Long-Term Variation of Polychaete Bioerosion of the Scallop *Mizuhopecten yessoensis* from the Northwest Part of the Sea of Japan

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**Abstract**—The bioerosion of shells of the Japanese scallop *Mizuhopecten yessoensis* by endolithic organisms over the last few decades and millennia in areas close to the main sources of organic pollution in Peter the Great Bay was studied. It was established that the occurrence of Japanese scallop shells damaged by borers increased over 2500 years practically from 0 up to 96% in the northern part of the bay at Mys Peschany Cape, which is subject to the impact of the Pazdol’nya River drain. The bioerosion of the Japanese scallop shells has increased considerably over the last two decades in the coastal zone, near the center of the city of Vladivostok, at one of the main sources of the city’s wastewater discharge. Thus, in 4-year old individuals $33.0 \pm 2.9\%$ of upper valves were eroded on average in 1982; in 1998 it was already $68.3 \pm 6.4\%$. In Reinike strait, that is, at some distance from the mouth of Razdol’naya River and from the main discharge sources of polluted waters of Vladivostok, the shells of the Japanese scallop were eroded to a lesser extent than in the population from the coastal region near the city. However, a significant increase in the degree of bioerosion of the scallop shells was observed over one-and-a-half decades: in 1987 in 4-year scallops $2.3 \pm 0.3\%$ of the area of the upper valve was eroded on average, and in 1999 that parameter increased and became $32.6 \pm 3.4\%$. In the western part of Peter the Great Bay near Furugelm Island, which is located 20 km away from the mouth of the Tumannaya River, the degree of bioerosion of scallop shells had also increased significantly over the last 30 years. The increase in the degree of bioerosion of the shell is connected to a gradual increase in the content of organic substances in the bottom sediments. This is a factor favorable for the development of bacteria and phytoplankton, which is a food source for polychaetes—the basic shell boring symbionts of the Japanese scallop.

**Key words:** bottom sediments, Peter the Great Bay, organic pollution, estuary, scallop, *Mizuhopecten yessoensis*, bioerosion, polychaetes, Sea of Japan.

The bottom deposits of coastal areas of seas of temperate latitudes are enriched everywhere by organic substances [11, 14]. The basic suppliers of organic substances in the near-shore zone are rivers and terrigenic drains, the saturation of which by organic and polluting substances in the 20th and 21st centuries has increased considerably, thanks to the increases in agriculture and in the population along riverine basins. The enrichment of bottom deposits with organic substances also increased because cities and settlements began to drain industrial and residential waster and then gradually increased the drainage, which was especially detrimental because of the insufficient recycling of the waters discharged into the sea. The organic substances are in a highly suspended state when they enter the seawater and are unable to decompose completely in the water. Thus, they gradually accumulate in the bottom sediments.

An intense development of heterotrophic bacteria is one of the consequences of the increase in the concentration of organic substances in the sediments. This, in turn, changes the trophic chains of the benthic community (increased potential for the prosperity of deposit feeders), the conditions of its existence (decrease of oxygen, change of water pH, etc.). Moreover, the enrichment of the water and sediments with phosphorus and nitrogen stimulates the development of phytoplankton, which sometimes results in eutrophication of the water areas [20]. Thus, near shore, especially close to the mouths of large rivers and cities, changes in the environmental quality take place continuously and presently also accelerate, which entails change in the environmental condition of the coastal biota.

Two large rivers, Tumannaya River and Razdol’nya River, run into Peter the Great Bay. The coasts of these rivers are densely populated, and plenty of organic particles and polluting substances are carried out with the water [3, 4, 10, 16, 19, 21]. The city of Vladivostok is located in the northern part of the bay,
from which unrecycled industrial and residential drains deliver dissolved and suspended organic substances to the coastal waters, which gradually accumulate in bottom sediments. It was formerly established that in some coastal areas of Peter the Great Bay the degree of damage to shells of the Japanese scallop *Mizuhopecten yessensis* (Jay, 1856) by endolithic organisms has gradually increased [1, 2, 6]. The purpose of our research was to analyze changes in the degree of the bioerosion of shells of the Japanese scallop by endolithic organisms in Peter the Great Bay in sites that are close to the basic sources of organic pollution for the last decades and for the same area for thousands of years.

**MATERIAL AND METHODS**

The Japanese scallop was sampled in various years with the use of SCUBA gear in the coastal zone of the northern and western parts of Peter the Great Bay (Fig. 1) from three areas near the mouths of large rivers. The first area was located at the Mys Peschany Cape, not far from the mouth of the Razdol’naya River. The scallop was sampled there in 1995. The bottom deposit was mostly silt there, and the depth was 10–15 m. Two other areas were near Furugelm Island, approximately 20 km to the north from the mouth of the Tumannaya River. In Zapadnaya Bay of that island the scallop was sampled in 1974–1976 and 1998–2001, in Severnaya Bay of the same island it was sampled in 1976–1979 and 1998–2001. The bottom sediment of Zapadnaya Bay was silted sand (depth 12–15 m) and that of Severnaya Bay was mostly sand (depth 10–12 m). For some years (1982–1999) we studied the scallops that inhabited the mouth area of the Pervaya Rechka River (not large in its annual flow), where the industrial and residential waste waters of Vladivostok were the main source of organic pollution and the impact of the Razdol’naya River run-off was appreciable [20]. The ground of that area was heavily silted sand with a pebble admixture, the depth was 6–8 m. In 1987 and 1999 we studied scallops from Reineke Strait, which is located in the open part of Peter the Great Bay, between Popov and Reineke Islands, where the depth was 9–15 m. Each sample comprised 50–150 individuals of the mollusk to study.

In all samples the ratio of scallops with the upper valve damaged by borers was determined. The degree of damage to the upper valve (the lower valve was usually free from endolithics or damaged only slightly) was assessed in each individual. For that purpose the area of the upper valve of the scallop occupied by endolithic organisms and having a dark brown or black color was measured on its inner side in transmitted light using a transparent plate with a 1 × 1 mm grid. The degree of bioerosion of the valve was estimated as the ratio of that area relative to its total area.

The shell area of the Japanese scallop increased with age, i.e., the biotope for settling juvenile endolithics and for the growth of young and adult borers increased. Therefore, a comparison of the degree of bioerosion of shells for different scallop samples was carried out for the average sample values from the population and individually for each age cohort. The age of each individual was determined by the microsculpture of the outer surface of the upper valve with the technique suggested formerly [6, 18].

The $t$-test with $P < 0.05$ confidence was used for determination of the significance of differences in the average degrees of bioerosion between various years of observation (separately in scallops of each age group).

**RESULTS AND DISCUSSION**

The site first studied was the closest to the mouth of the Razdol’naya River, in the central part of Peter the Great Bay along Peschany Peninsula (Fig. 1). Formerly, Kurochkin and Tsymbalyuk [1] had established, by studying shell heaps of the Japanese scallop near the peninsula dated to the seventh to fifth centuries BCE, that only individual shells were damaged by polychaete borers, and only slightly at that. As follows from our observations, in 1995 already 96% of the scallops sampled there had shells damaged by endolithics. For the past 2500–2700 years the degree of shell damage has also increased considerably. In 1995, 16.6% of the area of the upper valve was bioeroded on average in 3-year-old individuals and 38.9% was bioeroded in 6-year-old individuals. This is a high value for the Japanese scal-