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ДОКЛАДОВ КОНФЕРЕНЦИИ
Моллюски
восточной Азии
и прилегающих морей**

*6-8 октября 2014 г.
Владивосток, Россия*

**ABSTRACTS
OF THE CONFERENCE
Mollusks
of the Eastern Asia
and Adjacent Seas**

*October 6-8, 2014
Vladivostok, Russia*



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**Comparatory Method and diagnostics
of the freshwater large bivalve mollusks
(Bivalvia: Unionida)**

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At the initial stage of the Comparatory Method (CM) application all, more or less appreciable, distinctions of contours of the Bivalvia shell valve frontal section were interpreted as species attributes. It was shown that contours of valves frontal sections of mussels from the same species and with different shell sizes pass through different sites on the shell. Insufficient study of the first versions of CM has led to the unjustified description of new species. New modified version of CM, which allows investigation of contour of maximum convex sections of shells, is offered. This section passes from the apex through points maximally distant at different moments during the shell formation from the commissural plane. The maximum convex contour of shells does not change with increase in the mollusk size. This enables to correct the taxonomic mistakes made at the initial stages of CM application. Till now the species specificity of external contours of shell valves frontal sections were not confirmed by other methods. Further study of formation of shell curvature depending on bivalve growth based on statistic methods is required.

**Notes on *Yokoyamaia ornatissima* (Yokoyama, 1927)
and *Philine argentata* Gould, 1859
(Opisthobranchia: Cephalaspidea: Philinidae)
from the Sea of Japan**

Elena M. Chaban

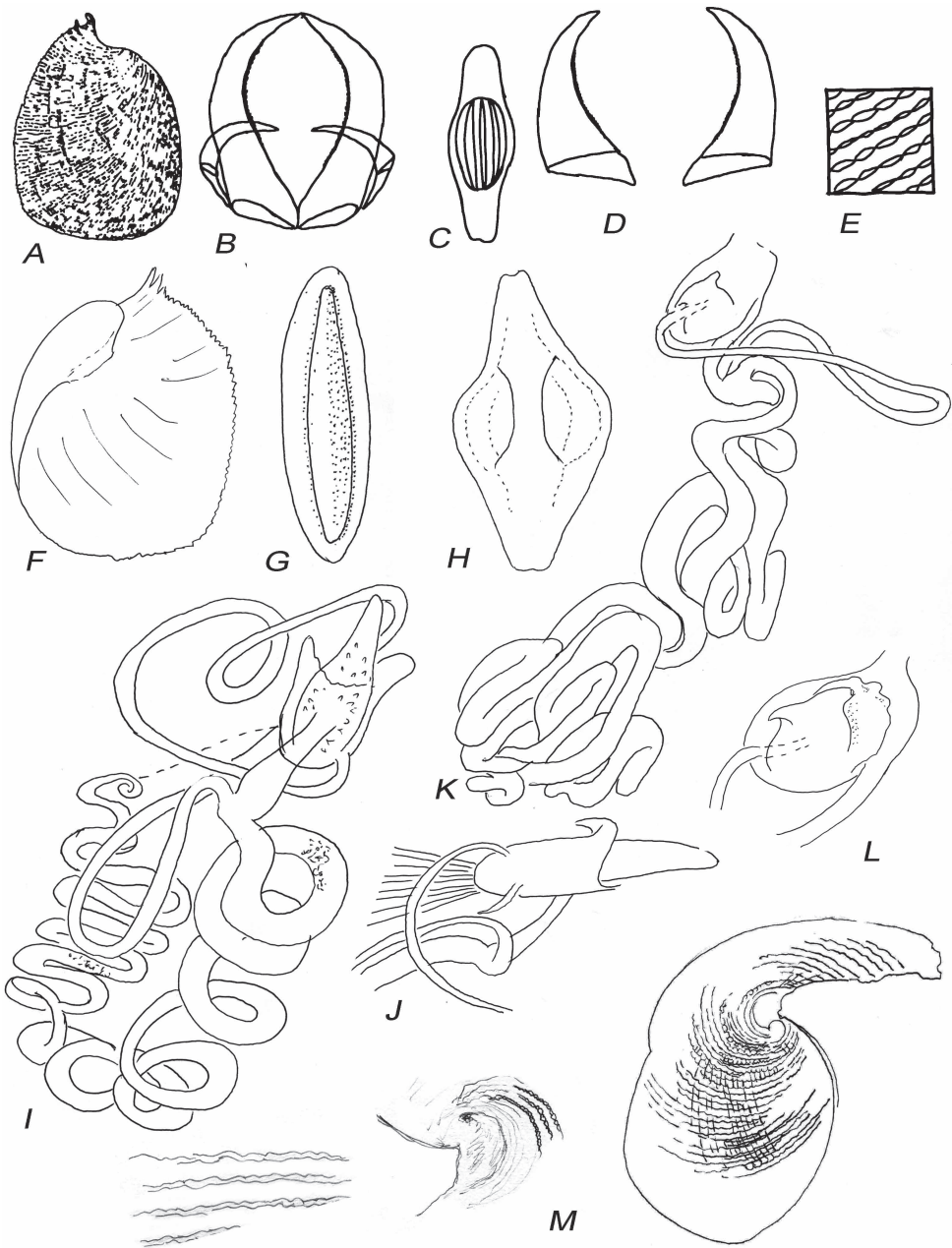
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Opisthobranchs of the family Philinidae have the most morphological diversity among cephalaspid mollusks. New philinids taxa have been described in recent years. Unfortunately there are old species which causes difficulties in definition. *Yokoyamaia ornatissima* (Yokoyama, 1927) is one of them. It is noted as *Philine* sp. A [Don Cadien, 1988] and *Philine* sp. 1 [Gosliner, 1996] from adjacent waters of California.

Ph. ornatissima was described as a fossil from the area of Tokyo City, but it was specified for the recent fauna due to the shell peculiarities and Habe [1950] established a new genus *Yokoyamaia* based on the species. It is interesting that *P. ornatissima* was noted as a type species of *Yokoyamaia*, but as junior synonym of *P. argentata* Gould, 1859. Why did Habe note both species as synonymies? Perhaps the species have the same radula formula in Habe's opinion [1950, pl. 9, fig. 18] (Fig., B). The diagnosis of *Yokoyamaia* is: "Shell like *Philine*, but with the posterior lip, strongly produced and dentate ... sculptures with punctuate grooves. Radula formula 2-0-2 ... stomachal plates fusiform and brownish in color" [Habe, 1950: p. 50]. Later Habe considered (without explanation) both *Y. ornatissima* and *Philine argentata* as different species and the second one as senior synonym of *P. japonica* Lischke, 1874 [Habe, 1964]. The shell with punctuate sculpture and radula formula 1-0-1 were also drawn by Habe [1950, pl. 9, fig. 13] for *Philine japonica* (Fig., D, E).

If *Philine japonica* and *P. argentata* are synonyms then what radula formula does *P. argentata* has? If *Yokoyamaia ornatissima* and *Philine argentata* are different species then which species has gizzard plates drawn by Habe [1950] on the plate 9, figure 17 as *Yokoyamaia argentata* (Fig., C)?

Yokoyamaia ornatissima is common species of the bays of the north-eastern part of the Sea of Japan [Gulbin, Chaban, 2007]. It can be identified easily by the posterior lip, strongly produced and dentate. Specimens from the Peter the Great Bay have radula formula 2-0-2 and gizzard plates identically shaped and sized (Fig., I). But these plates differ in shape from those illustrated by Habe [1950, pl. 9, fig. 17]. They are oval; inner surface of our plates is smooth, slightly convex; the outer surface without pits and slots but with median ridge (Fig., G). Therefore the plate on figure 17 belongs not to *Y. ornatissima*, but to *Philine argentata* sensu Habe, 1950.



A-C – “*Yokoyamaia argentata* (Gould)” (A – shell, B – radula, C – gizzard plate); D, E – *Philine japonica* Lischke (D – radula, E – spiral sculpture of the shell) [A–E – after Habe, 1950]; F, G, I, J – *Yokoyamaia ornatissima* (F – shell, ventral view, G – gizzard plate, I – male copulatory system, J – penial sac with penial papilla); H, K–M – *Philine argentata* (H – gizzard plate, K – male copulatory system, L – penial sac with penial papilla; M – spiral sculpture of the shell of the type specimen, partly drawn by E. Egorova).

For the first time *Philine argentata* was noted for the Russian fauna (Possiet Bay, Peter the Great Bay) by A.N. Golikov basing on punctuate spiral striation of the shell [Golikov, Scarlato, 1967]. Some specimens from the Possiet Bay determined by A.N. Golikov as *P. argentata* were studied [Chaban, 1999]. They have radula formula 2-0-2 and gizzard plates with two slit-like recess on outer surfaces (Fig., H) as shown by Habe [1950, pl. 9, fig. 17]. The shell of the type specimen of *P. argentata* has different sculpture in various parts (this study). Spiral striations in upper part of the shell are punctuate, but the lower part of the shell has simple spiral grooves without punctuations (Fig., N, O). Our shells from the Peter the Great Bay identified as *P. argentata* also have the same spiral sculpture. Some specimens have simple spiral grooves upon almost entire surface of the shell like *P. scalpta* A. Adams, 1862. But contrary to *P. scalpta*, the apex of *P. argentata* always carries punctuate grooves. Price et al. [2011] consider *P. japonica* and *P. argentata* as junior synonyms of *P. orientalis* A. Adams, 1854. We do not agree because of the different gizzard plates of *P. orientalis*.

The shell, radula and gizzard plates of *Philine argentata* sensu Chaban, 1999 from the Sea of Japan are close to *P. auriformis* from the New Zealand [Rudman, 1972a] and to specimens from California also identified by Gosliner as *P. auriformis* [Gosliner, 1995]. But the penial papilla of our specimens (Fig., L) differs from specimens from the New Zealand [Rudman, 1972b, fig. 6d].

Genus separation of *Philine* does not supported by many authors [Price et al., 2011; Ohnheiser, Malaquias, 2013] because it was based on the shell morphology. The same feature was used by Lin [1990] for his new species named as *Yokoyamaia (Choshiphiline) orientalis* Lin, 1990. But it does not belong to *Yokoyamaia*, because the gizzard plates of this species look like the plates of *P. auriformis*.

Peculiarities of the shell of *Yokoyamaia ornatissima* are result of shell reduction which is character of all philinid mollusks. *Y. ornatissima* has significant reduction of their shell, the last one even does not cover visceral sac [Don Cadien, 1988, Fig. 1]. But separation of *Yokoyamaia* is supported by morphology of the gizzard plates, and *Yokoyamaia* is a valid genus.

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**Systematics of the western Pacific “giant” dog-whelks
referred to *Nucella elongata*, *Nucella heyseana*,
and *Nucella lamellosa* (Muricidae, Gastropoda)**

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Our study is focused on big forms of muricid gastropods known from the Sea of Japan and adjacent waters of the Pacific. Most of them are referred in literature and collections to as *Nucella heyseana* (Dunker), *N. elongata* Golikov et Kussakin, and sometimes *N. lamellosa* (Gmelin). Firstly, we have studied recently discovered population of unusually big and elongated *Nucella* near Rudnaya Bay, NW Sea of Japan. Unlike *N. heyseana*, a widely distributed species in this area, these mollusks were never found in intertidal zone but are common at the depths of 5 to 30 m feeding on bivalve *Crenomytilus grayanus*, which had been never reported as a prey of *Nucella*. Comparison of COI, 16s and Histone H3 gene sequences has clearly demonstrated this form is unlikely conspecific with *N. heyseana*. Hence, we preliminary referred this form to *Nucella elongata* Golikov et Kussakin despite Golikov and Kussakin described the habitat of *N. elongata* as soft bottoms of shallow closed bays with sea grasses while our *N. cf. elongata* occurs at exposed rocky shores. Similar shells were found in the ZIN (St. Petersburg) and IMB (Vladivostok) collections and revealed this form distribution range from eastern Peter the Great Bay to Tatar Strait and along Sakhalin shore from Tatar Strait to Nevelsk.

Recently, we have found the holotype of *N. elongata* in ZIN collection, which believed to be lost for several decades. Golikov and Kussakin described this specimen in details in three subsequent publications dated 1962, 1974, and 1978. We also found one similar shell collected in 1999 from Kunashir Island in the IMB Museum. Surprisingly, these shells are very similar to common form of *N. heyseana* while rather different from those found in NW Sea of Japan. Moreover, the name *elongata* Golikov and Kussakin, 1962 is not an available name according the provisions of ICZN Articles 45.5 and 45.6.3 because it was expressly proposed as an infrasubspecific entity, *N. h. var. elongata*. It should be excluded from the species group as not regulated by the Code (Art. 1.3.4). Later, in 1974 Golikov and Kussakin re-introduced this name at specific rank, hence the valid name is *N. elongata* Golikov et Kussakin, 1974. These findings lead us to conclusion that *N. elongata* Golikov et Kussakin, 1974 is a junior synonym of *N. heyseana* (Dunker, 1862) while big *Nucella* species from the Sea of Japan remains unnamed. *N. lamellosa*, the last candidate name cannot be applied to this species because similar Alaskan and Aleutian forms (known as *ferruginea*, *lactuca*, *hormica*) are much smaller and possess more developed axial sculpture.

We also found several big shells in the ZIN and IMB collections from southern and SW Sakhalin referred to *N. elongata* or *N. heyseana*. Few of them can be recognized as *N. elongata* paratypes, and one of them was described by Golikov and Kussakin as the biggest known *N. elongata* individual. Like common form of *N. heyseana*, these mollusks were collected from shallow soft bottoms. Their shell proportions (last whorl height to shell length and last whorl width to shell length) are the same as in *N. heyseana* from Sakhalin, southern Kuriles and various locations along the shore of the Sea of Japan. This led us to conclusion that these individuals can be preliminary referred to a local ecological form of *N. heyseana*. However, more fresh samples are needed to support this hypothesis by the means of molecular analysis, soft body morphology and behavioral observations.

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Fauna, distribution and ecology of bivalves found on the shelf of Kronotskiy Gulf in May 2012

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The present information is based on the results of analyses of the material collected during benthic sampling carried out from the deck of the research ship “MRTK-316” in the water area of Kronotskiy Gulf (Eastern Kamchatka) in May 2012, at latitude range from 53°03' to 54°40' N. Surveying of benthos was conducted according to standard hydrobiological methods. “Okean-50” bottom-grab (0.25 m²) was used as a gear for quantitative collection of mollusks. Hydrobiological anchor-dredge with 1 meter wide cutting edge was used for estimation of the qualitative composition of bivalves. Collection of 2 samples at each of the 32 benthic stations and 6 qualitative stations was carried out. In total there were 58 species of living bivalves collected on the shelf of Kronotskiy Gulf from the depths of 9–296 meters, including 6 species new for the region. The most numerous were the representative the following families: Nuculanidae – 8 species, Tellinidae – 7 species, Thyasiridae – 6 species and Astartidae – 6 species.

According to the results of our research mollusks represent the second largest in biomass group of zoobenthos after echinoderms on the shelf of Kronotskiy Gulf. Bivalves reach average biomass of 120 g/m² in the central part of the Gulf at the depths of 100 meters where sandy-silty sediments mixed with gravel are widespread. Members of the family Astartidae dominate at these depths. The other most frequently met species is the representative of the family Tellinidae – *Macoma brota* Dall, 1916 with the number coming to 160 specimen/m². Bivalve *Megangulus luteus* reaching the number of 156 specimen/m² is a dominant species at the depths up to 10 meters. The maximal biomass of bivalves was observed in the southern and central part of the Gulf on the sandy-gravel and pebbly-sandy substrata. Absolute value of the biomass of bivalves was registered at the depth of 50 m in the southern part of the Gulf on gravel-sandy substratum (784.2 g/m²). Such high biomass at this station is reached due to two representatives of the family Astartidae: *Astarte arctica* and *A. borealis*. The largest number of bivalve mollusks was recorded at the depth of 50 m on the sandy-shelly bottom – 2820 specimen/m², with the biomass of 124 g/m². The basis of such a high number of mollusks at these depths is formed by two species: *Altenaeum dawsoni* (Jeffreys, 1864) – 1548 specimen/m² and *Mactromeris polynyma* (Stimpson, 1860) – 564 specimen/m². It is necessary to note that high number of the latter species is reached only due to young and juvenile samples caught with the bottom-grab. Large-size specimens of this mollusks were practically not caught by the bottom-grab because of their

deep burying, though in the hydrobiological anchor-dredge catch there were large mollusks reaching the weight of 100 g and more. Taking into account this fact and also the presence of numerous young specimens of large-size mollusks in the examined samples we consider that the hitherto existing opinion on the decrease of the biomass of bivalves in the direction of the coast in Kronotskiy Gulf is not quite correct.

The following new species for the fauna of Kronotskiy Gulf and near-Kamchatka water areas of the Pacific ocean were recorded: *A. dawsoni* (Jeffreys, 1864) met at 7 stations at the depths from 40 to 100 meters on silty-sandy and gravel-sandy substrata; *Limopsis kurilensis* Scarlato, 1981, met at 3 stations at the depths 200–205 meters on sandy substratum mixed with pebble and silt; *Parvithracia lukini* Kamenev, 2002, met at 3 stations at the depths from 180 to 220 meters on silty-sandy substratum mixed with pebble, *Cyrtodaria kurriana* Dunker, 1861, met at 2 stations at the depths from 50 to 70 meters on silty-sandy substratum, *Mysella derjugini* Gorbunov, 1952, met at a station at the depth of 100 meters on silty-sandy substratum mixed with pebble, *M. brota*, met at 6 stations at the depths from 70 to 150 meters on silty-sandy and silty substrata mixed with shell rock. Some of them reach considerable number and biomass.

Dominant species of the bivalves in Kronotskiy Gulf are as follows: *Crenella decussata* (Montagu, 1808), *Liocyma fluctuosum* (A.A. Gould, 1841), *Axinopsida serricata* (Carpenter, 1864), *Mactromeris polynyma* (Stimpson, 1860), *Astarte arctica* (Gray, 1824), *Astarte ioani* Filatova, 1957, *Megangulus luteus* (Wood, 1828), *Nuculana pernula* (Müller, 1779), *Clinocardium ciliatum* (Fabricius, 1780). Analysis of the density parameters of bivalves showed that 82% of the total biomass of mollusks was formed by only 8 species out of 58, and among them only 2 species formed more than a half of the total biomass: *A. arctica* and *Astarte ioani* Filatova, 1957 (45% and 13%, respectively).

Average biomass of the bivalves of Kronotskiy Gulf water area according to our data comes to 53.49 g/m², that is a little more than previously recorded. Maximal biomass of the bivalves in Kronotskiy Gulf amounts to 784.2 g/m². Average number comes to 267 specimen/m², maximal recorded number – 2820 specimen/m². Taking into account all above-stated it is possible to note that average values of the number and biomass of the bivalves on the shelf Kronotskiy Gulf has somewhat increased in the latest 50 years and form a good potential as a nutritive base for commercial hydrobionts.

Sperm prototype in bivalve molluscs

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Gametogenesis and gamete morphology, especially those of sperm, are among the main limitation factors of the evolution, since they cause reproductive isolation after copulation. We tried to establish the sperm prototype in bivalve mollusks for better understanding of evolution and phylogenetic relationships of bivalve molluscs. Evolution of some of the most important ultrastructural characters of sperm cells in bivalves has been studied. This class is characterized by the greatest variety of sperm types among molluscs: spherical, barrel-shaped, short and long conical, curved, spiral, rod-shaped, etc. Each family of bivalves, including such subfamilies of complex families as Mytilidae and Cardiidae, generally has specific sperm morphology. This means that the sperm ultrastructure in bivalves is specific not only to species, but also to genera and families, thus well correlating with their taxonomical status.

On the one hand, morphology of sperm cells depends on the type of insemination and appears to be an adaptation for moving in the environment around eggs. On the other hand, sperm morphology depends on the structure of the egg envelope, and it is an adaptation to penetrate into the egg.

Shape of the sperm head is determined mostly by the shape of nucleus and considered to be one of the main diagnostic characters, used to specify systematic status of some taxa and species. Flagellated sperm with spherical head, small acrosome and middle piece, varying number of mitochondria, and two centrioles should be considered plesiomorphic among all the other bivalves. Plesiomorphic, spherical-shaped sperm cells have remained in a few Protobranchia species, while more or less modified sperm morphology is typical for the most of the other families. Conical form, which is a synapomorphic character for scallops, is supposed to be the earliest modification, followed by other more modified types: rod-shaped, curved, spiral, etc.

Since the most primitive bivalves have sperm of the spherical type with relatively simplified middle piece, we assume this sperm as a prototype for other sperm among bivalves. The rest of the sperm shapes are derivatives from the prototype. The prototype is similar to Retzius-Franzen primitive spermatozoon. Subsequently, shape of sperm cells evolved in different ways. Sperm of Protobranchia, a primitive group of bivalves, which includes species of the genus *Yoldia*, are closest to prototype. Its sperm cells are characterized by the primitive spherical head and a varying number of mitochondria; only acrosome and middle piece underwent slight changes. The primitiveness of sperm cells correlates with the general primitiveness of this group. Formation of modiolin-type sperm

with spherical or barrel-shaped nucleus, well developed acrosome, and large number of small mitochondria in the middle piece was the most probable further tendency of modification. Sperm of *Bathymodiolus* species, which are inhabitants of deep-sea hydrothermal vents, were significantly changed: they became barrel-shaped, with 5 mitochondria and the acrosome of moderate size. The long isolation of this group and its history in the unique environment apparently played a significant role in these changes.

Based on the structural analysis, we suggest to divide the family Mytilidae into the following subfamilies: Modiolinae, Bathymodiolinae, Mytilinae, Musculinae, Septiferinae, Lithophaginae.

Spherical, barrel-shaped sperm have remained in the families Arcidae and Chrasostreidae. However, sperm cells of the representatives of these families are characterized by the well developed acrosome with prominent periacrosomal material. Another direction of the evolution of bivalve sperm is elongation of sperm head that results in a great variety of shapes, from conical to spiral. Regular conical sperm cells appeared first in *Glycemerys*. They have residual axial rod located under the acrosome. This sperm morphotype is typical for the whole family Pectinidae: head conical with slight variations and acrosome with periacrosomal material, which consists of fibrillar and granular components. Elongation of the head and formation of rod-shaped sperm were probably the following modifications. Sperm cells of this type are observed in the family Astartidae. More complicated changes appeared in the family Cardiidae: elongated conical curved head. Spiral head also occurs, being common for brackish-water cardiids. These significant differences in the shape of sperm cells are unusual among bivalves, and this enables us to suggest that the group Limnocardiidae, which includes brackish-water cardiids, deserves to have the family rank. Barrel-shaped sperm cells with relatively large and well developed acrosome are typical for the family Mactridae. And the last considered sperm morphotype with curved or crescent-shaped head is observed in the family Veneridae.

Sperm morphology in bivalve molluscs Cardiidae and related families

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Among nearly 10000 species of known bivalves, marine species constitute about 80%, and freshwater species do 20%. The issue of origin of freshwater bivalves is not resolved completely. Typically, marine and freshwater mollusks belong to different families. In this regard, the family Cardiidae, including euryhaline species, is of particular interest. This is mainly a marine family, some species of which can exist at a critical salinity of 5–8‰. This level represents a boundary for marine animals having no special organs of osmoregulation. Also, this barrier cannot be overcome by freshwater bivalves. When marine species get into a brackish-water environment, adaptive changes play a vital role in their physiology and reproductive processes.

Many researchers use the sperm morphology for phylogenetic and taxonomic characteristics of different taxonomic categories, from species to classes.

We studied the ultrastructure of sperm cells of some bivalves, particularly cardiids and related families: subclass Heterodonta, order Veneroida, superfamily Cardioidea, family Cardiidae: *Clinocardium (Ciliatocardium) ciliatum* (Fabricius, 1790), *Clinocardium (Keenocardium) californiense* (Deshaies, 1834), *Serripes groenlandicus* (Mohr, 1746); superfamily Astartoidea, families Astartidae, *Astarte borealis* (Schumacher, 1817), and Veneridae, *Mercenaria stimpsoni* (Gould, 1861); superfamily Arctoidea, family Trapezidae, *Trapezium liratum* (Reeve, 1843).

We also studied the structure of gametes of the brackish-water mollusc *Cerastoderma lamarcki* (Reeve, 1845). This is a polymorphic species inhabiting the Atlantic basin. It occurs in the Baltic, Azov, and Caspian seas. Some authors insist on distinguishing, at least, two more species: *C. edule* and *C. rusticum* [Kovalevsky, 1967].

Sperm cells of the studied species have a classic structure of aquatic sperm (aquasperm). While having the general structural plan typical for sperm of bivalves with external insemination, sperm cells of the studied species are morphologically different. Their acrosome differs in size and shape of the acrosomal vesicle and periacrosomal material; the shape of nucleus varies from spherical to elongated and curved. The middle piece of sperm cells does not differ significantly: it is formed by two perpendicular centrioles surrounded by four or five mitochondria.

The shape and size of sperm from various individuals within the same species living under the same conditions are quite stable and typical for the species. Dimensions of

their cells vary from 2 to 16 μm . The shape and size of sperm from representatives of the same family and even genus may vary.

Sperm and eggs of *C. lamarcki* manifest the most significant differences among all the other studied species, as they have a unique morphology, which is not found in other marine and freshwater bivalves. Nucleus in a mature sperm cell of *C. lamarcki* is twisted in spiral with 4–6 whorls. The sperm head, 12 μm in length, crowned by a small acrosome, grows narrower in the basal part and is surrounded by four mitochondria. When this sperm is released into water, its head makes undulating motions and thus the cell can abruptly change the direction of its movement.

Size and shape of sperm of *C. lamarcki* are identical to those of *C. edule* from the Mediterranean Sea [Sousa et al., 1995]. This may indicate both the identity of these species and the polymorphism of *C. lamarcki*. Brackish-water cardiids from the Atlantic Basin also have the shape of their sperm similar to *C. lamarcki*, particularly the spiral-twisted nucleus.

Late oocytes of *C. lamarcki* are about 70 μm in diameter and surrounded by dense egg envelope, the thickness of which is 35 μm . Each oocyte contacts with the acinus wall. At the place of contact, there is a bridge filled with cytoplasm, which apparently serves a micropyle for mature egg. The egg envelope becomes dense when it contacts with water, and its density depends on the water salinity. In this regard, the micropyle becomes necessary.

The presence of these types of gametes (sperm and eggs) in the brackish-water species *C. lamarcki* is presumably a result of adaptation, developed by marine bivalve species in response to low salinity.

Brackish-water cardiids are combined into the subfamily Lymnocardiinae. The unique structure of gametes of these molluscs is another argument for giving this taxon the family rank.

**Cryptic diversity in the genus *Dendronotus*
(Gastropoda: Nudibranchia) in north-west Pacific:
morphological, molecular and ontogenetic evidences**

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The opisthobranch mollusks of the genus *Dendronotus* are among the most common shallow-water bottom marine invertebrates of the Northern hemisphere. They as many other opisthobranchs are emerged model group in various fields including taxonomic, phylogenetic, developmental, physiological and molecular studies. However the diversity of *Dendronotus* in the Russian Seas remains poorly explored. Till recent, only three species of the genus were registered in the Russian seas – amphiboreal *D. frondosus* (Ascanius, 1774) and *D. dalli* Bergh, 1879 and circumpolar *D. robustus* Verrill, 1870.

We studied 298 specimens of the genus *Dendronotus* collected in the White, the Barents, the Japan, the Okhotsk, the Bering seas and on the east coast of Kamchatka peninsula. External and internal morphology was studied using stereomicroscope and scanning electron microscope. Serial stages of postlarval and juvenile radula were used for studying of their modifications through the late ontogenesis. Molecular analysis included an obtaining partial sequences of mitochondrial genes cytochrome *c* oxidase subunit I and 16S rRNA and nuclear genes Histone 3 and 28S rRNA.

Detailed morphological analysis reveals seven species of the genus *Dendronotus* inhabiting cold waters of the Northern hemisphere from the Barents Sea through Arctic to the North Pacific Kamchatka region and the Japan Sea. Molecular analysis based on the four genes confirms the morphological data. One of the most common species *D. frondosus* was previously considered as having very broad geographical range encompassing almost all Northern and Arctic seas. However, according to the present study *D. frondosus* is restricted only to the North Atlantic boreal and subarctic waters. This result thus corroborates recent analysis showed separate species status of the *D. venustus* MacFarland, 1966 (which for a long time was also considered as synonym of *D. frondosus*) in the north-east Pacific. *D. frondosus* commonly inhabits coastal shallow waters of the subarctic Barents and White seas and displays an extreme range of external colour variation from almost uniform milky white to variegated brown and red specimens. However both radular morphology and molecular analysis consistently

reveal all variously coloured specimens as a single species. In the north-west Pacific an opposite situation was found: present study reveals presence in this region two new species externally similar to the North Atlantic *D. frondosus* but significantly differing according to the four-gene analysis and radular morphology. For a long time *Dendronotus dalli* was considered as an amphiboreal species. Present study for the first time clearly shows that all records of *D. dalli* from the North Atlantic belong to another species new for science. The latter differs from *D. dalli* by four-gene analysis, dorsal appendages morphology and body colouration. Thus, the present study did not confirm the amphiboreal status of two common species of the genus *Dendronotus* – *D. frondosus* and *D. dalli*. These two species are restricted to the North Atlantic and North Pacific respectively. The discovery of two sympatric species in the north-west Pacific is of great importance both for taxonomy and biogeography because raises question about validity of the amphiboreal status of many marine invertebrates.

North Atlantic species *D. lacteus* (Thompson, 1840) is registered for the first time in the fauna of Russian seas. It has been found in the Barents Sea and also on the east coast of Kamchatka peninsula. Morphological and molecular data confirms it separate status from other *Dendronotus* species, including *D. frondosus* that is very similar in colouration pattern. Therefore it is the only species in the genus *Dendronotus* with confirmed amphiboreal status.

An important implication for taxonomy and phylogeny of the nudibranch mollusks is discovery in course of the present study the essential similarity of the shape of the radular teeth in early juvenile specimens of different species of the genus *Dendronotus* with considerably diverged adult radular morphology. This underestimated ontogenetic phenomenon potentially may greatly affect current systematics of the genus *Dendronotus* because radular patterns are important taxonomic characters.

1. Seven species of the genus *Dendronotus* inhabiting shallow waters of the Russian coast were described: *D. frondosus* (Ascanius, 1774), *D. lacteus* (Thompson, 1840), *D. dalli* Bergh, 1879, *D. robustus* Verrill, 1870 and three new species.

2. The boreal Atlantic species *D. frondosus* is the common species in the shallow Barents and White Seas. However in the northern part of the Pacific Ocean *D. frondosus* is absent and replaced by a number of cryptic species revealed not only by molecular analysis, but detailed studies of morphology, including the features of the radula and dorsolateral processes. Two new species of this complex are found on the Pacific coast of Kamchatka, in the Japan and Bering Seas.

3. The obtained new data have allowed excluding the Pacific species *D. dalli* from the lists of fauna of the White and the Barents Seas. Earlier this species has repeatedly pointed to these waters. At the same time, there were discovered a new species that on the one hand had similar radula to *D. dalli* and on the other, had a number of differences in external features and well differed genetically from the other species of *Dendronotus*.

4. At the first time *D. lacteus* were registered for the fauna of Russia. According to our data its distribution therefore includes north-east Atlantic, the Barents Sea and also the east coast of Kamchatka peninsula. Therefore it seems to be the only amphiboreal species within *Dendronotus*. Specimens of *D. lacteus* are well differed from other species of *Dendronotus* by both morphological and molecular data.

5. The ontogenetic heterochronies in the radula development were the one of the key evolutionary episodes of differentiation of some *Dendronotus* species.

The main conclusion of the present study is a probability for providing an integrative framework based on morphological, ontogenetic and molecular data for further investigations of the taxonomy and phylogeny of the one of the most common northern nudibranch of the genus *Dendronotus* and other opisthobranch mollusks.

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**Larval and juvenile morphogenesis
of *Acila insignis* (Bivalvia: Nuculidae)
and problems of phylogeny of some nuculid taxa**

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The form, sculpture, and morphological structure of the hinge plate were studied in the primary prodissoconch (PD-I), the juvenile and adult dissoconchs of *Acila insignis* (Gould, 1861), a common species in Peter the Great Bay (Sea of Japan), as well as of the other species of the same family distributed in the bay or other areas. Benthic samples used as the study material were collected in Peter the Great Bay with a dredge or manually by SCUBA-diving.

The family includes the taxa with pelagic and brooding development of larvae. *A. insignis*' larvae develop in the gill chamber until they reach a juvenile stage with a shell length of 350–400 μm . The dissoconch of juveniles from the collected benthic samples has usually already had an outer firm brown layer of argillic carbonate. This layer covers the primary prodissoconch (PD-I) 230–240 μm long with a wrinkled knobby sculpture and a dissoconch with a sculpture of thin radial ridges on the anterior and posterior surfaces. The dissoconch of the adults 18–22 mm long has a chevron-shaped sculpture of radial ridges covered only by a periostracum.

The brooding larval development of *A. insignis* is completed with the formation of a wide hinge plate. There are 3–5 primary teeth 20–30 μm long on its anterior and posterior regions, between which a trigonal chondrophore is situated. The primary teeth on the juvenile postprovinculum at a dissoconch length of 400–450 μm fuse on their ventral sides and form secondary teeth of irregular shapes. The 3–4 primary teeth of the right valve (RV) transform into one trigonal tooth in front of the chondrophore and one thin anterior tooth, divided from the trigonal one by a narrow ligament pit. The posterior region of the RV bears two teeth: the anterior one, adjacent to the chondrophore, is small and trigonal in shape and the posterior one is large and ventrally expanding, delimited by narrow ligament pits at the front and back. The anterior region of the left valve (LV) has three teeth: the anterior one is teardrop-shaped, the largest, and the most isolated; the posterior one is small and trigonal; and the medium one is formed of three dorsally fused primary teeth. The posterior region of the LV has two teeth: a large anterior trigonal tooth divided from the posterior one by a relatively wide pit and a thin posterior tooth looking very similar to the transformed primary tooth.

When a shell reaches a length of 450–600 μm , a wide hinge plate forms in the anterior region of the RV under the anterodorsal margin of the dissoconch. A deep pit of the first tooth of the dissoconch's LV, and the first tooth of the dissoconch's RV, about 50 μm

long and square, appears anteriorly to this pit. A wide pit forms instead of the trigonal tooth on the RV in the posterior region of the postprovinculum, and the ventral expansion of the posterior tooth transforms into the first posterior tooth of the dissoconch. The posterior region of the postprovinculum on the LV changes insignificantly. However, a deep pit appears on the marginal expansion under the postprovinculum, and the first dissoconch's tooth of the posterior tooth series forms behind this pit. An expansion with a small tuberculate "bump" forms in the anterior postprovinculum of the LV in front of its first large anterior tooth partially overlying this tooth. The "bump" broadens dorsally and posteriorly and finally transforms into the first dissoconch's tooth having a subsquare shape. A ligament pit of the dissoconch and the second tooth of the LV's front tooth series, 50 μm long, forms anterior to the first tooth.

As the dissoconch develops from 800 to 1200 μm , the number of teeth of the first tooth series increases to 4–5. When the fifth tooth appears, their length regularly grows by 20–30 μm , and a spine-like process forms on the proximal side of each tooth, including the first dissoconch's teeth. The chondrophore gradually becomes skewed, which is characteristic for the adult dissoconch. The remains of 3–4 primary and 2–3 postlarval teeth, differing in shape and size from the secondary postprovincular teeth, may still be present before and behind the chondrophore. When the dissoconch reaches a length of 2 mm, radial ridges appear on its external surface, and crenulation on its ventral margin, and these are the last morphological transformations of *A. insignis* at this stage.

Nucula ovatotruncata (Scarlato in Volova et Scarlato, 1980) is another species of the family occurring in Peter the Great Bay besides *A. insignis*. The ontogenetic patterns of these species differ in their general shape and sculpture, as well as in the structure of the early postprovinculum: the 600–700 μm shell of *N. ovatotruncata* has up to 5–7 teeth transformed from the larval ones in front of the ligament pit. The similar pattern is known for the other *Nucula* taxa [Gofas, Salas, 1996]. As for *Acila*, the only species, in which the early stages of development have been studied, is *A. insignis*. However, a comparison between *A. insignis* and the species *Nucula nucleus*, *N. hanleyi*, *N. turgida* [Webb, 1987] shows that its ontogenetic pattern differs in phylogenetically insignificant details of size or sculpture.

Analysis of the results obtained during the present study and some discrete data on the early ontogenetic stages of nuculid species distributed beyond Peter the Great Bay allows the following conclusions: (a) the presence or absence of the anterior series of up to 7–9 transformed teeth may be a trait separating the taxa of the family into two phylogenetic lines; (b) the hypermorphosis of PD-I and the absence of PD-II in about half number of species is one of important traits of the Nuculidae family, but as morphostructures are still poorly studied in the provinculum, the phylogenetic importance of this trait is unclear; (c) the morphostructures of the provinculum and early postprovinculum have some primitive features, similar to those in Turtoniidae having internal development and some members of Mytilidae, but distinctly differing the nuculid type of development from the heterodont type.

Mollusk assemblages and drilling predation in the Panama eastern Pacific coast

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Predation and competition play a fundamental role in ecosystems influencing the distribution and abundance of organisms at the ecosystem level, as well as the diversity and structure of communities. As such they have been fundamental in shaping life during all its history. Predator-prey interactions provide a unique system to study natural selection at the individual level. Drilling predation is quite common among gastropods in both recent and fossil settings. Boreholes are abundant and easier to recognize representing a good tool to study predator-prey relationships in marine mollusk communities through time and the influence of abiotic factors on in shaping these relationships.

Panama is located between 7 and 10° N and between 77 and 83° W and is delimited by the Caribbean Sea in the north and the tropical Eastern Pacific in the south. The Pacific coastline is divided by the Azuero Peninsula into two gulfs, the Gulf of Panama in the east and the Gulf of Chiriqui in the west. The Gulf of Panama covers a larger area showing a relatively gently dipping sea floor, with two island groups (Perlas and Taboga). In contrast, the Gulf of Chiriqui represents an elongated and narrow basin open to the east and south, with a highly structured seafloor and intersected by several islands and island groups (Coiba, Montuosa, Secas and Contreras). The shelf edge and the upper slope are extremely steep. In spite of distinct differences in hydrography, both gulfs show very similar habitats, making them especially interesting for comparative studies. This work aimed to analyze whether the composition and distribution of the mollusk fauna in both gulfs is more influenced by the differences in the productivity regime, or are they primarily controlled by local habitat differences. The Gulf of Chiriqui ranges from siliciclastic muds and silts along the coast brought in by rivers to carbonate sands and gravels around the islands. Coral reefs are frequent around the island groups whereas coralline algal beds (erect and rodoliths) are widespread between islands Secas and Montuosa. Mollusk facies occur in deeper shelf areas. The area has oligotrophic to mesotrophic conditions and shows little seasonality, with warm and relatively stable sea surface temperatures and salinities during the year. In contrast, the Gulf of Panama shows carbonate sediments dominated by cirripedian plates (balanids) and mollusk shells concentrated in the islands areas. Living reefs are sparse occurring mostly near the Perlas islands. The basin shows strong seasonality with dry season upwelling driven by NE trade winds, resulting in pronounced eutrophic nutrient conditions and extremely high productivity. Temperature and salinity change drastically during the dry season.

The complexity found in modern eastern Pacific environments is reflected in the mollusk assemblages it supports and its ecology. Earlier data showed a much higher trophic diversity and predation intensity in soft (muddy and sandy) substrate communities as compared with those from hard substrates (rock, coral rubble and coralline algae). Here we were interested in the possible influence of substrate type on feeding habits of predatory snails in upwelling (Gulf of Panama) versus non-upwelling (Gulf of Chiriqui) settings on the tropical eastern Pacific coast of Panama. Results show that taxonomic distribution and substrate type are directly related. Predation intensity varies from 35.1% in soft substrates to 13.0% in hard substrates for gastropods, and from 17.3–4.5% respectively for bivalves. On the other hand it seems that hydrology (i.e., upwelling/non upwelling) has no big influence in predation intensity. In both substrates gastropods show much higher predation intensity. Prey selectivity seems to be present only concerning gastropods and scarcely on bivalves. Naticids are the dominant predator in both habitat types. Muricids are responsible for less than 10% of total drill holes found mostly on hard substrate.

In both studied regions bivalves dominate. Pectenids are the most frequent taxon found in the Gulf of Panama, although at times other bivalve taxa may dominate. On the other hand *Caryocorbula* sp. appears as the most abundant bivalve taxon in the Gulf of Chiriqui although pectinids are once more the most frequent found. Suspension feeding is the predominant feeding type in these communities. Concerning gastropods, whereas *Crepidula aculeata* is the most abundant taxon in the Gulf of Panama, *Turritella leucostoma* dominates in the Gulf of Chiriqui. Whereas browsing and predatory active carnivores, as well as suspension feeders dominate in the Gulf of Panama, predatory gastropods are the most important in the Gulf of Chiriqui. These results reflect both the influence of substrates and nutrient levels in both regions.

**Differences in spatial distribution
of juvenile bivalve mollusks in Primorsky Krai
(Sea of Japan/East Sea)**

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Cultivation of sea organisms is highly demanded in all maritime countries, except for our one, and all our results in this promising industry are just nothing more than citation of outstanding achievements made by the nearest neighbors from China. At the same time, our waters provide more favorable conditions for cultivation of commercially valuable cold-loving species, such as the Japanese scallop *Mizuhopecten* (= *Patinopecten*) *yessoensis* and Swift scallop *Swiftopecten* (= *Chlamys*) *swiftii*, than our neighbors have. The lower diversity of competing and predatory species also facilitates their farming under natural conditions. However the problems, connected with the negative influence of competing species, have not been solved yet. Already at the first stage of testing of a foreign technology for cultivation of the Japanese scallop *M. yessoensis* (Jay) under conditions of Primorsky Krai it turned out that reproduction and habitat conditions of this species are significantly influenced by competing and predatory invertebrate species, which settle onto collectors along with scallop larvae and interfere obtaining marketable product. Earlier studies showed that the main fouling species on scallop collectors in Possyet Bay differ in their vertical distribution that provides an opportunity to optimize the process of reproduction of the cultivated species [Gabaev, 1981].

The goal of the present work is the study of spatial distribution of the main fouling species to find the optimum waters for cultivation of valuable marine bivalve mollusks.

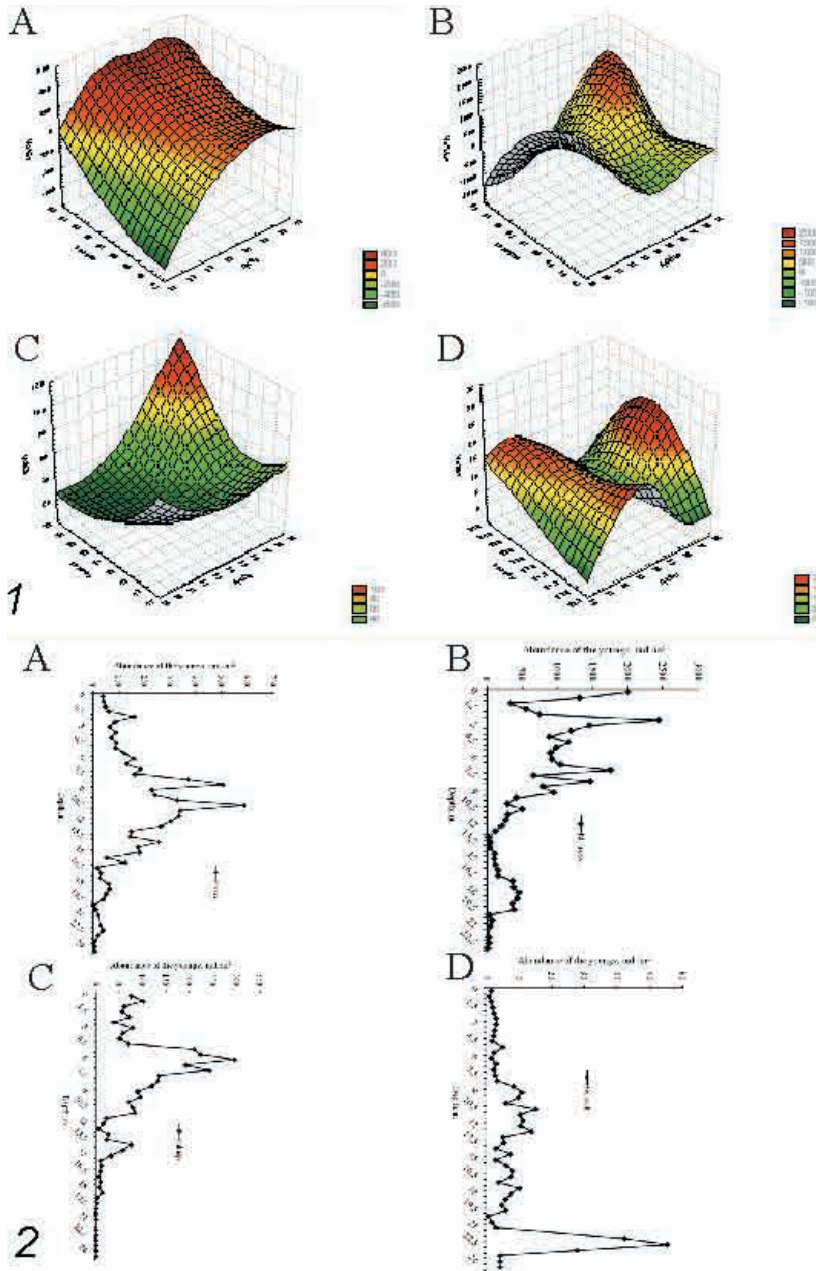
To solve this problem, reproduction of the Japanese scallop and accompanying species was studied by means of an artificial substrates (scallop collectors), exposed in Possyet Bay (42°36' N, 130°50' E) within the period optimum for larval settlement. To determine the period for submersion of collectors, the dynamics of gonadal index of scallop was analyzed; the abrupt reduction of the gonadal index was considered as the beginning of spawning. A week after spawning, plankton samples were taken with the Apstein plankton net every two or three days. The mesh size of the plankton net was 100 µm. The plankton samples were fixed in 4% formaldehyde solution. Larvae were counted and measured in the Bogorov chamber under a microscope MBS-9, and numbers of the larvae were calculated per 1 m³. Along with plankton sampling, the water temperature was measured at three horizons (0, 5, and 10 m). After scallop larvae

reached 250 μm in length (the stage of settling), series of bag collectors of Japanese design, attached to a caproic cord at a 0.5-meter interval, were submerged at 12 stations of the northwestern part of Possyet Bay in 1978–1982, 1985, 1988–1999. Depending on site, submerged collectors covered the depth range 0–24 m. After juvenile scallop reached 8–10 mm in shell height, a part of collectors were hauled up on the surface. Japanese scallops, Swift scallops, Pacific mussels *Mytilus trossulus*, and Azuma scallops *Chlamys nipponensis* were picked up from the substrate, and live and dead individuals were counted. The obtained results were expressed per 1 m^2 by dividing the values of counts by 1.44 m^2 , which is the standard area of the scallop collectors. The obtained data were analyzed statistically in STASISTICA 6.0. The outputs of regression analysis were tested at $\alpha=0.05$.

The study of the horizontal distribution of the main four species of bivalve mollusks has shown that it differs considerably. The Japanese scallop was found to increase the abundance of juveniles as the latitude of stations rises, and the particularly noticeable growth of spat abundance was at the stations located in northeastern Possyet Bay (Fig. 1A). Larvae of Pacific mussel abundantly occupied scallop collectors in two areas: the first is located in southwestern Possyet bay, in the area of the Far Eastern Marine Reserve; the second, which is more abundant, in northeastern part of the bay, off Cape Deger (Fig. 1B). Juvenile Azuma scallop, almost like Pacific mussel, also occurred in abundance in two areas: in the southwestern area (the Marine Reserve) and, much more abundantly, in the northeastern area (along the Krabbe Peninsula) (Fig. 1C). Among the studied bivalve mollusks Swift's scallop manifested the most complex horizontal distribution. The first area is situated along the Krabbe Peninsula coast, and the second, more abundant but localized, is situated in the north of the studied area, in Minonosok Inlet (Fig. 1D). In general, it can be concluded that spatial distribution of the Japanese scallop has much in common with that of the Swift's scallop, and the spatial distribution of the Pacific mussel resembles that of Azuma scallop.

Significant differences also exist in vertical distribution of the studied bivalve mollusks. Larvae of the Pacific mussel prefer to occupy collectors, located near the surface, and three peaks of abundance are observed in its vertical distribution (Fig. 2B). Azuma scallop prefers a little lower horizon. The maximum abundance of juveniles of this scallop was recorded at a depth of 6–7.5 m (Fig. 2C). Larvae of the Japanese scallop prefer to settle even lower (9–13.5 m) (Fig. 2A), and the lowest horizon is most preferred by Swift's scallop (at the maximum depth of 22.5 m) (Fig. 2D).

Vertical distribution of larvae of the bivalve mollusks can be judged, to a certain extent, from their location in plankton. In Lake Saroma (Hokkaido, Japan), *M. yessoensis* larvae are concentrated in the upper horizons during high tide and in the lower ones during low tide. In daytime, they occur at a depth of 6–12 m; before sunset, they rise to the surface layer 0–3 m; at night, they are found in near-surface layers [Maru et al., 1973]. Vertical migration of larvae is complicated by differences in phototaxis, arising during ontogenesis. Early larvae exhibit positive phototaxis;



Figs. 1, 2. (1) Long-term horizontal distribution of four species of the bivalve mollusks: **A** – the Japanese scallop, **B** – the Pacific mussel, **C** – the Azuma scallop, **D** – the Swift’s scallop; X – altitude of stations, Y – longitude of stations, Z – abundance of juveniles; (2) Long-term vertical distribution of four species of the bivalve mollusks: **A** – the Japanese scallop, **B** – the Pacific mussel, **C** – the Azuma scallop, **D** – the Swift’s scallop.

late ones, negative [Bayne, 1964; Mileykovskiy, 1979; Peteltihina, 1987]. Weight of the shell also influences on the larvae movements. Larvae smaller than 120 μm do not move to the layers below thermocline, but those larger than 170 μm are not subject to the thermocline effect [Gallager et al., 1994]. The similar results were obtained by Manuel et al. [2000]. The turbulent mixing affects on larvae distribution in plankton. It appears under the effect of dynamic factors, which most frequently have the wind-induced and tidal nature [Konev, 1990]. In mixed areas of water, scallop larvae are distributed evenly over 40–50 m water column [Tremblay, Sinclair, 1990a]; in stratified water they migrate above the thermocline [Tremblay, Sinclair, 1990b], however, in spite of the abundance of food in the upper 10 meters, they are concentrated deeper [Tremblay, Sinclair, 1990a]. In plankton, larvae behave as active particles. They are below the thermocline enough frequently and remain at the same site in spite of currents, induced by upwelling and downwelling [Shanks, Brinr, 2005]. Though behavior of larvae is species-specific [Ma et al., 2006], many of them ascend to the infraneuston, and if a pollution appears there, this poses a threat to existence of bottom biocenoses [Shuvalov, 1978].

Food availability can exert the same effect on vertical larvae distribution as the water turbulence does. The availability of food there is one of the main factors, which influence on development of both larvae and juveniles. In case of a low concentration of food, the water turbulence increases the probability of contacts between larvae and food particles [Raby et al., 1994]. For Japanese scallop, the necessary concentration of suspension is 11.0 mg/L and 2.5 mg/L for Pacific mussel. These biomasses of seston are typical just for the bays of the East Sea [Kolganova, Hrushkova, 1983], and while they vary from 2.4 to 5.0 mg/L in the surface layer of bays, the value in the near-bottom layer is 10.0 mg/L. Probably for this reason, mussels settle and grow best in the layer 0–5 m, whereas scallop does in the near-bottom layer [Kuznetsova, 1987]. At the shallow stations, concentration of foods is the highest at 9–10 m depth [Claereboudt et al., 1994; Zvalinskiy et al., 2006; Fréchette et al., 2000], however the largest quantity of juvenile Japanese scallop occurs at the horizon 9–16 m, where its main competitors, such as Pacific mussel and Azuma scallop, and predator, Amur seastar, are the least abundant [Gabaev, 1981]. In the upper layers of water, intensity of food consumption by mollusks grows [Soldatova et al., 1985] that increases competitors' negative influence. Thus, to optimize the cultivation process, collectors and cages are placed in that horizon, where abundance of competitors is the lowest. In many countries of the world, collectors and cages for scallop cultivation are lowered to 12 m depth [Naidu, Scaplen, 1976; Wallace, Reinsnes, 1984], 15 m [Aoyama, 1986; Claereboudt et al., 1994], 18 m [Allen, 1979], and even to 20 m [Fréchette et al., 2000]. As to cultivation of the scallop *Placopecten magellanicus*, the horizon 15–20 m suits more than 9–10 m [Claereboudt et al., 1994; Fréchette et al., 2000]. The total biomass of fouling organisms, which are competitors, depends on location of the farm and always falls with depth increase [Claereboudt et al., 1994]. As depth and distance from shallow waters grow, there is

a tendency of the species diversity and the quantitative characteristics of fouling on hydrotechnical structures to decline [Kashin, Maslennikov, 1993].

It is possible to judge about location of adult animals, as well as about population status of benthic groups, by location of larval concentrations [Sergeenko et al., 2005]. Most likely, the horizon, at which scallop parental individuals occur, is the optimum for their larvae to settle. After the experiment with albino breeding specimens was conducted in Minonosok Bay, most of white juvenile Japanese scallops settled on scallop collectors, located in Minonosok Bay at the horizon 7–10 m. Breeders for the experiment were caught also at these depths. Natural populations of scallop, inhabiting different horizons, probably have a specific genotype.

In Possyet Bay in 1978–1979, most of juvenile Pacific mussels were at shallow stations in Minonosok Inlet and off Cape Mramorny; the vertical distribution of these juveniles manifested two peaks of abundance, at the depths 0 and 3.5 m [Gabaev, 1981]. The third peak was found later at the depth of 7 m, probably, owing to the global warming (Fig. 2B). Detecting the optimum habitat temperature by larvae probably becomes the triggering mechanism for them to settle. Therefore, depending on hydrological features of the year, the optimum horizon for larval settlement can shift by 1–2 m [Gabaev, 1982].

The investigated invertebrates have specific thermopathy, and, because of water temperature variations with depth, each marine inhabitant has its most preferred horizon [Gabaev, 1981]. The farther southward the center of its geographic range is moved, the later the species spawns and the higher horizon its juveniles occupy. For successful rearing of valuable inhabitants of sea, it is necessary to know and use the pattern of juveniles' spatial distribution of not only cultivated, but also competing species. Hence, to optimize the process of Japanese scallop cultivation, the collector cages should be placed at the horizon with 10–15 m depth, where the abundance of competitors is the lowest.

Shell-bearing gastropods of the Commander Islands shelf

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The greater part of the material of gastropod mollusks of the Commander Islands shelf was collected by expeditions of the Institute of Marine Biology of the Eastern Branch of the USSR Academy of Sciences in 1972 and 1973. Samples were collected from the intertidal zone to depths of 250–300 m. In the intertidal zone, 26 hydrobiological stations were conducted and 264 samples were collected. In the upper subtidal, samples were collected by scuba divers using the quantitative method at 96 stations (456 samples) at depths of 10, 15, and 20 m. At each station, samples were taken from an area of 10 m² using three 1-m² frames and three 0.1-m² frames. In areas of high animal density, 0.025-m² frames were used. In the lower subtidal, sampling was carried out using a dredge and a bottom grab at depths of 40, 60, 80, 100, 130, 150, 200, and 250–300 m (32 samples).

During the period of 1986–1992, the staff of the Kamchatka Branch of the Pacific Institute of Geography of FEB RAS (Petropavlovsk-Kamchatsky) carried out hydrobiological investigations in the upper subtidal of the Islands to 46 m depths. Samples were collected at depths of 0–4, 5, 10, 15, 20, 25, and 30–46 m. A total of 361 scuba and 27 dredge samples were collected along with a large number of quantitative samples.

In addition, we used materials of numerous but less large-scale samplings performed by Soviet and Russian expeditions to the Islands in different years. Thus, the available material included more than 1300 samples that covered a period of 40 years and a depth range from the intertidal to 300 m.

A cluster analysis based on the Bray-Cutis similarity coefficient was used to compare the faunas of different areas. Data on gastropods of the Pacific coast of North America were derived from the literature sources.

Fauna composition. A total of 147 species and subspecies were found in the area studied. This is 17.5% of the total gastropod fauna of the Russian Far Eastern seas and 41% of the North Pacific gastropod fauna. This number of species is comparable with the number of species in different areas of the Asian coast but it is markedly lower than in the North American areas (see Table).

Vertical distribution. The smallest number of species occurs in the intertidal zone. With increasing depth, the number of species first increases to 62 at 20 m depth and then somewhat decreases to 41 at 60 m depth. With further increase in depth, the number of species again increases to 49 species and remains at this level until 200–300 m depth.

**The Bray–Curtis similarity coefficients (%) for the mollusks fauna
in the different areas of the North Pacific.
The number of species in these areas is given in bold type along the diagonal**

Area	S-E Kam.	N-E Kam	Comm. Isl	Aleut. Isl	S. Alaska	W. Alaska
S-E Kam.	105					
N-E Kam.	52	198				
Comm. Isl.	53	48	141			
Aleut. Isl.	37	41	44	225		
S. Alaska	29	33	34	75	262	
W. Alaska	37	47	38	73	63	212

Cluster analysis showed that according to the fauna composition all studied depths are grouped into three clusters: intertidal–20 m, 40–100 m, and 150–300 m. The fauna similarity coefficient for these depth ranges is 40–45% and it is up to 80% within each cluster. There is no shared species only between the intertidal zone and 200–300 m depth and their similarity coefficient is equal to zero.

Zonal-biogeographical characterization. The Commander Islands are located in the high-boreal subzone of the boreal Pacific zone. In connection with this, the fauna of mollusks consists of boreal (75%) and boreal-arctic (25%) species. Boreal species are divided into widespread amphi-Pacific boreal species (16% of the total number), wide-boreal Asian species (30%, with the main part of their ranges at the Asian coast), wide-boreal American species (1%, with the main part of their ranges at the American coast), and high-boreal species (28%, found only in the high boreal subzone). Boreal-arctic species are classified into wide-boreal arctic (19%, found in the Arctic and the entire boreal zone) and high-boreal–arctic (6%, found in the Arctic and the high-boreal subzone).

The most cold-loving psychrotropic species on the Commander Islands shelf are boreal-arctic and high-boreal species. Their sum is 53%. However, the proportion of these species changes at different depths: it is 49% at 20–30 m depth and increases to 60% with increase in depth.

This vertical distribution of mollusks mainly corresponds to the distribution of water masses. A superficial (summer) water mass occurs from the surface to 25–50 m depth and is characterized by a temperature of 7–10°C at the surface to 4–6°C. Cold intermediate water layer is located at 25–50 to 100–150 m and characterized by a temperature of 1–3°C. Below this layer is a Pacific water mass (warm intermediate layer) with a temperature of 3–4°C.

Biogeographical division. For biogeographical division, comparisons were made between the faunas of the following North Pacific areas (see Table): southeastern coast of Kamchatka (S-E Kam.); northeastern coast of Kamchatka (N-E Kam.); Commander Islands (Comm. Isl.); Aleutian Islands (Aleut. Isl.); southern Alaska (S. Alaska); and western Alaska (W. Alaska).

The similarity of the faunas was fairly low. The fauna of the Commander Islands was the most close to the southeastern Kamchatka fauna (53%) and less similar to that of the neighboring Aleutian Islands, and the more so to the fauna of the coast of Alaska. Cluster analysis separated the North Pacific into two regions at a similarity level of 41%: Asian and American. The fauna similarity between areas was markedly higher in the American than in the Asian cluster.

Such an isolation of the fauna of the Commander Islands can be explained by the system of currents and the physico-geographical position. The main flow of the Alaska (warm) Current about 360 km wide enters the Bering Sea between the Commander Islands and the Aleutian Islands (the Attu Current) at a velocity of 10 m/s. The Kamchatka (cold) Current flows from the Bering Sea between Kamchatka and the Commander Islands at a velocity of 15–20 m/s. The two counter currents form cyclonic water circulation around the Commander Islands. The width of the Kamchatka Pass is 191 km and the depth is 4 km. These physico-geographical conditions largely isolate the shelf fauna from the adjacent areas of the North Pacific.

**Taxonomic and biogeographical review
of the bathyal and abyssal Rissoidae
in the northwestern Pacific**

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The Rissoidae is a family of small to minute gastropods that are abundant in seas throughout the world from intertidal to bathyal and abyssal depths. Because of their size and considerable convergence in shell characters, they have proved to be very difficult to classify. There have been only a few comprehensive studies that treat this group, especially for deep-water inhabitants. Regarding the Japanese waters, only three species had been reported from bathyal depths (i.e., deeper than 200 m) by the end of the last century. Several additional species have been recorded in the last few decades from northwestern Pacific, especially in Russian waters, though most of them were described based on only a few specimens and many were even unidentified to species level.

The Department of Zoology of the National Museum of Nature and Science has been carrying out a deep-sea sampling program around the Japanese archipelago since 1993, and focused on the Suruga Bay (during the period in 1993–1996), Tosa Bay (in 1997–2000), off Okinawa Islands (in 2001–2004), off northeastern Honshu [Sanriku] (in 2005–2008), and in the Sea of Japan (in 2009–2013). A number of research vessels were used, and trawling and dredging were carried out at more than 900 stations, at depths down to 5680 m. Together with the results of other sampling programs and independent research cruises, a large number of deep-sea animal specimens, including mollusks, have been gathered in the museum. The present author has been carrying out a taxonomic study on the bathyal and abyssal gastropod, based on the material. In the present paper, bathyal Rissoidae mainly collected from the Sea of Japan and northern part of North Pacific is treated.

More than 660 rissoid specimens in 118 lots, including juveniles and empty shells, were obtained at 72 stations within a range of 200–1894 m in the Sea of Japan. They were classified into eight species, including five new species: i.e., *Frigidoalvania tanseimaruuae*, *Punctulum soyomaruuae*, *P. tanshumaruuae*, *Alvania nihonkaiensis* and *A. yamatoensis*. Examination of voucher material of previous studies resulted in the recognition of three more species in this area. Prior to the present study, eight recorded rissoid species were later re-classified into five species based on the examination of voucher material. As a result, 11 species in total are presently known to be distributed in this area.

Regarding geographical distributions, some species are currently known only from the Sea of Japan (*F. tanseimaruae*, *P. soyomaruae*, *A. akibai*, and *A. yamatoensis*), but others are considered to be also distributed in other areas, such as the Pacific coasts of Japan (*P. tanshumaruae*), Okhotsk Sea (*A. nihonkaiensis*), or both areas (*F. asura* and *P. flavum*). Among these, the last two show especially wide geographical distributions, with a wide range of intraspecific variations, and are suspected to be mixtures of several different species. To a greater or lesser extent, if a species is distributed in geographically separated areas (i.e. the Sea of Japan, the Pacific coast of Japan, and Okhotsk Sea, or even in the same area at different depths), specimens from different populations often have some differences in shell morphology. Based on the overall similarities among the populations and also the range of variations in conchological characters, they are regarded as geographical forms of single species. However, future more detailed study with molecular technique may prove that they would be mixtures of more than one species.

The distribution of the species that are considered to be endemic to the Sea of Japan and adjacent areas can be related to their geological history. The Sea of Japan underwent drastic environmental changes during glacial ages in the Early Quaternary. A considerable decline of the sea water level during the Last Glacial Maximum (LGM: ca. 20,000 years ago) resulted in extreme low salinity in the surface water and anoxia in the bottom water, and thus caused a large-scale extinction in the Sea. Prior to this event in the Late Miocene (Pliocene), a unique cold-water fauna, so called Omma-Manganji fauna that contains many endemic species, had formed in the Sea of Japan. Although most of these endemic species suffered extinction during the LGM, some are proved to have survived in the “intermediate water” probably formed between the depths of ca. 200 and 500 m, which had normal salinity and dissolved oxygen values. The rissoids treated here may thus represent such relict species. Actually at least four of them (*F. asura*, *F. sitta*, *A. akibai* and *A. awa*) have a representatives in the Late Miocene Sea of Japan. In addition, the number of species is largest between the depths of 200 and 800 m, which correspond to the depths of the “intermediate water” during the LGM. On the other hand, only two species occurred below 1000 m, and they can be considered to have adapted secondarily to this newly provided environment after the LGM.

Some species are shown to be distributed both in the Sea of Japan and off the Pacific coast of northern Honshu (e.g., *P. tanshumaruae*) across the Japanese archipelago, but in the case of *P. soyomaruae*, a counterpart population in the Pacific was considered to belong to a different new species, *P. sanrikuensis*. In the latter case, vertical distributions are significantly deeper than former cases (670–854 m for *P. soyomaruae* in the Sea of Japan, and 620–2183 m for *P. sanrikuensis* in the Pacific), and it is probable that the populations in both areas have been separated since the formation of the Sea of Japan by the rise of Tohoku Backbone Ranges in the end of the Pliocene.

**Some peculiarities of mussel fouling
on navigation buoys in Possjet Bay
(Peter the Great Bay, Sea of Japan) in 2011**

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The A.V. Zhirmunsky Institute of Marine Biology began to conduct studies dealing with risk assessment and monitoring of invasive species on the shelf of the Far Eastern seas of Russia [Zvyagintsev et al., 2012]. This necessitates the study of the biota of water areas subjected to the effect of ship ballast waters, particularly in Possjet Bay (Sea of Japan).

The study of mussel fouling was carried out on 10 navigational buoys installed in April 2011 at the beginning of navigation and raised aboard a GS-84 hydrographic ship upon termination of the navigation of small-size ships and boats in Possjet Bay on November 22, 2011. In all, 2050 specimens of mussels were opened and examined. Among the examined material, there was an introduced species *Mytilus galloprovincialis* Lamarck, 1819, a subspecies *Mytilus trossulus kussakini* Scarlato et Starobogatov, 1979, and their hybrids. *M. trossulus kussakini* is clearly differentiated from *M. galloprovincialis* by the presence of an unbroken border without a pearl layer along the inner margin of the shell. In addition, the scar of the posterior retractor lies very close to the border in *M. trossulus kussakini*, but in other mussels of the genus *Mytilus*, it deviates from the border. This feature allowed observation of the hybridization process on the morphological level [Ivanova, Lutaenko, 1998].

In Troitsa Bay with active navigation, three buoys near a shoal at Brauzer Island were examined. On the first buoy at the shoal of Brauzer Island (coordinates 42°38'01" N; 131°05'07" E), non-hybridized mussels (*Mytilus trossulus kussakini*) significantly prevailed (75.8%) over the hybrid *M. trossulus kussakini* x *M. galloprovincialis* (24.2%).

In mussel fouling on the second buoy (42°38'05" N; 131°05'04" E), hybrids *M. trossulus kussakini* x *M. galloprovincialis* (52.1%) insignificantly predominated over the non-hybridized mussel *M. trossulus kussakini* (47.6%). In addition, hybrids with the predominance of morphological features of *M. galloprovincialis*, namely *M. galloprovincialis* x *M. trossulus kussakini*, were found in single numbers (0.3%).

On the third buoy at the shoal of Brauzer Island (42°38'325" N; 131°05'13" E), the hybrid *M. trossulus kussakini* x *M. galloprovincialis* occurred in largest numbers (91.2%), non-hybridized *M. trossulus kussakini* was 7.2%. In addition, hybrids with the predominance of morphological features of *M. galloprovincialis* (*M. galloprovincialis* x *M. trossulus kussakini*) were found in low number (1.2%) and the introduced species *M. galloprovincialis* occurred in single numbers (0.4%).

At the exit from Vityaz Bay, at Cape Schultz, dense mussel fouling on the buoy (42°38'06" N; 131°05'01" E) was observed. The largest number of specimens was hybrids *M. trossulus kussakini* x *M. galloprovincialis* (87.7%), the proportion of non-hybridized mussels was 10.5% (*M. trossulus kussakini*). Hybrids with the predominance of morphological features of *M. galloprovincialis* (*M. galloprovincialis* x *M. trossulus kussakini*) were only 1.8%.

Mussel foulings on two buoys at Nazimov Spit and in Reid Pallada Bay (42°37'94" N; 130°48'04" E и 42°37'801" N; 130°47'950" E) were almost balanced. The proportion of non-hybridized mussels *M. trossulus kussakini* varied from 44.6 to 61.5%, hybrids *M. trossulus kussakini* x *M. galloprovincialis* constituted 38.5% to 54.5% of the total number of the specimens examined. Besides, hybrids with the predominance of morphological features of *M. galloprovincialis* were found in single numbers (0.9%) on the latter buoy.

Mussel fouling on the buoy located at Cherkavsky Island (42°37'94" N; 130°48'04" E) in Reid Pallada Bay was to a larger degree represented by the hybrid *M. trossulus kussakini* x *M. galloprovincialis* (77.6%) than the non-hybridized mussel *M. trossulus kussakini* (22.4%).

The Ryazanov pole is placed (42°38'70" N; 130°48'053" E) almost opposite Cherkavsky Island; the proportion of non-hybridized mussels *M. trossulus kussakini* in fouling was 40.0% with hybrids *M. trossulus kussakini* x *M. galloprovincialis* predominating (60.0%).

On the buoy that is most remote from the open sea, at a reef in Novgorodskaya Bay (42°38'82" N; 130°48'78" E), the proportion of non-hybridized mussels *M. trossulus kussakini* was 66.7%, of the hybrid *M. trossulus kussakini* x *M. galloprovincialis* 30.3%, the introduced species *M. galloprovincialis* occurred in single numbers 3.0%.

The composition of mussels fouling on the buoy over the Klykov Bank (42°33'82" N; 130°54'89" E) was unusually uniform, almost without variation. The Klykov Bank is situated at the entrance to Reid Pallada Bay, in which there is a cyclonic current [Grigoryeva et al., 1996] and is thus isolated from the rest of Possjet Bay. Here, foulers on the buoy were non-hybridized *M. trossulus kussakini*, whose population apparently inhabits a natural biotope at a depth of 1.8–2 m. *M. trossulus kussakini* represented almost 98.1% of the fouling and the hybrids *M. trossulus kussakini* x *M. galloprovincialis* were only encountered in few numbers (1.9%).

Thus, on all buoys non-hybridized mussels *M. trossulus kussakini* and hybrids *M. trossulus kussakini* x *M. galloprovincialis* were present in varying proportions. On four buoys, hybrids with the predominance of morphological features of *M. galloprovincialis* occurred in very few numbers; only on two buoys, the introduced species *M. galloprovincialis* was found in single numbers. It can be supposed that this structure of mussel fouling on the buoys is formed by the transport of larvae via currents and adult mussels via ship hulls and drift material from waters that are more southern and is maintained because of the viability of hybrids.

**Two new species of the genus *Silicula*
from the family Siliculidae (Bivalvia)
first recorded in the western Pacific**

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Allen and Sanders [1973] placed the genus *Silicula* Jeffreys, 1879 in the family Siliculidae, which they erected following the investigation of deep-water Protobranchia of the Atlantic Ocean. Earlier, the genus *Silicula* was comprised of three species: *Silicula fragilis* Jeffreys, 1879, *Silicula patagonica* (Dall, 1908), and *Silicula rouchi* Lamy, 1910. Allen and Sanders [1973] described two new species (*Silicula filatovae* Allen, Sanders, 1973 and *Silicula mcalesteri* Allen, Sanders, 1973) and examined, in great detail, the shell morphology and anatomy of all species of the genus *Silicula*, except *S. patagonica*, which was described from a single valve with a destroyed beak [Dall, 1908]. Later Bernard [1989] described one more species *Silicula alleni* Bernard, 1989. In the same work he described the species *Lamellileda sandersi* Bernard, 1989, which Coan et al. [2000] referred to the genus *Silicula*. Thus, the genus *Silicula* currently contains 7 species that were recorded in the bathyal and abyssal zones of different regions of the Atlantic and Pacific oceans. However, despite the wide distribution of Siliculidae representatives in the World Ocean, collections of *Silicula* species in most cases consist of a small number of specimens. In the Pacific Ocean, siliculids (*S. patagonica*, *S. alleni*, and *S. sandersi*) were found only at the coast of America, and all Pacific species were described from a minimal amount material (*S. patagonica* from one valve, *S. alleni* and *S. sandersi* each from one specimen).

Following the examination of extensive original material of bivalves collected during the period from 1950 to 2012 in the bathyal and abyssal zones of different regions of the northwestern Pacific, two new species of *Silicula* were discovered. One of them was recorded in the bathyal and abyssal of the deep-sea basin of the Bering Sea, and the other in an abyssal plain of the northwestern Pacific. Thus, the new representatives of the genus *Silicula* were first recorded in the western Pacific Ocean.

In this study I used the material collected by expeditions of P.P. Shirshov Institute of Oceanology (IO) (Moscow) in the bathyal and abyssal zones of the Bering Sea (R/V “Vityaz”, cruise no. 5, August 5 – October 5, 1950; R/V “Vityaz”, cruise no. 8, September 14 – October 28, 1951; R/V “Akademik Mstislav Keldysh”, cruise no. 22, July 25 – October 27, 1990) and in the abyssal zone of the northern Pacific (R/V “Vityaz”, cruise no. 45, April 23 – July 10, 1969; R/V “Akademik Mstislav Keldysh”, cruise no. 22, July 25 – October 27, 1990), as well as by the German-Russian

deep-sea expedition KuramBio (Kurile Kamchatka Biodiversity Study) in the abyssal zone of the northwestern Pacific (R/V “Sonne”, cruise no. 223, July 21 – September 7, 2012). The material of *Silicula* species collected by the IO was fixed and stored in 70% ethanol in the IO. The material collected by the KuramBio expedition was fixed in pre-cooled 96% ethanol and stored in the A.V. Zhirmunsky Institute of Marine Biology (IMB) (Vladivostok).

The following were used for the comparison purposes: the type material of *P. soyomaruuae* (holotype NSMT Mo 62762, paratype NSMT 49827), photos of type and other materials of *S. mcalesteri* (holotype MCZ 271974, paratype MCZ 361654, photos by A.J. Baldinger from MCZ web site), *S. filatovae* (holotype MCZ 271977, paratype MCZ 361653, photos by A.J. Baldinger from MCZ web site, “President and Fellows of Harvard Colledge”), *S. alleni* (holotype LACM 2344, photos by L.T. Groves and P. Valentich Scott), *S. sandersi* (holotype LACM 2348, photos by L.T. Groves and P. Valentich Scott), *S. patagonica* (holotype USNM 96914, photos from USNM web site (“information provided with the permission of the National Museum of Natural History, Smithsonian Institution, 10th and Constitution Ave. N.W., Washington, DC 20560-0193. (<http://www.nmnh.si.edu/>)”), *S. fragilis* (NMW, image numbers: M011725, NMW M011726, NMW M011727, from Marine Bivalve Shells of the British Isles web site (Oliver et al., 2010)), and *S. rouchi* (USNM 870326, photos from USNM web site (“information provided with the permission of the National Museum of Natural History, Smithsonian Institution, 10th and Constitution Ave. N.W., Washington, DC 20560-0193 (<http://www.nmnh.si.edu/>)”); photos of 2 specimens by D.G. Zelaya).

The genus *Silicula* is closest in terms of the hinge structure to the genera *Lamellileda* Cotton, 1930 and *Poroleda* Hutton, 1893. Like *Silicula*, species of *Lamellileda* and *Poroleda* have long and lamellate teeth [Hedley, 1905; Cotton, 1930; Ludbrook, 1961]. This has hampered the identification of generic status of species that occur in different regions of the World Ocean and have lamellate teeth in the hinge [Heinberg, 1989]. In the northern Pacific, such species are *Silicula sandersi* (Bernard, 1989) and *Propeleda soyomaruuae* (Okutani, 1962).

Huber [2010] suggested that Bernard [1989] originally correctly placed *S. sandersi* to *Lamellileda*. *Silicula sandersi* was described from one specimen from the abyssal plain (5180 m depth) of the northeastern Pacific. In contrast to other species of the genus *Silicula*, this species has a much more extended posteriorly and more rostrate shell; more than 10 relatively short posterior hinge teeth, becoming posteriorly shorter and oblique relative to the posterodorsal shell margin; more than 5 short subequal anterior teeth located horizontally and parallel to each other; a broad thickening of the hinge plate under the beak, in which an oblique resilifer is located [Bernard, 1989; Coan et al., 2000]. These peculiarities of the shell morphology and the hinge structure of *S. sandersi* correspond much more to the diagnosis of the genus *Lamellileda* [Cotton, 1930; Ludbrook, 1961; Heinberg, 1989]. The type species of this genus, *Lamellileda typica* Cotton, 1930, has analogous proportions of the shell, numerous relatively short lamellate

posterior teeth becoming posteriorly shorter and oblique to the dorsal shell margin, and short lamellate horizontal anterior teeth not parallel to the anterodorsal shell margin [Cotton, 1930]. Therefore, I share the Huber's [2010] viewpoint that Bernard [1989] correctly referred *S. sandersi* to *Lamellileda* and exclude this species from comparative analysis with other species of the genus *Silicula*.

The new *Silicula* species from the Bering Sea is easily distinguished from *S. fragilis*, *S. filatovae*, *S. rouchi*, and *S. alleni* by having a highly elongated shell with the posterior end produced like a rostrum and truncated. According to shell shape and proportions, this species is closest to *S. patagonica* and *S. mcalesteri*, which have an elongate shell with produced and truncated posterior end. Adult specimens of new species well differ from *S. mcalesteri* in having a more flattened, nontransparent, thicker shell with the beaks less displaced anteriorly, a more rounded anterior end and a straight or concave posterodorsal margin, no more than 6 instead of 8 posterior teeth in the hinge, a by far smaller prodissoconch, and two large loops of the gut in both sides of the body but not one loop only in the right side.

This species was found at depths of 489–4984 m. At present, this is the largest depth range for *Silicula* species. *S. patagonica*, *S. rouchi*, and *S. mcalesteri* were only recorded in the shelf and bathyal zones at depths of 135 to 1153 m [Dall, 1908; Lamy, 1910, 1911; Dell, 1964, 1990; Allen, Sanders, 1973; Egorova, 1982; Villarroel, Stuardo, 1998]. *S. fragilis* was found from the lower bathyal to abyssal zone (1493–4402 m), *S. alleni* (3650 m) and *S. filatovae* (3826–5042 m) in the abyssal zone [Allen, Sanders, 1973; Bernard, 1989].

Almost all specimens of this species were discovered in the deep-sea basin of the Bering Sea and in the deep-water Kamchatsky Strait connecting the Bering Sea and the Pacific Ocean. Only one specimen of this species was found in the Pacific Ocean to the south of the Kamchatsky Strait. However, 5 strongly damaged specimens of siliculids that closely resemble *S. beringiana* were taken at a depth of 4180 m in the Pacific Ocean to the south of Unimak Island (53°25'0 N, 163°23'0 W, Aleutian Islands, USA). It is therefore very likely that further studies will reveal *S. beringiana* in other regions of the North Pacific.

At stations 2316 and 2309 (R/V “Akademik Mstislav Keldysh”, cruise no. 22), conducted at maximum depths (3957–4294 m) of the Bering Sea, a new *Silicula* species was found in very large number. This species comprised more than 50% of the total number of all bivalve specimens in the sample. Therefore, it can be stated that it is one of the dominant species of bivalves at maximum depths of the deep-water basin of the Bering Sea.

Like the species from the Bering Sea, the new *Silicula* species from the abyssal plain of Pacific Ocean is readily distinguished from *S. fragilis*, *S. filatovae*, *S. rouchi*, and *S. alleni* by having a strongly elongate shell with its posterior end extended in the form of a rostrum and truncated. This species is closest in shell shape and proportions to *S. patagonica*, *S. mcalesteri* and *S. beringiana*, which also have elongate shells with extended

and truncated posterior end. However, in contrast to these three species, this new species has a markedly lower and elongate shell with more extended and tapering posterior end. Furthermore, it differs from *S. mcalesteri* in having a thinner and more flattened shell with more rounded and more extended anterior end, much smaller prodissoconch, fewer posterior teeth in the hinge, almost horizontal position of the posterior adductor muscle, the presence of large intestinal loops in both sides of the body, but not one loop in the right side [Allen, Sanders, 1973]. Compared to *S. patagonica*, the shell of new species, in addition to the differences in shape and proportions, is thinner, translucent and the apex of the pallial sinus does not project beyond posterior adductor scar.

The new species from the Pacific Ocean is closest to *S. beringiana*; from which it differs in its more flattened and elongate shell with more extended posterior end and more rounded anterior end. Besides, unlike *S. beringiana*, this species has a thinner, semitransparent shell with slightly convex posterodorsal margin, relatively longer posterior teeth of the hinge, almost horizontally located posterior adductor muscle, less deep pallial sinus, fewer palp ridges.

The latter *Silicula* new species is an abyssal species. This is the most deep water species of the genus *Silicula*. All specimens of this species were recorded in all samples collected with the different sampling gear at the two southernmost stations of the KuramBio expedition conducted at the coast of Japan at depth greater than 5200 m. Most often, there were several specimens in a sample. Thus, this species is a fairly common, though not as abundant species of the deep-sea macrobenthos fauna as the *Silicula* species from the Bering Sea. Interestingly, it was not found at the other 10 stations of the KuramBio expedition conducted to the north of Japan (up to the latitude of the northern Kuril Islands) at 4859–5780 m depths. It is possible that in the northwestern Pacific at latitudes north of Japan this species either may be rarer or may not occur whatsoever.

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Analysis of the shapes of *in vitro* attached hemocytes of *Callista brevisiphonata* (Bivalvia, Veneridae)

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The development of a numerical algorithm for formal description of the external morphology of cells *in vitro* has practical value for describing the morphology of cultured cells, where a non-formalized and inaccurate language is still used for the description of cell shapes. The theoretical interest of this study is based on the fact that the external morphology of a cell is determined by a number of factors, namely, their functional dynamics (in particular, the response to an environment, including the so important environmental feature as structure of the extracellular matrix). The systematic morphological description and classification of invertebrate hemocytes (including those of bivalves) based on the phylogenetic, physiological, and morphological criteria can be found in the fundamental works on evolutionary comparative histology by A.A. Zavarzin. This scientist hypothesized that cells of the connective tissue and blood of invertebrates are rather poorly differentiated and are presented by several basic cell types, which are common to all invertebrates.

This study involved 628 hemocytes of *Callista brevisiphonata* (Bivalvia, Veneridae) (Carpenter, 1864). The animals were sampled on September 10–15 in the Vostok Bay (Peter the Great Bay, Sea of Japan, Primorsky Krai, Russia). The hemolymph was applied to a cover glass incubated for 1 h at room temperature, and then fixed in 4% formaldehyde in sea water. After fixation, cells were stained with hematoxylin-eosin, dehydrated and embedded in Canada balsam for light microscopy. The images of cells were digitized and saved in a one-bit format. Parameters were calculated using silhouette and outline (contour) images of cells.

The analysis of cell shape was performed using 39 linear and nonlinear parameters, included Area; Circularity; Feret's Diameter; Roundness; Density; Hull's Perimeter; Hull's Circularity; Max/Min Radii from Hull's Centre of Mass; Mean Hull's Radius; Diameter of Bounding Circle; Max/Min Radii from Circle's Centre; Mean Radius from Circle's Centre; Perimeter of cell; Roundness of the outline picture of cells and several methods to calculate the fractal dimension and lacunarity. For more details about the nonlinear parameters, see the software website: <http://rsbweb.nih.gov/ij/plugins/fraclac/FLHelp/UseFracLac.htm>.

The correlation analysis showed that the majority of nonlinear parameters of silhouette images are highly correlated (or non-correlated) with each other, and so most of nonlinear parameters of contour images of cells are (0.8–0.97) ($p < 0.0005$). A high level of correlation between different types of lacunarities and fractal dimensions of silhouette

images was also observed. In addition, there was a high correlation between the density of the image cells and the majority of fractal dimensions and lacunarity of silhouette images (0.84–0.91). Of course, the highest correlations occurred between the parameters describing the similar aspects of cell morphology; however, the parameters were initially selected so as to avoid measuring the same properties in different ways; that is, the parameters were not functionally determined (i.e., parameters “a”, “b” and “c” were not simultaneously included if $c = a/b$).

The factors in the factor analysis were loaded using the Varimax method of orthogonal rotation of the major factor axes. Only the uncorrelated or weakly correlated variables were selected for factor analysis. When making a choice between two correlated variables, the preference was given to the primary variables describing direct features of cell morphology (size, roundness, the average fractal dimension); derivatives and secondary features were eliminated from the analysis.

Seventeen parameters were selected for the factor analysis; 8 of those significantly loaded 3 factors. Parameters that mainly loaded a single factor describe the relatively similar characteristics of cell morphology. Factor 1 was significantly loaded with features of cell size; Factor 2 was essentially loaded with nonlinear parameters of cell morphology; Factor 3 was loaded with the factors of cell roundness. The use of a small number of factors instead of the original variables reduced the number of parameters used, since an excessive number of parameters adds “statistical noise” to the result of cluster analysis and reduces the accuracy of the classification results.

The extracted factors were used as variables in a hierarchical cluster analysis. To equalize the influence of parameters on the results of cluster analysis, the values were normalized by subtracting the mean and dividing the result by the standard deviation. The unweighted Pair-Group method was used as a clustering algorithm. Euclidean distance was used as a measure of distance. The differences between clusters were assessed using the cophenetic correlation coefficient, which was equal to 0.669801 (the normal level of cluster differences). To determine the reliability of the solution, the accuracy of the intercluster differences was determined using the Kruskal-Wallis ANOVA-on-Ranks analysis and pairwise comparisons using the U Mann-Whitney test. Four clusters have been isolated.

Cluster I included very large and fairly symmetrical flattened cells with a large number of processes of approximately equal length and a large area of the cell “body”.

Cluster II combined large cells with a relatively small area of the “body”, often of irregular shape. Some cells in this cluster have very long processes that shift the “body” of cells to the highly asymmetric position compared to the center of the image.

Cluster III combined the elongated cells; this cluster included cells with one long massive appendage acquiring them an extended character, as well as moving amoeboid cells of lamellopodial type, which are elongated transversely to the direction of motion. That is, the elongation of cells combined in cluster III is of different nature.

Cluster IV, the largest one, comprises all the intermediate cell types.

Comparison of the average values for the 17 selected cell parameters in different clusters yielded the following results:

Cluster I: cells belonging to this cluster were significantly greater compared to those in the other clusters for the following parameters: Area, Hull's Circularity, Mean Mass Fractal Dimension. Significant difference from all other clusters was also found for the parameter value Diameter of Bounding Circle.

Cluster II: cells in this cluster were significantly superior to the members of the other clusters for the following parameters: Diameter of Bounding Circle, Mean Mass Fractal Dimension of the outline picture of cells, Average lacunarity calculated for different orientations of the square grid (Mean Λ). Parameters Circularity, Density, The lacunarity based box counting dimension (Mean ΔD) were significantly lower than those for cells in the other clusters. Significant differences were also found for the parameter Roundness of the outline picture of cells.

Cluster III: cells in this cluster were significantly superior to those in the other clusters for the parameter value Max/Min Radii from Hull's Centre of Mass. Compared to the other clusters, this cluster is significantly lower located for the values of the parameters: Mean D box counting dimension of the outline picture of cells, Perimeter, Roundness of the outline picture of cells; it is also located well below for the values of the parameters Roundness and Hull's Circularity.

Significant differences for the cells in cluster IV were found for the following parameters: Mean D box counting dimension, Mean D box counting dimension of the outline picture of cells, The lacunarity based box counting dimension (Mean ΔD).

When considering the two initial parent clusters, which are divided below to yield four clusters, we can see that they also significantly vary for certain parameters: clusters I and II, belonging to one parent cluster are far superior to clusters III and IV for the values of the parameters Perimeter of cell, Mean D box counting dimension of the outline picture of cells, Diameter of Bounding Circle; whereas clusters III and IV are significantly superior to clusters I and II for the value Circularity.

Speaking about the analysis of cell shapes in general, the morphology of neurons, which have so often been described in literature using the fractal analysis methodology, has a lot of distinct morphological features that can be well digitized using the classical morphometric methods (area of the dendritic tree, the number of branch points, cell border roughness coefficient, the total length of dendrites, etc.). A set of linear morphological features allows most researchers to adequately typologize neurons without fractal formalism. The flattened amoeboid cells represent a variation of "irregular" shapes, which makes the standard description with the use of such concepts as processes, filopodia, lamellipodia, "body" cells poorly applicable because of transitional shapes. Discontinuities inside the cellular layer of a flattened cell may be the fractures of plasma membrane being indistinguishable from the closed down pseudopodias; the process area can be larger than the area of the part of the cell containing a nucleus; the cytoplasm and plasma membrane of highly flattened cells can be fragmented into separate "drops".

Having such a variety of shapes, one can use only the most general linear morphometric characters reflecting the cell size, its density, perimeter, which describes the size and asymmetry of the cell, the convex hull and the bounding circle, and a number of derivatives of these parameters. Nonlinear methods of morphology description broaden the range of the characteristics under analysis.

The visually identifiable and numerically characterized cell types of *C. brevisiphonata* may either belong to different morphological and physiological types of hemocyte population or to be cells of the same type that *in vitro* exhibits various stereotypical responses to cell behavior. These issues require further research that can be conducted using the statistical methodology described in this article.

The study of the interrelations between the parameters of linear and quasi-fractal organization of cells, on the one hand, and structural, functional, and biological characteristics of cells, both in nature and in the experiment, on the other hand, is of great value, first, for the use of the quasi-fractal organization as indicators of cell processes, and, second, for modeling morphogenesis at the cellular level using nonlinear analysis of shapes.

Types of relationships between mollusks and sea anemones

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The behavioral and ecological relationships between mollusks and sea anemones frequently occur in nature. There are symbiotic relationships in which different species of mollusks and sea anemones have a close and often long-term interaction. In a facultative symbiotic relationship, the animals are not dependent upon the relationship, and therefore can exist independently of one another under natural conditions. In an obligate relationship, at least, one of the symbionts has become entirely dependent upon the relationship for survival. Predator-prey relationships are other interactions between mollusks and sea anemones. At least, four types of relationships between mollusks and sea anemones are recognized, ranging from parasitism and predation, where one species benefits and the other species is harmed, to mutualism, where both species benefit from the relationships.

Harmful relationships

Parasitism. Parasitism is a symbiotic relationship between species, where one species, the parasite, benefits at the expense of the other, the host. Parasites feed on host tissue and can be found within (endoparasites) or outside (ectoparasites) of the host body. Parasites typically do not kill their hosts, but can significantly weaken them indirectly causing the host to die via illness. Wentletraps (Gastropoda: Epitoniidae) are known to be associated with sea anemones (Anthozoa: Actiniaria) and other coral polyps in various part of the World Ocean (Fig. 1A). They prefer anemones inhabiting a mixture of sand, coral-rubble or shell-gravel, in which they bury themselves and with which they agglutinate their egg capsules. The live epitoniid species are clustered around or underneath the host sea anemone's pedal disc or attached to the column of the host anemones. More than 100 species of mollusks are adapted to a parasitic mode of life, being facultative ectoparasites, though they can be predators too. Wentletraps feed by insertion of its proboscis into the sea anemones column and sucking up the body tissues and fluids or eat small (less than 1 cm in height) anemones and swallow these entirely. Though *Epitonium echinaticostum* (Orbigny, 1842), for example, feeds on the tentacles of sea anemones by enclosing the tip of a tentacle with its proboscis and then eating it. The same behaviour has been observed in *E. albidum* (d'Orbigny, 1842), *E. tinctum* (Carpenter, 1864) and *E. indianorum* (Carpenter, 1864) [Kokshoorn et al., 2007]. Wentletraps locate its prey, at least, over short distances, by chemosensory recognition [Perron, 1978]. They produce a toxin fluid that is thought to be an anesthetic allowing the animal to pierce the body of resisting anemone with its proboscis [Ricketts et al., 1985]. The snails may

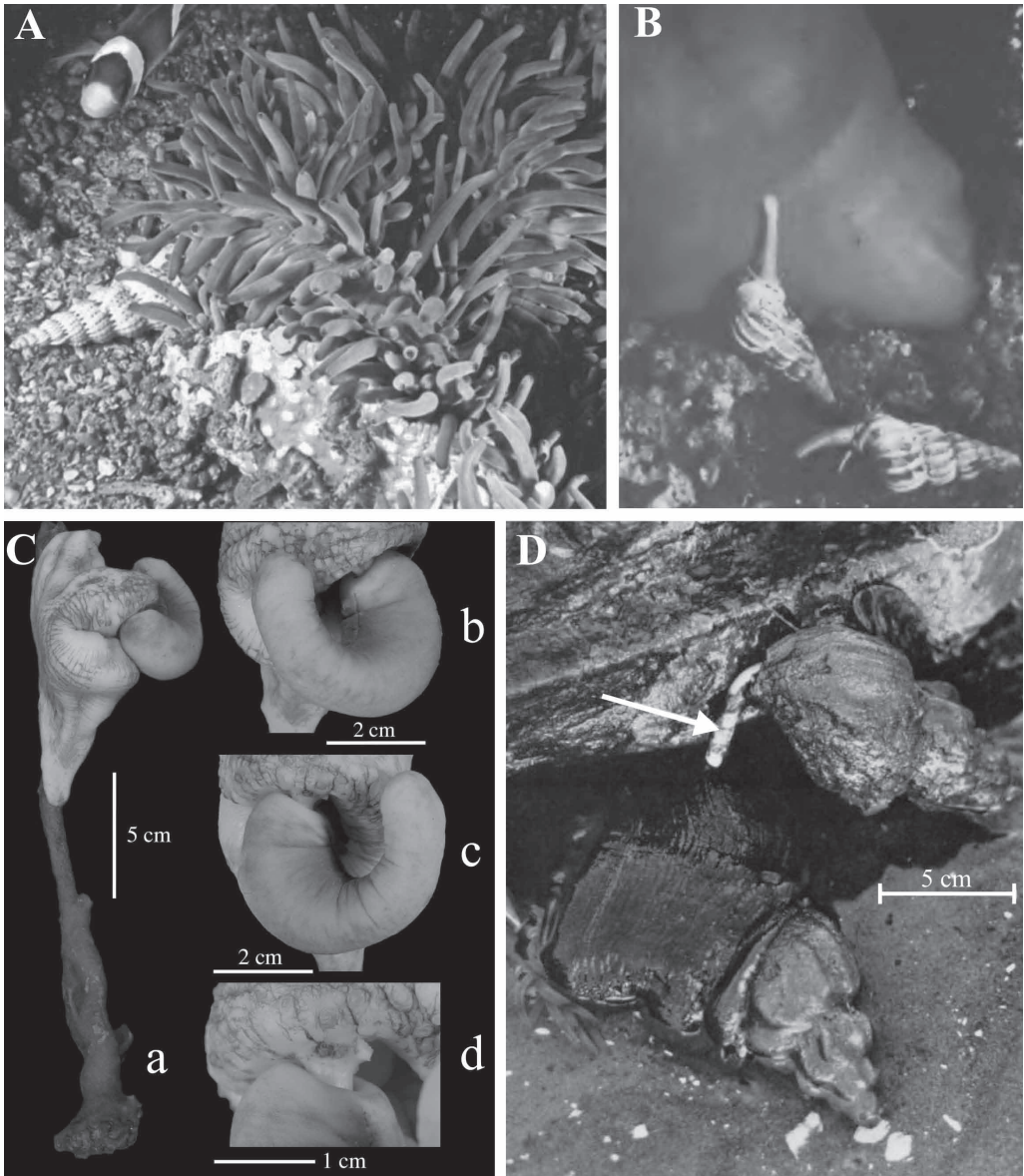


Fig. 1. Harmful relationships of mollusks and sea anemones. **A** – wentletrap *Cirsotrema varicosum* (Lamarck, 1822) under the sea anemone *Heteractis crispa* (Hemprich et Ehrenberg in Ehrenberg, 1834) [after Kokshoorn et al., 2007]; **B** – specimens of *Epitonium greenlandicum* attacking a large *Metridium senile* (height 8 cm) [after Perron, 1978]; **C** – *Neomenia yamamotoi* attached to a sea anemone: a – whole view of the specimen with the sea anemone, b, c – left and right lateral views of *N. yamamotoi* respectively, d – enlarged view of oral region, showing the body wall of the sea anemone sucked into the mouth of *N. yamamotoi* [after Sasaki, Saito, 2005]; **D** – *Beringius kennicottii* (Dall, 1871) feeding on *Urticina crassicornis* (Müller, 1776), the arrow indicates the proboscis of the feeding snail [after Shimek, 1980].

extend their proboscis to up to three-four times the shell-length towards the column or the tentacles of the host [Robertson, 1993]. Many (but not all) of wentletraps live with a particular genus or species of sea anemones upon which they feed (*E. echinaticostum* with sea anemone *Bunodeopsis globulifeiera* (Duchassaing, 1850), *Opalia funiculata* (Carpenter, 1857) shows a preference for *Anthopleura elegantissima* (Brandt, 1835), *E. phymanthi* Robertson, 1993 – *Phymanthus crucifer* (Le Sueur, 1817), *E. greenlandicum* (Perry, 1811) – *Metridium senile* (Linnaeus, 1761) (Fig. 1B), though it can feed on at least 6 species of anemones). In general, wentletraps are not species-specific in terms of their prey and capable of feeding on several species of sea anemones. Epitoniids can vary their host preferences from place to place. It is suggested that the epitoniid species and sea anemones could be involved to some extent in a parasite-host or predator-prey relationships. In some cases, it may not be possible to identify ecological factors which determine whether an epitoniid functions as an ectoparasite or as a predator. Many sea anemones occur on hard substrates (the stone and rock ledges) and are not accessible to the infaunal wentletraps. Consequently, wentletraps should forage for food among small anemones on mixed mud-cobble bottom. Habitat restraints, especially the lack of hiding places near sea anemones, prevent the wentletraps from being ectoparasitic. It is suggested that epitoniids are able to occupy a purely ectoparasitic niche only in areas where both suitable environment for the host sea anemones and for wentletraps are present [Perron, 1978].

Predation. Predator-prey relationships are another interactions between mollusks and sea anemones. In that case, one of organisms acts as a predator that captures and feeds on the other. Predators may or may not kill their prey prior to feeding on them, but the act of predation often results in the death of its prey. Among mollusks, the soft-bodied, marine gastropods Nudibranchia are important predators of sea anemones, particularly those belonging to the family Aeolidiidae. Although sea anemones are a component of most nudibranch's diet, widespread amphiboreal species *Aeolidia papillosa* (Linnaeus, 1761) feeds almost entirely on many various species of anemones [Ottaway, 1977]. Nudibranchs that feed on sea anemones must defend themselves from the prey's nematocysts. It appears that mucus from *A. papillosa* inhibited the discharge of nematocysts from sea anemone tentacles [Greenwood et al., 2004].

There are other examples of predator-prey relationships between mollusks and sea anemones. Solenogastres are a subclass (in other classification – class) of worm-like, small, shell-less mollusks. These mollusks are predators, feeding predominantly on Cnidaria including sea anemones. Some groups of Solenogastres, (genera *Nematomenia* Simroth, 1893, *Strophomenia* Pruvot, 1899, *Epimenia* (Thiele, 1897), and others) live epizoically on sea anemones. In this case, the Solenogastres use their hosts both as food and as substrate. Direct well-documented observations of feeding these mollusks, however, are not numerous. *Neomenia yamamotoi* Baba, 1975 (Neomeniidae) from the Pacific coast of middle Honshu (763–796 m in depth) was collected with the head part firmly attached to the upper body wall of a sea anemone of family Hormathiidae (Fig. 1C). The observations revealed that *N. yamamotoi* sucks the tissue of a sea

anemone forcefully [Sasaki, Saito, 2005]. Also some species of Buccinidae are predators of relatively large sea anemones *Urticina* Ehrenberg, 1834 from the northeastern Pacific and Arctic waters (Fig. 1D) [Shimek, 1980].

Beneficial relationships

Mutualism. Mutualism is symbiosis where both species benefit from the relationship. Symbiotic relationships include those associations in which sea anemones live on mollusks (ectosymbiosis). An instance of such relationship is mutualism a hormathiid sea anemone, *Allantactis parasitica* Danielssen, 1890 and a gastropod, *Buccinum undatum* Linnaeus, 1758 (Buccinidae). Sea anemones were found living as epibionts (1–6 sea anemones per snail) on numerous gastropods at depths of 725–1100 m along the continental slope of eastern Canada. Although *A. parasitica* was occasionally found on other substrata (i.e. empty shells, pebbles), laboratory trials confirmed that they preferably associate with living gastropods (Fig. 2B). This mutualistic relationship may have evolved in response to predation pressure of, for example, sea stars *Leptasterias polaris* (Müller et Troschel, 1842) and *Crossaster papposus* (Linnaeus, 1767). *L. polaris* evokes a negative response from the snails. Snails with anemones were able to thwart the sea star's approach. In fact, 90% of the time when the anemones were under observation, their tentacles were outspread, on guard and ready to defend their mobile home. The while *C. papposus* is predator of sea anemones. Hence, anemones were protected from their predator by sticking with the snail [Mercier, Hamel, 2008].

Many sea anemones live attached to any suitable hard substrata including shells of mollusks. However some species of sea anemones are known to be carried by living mollusks more or less regularly. For instance, sea anemone *Anthosactis nomados* White, Wakefield Pagels et Fautin, 1999 lives attached to shells of a scaphopod *Fissidentalium actiniophorum* Shimek, 1997 (Dentaliidae) (Fig. 2A) on the soft-sediment abyssal plain (about 4000–5000 m depths) of the northeastern Pacific. There is a hypothesis that anemone-mollusk symbioses are mutualistic. *A. nomados* protects the aragonitic scaphopod shell from dissolution in this environment where the sea water is undersaturated with respect to CaCO₃. Also, sea anemones have increased access to food as they are carried across the sea floor by the mollusk. *F. actiniophorum* offers the anemone a benefit in addition to the hard substratum for attachment, and the anemone may protect its host from predators. However, there is another point of view. Whether the symbiosis of sea anemones and scaphopods is mutually beneficial or not is unclear. Arrowheads of some scaphopods indicate areas of slight shell erosion at the edges of the attachment of the sea anemones [White et al., 1999].

Commensalism. Commensalism is a symbiotic relationship in which one individual benefits while the other is neither helped nor harmed. Commensal associations between mollusks and sea anemones are rare and restricted to some known cases. *Nipponomontacuta actinariophila* Yamamoto and Habe, 1961 (Lasaeidae) is a small Japanese bivalve that has been found attached immediately outside the ring of tentacles of a sea anemone

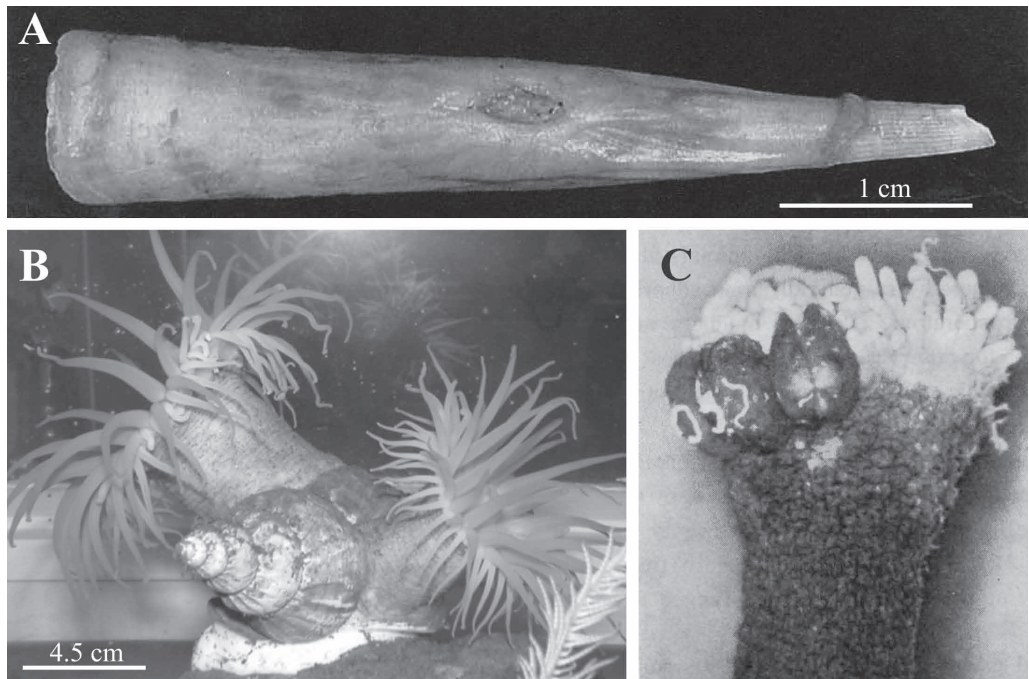


Fig. 2. Beneficial relationships of mollusks and sea anemones. **A** – sea anemone *Anthosactis nomados* attached to a scaphopod shell [after White et al., 1999]; **B** – sea anemone *Allantactis parasitica* living as epibionts on the gastropod *Buccinum undatum* [after Mercier, Hamel, 2008]; **C** – *Nipponomontacuta actinariophila* attached immediately outside the ring of tentacles of the sea anemone *Halcampella maxima* [after Habe, 1973].

Halcampella maxima Hertwig, 1888. Details of the relationship are not known, except that three specimens attaching closely to each other outside of tentacles were illustrated by Habe [1973] (Fig. 2C). Later, it was found what the host species was misidentified in the original paper, and it was confirmed recently that records of *N. actinariophila* were a symbiotic bivalve species with their host, sea anemone genus *Telmatactis* Gravier, 1916. [Goto et al., 2012]. A single bivalve *Halcampicola tenacis* Oliver, 1993 (Galeommatidae) was found on a sea anemone *Halcampoides* Danielssen, 1890 near Rottneest Island off Perth, SW Australia. Several individuals of *Mysella gregaria* Rotvit, Lützen, Jespersen et Fox, 2007 (Lasaeidae) were collected from the column of an intertidal, burrowing and unidentified sea anemone from Wrightsville Beach, North Carolina, USA. It seems fairly obvious that all sea anemone-associated bivalve species are not specifically interrelated [Rotvit et al., 2007].

The females of an intertidal gastropod *Neptunea pribiloffensis* (Dall, 1919) (Buccinidae) near Homer, Alaska lay their egg capsules in a large “corn-cob” shaped capsular mass near the relatively common large sea anemones *Urticina*. Some boreal and arctic mollusks often have reduced planktonic larval stages. This phenomenon is particularly well documented in gastropods from northern seas, some of which

have long encapsulated developmental periods (3–6 months). The risks during long developmental time include mortality caused by predation and environmental instability. Observations support the hypothesis that the anemone babysitter protects the capsular masses from predations by the sea urchins, and, perhaps, from other predators as well. The snails obtain benefit from depositing its egg capsules near the sea anemones [Shimek, 1981].

Symbiotic relationship between sea anemones and hermit crab with gastropod shell is usually known as an ecological triangle. For some species, supporting one or more sea anemones on the shell can scare away predators. The sea anemone benefits because it is in position to consume fragments of the hermit crab's meals, and crab transfers anemone from one shell to another. Even a case of an anemone/crab relationship was observed where no shell is involved, but the anemone secretes a shell-like material that forms around the crab. However, that relationship as a matter of fact is symbiosis between hermit crabs and sea anemones.

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**Vesicomyninae (Bivalvia: Vesicomynidae)
of the Northwestern Pacific**

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The Vesicomyninae Dall et Simpson, 1891, one of the two subfamilies of the family Vesicomynidae, comprises deep-water tiny bivalves distributed from mid-slope to hadal depths in all large oceanic basins. Up to now vesicomyns are a little-known group with uncertain taxonomy, being often considered as a synonym of the family Kelliellidae P. Fischer, 1887.

Presently Vesicomyninae comprises one genus *Vesicomya* Dall, 1886 with about 14 described species. Vesicomyns are mostly millimetric in size with maximum shell length to 14 mm. In contrast to their larger-sized relatives, pliocardiiins, which are living in symbiosis with sulphur-oxidizing bacteria, chemosymbiotrophy has not been proved for vesicomyns so far. At the same time vesicomyns are an important constituent of deep-water trench communities where they were recovered in very large abundances of thousands specimens in one trawl catch.

At present three species have been recorded from the Northwestern Pacific: *V. pacifica* (Smith, 1885), *V. profundus* Filatova, 1971 and *V. sergeevi* Filatova, 1971. The former species is known from the Mid North Pacific at depth of 5304 m, and the two latter occur in the Kuril-Kamchatka Trench, *V. profundus* – at depths of 7120–9050 m and *V. sergeevi* – at 6090–9530 m at depths of 8125–9530 m.

During recent German-Russian deep-sea expedition KuramBio on board of the R/V Sonne, cruise no. 223, to the Kuril-Kamchatka Trench and adjacent abyssal plain new material on vesicomyns was collected from the depths of about 5170–5800 m. Morphological analysis showed that the collection includes two new species. One species is close to the type of the genus, *V. atlantica* (Smith, 1885), and as well to the representatives of the genus, recorded earlier from the North Pacific. There are such features in common as narrow hinge margins with thin plate-like teeth and the presence of two pairs of demibranchs. The second new species differs from *Vesicomya* s.s. by broader

hinge margin with more radiating teeth and the presence of only one, inner, pair of demibranchs. In contrast to the chemosymbiotic pliocardia that often have only one pair of demibranchs, gill filaments in the new vesicomyn are not thickened and presumably do not contain symbiophilic bacteria. Results of molecular analysis of *Vesicomyn* s.s. new species based on COI sequences, suggests close relationships of vesicomyns and pliocardia. Newly received morphological and molecular data are important for understanding of plesiomorphic character states and trends of morpho-functional adaptations within the vesicomynids in general.

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**Chemosymbiotic vesicomyids
(Bivalvia: Vesicomyidae: Pliocardiinae)
from cold seeps of the Sea of Okhotsk**

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Bivalves of the subfamily Pliocardiinae Woodring, 1925 (Vesicomyidae) are among the most prominent components of chemosynthetic communities. All studied pliocardiaans are highly specialized molluscs containing within their gills sulphide-oxidizing chemosymbiotic bacteria on which they rely for nutrition.

In the Sea of Okhotsk vesicomyids had been described before than extensive areas of methane seepage were discovered in this region. Four species assigned to four genera were recorded [Scarlato, 1981]: *Waisiuconcha katsuae* (Kuroda in Habe, 1952); *Akebiconcha soyoae ochotensis* Scarlato, 1981; *Archivesica ochotica* Scarlato, 1981 and *Calyptogena rectimargo* Scarlato, 1981. Three of these species were considered as endemics of the Sea of Okhotsk. Interest to these records increased after understanding the chemosymbiotic nature of vesicomyids and their strict association with reducing habitats.

Despite the vesicomyids are restricted to reducing environments, many of them have really broad distribution ranges. Using molecular methods it was approved that six species occur in reducing habitats both off Japan and off the North America [Kojima et al., 2004; Audzijonyte et al., 2012], their distribution ranges thus being trans-Pacific. In this context, vesicomyids of the Sea of Okhotsk are of a special interest since they are endemics of the sea or part of broadly distributed Pacific fauna.

During the 61st cruise of the RV “Akademik M.A. Lavrentyev”, extensive material on two vesicomyid species, *A. soyoae ochotensis* and *A. ochotica*, was collected. Preliminary morphological and molecular data show that at least *A. soyoae ochotensis* is widely distributed occurring both in the western and eastern regions of the Pacific.

It was shown that in spite of co-occurring of these species on a large scale, they differ in microdistribution patterns and this is related to narrow ecological niche specialization. *A. ochotica* does not form large aggregations, it is more mobile and

seemingly prefers habitats with soft sediment and higher sulphide level. In contrast, *A. soyoae ochotensis* often lives in dense clusters, in more solid sediment and at sites with presumably lower methane fluxes.

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Intertidal gastropod mollusks of the Far Eastern Marine Biosphere Natural Reserve

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Gastropods are one of the most widespread groups of bottom organisms. Their role for the intertidal and upper subtidal zones is particularly high. Investigations of benthic gastropods in Peter the Great Bay, including the Far Eastern Marine Biosphere Natural Reserve, are topical in connection with the increased anthropogenic pressure and the threat of introduction of new species.

The aim of this study was to determine the present species composition and distribution of gastropods in the intertidal zone of the Reserve. The material was samples of macrobenthos collected in the eastern and southern sectors of the Reserve in the summer of 2012. In the eastern sector, investigations were conducted in June in Srednyaya Bay (continental coast, site I) and in Molchansky Bay (Bolshoy Pelis Island, site II). In the southern sector, investigations were conducted in Pempzovaya Bay (coast, site III, July–August) and in Kalevala Bay (coast, site IV, August), as well as in Zapadnaya Bay (Furugelm Island, site V, July) and in the intertidal at Cape Ostrovok Falshivy (site VI, July–August).

Sampling was carried out on various types of bottom substrates according to the standard chorological methods. A total of 140 quantitative and qualitative samples were collected along 17 hydrobiological transects. Gastropoda were found in 115 samples. The water temperature varied from 18 to 22°C and the salinity was 28–34‰.

In 2012, 26 species of gastropods belonging to 16 genera, 14 families, 9 superfamilies, and 5 clades were found in the intertidal zone of the reserve. The largest families (Lottiidae and Littorinidae) were represented by 7 and 5 species, respectively. One species, *Lottia tenuisculpta* Sasaki et Okutani, 1994, is new for the malacofauna of the reserve. An average of 14–15 species were found in the intertidal of each site, with the highest number (19) at Furugelm Island and the smallest number (11) in Kalevala Bay. Five species were found at all sites: *Falsicingula mundana*, *Littorina sitkana*, *L. squalida*, *Lottia kogamogai* and *Nucella heyseana*. At five sites, three out of six species were encountered: *Lottia persona*, *L. versicolor*, and *Nipponoacmaea moskalevi*. At four sites, 6 species were found: *Ansola angustata*, *Homalopoma sangarense*, *Littorina brevicula*, *L. mandshurica*, *Mitrella burchardi*, and *Pusillina plicosa*. Thus, the proportion of abundant and common species was 61% of the species composition of the gastropod fauna. The number of rare species found either only in a sample or only at a site or in single numbers was not high, 17%. These were *Epheria turrita*, *Lottia pelta*, *Ocenebra inornata*, and *Olivella borealis*.

A list of intertidal gastropods of the Reserve based on the results of studies in 2012:

Clade **Patellogastropoda**

Family **Lottiidae**

1. *Lottia kogamogai*

Sasaki et Okutani, 1994

At all localities; previously recorded only for Bolshoy Pelis Island and Furu-gelm Island.

2. *L. ochracea* (Dall, 1871)

Srednyaya and Zapadnaya bays; previously recorded as a common intertidal species.

3. *L. pelta* (Rathke, 1833)

Molchansky Bay; previously recorded as a common intertidal species.

4. *L. persona* (Rathke, 1833)

Molchansky, Pempzovaya, Kalevala, and Zapadnaya bays, as well as Cape Ostrovok Falshiviy.

5. *L. tenuisculpta*

Sasaki et Okutani, 1994

Pempzovaya and Zapadnaya bays; a new record for the Reserve fauna.

6. *L. versicolor*

(Moskalev in Golikov et Scarlato, 1967)

At all localities, except Kalevala Bay; previously recorded as a common intertidal species.

7. *Nipponoacmaea moskalevi*

Chernyshev et Chernova, 2002

At all localities, except Srednyaya Bay; previously recorded for the Reserve as *Tectura concinna* (Lischke, 1870) and *T. schrenkii* (Lischke, 1870); a common intertidal species.

Clade **Vetigastropoda**

Family **Trochidae**

8. *Tegula rustica* (Gmelin, 1791)

Srednyaya and Zapadnaya bays; an abundant species in Minonosok Bay (data for 2012).

Family **Turbinidae**

9. *Homalopoma sangarense*

(Schrenck, 1861)

Srednyaya, Pempzovaya, Molchansky, and Zapadnaya bays; previously recorded as an abundant intertidal species.

Clade **Calyptraeoidea**

Family **Littorinidae**

10. *Littorina brevicula*

(Philippi, 1844)

Srednyaya, Molchansky, Pempzovaya, and Zapadnaya bays; previously recorded as a common intertidal species.

11. *L. mandshurica*

(Schrenck, 1861)

Srednyaya, Molchansky, Pempzovaya, and Zapadnaya bays; previously recorded as a common intertidal species.

12. *L. sitkana* Philippi, 1846

At all localities; an abundant species.

13. *L. squalida*

Broderip et Sowerby, 1829

At all localities; an abundant species.

14. *Epheria turrita*

(A. Adams, 1861)

Pempzovaya Bay; previously recorded as a common intertidal species.

Family **Rissooidae**

15. *Pusillina plicosa* (Smith, 1875)
Molchansky, Srednyaya, Kalevala, and Zapadnaya bays; previously recorded as an abundant intertidal species.

Family **Assimineidae**

16. *Assiminea lutea*
(A. Adams, 1861)
Mouth of Talmi Lagoon (near Cape Ostrovok Falshivy), freshened conditions; previously recorded as a rare species.

Family **Barleecidae**

17. *Ansola angustata* (Pilsbry, 1901)
Srednyaya, Molchansky, Pemzovaya, and Zapadnaya bays; previously recorded as a common intertidal species.

Family **Falsicingulidae**

18. *Falsicingula athera*
Bartsch in Golikov et Scarlato, 1967
Pemzovaya and Molchansky bays; previously recorded as a common intertidal species.

19. *F. mundana* (Yokoyama, 1926)
At all localities; an abundant intertidal species.

Family **Iravadiidae**

20. *Iravadia elegantula*
(A. Adams, 1861)
Mouth of Talmi Lagoon (near Cape Ostrovok Falshivy), freshened conditions.

Clade **Neogastropoda**

Family **Muricidae**

21. *Ocenebra inornata*
(Récluz, 1851)

Pemzomaya Bay in the southern sector; previously recorded in Minonosok Bay in the western sector of the reserve; a rare species.

22. *Nucella heyseana*
(Dunker, 1882)

At all localities; an abundant intertidal species.

Family **Olivellidae**

23. *Olivella borealis*
Golikov in Golikov et Scarlato, 1967
Zapadnaya Bay, Furugelm Island; previously recorded only for the southern sector of the Reserve.

Family **Columbellidae**

24. *Mitrella burchardi*
(Dunker, 1877)
Molchansky, Srenyaya, Pemzovaya, and Zapadnaya bays; previously recorded only in Minonosok Bay in the western sector of the Reserve.

Family **Nassariidae**

25. *Nassarius fraterculus*
(Dunker, 1860)
Molchansky, Kalevala, and Zapadnaya bays in the southern and eastern sectors of the Reserve; previously recorded as *Tritia fratercula* (Dunker, 1860) only in Minonosok Bay in the western sector.

Clade **Pulmonata**

Family **Siphonariidae**

26. *Williamia oblongata*
(Yokoyama, 1926)
Sandy intertidal at Cape Ostrovok Falshivy; a rare species.

In the upper horizon of a stony-rocky intertidal of the reserve, the dominant species were *L. brevicula* at sites I, IV, and V, *L. sitkana* at site II, and *L. mandshurica* at site III. In the stony-sandy intertidal of site VI, the dominant was *L. kogamogai*. The subdominant species were *L. sitkana* (sites I and V), *L. mandshurica* (site IV), *L. kogamogai* (site II), *L. brevicula* (site III). The mid-intertidal zone was dominated by *L. brevicula* (site I), *L. sitkana* (site II), *L. mandshurica* (site V), and *L. squalida* (sites IV and VI). At site III, *L. brevicula* and *L. sitkana* dominated together. The subdominant species were *L. mandshurica* (site I), *L. squalida* (sites III and V), *L. kogamogai* (site II), and *L. versicolor* (site VI). In the lower intertidal horizon, the dominants were *L. squalida* (sites III and IV), *N. heyseana* (sites I and VI), *H. sangarensis*, and *F. mundana* (site V). The subdominants were *H. sangarensis* (sites III and V), *F. mundana* (sites I, II, and V), and *N. moskalevi* (site VI).

On the whole, *L. brevicula* reached maximum density (1125 indiv./m²) and biomass (632 g/m²) on an intertidal shore of large-sized boulders in Kalevala Bay (site IV). *L. sitkana* had maximum density (7600 indiv./m²) and biomass (570 g/m²) on a shore of cobbles and boulders of varying size in Molchansky Bay (site II). *L. squalida* and *L. mandshurica* had maximum density (430 and 1532 indiv./m², respectively) and biomass (253 and 396 g/m², respectively) on a stony intertidal of Pemzovaya Bay (site III).

Thus, out of 26 species of Gastropoda found in the intertidal zone of the Reserve, two species, *L. brevicula* and *L. sitkana*, dominated on hard bottoms at most sites. In the eastern sector, *L. brevicula* reached maximum density and biomass in the upper horizon of a stony-rocky intertidal, while in the southern sector the maximum values were observed in the upper horizon of a shore of large-sized boulders. *Littorina* was accompanied by *Lottia* spp. at most sites and only at Cape Ostrovok Falshivy *L. kogamogai* was the leading species. This rare species became common to the continental coast of the Reserve in the last decade.

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Carl Lischke historical molluscan collection in the Zoological Institute, St.-Petersburg (Birileff'schen Sammlung)

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Carl Emil Lischke (1813–1886) was one of the pioneers of Japanese marine malacology who published “Japanische Meeres-Conchylien”, the Japanese molluscan fauna in three volumes [Lischke, 1869b, 1871, 1874], the most extensive, detailed and systematic work on mollusks of Japan at that time (Fig. 1). R. von Cosel [1998] described life and malacological contribution of C.E. Lischke and provided a list of 64 Japanese marine species of Mollusca introduced by C. Lischke, along with illustrations of 20 type lots of the 36 taxa, the type material of which was found in the Löbbecke Museum in Düsseldorf. Lischke sold his collection and his large malacological library in 1873 to the pharmacist Theodor Löbbecke, a long-time friend and owner of one of the largest mollusk collections of that time in Germany [Cosel, 1998]. The collection of Löbbecke, donated by his widow to the City of Dusseldorf in 1904, was combined with the aquarium in 1948 and called now *Aquazoo und Löbbecke-Museum*.



Fig. 1. Carl Emil Lischke (1813–1886)
(source: www.tumblr.com).

C. Lischke never traveled to Japan but he had extensive contacts among diplomats, merchants and sea captains. One of these was a Russian captain Nikolay Alekseevich Birilev (December 9 (21), 1829–May 24 (June 5) 1882), a Russian Rear-Admiral (Fig. 2). He was mentioned as “Russischen Flügel-Adjutanten, Herrn Nicolaus *Birileff*...” in the second volume of the Lischke’s monograph [Lischke, 1871, p. 1], and then often in the text with a locality name “**Nagasaki, Birileff**” or “**Birileff’schen Sammlung**” (collection of Birileff). Nikolay A. Birilev served in the Russian Imperial Black Sea Fleet from 1845 to 1855, and he is known in Russia as the hero of the Siege of Sevastopol (1854–1855) during the Crimean War of the 1853–1856. In 1859–1863, N.A. Birilev commanded the screw frigate *Posadnik*, and as a leader of a force of two screw clippers he completed a round-the-world cruise from Kronstadt

to the mouth of the Amur River, then along the Japanese coast, and back to Kronstadt. So, the material studied by Lischke and published in his monograph, came from this cruise. Lischke must have borrowed the Birilev's material and must have returned most of it to the St.-Petersburg Zoological Museum after study except for some duplicates (at least, three species of gastropods), which he retained (R. von Cosel, e-mail message, January 12, 2013). When working with arcid (Arcidae) collections in the Zoological Institute, then the USSR Academy of Sciences (now the Zoological Institute, Russian Academy of Sciences in St.-Petersburg; hereinafter referred to as ZIN) in the 1989–1991, I noticed that some old lots from Japan (“Jedo”, “Nagasaki”) were marked with “Lke” (Fig. 3), but at that time I did not see the handwriting of Lischke published later by von Cosel [1998]. After many years break, I have finally located the Lischke's bivalve collection from Japan. Recently, R. Houart et al. [2013] discovered syntypes of *Trophon birileffi* Lischke, 1871 (now *Bedevina birileffi* (Lischke, 1871), a muricid gastropod) in the same collection. Previously, von Cosel [1998] mentioned that material from the Birilev's collection is presumed to be in the Zoological Museum of St.-Petersburg, Russia.

In fact, Lischke in the second volume of his monograph [1871] referred to the Birilev's collection so many times and in many cases to the only locality in Japan that I have an impression that a significant portion of the studied material from Japan in the possession of Lischke belonged to the Birilev's collection. Lischke [1871] mentioned dozens of gastropods and 21 species of bivalves with the locality “Nagasaki, Birileff” (in original spelling, in order of appearance in the text): *Cytherea indecora* Philippi, *Tellina diaphana* Deshayes, *Tellina pallidula* Lischke, *Tellina rutila* Dunker, *Tellina inquinata* Deshayes, *Petricola mirabilis* Deshayes, *Lucina pisidium* Dunker, *Diplodonta orbella* Gould, *Kellia subsinuata* Lischke, *Cardita leana* Dunker, *Cypricardia vellicata* Reeve, *Arca kraussii* Philippi, *Arca domingensis* Lamarck, *Mytilus atratus* Lischke, *Modiola senhausii* Reeve, *Modiolaria divaricata* Philippi, *Lithophagus aristatus* Solander, *Lithophagus nasutus* Philippi, *Perna vulsella* Lamarck, *Lima squamosa* [Lamarck],



Fig. 2. Nikolay Alekseevich Birilev (1829–1882) (source: <http://commons.wikimedia.org/wiki/File:Birilevna.jpeg?uselang=ru>).

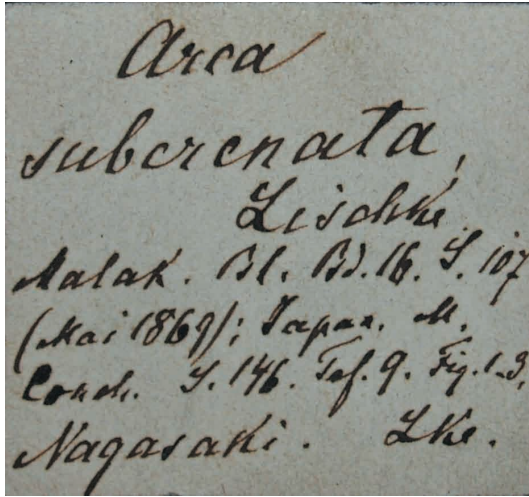


Fig. 3. An example of the label and hand-writing of C.E. Lischke (collection of the Zoological Institute, Russian Academy of Sciences).

with the name of Birlev. However, as we can see from the arcid material, at least, six arcid species collected in Nagasaki and Jedo (now Tokyo) were returned by Lischke to the Zoological Museum in St.-Petersburg, so they were presumably collected by Birlev, but this was not mentioned in the text of his books. Consequently, the collection in St.-Petersburg may contain more material studied by Lischke, which can be identified by his handwriting.

At present, I identified 7 species of Arcidae labeled by Lischke in the ZIN collection: *Arca kraussii* Krauss, 1848 (= *Arca avellana* Lamarck, 1819), *Arca obtusa* Reeve, 1844 (= ?*Barbatia virescens* (Reeve, 1844)), *Arca decussata* G.B. Sowerby I, 1833 (= *Barbatia decussata* (G.B. Sowerby I, 1833)), *Arca decurvata* Lischke, 1869 (= ?*B. virescens*), *Arca domingensis* Lamarck, 1819 (misidentification of *Acar congenita* (Smith, 1885) or *Acar plicata* (Dillwyn, 1817)), *Arca subcrenata* Lischke, 1869 (= *Anadara subcrenata* (Lischke, 1869)) and *Arca granosa* Linne, 1758 (= *Anadara granosa* (L., 1758)). In total, in three volumes Lischke enumerated ten species of Arcidae, described one new species (*A. subcrenata*) [Lischke, 1869a] and proposed a new name (*Arca decurvata* Lischke, 1869 nom. nov. pro *Arca obliquata* Reeve, 1844 non *Arca obliquata* W. Wood, 1828). So, the collection contains the syntypes of one arcid species, *A. subcrenata*, an important commercial Asian mollusk.

Later, we searched for other species (jointly with Dr. Elena M. Chaban) and checked a hand-written catalogue of the ZIN collection of molluscs and found out that the catalogue contains *T. pallidula* and *M. atratus* (possible types) but we did not check the collection yet. Two other species (non-types), *T. diaphana* (= *Serratina diaphana* (Deshayes, 1855)) and *T. rutila* (= *Moerella rutila* (Dunker, 1860)) were found in the

Pecten irregularis [Sowerby]. We enumerate these bivalve species in order to indicate their possible presence in the collection of the ZIN. Three species (*T. pallidula* = *Nitidotellina pallidula* (Lischke, 1871); *K. subsinuata* = *Squillaconcha subsinuata* (Lischke, 1871); *M. atratus* = *Xenostrobus atratus* (Lischke, 1871)) from the Birlev's collection were described as new, thus, their syntypes should be in the general collection of bivalves of the ZIN as pointed out earlier by von Cosel [1998].

Nagasaki is also often mentioned as a habitat in the first and third volume of the Lischke's monograph [1869b, 1874] but without association

catalogue as identified by Lischke. This work will be continued to locate all Lischke and Birilev materials in the ZIN; a separate paper on Lischke's arcids with comments on species taxonomy is being prepared.

I am grateful to Mrs. Raisa A. Pikalova and Dr. Elena M. Chaban (ZIN) for help in collection study.

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**Phylogenetics of the gastropod genus *Nucella*
(Neogastropoda, Muricidae):
species identities, timing of diversification,
and correlated patterns of life-history evolution**

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Despite its importance as a model system in numerous fields of biology, no phylogenetic analysis with every widely recognized species of *Nucella* has been conducted. We have analyzed ~4500 base pairs of DNA from six different genes (three mitochondrial, three nuclear) from each taxon in the genus. Our results showed western Pacific *Nucella heyseana* and *Nucella freycinetii* as highly distinct and distantly related, but found no evidence that *N. elongata* is distinct from *N. heyseana*. We also resolved *N. heyseana* as the closest living relative of the North Atlantic *N. lapillus*, and, using the fossil record for calibration, inferred a minimum separation time between Atlantic and Pacific lineages of at least 6.2 MY, slightly pre-dating the opening of the Bering Strait. Comparative analyses showed egg size to be highly evolutionarily labile, but also revealed a highly significant negative relationship between egg size and the nurse-egg-to-embryo ratio. The negative correlation indicates that evolutionary changes in egg size among species are balanced by changes in the number of nurse eggs allocated to each offspring, indicating that interspecific variation in the nurse-egg-to-embryo ratio has not been driven by divergent selection on hatching size, but may instead be a response to variation in other factors, such as parent-offspring conflict.

Phenotypic divergence and convergence of the bradybaenid land snails in Northeast Asia

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Understanding the mechanisms of genetic diversity and how they lead to phenotype diversity remain a fundamental question in evolutionary biology. Although mechanisms of radiations were still not fully understood, ecological factors have been considered as a major synthesis of ideas to explain the processes driving divergence of lineage.

Land snails are potentially excellent systems to investigate phenotypic evolution, because shell shape and color, both of which are inherited characters, tend to show high variability, as a result of low mobility and strict habitat dependences. Extreme shell shape variation is recognized in the bradybaenid land snails of Northeast Asia. Phenotypic traits of this group have been much diversified in inter- and intra-species levels, and usually indicate sympatric distribution pattern.

In the previous study, molecular phylogenetic relationships were inferred from the bradybaenid land snails (*Ainohelix*, *Ezohelix*, *Karaftohelix*, *Paraegista*) in Hokkaido Island, Japan, suggesting that these genera were genetically fairly close to each other and have evolved rapidly. Especially, the patterns of the introgressive hybridization were observed between the species of different genera.

In the present study, we focused on the inter- and intra-specific relationships among the Northeast Asian bradybaenid land snails including species of both Far East Russia and Hokkaido. We estimated phylogenetic relationships among these species using nuclear DNA (ITS-1, 2) and mitochondrial DNA (16S rDNA). On the basis of the inferred phylogeny, we documented phenotypic diversity patterns and historical biogeography, and discuss the mechanisms of patterns of radiation observed in these species.

**Mollusks associated with the encrusting coral
Alveopora japonica Eguchi, 1968 (Poritidae)**

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The Poritidae is a family of reef-building corals found in tropical and temperate waters throughout the world. The genus *Alveopora* includes a number of encrusting or solitary species, such as *Alveopora japonica*, which has a relatively restricted range, being found only in southern Korea, southern Japan, Taiwan, and a small area on the eastern China coast [Sheppard et al., 2013]. In Jeju Island, *A. japonica* is the only dominant coral species. It has been reported from the south coast, around Mun Island, near Seogwipo, for many years. However, recently, this species is experiencing a population explosion, and is rapidly extending its range around the island [Vierra et al., 2011].

Coral communities in warm water areas can be separated into two basic types: coral reefs and coral carpets. Coral carpets are defined as more or less continuous, relatively thin, layers of coral framework. They are ecologically rather uniform. Often they tend to occur in a near-shore area, are largely monospecific, and form an open, continuous framework. This type of coral growth produces numerous cavities which become filled with sediment which remains within the carpet [Riegel, Piller, 1999]. The colonies of *A. japonica* in Jeju Island also form coral carpets in various localities.

To further investigate the rate of increase and examine associated benthic fauna, several surveys have been conducted at various locations around the island during the past three years. In 2012 a sample of *A. japonica* was obtained by SCUBA diving from Keumneung, on the northwest coast, and its mollusk fauna was examined. In 2013 samples were again obtained from Keumneung for comparing colony density, and surveys were also conducted at Biyangdo and Gwideok, also on the northwest coast. A nearby locality at Dong-gwi, which lacked coral, was sampled to examine any faunal differences. The two Keumneung samples were somewhat uniform in composition; 12 species (43%) – 11 bivalves and one gastropod, *Purpuradusta gracilis* – occurred in both samples. In 2014, three localities on the north and east coasts, at Bukchon, Shinheung, and Seongsan, were also surveyed. All cryptofauna from each locality was removed, stored in 70% ethanol, and the mollusks were later identified. Those were also counted, measured, and assessed for maturity for comparison between and within populations.

A total of 61 species from all six locations was obtained, mainly from the base of the coral. Gastropod and bivalve species were almost equal in number: 51% (31) and

48% (29), respectively, with one chiton. Of the 33 families represented in the collections, there were almost an equal number of bivalves and gastropods: 17 and 15, respectively, as well as the chiton family Acanthochitonidae. The most speciose gastropod families were the Trochidae, with seven species, the Muricidae and Columbelloidae with four, and the Turbinidae with three. The Mytilidae, Chamidae, and Arcidae were the most speciose of the Bivalvia, with five, four, and three species, respectively.

Among the localities, Bukchon had the most species, with 34, Shinheung had 31, and Keumneung had 29; the remaining three localities having far lower species diversity. Bivalve species outnumbered gastropods in all localities except Seongsan, which had a much smaller coral cover, the majority of the surface area being occupied by the brown seaweed *Eklonia cava*. However, at Dong-gwi, the non-coral area, gastropods outnumbered bivalves by a ratio of 3:1, showing that bivalves tend to regard the coral carpet provided by *A. japonica* as a more suitable substrate. Most bivalve species were obtained at Keumneung, with 21, followed by Bukcheon, Shinheung, and Biyangdo, with 19, 16, and 15, respectively. Gastropods were most common at Shinheung, Bukchon, and Seongsan, with 17, 16, and 15 species, respectively. Only six species occurred in all six localities: four bivalves, *Lithophaga curta*, *Barbatia stearnsi*, *Chama cerinohodon*, and *Cardita leana*, and the gastropods *Astrarium haematragum* and *Pollia mollis*. *Engina* cf. *menkeana* was the only gastropod occurring at five locations, as compared with two bivalves, *Lithophaga malacannus* and *Arca avellana*. Most of the dominant species were bivalves: *Lithophaga curta* (213 specimens), *Arca avellana* (119 specimens), *Barbatia stearnsi* (451 specimens), and *Cardita leana* (131 specimens). The dominant gastropod species was *Astrarium haematragum* (192 specimens). Live specimens of all species except two, *Omphalius pfeifferi carpenteri* and *Euplyca scripta*, were obtained.

An examination of the feeding habits of the mollusks inhabiting *A. japonica* revealed that most of the gastropods were grazers, mainly the Trochidae and Turbinidae, but there was also a substantial number of carnivores, including species that are also scavengers. The Columbelloidae are regarded as both carnivores and grazers [Okutani, 2000], as is the trochid *Calliostoma unicum*. The vermetid *Serpulorbis imbricatus* is a filter feeder; the single polyplacophoran, *Cryptoplax japonica*, is a grazer. Almost all the bivalves were suspension feeders, with the exception of *Felaniella sowerbyi* and *Diplodonta gouldi*, in the Ungulinidae, which are possible detritus feeders, and Cf. *Nesobornia bulla* which may be commensal or parasitic [Okutani, 2000].

Following to Zuschin and Piller [1997], bivalves can be classified according to their habitats in the coral: borers, encrusters, and crevice dwellers. Most of the bivalve species from the six localities (55%) were crevice dwellers, such as the Arcidae and Carditidae, which attach themselves by a byssus to the substrate or nestle in crevices, with the exception of *Felaniella sowerbyi* which inhabits a variety of habitats but has also been found associated with coral [Qi, 2004]. The irregular base of the coral encrustation provided an ideal habitat for byssal attachment and nestling. Other bivalves were either encrusters (31%), such as the Chamidae or Spondylidae, which cover dead coral or other hard

substrates, and borers (10%), e.g. *Lithophaga*, which penetrate corals or other calcareous substrata. The larger gastropods inhabited indentations between colonies on the surface of the coral, although some, usually subadult, were found in crevices at the base. Most of the smaller species were found at the base of the coral.

A zonal-geographical examination of the distribution ranges of the mollusks associated with *A. japonica* demonstrated that the majority of species (57%) have tropical-subtropical affinities, while 39% are either subtropical or subtropical-lowboreal, preferring cooler water. Two only are cool water species. Of the tropical-subtropical (warmer water) species, 60% are bivalves; however, 67% of subtropical and subtropical-lowboreal species are gastropods. *Cryptoplax japonica*, the single chiton species, is subtropical-lowboreal in affinity. The bivalve larvae of many species can remain viable in the water column longer than gastropod larvae [Brusca, Brusca, 2003], enabling them to travel longer distances in northward-flowing currents, and this may account for the preponderance of tropical-subtropical bivalves occurring in the coral carpet in Jeju Island.

The rich mollusk diversity at the base of *A. japonica* suggests a number of possible reasons for the selection of this habitat. It may provide a source of food, as organic detritus may be concentrated there by currents or tides, and microalgae may also colonize the dead coral base. It may provide a refuge from predators which may find it difficult to enter the narrow crevices beneath the coral, and may also be used as a nursery, considering the significant number of juvenile and subadult specimens found there. More surveys of this coral species and a closer examination of other mollusk assemblages may reveal fresh insights.

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Diversity and genesis of the Amur River malacofauna

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The Amur River is one of the biggest rivers in the world (4 410 km long), draining a huge area of nearly 2 million square km. The river drainage has very long and complicated geological and paleogeographical history. The most ancient fragment of the Amur River network recorded within the riftogenic depressions of the Zeya-Bureya basin is of Cretaceous age [Artemenko, Sorokin, 2009].

Asian drainages are usually characterized by a highly diverse and largely endemic fauna of freshwater snails [Strong et al., 2008] and bivalves [Graf, Cummings, 2007; Bogan, 2008]. The Amur malacofauna is conservatively estimated of nearly 160 mollusk species, including 116 endemics, in 47 genera and 16 families [Starobogatov et al., 2004; Prozorova, 2013]. Gastropod family Amuropaludinidae and 16 taxa of the genus group (*Amuropaludina*, *Ussuripaludina*, *Parajuga*, *Microanisis*, *Vitreoplanorbis*, *Ussuriphysa*, *Culmenellina*, *Amuranodonta*, *Dahurinaia*, *Amureuglesa*, *Ussuripisidium*, *Amurohenslowiana*, *Ladislavella*, *Ussuriradix*, *Amurlymnaea*, *Amuracroloxus*) are endemic and subendemic for the Amur River system and spread partly in adjacent maritime or/and interior basins.

The diversity and endemism of the Amur malacofauna are the highest among riverine basins of the Northern Eurasia and only conceded to those for the South Asian drainages of Yangtze [Prozorova et al., 2005] and Mekong [Köhler et al., 2012]. While analyzing the literature and original data, a comparative assessment of the biodiversity of the Amur freshwater mollusk fauna shows that the river system has the third highest diversity in the whole Eurasia.

The Amur River malacofauna is mainly of Oriental origin. Prevalent Oriental genera are mixed here with Palaearctic those spread from the north and west. Biogeographically the river basin belongs to the Amurian subregion of the Sino-Indian malacogeographic region [Starobogatov, 1970; Kruglov, Starobogatov, 1993; Prozorova, 1991, 2001].

Two main problems, concerning genesis of the Amur malacofauna, are the following:

1. Where is the origin and what is the age of endemic Amurian mollusk taxa?

2. Where did ancestors of the most common endemic Amurian gastropod genera *Amuropaludina* in Viviparoidae and *Parajuga* in Semisulcospiridae come from? And what are their sister groups?

To solve these problems integrated theory on the origin and time of colonization of the Amur River by main mollusk groups is suggested. Theory is based on data about 1) fauna and biogeography, 2) morphology, 3) molecular genetics, 4) geology, 5) paleontology.

Faunogenesis of the river basin is closely related with its geology. During Cretaceous–Paleocene Paleo-Amur was flowing southward. The most ancient Zeya-Bureya fragment of the Amur network was connected with Yellow Sea through the Songliao Basin of the Northeast China [Artemenko, Sorokin, 2009]. In Paleocene the Amur River had changed its flowing direction from meridian to latitudinal and since Late Miocene–Early Pliocene the river flows to the north [Murzaeva, 1964; Artemenko, Sorokin, 2009]. At the turn of the Pliocene–Pleistocene the Amur had lost a connection with the Lake Baikal catchment area. Since Quaternary the Amur network is similar to the recent one [Chemekov, 1964].

The Songliao basin is known by its ancient endemic “Jehol” biota, including gastropods presented by amphi-Pacific taxa with many records in Cretaceous deposits both in Eastern China and in North America: *Mesolanistes* in Ampullariidae, *Reesidella* in viviparoid family Pliopholygidae, *Goniobasis*–? in Cerithioidea, various Amnicolidae [Yu, Zhang, 1982; Yu et al., 1990; and others]. Interior part of Songliao Basin including Lower Paleo-Amur lake-river system is probably the origin of Amuropaludinidae, closely related with extinct to/in Eopleistocene Pliopholygidae, and of some Asian genera of amphi-Pacific Semisulcospiridae in Cerithioidea.

Amuropaludinidae is one of 4 recent families of paleolimnic superfamily Viviparoidea known in freshwaters since Trias [Henderson, 1935 in: Starobogatov, 1970]. Fossils regarded to Amuropaludinidae were found in Oligocene–Miocene from the Lower-Bikin depression (Middle Amur R. basin) [Popova, 1964, 1981; orig. data], in Miocene from the East Siberia [Starobogatov, 1970; orig. data] and in Pliocene from the Chuya depression (Altai) [Popova et al., 1970; Popova, 1981; orig. data]. Nowadays the family inhabits Amur with Sungari (*Amuropaludina*) and Yangtze (undescribed genus) where it is known as *Viviparus tricinctus*. Phylogeny of Viviparoidea is poorly studied yet. We hypothesize that ancestors of Amuropaludinidae were belonged to Mesozoic Pliopholygidae. If *Amuropaludina* and *Pliopholyx* are sister taxa, Amuropaludinidae may be junior synonym of Pliopholygidae.

Phylogenetically Amurian *Parajuga* is closely related with East Asian *Semisulcospira* and Korean *Koreanomelania* [Strong et al., 2012]. Fossil shells of Semisulcospiridae were found in Pliocene from western North America [Steward, 1926; Pilsbry, 1934; Taylor, 1966], Oligocene–Pliocene from China and Japan [Ping, 1931; Suzuki, 1949; Starobogatov, 1970]. In Pliocene–Eopleistocene, tributaries of the Lake Baikal were inhabited by *Semisulcospira* and *Parajuga* [as *Juga* in: Popova, 1978, 1981; Popova, Shibanova, 1994]. Before Pleistocene cooling both genera were occurred in the Amur and Razdol'naya R. basins (orig. data). Nowadays northern area of *Semisulcospira* is restricted by Korean Peninsula. Recent Semisulcospiridae inhabit western North American states California, Oregon, Idaho and Arizona (*Juga*, *Oreobasis*, *Calibasis*) and eastern Asia from the Amur (*Parajuga*) to Yangtze (*Hua*, *Semisulcospira*) with endemic genera in Japan (*Biwamelania*) and at Korean Peninsula (*Koreanomelania*, *Koreoleptoxis*). The sister taxon of Amurian *Parajuga* is *Semisulcospira* or *Koreanomelania* [Strong et al., 2012]. All these 3 taxa have probably common ancestor not early than in Palaeogene.

Amuropaludinidae, Semisulcospiridae, and some other large mollusk taxa probably originated from Cretaceous Songliao basin. Basing on paleontological data endemic Amurian *Amuropaludina* and *Parajuga* are nearly of Oligocene age. The recent stage of the Amur mollusk radiation probably started in the aftermath of dramatic Pliocene climatic changes in the region, and linked to alteration of the Amur River network, Baikal-Amur lake-river system disintegration and further the East Asian and western North American freshwater basins separation. The hypothesis is in good coincidence with data on phylogeny of monophyletic Acroloxidae inhabiting Amur, Baikal and North America which had two main divergence events in Pliocene 4 and 2.5 Mya [Albrecht et al., 2007].

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**Terrestrial molluscs of Khingansky Nature Reserve
with notes on other reserve fauna and
a new species for the territory**

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We present the first data on the land snail fauna of Khingansky Nature Reserve, located in the Middle Amur River basin. The valley part of the reserve makes about 70% of the total area. Main landscapes are meadows and marshes there. The rest territory with average 350–450 m above the sea level lies on the spurs of Maly Khingan Range. In the mountain part oak woods and coniferous broad-leaved forests prevail. In 2009–2013 land snails were collected in both valley and mountain parts of the Khingansky Nature Reserve. In sorted material 28 species from 17 genera belonging to 13 families were revealed (see Table). Four other species listed in the table were known in the Middle Amur River basin. These and some other species may be found in the reserve in future.

Among 28 species inhabiting Khingansky Reserve 12 species are new for the Middle Amur, 10 – for the whole Amur basin, 3 – for southern part and 2 – for the entire Russian Far East (table). Two Palaearctic species *Vertigo antvertigo* and *Cochlicopa lubrica* were earlier known eastward to Transbaikalia [Sysoev, Schileyko, 2009], in addition noted *C. lubrica* spreads not only in the middle, but in the lower part of the Amur R. valley. Two other *Cochlicopa* species *C. lubricella* and *C. likharevi* recently found in the Lower Amur [Kavun, 2009] are new for the Middle Amur basin as well.

Small snail *Gastrocopta theeli* found in Northern Asia in several disjunctive areas is also known on the Korean Peninsula as *G. coreana* Pilsbry, 1916 [Likharev, Rammelmeyer, 1952; Schileyko, 1984; Sysoev, Schileyko, 2009]. In the Southern Russian Far East *G. theeli* occurs in undisturbed biotopes of southern maritime areas and islands of the Peter the Great Bay, Lake Khanka drainage, Ussuri River valley, “Kedrovaya Pad” Nature Reserve [Prozorova, 2004, 2006; orig. data], and Ussuriyski Nature Reserve [Likharev, Rammelmeyer, 1952]. We found this species in the Middle Amur R. basin for the first time. The species is recorded in both Bolshehehcyrski and Khinganski Nature Reserves. These records make formerly disjunctive area of the species more continuous, at least in its southern regions.

In 2013 the last new record was made. Minute snail *Paralaoma servilis* (Shuttleworth, 1852) was found in leaf litter of mixed forest in Ussuriyski Nature Reserve (southern Primorye). The species, rapidly expanding its range elsewhere, is known from New Zealand (origin), North and South America, Africa, Australia, Europe, Madeira,

**List of land snail species inhabiting Middle Amur River basin
and Khingansky Nature Reserve**

Species	Distribution in Amur R. basin	Total distribution
<i>Carychium sibiricum</i> Westerlund, 1897	Middle Amur R. basin	Southern Russian Far East, southern Kamchatka
<i>C. pessimum</i> Pilsbry, 1902	Middle Amur R. basin	New for Amur R. basin Middle Amur R. basin, Primorye, Sakhalin, Southern Kuril Islands, Japan, Korea
<i>Succinea lauta</i> Gould, 1858	Middle Amur R. basin	Southern Far East including Japan and Southern Kuril islands
<i>Cochlicopa likharevi</i> Starobogatov, 1996	Middle Amur R. basin	New for Middle Amur R. basin Continental Southern Russian Far East, Sakhalin
<i>Cochlicopa lubrica</i> (Muller, 1774)	Probably entire Amur R. basin	New for Amur R. basin Palearctic species
<i>Cochlicopa lubricella</i> (Ziegler in Porro, 1838)	Probably entire Amur R. basin	New for Middle Amur R. basin Circumboreal-Alpine species
<i>Cochlicopa maacki</i> Starobogatov, 1996	Middle Amur R. basin	Continental Southern Russian Far East, Sakhalin
<i>Zoogenetes harpa</i> (Say, 1824)	Probably entire Amur R. basin (mountain regions)	Circumboreal-Alpine species. In East Asia: Southern Russian Far East, Hokkaido, South Korea
<i>Vallonia kamtschatica</i> Likharev, 1963	Probably entire Amur R. basin	New for Amur R. basin From Krasnoyarsk to Kamchatka and Kuril Islands
<i>Vallonia patens patens</i> Reinhardt, 1883	Middle Amur R. basin	Continental Southern Russian Far East
<i>Vallonia pulchellula tenerrima</i> Gerber, 1996	Middle Amur R. basin	New for Amur R. basin Middle Amur R. basin and Primorye
<i>Vallonia tenuilabris</i> (Braun, 1843)	Probably entire Amur R. basin	From Siberia and mountain regions of Central Asia to Amur R. basin
<i>Gastrocopta theeli</i> (Westerlund, 1877)	Middle Amur R. basin	New for Amur R. basin Patchily from Caucasus and Kirgiz Range to Southern Primorye
<i>Vertigo antivertigo</i> (Draparnaud, 1801)	Middle Amur R. basin	New for the Russian Far East Palearctic species, eastward to Middle Amur

Table (Continued)

Species	Distribution in Amur R. basin	Total distribution
<i>Vertigo extima</i> (Westerlund, 1876)	Middle Amur R. basin	New for the Southern Russian Far East Siberian species spread in Middle Amur basin
<i>Discus depressus</i> (A. Adams, 1868)	Probably entire Amur R. basin	From Baikal to Sakhalin, Kamchatka, Komandor, Kuril Islands and Japan
<i>Perpolita hammonis</i> (Strøm, 1765)	Probably entire Amur R. basin	Palearctic species common in the Russian Far East
<i>Euconulus fulvus</i> (Müller, 1774)	Probably entire Amur R. basin	Holarctic species common in the Russian Far East
<i>Deroceras agreste</i> (Linnaeus, 1758)	Probably entire Amur R. basin	Almost everywhere
<i>Deroceras altaicum</i> (Simroth, 1886)	Probably entire Amur R. basin	From Tien-Shan and Caucasus to Kamchatka, Kuril Islands and Southern Russian Far East
<i>Deroceras laeve</i> (Müller, 1774)	Probably entire Amur R. basin	Holarctic species common in the Russian Far East
<i>Arion (Mesarion) sibiricus</i> Simroth, 1901)	Probably entire Amur R. basin	From Central Siberia to Southern Russian Far East
<i>Acusta ravidia</i> (Benson, 1842)	Middle and Lower Amur R. basin	Entire continental part of the SRFE including basin of Middle and Lower Amur River
<i>Karafiohelix arcasiana</i> (Crosse et Debeaux, 1863)	Middle Amur R. basin (Khingán-?)	Middle Amur R. basin and Primorye
<i>K. dieckmanni</i> (Mousson, 1887)	Middle and Lower Amur R. basin (Khingán-?)	Entire continental part of the SRFE including basin of Middle and Lower Amur River and small islands of the Peter the Great Bay
<i>K. maacki</i> (Gerstfeldt, 1859)	Middle and Lower Amur R. basin	Entire continental part of the SRFE including basin of Middle and Lower Amur River.
<i>K. middendorffi</i> (Gerstfeldt, 1859)	Middle Amur R. basin (Khingán-?)	Middle Amur R. basin and Primorye
<i>K. incognita</i> (Schileyko, 1988)	Middle and Lower Amur R. basin	New for Amur R. basin Probably entire basin of Middle and Lower Amur River

Table (Continued)

Species	Distribution in Amur R. basin	Total distribution
<i>Chilanodon gerstfeldti</i> (W. Dybowski, 1901)	Upper and Middle Amur R. basin (Khingang-?)	From Cisbaikalia along the Upper and Middle Amur R. valley up to Khabarovsk
<i>Lindholmomneme notophila</i> (Cockerel, 1924)	Middle and Lower Amur R. basin	New for Amur R. basin Probably entire continental part of the SRFE including basin of Middle and Lower Amur
<i>Pseudotrichia rubiginosa</i> (Rossmassler, 1838)	Probably entire Amur R. basin	Almost entire Palaearctic
<i>Stygius stuxbergi</i> (Westerlund, 1876)	Probably entire Amur R. basin	New for the Russian Far East From Central Siberia to Middle Amur River basin and Primorye

Canary, Hawaii and other Pacific islands [Christensen et al., 2012]. The recent record in Primorye is new for Asia.

All mentioned here material is deposited in malacological collection of the Institute of Biology and Soil Science FEB RAS (Vladivostok).

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**Distribution and morphology of the *Amuropaludina*
species (*Architaenioglossa*, *Viviparoida*)
from the Amur River basin**

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Distribution of riverine viviparoid gastropods inhabiting the Amur River drainage is examined. The Amur River system excluding upper reaches of the river is inhabited by four species of the genus *Amuropaludina* Moskvicheva: *A. chloantha* (Bourguignat, 1860), *A. praerosa* (Gerstfeldt, 1859), *A. pachya* (Bourguignat, 1860), and *A. chui* (Yen, 1943). The last one, originally described in the genus *Viviparus* Montford by Yen [1943] is the only *Amuropaludina* species, known in Sungari River, the main Chinese tributary in north-east Jilin [Yen, 1943] and Heilundzian [Claude, Amandine Evanno, 2013] provinces. Morphologically Sungarian *A. chui* is closely related to *A. chloantha* and *A. praerosa*.

Three Russian *Amuropaludina* species occur in the Amur, its tributaries and lakes of the river valley. The most widely distributed *A. chloantha* is known in the Amur from its estuary to Zeya River mouth, including the Amgun and Ussuri Rivers, also the Khanka Lake. Distribution of both *A. praerosa* and *A. pachya* upstream the Middle Amur River is restricted by the Malyi Khingan Range. Species *A. praerosa* is common for the Middle and Lower Amur, including estuary. Rarer *A. pachya* does not spread downstream Bogorodskoye Settlement. Both species occur in the Ussuri River system and Lake Khanka.

Shell morphology of three Russian *Amuropaludina* species is studied. Specific differences in embryonic shell shape are revealed. Sexual dimorphism in the *Amuropaludina* shell morphology is similar to that in genera *Cipangopaludina* Hannibal species [Moskvicheva, 1979; Starobogatov et al., 2004] and species *Viviparus viviparus* (L.) [Berezkina, Zotin, 2013]. Last whorl of male shell is usually more oblong. *Amuropaludina* males are rare than females. Sex ratio in different species is nearly 1:3–9.

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Distribution and morphology of the Amuropaludina species from the Amur River basin

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**New taxa and new records of freshwater mollusks
of Jeju Island, South Korea,
with notes on Korean Peninsula malacofauna**

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Previously, ten freshwater mollusk species from ten genera and six families were known in Jeju Island [Noseworthy et al., 2007; Noseworthy, Choi, 2012]. In December 2013, a survey of the freshwater mollusks of Jeju Island was conducted. Fifteen localities were examined, mainly in the Seogwipo city vicinity, and also along the southern and eastern coasts of the island. Specific habitats within these localities were sometimes included. As a result, new populations of known species, and several species and higher taxa new for the island were found. Some taxa are new for the entire Korean Peninsula. Below the first preliminary results of the survey are presented.

No freshwater bivalves had previously been reported from Jeju Island. Min with co-authors [2004] includes two mainland Korean species in the Sphaeriidae: *Sphaerium (Musculium) lacustre japonicum* Westerlund and *Pisidium (Neopisidium) sp.* Three species in the family Pisidiidae – *Sphaerium japonicum*, *Pisidium coreanum* Kwon, and *Musculium sp.* – were recognized by Chung [2003]. The taxonomy and phylogeny of small freshwater bivalves are still not adequately known. In Russian malacological literature this mollusk group is divided in three families Pisidiidae, Sphaeriidae, and Euglesidae in accordance with both shell and soft body morphology [Korniushin, 1996; Starobogatov et al., 2004]. Here we use a consensus version of sphaeriid taxonomy [Alder, 1994; Baba, 2001], which takes into consideration the morphology of soft tissue: gills, siphons, mantle, muscles, and nephridium.

Three species of small bivalves were found in Jeju Island for the first time. *Musculium japonicum* was obtained from still water in a field of aquatic plants in Seogwipo and a specimen similar to *Neopisidium coreanum* was collected from a small muddy stream near Gangjeong on the southern coast of the island. Also, in a slowly flowing stream in Seogwipo we found minute bivalves belonging to the Euglesidae, in Russian malacological classification. This species may be provisionally identified as *Casertiana sp.* Thus, for the first time in Jeju we report three bivalve genera, *Musculium*, *Neopisidium*, and *Casertiana*. The last genus is new for the Korean malacofauna. Small bivalves are able to colonize new areas very quickly; eg. *Casertiana casertanum* (Poli)

is found in every region of the world [Smith, 1989]. Their dispersal is determined by self-fertilization and passive transportation by birds, by adhering to their feathers [Kuiper, 1982].

The Physidae has been previously reported for the island [Min et al., 2004]. Now distributed worldwide [Parensse, Pointier, 2003], *Haitia acuta*, an invasive sinanthropic species, was collected in the same habitat as *Sphaerium (Musculium) japonicum*, in a farm area in Seogwipo. It was originally described in the genus *Physa* then regarded *Physella* or *Costatella*. As a result of a revision of this family, including the study of type species of all described genera, this species was transferred to *Haitia* [Taylor, 2003].

Various Lymnaeidae and Planorbidae species were collected in the rice paddies and aquatic plant fields in the vicinity of Seogwipo. We did not include these data because the taxonomy of those families in Korea needs revision.

Recently the neritid gastropod *Clithon retropictus* Martens, 1879 was first recorded in Jeju Island [Noseworthy, 2012]. We discovered specimens of this species at Daehong-ri Lagoon, near the mouth of a river southwest of the town of Pyeosen on the south coast. Dead specimens of three species of Potamididae have previously been obtained at several localities on the island; however, for the first time, a live specimen of *Cerithideopsilla djadjariensis* (Martin, 1899), was collected in Daehong-ri Lagoon. *Batillaria attramentaria* was also obtained in the same locality.

The cerithioidean gastropod *Semisulcospira libertina* is widely distributed in streams and small rivers of the island. The typical morph occurs widely, but a new population with a more elongate shell was recorded in a small stream near Pyeosen.

In summary, four mollusk species from three genera (*Musculium*, *Neopisidium*, and *Casertiana*) are new records for Jeju Island, including one species and genus (*Casertiana*) as new for Korea. New records demonstrate that the freshwater malacofauna of both Jeju Island and the Korean Peninsula is more varied than previously believed. A recent discovery of hypogean Amnicolidae in an adjacent territory of the southern Russian Far East [Sidorov, Semenchenko, 2009; Prozorova, 2013] indicates as well the potential richness of the Korean freshwater malacofauna which therefore merits further study.

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Structure of the pallial oviduct of some mollusks of the genus *Juga* (Gastropoda, Cerithioidea)

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The oviparous mollusks of the genus *Juga* from freshwater Cerithioidea (family Semisulcospiridae) inhabit two regions of the South-Eastern Asia: South Korea and south of the Russian Far East. In this investigation anatomy of the pallial oviduct of three *Juga* species from these regions were studied by histological methods.

Oviduct structure of *Juga extensa* and *J. tegulata* from Primorye Region (Russia), *J. tegulata* and *Juga* sp. from Chungcheongnam-do Province (South Korea) were studied.

All members of Cerithioidea have oviducts with lateral and medial laminae. Distal part of the lateral lamina of *Juga* species has small pararenal glands while the other part of lateral lamina is formed by glandular tissue and consists of albumen and nidamental glands. Cytoplasm of the pararenal gland cells was slightly stained with hematoxylin and lavender color of the cells differs from pink color of the albumen gland cells. Pararenal cells occur only near seminal receptacle so it is possible to conclude that secret of the pararenal gland is used for eggs covering or insemination. Medial lamina of *Juga* species has pallial pocket and seminal receptacle both covered by connective tissues. Pallial pocket is represented by the tube with muscle walls only in distal part of the pocket and disintegrated spermatozoa inside. Pallial pocket is connected with seminal receptacle by sperm gutter located along the external side of the pocket. The relative position and sizes of these organs are species-specific.

Seminal receptacle of *Juga extensa* is the largest among the investigated species with its top located above a top of pallial pocket. Seminal receptacle of *J. tegulata* is smaller with its top located below (for specimens from the Russian Far East) or at the level of a top of pallial pocket (for mollusks from South Korea). Specimens of *J. tegulata* from the Russian Far East have the smallest seminal receptacle in compare with the specimens of *J. tegulata* from South Korea. Seminal receptacle of *Juga* sp. is located above a top of pallial pocket.

Lateral and medial laminae of all investigated specimens from Korea are closed without a layer of connective tissue; pallial pocket adjoins to glands of lateral laminae the entire length of the laminae. From the other hand, specimens of *Juga* from the Russian Far East have a layer of connective tissue between pallial pocket and lateral lamina.

Thus, specimens of *Juga* from Russia and Korea differ by size and position of pallial pocket and seminal receptacle.

**Two forms of *Mactra chinensis* Philippi, 1847
(Bivalvia, Mactridae)
show disproportional heteromorphism of sperm**

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The bivalve mollusk *Mactra chinensis* is a common species with has very important commercial significance for Primorsky Krai. On the basis of morphological data, researchers suggested a divergence of this species in the Sea of Japan. As a consequence of the divergence, the southern and northern populations have already appeared, and they are different in the shape, color, and the shell pattern. For example, in the South Korean part of the Sea of Japan, the *Mactra* shell is described as faintly colored, yellowish, without any brown rays, while in the Russian part of the Sea of Japan, there is *Mactra* with brownish-purple shell and brown and violet purple rays. Since the exact identification of this species is of important commercial value, some additional approaches are necessary to define *M. chinensis* more accurately. Along with shell morphology, analysis of the gamete structure can be also used to determine species divergence. Compared with the body as a whole, the reproductive cells were found out to undergo more rapid evolution and, hence, different morphologies of sperms in the remote geographic populations of the species is a sign of probable divergence and speciation. This study is a comparative analysis of male gametes in the members of the northern and southern populations of Chinese *Mactra* in the Sea of Japan. In addition, in genetic analysis of the representatives of both populations, we used DNA barcoding, which is an acknowledged method of species identification. Three specimens of reproductively active *M. chinensis* of the northern population were collected in the Vostok Bay (the Sea of Japan, Russia) in July–August 2012 on the marine biological station Vostok, Institute of Marine Biology, Far East Branch, Russian Academy of Sciences (42°53' N, 132°44' E). Two specimens of the southern population were collected in July 2012 in the South Korean area near the Uljin Village, Gyeongsangbuk Province (37°4' N, 129°24' E). Male gametes were examined under a scanning electron microscope. For this purpose, the seminal vesicle fragments were fixed for 2–4 h at 4°C in a solution of 2.5% glutaraldehyde prepared on 0.2 M cacodylate buffer (pH 7.4). Afterwards, the samples were washed out in 0.1 M cacodylate buffer for 15–20 min. Sperm suspension was pipetted on the surface of Thermanox coverslips (Cat. no. 72 280). After sperm precipitation for 30 min, the preparations

were dehydrated in increasing concentration of alcohol to get them gradually into acetone. Thereafter, the samples were dried completely in carbon dioxide in a critical point dryer 030 (BAL-TEC) and placed on the aluminum surface to perform carbon sputter coating. The samples were examined using a Zeiss EVO 40 microscope. The resultant images were edited using a graphic program Adobe Photoshop 7.0. Statistical processing of the quantitative data was performed by means of the Microsoft XL software using Student's *t* test. When studying the male gametes of *M. chinensis* in the southern and northern populations of the Sea of Japan, we have found out that so-called "primitive sperm cells", the structure of which is adapted to external insemination, is characteristic of the members of both populations. These cells have a streamlined head consisting of an acrosome, a nucleus, four mitochondria, and flagella. There are three variants of this morphotype in molluscs of both populations. In one of them, the acrosome has a concave apical surface without any other structures; in the second variant, the acrosome has a small ledge, while in the third variant, the ledge is relatively extended and slightly curved. Quantitative morphotypes in molluscs of the northern and southern populations. The morphotype having acrosome without a ledge is typical of the northern population (76%); the morphotypes with short and elongated ledges on the acrosome surface accounted for about 16% and 8%, respectively. In molluscs of the southern population, only 12% of the morphotypes have no any acrosomal ledge; in 19% of morphotypes, gametes with a short acrosomal ledge are observed, and the major part of the morphotypes, 69%, are those with gametes having an elongated acrosomal ledge. Thus, in addition to previous data that describe *M. chinensis* as the monogametic species, we have found out that heteromorphism is characteristic of *Mactra*, which is manifested in that they have three variants of the sperm cells. Note that heteromorphism of male gametes has been recently found out in some other bivalve mollusks that were earlier considered monogametic, and this phenomenon has no explanation so far. Of interest is the fact that, in the northern and southern *M. chinensis* populations, heteromorphism of sperm cells is disproportional. Predomination of one of the three morphotypes is characteristic of the southern population, while another variant predominates in the northern population; the third morphotype seems to be a reserve one in both cases because of a small number of these gametes. The reasons for quantitative predomination of a certain morphotype remain still unclear. It may well be that the species divergence that has been suggested on the basis of differences in shell coloration is the cause of a shift to a certain variant of sperm cells. To verify this hypothesis, we compared the nucleotide sequences of the *COI* mitochondrial gene in the specimens studied. DNA was isolated, and the amplified fragments of the first half of *COI* gene (658 bp) were analyzed using a ABI3730xl automated sequencer. As a result, we have obtained five sequences. The metadata for all species in the database BOLD (Barcode of Life Data System) (<http://boldsystems.org>). For more complete identification of the *Mactra* species status, we used also the data on *M. chinensis* and *Mactra* sp. collected along the coast of China. In total, 16 sequences

of the species *M. chinensis* and *Mactra* sp. were used and one sequence of *M. veneriformes* served as an outgroup. The length of sequences after alignment and reduction to a certain length was 591 bp. The number of the variable sites was 126 bp, of which 78 bp were parsimoniously informative. The phylogenetic trees were constructed on the basis of the aligned set of sequences. According to the Hierarchical Likelihood Ratio Test, the model TN + I (Tamura–Nei model) has been chosen as the best one for the set of sequences of *COI* gene. The following approaches were used to construct the phylogenetic tree: the Bayesian (BA), maximum parsimony (MP), maximum likelihood (ML), and the neighborjoining (NJ) methods. The nucleotide sequence analysis of the mitochondrial gene *COI* has demonstrated that there are three clades of *M. chinensis* in the Yellow Sea and the Sea of Japan. The average distances within clades I, II, and III were the following: $0.18\% \pm 0.03\%$, 0% , and $0.65\% \pm 0.08\%$, respectively (the average distance \pm standard error). Hence, according to average distances, the three clades representing *M. chinensis* are assumed to constitute separate species taxa with a high significance, if we take into account the Rule 10-fold that has been proposed earlier in the reports on DNA-barcoding of species. Thus, *M. chinensis* species is likely to be revised as a complex that consists of three divergent species. Since the members of the northern and southern populations in the Sea of Japan belong to different clades (clades I and II, respectively), the assumption on *M. chinensis* divergence in the Sea of Japan is most probably correct. Thus, the fact that different variants of sperm cells predominate in the northern and southern populations is probably related to genetic divergence, which is accompanied by optimization of the species-specific pattern of male gametes in arising subspecies of Chinese *Mactra*. It may well be that the gamete heteromorphism is a specific phenomenon characteristic of the diverging species, whose genome produces “a set for choice”. Since three clades of the Chinese *Mactra* appeared due to genetic divergence, the members of the third clade should be studied for possible predomination of the third morphotype of sperm cells, which is the reserve variant in the members of two other clades. We are going to study this issue in the near future.

Glochidia of *Nodularia vladivostokensis*
(Bivalvia: Unionidae: Nodulariinae)
from Razdolnaya River basin, Southern Primorye

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Freshwater bivalves of naiad species *Nodularia vladivostokensis* Moskvicheva, 1973 inhabit Razdolnaya River basin, the largest river of Southern Primorye. Glochidia of *N. vladivostokensis* were firstly investigated a few years ago by light microscope [Sayenko, Kholin, 2007].

This investigation is based on samples collected in May-June 1990–1997 from 4 localities of the lower reach of the river from Ussuriysk city to Razdolnoye village. Mature glochidia were recovered from the demibranchs of gravid females and fixed in 75% ethanol for investigation with both light (conchological features) and scanning electron microscopy (ultra-structural features).

To prepare glochidia for light microscope bivalve demibranchs with mature glochidia were cleaned in 5% KOH during 1–1.5 h to remove all soft tissues, then washed in distilled water at least 10–15 times and in the end preserved in 75% ethanol. Valve length of glochidium was measured parallel to the hinge (*L*) ($n = 6–12$ per locality), valve height perpendicular to the hinge (*H*) ($n = 6–9$); length of hinge (*lig*) ($n = 7–11$), and length of the hook (*hook*) ($n = 6–9$) were also measured by light microscope. To standardize the measurements, three ratios were calculated: H/L , lig/L , and $hook/H$. To prepare specimens for scanning electron microscope (SEM), already cleaned in KOH glochidia were then washed in 80%, 90%, and 96% ethanol consecutively. Moist glochidia were placed on double-sided carbon tape on a SEM stub and coated with gold-platinum.

Investigated glochidia belong to *Anodonta*-type: shells are subtriangular with height 150–165 μm and length 170–185 μm (see Table). Shells are always stretched longitudinally ($L > H$). Shells are very prominent; a prominence of a valve is 70–75 μm .

Ventral edge of each valve has large styliiform hook. Length of the hook was measured in two projections: front (42–55 μm) and profile (48–53 μm). In summary length of the hooks is up to 1/3 of the glochidial valves height (27–31%). Width of the hooks is 53–55 μm (30–31% of the valve length).

SEM allows investigation of ultra-structure of the outer surface of glochidial valves. Based on investigation of some European, North-American and Asian glochidia a few types of sculpture on the outer valve surface were distinguished: coarse (from smooth to granulate), vermiculate, and net (rosette, looped, etc.) [Panha, Eongprakornkeaw, 1995; Hoggarth, 1999; Sayenko, 2012a, b, 2013].

Measurements of mature glochidial shells of *Nodularia vladivostkensis* (µm)

Locality; data	<i>H</i>	<i>L</i>	<i>lig</i>	<i>H/L</i>	<i>lig/L</i>
Razdolnaya River nearby Ussuriysk city	<u>150.0–162.5</u> 156.3±4.11	<u>175.0–182.5</u> 178.3±2.58	<u>137.5–150.0</u> 139.3±1.12	<u>0.85–0.92</u> 0.88±0.03	<u>0.77–0.80</u> 0.78±0.01
Kedrovaya River near Terekhovka village	<u>152.5–162.5</u> 157.9±1.14	<u>170.0–182.5</u> 179.7±1.45	<u>143.8–150.0</u> 146.3±0.66	<u>0.85–0.90</u> 0.89±0.01	<u>0.81–0.85</u> 0.82±0.01
Razdolnaya River at a sand-pit nearby Razdolnoye village	<u>150.0–162.5</u> 155.2±1.04	<u>175.0–185.0</u> 179.3±8.9	<u>137.5–147.5</u> 142.2±1.01	<u>0.85–0.89</u> 0.87±0.01	<u>0.78–0.83</u> 0.80±0.01
Razdolnaya River near the railway station “Razdolnoye”	<u>155.0–165.0</u> 158.5±3.76	<u>175.0–182.5</u> 179.3±2.06	<u>120.0–147.5</u> 135.6±8.4	<u>0.86–0.92</u> 0.89±0.02	<u>0.67–0.82</u> 0.75±0.04

Above the line – limit of variation (min-max) of every character; under the line – mean arithmetical value (bold type) with standard error.

Investigated glochidia of *N. vladivostkensis* had a combination of two types of sculpture of the outer valve surface: vermiculate in central part of a valve (mean length of “a vermicle” is 0.24–0.36 µm) and granulate nearby ligament (mean dimension of “a granule” is 0.18 µm). Comparing the outer surface sculpture of other najad bivalves we can see that both *Lanceolaria grayana* (Lea, 1834) (subfamily Unioninae) and *Nodularia biwae* Kobelt, 1879 (subfamily Nodulariinae) have granulate type (with mean dimensions of a granule: 0.07 µm for *L. grayana* and 0.13 µm for *N. biwae*) [Sayenko, 2012b]. The mentioned three najad species have almost psilate in a low magnification but malleated and shallow-pitted in a higher magnification outer valve surface as tiny pores can be observed only with a high magnification even by SEM.

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**Taxonomical status of the limpets
Erginus sybariticus and *Erginus puniceus*
(Patellogastropoda, Lottiidae)**

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Genus *Erginus* includes six limpet species [Lindberg, 1988; Chernyshev, Chernova, 2002]; two sympatric species, *E. sybariticus* (Dall, 1871) and *E. puniceus* Lindberg, 1988, are widely distributed in boreal waters of North Pacific. These species differ one from another by shell color: *E. puniceus* has uniformly colored pink or rich red shell, but the shell of *E. sybariticus* has radial pink and white stripes. Furthermore the shell of *E. puniceus* doesn't exceed 9 mm in length while in *E. sybariticus* it is up to 21 mm. The aim of the present investigation is to estimate genetic differences of these species from Vostok Bay (Peter the Great Bay) using allozymes (18 loci) and molecular markers (COI (648 bp) and 28S (982 bp)) of genes.

Genetic similarity [Nei, 1978] between sympatric populations of *E. sybariticus* and *E. puniceus* was 0.786. It is higher than between sympatric species of the patellogastropod genera *Lottia* (from 0.021 to 0.680) and *Nipponacmea* (0.119–0.417) but lower than between allopatric populations of one species (0.985–0.999 for *Nipponacmea moskalevi* and 0.971–0.992 for *Lottia kogamogai*). Although we did not find fixed differences between the species, they had different most frequently occurring alleles at 7 loci.

Analysis of sequences of the genes COI and 28S of three specimens of *E. sybariticus* and three specimens of *E. puniceus* doesn't reveal differences between these two species, but both *E. sybariticus* and *E. puniceus* from Vostok Bay had clear distance from *E. sybariticus* from Hokkaido (GenBank AB238461) – 7.36–7.54% (COI) and 0.41–0.51% (28S). However these distances are lower than those between congeneric patellogastropod species (15–25% for COI).

Our data testify that *E. sybariticus* and *E. puniceus* are more likely the morphs of one species rather than two sibling species.

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The freshwater mollusc fauna (Bivalvia: Pisidioidea) of the Upper Yenisei River basin (the Republic of Tuva)

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Species composition of small bivalves (Mollusca: Bivalvia: Pisidioidea) living in water bodies within the Republic of Tuva is very interesting. Tuva lies in geographical centre of Asia and there is one of biggest watersheds in the world. Three endemic species of the subgenus *Tuvapisidium* from the genus *Odhneripisidium* (Pisidiidae) were described by Y.I. Starobogatov, E.A. Streletzkaja [1967] and Z.I. Izzatullaev, Y.I. Starobogatov [1986] in freshwater Tore-Khol' Lake of the Central Asian inland basin in southern Tuva. Forty two species of four bivalve's families were represented in the Yenisei River basin in northern Tuva. First data on the Upper Yenisei River mollusc fauna from Tuva were reported by V.N. Greze and I.I. Greze in 1957–1958; first checklist included three Pisidioidea species: *Sphaerium scaldianum*, *S. lacustre*, *Pisidium amnicum* (author's classification). Later in 1969, A.N. Gundrizer and M.A. Ivanova reported in a short publication about 9 species of the Sphaeriidae with special attention to the Bii-Khem River basin in north-eastern Tuva.

The Bii-Khem River of the Upper Yenisei River basin is one of a few rivers in Siberia with minor human transformation. The focus of this report is to show species composition of small bivalves (Mollusca: Bivalvia: Pisidioidea) in the Bii-Khem River basin within the Azas State Nature Reserve where during 1994 and 2004 in all freshwater kinds of lotic and lentic habitats were collected the pea clams. Almost 1850 shells and specimens were fixed in 75% alcohol; the collection is now deposited at the Institute of Biology and Soil Science FEB RAS, Vladivostok. Shells and specimens were investigated by conchological, anatomical and SEM methods based on original study. Conchological characters include shell outline, sculpture, features of hinge, ligament, muscle scars and pores; the most important structures are illustrated on the SEM photographs. Anatomical characters were studied in situ and figured with a camera lucida.

At present, in total among 50 Bivalvia species 46 Pisidioidea species in 3 families (Sphaeriidae, Pisidiidae and Euglesidae) were found. Ten species in 5 genera of the Sphaeriidae were represented: *Amesoda (Clessinicyclas) scaldiana* (Normand, 1844), *Nucleocyclas radiata* (Westerlund, 1897), *Sphaerium mamillanum* Westerlund, 1871, *S. (Sibirisphaerium) levinodis* Westerlund, 1876, *S. (S.) capiduliferum* Lindholm, 1909, *S. (S.) westerlundi* Clessin in Westerlund, 1873, *Parasphaerium nitidum* (Clessin in Westerlund, 1876), *P. rectidens* (Starobogatov et Streletzkaja, 1967), *Musculium (Parvimusculium) creplini* (Dunker, 1845), and *M. (Musculium) lacustre* (Müller, 1774). Three species in two genera of the Pisidiidae were distinguished: *Europisidium*

tenuilineatum (Stelfox, 1918), *Pisidium amnicum* (Müller, 1774), and *P. decurtatum* Lindholm, 1909. Thirty three species in 11 genera of the Euglesidae were represented: *Cingulipisidium*, *Conventus*, *Cyclocalyx*, *Euglesa*, *Henslowiana*, *Hiberneuglesa*, *Pseudeupera*, *Pseudosphaerium*, *Pulchelleuglesa*, *Roseana*, and *Tetragonocyclas*.

Thirteen species were listed for the first time for the Republic of Tuva, ten species were found in the Upper Yenisei River basin for the first time, five European species were noted to have disjunction in Siberia for the first time: *Sphaerium mamillanum* Westerlund, 1871, *Euglesa obliquata* (Clessin, 1874), *Pseudosphaerium favrei* (Kuiper, 1947), *P. pseudosphaerium* (Favre, 1927), *Roseana rosea* (Scholtz, 1843). The majority of species are distributed in the Palaearctic Region (80%), while the other species have Siberian distribution (10%).

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**The recent terrestrial mollusc fauna
(Pulmonata: Stylommatophora)
of the Republic of Tuva**

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The recent terrestrial mollusc fauna of Tuva is poorly known. The paradox is that the first published paleontological records on the terrestrial mollusc from the Neogene of Tuva were made by N.S. Zaitsev [1947], L.D. Shorygina [1957, 1960] and A.A. Steklov [1967], who described five species of the genus *Gastrocopta* Wollaston, 1878 and one species of the genus *Vertigo* Müller, 1774.

The classic publications written by A.T. Middendorff [1851] and C.A. Westerlund [1876, 1885] and devoted to vast terrestrial malacofauna of Palaearctic were concerned in particular Siberia, Altay and Mongolia, regions surrounded Tuva, while malacofauna of Tuva itself was ignored. I.M. Likharev and E.S. Rammel'meier [1952] included Siberian and Altay-Sayan localities in their monograph "*Terrestrial Molluscs of the USSR Fauna*". However, in purely taxonomic paper on recent mollusc of the family Succineidae in the USSR A.A. Schileyko and I.M. Likharev [1986] described *Succinea gladiator* (Pulmonata: Stylommatophora) from the Aradansky Mountain Ridge in northern Tuva, recorded two species in the genus *Novisuccinea* Pilsbry, 1948 – *N. altaica* (Martens, 1871), *N. evoluta* (Martens, 1879) – and two species of the family Hygromiidae: *Lindholmemneme nordenskioldi* (Westerlund, 1876) and *Monachoides* aff. *stuxbergi* (Westerlund, 1876).

Interest to extant terrestrial molluscs within Tuva, the ancient country with complex geological history, was constant but special malacological investigation was started only in 1994. Sampling of terrestrial molluscs (snails and slugs) was carried out in 1994 during first private visit and later in 2001–2004 during scientific expeditions to "Azas" State Nature Reserve and "Ubsunur Hollow" State Nature Biosphere Reserve (UNESCO list). Two further collections were made in 2011 and 2013. Over 2130 shells and alcohol-preserved specimens were sampled and are deposited now at the scientific malacological collection in the Institute of Biology and Soil Science FEB RAS, Vladivostok. Shells and specimens were investigated by conchological, anatomical and SEM methods. Conchological characters included shell outline, sculpture of protoconch and teleoconch, the most important structures were illustrated in the SEM photographs. Anatomical characters were studied in situ and figured with a camera lucida.

At present the recent terrestrial molluscan fauna within the Republic of Tuva was represent by 51 species in 23 genera from 17 families [Zasypkina, 2009, 2010, 2011a, 2012, Sharyi-ool, 2013]. List of terrestrial mollusc from the Tuvian reserves consists

of 15 species. Four species – *Punctum pygmaeum* (Draparnaud, 1801) (Punctidae), *Vertigo alpestris* (Alder, 1838), *V. lilljeborgi* (Westerlund, 1868), *V. microsphaera* Schileyko, 1984 (Vertiginidae) – were recorded in the Azas Reserve for the first time, 2 species of genus *Vertigo* were found in the eastern part of Siberia for the first time. Two species – *Pupilla pratensis* (Clessin, 1871) and *Vertigo lilljeborgi* (Westerlund, 1868) – were listed for Republic of Tuva for the first time. The relict and rare species *Vertigo lilljeborgi* (Westerlund, 1871) (Vertiginidae) are recommended for the Red Book of the Republic of Tuva.

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**Microgastropods associated with
Corallina pilulifera (Rhodophyta, Corallinales)
from Oshoro, Hokkaido, Japan**

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Our understanding of molluscs is based mostly on large-size species, and much less is known from small taxa although they are expected to be as diverse and abundant. Micromolluscs are small-sized molluscs (<5 mm) and include the great majority of undescribed molluscan taxa. The actual level of anthropogenic impact and its effects on biodiversity has led many researchers to pay more attention to these many undescribed taxa, especially small sized. Micromolluscs can be especially important to study changes in diversity and help assess environmental impacts.

For the most part micromolluscs cannot be identified in the field without magnification, thus making targeted collecting for particular taxa difficult. Usually, the likely habitats of the target organisms, or a range of microhabitats in the case of surveys, need to be sampled. Algae serve as habitats for many micromolluscs and certain species can even show high levels of habitat specificity being found only on particular algae species. The aim of this work was to survey the micromollusc fauna of *Corallina pilulifera* from the Oshoro bay, Sea of Japan, western Hokkaido in order to increment our knowledge of the local diversity of this group.

Twelve samples of 0.5 L of coralline alga *Corallina pilulifera* were collected in the intertidal area of Oshoro bay in May and June 2014. Algae samples were vigorously washed in trays with seawater. The algal material was then removed, the sample allowed to settle briefly and the water gently decanted. All molluscs were picked from the sediment residual. For identification, shell morphology, protoconch, radula, operculum, head-foot and gross anatomy were analysed using both optical and scanning electron microscopy (SEM).

A total of 28475 mollusc specimens were obtained. Concerning diversity it seems to be relatively low (only nine species identified up to now). Rissoids are the most abundant representing over 90% in each sample. Trochids and caecids were also present but in much less quantities. These are very preliminary results but seem to confirm the idea that the abundance of micromolluscs can be very patchy in coralline habitats. The very large differences in abundances may reflect the action of such processes as competition, predation, immigration and emigration, ect. All of these can help assess the distributional patterns in these organisms in patchy habitats such as those represented by coralline algae growths.

***Ruditapes bruguieri* (Bivalvia: Veneridae) at the coasts of Jeju Island**

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Two species of the genus *Ruditapes* are found along the coasts of Korea: the Manila clam *Ruditapes philippinarum* (Adams et Reeve, 1848) and the clam *Ruditapes bruguieri* (Hanley, 1845) [Noseworthy et al., 2007]. The commercial species *R. philippinarum*, including its populations in coastal waters of Korea, is considered in a variety of papers published, but studies on *R. bruguieri* are few in number, despite the latter species is widely spread in the Indo-West Pacific. According to OBIS Indo-Pacific Molluscan Database, 2006-05-17, the synonyms of mollusk *R. bruguieri* are as follows: *Paphia (Amygdala) bruguieri* auct.; *Venus bruguieri* Hanley, 1845; *Tapes tessellata* Adams & Reeve, 1850; *Tapes variegata* Sowerby, 1852; *Ruditapes variegata* (Sowerby, 1852); *Tapes violacens* Deshayes, 1853; *Tapes japonica* Deshayes, 1853; *Tapes cinerea* Deshayes, 1854; *Tapes punicea* Deshayes, 1854; and *Tapes semidecussata* Reeve, 1864. There are also such synonyms as *Tapes bruguieri*, *Venerupis (Ruditapes) bruguieri*, and *Venerupis bruguieri*.

R. bruguieri is a tropical-subtropical species [Noseworthy et al., 2007]. It is distributed in the tropical Indo-West Pacific: Central and East Indian Ocean (West India and East India, Andhra Pradesh, Thailand, Andaman, and Nicobar), Indo-Malaysia (northwestern, northern and northeastern coasts of Australia, Philippines, Indonesia, and Oceania), Papua New Guinea, China (South China Sea, including Hong Kong, and East China Sea), Japan. It also occurs in the Temperate West Pacific of the Northern Hemisphere: South Korea, Korea Bay, and North China [Noseworthy et al., 2007]. Huber [2010] believes that the range of *R. bruguieri* is limited to the Indian Ocean. From Japan and Australia, only *Ruditapes aspera* (Quoy & Gaimard, 1835) is known, whereas both species occur in waters of India.

Little is known about the biology and ecology of *R. bruguieri*. There are no data on growth of this bivalve species. Therefore, the present study investigates some ecological preferences and growth of *R. bruguieri*. Usually, surveys of populations inhabiting marginal areas of the species range are of particular interest for the study of biological and ecological characteristics of the species as in such cases it is possible to reveal threshold values of some environmental parameters that restrict the area of the species natural habitat. For instance, a sea water temperature at the northern boundary of species limits can indicate the thresholds of tolerant temperature limits for the species. As for the range of the tropical-subtropical *R. bruguieri*, its northern boundary runs

particularly along the coasts of Korea, and for this reason the samples of *R. bruguieri* from the coastal waters of Jeju Island, South Korea, were studied in the work.

Materials

Jeju Island is a volcanic formation located about 80 km south of the mainland. Its coastline is mainly rocky with several sandy and pebble beaches. The warm Tsushima Current flowing from the southwest creates a subtropical climate on the island with an average annual water temperature of about 15°C [Noseworthy et al., 2007]. In the studied area, the water salinity is normal, usually oceanic. The island is subject to moderate tides and strong wave action.

Searches for clam *R. bruguieri* shells that were stranded on the beach were carried out in the littoral zone (in the upper-tide and mid-tide levels) of several bays situated on the northwestern, southern, and eastern coasts of Jeju Island during low tides in 2008. Some of clam shell samples collected in 2007, 2008, 2011, and 2012 from the littoral zone of the northern, northwestern, southern, and eastern coasts of the island were kindly provided by K.A. Lutaenko (Institute of Marine Biology, FEB RAS).

Results and Discussion

The largest in number samples of *R. bruguieri* shells were collected on the middle- and coarse-grained sand and sand/gravel beaches on the open eastern coast of the island. However, shells of the studied bivalve species were almost absent on bottom sediments with a high content of fine-grained sand and silt at the southern site. Earlier, shells of *R. bruguieri* were collected on the western littoral zone of small Seogundo Island, near Jeju Island. This Island has a mainly rocky coastline with small sand and gravel areas [Noseworthy et al., 2007]. Here, shells were also found on coarse-grained sand. Thus, these data can be sign for a conclusion that *R. bruguieri* prefers coarse- and middle-grained sand with a slight admixture of silt. The silt content in the bottom sediments may constitute 1–2%. It indicates that the species is, most likely, sensitive to mud resuspension in the water.

Shells of the clam *R. bruguieri* were found in the open bays exposed to strong wave action. Here, the clam habitats are washed only by oceanic waters. At the eastern site, situated in the protected Seongsan lagoon, shells of this species were not found despite the bottom sediments there were suitable for the clam.

As is known, the water salinity at the coasts of Jeju Island is 33.0–34.9‰. The oxygen concentration in the water is high, 7.29–8.14 mg L⁻¹ [Ko et al., 2012]. The chlorophyll concentration ranges from 0.71 to 1.71 mg L⁻¹. The concentrations of nitrate, phosphate, and silicate are 0.029–0.206 mg L⁻¹, 0.001–0.027 mg L⁻¹, and 0.024–0.682 mg L⁻¹, respectively [Ko et al., 2012]. This can be sign that *R. bruguieri* prefers habitats with good water aeration, stable oceanic water salinity and high oxygen concentration.

All the samples of *R. bruguieri* from the coasts of Jeju Island were not large in number. This is an evidence of sparseness of the *R. bruguieri* populations in these waters. This is typical for populations inhabiting marginal areas of the species range. Jeju Island is situated at the northern boundary of *R. bruguieri* range. In cases like this, it is just the winter water temperature that restricts vital functions of animal and determines the lower threshold of temperature favorable for the species. The minimum temperature, 13–14°C, is observed in January and February along the coasts of Jeju Island [Noseworthy et al., 2007]. Therefore, a water temperature of about 13–14°C is close to the lower limit of favorable temperatures for *R. bruguieri*. In summer, the water temperature at the coasts of the Island is about of 22–26°C with the maximum in August [Noseworthy et al., 2007]. At the southern coast of the island, surface water temperature varies from 14.5°C in March to 29.5°C in August; at the depth of 20 m, the water temperature ranges from 14.2°C in March to 27.2°C in September [Ko et al., 2012]. Thus, the annual fluctuations of the water temperature from 13–14°C to 22–29°C can be considered close to the temperature range, within which the studied bivalve species can exist.

The mean value of the ratio of shell length to shell height was 1.47 ± 0.00 , which means that shell is elongated. This ratio was not found to vary with age, i.e. the shape of shell does not change as mollusk grows, and the shell proportions remain almost constant during its lifecycle.

Shells of *R. bruguieri* have rings similar to those of Manila clam *R. philippinarum* that forms annual winter rings on the outer surface of its shell. It is logically to suppose that *R. bruguieri* also forms growth ring during the cold winter period, taking into account that Jeju Island is situated near the northern boundary of *R. bruguieri* range, and retardation in its shell growth is most probable just in winter. Moreover, in late October, two clams with remains of soft tissues were found, i.e. they had died shortly before. Near the shell edge, each specimen had almost complete annual increment. Therefore, the number of rings on the outer surface of *R. bruguieri* shell was used in this work to estimate age of mollusks, and the distance from shell apex to each ring was measured to determine their growth rates retrospectively.

The obtained data on growth of *R. bruguieri* showed a high variability of this process in the studied area. It is partly explained by the interannual fluctuations of environmental parameters, as the specimens were from different age cohorts. As a rule, scattering of the morphometric indices is more than usual for organisms inhabiting areas near boundaries of their species range, where one or several environmental parameters are close to the threshold values for the species tolerance and especially affect its growth rate.

At a level of 95% (t-test) the differences were revealed between the shell heights of the clams collected from the northwestern and southern coasts. It is known that the sea water at the southern coast of Jeju Island is warmer than one at the northern coast due to the warm Tsushima Current flowing from the southwest. Most likely,

this is the reason of higher clam growth rates at the south, than at the north. Along the coasts of Jeju Island, which is near the boundary of the species range, 83.8% of all individuals die during the coldest period of the year.

The maximum age of *R. bruguieri*, determined during the study, is 6.5 years, but the clam samples contain mainly individuals at 3.0–3.5 years of age (34%). The largest clam dimensions are 36.0×26.5 mm (length×height of shell). At the study area, a usual shell length is 20.0–32.0 mm (75% of all the collected individuals).

This work is the first attempt to study growth and some morphological parameters of the clam *Ruditapes bruguieri*, as well as its habitat preferences.

Acknowledgments

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History and an overview of current knowledge on gastropod molluscs in Lake Baikal

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Studies of the first 5 gastropod molluscs in Lake Baikal, its single outlet Angara River and adjacent water bodies were started by Heinrich Gerstfeldt [Gerstfeldt, 1859] who examined collections of Richard Maack. One hundred and fifty five years passed since that and it is time to make an overview. The first researchers needed to mention are brothers Benedict and Wladislav Dybowski. While B. Dybowski was living in exile in the village Kultuk (southern part of Baikal), he with Jan Grochmalicki collected a lot of samples of molluscs, part of which were passed to W. Dybowski [W. Dybowski, 1875] in L'viv and others were studied by themselves (B. Dybowski, J. Grochmalicki, 1913–1927). W. Dybowski described 22 new species of gastropods, whereas B. Dybowski and J. Grochmalicki were the firsts who described the shell variability of Baikal snails.

Large mollusk collections were subsequently made during two-year expeditions of the Russian Imperial Academy of Sciences headed by Prof. A.A. Korotnev covering all perimeter of the lake. These collections were investigated by V. Lindholm [Lindholm, 1909, 1924, 1927], who described 48 new gastropod species and analyzed the zoogeographic relationship between Baikal and non-Baikal freshwater faunas.

The next stage of this research was carried out by M.M. Kozhov (1928–1963) who made extensive investigations, including description of new species and subspecies, taxonomic revision of Baikal molluscs, analysis of the morphology, reproduction, distribution and species relationships and origin.

In the 1970s and '80s the descriptions of new species were continued [Beckman, Starobogatov, 1975], besides the origin, relationships with the non-Baikal malacofauna and zoogeographical zonation were studied [Starobogatov, 1970]. Discoveries of fossil molluscs in the Baikal region, the Altai Mountains, Primorye and Mongolia have allowed for decades to hold paleontological research and hypothesize on the origin of the Baikal endemic molluscs, changing faunas in different geological periods (Martinson, 1949–1961; Popova, 1964–1981).

Complex investigations of Baikal gastropods have been carried out over the past three decades by the researches of the Limnological Institute SD RAS in collaboration with scientists by Institute of biology of Irkutsk State University, Zoological Institute of RAS (St.-Petersburg), Zoological Museum at Moscow State University (Moscow), Institute of Biology and Soil Science of FEB RAS and Institute of Marine Biology

(Vladivostok), Smolensk State Pedagogical University, Institute of Geology and Geophysics SB RAS (Novosibirsk) and others, as well as with researchers from Ukraine (V. Anistratenko, O. Anistratenko), Uzbekistan (Z. Izzatullaev), Germany (F. Riedel, P. Roepstorf, T. Wilke, C. Albrecht), Japan (E. Wada, H. Morino, and others) and Great Britain (E. Michel).

Morphology of embryonic and definitive shell, radula and copulative organs of gastropods were analyzed by means of scanning electron microscopy [Sitnikova et al., 2001; Shirokaya et al., 2003]. We studied the anatomy of snails, revised the species composition of several families and described some new species [Sitnikova, 2001; Sitnikova et al., 2004; Shirokaya, 2007; and others].

Spatial (geographic and vertical) distribution of gastropods, their habitat preferences, environmental impacts affecting taxocenoses and quantitative distribution of species were investigated in Baikal biocenoses [for instance, Sitnikova, Shimaraev, 2001; Sitnikova et al., 2010; Shirokaya et al., 2008].

For the first time reproductive cycles of gastropods were defined, egg mass morphology, duration of embryogenesis, growth rate, age and life history were investigated under conditions maximally adapted to their natural habitat [Sitnikova et al., 2001; Roepstorf et al., 2003; Shirokaya, Roepstorf, 2003; Maximova, Sitnikova, 2006; Maximova et al., 2007].

As a result of our joint work with the colleagues of Department of Cell Ultrastructure of LIN, as well as of FEB RAS and the Natural History Museum (Great Britain) we investigated resource partitioning in endemic coexistent species indicated by gut contents, stable isotopes, radulae morphology and fracturing of large and small diatoms by radular teeth [Shirokaya, 2003; Sitnikova et al., 2012, 2014].

Researchers of LIN SB RAS in collaboration with ISU carried out karyological studies [Poberezhny, Sitnikova, 1978; Poberezhny, 1989; Ostrovskaya et al., 1983–2004], including anthropogenic impacts on gastropod chromosome aberrations [Novikova et al., 1993; Ostrovskaya et al., 1984; Sitnikova et al., 1997 and others].

Isolating mechanisms responsible for adaptive radiation in Baikal were identified for some gastropod families [Sitnikova, 2004; Shirokaya, 2005].

Joint efforts with the Laboratory of Gene Systematics and Ichthyology (LIN) allowed us to study molecular and genetic mechanisms, population variability of widespread Baikal species and evolutionary correlations between closely related gastropod species, polychaetes, symbiotic relations of gastropods and gregarines [Zubakov et al., 1997; Peretolchina et al., 2006, 2007; Kovalenkova et al., 2013; Bukin et al., 2007; Shirokaya et al., in prep.], as well as the correlations of size and growth of snails, and DNA telomere length [Koroleva et al., in press].

Intestinal bacterial flora of gastropod is analyzed in collaboration with the Laboratory of Microbiology [Sitnikova et al., 2012; Tulupova et al., 2012].

Complex investigations of the abyssal malacofauna, including organisms inhabiting hydrothermal, oil and gas hydrate seepage have been recently done with the

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laboratories of Hydrocarbon microbiology, Hydrochemistry and Geology of Lake Baikal [Zemskaya et al., 2012; Sitnikova, Shirokaya, 2013].

Besides gastropods of Lake Baikal, we study malacofaunas of other continental water bodies [Sitnikova et al., 2006; Shirokaya et al., 2012; Sitnikova et al., 2010].

A full report on the research of Baikal gastropods and other continental water bodies is provided by the website of the Limnological Institute SB RAS (www.lin.irk.ru), Section “Bibliography”.

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Feeding habits of *Glycymeris yessoensis* (Bivalvia: Glycymerididae)

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Glycymeris yessoensis (G.B. Sowerby, 1889) is a common, frequently occurring species of bivalves. It inhabits waters near open shores of the Korean Peninsula, south Primorsky Krai, North Japan, southern Kuril Islands, and south Sakhalin (see Figure). The length of its shell is up to 50 mm. Shell is rounded, thick-walled. It occurs at a depth of 1–5 m, burrowing in sand or sand/gravel bottom to a depth of 2–4 cm.

Feeding habits of species of the genus *Glycymeris* are studied poorly. Most authors classify them as suspension-feeders [Hunt, 1925; Reid, 1968; Savina, Pouvreau, 2004; et al.], however studies of fatty acid profiles in *G. glycymeris* showed that the species feeds both on bacteria-enriched detritic matter and on phytoplankton [Galap et al., 1999].

Glycymeris serves food for predatory gastropods [Calvet, Cathl, 1992] and other groups of animals, such as seastars, fish, and reptiles [Powell, 1937; Brun, 1972; Lyle, 1983; Lazar et al., 2011; Baeta, Ramón, 2013; et al.].

The goal of this work is to analyze trophological characteristics of *G. yessoensis* (feeding spectrum, coelenteron fullness index, frequency of occurrence, trophic value, and proportion of food items in the total amount of food).

To study a food contents in *Glycymeris*, we used the method proposed and developed by A.A. Shorygin [1952] for quantitative assessment of feeding habits of fish and subsequently applied for studies of invertebrates [Turpaeva, 1953; Tsurpalo, 1995; Tsurpalo, Kostina, 2003]. Content of digestive tract was retrieved and weighed on a torsion balance with the accuracy of up to 0.001 g. For each specimen of *Glycymeris*, the feeding spectrum or the composition of food items was analyzed, the coelenteron fullness index (the ratio of gut content weight to body weight, multiplied by 10,000) calculated, and the proportions of items in the total amount of food and the frequency of their occurrence (the proportion of organisms with a certain item found in their food in the total number of studied organisms) found. Trophic value of items in a food contents was calculated by the formula, proposed by E.A. Tsikhon-Lukanina [1987]:



Glycymeris yessoensis from Peter the Great Bay (Sea of Japan) [after Lutaenko, Noseworthy, 2012].

$$I = v + w/2,$$

where I is the trophic value, %; v is the proportion of the item in the total amount of food, %; w is the frequency of occurrence of food item, %.

Content of digestive tracts of 18 *Glycymeris* specimens is studied. Body weight of animals varied from 7.06 to 30.01 g. Since body of these organisms is confined within two heavy calcareous valves, the fullness index is very low, averaging at 1.28‰ (from 0.06 to 4.03‰).

The feeding spectrum of *Glycymeris* is enough wide and comprises 17 items. It includes 5 species of diatom algae (*Cylindrotheca closterium*, *Cocconeis costata*, *Navicula directa*, *Trachyneis aspera*, and *Diploneis smithii*), 5 macrophytes (*Gloio-peltis furcata*, *Grateloupia divaricata*, *Ulva* sp., *Blidingia* sp., and *Coilodesme* sp.), 4 nematode species (*Anticoma* sp., *Daptonema* sp., *Enoploides* sp., *Oxistomina* sp.), and also detritus, chitin of crustaceans, and mineral particles.

A food contents from *Glycymeris* usually comprises 1–3 items, rarer 4–5, such as, for instance, detritus, nematode (*Oxistomina* sp.), and debris of green alga (*Blidingia* sp.); another variant: detritus, mineral particles, and diatoms (*Trachyneis aspera*).

One main item in a food contents of *Glycymeris* is detritus, frequency of occurrence of which is 100%. Mineral particles occur enough frequently (77.8%). Diatom algae occur in 33.3% of cases; nematodes and macrophytes, in 22.2%. Chitin of crustaceans is found rarer, in 16.7%.

In the total amount of food in *Glycymeris*, the proportion of detritus is also high (for one-third of mollusks, it occupies up to 100% of volume of the digestive tract). The proportion of macrophytes in the total amount of food is enough high (8.2%), as compared to the other items. The proportions of the other items are insignificant (mineral particles, 0.5%; nematodes, 0.15%; diatoms, 0.1%; chitin of crustaceans, 0.1%).

In *Glycymeris*, the maximum value of trophic significance is recorded for detritus (95.5%). Taking into account that macrophytes (plant-derived detritus) are a constituent of detritus, and the value of their trophic significance reaches 15.2%, the significance of this item in diet of *Glycymeris* grows even more. Significance of diatom algae and nematodes is low (16.7% and 11.2%, respectively). Mineral particles and chitin of crustaceans are excluded from the analysis, as they do not have any trophic significance.

Thus, the main source of food for *G. yessoensis* is detritus, and, consequently, this species is considered by us as a deposit-feeder. Diatom algae and nematodes serve an additional source of food.

The taxonomic identification of the material during the studies of trophological characteristics was conducted by the following experts from A.V. Zhirmunsky Institute of Marine Biology, FEB RAS: A.A. Begun (diatom algae), I.R. Levenets (macrophytes), O.N. Pavlyuk (nematodes). Author would like to express her sincere gratitude to them.

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Interspecific comparison of the spermatozoa heteromorphism in three mussel species (Mytilidae: Bivalvia) from the Sea of Japan

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Bivalve mollusks of the family Mytilidae are the common representatives of benthic communities of the Sea of Japan. Among of them, Gray's mussel *Crenomytilus grayanus* (Dunker, 1853), the Korean mussel *Mytilus coruscus* Gould 1861, and the Pacific blue mussel *Mytilus trossulus* Gould, 1850 are important objects of the mariculture and commercial catching, and often dominate in the upper subtidal zone of the Sea of Japan. In the study of reproductive strategies of mytilids, their spermatozoa were described by a number of authors. The data covered, mainly, peculiarities of morphology and ultrastructure of spermatozoa and traditionally were used for decision of questions in taxonomy of this group of mollusks. It was shown that mytilids are characterized by a "primitive" type of the spermatozoon, which is usually found in invertebrate animals with external fertilization. Until recent time, it was considered that each species of mytilids has only one sperm type. However, we have revealed the cases of heteromorphism in the sperm of Gray's mussel, the Korean mussel, and the Pacific blue mussel.

The goal of this study was detailed, comparative analysis of the heteromorphism phenomenon in male gametes of these three mussel species. It is possible that investigation of this phenomenon can help further development of new approaches underlying in the modern comparative spermatology.

Mature gonads of three mussel species, collected in the Vostok Bay (the Sea of Japan) in July–August 2011 were used for the study. Material was collected at the Vostok Marine Biological Station of the A.V. Zhirmunsky Institute of Marine Biology. Under laboratory conditions, gonads were removed and crashed into small pieces, which were fixed at 4°C in 2.5% glutaraldehyde in 0.2 M cacodylate buffer solution (pH 7.4) for 2–4 h. Then, the specimens were washed in 0.1 M cacodylate buffer solution for 15–20 min. The sperm suspension was placed by a pipette onto the surface of Thermanox cover slips (Cat. no. 72280), incubated until they sedimented (for 30 min). After the preparations were dehydrated in increasing concentration of alcohol to get them gradually into acetone. Thereafter, the samples were dried completely in carbon dioxide in a critical point dryer 030 (BAL-TEC) and placed on the aluminum surface to perform carbon sputter coating. Male gametes were examined under a scanning electron microscope Karl Zeiss Evo 40. The images were edited with the use of the Adobe Photoshop 7.0 graphic

software. Quantitative data were obtained statistically in the Microsoft XL software with the use of Student's *t* test. Comparative analysis of the sperm morphology was done with the help of a TPS software package, with the use of the Kruskal–Wallis test.

We have established the following:

1. Our studies have demonstrated that spermatozoa of these mussels correspond to the morphological description earlier made on ultrastructural level, and consist of the head, with an apical acrosome, a nucleus with basally adjoining mitochondria, and a flagellum protruding from the head.

2. Male gametes of mussels *M. trossulus*, *C. grayanus*, *M. coruscus* are identified as heteromorphic cells. The phenomenon of sperm heteromorphism in the mytilids has been revealed for the first time. Each mussel species produces several morphologically different patterns of mature sperm cells.

3. The greatest number of spermatozoa morphotypes, which is equal to 7, was found in the mussel *M. trossulus*. In one cell population there are 6 different spermatozoa morphotypes in *M. coruscus*, while there are just 5 morphotypes of sperm cells in *C. grayanus*. Differences between these patterns of spermatozoa appear at the level of small size variations and also in the form of acrosome and nucleus.

4. Statistical analysis shows the frequency of occurrence of each sperm morphotype changes. The reasons for quantitative predomination of a certain morphotype in one cell population still remain unclear. Different number of morphotypes spermatozoa might be related with the reproduction adaptivity that is typical for these species.

5. *M. trossulus* and *C. grayanus* have one general morphotype of spermatozoon; a morphotype with trapezium-shaped nucleus and a straight acrosome with a widened basal ring. Comparative analysis of spermatozoa morphology with the use of the Kruskal–Wallis test has shown that the morphological structure of present morphotype is similar in both species ($H = 3.615$, $p = 0.306$). The authors suggest that this fact might be useful for definition of phylogenetic relationship between three investigated mussel species.

6. We have received the sequences of the first part of *COI* gene (658 bp) in *M. coruscus* for the first time. Mean *p*-distances between pairs *M. coruscus* – *C. grayanus* is $21.391\% \pm 2.261$ (mean \pm SE), and *C. grayanus* – *M. trossulus* – $23.356\% \pm 2.345$. Obtained data have evidenced that the sequences of investigated species belong to different species.

Mollusk collection of the Zoological Museum, Far Eastern Federal University, Vladivostok

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The Zoological Museum of the Far Eastern Federal University (Vladivostok, Russia) possesses one of the largest malacological collections in the Russian Far East and in Russia as a whole (see Figure).

The collection of gastropods (Gastropoda) is the largest of all mollusk collections. It includes 8940 lots and over 26 thousand specimens of 2578 species (185 families) from different geographical regions. For most gastropods, only their shells are stored in the collection. The most numerous collections are from the Pacific Ocean. The Indian



View of part of the exhibition of mollusks in the Zoological Museum, Far Eastern Federal University.

Ocean malacofauna is represented by shells collected along the coasts of Africa, India, Indochina and a small collection from the Atlantic and the Arctic oceans. Almost one third of the collection (2098 lots) is comprised of species from Russian, first of all, Far Eastern seas.

The most diverse are the collections of the families Buccinidae (over 209 species), Conidae (180), Cypraeidae (138), and Trochidae (127). Almost two thirds of the collection of Buccinidae, or true whelks, are inhabitants of the Russian Far East seas.

The most valuable part of the research collection is type material. It is represented by the holotype of *Aenigmastyletus alexeii* Martynov, 1998; the holotype and paratypes of *Nipponacmea moskalevi* Chernyshov et Chernova, 2002; the holotype and a paratype of *Runcinida marisae* Chernyshov, 1998; the holotype and a paratype of *Ammonicera vladivostokensis* Chernyshev, 2003; paratypes of *Erginus galkini* Chernyshev et Chernova, 2002; *Ammonicera chosenica* Chernyshev, 2003, and *Nipponacmea vietnamensis* Chernyshev, 2008.

Some shells are very beautiful and thus are especially valuable for the Museum display. Over 400 species of permanently displayed marine gastropods always attract attention of visitors. The most significant contribution to the collection was made by specialists of the Pacific Ocean Research Institute of Fish Industry and Oceanography (TINRO), TINRO Research Fleet Base (TURNIF), and the Institute of Marine Biology, Far Eastern Branch of the Russian Academy of Sciences (FEB RAS: before 1992, Far Eastern Scientific Center, then Far Eastern Branch of the USSR Academy of Sciences).

The terrestrial gastropods' collection includes 183 species from 35 families (548 lots). The families represented by the largest numbers of species are: Bradybaenidae (26 species), Helicidae (17 species), Clausiliidae, and Hygromiidae (16 species each). Most gastropods for this collection were gathered in Primorsky Krai (153 lots), 57 from them in the areas around Vladivostok. A collection of terrestrial gastropods has been presented to the Museum recently by L. Koloukh, the private collector from the Czech Republic. He passed to the Museum 125 lots: 38 species from 11 families.

The collection of freshwater gastropods includes 3155 specimens (555 lots). They represent 150 species from 18 families, and over half of them were collected in Primorsky Krai (232 lots). The malacofaunas of the Baikal Lake and basins of the Amur, Vyatka, and Dniester rivers are also rather diverse. The collection of tropical freshwater gastropods, mainly from the Southeast Asia, has increased for the last several years (162 lots). The shells of endemic species from Sri Lanka are of special interest. The most numerous in the number of species are the families Lymnaeidae and Viviparidae (24 species each).

The bivalve mollusks' collection is one of the most valuable collections in the Zoological Museum. It includes 1102 species (145 of them identified only to genus) from 85 families or 6053 lots (20,869 specimens) in summary. Most species belong to the families: Veneridae (124), Arcidae (93), Cardiidae (90), Unionidae (87), and Tellinidae (82).

The collection includes species type material described by K. Amano, A.V. Martynov, A.V. Chernyshev [Tshernychev], V.S. Labay, O.P. Sulga, O.A. Scarlato, V.S. Slodkevitsch, A.I. Kafanov and K.A. Lutaenko (Nuculidae, Nuculanidae, Arcidae, Limopsidae, Unionidae, Cuspidariidae), and detailed information and photos of the type material are published by Lutaenko and Volvenko [2009].

Museum specialists, students and professors of the FESU are collectors of most bivalves of the collection taken from the Russian Far East seas, mainly the Sea of Japan. Many bivalves were collected there by the IMB and TINRO. Low-boreal bivalve fauna is well represented in the collection, though the number of specimens is not so large, while the high boreal fauna is represented relatively poor. In the 2000s, the research collection of bivalves almost doubled mainly due to K.A. Lutaenko collecting activity (1673 lots), a Curator of the Museum collection, who brings large collections from all his private trips. He greatly contributed to the large malacofauna collection of Vietnam, Hong Kong, Korea, China, India, as well as supplemented the Sea of Japan collection. A number of taxonomic and faunistic papers have been written based on this material.

The bivalve mollusks' collection stored in the Zoological Museum were used by K.A. Lutaenko and R.J. Noseworthy (Canada/Korea) for compiling *Catalogue of the Living Bivalvia of the Continental Coast of the Sea of Japan* [Lutaenko, Noseworthy, 2012]. A full catalogue of the collection was published in the 1990s and now is largely outdated [Darkina, Lutaenko, 1996].

The collection of cephalopods (Cephalopoda) includes 208 lots (481 specimens): 86 species belonging to 35 families. Octopodidae and Sepiidae are represented by ten species, Ommastrephidae by eight species. The collection includes some rare species: deep-water octopus *Opistoteuthis californiana* and squid *Histioteuthis hoylei*. The cephalopod specimens were received from various parts of the world. The collection includes several fossil cephalopods: ammonites and belemnites (elf-bolts).

A collection of chitons (Loricata) includes 75 lots (158 specimens) belonging to 32 species from 7 families. The collection of scaphopods is small, 84 specimens (22 lots). It consists of collections sporadically gathered in New Zealand, Jeju Island (South Korea), along the Pacific coast of Russia and America, in the South China Sea.

Solenogasters (Solenogastres) are represented by two specimens (2 lots) identified to genus level and displayed at the exhibition. One specimen was collected in the Pacific Ocean (east of Hokkaido Is.), another one near the Orkney Islands. Caudofoveates (Class Caudofoveata) are represented by a single specimen from the Sea of Okhotsk.

Information about collection was entered into the computer Access database. It facilitates are quick sorting, grouping and selection of the objects meets users requirements. Required information can be obtained in a split second on the basis of any features included into description.

Mollusk collection of the Zoological Museum is very important from the scientific, educational, and aesthetic points of view, and we hope that its development would increase its value for researchers and public.

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