasites.

Twelve metazoa parasite species, including one Cestoda species, four Trematoda, three Nematoda, two Acanthocephala, one Hirudinea, and a single Crustacea species, were noted (Table 1). Monogenea were not found. *Piscicola geometra* was found, which is of interest as it has not previously been found in round goby. The core of the parasite fauna was two species: *Cryptocotyle concavum* and *D. spathaceum*; secondary species were absent, satellite species included Cercariae gen. sp. and *E. sieboldi*, and other species are rare (Table 1).

Six species (50% of the total metazoan parasite fauna) were present as adults (Table 1). One species, *H. aduncum*, was present in both adult and larval stages. Many of species in the Baltic round goby parasite fauna (7 species=58.3%) were represented by their larval stages: including plerocercoids, metacercariae, and third stage larvae, L3 (Table 1).

The parasite fauna consists of seven limnetic species (58.3%): *A. crassus*, *A. lucii*, *D. spathaceum*, *E. sieboldi*, *P. geometra*, *P. laevis*, and *Tylodelphys clavata*. Only two of these species (16.7%), *Bothriocephalus* sp. (larvae are related to “*B. scorpii* complex,” an undescribed species inhabiting the Baltic Sea) and *H. aduncum*, can be characterized as marine; and two others, *C. concavum*, *Dichelyne minutus*, brackish water.

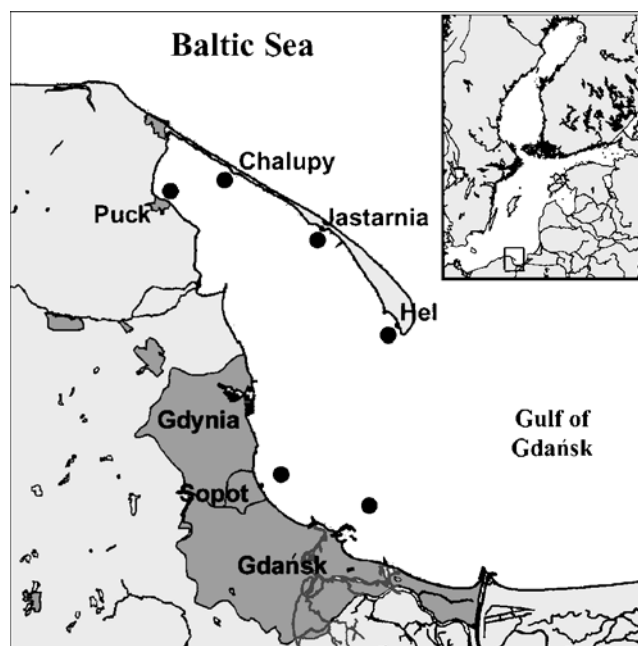


Fig. 1 Schematic map of the investigation area. Filled circles: sampling sites

Table 1 Infestation the round goby *N. melanostomus* with metazoa parasites in the Gulf of Gdańsk

	Location	Indices	Region				
			Hel	Jastarnia	Chałupy	Puck	Sopot
Number of host individuals			108	18	20	74	9
Host standard length (M±SD), cm			8.5±2.8	5.9±2.0	11.9±2.9	14.0±3.1	4.8±1.7
Cestoda							
<i>Bothriocephalus</i> sp. pl	Intestine	P	0.9				
		MI (M±SD)	2.0				
		IR (min–max)	2				
		A	0.02				
Trematoda							
Cercariae gen. sp.	Gills	P	4.1				
		MI (M±SD)	41.0±51.8				
		IR (min–max)	3–100				
		A	1.7				
<i>Cryptocotyle concavum</i> met	Skin, fins, gills	P	6.5				
		MI (M±SD)	8.6±12.1				
		IR (min–max)	1–35				
		A	0.6				
<i>Diplostomum spathaceum</i> met	Eyes lenses	P	18.5	5.6	65.0	36.5	
		MI (M±SD)	12.8±13.4	31.0	26.8±15.6	15.6±19.3	
		IR (min–max)	1–50	31	12–57	1–74	
		A	2.4	1.7	17.5	5.7	
<i>Tylodelphys clavata</i> met	Eyes lenses	P	2.7				
		MI (M±SD)	1.0±0.0				
		IR (min–max)	1				
		A	0.03				
Nematoda							
<i>Anguillicola crassus</i> L3	Mesentery	P	13.9				
		MI (M±SD)	1.5±0.9				
		IR (min–max)	1–4				
		A	0.2				
<i>Dichelyne minutus</i>	Intestine	P	0.9				
		MI (M±SD)	1.0				
		IR (min–max)	1				
		A	0.01				
<i>Hysterothylacium aduncum</i>	Intestine	P	2.8				
		MI (M±SD)	1.3±0.6				
		IR (min–max)	1–2				
		A	0.04				
<i>Hysterothylacium aduncum</i> L3	Mesentery	P	5.6		10.0	9.5	11.1
		MI (M±SD)	1.3±0.5		1.0±0.0	1.1±0.4	1.0
		IR (min–max)	1–2		1	1–2	1
		A	0.1		0.1	0.1	0.1
Acanthocephala							
<i>Acanthocephalus lucii</i>	Intestine	P	0.9				
		MI (M±SD)	1.0				
		IR (min–max)	1				
		A	0.01				
<i>Pomphorhynchus laevis</i>	Intestine	P	0.9				
		MI (M±SD)	1.0				
		IR (min–max)	1				
		A	0.01				
Hirudinea							
<i>Piscicola geometra</i>	Skin	P	0.9				
		MI (M±SD)	1.0				
		IR (min–max)	1				
		A	0.01				

Table 1 (continued)

	Location	Indices	Region				
			Hel	Jastarnia	Chałupy	Puck	Sopot
Number of host individuals			108	18	20	74	9
Host standard length (M±SD), cm			8.5±2.8	5.9±2.0	11.9±2.9	14.0±3.1	4.8±1.7
Crustacea							
<i>Ergasilus sieboldi</i>	Gills	P			25.0		
		MI (M±SD)			10.0±10.1		
		IR (min–max)			1–27		
		A			2.5		

pl Plerocercoid, met metacercaria, and L3 third-stage larva

Discussion

Comparison of the parasite faunas of the invasive and resident gobies

The data on parasites of various gobiid species of the Gulf of Gdańsk are given by Markowski (1935), Cichowlas (1961), Koter (1962), and (Sołtyńska 1964). These studies describe the parasites of four gobiid species (the black goby *Gobius niger*, the two-spotted goby *Gobiusculus flavescens*, the common goby *Pomatoschistus microps*, and the sand goby *Pomatoschistus minutus*) and encompass 11 metazoa parasite species. Most of the parasites (six species) found in the round goby in the Gulf of Gdańsk were found in other gobiids: *Bothriocephalus* sp., *C. concavum*, *D. minutus*, *D. spathaceum*, *H. aduncum*, and *P. laevis* (Markowski 1935; Cichowlas 1961; Koter 1962; Sołtyńska 1964). Consequently, 50% of metazoan parasites occurring in the invasive goby are typical for the resident gobiids. The cestodes *Ligula* sp., *Proteocephalus* sp., trematodes *Asymphylogora demeli*, *Tetracotyle* sp., and nematode *Contracaecum* sp., which were found in native gobies (Koter 1962; Sołtyńska 1964), did not occur in the invasive round goby. Parasitic species, such as *A. crassus*, *A. lucii*, Cercariae gen. sp., *E. sieboldi*, *P. geometra*, and *T. clavata*, were not previously reported in resident gobies in the Gulf of Gdańsk. The Ics shared between metazoan parasite faunas of resident gobiids and the round goby is 52.2%. The invasive round goby parasite fauna is most similar to that of the sand goby (Ics=45.5%), but less similar to black (Ics=38.1%) and common (Ics=33.3%) gobies, and least similar to the two-spotted goby (Ics=14.3%).

Most of the parasite species that infest the round goby were observed in gobiids from the other localities of the Baltic Sea. Notably, *C. concavum* is the core species (in some seasons) in the parasitic fauna of four gobiids (black, common, sand gobies, and also painted goby *Pomatoschistus pictus*) in the southwestern Baltic, but secondary or satellite in the two-spotted goby (Zander 2003). *Hysterothylacium* sp. and *Bothriocephalus* sp. were rare in the same gobiids (except

Bothriocephalus sp. that was absent in the black goby). *D. spathaceum* is rare in common and black gobies at some sites of the western Baltic (Zander et al. 1999; Zander 2003). *A. crassus* was found in the black goby from the Swedish nearshores (Höglung and Thomas 1992), and *P. laevis* in sand goby from Salzhaff (Zander et al. 1999).

Colonization of the round goby by parasites

Most of the parasite species (58.3%) that infect the round goby in the Gulf of Gdańsk (*A. lucii*, *C. concavum*, *D. minutus*, *D. spathaceum*, *H. aduncum*, *P. laevis*, and *T. clavata*) were earlier found in this fish in various sites within the Black Sea basin (e.g., Rădulescu and Vasiliu 1951; Chernyshenko 1957; Koval 1961, 1962; Naidenova 1974; Florescu and Ienișteea 1984; Machkevsky et al. 1990; Kvach 2004b, 2005). A comparison of the parasite fauna of the invasive round goby in the Gulf of Gdańsk to the data from the round goby parasites in native habitats within the northwestern Black Sea (recently presented in Kvach 2005) reveals little similarity. Only three parasite species (25%) of the invasive goby parasite fauna (*A. lucii*, *C. concavum*, and *D. minutus*) were noted in the round goby from the northwestern Black Sea (Table 2) with a corresponding Ics of 21.4%.

Limnetic parasite species are atypical for the round goby in the Black Sea, but occur in the fresh (or desalinated) waters of its basin: *D. spathaceum* in the Tyligul Estuary (~4%; Chernyshenko 1957), *T. clavata* in the Dnieper River delta (fresh water; Koval 1962), *P. laevis* in Danube River delta (fresh water; Florescu and Ienișteea 1984), *A. lucii* in the Khadzhibey Estuary (2–3%; Kvach 2004b), *E. sieboldi* in Dnieper River delta and estuary (0–2%; Koval 1961, 1962), and Golovița Lake (3.1%; Rădulescu and Vasiliu 1951). Most species rarely occurred in the round goby both in the Baltic and Black Sea basins. Only *D. spathaceum* was a core species in the Baltic round goby (Table 1), while in the Black Sea basin it was rare (Chernyshenko 1957).

The marine nematode *H. aduncum* is rare in the round goby parasitofauna both in the Baltic (Table 1) and the Black Sea (occurred in the Gulf of Yegorlyk; Machkevsky et al. 1990).

Table 2 Parasitization of the round goby (P/MI/A) in the Gulf of Gdańsk (present data) and in the northwestern Black Sea according to Kvach (2005)

Region	Gulf of Gdańsk	Northwestern Black Sea
Number of host individuals	232	775
Host standard length (M±SD), cm	11.3±4.3	9.6±5.6
Cestoda		
<i>Bothriocephalus</i> sp. pl	0.4/2.0/0.01	
<i>Proteocephalus gobiiorum</i> pl		0.1/1.0/0.001
Trematoda		
<i>Timoniella imbutiforme</i> met		2.3/10.4/0.2
<i>Asymphylodora pontica</i>		4.6/19.3/0.9
<i>Bucephalus polymorphus</i> met		1.7/8.2/0.1
Cercariae gen. sp.	1.3/41.0/0.5	
<i>Cryptocotyle concavum</i> met	17.7/62.8/11.1	28.5/141.4/40.3
<i>Cryptocotyle lingua</i> met		26.2/224.9/58.9
<i>Diplostomum spathaceum</i> met	26.3/17.3/4.6	
<i>Pygidiopsis genata</i> met		4.0/105.0/4.2
<i>Tylodelphys clavata</i> met	0.9/1.0/0.01	
Nematoda		
<i>Anguillicola crassus</i> L3	6.5/1.5/0.1	
<i>Contracaecum microcephalum</i> L3		0.1/1.0/0.001
<i>Contracaecum rudolphii</i> L3		0.1/1.0/0.001
<i>Dicheilyne minutus</i>	0.4/1.0/0.004	25.5/9.1/2.3
<i>Eustrongylides excisus</i> L3		0.9/1.0/0.01
<i>Hysterothylacium aduncum</i>	1.3/1.3/0.02	
<i>Hysterothylacium aduncum</i> L3	6.9/1.2/0.1	
<i>Raphidascaris</i> sp. L3		0.3/1.0/0.003
<i>Streptocara crassicauda</i> L3		0.8/9.7/0.1
Acanthocephala		
<i>Acanthocephaloides propinquus</i>		6.3/5.1/0.3
<i>Acanthocephalus lucii</i>	0.4/1.0/0.004	2.1/2.4/0.05
<i>Pomphorhynchus laevis</i>	0.4/1.0/0.004	
<i>Telosentis exiguus</i>		2.3/2.4/0.1
Hirudinea		
<i>Piscicola geometra</i>	0.4/1.0/0.004	
Crustacea		
<i>Ergasilus sieboldi</i>	2.2/10.0/0.2	

pl Plerocercoid, met metacercaria, and L3 third-stage larva

Two brackish water species, *C. concavum* and *D. minutus*, found in the round goby in the Gulf of Gdańsk are common in gobies from various sites of the Black Sea (Rădulescu and Vasiliu 1951; Naidenova 1974; Machkevsky et al. 1990; Kvach 2005). Both species are adapted to a wide salinity range; therefore, their abundance is more likely determined by the distribution of first intermediate hosts as opposed to salinity.

Three parasitic species were unique to the Baltic round goby in comparison to the Black Sea goby: *Bothriocephalus* sp., *A. crassus*, and *P. geometra*; all were rare (Table 1). In the invasive round goby *Bothriocephalus* sp. first occurred near Gdynia (Rokicki and Rolbiecki 2002). *A. crassus* is a common eel parasite of *Anguilla* spp. that originated in Southeast Asia (Kuwahara et al. 1974). In Europe this species was first reported in Germany in 1982 (Koops and Hartmann 1989), but in the Gulf of Gdańsk, it

first was found off Rewa in 1997–1998 (Rolbiecki et al. 2000). L3 larvae of this nematode were found in gobies caught in the Gulf of Gdańsk off Hel. The leach *P. geometra* is atypical for gobiids, but was found on the tubenose goby *Proterorhinus marmoratus* in coastal Lake Beloslavsko, Bulgaria (Margaritov 1960).

During a study held of the Gulf of Gdańsk from 2001 to 2003, we noted some changes in the round goby metazoan parasite fauna (Table 3). In contrast to our previous data (published in Kvach 2002), the parasite fauna increased from 4 species to 12 species, Ics=25% (Table 3). Only two helminth species, *D. spathaceum* and *H. aduncum*, were noted in the goby both in 2001 and 2003. The significance of these species in the parasitofauna is not changed (Table 3). The metazoan parasite fauna of the round goby off Puck is more changed than off Hel (Table 3).

Table 3 The changing of the parasite fauna and abundance during the study

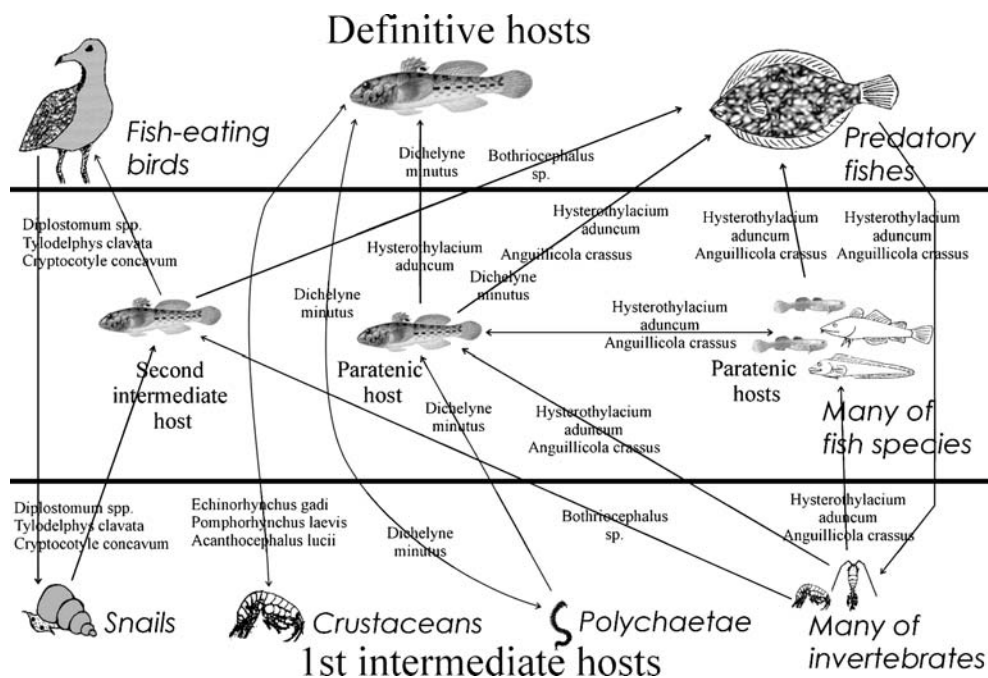
Region	Hel	Jastarnia	Chałupy	Puck	Sopot	Total			
Number of hosts	15	93	18	20	34	40	9	90	142
Host standard length (M±SD), cm	14.0±3.0	9.0±2.3	5.9±2.0	11.9±2.9	7.1±3.5	14.0±3.1	4.8±1.7	12.0±4.1	9.6±4.3
Year	2001	2003	2001	2001	2001	2003	2003	2001	2003
Cestoda									
<i>Bothriocephalus</i> sp. pl		0.02							0.01
Trematoda									
Cercariae gen. sp.						3.1			0.9
<i>Cryptocotyle concavum</i> met		0.6				62.9			18.1
<i>Diplostomum spathaceum</i> met	3.4	2.2	1.7	17.5	0.3	10.3		4.9	4.3
<i>Tyloodelphys clavata</i> met						0.1			0.01
Nematoda									
<i>Anguillicola crassus</i> L3		0.2							0.1
<i>Dichelyne minutus</i>		0.01							0.01
<i>Hysterothylacium aduncum</i>		0.04							0.03
<i>H. aduncum</i> L3		0.1		0.1		0.2	0.1	0.02	0.1
Acanthocephala									
<i>Acanthocephalus lucii</i>	0.07							0.01	
<i>Pomphorhynchus laevis</i>		0.01							0.01
Hirudinea									
<i>Piscicola geometra</i>		0.01							0.01
Crustacea									
<i>Ergasilus sieboldi</i>				2.5				0.6	
Species number	2	8	1	3	1	5	1	4	12
<i>Ics</i>	20.0				33.3			25.0	

In “total,” column 3 gobies caught near Gdańsk that were free from parasites is accounted

Two parasites, *C. concavum* and *D. minutus*, were not found in the Baltic round goby in 2001 but were observed the following year (Kvach 2002; Table 3). The metacercariae of *C. concavum* start as secondary species in the round

goby parasite fauna off Hel and core species off Puck in 2003. *D. minutus* is a rare species in the Gulf of Gdańsk, so it is possible that this nematode was present earlier but was not found.

Fig. 2 The role of the round goby in parasitic systems in the Gulf of Gdańsk



A. lucii and *E. sieboldi* occurred in the round goby in 2001 off Hel and Chałupy, respectively (Tables 1 and 3), but were not found in 2003; however it is not plausible to conclude that these two species have completely disappeared from the parasite fauna of the round goby. *P. laevis* occurred in gobies caught off Hel in 2003 (Table 3) and had previously been noted for this fish in the southern part of the Gulf of Gdańsk in 1994–2000 (Rokicki and Rolbiecki 2002).

During the last period the process of the round goby, parasite fauna formation in the place of invasion was coming on. The round goby hosts typical fish parasite species, *C. concavum* and *D. minutus*, but none that were unique to the species and no Ponto–Caspian parasites. Also, the parasitic species of the invasive round goby in the Gulf of Gdańsk includes species that are atypical for this species in native habitats.

The role of the round goby in parasitic systems in the Gulf of Gdansk

In the Baltic Sea the round goby is a definitive host for two nematodes (*H. aduncum* and *D. minutus*) and three acanthocephalans (*P. laevis*, *E. gadi*, and *A. lucii*). All these species were found in the round goby outside the Puck Lagoon: *D. minutus* and *A. lucii* occurred off Hel while *E. gadi* and *P. laevis* occurred near Hel and Gdynia (Rokicki and Rolbiecki 2002; present data). The life cycle of *D. minutus* is influenced by nereids (Køie 2001), which are one of most preferred food sources of the round goby (Kvach and Zamorov 2001) and small gobies can serve as paratenic hosts of this parasite (Køie 2001). Contrary to the Black Sea this nematode is rather rare in the Baltic Sea. Many amphipod species serve as the intermediate hosts of acanthocephalans but because these crustaceans are not intensively consumed by the round goby (Skóra and Rzeznik 2001), acanthocephalans rarely parasitize the Baltic round goby (Table 1).

The round goby is a second intermediate host for five parasite species: *Bothriocephalus* sp., Cercariae gen. sp., *C. concavum*, *D. spathaceum*, and *T. clavata*. The definitive hosts of trematodes *C. concavum*, *D. spathaceum*, and *T. clavata* are fish-eating birds, but the first intermediate hosts are snails: *Hydrobia* spp. for *C. concavum* and *Lymnaea* spp. for *D. spathaceum* and *T. clavata*. Snails *Lymnaea peregra*, *Hydrobia ulvae*, and *Hydrobia ventrosa* are common inhabitants of coastal nearshores of the Puck Bay (Osowiecki 2000).

The round goby in the Gulf of Gdańsk serves as a paratenic host for two nematode species: *H. aduncum* and *A. crassus*. The adult life stage of *H. aduncum* commonly infects the eelpout *Zoarces viviparus* and also other predatory fishes, but the first intermediate hosts are mostly

planktonic crustaceans (Køie 1993). The paratenic hosts, with the exception of gobies, are many small-sized fishes, such as eelpouts, flounders, and sticklebacks (Køie 1993).

In Europe the definitive host of *A. crassus* is the European eel *Anguilla anguilla* (Moravec 1994). In the Baltic Sea the paratenic hosts of this species are many limnetic fishes (perch *Perca fluviatilis*, ruff *Gymnocephalus cernuus*, carp *Cyprinus carpio*, bream *Abramis brama*, etc.) (Rolbiecki 2002) and also the black goby (Höglung and Thomas 1992). Cases of infection in the Ponto–Caspian monkey goby *Apollonia (Neogobius) fluviatilis*, an invasive species in Lake Balaton, Hungary, were previously noted (Székely 1992).

Taking into account the life cycles of all parasites occurring in the round goby in the Baltic Sea, a schematic of the role of the round goby in parasitic systems was built (Fig. 2).

In the Gulf of Gdańsk the round goby serves the role of definitive, secondary intermediate, and paratenic host for different parasite species. The fish species is involved in a parasitic system that includes fish-eating birds, fishes of different ecological groups (predatory, planktivorous, and benthivorous), and invertebrates.

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