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The Soft-Shell Clam (*Mya arenaria* Linnaeus 1758 (Myidae)) in Shallow Waters of Zelenetskaya and Yarnyshnaya Inlets of the Barents Sea: Allometric Growth

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Abstract—Information concerning the allometric growth of the bivalve mollusk (*Mya arenaria*) populations in the intertidal zones of Zelenetskaya and Yarnyshnaya inlets, Barents Sea, is presented. The population density in Zelenetskaya Inlet averages 40 ind./m^2 and the biomass is 280 g/m^2 versus 62.6 ind./m^2 and 142 g/m^2 in Yarnyshnaya Inlet, respectively. A detailed analysis of the granulometric composition of bottom sediments of the intertidal zone and the content of organic matter are determined for the first time. The study areas are found to differ in the composition of bottom sediments. The organic matter in Zelenetskaya Inlet averages 0.8% versus 2.2% in Yarnyshnaya Inlet. Shell formation is determined by adaptations to living conditions, also reflecting the different size and age structure of *M. arenaria* populations. Among the mollusks of older age groups, the shell grows allometrically, following the principle of weak negative allometry versus isometrically among young individuals.

Keywords: bivalve, ecology, benthos, intertidal zone
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INTRODUCTION

Mya arenaria (L. 1758) are large bivalve mollusks that burrow into the ground. Mollusks are widespread in the Northern Hemisphere (Conde et al., 2010). They are found both on the Atlantic and Pacific coasts of North America and in the seas of the Arctic region (Barents Sea, White Sea) and the Eastern Atlantic (Baltic, Black, and Mediterranean seas) (Maximovich, 1979; Carlton, 1992; Strasser, 1999; Wheaton, 2008). *M. arenaria* live in the littoral and lead a sedentary lifestyle, able to withstand changes in environmental factors in a wide range. The favorable temperature for their life activity ranges from 2 to 28°C (Baker and Mann, 1990). Absolutely acceptable for this species is salinity change from 1 to 30‰ (Khlebovich and Stankyavichyus, 1979). In addition, this mollusk has a significant resistance to high levels of hydrogen sulfide and oxygen deficiency (Thamdrup, 1935; Baker and Mann, 1990). However, despite the high tolerance of *M. arenaria* to changes in salinity, temperature, and the chemical composition of the environment, the distribution of the mollusk in the littoral is closely related to the composition of the soil (Sveshnikov, 1963). Mollusks play an important role in coastal waters as filter feeders, binding suspended organic matter in the water column, contributing to the accumulation of sediments on the bottom, and thus using primary production and improving water quality (Pedersen, 1992; Riisgard and Seerup, 2003; Forster and Zettler, 2004).

The study of the features of the biology and ecology of *M. arenaria* in many works has been devoted to these activities (Maksimovich, 1978; Schaffer and Zettler, 2007; Cardoso et al., 2009; Gerasimova et al., 2016). In Russia, studies of this species have been carried out mainly in the White and Baltic seas and there are also some works on the study of these clams from the Sea of Azov–Black Sea basin (Beshevli and Kolyagin, 1967; Savchuk, 1970; Zolotnitsky and Sytnik, 2020). Many works are related to the evolutionary history and taxonomy of mollusls of the genus *Mya* (MacNeil, 1965; Bernard, 1979; Petersen, 1999; Bouchet and Gofas, 2013; ITIS, 2017). In the Far Eastern seas, complex taxonomic work is underway to study the ecology, morphology, and distribution features of *M. japonica*, which is closely related to the species *M. arenaria* (Zhang et al., 2018). Information about the biology and distribution of *M. arenaria* mollusks in the Barents Sea is very fragmented. Since the beginning of the last century, this species has been repeatedly recorded in the composition of the littoral fauna of the Barents Sea (Deryugin, 1915; Guryanova et al., 1929; Lyubina et al., 2009; Frolov, 2009); however, quantitative presentations about the present-day state of *M. arenaria* in the Barents Sea and about the

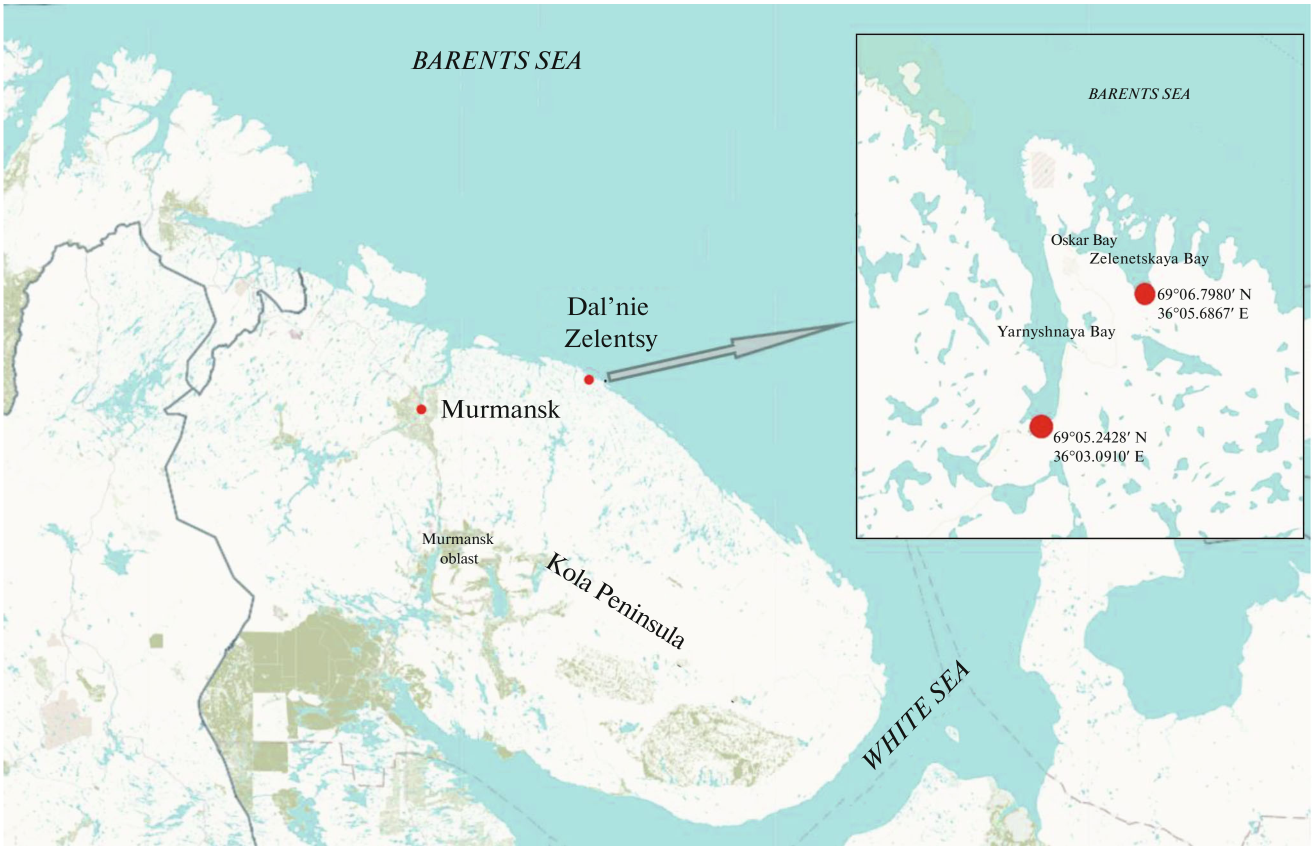

Fig. 1. Map-scheme of the study area.

features of growth and the production potential of this species have not been established. Nonetheless, the study of the biology of long-lived eurybiont species is of great scientific interest both for understanding the adaptive characteristics of organisms in ontogeny and for assessing the impact of various environmental factors on these organisms (salinity and temperature fluctuations, severe storms, pollutant emissions). In the literature, there are studies indicating the importance of shell growth analysis methods for the reconstruction of ecological events for the purpose of monitoring the environment (Kennish and Olsson, 1975). In addition, growth models show how tidal, diurnal, and seasonal cycles affect the course of basic physiological processes in the body (nutrition, respiration, metabolic rate, and reproductive cycle).

The purpose of our study is to study settlements of *M. arenaria* bivalves in shallow areas of Zelenetskaya Bay and Yarnyshnaya Bay of the Barents Sea, calculation and analysis of morphometric characteristics of the growth of various parts of the body of the mullosk, and detailed description of the granulometric composition of bottom sediments in the place of the greatest accumulation of mollusks in the littoral zone.

MATERIALS AND METHODS

Research was conducted in the littoral of Yarnyshnaya Bay and Zelenetskaya Bay (Dal'nii Beach) of the Barents Sea in July 2021 (Fig. 1).

A quantitative census of *M. arenaria* was conducted in the littoral at low tide with a frame of 0.1 m^2. Samples were taken from a depth of 30 cm and washed through a sieve with a mesh size of 0.5 mm. The harvested mollusks were placed in buckets of seawater and transported to a laboratory for biological analysis. Ten samples were taken in each region. The salinity and water temperature were measured simultaneously with sampling using a portable refractometer and thermometer.

To determine the granulometric composition of the soil, two sections were made in the tidal zone of the studied areas (Figs. 2a, 2b). Each section includes three sampling stations oriented in the direction from the coast to the edge of the water at low tide. The soil was sampled using cores with an inner diameter of 7 cm. The thickness of the exposed sedimentary strata at each point was 20 cm. Three horizons were identified in each core: 0–5, 5–10, and 10–20 cm. Using probes developed by the All-Russia Scientific Research Institute Okeangeologiya (Andreeva and Lapina, 1998), the types of bottom sediments were distinguished according to the interpretation of Klenova (1948). We also determined the proportion of sediment mass loss on ignition (LOI) as an indirect indicator of the organic content in bottom sediments. A total of 18 samples of bottom sediments was collected, processed, and analyzed.

In the biological analysis, each mollusk was measured by the length (L, mm), height (H, mm), and convexity of the shell (D, mm) (Fig. 3). These parameters were used to calculate the coefficients of elongation (H/L) and convexity (D/L, D/H) of the mussel shell during mollusk growth. At the same time, we determined the total (live) weight of the mollusk (W, g), shell weight (W_r, g), soft tissues (W_m, g), and siphon (W_s, g). Weighing was carried out on an electronic balance with an accuracy of 0.01 g after drying the components on filter paper. The age was determined from the external shell morphology by counting the growth rings that are formed during the winter stunting and which are thickened growth lines (Scarlato, 1990; Haskin, 1954). A total of 103 specimens of *M. arenaria* were collected and processed during the study period (40 in Zelenetskaya Bay and 63 in Yarnyshnaya Bay).

Communication of changes between different parts of the body of the mission studied on the basis of ontogenetic changes in mollusk shells is described by the equation of simple allometry (Alimov, 1981):

$$Y = aX^b,$$

where X and Y are the studied parameters of mollusks; a and b are coefficients. The analysis of the sample was carried out from a population that included individuals of different sizes and ages.

The data was analyzed using regression analysis.

The nature of the distribution of the quantitative and dimensional indicators was evaluated by the Kolmogorov–Smirnov criterion. The significance of differences between the means was determined using the Wilcoxon–Mann–Whitney index. Differences were considered insignificant at $p \geq 0.05$. Mathematical calculations were carried out using the STATISTICA 10.0 software package and MS Excel-2010 spreadsheets.

RESULTS

Living conditions of *Mya arenaria*. Examination of the coastal part of Zelenetskaya Bay showed that mollusks live mainly in the eastern part of the bay on the silty–sandy littoral (Dal'nii Beach), in Oskar Bay they occur singly, without forming a dense settlement. The littoral of Dal'nii Beach is gentle, and in the apex part it has a length of more than 200 m. The salinity at the water's edge at low tide and in the littoral puddles in July 2021 was 32–34‰. The water temperature rose to 15°C, and the surface layer of the soil (5 cm) warmed up to 21°C.

The settlement of mollusks of Dal'nii Beach is concentrated in the middle and lower horizons of the littoral, near the stream. According to our studies, the bottom sediments of the Zelenetskaya Bay in the lower part of the littoral (station no. 3) are represented by sand, which at a depth of 10 cm is replaced by sandy silt with an admixture of inequigranular sand and gravel (Fig. 4a). In the central part of the littoral (station no. 2), bottom sediments are also represented by sand, which at a depth of 10 cm is replaced by a finer material, silty sand. In the upper part of the littoral (station no. 1), sand is distributed throughout the exposed stratum. The content of organic matter increases from 0.4% in the upper part of the littoral to 0.8–2.8% towards the water's edge.

The population density of mollusks on Dal'nii Beach varies from 1 to 64 ind./m^2. The average density of the settlement is 40.0 ± 0.13 ind./m^2, and the biomass is 279.7 ± 0.86 g/m^2. The highest density (more than 60 ind./m^2) of the settlement is reached in areas of the lower part of the littoral, represented by inequigranular sand, with an admixture of coarse silt (12%), pelite (up to 14%), and a maximum content of organic matter (up to 2.8%). In the upper part of the littoral, where the bottom sediments are composed exclusively of sandy fractions (93%) and the content of organic matter does not exceed 0.4%, the population density is minimal and does not exceed 3–7 ind./m^2.

In Yarnyshnaya Bay *M. arenaria* is found in the southern apex. The littoral has a length of up to 400 m at the apex, gently sloping. The salinity in the northern part is 33‰, and to the south it decreases to 19‰. The water temperature in littoral puddles and on the ground surface (5 cm) reached 20°C in summer; near the water's edge at low tide it was 17°C.

In the lower part of the littoral zone (station no. 3), the sediments are represented by uneven-grained sand with an admixture of gravel of more than 25% (Fig. 4b). With an increase in the depth of occurrence, the proportion of gravel increases, at a depth of 5–10 cm it increases up to 40% and after 10 cm, up to 70%. The central part (station no. 2) of the littoral is characterized by the spread of silty sand, which is replaced by silt with increasing depth. At the same time, an admixture of gravel material (7–9%) is noted throughout the entire exposed sedimentary sequence. In the upper part of the littoral (station no. 1), the upper layer of sediments is composed of inequigranular sand and gravel; at a depth of 5–10 cm, a facies of poorly sorted sediments is noted, composed equally of gravel, inequigranular sand, and aleurite–pelite material. At a depth of 10–20 cm, the sediments are silt with an admixture of inequigranular sand and gravel. The content of organic matter in the littoral also varied. In the lower part of the littoral zone (near the stream), the share of organic matter ranges from 0.3 to 1%, with the maximum value of this indicator recorded in the layer of 5–10 cm. The highest content

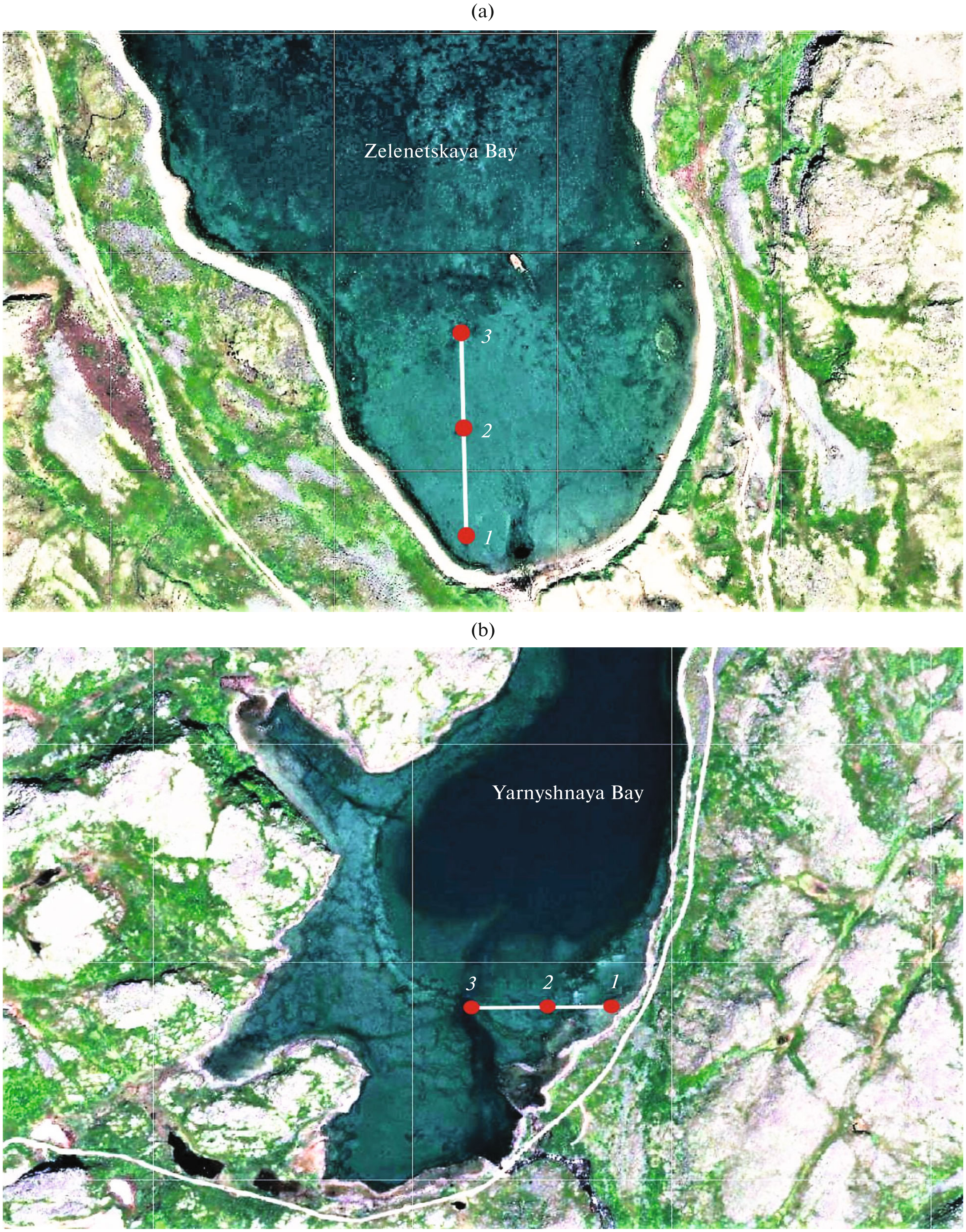

Fig. 2. Transect layouts for quantification of *M. arenaria* and sampling stations for granulometric analysis of bottom sediments: (a) Zelenetskaya Bay (Dal'nii Beach), (b) Yarnyshnaya Bay; *1–3,* numbers of soil sampling stations.

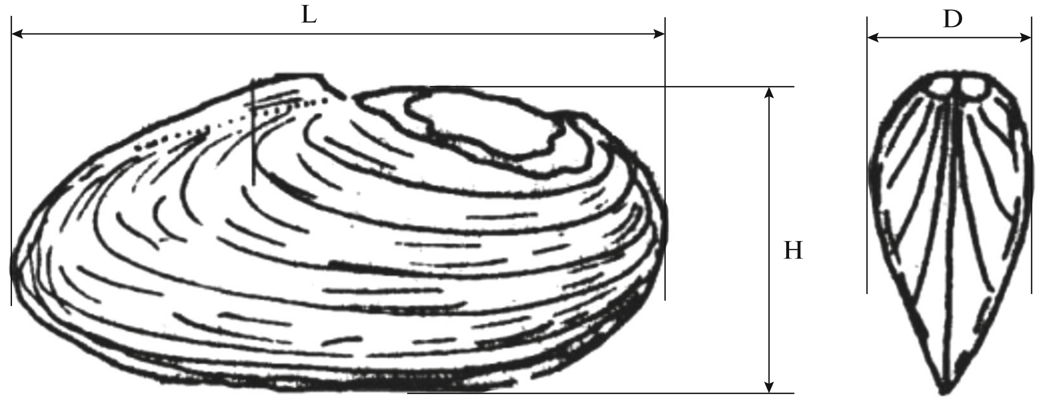

Fig. 3. Scheme for measuring (mm) shells of bivalve mollusks (Naumov, 2006): L, length; H, height; and D, convexity.

of organic matter in bottom sediments (4.5%) is recorded in the central part of the littoral zone. At the same time, the content of organic matter on the surface is 1% and increases to 6.3% with depth. In the upper part of the littoral, the amount of organic matter increases from 0.5% on the surface to 2.9% in the 10- to 20-cm layer.

The settlement of *M. arenaria* is located in the southern part of the bay, where bottom sediments are represented by uneven-grained or silty sand with an admixture of gravel material. Clams predominantly occupy the middle littoral horizon. The population density varies from 5 to 74 ind./m^2. The average density of the mollusk colony is 62.6 ± 0.29 ind./m^2 at a biomass of 141.9 ± 0.60 g/m^2. The greatest density (75 ind./m^2) of the settlement is reached in silty sand in areas replaced by silt with an admixture of gravel material (7–9%) with depth. The lowest density (3 ind./m^2) was noted in areas where bottom sediments are composed of uneven-grained sand with an admixture of gravel of more than 25%.

For the areas studied, a strong inverse correlation was noted between the content of fine silty and pelitic fractions in the soil and the density of mollusk settlements ($r = -0.9995$). In addition, by a negative correlation dependence ($r = -0.9979$), the density of the settlement is related to the content of organic matter in the surface layer of the soil.

Biology of *Mya arenaria*. Size and age composition of settlements. The sizes of mollusks in the studied areas varied from 16.9 to 63.7 mm in Zelenetskaya Bay and from 10.2 to 66.9 mm in Yarnyshnaya Bay. In Zelenetskaya Bay, mollusks are most common, the size of which ranges from 50.0 to 59.9 mm (30%) and 40.0–49.9 (27.5%). The largest specimen found from the area indicated was 63.1 mm, and its age was 9 years (Fig. 5b). The size distribution of these clams in the littoral zone of Yarnyshnaya Bay is represented by medium-sized mollusks with a shell length of 10.0–19.9 mm (39.7%) and 20.0–29.9 mm (44.4%) (Fig. 5a). The proportion of individuals larger than 60 mm was insignificant (4.6%). The length of the largest mollusk was 66.9 mm. The greatest body weight was 24.62 g, and the age was 13 years. Table 1 shows the morphometric measurements of mollusks living in Zelenetskaya and Yarnyshnaya bays.

The age composition of the clam settlements in 2021 in the bays varied significantly. In the littoral zone of Zelenetskaya Bay (Fig. 6b), the age range of mollusks was quite uniform and was represented by mollusks from two to 12 years old, the highest frequency of occurrence was observed in age group 9+ (15.8%). Mollusks 4–7 and ten years old each accounted for 10.5% in the sample. A single mollusk of 12 years of age was found.

In Yarnyshnaya Bay (Fig. 6a) the age of these clams ranged from one to 13 years. Mollusks of younger age groups 2–4 years old dominated here (79.4%) with a shell length from 10.2 to 29.6 mm. The proportion of individuals five and ten years old was 9.5 and 4.8%, respectively. Individuals of six, eight, or 13 years of age (1.6%) were singled out in the sample. The significant proportion of juveniles indicates that the years 2017–2019 were favorable for the replenishment of the settlement.

Allometric growth. The study of the relative changes in the length (L) and height (H) of the clam shells showed that the relationship between the parameters for the mollusks of Zelenetskaya Bay has the form $H = 0.715 \pm 0.004L^{0.9499 \pm 0.031}$, $n = 40$, $R^2 = 0.991$ (Fig. 7a), and in Yarnyshnaya Bay $H = 0.595 \pm 0.002L^{1.0007 \pm 0.026}$, $n = 63$, $R^2 = 0.993$ (Fig. 7b). The average height-to-length ratio (H/L index) in Zelenetskaya Bay and Yarnyshnaya Bay is 0.597; the height averages 59.7% of the length of the mollusk, with a standard deviation SD = 0.026 and a variation of the minimum and maximum values within 0.53–0.64.

The equation for the dependence of the convexity of the shell (D) on the length of the shell (L) for *M. arenaria* in Zelenetskaya Bay has the form D =

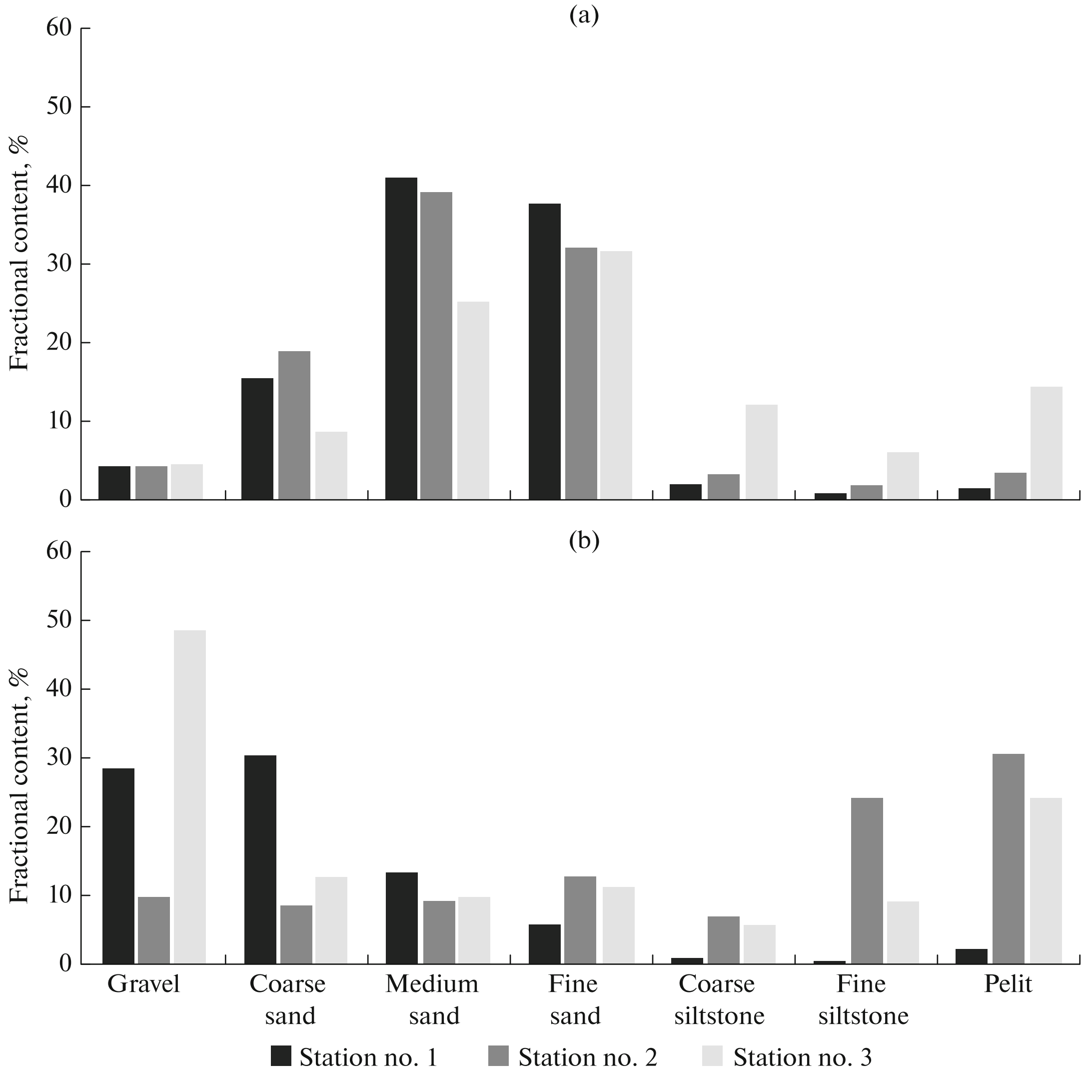

Fig. 4. Granulometric composition of the bottom sediments of (a) Zelenetskaya Bay and (b) Yarnyshnaya Bay.

$0.343 \pm 0.004L^{1.0208 \pm 0.037}$, $n = 40$, $R^2 = 0.972$ (Fig. 7a), and in Yarnyshnaya Bay $D = 0.245 \pm 0.003L^{11202 \pm 0.024}$, $n = 63$, $R^2 = 0.988$ (Fig. 7b).

The thickness-to-length ratio (D/L) was 0.371 (37.1%) at SD = 0.023 in Zelenetskaya Bay, and it had a slightly lower value of 0.359 (35.9%) in Yarnyshnaya Bay.

Calculations carried out for mollusks from Yarnyshnaya Bay showed that the relationship between the length and height of the shell characterized by isometry (regression coefficient *b* slightly greater than or equal to 1), and changes in the thickness (bulge) of the shell relative to its length have a pronounced positive allometry (*b* is more than 1.1).

The ratio of the size–weight characteristics of mollusks is described by allometric equations:

$$W = 1.0 \pm 0.34 \times 10^{-4} L^{2.9 \pm 0.07},$$

$$R^2 = 0.96 \text{ for Yarnyshnaya Bay;}$$

$$W = 0.6 \pm 0.41 \times 10^{-4} L^{3.1 \pm 0.2},$$

$$R^2 = 0.99 \text{ for Zelenetskaya Bay.}$$

In Yarnyshnaya Bay, the increase in the body weight of mollusks occurs more slowly than the growth of the shell in length and the dependence of the parameters is characterized by negative allometry ($b < 3$). In Zelenetskaya Bay, $b = 3.1$; i.e., growth proceeds with the preservation of geometric similarity, without changing the shape of the shell (isometric growth).

The study of the allometric relationships between the weight parameters of mollusks and the analysis of the relative growth of the soft tissue mass (W_m), siphon mass (W_s), and shell mass (W_r) from the total mass of the whole mollusk (W) is of particular interest for solv-

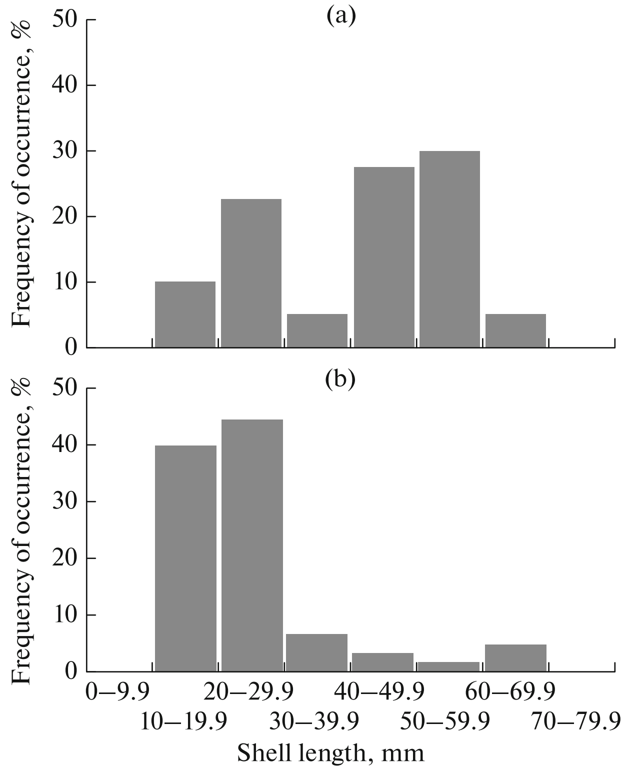

Fig. 5. Size distribution of mollusks in (a) Zelenetskaya Bay and (b) Yarnyshnaya Bay of the Barents Sea.

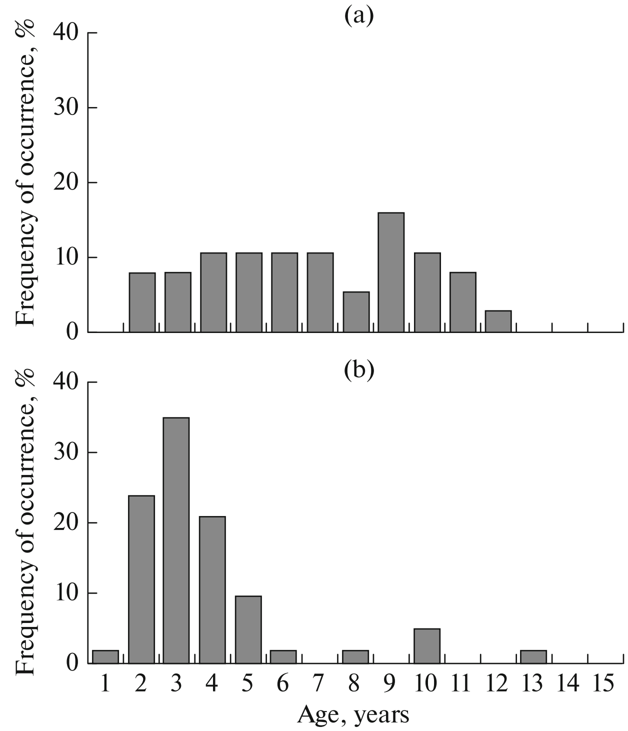

Fig. 6. Age structure of mollusk settlements in (a) Zelenetskaya Bay and (b) Yarnyshnaya Bay.

ing a number of practical problems and evaluating the possibility of using *M. arenaria* in mariculture. Statistical analysis showed that the relationship between the parameters is described by a linear function with determination of the coefficients $R^2 = 0.95–0.99$. The proportion of the average shell weight (W_r/W) of this mullosk in Zelenetskaya Bay was 45%, with fluctuations from 37 to 59% (Table 2). The average mass of soft tissues is 55% relative to the total mass (Table 2) with variability from 41 to 63%. The weight of the siphon is 19% of the total body weight. The ratio W_r/W in Yarnyshnaya Bay is 47%. The mass of soft tissues is 53%, and the mass of the siphon is 8% of the total mass of mollusks. The values of the correlation coefficients are presented in Table 2. The values vary weakly and are in the range of 0.95–0.99. The lowest r values are for ratio W_s/W, %.

DISCUSSION

According to the results of our study, shallow areas of the Yarnyshnaya and Zelenetskaya bays of the Barents Sea are typical, typical for settlements *M. arenaria* biotopes. These are the apex areas of various bays with

Table 1. Morphometric indicators of *M. arenaria* mollusks living in Zelenetskaya and Yarnyshnaya bays

Index	Research areas			
	Yarnyshnaya Bay		Zelenetskaya Bay	
	average	standard error	average	standard error
Shell length, mm	25.2	1.5	41.2	2.3
Shell height, mm	15.0	0.9	24.4	1.3
Convexity of the shell, mm	9.2	0.6	15.3	0.9
Total weight, g	2.3	0.6	7.0	0.9
Shell weight, g	1.6	0.4	3.2	0.4
Weight of soft tissues, g	1.4	0.3	3.8	0.4
Siphon weight, g	1.5	0.1	1.7	0.2

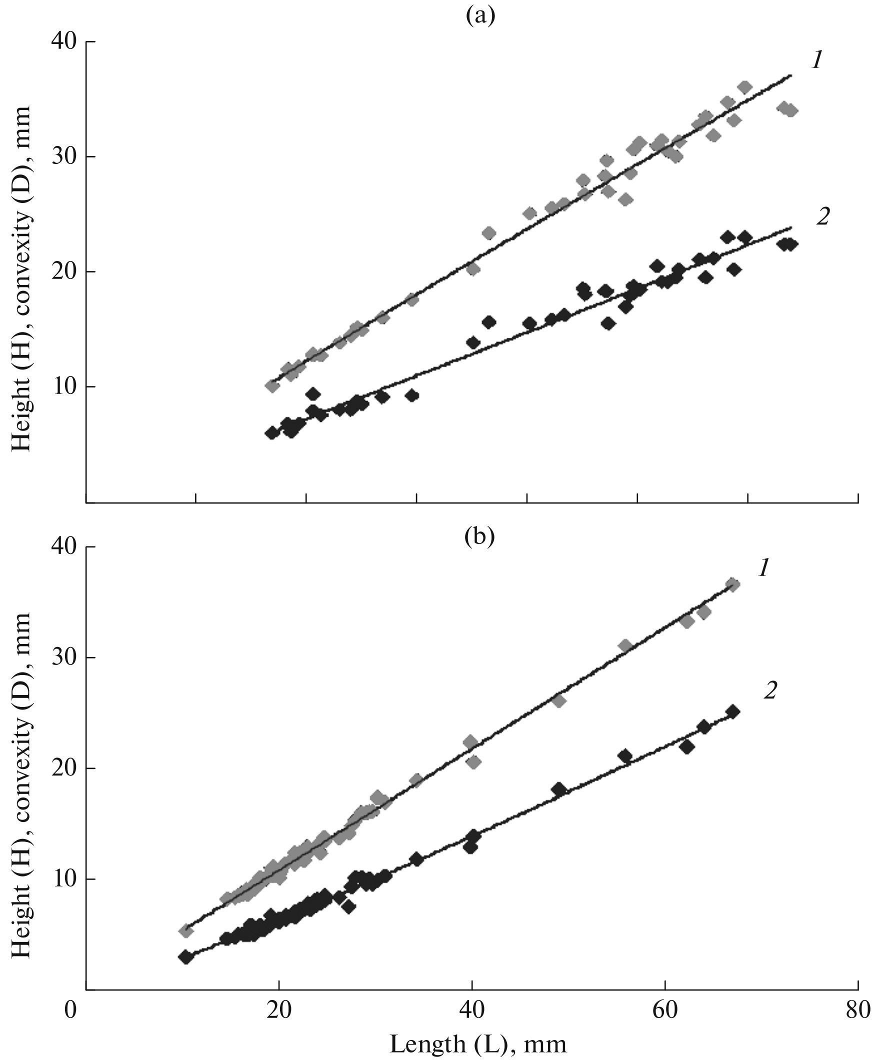

Fig. 7. Height dependence (H, *1*) and thickness (D, *2*) from the length (L) of the shell of *M. arenaria* in (a) Zelenetskaya and (b) Yarnyshnaya bays.

a silty-sandy littoral, where mollusks form rather dense settlements.

The granulometric composition of the soil in the littoral of Yarnyshnaya Bay is diverse and varies from uneven-grained sand with an admixture of gravel in the lower and upper parts of the littoral to silty sand in the central part. The bottom sediments of Zelenetskaya Bay in the lower part of the littoral are represented by sand, which at a depth of 10 cm is replaced by sandy silt with an admixture of inequigranular sand and gravel. The average content of organic matter is 0.8% in Zelenetskaya Bay and 2.2% in Yarnyshnaya Bay.

The average density of mollusk colonies in Zelenetskaya Bay is 40.0 ± 0.13 ind./m^2, and the biomass is 279.7 ± 0.86 g/m^2. The highest population density (75 ind./m^2) of mollusks forms in areas represented by silty sand with an insignificant (up to 9%) admixture of gravel material, and the smallest (3 ind./m^2) is in areas composed of uneven-grained sand with an admixture of gravel of more than 25%. In Yarnyshnaya Bay, the average population density is 62.6 ± 0.29 ind./m^2 at a biomass of 141.9 ± 0.60 g/m^2. The largest (60 ind./m^2) is in areas of uneven-grained sand with an admixture (up to 14%) of silty and pelitic fractions, while the smallest is in places where bottom sediments consist of more than 90% sandy fractions.

The close relationship between the soil composition and the quantitative indicators of settlements of *M. arenaria* was shown in the works of V.A. Sveshnikov on the White Sea in 1963, where it is noted that the presence of coarse clastic material in the soil adversely affects the life of mollusks, makes it difficult to burrow, and leads to squeezing of mollusk shells. According to the results of a detailed analysis of bottom sediments in the shallow areas of Yarnyshnaya and Zelenetskaya bays, it was revealed that the pres-

Table 2. Regression analysis data and correlation coefficient calculated for shellfish weight parameters

Index, %	M ± SD	min–max	*a*	*b*	r
Zelenetskaya Bay					
W_r/W	45.3 ± 0.05	37.1–58.7	0.05 ± 0.007	0.45 ± 0.123	0.988
W_m/W	54.7 ± 0.05	41.3–62.9	–0.05 ± 0.007	0.55 ± 0.324	0.981
W_s/W	18.7 ± 0.07	3.6–37.9	–0.05 ± 0.008	0.21 ± 0.076	0.955
Yarnyshnaya Bay					
W_r/W	47.2 ± 0.05	32.5–58.4	–0.57 ± 0.005	0.11 ± 0.009	0.997
W_m/W	52.9 ± 0.05	41.6–67.5	0.09 ± 0.005	0.45 ± 0.360	0.998
W_s/W	7.7 ± 0.05	4.1–23.2	–0.05 ± 0.006	0.14 ± 0.113	0.975

M, average values of the studied relations; SD, standard deviation; W, g, total (live) weight of the mollusk; W_r, g, is the mass of the shell; W_m, g, is the wet weight of soft tissues; W_s, g, is the mass of the siphon; *a* and *b,* regression equation parameters $y = a + bx$; r is the correlation coefficient.

ence of gravel material within 7–9% is acceptable for life and successful instillation of *M. arenaria*. Ground represented by silty or uneven-grained sand with a content of silty and pelitic fractions of at least 20% is quite suitable for building nonfloating burrows.

The quantitative characteristics of *M. arenaria* in the areas studied are quite high and comparable with the indicators of the abundance of mollusks in other geographical areas and are sometimes much higher than these indicators. Similar abundance indicators are observed in the White Sea in the littoral Northern Bay (46.7 ind./m^2) of Kandalaksha Bay (Shcherbakova, 2006) and Kolezhemskaya Bay (66.7 ind./m^2) of Onega Bay (Smolkova, 2021). In Kerch Strait of the Black Sea, the density of settlements of the shellfish *M. arenaria* is 23 ind./m^2 (Ivanov and Sinegub, 2008), and in the littoral zone of Dolgaya Bay of Kandalaksha Bay, it is 25.4 ind./m^2 (Shcherbakova, 2006), which is almost two times lower than the abundance of this species in the littoral of the areas of Eastern Murman studied.

The nature of allometric growth and of mollusks from various settlements differs. The calculated values of the parameters of the allometric growth equation showed that in Zelenetskaya Bay shell shaping of *M. arenaria* occurs according to the principle of weak negative allometry ($b \leq 1$) close to isometry. Negative allometry indicates that the increase in height and thickness (bulge) of the shell relative to its length from mollusks collected in Zelenetskaya Bay occurs more slowly, so the shell has a flattened shape. The data obtained are consistent with the results of studies conducted for *M. arenaria* mollusks in the northwestern part of the Black Sea (Savchuk, 1976), the southern part of the Sea of Azov (Zolotnitsky and Sytnik, 2020), and Khlebnaya Bay of Kola Bay (Smolkova and Meshcheryakov, 2022).

Settlements of *M. arenaria* in Yarnyshnaya Bay are characterized by higher growth rates (coefficients *a* and *b*) compared to the indicators for Zelenetskaya Bay. Most likely this is due to the size and age characteristics of the settlements. In Zelenetskaya Bay, the majority of the population in the colony is made up of adult clams, the relative growth of which proceeds according to the principle of negative allometry, and individuals have a flattened shell. In Yarnyshnaya Bay the settlement consists mainly of mollusks of younger age groups (2–4 years), and the relative change in size is characterized by pronounced positive allometry. The shell growth vector of thickness (bulge) prevails. Juvenile mollusks inhabiting the surface layer of the soil are more susceptible to the impact of a dynamic environment (tidal currents, wave surges) than adults, which occupy deeper soil horizons. The convex shell makes it easier for young mollusks to stay in the surface layers of silty–sandy bottom sediments.

Analysis of the ratio of the size-weight characteristics showed that the coefficients *a*, reflecting the strength of the interaction of the studied parameters relative to each other, have significant differences in the areas studied. Weight gain in mollusks in Yarnyshnaya Bay occurs faster than in mollusks from Zelenetskaya Bay (Table 2). The greater increase in biomass in mollusks from Yarnyshnaya Bay in 2021 is most likely associated with the trophic factor and the content of organic matter in the soil.

For *M. arenaria*, which are faunal sedentary animals and spend their entire lives in the ground, an important factor determining the increase in biomass is trophic. Mollusks inhabit the apex of various bays with streams flowing into the littoral, which carry out a sufficient amount of organic matter, which in turn ensures the successful flow of important physiological processes in mollusks (nutrition, respiration, and reproduction). The content of organic matter in bot-

Table 3. Parameters of the equations for the dependence of the total mass on the length of the shell of *M. arenaria* mollusks in Zelenetskaya and Yarnyshnaya bays and other study areas

Study area	*a*	*b*	Link
Barents Sea (Zelenetskaya Bay)	0.6×10^{-4}	3.10	Smolkova, 2021
Barents Sea (Yarnyshnaya Bay)	1.0×10^{-4}	2.90	Smolkova, 2021
Barents Sea (Khlebnaya Bay)	3.5×10^{-4}	2.08	Smolkova, 2022
White Sea (Chupa Bay)	2.0×10^{-4}	2.86	Maksymovich, 1978
Baltic Sea (mouth of the Varnov River)	1.8×10^{-4}	2.75	Schaffer and Zettler, 2007
Sea of Azov (Bulganak Bay)	1.6×10^{-4}	2.90	Zolotnitsky and Sytnik, 2020

tom sediments in the places of the greatest accumulation of mollusks in the littoral of Yarnyshnaya Bay varies from 1.6 to 4.5%; in Zelenetskaya Bay, this figure does not exceed 1.4%.

The relationship between length and body weight can vary significantly depending on various environmental factors (Feder and Paul, 1974; Miac et al., 1997). Slightly different coefficients *a* and *b* (Table 3) were obtained in studies of the allometric growth of these clams in the White (Maksimovich, 1978) and Baltic seas (Schaffer and Zettler, 2007) and the Sea of Azov (Zolotnitsky and Sytnik, 2020), which is explained by different environmental conditions in different geographical areas.

Among other things, *M. arenaria* have high plasticity and are able to withstand critical values of various environmental factors (salinity, temperature, oxygen and hydrogen sulfide content), which makes it possible for mollusks to adapt and form settlements with a high density in areas unfavorable for other competing species that are less resistant to environmental changes.

CONCLUSIONS

The studies presented made it possible to obtain information on the current state of bivalve mollusk settlements of *M. arenaria* on the littoral of Zelenetskaya and Yarnyshnaya bays of the Barents Sea and to characterize some features of the relative growth of various parts of the body. For the first time, a detailed granulometric analysis of bottom sediments in the studied areas and the content of organic matter were determined.

The formation of the shell reflects the different size and age structure of the settlements of *M. arenaria*. In mollusks of older age groups, relative growth occurs according to the principle of weak negative allometry; in young individuals, the shell grows isometrically. The increase in the total mass of mollusks in Yarnyshnaya Bay is higher than in Zelenetskaya Bay. The main indicators that determine the most favorable living conditions are the content of organic matter in the soil in the range from 1.6 to 4.5%, the composition of bottom sediments, characterized by the predominance of silty sand with an admixture of gravel material of no more than 7–9%, and the high resistance of mollusks to changes in the environmental conditions.

The data obtained on the biology of the bivalve mollusk *M. arenaria* in the shallow areas of Yarnyshnaya and Zelenetskaya bays of the Barents Sea will further serve as a basis for monitoring possible changes caused by anthropogenic impacts or climatic fluctuations. In addition, with the help of these data, it is possible to solve practical problems related to the use *M. arenaria* in mariculture.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This article does not contain any studies involving animals or human participants performed by any of the authors.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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