Distribution, Population Structure and Growth of *Protothaca euglypta* (Sowerby, 1914) (Bivalvia: Veneridae) from the Northwestern Part of the East Sea of Russia

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ABSTRACT

Distribution, population structure, and growth of the bivalve *Protothaca euglypta* were investigated for clams collected from the northwestern part of the East Sea of Russia. This species is distributed in further northern area than it was found earlier. In the southern area, this clam is found in the intertidal zone, up to 8 m in depth. It is one of the most numerous infaunal species of bivalves, and protected to wave action in the gravel-pebble and sand with rubble biotope. Population density of *P. euglypta* reaches 500 spc./m^2, and biomass 2 kg/m^2. Size and age composition of the local settlements and allometric growth of *P. euglypta* depend on a biotope. The growth rate of *P. euglypta* considerably reduces in case of the northern boundary area, whereas life span increases.

Key words: Bivalve, *Protothaca euglypta*, distribution, growth, population structure.

INTRODUCTION

Bivalve *Protothaca euglypta* (Sowerby, 1914) is an important species of the coastal bottom communities of the northwestern part of the East Sea of Russia (Scarlato *et al.*, 1967; Scarlato, 1981; Adrianov and Kussakin, 1998). In epifauna representatives of family mytilidae usually dominate by abundance and biomass, whereas in infauna bivalves, family veneridae dominate a substantial portion. Visual observations indicate that one of representatives of this family veneridae is *P. euglypta* dwelling near Korea Peninsula, Japanese Island, in Primorye, near the southern part of Sakhalin Island, and near the Southern Kuril Islands (Scarlato, 1981; Okutani, 2000; Kwon *et al.*, 2001; Min, 2004) is a usual component of the bottom communities. Valves of this species, that is perforated by predatory gastropod, have been frequently found in shell accumulation in the carry-over and underwater areas. It suggests that the role of *P. euglypta* in the function of shallow water communities is more important than that in the published data. However, information on biology and ecology of this species is very insufficiency. Therefore, the purpose of the present study is to investigate habitats, size and age structure and growth of *P. euglypta* in a number of areas of the northwestern part of the East Sea.

MATERIALS AND METHODS

1. Sampling

The specimens were collected in 2007 at three stations in Vostok Bay, where hydrological conditions and sea fauna and flora diversity represent a typical situation in Peter the Great Bay (Fig. 1). Station 1 was located at 1.0-1.5 m depth and represented a gravel-pebble bottom site with water worn rubbles exposed to a periodical wave action. Station 2 was located at shallow water (0.8-1.0 m) cracks and channels in a rocky reef filled with small rock and dead shell debris. Station 3 was located at 2-8 m depth on sand with pebbles and rubbers. Samplings of *P. euglypta* were

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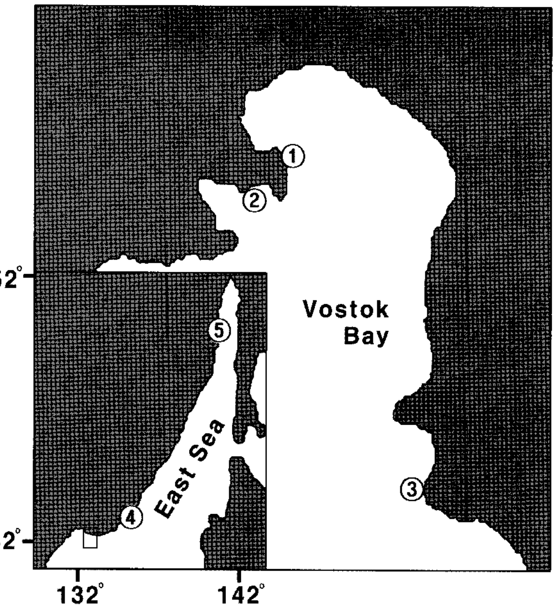

Fig. 1. A map of sampling sites. 1-3, stations in Vostok Bay; 4, Melkovodnaya Bight; 5, Surkum Cape.

taken at every stations, using a 0.25 m^2 sampling frame (30 samplings at every stations), which was randomly located on the bottom. Quantitative data were calculated per m^2, the mean population density was calculated (N, spc./m^2), as well as biomass (B, gm/m^2) and a standard deviation (SD).

For comparative analysis of *P. euglypta* growth we used bivalves collected earlier northwards from Peter the Great Bay in Melkovodnaya Bight at 1 m depth (station 4; 30 living individuals) and from the coastal carry-over at Surkum Cape (station 5; 30 shells).

2. Investigation of population structure and growth of *P. euglypta*

Shell length (SL) of all clams (Station 1: 226 specimens, Station 2: 473 specimens, Station 3: 557 specimens) was measured using a sliding calipers with the accuracy up to 0.1 mm, and for some individuals height (SH) and width (SW) of a shell were also measured. Based on SL bar charts of size structure of populations were constructed. Total weight (TW) was measured using WLKT-500 scales with 0.1 g accuracy. The obtained data were used for calculation of equations of a simple allometry (Y=aXb), reflecting changes in *P. euglypta* body proportions (Huxely, 1932).

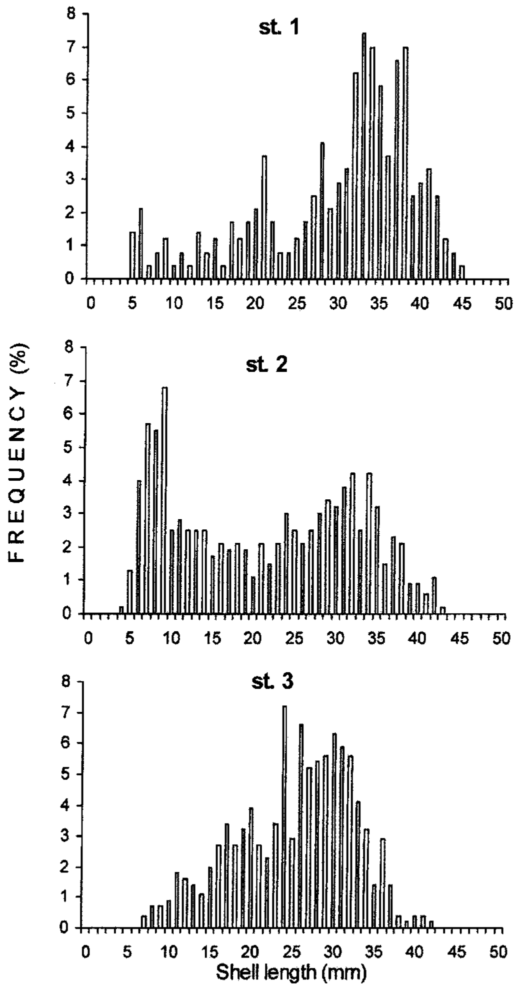

Fig. 2. Size structures of *Protothaca euglypta* populations in the coastal waters of Vostok Bay at stations 1, 2 and 3.

Age determination of this species was estimated by growth rings on the outer shell surface in accordance with the method used by Kim *et al.* (2003) on *Protothaca jedoensis*. Based on the results of individual age determination, I made bar charts of the age structure of bivalves at different stations. Growth rings were also used for retrospective estimation of *P. euglypta* growth. Shell lengths of 30 big individuals were measured at the age of 1-15 years. The mean size of shell length was used for reconstruction of curves of the group linear growth and for approximation of this process by Bertalanffy's growth equation (Mina and Klevesal, 1976).

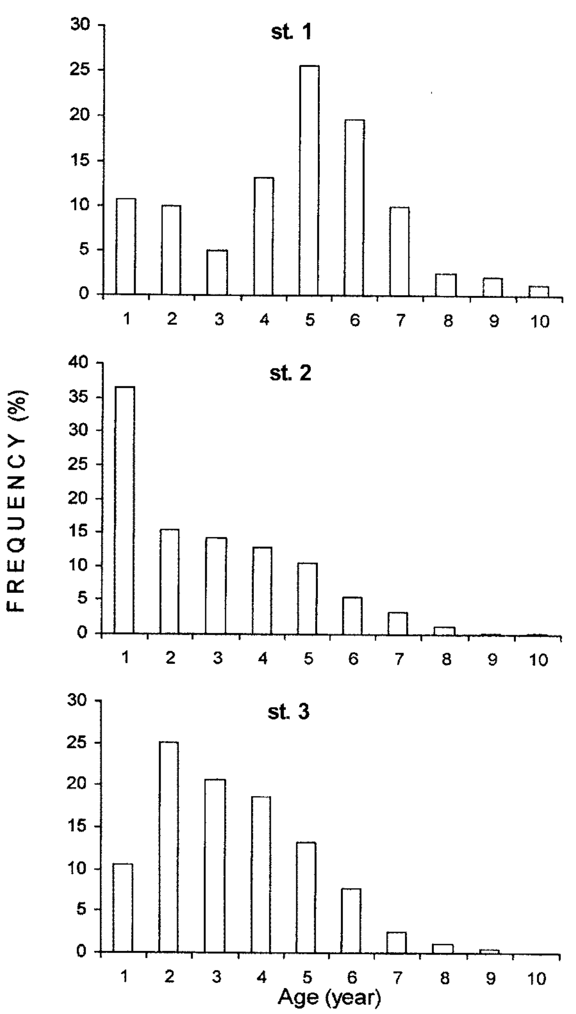

Fig. 3. Age structures of *Protothaca euglypta* populations in the coastal waters of Vostok Bay at stations 1, 2 and 3.

3. Statistical treatment

Size and age distribution, their pair comparison, correlation and regression analysis, analysis of variance, and other calculations were carried out using PC and standard techniques of the variational statistics (Urbakh, 1964). Distinction of analogous dependences was considered significant, if compared regression lines differed by a slope or intercepted at the level not less than 95%.

RESULTS

1. Abundance

Population density and biomass of *P. euglypta* differ several times at different stations. They are the highest at station 2 (N±SD=462.7±60.8 spc./m^2; B±SD=1774.0±206.2 gm/m^2), and the lowest - at station 1 (N±SD=33.0±10.3 spc./m^2; B±SD=330.9±127.8 gm/m^2). At station 3 these values make 106.4±44.6 spc./m^2 and 568.1±338.86 gm/m^2, respectively.

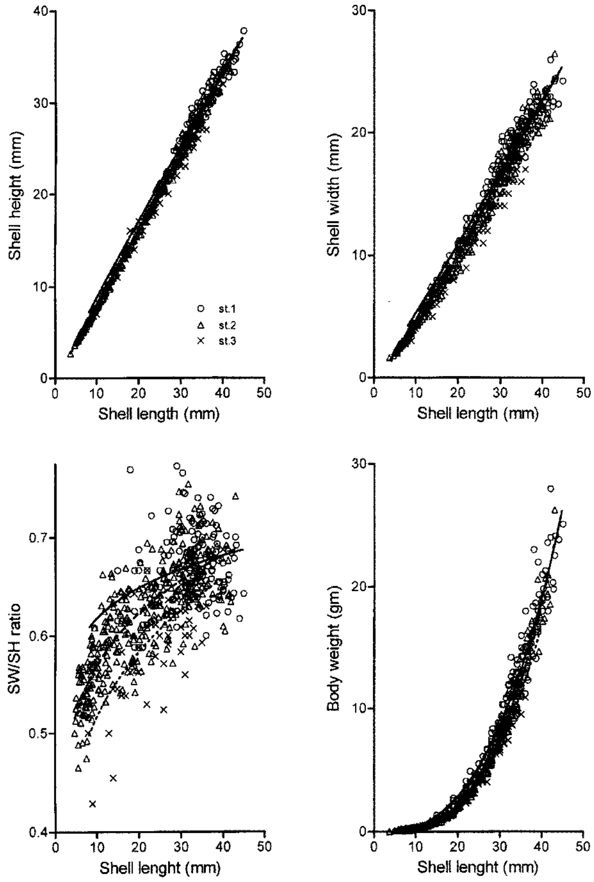

Fig. 4. Ontogenetic changes in shell characteristics and body weight of *Protothaca euglypta* from Vostok Bay at stations 1 (solid lines), 2 (interrupted lines), and 3 (dotted lines).

2. Size and age structure

Populations were clams of almost equal size range (Fig. 2). Individuals with shell length of 32-38 mm dominated at station 1 (about 44% of a sample). At station 2 size distribution of clams is clearly bimodal. The first abundance peak falls with shell length of 6-9 mm, and the second one is 29-35 mm. At station 3 individuals ranging from shell length of 24-32 mm predominated (45%). Pair comparison suggests about

Table 1. Parameters of equations describing the dependence between linear characteristics of a shell and body weight of *Protothaca euglypta* from different populations in Vostok Bay

Stations	Coefficient a	Coefficient b	SE*a*	SE*b*	R^2	n	T
$SH = aSL^b$							
1	0.7680	1.023	0.0385	0.0142	98.1	142	2** and 3*
2	0.6912	1.051	0.0109	0.0047	99.6	328	1** and 3*
3	0.7373	1.020	0.0447	0.0181	98.5	74	1* and 2*
$SW = aSL^b$							
1	0.4733	1.048	0.0416	0.0249	94.8	142	2** and 3**
2	0.2954	1.177	0.0106	0.0105	98.6	328	1** and 3*
3	0.2616	1.186	0.0270	0.0306	97.0	74	1** and 2*
$SW/SH = aSL^b$							
1	0.5241	0.0713	0.0292	0.0163	12.6	142	2* and 3*
2	0.4215	0.1303	0.0064	0.0050	68.2	325	1* and 3**
3	0.3435	0.1765	0.0241	0.0216	50.1	74	1* and 2**
$TW = aSL^b$							
1	0.0007	2.763	0.00018	0.0681	95.7	142	2* and 3*
2	0.0002	3.124	0.00002	0.0340	98.5	328	1*
3	0.0002	3.093	0.00005	0.0835	97.3	74	1*

Note. SE: standard error; R^2: determination coefficient, %; n: volume of sample, spc.; T: number of stations, with which a given station has statistically significant difference of regression lines ($P<0.05$); *: differ by slope; **: differ only by interception; the rest designations are in the text.

significant distinctions of *P. euglypta* size structure at stations 1, 2 and 3: nonparametric Mann-Whitney test in all cases was more than 22420.5, and significance level was less than 0.0001.

Populations at stations 1 and 2 were 1-10-year old individuals, and that at station 3 was 1-9-year old ones (Fig. 3). At station 1, 5-year old individuals prevailed in number (about 26%), one-year old (36.4%) at station 2, and 2-year old ones prevailed in number (25.1%) at station 3. Pair comparison of *P. euglypta* testifies significant distinctions of age structure at stations 1, 2 and 3: nonparametric Mann-Whitney test in all cases made > 23320.5, and significance level made < 0.0001.

3. Allometric growth

Ontogenetic changes both linear and weight parameters of *P. euglypta* can be well approximated by the equation of simple allometry ($P<0.01$). Linear parameters of a shell vary according to the principle of positive allometry (coefficient $b>1$) (Table 1). Statistically significant distinctions at significance level of 0.01 can be observed between stations. If clams have equal shell length, maximal height and width can be attributed to clams from station 1, and minimal ones in station 3 (Fig. 4). Shell width to height ratio varies very much. This ratio is maximal in clams from station 1, and that is minimal in station 3, i. e. in the first case clam shell is the most bulging and ball-shape, whereas in the second case it is slightly flat.

Body weight of *P. euglypta* from station 1 ontogenetically changes according to the principle of negative allometry ($b<3$), that of stations 2 and 3 - according to the principle of positive allometry ($b>3$) (Table 1). If shells have equal length, maximal body weight is attributed to clams from station 1, and the minimal one to clams from station 3 (Fig. 4). Distinctions between clams from stations 1 and 2, as well as from stations 1 and 3, are statistically significant at the level of $p<0.05$; there are no significant distinctions between clams from stations 2 and 3 ($p=0.1017$).

4. Linear growth

The most active growth of clams can be observed

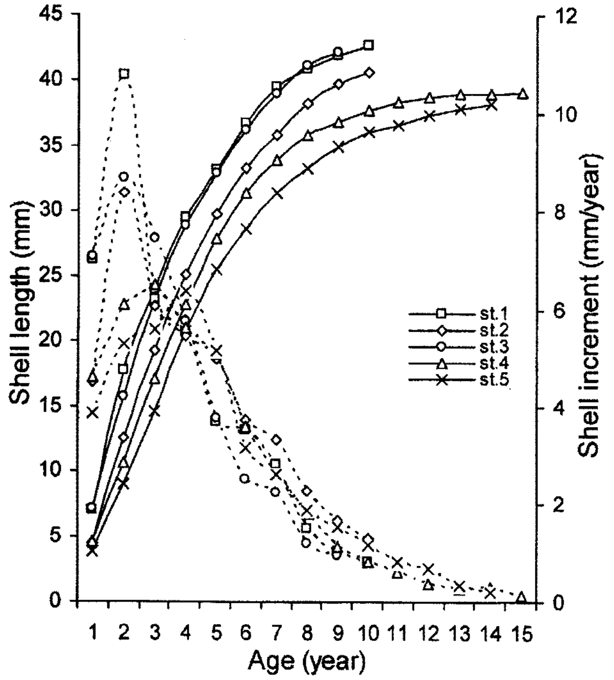

Fig. 5. Age changes in shell length (solid lines) and annual increments (dotted lines) of *Protothaca euglypta* in populations at stations 1-5.

during the first three years of their life, when their shell becomes 7-10 mm longer every year (Fig. 5). During the following years annual growth of a shell monotonely reduces. The mean yearly growth of 8-9-year old individuals makes about 1 mm, where that of 14-15-year old ones - less than 0.1 mm.

Growth rate of *P. euglypta* slightly varies in different habitats. It is well reflected by growth curves and Bertalanffy's growth equation coefficients (Table 2). In Vostok Bay clams grow the most quickly at stations 1 and 3, which differ from station 2 only by mean values. The lowest growth rate of this species is observed at stations 4 and 5, but there are no significant differences between these two stations. Significant differences ($p<0.05$) are observed only between stations 1, 3 and stations 4, 5.

DISCUSSION

Frequent finding of *P. euglypta* shells in the coastal carry-over (Evseyev, 1976; Selin and Dolganova, 2003) is a graphic evidence of the fact that this species is a common component of the coastal bottom communities of the Russian waters of the East Sea and Okhotsk Sea. However, up to the present time extremely low values of this species abundance were registered in the process of quantitative monitoring of the bottom invertebrate animals. Thus, near the northeastern, southeastern and southwestern coasts of Sakhalin Island population density of *P. euglypta* did not exceed 13 spc./m^2, in Vostok Bay - 0.3 spc./m^2 and 0.1 g/m^2, and in Possyet Bay only clam shells were found (Golikov and Scarlato, 1967; Scarlato *et al.*, 1967; Pogrebov and Kashenko, 1976; Golikov *et al.*, 1985). Our studies showed that in Peter the Great Bay *P. euglypta* forms populations with the density of almost 500 spc./m^2 and biomass of up to 1.5-2 kg/m^2. These distinctions between our and published data are apparently due to different frequency of location of sampling stations in different studies. It is quite possible that distinctions in abundance values of *P. euglypta* were also caused by long-term dynamic processes in the communities resulted in development of atypical bivalve colonies in Peter the Great Bay

Table 2. Parameters of Bertalanffy's equation of linear growth of *Protothaca euglypta* from different habitats

Stations	$L_\infty \pm SE$	$k \pm SE$	$t_0 \pm SE$
1	45.9±0.6	0.2885±0.0120	0.3961±0.0496
2	46.6±0.7	0.2281±0.0085	0.5907±0.0394
3	46.7±0.6	0.2666±0.0089	0.4097±0.0350
4	41.0±0.6	0.2596±0.0154	0.6899±0.0899
5	41.1±0.8	0.2185±0.0141	0.7154±0.0936

Note. L_∞, k and t_0: constants of Bertalanffy's equation; SE: standard error. interception; the rest designations are in the text.

water area during the recent decades (Golikov *et al.*, 1986).

The obtained data show that *P. euglypta* is one of the most abundant species of burying bivalve mollusks in Vostok Bay. According to our data, I obtained earlier by the same methods for the estimation of mollusks abundance, population density of such infaunal species, common for the Bay, as *Clinocardium californiense*, does not exceed 11 spc./m^2, and biomass - 130 g/m^2 (Selin, 1993), *Mactra chinensis* - 7 spc./m^2 and 130 g/m^2, respectively, *Spisula sachalinensis* - 4.5 spc./m^2 and 320 g/m^2, respectively (Selin, 1990), *Mercenaria stimpsoni* - 14 spc./m^2 and 1400 g/m^2 (Selin, 1995). Greater population density and biomass than that of *P. euglypta* were registered only for *Ruditapes philippinarum* - almost 950 spc./m^2 and about 8000 g/m^2, respectively (Ponurovsky and Selin, 1988).

Protothaca euglypta inhabits a wide range of biotopes from shallow pools to rubble-pebble bottom areas at depths down to 8 m in Vostok Bay and down to 20 m in a number of other areas (Scarlato, 1981; Golikov *et al.*, 1985). In Vostok Bay the most abundant population of this species is typical for shallow reefs, where some other epi- and infaunal bivalve mollusks - *Modiolus kurilensis*, *Arca boucardi*, *Ruditapes philippinarum*, *Macoma irus*, *Callista brevisiphonata*, which are met as single instances in the area of stations 1 and 3, which are also abundant. Here, in channels and cracks, water is heated up to 28-30℃ in summer, a small wave action can be observed very seldom, and in winter cracks and reefs on the whole are covered with ice. In such conditions, annual abundant replenishment of *P. euglypta* population with young individuals and a moderate mortality of individuals by all age classes were observed. It results in formation of population with a balanced age structure. However, in this biotope a high population density of this species and accompanying clams of the other species, as well as high summer water temperature apparently limit *P. euglypta* growth.

The obtained data indicate that with depth and under the surf condition replenishment of *P. euglypta* populations is not always regularly abundant due to a small number of settling juveniles and/or its high mortality. That is why *P. euglypta* abundance in these biotopes is not high. Under the condition of periodical surfs on shallow gravel-pebble with rubbles bottoms *P. euglypta* develops a comparatively bulging shell, whereas at a significant depth on chiefly sand bottom it is rather flat. The absence of intra- and inter-specific topic and trophic competition ensures favorable conditions for growth of *P. euglypta*. It is possible that comparatively active growth of clams at stations 1 and 3 is connected with water temperature: in the summer season water temperature does not exceed 20-25℃ (Stepanov, 1976).

According to Scarlato (1981), *P. euglypta* is spread to the north up to Olga Bay along the land coast of Russia (43°40′N; 135°14′E). It is connected with the fact that moving to the north from Peter the Great Bay, environmental conditions (first of all temperature) associated with this species. In summer water temperature at stations 4 and 5 does not exceed 17℃ and 15℃, respectively (Atlas Oceans, 1974). Such water temperature decrease results in growth rate of *P. euglypta* drop, as well as apparently to the reduction of mollusks survival as their habitat becomes closer to the northern boundary of their area. At the same time, mollusks life span increases: even small in number, samples of *P. euglypta* from stations 4 and 5 are individuals older than 10 years. Such latitudinal variation of the growth rate and life span of clams corresponds to the situation observed earlier for the other species of bivalve mollusks, and is usually explained by temperature conditions (Weymouth *et al.*, 1931; Brousseau, 1979; Selin, 1991), though this tendency is not always observed and even has been called in question more than once (Gilbert, 1973; Selin *et al.*, 1991; Sukhotin *et al.*, 2007).

Thus, *P. euglypta* forms populations with high density and biomass in some biotopes of Peter the Great Bay, East Sea. It suggests that in this area this species finds favorable conditions for life and plays an important role in the function of the coastal ecosystems. Finding *P. euglypta* shells with soft tissues remainder in the coastal carry-over near Surcum Cape indicates that in the northwestern part of the East Sea, the northern boundary of distribution of this species is significantly further northern area (50°06′N; 140°41′E) than it was found earlier by Scarlato (1981).

REFERENCES

Adrianov, A.V. and Kussakin, O.G. (1998) A check-list of biota of the Great Bay the Sea of Japan. pp. 350. Vladivostok, Dalnauka. [in Russian]

Atlas Oceans. The Pacific. (1974). pp. 140. Moscow, Department of Defense SSSR.

Brousseau, D.J. (1979) Analysis of growth rate in *Mya arenaria* using the von Bertalanffy equation. *Marine Biology*, **51**: 221-227.

Evseyev, G.A. (1976) The origin of the Vostok Bay (the Sea of Japan) and the history of its fauna of bivalves. *Biological Investigations in Vostok Bay. Collected Papers of the Institute of Marine Biology AN SSSR*, **5**: 23-62. [in Russian]

Gilbert, M.A. (1973) Growth rate, longevity and maximum size of *Macoma balthica* (L.). *Biological Bulletin*, **145**: 119-126.

Golikov, A.N. and Scarlato, O.A. (1967) Molluscs of the Possjet Bay (the Sea of Japan) and their ecology. *Proceedings of the Zoological Institute, USSR Academy of Sciences*, **42**: 5-154. [in Russian]

Golikov, A.N., Scarlato, O.A. and Tabunkov V.D. (1985) Biocenoses of shallow waters of southern Sakhalin (supplement to a paper). *Explorations of the Fauna of the Seas*, **30**: 1-64. [in Russian]

Golikov, A.N., Scarlato, O.A., Buzhinskaja, G.N., Vasilenko, S.V., Golikov, A.A., Perestenko, L.P. and Sirenko, B.I. (1986) Changes in benthos of the Possjet Bay (Japan Sea) over the last 20 years as a result of accumulation of organic matter in bottom sediments. *Oceanology*, **26**: 131-136. [in Russian]

Huxely, J.S. (1932) Problems of Relative Growth. (2nd Ed.). pp. 312. Dover Publications Inc., New York.

Kim, J.H., Kim, J.S., Kim, Y.H., Chung, E.Y. and Ryu, D.K. (2003) Age and growth of the Jedo Venus Clam, *Protothaca jedoensis* on the west coast of Korea. *The Korean Journal of Malacology*, **19**: 125-132.

Kwon, O.K., Min, D.K., Lee, J.R., Lee, J.S., Je, J.-G. and Choe, B.L. (2001) Korean Mollusks with Color Illustration. pp. 332. Shell House, Pusan.

Min, D.K. (2004) Mollusks in Korea. pp. 566. Min Molluscan Research Institute, Seoul.

Mina, M.V. and Klevezal, G.A. (1976) Animal Growth. pp. 291. Nauka, Moscow. [in Russian]

Okutani, T. (2000) Marine Mollusks in Japan. pp. 1174. Tokyo, Tokai University Press.

Pogrebov, V.B. and Kashenko, V.P. (1976) Benthic communities of hard substrates of Vostok Bay, Sea of Japan. *Biological Investigations in Vostok Bay. Collected Papers of the Institute of Marine Biology AN SSSR*, **5**: 63-82. [in Russian]

Ponurovsky, S.K. and Selin, N.I. (1988) Distribution, population structure, and growth of the bivalve mollusk *Ruditapes philippinarum* in Vostok Bay, Sea of Japan. *The Soviet Journal of Marine Biology*, **14**: 11-15.

Scarlato, O.A. (1981) Bivalve mollusks of temperate latitudes of the western portion of the Pacific Ocean. *Opredeliteli po Faune SSSR, Izdavayemye Zoologicheskim Institutom AN SSSR*, **126**: 1-479. [in Russian]

Scarlato, O.A., Golikov, A.N., Vasilenko, S.V., Tzvetkova, N.L., Grusov, E.N. and Nesis, K.N. (1967) Composition, structure and distribution of bottom biocenoses in the coastal waters of the Possjet Bay (the Sea of Japan). *Explorations of the Fauna of the Seas*, **5**: 5-61. [in Russian]

Selin, N.I. (1990) Distribution and growth of the bivalve mollusks *Mactra sachalinensis* and *Mactra chinensis* in Peter the Great Bay. *The Soviet Journal of Marine Biology*, **16**: 146-155.

Selin, N.I., Gogolev, A.Y. and Buyanovskii, A.I. (1991) Local latitudinal variation in linear growth of bivalve mollusk *Modiolus kurilensis*. *Russian Journal of Marine Biology*, **17**: 152-157.

Selin, N.I. (1993) Production and growth of the bivalve mollusk *Keenocardium californiense* in the northwestern part of the Sea of Japan. *Russian Journal of Marine Biology*, **19**: 26-34.

Selin, N.I. (1995) Spatio-temporal changes of population structure and growth of the bivalve mollusk *Mercenaria stimpsoni* in the Sea of Japan. *Russian Journal of Marine Biology*, **21**: 47-53.

Selin, N.I. and Dolganova, A.S. (2003) Distribution patterns and size-age composition in aggregations of the gastropod mollusk *Nucella heyseana* in Peter the Great Bay, Sea of Japan. *Russian Journal of Marine Biology*, **29**: 348-357.

Stepanov, V.V. (1976) Water temperature and salinity characteristics of the Vostok Bay (Sea of Japan). *Biological Investigations in Vostok Bay. Collected Papers of the Institute of Marine Biology AN SSSR*, **5**: 12-22. [in Russian]

Sukhotin, A.A., Strelkov, P.P., Maximovich, N.V. and Hummel, H. (2007) Growth and longevity of *Mytilus edulis* (L.) from northeast Europe. *Marine Biology Research*, **3**: 155-167.

Urbakh, V.Y. (1964) Biometric Methods. pp. 412. Nauka, Moscow. [in Russian]

Weymouth, F.W., McMillan, H.C. and Rich, W.H. (1931) Latitude and relative growth in the razor clam, *Siliqua patula*. *Journal of Experimental Biology*, **8**: 228-249.