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Dynamics of the Baltic clam *Macoma balthica* (Mollusca: Bivalvia) infection with digeneans from the Gymnophallidae family in the Gulf of Gdańsk

Izabela Zgud[1,*], Leszek Rolbiecki[2], Maciej Wołowicz[1]

[1]Department of Marine Ecosystems Functioning, Institute of Oceanography, University of Gdańsk, Al. Marszałka Piłsudskiego 46, 81-378 Gdynia, Poland
[2]Department of Invertebrate Zoology and Parasitology, University of Gdańsk, Wita Stwosza 59, 80-308 Gdańsk, Poland

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Abstract

Macoma balthica is a marine bivalve commonly occurring in the boreal zone. It is one of the most common zoobenthos species in the Baltic Sea, including the Gulf of Gdańsk, and a significant element of the food web. Observations of the infection prevalence in *M. balthica* from different parts of Gulf of Gdańsk were conducted in 2007-2008, taking into account the water depth. Metacercariae of *Gymnophalloides* (=*Lacunovermis*) *macomae* (prevalence: 89.0%) were found, as well as sporocysts with metacercariae of *Parvatrema affinis* (prevalence: 1.1%) and unidentified sporocysts with cercariae (prevalence: 1.3%). The most infected clams were found on the shallowest research station (30 m).

* Corresponding author: *izgud@ocean.ug.edu.pl*

INTRODUCTION

Macoma balthica (Linnaeus, 1758) is a common species in the boreal zone. It has been found along the coasts of the North Pole, at the western, Atlantic coasts of Europe and at the eastern coasts of North America. It basically lives all over the Baltic Sea except for the most brackish peripheral waters in the Gulf of Finland and the Gulf of Bothnia (Żmudziński 1967). It is a characteristic species of the intertidal and shallow zone. Occasionally it occurs up to the depth of 30 m (Scarlato 1981, Hummel 1985). The Baltic is the only sea where *M. balthica* was found at a depth below 80 m (Wenne and Klusek 1985).

The best substrate for *M. balthica* is coarse-grained silt or, to a lesser extent, fine sand. Silty bottom of finer fraction or clay are the least suitable. The Baltic clam avoids infertile, coarse-grained sand (Mulicki 1957). Food preferences of *M. balthica* are determined by the substrate on which it burrows. This species is a facultative filtrator − a detritivore (Wiktor 1985). At sandy bottom, it absorbs detritus and plankton suspended in the water column, on the soft ground, it feeds on the organic matter absorbed from the bottom (Olafsson 1986) through a siphon that can be up to 10 cm long (Zwarts and Wanink 1989). Baltic clams bury themselves in the sediment up to a depth of 2-8 cm (Smolarz 2005).

M. balthica is one of the most common zoobenthos species in the Gulf of Gdańsk (Janas and Szaniawska 1996) and a significant element of the food web in the entire Baltic Sea. Due to the widespread occurrence of the species, its resistance and sessile nature, it is an interesting object of research, particularly as a bioindicator (Mulicki 1957, Wenne and Wiktor 1982, Warzocha 1984, Okołotowicz 1985, Herra and Wiktor 1985, Sokołowski et al. 1999, Hummel et al. 2000).

Furthermore, genetic differences were determined (a different number of heterozygotic alleles) between *M. balthica* collected in the Vistula River estuary and along the outer shores of the Hel Peninsula, and Baltic clams occurring in the Bay of Puck (Hummel et al. 2000).

The Baltic clam is a host for at least four species from the family of Gymnophallidae: *Gymnophallus gibberosus* Loos-Frank, 1971, *Gymnophalloides* (=*Lacunovermis*) *macomae* (Lebour, 1908), *Parvatrema affinis* (Jameson et Nicoll, 1913) and *Cercaria baltica* Markowski, 1936 (Markowski 1936, Pekkarinen 1984a). It is assumed that *C. baltica* is a cercaria of *G. macomae* (Cable 1953).

Only single studies of Baltic clam parasites were conducted in the Polish zone of the Baltic Sea, including the Gulf of Gdańsk, (Markowski 1936, Wenne and Klusek 1985, Rolbiecki et al. 2007), therefore it has been necessary to update them.

The objective of this study was to assess the prevalence of *M. balthica* infection with digenenas from the Gymnophallidae family in different parts of Gulf of Gdańsk, taking into account the water depth.

MATERIALS AND METHODS

Study site

The Gulf of Gdańsk is one of the open bays. The exchange of waters with the open Baltic Sea is smooth except for the part separated by the Hel Peninsula (the Bay of Puck) and the Vistula Lagoon, which is separated from the bay by the Vistula Spit.

In hydrological terms, it is a homogeneous area and a shallow water region covered with vegetation to a small extent only. The basin of Gdańsk Bay is largely covered with sediments consisting of fine-grained sand and silt fractions.

Seasonal changes in water temperature range from −0.6 to 24.9°C. In terms of salinity, it is a brackish, mixoeuhaline water body from the β-mesohaline zone with salinity ranging from 2.65 to 8.91 PSU. Mean annual salinity of surface waters in the Bay of Gdańsk comes to 8.3 PSU. Stratification at a depth of 40-50 meters was determined based on the measurements of temperature and salinity gradients. Below this depth, the water masses are cooler and more saline (Rumohr et al. 1996, Hummel et al. 2000).

Field sampling and parasitological analysis

Specimens of *M. balthica* were collected from four research stations of different depths (figures quoted with identification) MW30 (54°37.40'N/18°37.51'E), Hel70 (54°35.3'N/18°54.4'E), SW40 (54°25.07'N/18°59.00'E), SW60 (54°26'N/18°59.50'E) (Fig. 1). The material was collected with a bottom dredge. Clams were removed from a dredge immediately after pulling it on a vessel deck. The collected material was kept in a laboratory in conditions similar to those prevailing in nature. Fifty specimens were analyzed from each sampling site. Bivalves were measured with an accuracy of 0.1 mm. All analyzed individuals ranged in size from 14.3 to 24.2 mm in length and from 11.2 to 18.9 mm in width (mean 18.7 × 14.9) mm.

Standard parasitological examination was performed on Baltic clams; only internal organs were examined in the material collected in 2007 and 2008 (all stations), and in the material from April 2008 (station SW40) – also the inner surface of shells. Parasites were killed with hot 70% ethanol. The collected digeneans were stained in iron-acetic carmine or borax carmine, dehydrated in alcohol series, cleared in benzyl alcohol and embedded in Canada balsam (Rolbiecki 2007).

In order to define the infection rate in Baltic clams, the prevalence was applied, i.e. the percentage ratio of the number of hosts infected with a given parasite species to the number of examined hosts (Margolis et al. 1982).

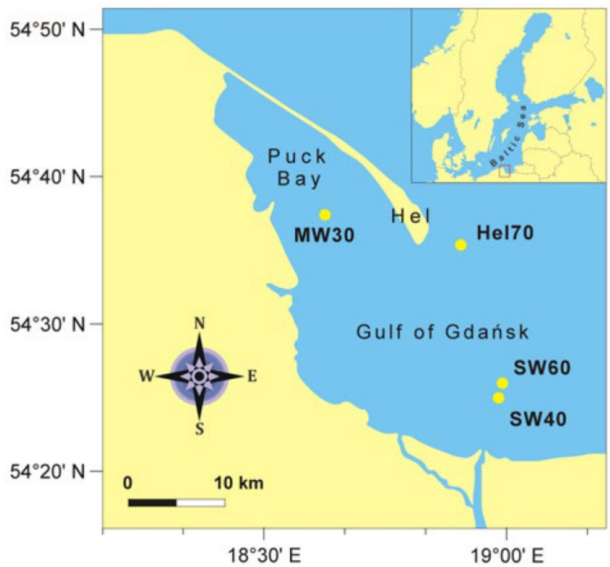

Fig. 1. Location of sampling stations.

RESULTS

Three representatives of the Gymnophallidae family were determined in the examined Baltic clams, including *G.* (=*Lacunovermis*) *macomae*, *P. affinis* and unidentified sporocysts with cercariae (Table 1).

Table 1

Infection prevalence of gymnophallid digeneans (*Parvatrema affinis* and sporocysts with cercariae n.det.) in *Macoma balthica.*

Parasite	Season	Study site	Prevalence (%)
Parvatrema affinis	August 2007	MW30	4.0
		SW40	0.0
		SW60	0.0
	November 2007	MW30	2.0
		Hel70	0.0
	April 2008	MW30	2.0
		SW40	0.0
		SW60	0.0
		Hel70	2.0
Total *P. affinis*			1.1
sporocysts with cercariae n.det.	August 2007	MW30	2.0
		SW40	0.0
		SW60	2.0
	November 2007	MW30	2.0
		Hel70	2.0
	April 2008	MW30	2.0
		SW40	0.0
		SW60	2.0
		Hel70	0.0
Total sporocysts with cercariae n.det.			1.3
Gymnophalloides macomae	April 2008	SW40	89.0

P. affinis was represented by sporocysts with metacercariae. Parasites were located in gonads, filling up their entire space. The infection prevalence in all examined Baltic clams (n=450) was 1.1%. In August 2007, two infected Baltic clams were found near station MW30 (19.3 and 19.8 mm long). In November 2007, parasites were found in one Baltic clam (20.1 mm) collected near the same station MW30. Whereas in April 2008, two infected Baltic clams were found. The first one, 18.9 mm long, came from station MW30 and the second one (17.9 mm long) − from station Hel70.

Unidentified sporocysts with cercariae (Fig. 2) were found in 1.3% of all examined Baltic clams (n=450). Sporocysts were 780-900 × 180-220 (mean 829 × 196) µm large. Parasites were located in gonads. In August 2007, two infected Baltic clams were found: one specimen (22.4 mm long) came from station MW30 and the second one (21.7 mm long) − from station SW60. In November 2007, two infected Baltic clams were found at stations MW30 and Hel70 − one specimen at each station (20.4 and 19.3 mm long, respectively). Also in April 2008, two infected Baltic clams were found. The first one, 23.6 mm long, came from station MW30 and the other one, 21.6 mm long − from station SW60.

The presence of metacercariae *G.* (=*Lacunovermis*) *macomae* was observed in 89.0% of the Baltic clams collected in April 2008 from station SW40. Parasites were located on both valves of shells, usually beneath the apex of shells. Sometimes metacercariae occurred near aductor. The length of the infected bivalves was 10.2 – 19.1 mm.

Fig. 2. Cercariae in gonad of *Macoma balthica* individual.

DISCUSSION AND CONCLUSIONS

The family of Gymnophallidae is a small group of digeneans whose adult stage occurs in intestine, gallbladders or the bursa of Fabricius in sea birds from the order Charadriiformes, including gulls and birds from the order of Anseriformes. Sometimes Gymnophallidae is found in intestine of mammals. Bivalves, less frequently polychaetes, gastropods and brachiopods are the intermediate hosts of these digeneans (Scholz 2002, Chai et al. 2007).

Three taxa of digeneans were found in the Baltic clams examined in the presented study; they were represented by *G. macomae*, *P. affinis* and unidentified sporocysts with cercariae. The first two species were already recorded in the Baltic Sea, including the Gulf of Gdańsk (e.g. Markowski 1936, Wenne and Klusek 1985, Pekkarinen 1984a, 1984b, 1987a, 1987b, Rolbiecki et al. 2007), whereas it is difficult to determine the previous occurrence of the unidentified sporocysts with cercariae. In Poland, adult stages of *P. affinis* were recorded in the common eider *Somateria mollissima* (Linnaeus, 1758), the common scoter *Melanita nigra* (Linnaeus, 1758), the velvet scoter *Melanita fusca* (Linnaeus, 1758) near the housing development Górki Wschodnie and the town of Hel (the Baltic Coast), and in the long-tailed duck *Clangula hyemalis* from the Gulf of Gdańsk (Sulgostowska and Grytner-Zięcina 1974, Grytner-Zięcina and Sulgostowska 1978).

In the present study, sporocysts with metacercariae of *P. affinis* were found in gonads. Wenne and Klusek (1985) also used to find them only in gonads, while Swennen and Ching (1974) and Pekarinnen (1987a) additionally observed them in pancreas-liver, and occasionally attached to mantle epithelium, in kidney, or gills. Whereas similarly to Pekkarinen (1984b), metacercariae of *G. macomae* were currently found only on the inner surface of shell valves. While Loos-Frank (1971) observed them only in the space between the shell and the bivalve mantle.

The infection prevalence in the currently examined *M. balthica* with digeneans from the family of Gymnophallidae is basically comparable with the literature data.

The prevalence of infection with *P. affinis* currently observed in Baltic clams corresponds to the results obtained from the Polish zone of the southern Baltic. Although the prevalence of infection with *P. affinis* in *M. balthica* collected in the vicinity of the Hel Peninsula was 0.7% (Markowski 1936), in the Gulf of Gdańsk – it was as much as 1.4-3.7% (Wenne and Klusek 1985) and 4.2% (Rolbiecki et al. (2007). Observations of *P. affinis* digeneans present in Baltic clams from the northern part of the Baltic Sea (the Gulf of Bothnia) and the Dutch Wadden Sea were conducted by Pekkarinen (1987a). The percentage of infected bivalves from the Gulf of Bothnia was below 1. None of the 1402 examined bivalves from a depth of 7-8 m was infected. Whereas two specimens were infected per 1003 bivalves collected from a depth of 20-40 m (0.2%). The percentage of *P. affinis* infected specimens from the coast of Germany, near the island of Hiddensee, was 7.0% (Reimer 1962). In the North Sea waters, the prevalence of infection in the Baltic clams from subtidal or lower parts of the tidal flats (1-15 m) was very low (<1%), but in the higher parts of the tidal flats, it ranged from 1.5 to 20.0% (Swennen and Ching 1974). *M. balthica* from the intertidal zone of the North Sea (1-1.5 m) was infected at the rate of 3.5% (Pekkarinen 1987a).

Digeneans *G. macomae* were found only in April, although with very high infection rate (89.0%). This is reflected also in the research by other authors. For example, Pekkarinen (1984b) observed from 20 to 100% infected Baltic clams in the southwestern Baltic Sea. The prevalence of *G. macomae* infection in the Baltic clams collected near the Hel Peninsula was 34.3% (Markowski 1936). Whereas along the German coast, *G. macomae* was observed in 46% of bivalves (Reimer 1962).

There are several factors that affect the prevalence of *M. balthica* infection with digeneans. The most important factors include the presence, species richness and abundance of definitive hosts (birds), inside which digeneans reach their sexual maturity (Pekkarinen 1984a). Depth is another important factor. In most of the studies conducted so far, Baltic clams came from the waters of higher salinity (Hulscher 1973, Swennen and Ching 1974, Edelaar et al. 2003), where they occur at shallower depths compared to bivalves examined in this study. Swennen and Ching (1974) observed that together with the decreasing depth at which Baltic clams occur, the rate of their infection with *P. affinis* digeneans increases. And thus, less than 1.0% of clams were infected at a depth of 15-20 m, and more than 20.0% in the intertidal zone. Additionally, Hulscher (1973) proved that bivalves in the intertidal zone emerge during low tide and move over the sand. It seems that the presence of parasites in bivalves triggers reactions that make it easier for predators (definitive hosts) to catch them. Researches on this subject were conducted by Edelaar et al. (2003) who tried to explain the fact that infected specimens of *M. balthica* bury themselves not so deep as the healthy ones. They assumed that if dwelling of infected bivalves in shallower sediment resulted from parasite influence, they should occur in large numbers throughout the year or at least during a season with abundant occurrence of birds. The authors conducted observations of a single population for seven years, comparing the depths at which healthy and infected bivalves were buried. The results obtained were, however, different than expected. Although Baltic clams infected with digeneans had reduced ability to bury themselves in sand, they were the least available clams for predators in the season with the highest number of definitive hosts. Also the hypothesis was rejected about possible competition between one of the parasites − *P. affinis* and the Baltic clam for the reduced (due to the presence of the parasite) resources of energy, which could cause shallower burying of hosts in the sand.

In the currently examined Baltic clams, differences were observed in the incidence of digeneans (*P. affinis* and unidentified sporocysts with cercariae) in the Baltic clams from different stations (Table 1). This could be caused by different health states of hosts. As evidenced by the results of the presented study, it is possible that conditions prevailing on the sandy bottom (less suitable for the Baltic clam) may negatively affect the health of clams (Pierścieniak et al. 2010), which in turn may contribute to their infection (Pekkarinen 1984a). A larger number of infected Baltic clams come from station MW30. It seems that the type of sediment in which a Baltic clam lives affects its infection. Coarse-grained sand occurs at site MW30, and sites SW40, SW60 and Hel70 are situated on the edge of bottom area covered with fine-grained sand.

In conclusion, Baltic clams from the Gulf of Gdańsk have qualitatively and quantitatively similar (in the shallow zone) species composition of parasitofauna compared to bivalves from other waters. *G. macomae* is the dominant species.

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