Parasitol Res (2011) 109:769–780
DOI 10.1007/s00436-011-2321-8

ORIGINAL PAPER

The colonization of the invasive round goby *Neogobius melanostomus* by parasites in new localities in the southwestern Baltic Sea

Yuriy Kvach · Helmut M. Winkler

Received: 17 December 2010 / Accepted: 23 February 2011 / Published online: 16 March 2011
© Springer-Verlag 2011

Abstract The round goby *Neogobius melanostomus* is a bottom-dwelling fish native for the Ponto-Caspian basin, which started to colonize the Baltic Sea since 1991. The parasites of this fish species in the southwestern Baltic region are studied for the first time. The round goby in the SW Baltic Sea was infected with 12 parasite species: 1 species of Microsporidia, 1 species of Monogenea, 1 of Cestoda, 3 species of Trematoda, 3 species of Nematoda, 2 of Acanthocephala, and 1 species of Bivalvia. Microsporidia genus species have the great tendency to join the infracommunity in all localities, except the Stettiner Haff, where this tendency have *Diplostomum spathaceum* met and *Unio* sp. glochidia. The round goby was colonized by seven new parasites species not found in this fish in the Baltic Sea earlier: Microsporidia gen. sp., *Gyrodactylus rugiensis*, *Bucephalus polymorphus*, *Cosmocephalus obvelatus* L3, *Eustrongylides excisus* L3, *Paracuaria adunca* L3, *Unio* sp. glochidia. Microsporidia gen. sp., *G. rugiensis*, and *Unio* sp. are new parasites for the round goby. In general, the processes of colonization have the same tendency as in the Gulf of Gdańsk.

Y. Kvach (✉) · H. M. Winkler
Institut für Biowissenschaften/Zoologie,
Universität Rostock,
Universitätsplatz 2,
18055 Rostock, Germany
e-mail: kvach@localka.net

Y. Kvach
Odessa Branch of the Institute of Biology
of the Southern Seas of NAS of Ukraine,
Vul. Pushkinska 37,
65125 Odessa, Ukraine

Introduction

Exotic species also may serve as sources for new parasite species to invade native host populations (Mack et al. 2000). Following a successful introduction, one would expect exotic species to become increasingly parasitized by the parasites harboured by ecologically similar native species. On the other hand, the release from parasites and pathogens, which is predicted to be greatest early in the invasion, forms part of the "enemy release hypothesis" (Keane and Crawley 2002; Torchin et al. 2003). It thus appears likely that sampling the parasite load of an exotic population over the time course following an introduction would yield increasing numbers of parasites, until the new hosts reach a parasite load similar to that of native species.

The round goby *Neogobius* (*Apollonia*) *melanostomus* (Pallas, 1814) is a bottom-dwelling fish native for the Ponto-Caspian basin (Smirnov 1986). The processes of invasion of the round goby were started by its introduction to Lake St. Clair (Great Lakes, North America) and the Gulf of Gdańsk (southern Baltic Sea) in 1990 (Skóra and Stolarski 1993; Jude et al. 1992). Now, it is widely distributed in all Great Lakes basin (Charlebois et al. 1997). Recently, the cases of the round goby invasion are mentioned in the Aegean Sea (Eryilmaz 2002), in the different parts of the Baltic Sea (Sapota and Skóra 2005), North Sea basin (van Beek 2006), and basins of the rivers Danube and Rhine (Jurajda et al. 2005; van Kessel et al. 2009). In the German part of the Baltic Sea, this fish was first noted in 1998 near the Rügen Island (Winkler 2006). Now, it is distributed along all southwestern Baltic coast and includes the Stettiner Haff (Szczecin Lagoon), the Unterwarnow (the estuary of the Warnow River), the mouth of the Trave River, and in the Nord-Ostsee (Kiel) Kanal.

In the Baltic Sea (Gulf of Gdańsk), the round goby *N. melanostomus* is entered to parasitic system that includes fish-eating birds, fishes of different ecological groups (predatory, planktivorous, bentivorous), and invertebrates (Kvach and Skóra 2007). Non-indigenous gobies colonizing the Baltic Sea and the Great Lakes apparently did not introduce new parasites to native fishes because they were introduced with ballast waters (Kvach and Stepien 2008). They were colonized by native parasite fauna. The processes of colonization of the invasive round goby by parasites in the Baltic Sea and the Great Lakes support the "enemy release hypothesis". Opposite to these processes, in the Danube basin, the invasive round goby introduced the digenean *Bucephalus polymorphus* following the invasion of the first intermediate host *Dreissena polymorpha* into mid-European waters (Mühlegger et al. 2009, 2010). The parasite fauna of the round goby from the Gulf of Gdańsk is characterized by low similarity with one from the Black Sea. The southwestern part of the Baltic Sea is characterized by higher salinity and presence of the higher number of marine species in the parasite fauna of gobiids (Zander 1998; Zander 2004; Zander et al. 2000). In this view, the southwestern (SW) Baltic Sea is more similar to the Black Sea than the Gulf of Gdańsk. But the parasite communities of the round goby in the western Baltic are not yet studied.

The objectives of the study were:

1. To study the parasite communities of the invasive round goby *N. melanostomus* in the SW Baltic Sea.
2. To analyze the parasite fauna of the resident gobiids and compare it with the round goby. To study the processes of adaptation of local parasite system to the new host.
3. To compare it with the published data from the Gulf of Gdańsk, Great Lakes, and native habitats in the Black Sea basin.

Material and methods

The study was carried out between July 5 and September 5, 2010. The fish were sampled by fishermen using fyke nets and personally using seine. The fish were transported in buckets with the aerated water (water was got in the place of sampling) to the laboratory of the University of Rostock; then the fish were dissected in 3 days. The salinity of water from each locality was measured. The round goby *N. melanostomus* was caught in next localities in the SW Baltic Sea (Fig. 1): 1. Stettiner Haff (Szczecin Lagoon) in Ueckermünde, S=0.3 PSU; 2. Peenemünde (the mouth of the Peene River) near Freest, S=4.2 PSU; 3. Strelasund Strait, in Stralsund and near the Rügen Island coast opposite the Stralsund downtown, S=6.9–7.1 PSU; 4. Unterwarnow (the estuary of the Warnow River) Rostock near Kleine Warnow and Peez, S=9.1–9.3 PSU; 5. Nord-Ostsee Kanal (Kiel Canal) near Rade, S=7.0 PSU. The sampling in the localities in the eastern coast of the Rügen Island showed no round gobies. But round gobies where caught later on (September) nearly everywhere in the Baltic Sea close to the Greifswalder Bodden and the Usedom Island.

In total, 148 individuals of the round goby were examined for parasites. The total weight and standard length of each goby were measured before dissection. The numbers of gobies from each locality and their weights and lengths are presented in Table 1. In addition, 33 individuals of the black goby *Gobius niger* L., 1758 (from the Greifswalder Bodden, near Thiessow, Rügen Island, and the Unterwarnow, Rostock), 19 individuals of the sand goby *Pomatoschistus minutus* (Pallas, 1770), and 20 individuals of the common goby *Pomatoschistus microps* (Krøyer, 1838) (both from the Unterwarnow) were examined for parasites for comparative study. The weight of *Pomatoschistus* spp. was not measured due to the small sizes.

The parasitological indices were calculated according to Bush et al. (1997): prevalence (P %), intensity (presented as min–max), mean intensity (MI), and abundance (A). The importance of parasites was judged by an altered core-/satellite concept according to their abundance: >2=core species, 0.6–2=secondary species; 0.2–0.6=satellite species; and <0.2=rare species (Zander et al. 2000). The tendency to join the infracommunity was evaluated according to the Infracommunity Index, ICI; the great tendency to join the community was determined by the ICI level more then 0.30 (Zander 2004). To compare the parasite faunas, the Index of Czekanowski-Sørensen, ICS (Czekanowski 1909; Sørensen 1948), was used.

Results

In total, 86 individuals of examined fishes (58.1%) were infected with parasites (Table 1). The maximal prevalence was in the Stettiner Haff (96%), but minimal in the Nord-Ostsee Kanal (40.1%). The round goby in the SW Baltic Sea was infected with 12 parasite species (Table 1): 1 species of Microsporidia, 1 species of Monogenea, 1 of Cestoda, 3 species of Trematoda, 3 species of Nematoda, 2 of Acanthocephala, and 1 species of Bivalvia. The maximal number of parasite species was registered in the Stettiner Haff near Ueckermünde—six species. Also, almost the same number of parasite species was in the Peenemünde—five species. Only one parasite species, Microsporidia gen. sp., occurred in the Strelasund.

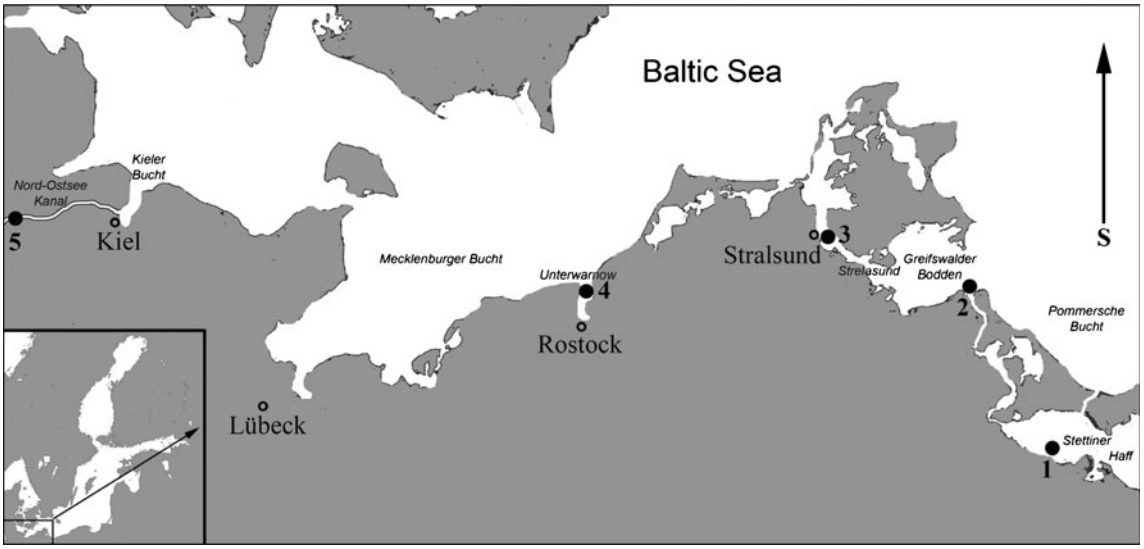

Fig. 1 Schematic map of investigated area in the SW Baltic Sea. *Black circles with numbers* are sampling localities

The core of the round goby parasite community consists of two species: *Diplostomum spathaceum* and Unionidae gen. sp. glochidia (Table 1). Metacercariae of *D. spathaceum* occurred in eyes of fishes from the Stettiner Haff and Peenemünde. It was most abundant parasite of the round goby in the SW Baltic Sea. Another abundant parasites were glochidia of Unionidae, located in gills of gobies from the Stettiner Haff. Only microsporidians played the role of secondary species. These parasites were found in all localities (Table 1). The taxonomic status of these microsporidia is unclear, but the preliminary investigation shows that they are differs from the microsporidia infest gobiids in the Black Sea. This is most prevailed parasite species. The larvae of *Pomphorhynchus laevis* played a role of satellite species in the Stettiner Haff and Peenemünde. All other species were rare.

The infracommunity of the invasive round goby in the SW Baltic Sea consists of one to four species (Table 2). The infracommunities formed by one species are prevailed in the Strelasund, Unterwarnow, and the Nord-Ostsee Kanal, but in the Stettiner Haff the infracommunity formed by three species was prevailed (Fig. 2). In the Peenemünde the prevailed communities were two and three components. In total, 19 types of infracommunities were registered. One-component community, composed by microsporidians only, was most common. According to ICI, the great tendency to join the infracommunity have microspiridians (Table 3). Only in the Stettiner Haff, the great tendency has *D. spathaceum* met and *Unio* sp. glochidia.

Ten parasite species occurred in resident gobiids (Table 4). Six species were found in the black goby, four in the sand goby, and nine in the common goby. All these parasites were registered in the SW Baltic Sea earlier.

Discussion

Communities of parasites of the invasive round goby in the SW Baltic Sea

The microsporidians, which are most prevailed parasites in the round goby in the SW Baltic Sea, had the great tendency to join the infracommunity (Table 3). The parasite community, consisting of only microsporidians, was also most common in the region (Table 2). This tendency was common for all localities accept the Stettiner Haff, where microsporidians were presented only in composition with other species (Table 2). In this locality, the great tendency to join infracommunity has limnetic parasite species, such as *D. spathaceum* met and *Unio* sp. glochidia. The Stettiner Haff is the estuary of the Oder River, connected with the Baltic Sea via the rivers Peene, Swina, and Dziwna. This waterbody has low instable salinity from 0.3 to 4.5 PSU (mean salinity 1.4 PSU) (Radziejewska and Schernewski 2008). In the sampling place, the salinity was 0.3 PSU; this is the locality with the lowest salinity between the waterbodies studied. The limnetic parasites, such as *B. polymorphus* met, *Tylodelphys* sp. met, *Unio* sp. glochidia, occurred only in these waterbody and absent in all other localities (Table 1). Another locality with low salinity was the Peenemünde, the mouth of the Peene River (one of the rivers, which connect the Stettiner Haff with the main Baltic Sea)—*S*=4.2 PSU. Some of limnetic parasite species (*D. spathaceum* met, *E. excisus* L3) were presented here

Table 1 The parasitization of the round goby by parasites in the different regions of the SW Baltic Sea

Parasite species\locality		Stettiner Haff	Peenemünde	Strelasund	Unterwarnow	Nord-Ostsee Kanal	Total
Number of fish studied		25	11	15	50	47	148
Total weight, g		27.79±11.01	24.65±17.82	11.34±5.05	5.40±3.32	13.63±7.34	13.83±11.45
Standard length, cm		10.0±1.4	10.0±2.0	7.8±1.1	6.0±1.4	7.9±1.5	7.7±2.1
Number of infected fish (ind./%)		24/96.0	7/63.6	7/46.7	29/58.0	19/40.4	86/58.1
MICROSPOREA							
Microsporidia gen. sp.	P,%	44.0	36.4	46.7	56.0	38.3	45.9
	MI ± sd	3.0±2.3	2.3±1.3	1.7±1.5	2.3±1.9	2.4±2.3	2.4±2.0
	Min–max	1–8	1–4	1–5	1–7	1–9	1–9
	A	1.3	0.8	0.8	1.3	0.9	1.1
MONOGENEA							
Gyrodactylus rugiensis	P,%				4.0		1.4
	MI ± sd				1.0±0.0		1.0±0.0
	Min–max				1		1
	A				0.04		0.01
CESTODA							
Bothriocephalus scorpii pl	P,%				8.0		2.7
	MI ± sd				1.8±1.0		1.8±1.0
	Min–max				1–3		1–3
	A				0.1		0.05
TREMATODA							
Bucephalus polymorphus met	P,%	8.0					1.4
	MI ± sd	1.0±0.0					1.0±0.0
	Min–max	1					1
	A	0.1					0.01
Diplostomum spathaceum met	P,%	80.0	27.3				15.5
	MI ± sd	20.3±21.5	37.0±34.1				22.5±23.2
	Min–max	1–87	13–76				1–87
	A	16.2	10.1				3.5
Tylodelphys sp. met	P,%	4.0					0.7
	MI ± sd	3.0					3.0
	Min–max	3					3
	A	0.1					0.02

NEMATODA							
Cosmocephalus obvelatus L3	P,%					6.4	0.7
	MI ± sd					1.0±0.0	1.0
	Min–max					1	1
	A					0.1	0.01
Eustrongylides excisus L3	P,%		9.1				0.7
	MI ± sd		1.0				1.0
	Min–max		1				1
	A		0.1				0.01
Paracuaria adunca L3	P,%					2.1	4.3
	MI ± sd					1.0	1.0±0.0
	Min–max					1	1
	A					0.02	0.04
ACANTHOCEPHALA							
Echinorhynchus gadi	P,%		9.1				0.7
	MI ± sd		1.0				1.0
	Min–max		1				1
	A		0.1				0.01
Pomphorhynchus laevis	P,%		18.2				1.4
	MI ± sd		1.0±0.0				1.0±0.0
	Min–max		1				1
	A		0.2				0.01
P. laevis cystacanth	P,%	20.0	9.1				4.1
	MI ± sd	2.6±2.5	1.0				2.3±2.3
	Min–max	1–7	1				1–7
	A	0.5	0.1				0.1
BIVALVIA							
Unio sp. glochidia	P,%	68.0					11.5
	MI ± sd	18.6±18.1					18.6±18.1
	Min–max	1–58					1–58
	A	12.6					2.1
Total		6	5	1	3	3	12

P prevalence, *MI* mean intensity, *A* abundance, *sd* standard deviation, *pl* pleurocercoids, *met* metacercariae, *L3* 3rd stage larvae.

Table 2 Composition of infracommunities of different types (number of cases/% to total number of fish infected)

No of components	Parasite species\locality	Stettiner Haff	Peenemünde	Strelasund	Unterwarnow	Nord-Ostsee Kanal	Total
1	Microsporidia gen. sp.		2/28.6	7/100.0	23/79.3	16/84.2	48/55.8
	Bothriocephalus scorpii pl				1/3.4		1/1.2
	Diplostomum spathaceum met	4/16.7	1/14.3				5/5.8
	Paracuaria adunca L3					1/5.3	1/1.2
2	Microsporidia gen. sp. + *Gyrodactylus rugiensis*				2/6.9		2/2.3
	Microsporidia gen. sp. + *B. scorpii* pl				3/10.3		3/3.5
	Microsporidia gen. sp. + *Pomphorhynchus laevis*		2/28.6				2/2.3
	Microsporidia gen. sp. + *Unio* sp. glochidia	2/8.3					2/2.3
	Microsporidia gen. sp. + *Cosmocephalus obvelatus* L3					1/5.3	1/1.2
	Microsporidia gen. sp. + *P. adunca* L3					1/5.3	1/1.2
	D. spathaceum met+*Echinorhynchus gadi*		1/14.3				1/1.2
	D. spathaceum met+*P. laevis*	2/8.3					2/2.3
	D. spathaceum met+*Unio* sp. glochidia	5/20.8					5/5.8
3	Microsporidia gen. sp. + *Bucephalus polymorphus* met+*Unio* sp. glochidia	2/8.3					2/2.3
	Microsporidia gen. sp. + *D. spathaceum* met+*P. laevis*	1/4.2					1/1.2
	Microsporidia gen. sp. + *D. spathaceum* met+*Unio* sp. glochidia	5/20.8					5/5.8
	D. spathaceum met+*Eustrongylides excisus* L3+*P. laevis*		1/14.3				1/1.2
	D. spathaceum met+*P. laevis*+*Unio* sp. glochidia	2/8.3					2/2.3
4	Microsporidia gen. sp. + *D. spathaceum* met+*Tylodelphys* sp. met+*Unio* sp. glochidia	1/4.2					1/1.2

(Table 1). But metacercariae of *D. spathaceum* lost the tendency to join infracommunity (Table 3).

In the localities, such as the Strelasund, Unterwarnow, and the Nord-Ostsee Kanal, the parasite community was rather poor. Also, the percent of infected fishes was lower there (Fig. 2). These waterbodies have "normal" Baltic salinity, from 6.9 to 7.1 PSU in the Strelasund and Nord-Ostsee Kanal to 9.1–9.3 PSU in the Unterwarnow. In all these localities, the microsporidians have very high tendency to join infracommunity (in the Strelasund, it was only parasite occurred) (Table 3). The marine species, such as monogeneans *Gyrodactylus rugiensis* and cestodes *Bothriocephalus scorpii* pl, occurred only in the Unterwarnow (Table 1).

Parasite fauna of resident gobiids and its comparing with the round goby one

All parasites found have local origin and common in another species of Baltic fishes. The parasites specific for

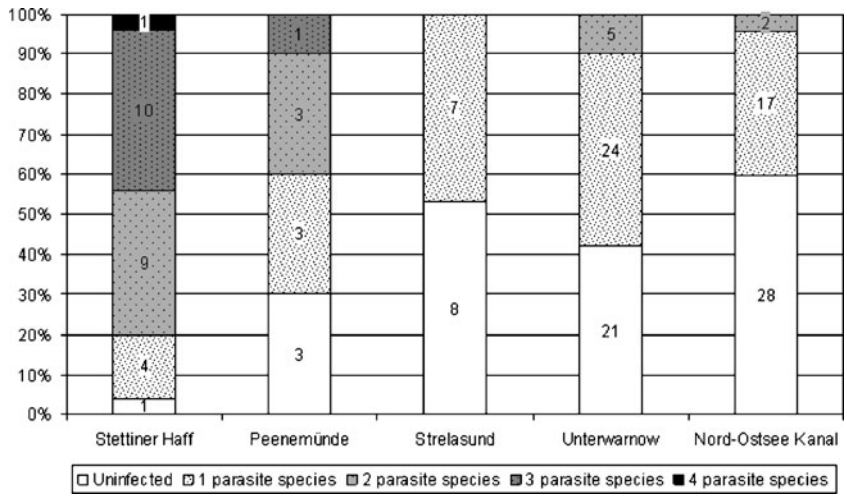

Fig. 2 The percentage of different types of infracommunities of parasites of the round goby in different localities of the SW Baltic Sea

Table 3 Infracommunity index

Parasite species\locality	Stettiner Haff	Peenemünde	Strelasund	Unterwarnow	Nord-Ostsee Kanal	Total
Microsporidia gen. sp.	0.20	**0.33**	**1.00**	**0.82**	**0.86**	**0.52**
Gyrodactylus rugiensis				0.06		0.02
Bothriocephalus scorpii pl				0.12		0.03
Bucephalus polymorphus met	0.04					0.02
Diplostomum spathaceum met	**0.36**	0.25				0.18
Tylodelphys sp. met	0.02					0.01
Cosmocephalus obvelatus L3					0.05	0.01
Eustrongylides excisus L3		0.08				0.01
Paracuaria adunca L3					0.10	0.02
Echinorhynchus gadi		0.08				0.01
Pomphorhynchus laevis	0.09	0.25				0.06
Unio sp. glochidia	**0.30**					0.13

The great tendency to join the infracommunity is in boldface

the Ponto-Caspian gobiids did not occur. Most of the parasites are generalists and can infest many of fish hosts. Only exception is the monogenean *G. rugiensis*. This is the most interesting finding, because of its host specificity; it is a specific parasite of the common goby (Huyse et al. 2003). This is a case of occasional infestation of the round goby, but shows the possibility of *G. rugiensis* to switch to alien gobiid species. Most of the parasites registered in the round goby were not found in local gobiids (Table 2).

Only four parasite species occurred in both round goby and another gobiids: Microsporidia gen. sp., *G. rugiensis*, *B. scorpii*, and *D. spathaceum*. The Czekanowski-Sørensen Index (ICS) shows the low similarity between the parasite

Table 4 The parasite of three species of native gobiids in SW Baltic Sea

Parasite species\fish species		*Gobius niger*			*Pomatoschistus minutus*	*Pomatoschistus microps*
Locality		Greifswalder Bodden	Unterwarnow	Total	Unterwarnow	Unterwarnow
Number of fish studied		10	23	33	19	20
Total weight, g		3.98±0.88	2.99±1.91	3.29±1.20	Not measured	Not measured
Standard lenght, cm		5.7±0.5	5.0±0.7	5.2±0.7	3.8±0.5	3.2±0.3
MICROSPOREA						
Microsporidia gen. sp.	P,%	60.0	56.5	57.6		10.0
	MI ± sd	2.2±1.9	2.2±1.7	2.2±1.8		1.0±0.0
	Min–max	1–6	1–7	1–7		1
	A	1.3	1.3	1.3		0.1
MONOGENEA						
Gyrodactylus rugiensis	P,%					45.0
	MI ± sd					5.3±2.8
	Min–max					1–9
	A					2.4
CESTODA						
Bothriocephalus scorpii pl	P,%		4.1	3.0		30.0
	MI ± sd		1.0	1.0		7.7±7.3
	Min–max		1	1		1–21
	A		0.4	0.03		2.3
Ligula pavlovskii pl	P,%				5.3	5.0
	MI ± sd				1.0	1.0
	Min-max				1	1
	A				0.1	0.1

Table 4 (continued)

Parasite species\fish species		*Gobius niger*			*Pomatoschistus minutus*	*Pomatoschistus microps*
Locality		Greifswalder Bodden	Unterwarnow	Total	Unterwarnow	Unterwarnow
Number of fish studied		10	23	33	19	20
Total weight, g		3.98±0.88	2.99±1.91	3.29±1.20	Not measured	Not measured
Standard lenght, cm		5.7±0.5	5.0±0.7	5.2±0.7	3.8±0.5	3.2±0.3
Proteocephalus sp. pl	P,%	40.0	21.7	27.3		10.0
	MI ± sd	2.0±0.8	1.4±0.9	1.7±0.9		1.0±0.0
	Min–max	1–3	1–3	1–3		1
	A	0.8	0.3	0.5		0.1
TREMATODA						
Aphalloides timmi	P,%					80.0
	MI ± sd					7.9±5.7
	Min–max					1–25
	A					6.4
Cryptocotyle concavum met	P,%	10.0	13.0	12.1	21.1	40.0
	MI ± sd	1.0	2.3±1.2	2.0±1.2	8.3±12.6	24.6±22.2
	Min–max	1	1–3	1–3	1–27	1–50
	A	0.1	0.3	0.2	1.7	9.9
Diplostomum spathaceum met	P,%				5.3	
	MI ± sd				1.0	
	Min–max				1	
	A				0.1	
Timoniella balthica met	P,%				57.9	10.0
	MI ± sd				1.4±0.7	1.0±0.0
	Min–max				1–3	1
	A				0.8	0.1
NEMATODA						
Camallanus lacustris	P,%		4.1	3.0		
	MI ± sd		1.0	1.0		
	Min–max		1	1		
	A		0.4	0.03		
Hysterothylacium aduncum L3	P,%	40.0	13.0	21.2		5.0
	MI ± sd	1.0±0.0	2.0±1.0	1.4±0.8		1.0
	Min–max	1	1–3	1–3		1
	A	0.4	0.3	0.3		0.1
Total		4	6	6	4	9

faunas of the round goby and local gobiids in the total SW Baltic. So, the similarity between the round goby and the black goby was 22.2%; between the round goby and the sand goby, it was 12.5%, but between the round goby and the common goby, it was 28.6%. Comparing the parasite fauna in the same locality (all three species occurred together in the Unterwarnow), we found the similarity higher: round goby/black goby—ICS=44.4%, round goby/common goby—ICS=50.0%. But it was no similarities in the parasite fauna of the round goby and the sand goby in the Unterwarnow (Table 2).

The parasites, such as *D. spathaceum* met, *B. scorpii* pl, *Proteocephalus* sp. pl, *Echinorhynchus gadi*, *P. laevis* have been already noted in different gobiid species in the SW Baltic Sea according to the published data (Zander et al. 1999; Zander 2004; Josten et al. 2009). The larvae of *Cosmocephalus obvelatus* were registered in the common goby from the Flensburg Fjord (Josten et al. 2009).

Table 5 The Czekanowski-Sørensen Index between the parasite fauna of the round goby in different part of the Baltic Sea and the NW Black Sea (native area)

	SW Baltic Sea	Gulf of Gdańsk	Vistula lagoon	Curonian lagoon	NW Black Sea
SW Baltic Sea	100				
Gulf of Gdańsk	38.5	100			
Vistula lagoon	32.3	60.6	100		
Curonian lagoon	31.6	38.1	38.5	100	
NW Black Sea	13.8	25.8	11.1	0.0	100

Role of the round goby in the parasite life cycles

Three of the parasite species were presented by adult stages: *G. rugiensis*, *E. gadi*, *P. laevis*. The acanthocephalan *P. laevis* was presented by both adults and larvae. *G. rugiensis* is viviparous ectoparasite, very specific to fish host. The acanthocephalans found in the round goby are parasites of different fish species in the Baltic Sea. The infestation of fish comes due to consumption of the gammarids infected with cystacanths (Petrochenko 1956).

Five parasite species are parasites of fish-eating birds in adult stages, but larvae are in fishes: *D. spathaceum*, *Tylodelphys* sp., *C. obvelatus*, *Eustrongylides excisus*, and *Paracuaria adunca*. *D. spathaceum*, *Tylodelphys* sp., and *C. obvelatus* are generalists, which infest many species of fish-eating birds (Gaevskaya et al. 1975;

Table 6 Parasites of the round goby in the different parts of the Baltic Sea comparing to the Black Sea data

Status of the round goby population	Invasive				Native
Region	SW Baltic Sea (current data)	Gulf of Gdańsk (Kvach 2002; Rokicki and Rolbiecki 2002; Kvach and Skóra 2007)	Vistula Lagoon (Rolbiecki 2006)	Curonian Lagoon (Rakauskas et al. 2008)	Northwestern Black Sea (Kvach 2005)
MICROSPORA					
Microsporidia gen. sp.	+				
MESOMYCETOZOEA					
Dermocystidium sp.			+		
CILIOPHORA					
Trichodina domerguei		+	+		+
MONOGENEA					
Gyrodactylus rugiensis	+				
CESTODA					
Bothriocephalus scorpii pl	+	+	+		
Eubothrium crassum pl			+		
Paradilepis scolecina pl			+		
Proteocephalus filicollis			+		
Proteocephalus gobiorum pl					+
Proteocephalus sp. pl			+	+	
TREMATODA					
Asymphylodora pontica					+
Bucephalus polymorphus met	+				+
Bunodera luciopercae			+		
Cercaria gen. sp.		+	+		
Cryptocotyle concavum met		+			+
C. lingua met					+
Diplostomum spp. met	+	+	+	+	
Pygidiopsis genata met					+
Timoniella imbutiforme met					+
Tylodelphys sp. met	+	+	+		

Table 6 (continued)

Status of the round goby population	Invasive				Native
Region	SW Baltic Sea (current data)	Gulf of Gdańsk (Kvach 2002; Rokicki and Rolbiecki 2002; Kvach and Skóra 2007)	Vistula Lagoon (Rolbiecki 2006)	Curonian Lagoon (Rakauskas et al. 2008)	Northwestern Black Sea (Kvach 2005)
NEMATODA					
Anguillicola crassus L3		+	+		
Camallanus lacustris				+	
C. truncata			+		
Contracaecum sp. L3			+		
Contracaecum microcephalum L3					+
C. rudolphii L3					+
Cosmocephalus obvelatus L3	+				
Cystidicoloides ephimeridarum			+		
Dichelyne minutus		+	+		+
Eustrongylides excisus L3	+				+
Hysterothylacium aduncum		+	+	+	
Paracuaria adunca L3	+				
Raphidascaris sp. L3					+
Streptocara crassicauda L3					+
ACANTHOCEPHALA					
Acanthocephaloides propinquus					+
Acanthocephalus lucii		+			+
A. anguillae				+	
Echinorhynchus gadi	+	+	+	+	
Pomphorhynchus laevis	+	+	+	+	
Telosentis exiguus					+
HIRUDINEA					
Piscicola geometra		+			
CRUSTACEA					
Ergasilus sieboldi		+			
BIVALVIA					
Unio sp. glochidia	+				
Species number	12	14	19	7	17

Anderson 2000). They are also generalists in larval stages. Both larvae and adults are common in different parts of Europe. The nematode *E. excisus* is specific parasite of cormorants *Phalacrocorax carbo* (Anderson 2000). The first intermediate host is the freshwater oligochaets *Tubifex* sp., which is dietary item for gobiids. For the digeneans, the round goby plays a role of the second intermediate host. For nematodes fishes are paratenic hosts.

Another three species are parasites of fishes in adult stage, but the larvae are also in fishes: *B. scorpii*, *B. polymorhus*, and *P. laevis*. The cestode *B. scorpii* is a parasite of scorpionfishes *Myoxocephalus* sp. and flounders *Platichthyes flesus* (Renaud et al. 1984). Intermediate hosts are planktonic crustaceans, but small-sized gobiids (mostly *Pomatoschistus* spp.) play the important role in the realization of the life cycle to be hosts of post-pleurocercoids (Robert et al. 1988). The round goby got the same ecological niche in the Baltic Sea, to be the host of the post-pleurocercoids of *B. scorpii*, which located in the gut of fishes. The trematode *B. polymorphus* in adult stage is parasite of zanders *Sander lucioperca*, sometime another predatory percids (like perch *Perca fluviatilis*). The gobiids, which plays important role in the diet of the zander, are second intermediate hosts (Gaevskaya et al. 1975). In the case of *P. laevis*, the round goby plays a role of definitive host and also paratenic. The encysted larvae of this acanthocephalan were located in the intestinal walls of gobies.

Unionidae are free-living mussels in adult stages, but parasites as larvae. The glochidia have no host specificity, located in the gills of many of fish species. Microsporidia were presented by xenomas, which located in the mesentery of gobiids.

Comparing with the data from the other sites of the Baltic Sea, Great Lakes, and the Black Sea basin

According to the data of Czekanowski-Sørensen Index, the similarity with the other part of the Baltic Sea is rather low, less than 50% (Table 5). In total, five species of parasite found in the round goby in the SW Baltic Sea were already mentioned in this host species in the other parts of this water basin (Table 6). The similarity with the Black Sea is also low. The parasite fauna of the round goby in the SW Baltic Sea consists of only two parasites, which were registered in the northwestern (NW) Black Sea (Table 6; Kvach 2005): *B. polymorphus* met and *E. excisus* L3. Both of these parasites were never mentioned in the round goby in the Baltic Sea earlier. Another two parasite species, *D. spathaceum* met and *P. adunca* L3, were not mentioned in the NW Black Sea, but registered in the other parts of the Black Sea basin (Chernyshenko 1957; Korniychuk et al. 2008).

Between 25 parasite species found in the Great Lakes according to the published data (Muzzall et al. 1995; Pronin et al. 1997; Camp et al. 1999; Kvach and Stepien 2008), only one species, *Diplostomum* spp. met was registered in the Baltic Sea (Ics=5.4%). In general, the parasite fauna of the round goby in the Great Lakes consists of local species and not similar to the European one (Kvach and Stepien 2008).

Processes of colonization of the invasive round goby by parasites

In the SW Baltic Sea, the round goby was colonized by seven new parasites species, did not found in this fish in the Baltic Sea earlier: Microsporidia gen. sp., *G. rugiensis*, *B. polymorphus*, *C. obvelaus* L3, *E. excisus* L3, *P. adunca* L3, *Unio* sp. glochidia. Microsporidia gen. sp., *G. rugiensis*, and *Unio* sp. are new parasites for the round goby.

The processes of colonization have same tendency as in the Gulf of Gdańsk. The typical gobiid parasites, like the trematode *Cryptocotyle concavum* met and the nematode *Dichelyne minutus*, which are common in the round goby in the Black Sea (Kvach 2005; see Table 6), were not registered in the round goby from the SW Baltic. Both of these parasites are presented in resident gobiids (see Table 4; Zander 2004; Zander et al. 1999, 2000). The same situation was in the Gulf of Gdańsk in 2001, at the beginning of the study of the invasive round goby parasites (Kvach 2002; Rokicki and Rolbiecki 2002). Later, both these parasites occurred in the parasite fauna of the round goby in Polish waters (Rolbiecki 2006; Kvach and Skóra 2007).

The introduction of the Ponto-Caspian round goby to the SW Baltic Sea makes the life cycles of the digenean *B. polymorphus* and the nematode *E. excisus* in this waterbody identical to that in the Ponto-Caspian region. On the other hand, due to the presence of these parasites in the SW Baltic Sea, the invasive round goby starts to play the same role in this ecosystem, as in their native habitats. The presence of this invasive component in the life cycles supports the further distribution and spreading of *B. polymorphus* and *E. scisus* at the colonized area.

Acknowledgments The study was supported by Deutsche Akademischer Austausch Dienst, Forschungs-/Arbeitsaufenthalte ausländischer Hochschullehrer. The sampling of gobiids in the Rügen Island, Strelasund Strait, and Greifswalder Bodden was carried out in the collaboration with Dr. Patrick Polte and Paul Kotterba, Institute of Baltic Sea Fisheries, Rostock. Thanks are given to the fishermen Gutzmann (Freest), Dieckmann (Ueckermünde), and Brauer (Rade near Rendsburg) providing round gobies to our studies.

References

Anderson RS (2000) Nematode parasites of vertebrates. Their development and transmission, 2nd edn. CABI Publishing, Wallingford, Oxon, UK

Bush AO, Lafferty KD, Lotz JM, Shostak AW (1997) Parasitology meets ecology on its own terms: Margolis et al. revisited. J Parasitol 83:575–583

Camp JW, Blaney LM, Barnes DK (1999) Helminths of the round goby, *Neogobius melanostomus* (Perciformes: Gobiidae), from southern Lake Michigan, Indiana. J Helminthol Soc Wash 66 (l):70–72

Charlebois PM, Marsden JE, Goettel RG, Wolf RK, Jude DJ, Rudnicka S (1997) The round goby *Neogobius melanostomus* (Pallas), a review of European and North American literature [In] INHS Special Publication №20, pp 1–76

Chernyshenko AS (1957) Rasprostraneniye lichinok trematod sredi ryb Tiligulskogo limana. Nauchnyi yezhegodnik Odesskogo Universiteta 261–262, in Russian

Czekanowski J (1909) Zur differential diagnose der Neandertalgruppe. Korespondblatte der deutschen. Gesellschaft der Anthropologie 40:44–47

Eryilmaz L (2002) A new fish record for the Aegean Sea: round goby *Neogobius melanostomus* (Pallas, 1814) (Gobiidae). Isr J Zool 48:251–252

Gaevskaya AV, Gusev AV, Delamure SL, Donets ZS, Iskova NI, Kornjushin VV, Kovaleva AA, Margaritov NM, Markevich AP, Mordvinova TN, Najdenova NN, Nikolaeva VM, Paruhin AM, Pogoreltseva TP, Smogorzhevskaja LA, Solonchenko AI, Shtein GA, Shulman SS (1975) Key to parasites of vertebrates of the Black and Azov Seas. Naukova dumka, Kiev

Huyse T, Audenaert V, Volckaert FAM (2003) Speciation and host–parasite relationships in the parasite genus *Gyrodactylus* (Monogenea, Platyhelminthes) infecting gobies of the genus *Pomatoschistus* (Gobiidae, Teleostei). Int J Parasitol 33:1679–1689

Josten N, Detloff KC, Zander CD (2009) Analysis of a parasite supra community from the Flensburg fjord. Parasitol Res 104:449–461

Jude DJ, Reider RH, Smith GR (1992) Establishment of Gobiidae in the Great Lakes basin. Can J Fish Aquat Sci 49:416–421

Jurajda P, Černý J, Polačik M, Valová Z, Janáč M, Blažek R, Ondračková M (2005) The recent distribution and abundance of non-native *Neogobius* fishes in the Slovak section of the River Danube. J Appl Ichthyol 21(4):319–323

Keane RM, Crawley MJ (2002) Exotic plant invasions and the enemy release hypothesis. Trends Ecol Evol 17:164–170

Korniychuk YuM, Pronkina NV, Belofastova IP (2008) Fauna nematode bychka-krugliaka *Apollonia* (*Neogobius*) *melanostomus* v Chernom i Azovskom moriah. Ekologiya morya 76:17–22, in Russian

Kvach Y (2002) The round goby parasites in native habitats and in a place of invasion. Oceanol Stud 31(1–2):51–57

Kvach Y (2005) A comparative analysis of helminth faunas and infection of ten species of gobiid fishes (Actinopterygii: Gobiidae) from the North-Western Black Sea. Acta Ichthyol Piscat 35(2):103–110

Kvach Y, Skóra KE (2007) 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. Parasitol Res 100:767–774

Kvach Y, Stepien CA (2008) Metazoan parasites of introduced round and tubenose gobies in the Great Lakes: support for the "Enemy release hypothesis". J Great Lakes Res 34:23–35

Mack RN, Simberloff D, Lonsdale WM, Evans H, Clout M, Bazzaz FA (2000) Biotic invasions: causes, epidemiology, global consequences, and control. Ecol Appl 10:689–710

Mühlegger JM, Jirsa F, Konecny R, Sattmann H, Frank C (2009) *Bucephalus polymorphus* Baer, 1827—a new fish parasite in Austria? Wien Klin Wochenschr 121(suppl 3):50–52

Mühlegger JM, Jirsa F, Konecny R, Frank C (2010) Parasites of *Apollonia melanostoma* (Pallas 1814) and *Neogobius kessleri* (Guenther 1861) (Osteichthyes, Gobiidae) from the Danube River in Austria. J Helminthol 84:87–92

Muzzall PM, Peebles CR, Thomas MV (1995) Parasites of the round goby, *Neogobius melanostomus*, and tubenose goby, *Proterorhinus marmoratus* (Perciformes: Gobiidae), from the St. Clair River and Lake St. Clair, Michigan. J Helminthol Soc Wash 62(2):226–228

Petrochenko VI (1956) [Acanthocephala of domestic and wild animals.], vol 1. Izdatelstvo AN SSSR, Moscow

Pronin NM, Fleischer GW, Baldanova DR, Pronina SV (1997) Parasites of the recently established round goby (*Neogobius melanostomus*) and tubenose goby (*Proterorhinus marmoratus*) (Gobiidae) from the St. Clair River and Lake St. Clair, Michigan, USA. Folia Parasitol 44:1–6

Radziejewska T, Schernewski G (2008) The Szczecin (Oder) Lagoon. In: Schiewer U (ed) Ecology of Baltic Coastal Waters Series. Ecological studies, vol 197. Springer, Berlin, pp 115–129

Rakauskas V, Bacevičius E, Pūtys Ž, Ložys L, Arbačiauskas K (2008) Expansion, feeding and parasites of the round goby, *Neogobius melanostomus* (Pallas, 1811), a recent invader in the Curonian Lagoon, Lithuania. Acta Zool Litu 18(3):180–190

Renaud F, Gabrion C, Romestand B (1984) La complexe *Bothriocephalus scorpii* (Mueller, 1776) différenciation des espèces parasites du turbot (*Psetta maxima*) et de la barbue (*Scophtalmus rhombus*). Etude des fractions protéiques et des complexes antigéniques. Ann Parasitol Hum Comp 16(5):553–558

Robert F, Renaud F, Mathieu E, Gabrion C (1988) Importance of the paratenic host in the biology of *Bothriocephalus gregarius* (Cestoda, Pseudophyllidea), a parasite of the turbot. Int J Parasitol 18(5):611–621

Rokicki J, Rolbiecki L (2002) Colonization of the round goby, *Neogobius melanostomus* (Gobiidae) by parasites in the new environment of the Gulf of Gdańsk (Southern Baltic). Wiad Parazytol 48(2):197–200

Rolbiecki L (2006) Parasites of the round goby, *Neogobius melanostomus* (Pallas, 1811), an invasive species in the Polish fauna of the Vistula Lagoon ecosystem. Oceanologia 48(4):545–561

Sapota M, Skóra KE (2005) Spread of alien (non-indigenous) species *Neogobius melanostomus* in the Gulf of Gdańsk (south Baltic). Biol Inv 7:157–164

Skóra KE, Stolarski J (1993) New fish species in the Gulf of Gdańsk *Neogobius* sp. [cf.] *Neogobius melanostomus* (Pallas 1811). Bull Sea Fish Inst 1(128):83

Smirnov AI (1986) Okuneobraznye (bychkovidye), skorpenoobraznyje, kambaloobraznyje, udiljshchikoobraznye [Perciformes (Gobioidei), Scorpaeniformes, Pleuronectiformes, Lophiiformes] [In:] Fauna Ukrajiny, Vol. 8, pp. 7–183, in Russian

Sørensen TA (1948) A new method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analysis of vegetation on Danish commons. Rgl Dan Vidensk Selsk Biol Skr 5:1–34

Torchin ME, Lafferty KD, Dobson AP, McKenzie VJ, Kuris AM (2003) Introduced species and their missing parasites. Nature 421:628–629

van Beek GCW (2006) The round goby *Neogobius melanostomus* first recorded in the Netherlands. Aquat Inv 1:42–43

van Kessel N, Dorenbosch M, Spikmans F (2009) First record of Pontian monkey goby, *Neogobius fluviatilis* (Pallas, 1814), in the Dutch Rhine. Aquat Inv 4(2):421–424

Winkler HM (2006) Die Fischfauna der südlichen Ostsee. Meeresangler-Magazin 16:17–18

Zander CD (1998) Ecology of host parasite relationships in the Baltic Sea. Naturwissenschaften 85:426–436

Zander CD (2004) Four-year monitoring of parasite communities in gobiid fishes of the south-western Baltic. II. Infracommunity. Parasitol Res 93:17–29

Zander CD, Reimer LW, Barz K (1999) Parasite communities of the Salzhaff (Northwest Mecklenburg, Baltic Sea). I. Structure and dynamics of communities of littoral fish, especially small-sized fish. Parasitol Res 85:356–372

Zander CD, Reimer LW, Barz K, Dietel G, Strohbach U (2000) Parasite communities of the Salzhaff (Northwest Mecklenburg, Baltic Sea). II. Guild communities, with special regard to snails, benthic crustaceans, and small-sized fish. Parasitol Res 86:359–372