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GENERAL BIOLOGY

Parasitizing of Trematodes Provokes Warts on the Hinge Plate of the Bivalve Mollusk *Macoma balthica* Linnaeus, 1758 (Veneroida, Tellinidae)

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Abstract—The hypothesis on non-random correlation between abnormalities in the structure of hinge plate and infection of mollusks *Macoma balthica* with trematodes of the family Gymnophallidae has been tested on the basis of material from the Barents Sea. Significant correlation between the presence of warts and infection was established upon intra- and interpopulation comparison. The hypothesis states that parasitizing of trematodes in the extrapallial cavity of mollusks influences the mantle functioning and provokes abnormalities in the hinge plate structure.

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The structure of the hinge plate of bivalve mollusks is the most important systematic character used in construction of the Class system and species identification [2, 13]. Intraspecific variability in the structure of hinge plate can be caused by both genetic variability and the influence of environmental factors [4, 5]. The latter include infection with parasites; as can be assumed, they may cause abnormalities in the structure of various organ systems. Marine bivalves are intermediate hosts of trematodes of the family Gymnophallidae, whose definitive hosts are usually birds [9, 12].

The goal of this study was to estimate correlation between infection of *Macoma balthica* L., 1758 with trematodes and abnormalities in the structure of the hinge plate of the shell of this mollusk.

Adult mollusks were collected at six stations located in Kola Bay and Pechenga Bay of the Barents Sea (Fig. 1) in summer periods of 2004–2005. Material was processed in 2014. The range of samplings is presented in the table. All mollusks were examined for abnormalities in the hinge plate structure, presence/absence of metacercariae in the extrapallial cavity, and sporocysts in the gonadal tissue. Mollusks with metacercariae and/or sporocysts were assigned to the "infected" category. A set of poorly distinguishable trematode species of the family Gymnophallidae, *Par-*

Studies of populations of *Macoma balthica*, ranges of samplings, frequencies of infected mollusks, mollusks with different types of abnormalities in the structure of hinge plate and infected mollusks with warts

No. of the station	Name of the station	Sample size	Rate of infected mollusks	Rate of mollusks with deformed hinge plate	Rate of mollusks with hinge plate with warts	Observed and expected (in brackets) frequency of infected mollusks with warts
1	Severnoe Nagornoe	62	0.56	0.13	0.26	10 (9.0)
2	Zelenyi Mys	71	0.08	0.06	0.17	2 (1.0)
3	Belokamenka	52	0.23	0.13	0.19	4 (2.3)
4	Retinskoe	62	0.18	0.02	0.15	5 (1.6)*
5	Bol'shaya Volokovaya	78	0.21	0.12	0.19	9 (3.2)*
6	Pechenga	50	0.30	0.10	0.20	5 (3.0)

* $p < 0.05$.

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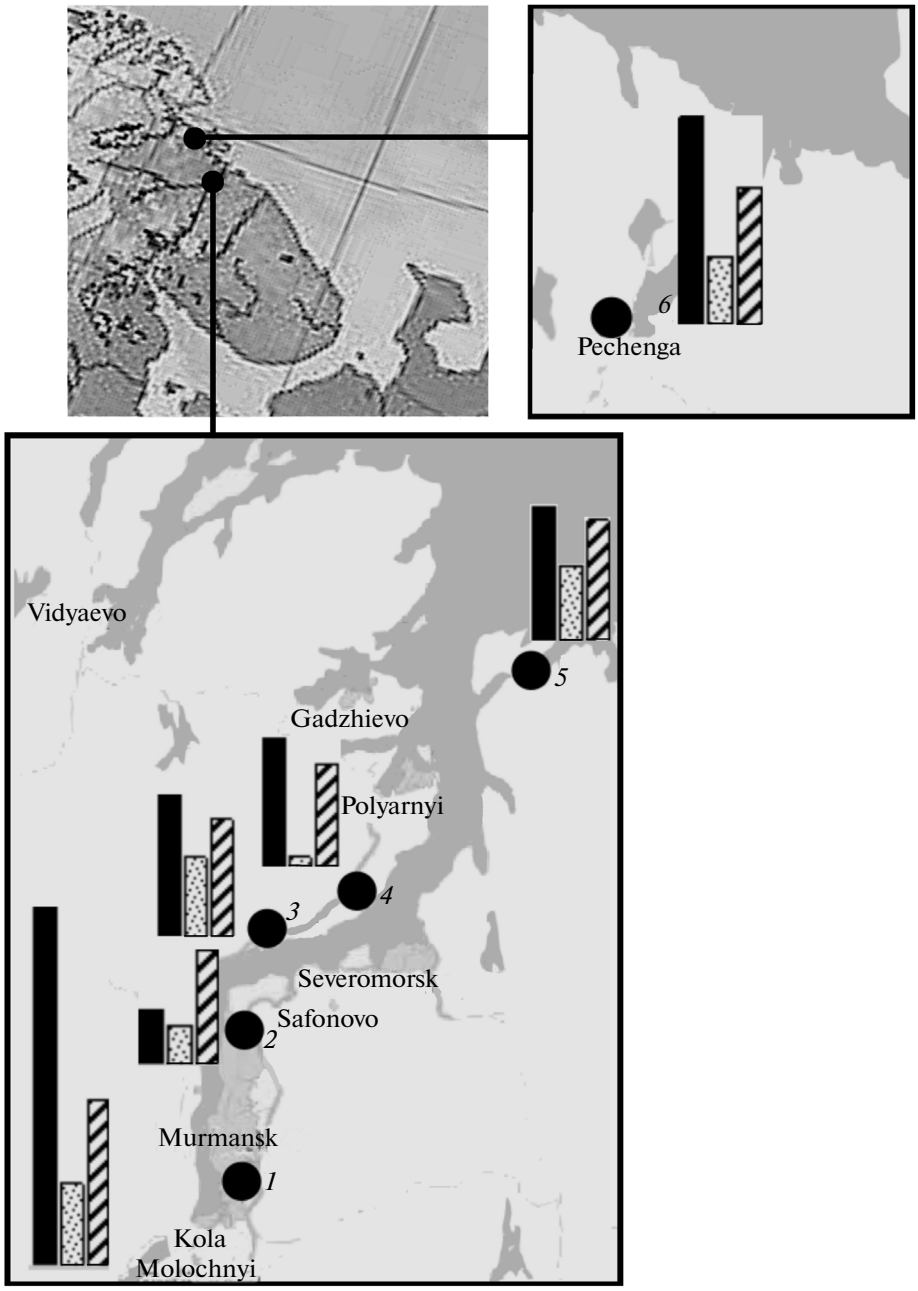

Fig. 1. Rate of infected mollusks and mollusks with abnormities in the hinge plate at different stations. The figures indicate the number of stations. The histograms show the rate of infected mollusks in percentage (solid filling), mollusks with deformed hinge plate (dots), and mollusks with hinge plate having warts (oblique line shading).

votrema affinis, Lacunovermis macomae, and *Gymnophallus gibberosus*, parasitize in *Macoma* [11]. The species of the parasites were not identified. For estimating the relationship between characters in interpopulation comparisons, the non-parametric Spearman's (ρ) rank-order correlation coefficient was used; for detecting nonrandom association of characters within populations, Fisher's exact test was used. Statistical processing was performed using the PAST software [5].

According to earlier studies [1], abnormalities in the structure of the hinge plate of *M. balthica* were divided into two groups. A deformed hinge plate in the form of the arcuation of one or several teeth, nonbifurcation of teeth, or partial or complete reduction of teeth (reduction of some or all teeth) was assigned to the first group. Hinge plates with warts, which represent conchiolin formations behind or in front of teeth of the hinge plate or immediately behind the hinge plate, were assigned to the second group (Fig. 2). A

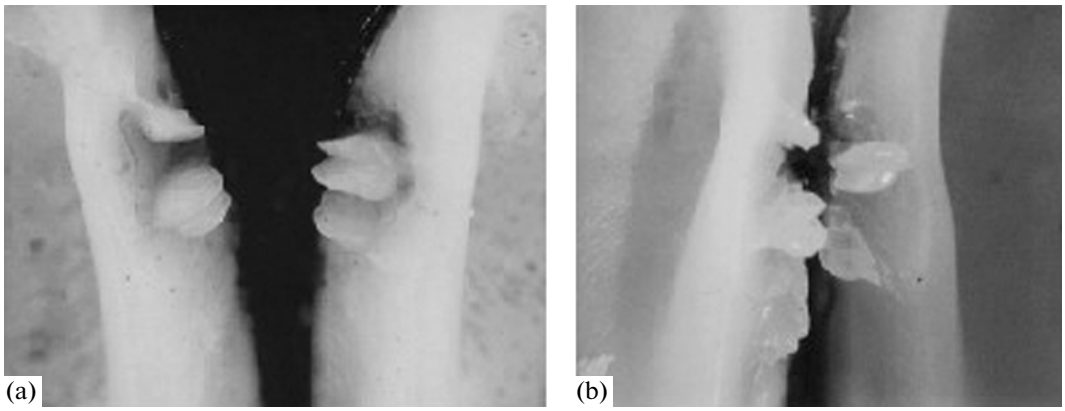

Fig. 2. (a) A normal hinge plate of *Macoma balthica* and (b) a hinge plate with warts.

few individuals (frequency, 1–5%) that had both a deformed hinge plate and warts were found in samplings. These individuals did not influence the results of the statistical analysis.

The frequency of infected mollusks varied from 8% at station 2 to 56% at station 1. The frequency of mollusks with warts was 17–26% at stations 2 and 4 and 26% at station 1 (Fig. 1). The frequency of mollusks with a deformed hinge plate fluctuated from 2% at station 4 to 13% at stations 3 and 1 (Fig. 1).

Statistical analysis has revealed close positive correlation between infection of mollusks with trematodes and the frequency of hinge plates with warts at the interpopulation level ($\rho = 0.93$, $p = 0.008$). The correlation between infection of mollusks and frequency of deformed hinge plate is statistically nonsignificant ($\rho = 0.73$, $p = 0.103$), as well as the correlation between the frequencies of the two types of abnormalities, deformed hinge plates and hinge plates with warts ($\rho = 0.75$, $p = 0.086$). At the intrapopulation level, in all cases, there was an increased frequency of infected mollusks with warts on the hinge plate compared to the frequency expected in the case of random combination of these characters; at two stations, this correlation was statistically significant (table). There is evidence that trematodes of the family Gymnophallidae cause different damages of bivalve shells, including those in representatives of the genus *Macoma* [6, 8, 10]. It has been shown that *M. balthica* has a high variability of the structure of the hinge plate [1].

Earlier [1], we proposed that abnormalities in the structure of the hinge plate of *Macoma r*esult from teratogenesis caused by chemical pollution of the environment. The results of the present study demonstrate that abnormalities of the hinge plate in the form of warts are connected with the infection with trematodes of the family Gymnophallidae. Considering that metacercariae of trematodes parasitize in the extrapallial cavity, it is assumable that they influence mantle functioning and can provoke abnormalities in the structure of the hinge plate. It is known that bivalve mollusks react to foreign objects in the conchiolin layer (e.g., formation of pearls). Probably, the same mechanism underlies wart formation.

Infection of *M. balthica* and abnormalities in the structure of the hinge plate that are presumably connected with it varies at different points of the coast located at distance from several meters to tens of kilometers from one another (Fig. 1). Probably, this is connected with the characteristics of the distribution of the definitive hosts of parasites, marine birds. It is believed that *M. balthica* infected with gymnophallids are characterized by abnormal behavior. Specifically, infected mollusks, normally actively moving in the thickness and along the surface of the soil, most of the time spend at the surface, which increases the probability of their being eaten by birds [3]. Warts at the hinge plate should destroy its normal functioning and prevent the shell impermeability. Thus, it can influence the migratory activity of mollusks. The hypothesis on correlation between the structure of the hinge plate, behavior of mollusks, and transmission of parasites in the parasite system is quite promising.

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