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Taxonomy and Diversity of Freshwater Bivalve Mollusks (Bivalvia) of China (Based on Analysis of the Catalog by He and Zhuang, 2013)

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Abstract—The diversity of freshwater Bivalvia in China was assessed on the basis of critical analysis of original and published data on the fauna, morphology, taxonomy, and molecular genetics of this group. The taxonomic composition of the following genera has been considered in depth: *Anemina* Haas 1969, *Cristaria* Schumacher 1817, *Sinanodonta* Modell 1944, *Lanceolaria* Conrad 1853, *Middendorffinaia* Moskvicheva et Starobogatov 1973, *Nodularia* Conrad 1853, *Unio* Philipsson in Retzius 1788, *Inversidens* Haas 1911, *Sphaerium* Scopoli 1777, *Pisidium* Pfeiffer 1821, *Odhneripisidium* Kuiper 1962, and *Euglesa* Leach in Jenyns 1832 = *Cyclocalyx* Dall 1905. No fewer than 170 bivalve species were demonstrated to occur in the freshwater areas of China. Underestimation of the Bivalvia species abundance in previous studies, including the latest catalog of the Chinese Bivalvia (He and Zhuang, 2013), may be accounted for mostly by inadequate use of morphological methods and limited faunistic data, as well as a little number of taxonomic works supported by molecular data. Both the generic and specific compositions of the Chinese Unioniformes and Luciniformes have been significantly extended and updated. Based on a complex study of conchological characters, the following synonymy was established for three species: *Sinanodonta qingyuani* He et Zhuang 2013 = *S. woodiana* (Lea 1834) syn. n., *Lanceolaria yueyingae* He et Zhuang 2013 = *L. eucylindrica* C. Lin 1962 syn. n., *Acuticosta jianghanensis* He et Zhuang 2013 = *Nodularia douglasiae* (Griffith et Pidgeon 1833) syn. n.

Keywords: China, Bivalvia, Unioniformes, Unionidae, Luciniformes, Sphaeriidae, fauna, morphology, taxonomic diversity

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INTRODUCTION

The present work was motivated by analysis of the catalog of freshwater Bivalvia of China and the adjacent territories, including the territories of the Russian Federation within the limits of the Amur River basin and Primorskii krai, which was published by Conch Books Publishers in 2013 (He and Zhuang, 2013). The authors of the catalog, the Chinese malacologists and collectors Jing He and Zimin Zhuang, recorded 1004 freshwater Bivalvia species belonging to seven families with 126 valid species being included in the malacofauna of China, five of them are new species, and the remaining 878 names were put on the corresponding synonymy lists.

The catalog on the whole could be considered a considerable step forward if compared with the previous faunistic report (Liu et al., 1979), which contained only 44 Chinese Bivalvia species. Nonetheless, the new book is just a new step which brings us closer to understanding the actual species diversity of the Chinese Bivalvia. While exploring the catalog (He and Zhuang, 2013), we have noted certain questionable points mainly concerning the taxonomy of the shared groups of mollusks occurring in the basins of the Amur River and the rivers of the southern part of Primorskii krai. This work pays greatest attention to the species composition and the taxonomy problems of the Unioniformes belonging to the following genera: *Anemina* Haas 1969, *Cristaria* Schumacher 1817, *Sinanodonta* Modell 1944, *Lanceolaria* Conrad 1853, *Middendorffinaia* Moskvicheva et Starobogatov 1973, *Nodularia* Conrad 1853, *Unio* Philipsson in Retzius 1788, and *Inversidens* Haas 1911, and Luciniformes belonging to the genera *Sphaerium* Scopoli 1777, *Pisidium* Pfeiffer 1821, *Odhneripisidium* Kuiper 1962, and *Euglesa* Leach in Jenyns 1832 = *Cyclocalyx* Dall 1905. Some of our comments refer to the unfounded synonymy and unjustified, in our view, description of three new species to the genera *Acuticosta* Simpson 1900, *Sinanodonta*, and *Lanceolaria*.

THE MAIN TAXONOMIC PROBLEMS

In the early 1970s, there was a common opinion among Russian malacologists that the Amur basin and Primor'e are mainly inhabited by the Chinese subtropical Unioniformes species, which occasionally produce intraspecific forms there (Starobogatov, 1970). At the same time, a valid question arose as to how species living in the warm climate of southern China could also occur under the much more rigorous climatic conditions of northeastern China and the southern regions of the Far East of Russia, which are located in the continental and northern regions of the Amur basin. It is well-known that the body temperature of mollusks coincides with the temperature of the environment, which means that their biological functions become limited when they inhabit colder waters. In this view, it was suggested that the mollusks from the Amur basin and Primor'e belong to individual species that are similar to the species from Southern China only by their exterior. The following taxonomic revision accompanied by redescription of the Amur and Primor'e taxa of different levels (Moskvicheva, 1973, 1973a; Moskvicheva and Starobogatov, 1973, and many other works) revealed that the Amur basin and Primor'e share no common large Bivalvia species with the Yangtze River basin (Prozorova et al., 2005). In addition, study of the collections of the Zoological Institutes of the Russian Academy of Science (St. Petersburg) and the Chinese Academy of Sciences (Beijing) allowed us to confirm that the Yangtze species did not reach farther northwards than the Chendge Shi region (Hebei Province) on the Luan River (*Anemina arcaeformis* (Heude 1877)). The Amur basin and the basins of the main rivers of southern Primor'e (Razdol'naya = Suifun = Razdolnaya = Suifen = Suifen He and Tumannaya = Tumnin = Tumangan = Tumen = Tumyntszyan) differ by the Unioniformes species composition. The *Buldowskia* Moskvicheva 1973 genus is absent in the Amur River basin, while the *Cristaria*, *Amuranodonta* Moskvicheva 1973, and *Lanceolaria* genera are not present in southern Primor'e (Starobogatov et al., 2004), this being caused not only by faunogenetic factors, as was considered previously, but also ecological ones.

We must further add that, in the 1970s–1980s, Russian malacologists often used the underdeveloped modifications of the so-called Comparatory Method to revise the taxonomy of Bivalvia, which represent a complex of approaches to comparison of the outer shell contours of Bivalvia, including both the frontal contours (the most convex in modern terms) and the lateral contours (lateral view and top view). Based on Thompson's concept postulating the development of specific logarithmic helices in representatives of the animal world (Thompson, 1946), certain researchers considered all the more or less observable differences in the contours of the frontal sections of the valves as obviously specific differences, which resulted in unjustifiable description of new taxa (Bogatov, 2014). After the development of the methods has been completed, a great number of the newly described species was abolished. However, many malacologists consider invalid those species that were described, or redescribed, using the modified comparatory methods as well (Graf, 2007; Graf and Cummings, 2007). For example, among all endemic Amur Unionidae redescribed using the new modification of the Comparatory Method, the He and Zhuang catalog (2013) includes only *Middendorffinaia ussuriensis* Moskvicheva et Starobogatov 1973, as well as three "comparatory" *Corbicula* species belonging to the family Cyrenidae (*Corbicula amurensis* Bogatov et Starobogatov 1994, *C. nevelskoyi* Bogatov et Starobogatov 1994, and *C. sirotskii* Bogatov et Starobogatov 1994 (p. 157)) inhabiting the freshwater of the Amur River upstream from Khabarovsk.

Within the framework of the current report, we find it impossible to discuss the taxonomic approaches utilized by different schools of malacology. We just want to emphasize that the shell contour shape and shell convexity have already been used as important taxonomic characters for species identification of certain freshwater Bivalvia for a long time (Zhadin, 1938, 1952) and are invariably used by all those who study bivalves, including the authors of the Chinese catalog (He and Zhuang, 2013), to distinguish, for example, *Anemina angula* (Tchang et al., 1965), which has the flattest shell compared to all other *Anemina* species. It is important to keep in mind that the shape of the spiral/curve of the valve cross section is just one of the many morphological characters of the shell, and each of these characters may be more or less important in certain species and hence should not be used in isolation from the whole array of morphological characters (Bogatov, 2014, 2015).

At the same time, it should be taken into account that the accurate species, and at times generic, identification of Unioniformes based on conchological traits may be a challenging task because of the naturally occurring individual mollusks with the transitional shell forms, which may result from both hybridization and the work of ecological factors. In the latter case, the initial shell margin outlines, which can be seen as the growth rings on the shell, usually correspond to the standard ones for the species (Bogatov, 2015).

Since the taxonomy of Bivalvia is still far from being fully established, we should specify that in the current work we use the order classification provided by Starobogatov (1992) which is based on the morphology of the shell, hinge, and soft body. We that is accepted by Western scientists and is based on present-day phylogenetic studies using complex molecular and morphological approaches (Graf, 2007, 2013; Graf and Cummings, 2006, 2007; Walker et al., 2006; etc.). The results of these studies in large part did not support the previous systems of grouping the genera into families, including those developed by Modell (1964) and Starobogatov (1970) on the basis of the conchological and selected anatomic traits. This was the case in particular for the size of the family Margaritiferidae.

The current data showed that the presence of this family in the Yangtze River basin (Prozorova et al., 2005) was reported erroneously, while the genera assigned to this family appeared to be closer to the North American Ambleminae (Graf, 2007, 2013; Graf and Cummings, 2006, 2007; Walker et al., 2006).

The taxonomic classification of small freshwater Bivalvia is even less clear than the classification of large Bivalvia. According to Starobogatov (1992), this group belongs to the order Luciniformes, whereas Western scientists currently assign it to Veneroida (Bogan, 2008; Graf, 2007, 2013, etc.), which combines a part of Luciniformes and a part of Cardiiformes. In the previous works of the researchers belonging to the Russian School of malacology, the families Sphaeriidae, Pisidiidae, and Euglesidae containing a vast variety of genera were distinguished on the basis of a whole array of morphological characters (Korniushin, 1996; Starobogatov et al., 2004, and many other works). This system proved to be largely artificial, in so far as the ecological and biogeographical characteristics were in many cases used to define the taxons at the specific and generic levels. However, the somewhat opposite approach, currently used by Western scientists and exploited by the authors of the Chinese catalog, which encloses the rich diversity of this group into just two genera, *Sphaerium* and *Pisidium*, does not provide an accurate reflection of the actual situation as well. This was clearly demonstrated by the phylogenetic studies that involved an analysis of 159 morphological characters (Korniushin, 2002; Korniushin and Glaubrecht, 2002, 2006) and three molecular markers (Lee and Foighil, 2003; Clewing et al., 2013). The two latter works revealed five large clades of Luciniformes from Eurasia and Indo-China, whose taxonomic rank may well be subject to discussion, but nonetheless indicate the presence of five, but in no way two, genera, namely *Sphaerium, Pisidium, Odhneripisidium, Euglesa,* and *Afropisidium* Kuiper 1962. In view of the controversy over the data on the phylogenetic relationships between these genera, we adopt the point of view shared by the majority of Western malacologists and consider these genera as part of the single family Sphaeriidae. In the present work, we accept a compromise variant of the classification system based on the above-mentioned phylogenetic studies and on the author's data proper on the morphology of pisidiids and sphaeriids.

Order **Unioniformes**

Family **Unionidae**

Subfamily **Unionininae**

Tribe **Anodontini**

Genus ***Anemina*** Haas 1969

After the manner of Graf and Cummings (2007), the authors of the catalog discussed here describe five species in the genus *Anemina,* namely *A. angula* (Tchang et al. 1965), *A. arcaeformis* (Heude 1877), *A. euscaphys* (Heude 1870), *A. fluminea* (Heude 1877), and *A. globosula* (Heude 1878) (He and Zhuang, 2013, pp. 28–33) occurring in China. It is worth noting that the Chinese malacologists included 22 species names in the list of synonyms to the name *A. arcaeformis*, among which 19 occur in the southern regions of the Far East of Russia. Among the names listed, in addition to the true *Anemina,* we can find the representatives of the closely related genera *Amuranodonta* and *Buldowskia,* as well as the coastal genus *Kunashiria* Starobogatov in Zatravkin 1983 inhabiting the Sea of Japan, which contains the *K. iwakawai* (Suzuki 1939) species occurring on Hokkaido, Southern Sakhalin, and the Southern Kuril Islands. At the same time, the names for the other eight *Kunashiria* species described so far (Saenko et al., 2009) were not included in the list of the *A. arcaeformis* synonyms for some unknown reason. The inadequacy of the synonymy suggested may be illustrated clearly by the images of the shells of the species included in the list (Fig. 1). An examination of these images reveals that the name *Anemina arcaeformis* equally refers to the forms for which the conchological differences are apparently more profound than the differences between the *Anemina* species listed in the catalog (He and Zhuang, 2013, pp. 28–33). In particular, these included representatives of the genus *Amuranodonta* (Figs. 1a*,* 1b), endemic for the paleo-Amur. These mollusks differ markedly from the true *Anemina* (Fig. 1c) by the specific shape of their shell, which is highly elongated with an angular posterior part, this excluding any possibility not only to reduce their names to synonyms of *A. arcaeformis*, but also to assign them to the genus *Anemina*. The specific names of the representatives of the genus *Buldowskia* cannot be considered as synonyms to *A. arcaeformis* as well, since the representatives of this genus differ from aneminas by a more elongated shell (Fig. 1d). We also consider the mention of *Kunashiria iwakawai* in this regard a regrettable mistake. Apparently, the list of synonyms to *Anemina arcaeformis* was formally transferred by our Chinese colleagues from the North American interactive database developed by Graf and Cummings (2015) in accordance with their unification concept (Graf, 2007; Graf and Cummings, 2007). While the taxonomic classification of the Far East mussels at the level of the genera undoubtedly requires additional research involving a broad array of molecular techniques, the rushed reduction of the endemic Far East species clearly distinguishable by important conchological characters to synonyms seems to us to be somewhat premature.

Generic identification of the species of the *Anemina* genus listed in the catalog also raises doubts. In particular, the shape of the shell of the *A. angula* holotype provided in "Fig. 54" (from this point on the references to the figures in the He and Zhuang catalog, 2013, are given as "Fig. ..." with the numbering corresponding to that in the catalog), is more like that of the

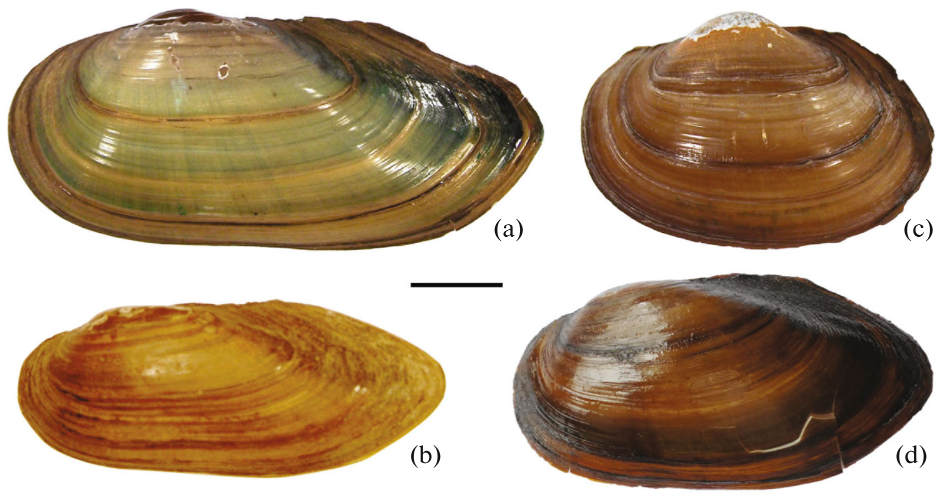

Fig. 1. Anodontini from the Far East: (a) *Amuranodonta kijaensis* Moskvicheva 1973 holotype from Zarechnoe Lake, Kiya River basin; (b) *A. pulchra* Bogatov et Starobogatov 1996 paratype from a small lake near the settlement of Vostretsovo, Bol'shaya Ussurka River basin; (c) *Anemina shadini* (Moskvicheva 1973) lectotype from the Manchzhurka River, Lake Khanka basin; (d) left valve of *Buldowskia flavotincta* (Martens 1905) from the former riverbed of the Gladkaya River, Khasanskii region, Primorskii krai ((a–c) collection of the Zoological Institute of the Russian Academy of Sciences; (d) collection of the Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far East Branch, Russian Academy of Sciences). Scale bar 2 cm.

representatives of the genus *Sinanodonta*. The more elongated shell of the specimen of the same species from Sichuan (Xiushan Xinzhen, Sichuan Province), whose image is provided in "Fig. 55," differs noticeably by its proportions from the holotype, but is almost undistinguishable from the shell of the specimen from Jiangxi (Nanchang, Jiangxi Province), the image of which is provided in "Fig. 275" under the name *Sinanodonta woodiana* (Lea 1834) (Figs. 2a–2d). In addition, the shell of *Anemina arcaeformis* depicted in "Fig. 57" differs markedly from the original drawing by Heude (Heude, 1877) (see the copy of the drawing provided in "Fig. 56") by the umbo shape, broad anterior margin, and updrawn "wing," but is almost undistinguishable from the large *Sinanodonta woodiana* shell from Hubei (Shayang, Hubei Province) by the proportions of the initial shell outlines indicated by the growth rings, the image of the latter being provided in "Fig. 283" (Figs. 3a–3d). The accuracy of the description of the shells on other figures in the discussed section ("Figs. 58–68") as representatives of genus *Anemina*, but not as representatives of genus *Sinanodonta,* is also questionable.

Genus **Cristaria** Schumacher 1817

The catalog includes three species in the genus *Cristaria,* namely *C. plicata* Leach 1814, *C. radiata* Simpson 1900, and *C. tenuis* Griffith et Pidgeon 1833 (He and Zhuang, 2013, pp. 39–43). The first species, in contrast to other Yangtze Unioniformes, is referred to as ubiquitous in China, including the northeastern Amur region, for which reason both endemic Amur *Cristaria* species, *C. herculea* (Middendorff 1847) and *C. tuberculata* Schumacher 1817, are included in its synonymy list. We find it impossible to agree with this synonymy, as we possess enough evidence indicating the complete absence of any species common for the Yangtze basin and the Amur basin among the modern Unioniformes (not taking into account the cases of species introduction). We consider the independency of these two species to be beyond doubt not only on the basis of the noticeable differences in the degree of convexity of their shell valves (Zatravkin and Bogatov, 1987). Although *C. tuberculata* is far more rare than *C. herculea,* we were able to observe the sympatric occurrence of these two species in nature without any transitional forms and the differences in their mobility, microbiotopic confinedness, etc. (Prozorova and Saenko, 2001).

With regard to *C. radiata* and *C. tenuis,* we believe that the shells that are depicted in the catalog under the corresponding names belong to the genus *Sinanodonta*, since these specimens lack the crest and transverse wavelike folds along the anterior part of the dorsal margin and their hinge lacks the back teeth typical for *Cristaria*, which in *Sinanodonta* are often mistaken as ridges on the hinge plate.

Therefore, in China there occur no fewer than three *Cristaria* species, namely, *Cristaria plicata*, which unites the forms described in southeastern Asia, and the two species, *Cristaria herculea* and *C. tuberculata,* widely distributed in the Amur region, which are in some cases referred to as *C. plicata* without good reason (Graf, 2007; He and Zhuang, 2013; Klishko et al., 2014, 2016).

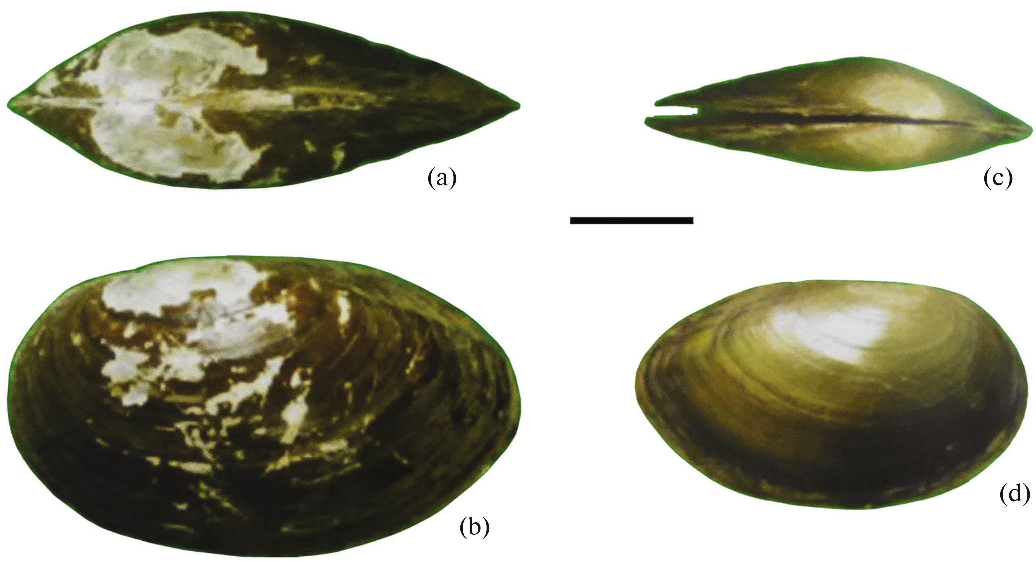

Fig. 2. Shells of the genera *Anemina* and *Sinanodonta*: (a, b) shell of *Anemina angula* (Tchang, Li et Liu 1965) from Sichuan (Xiushan Xinzhen, Sichuan Province) (according to He and Zhuang, 2013, "Fig. 55"); (c, d) shell of *Sinanodonta woodiana* (Lea 1834) (first described as *Anodonta lucida* (Heude 1877) from Jiangxi (Nanchang, Jiangxi Province) (according to He and Zhuang, 2013, "Fig. 275"). Scale bar 2 cm.

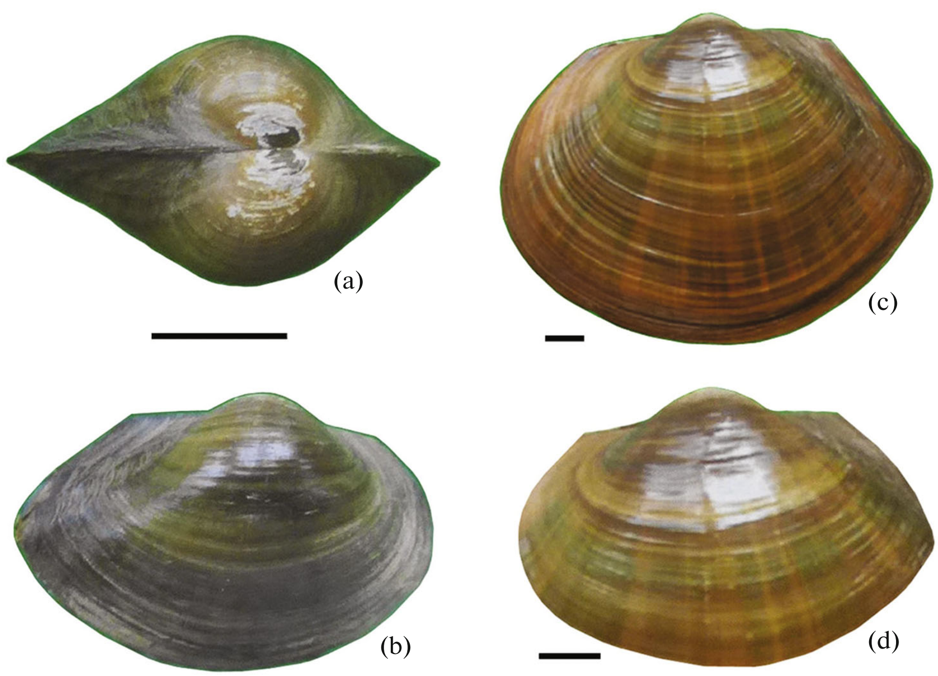

Fig. 3. Shells of the *Anemina* and *Sinanodonta* genera: (a, b) shell of *Anemina arcaeformis* (Heude 1877) from Poyang Lake (Jiangxi Province) (according to He and Zhuang, 2013, "Fig. 55"); (c) large shell of *Sinanodonta woodiana* (Lea 1834) from Hubei (Shayang, Hubei Province); (d) upper part of the same shell (according to He and Zhuang, 2013, "Fig. 283"). Scale bar 2 cm.

Genus *Sinanodonta* Modell 1944

According to the authors of the catalog, the genus *Sinanodonta* in China is represented by two species, namely, *Sinanodonta woodiana,* the list of synonyms for which includes 84 names, and the new species *S. qingyuani* He et Zhuang (He and Zhuang, 2013, pp. 108–114). The synonyms list for *S. woodiana* was found to contain not only all known Chinese *Sinanodonta* species, including the true S*inanodonta* from the Amur basin and Southern Primor'e (Bogatov, 2007),

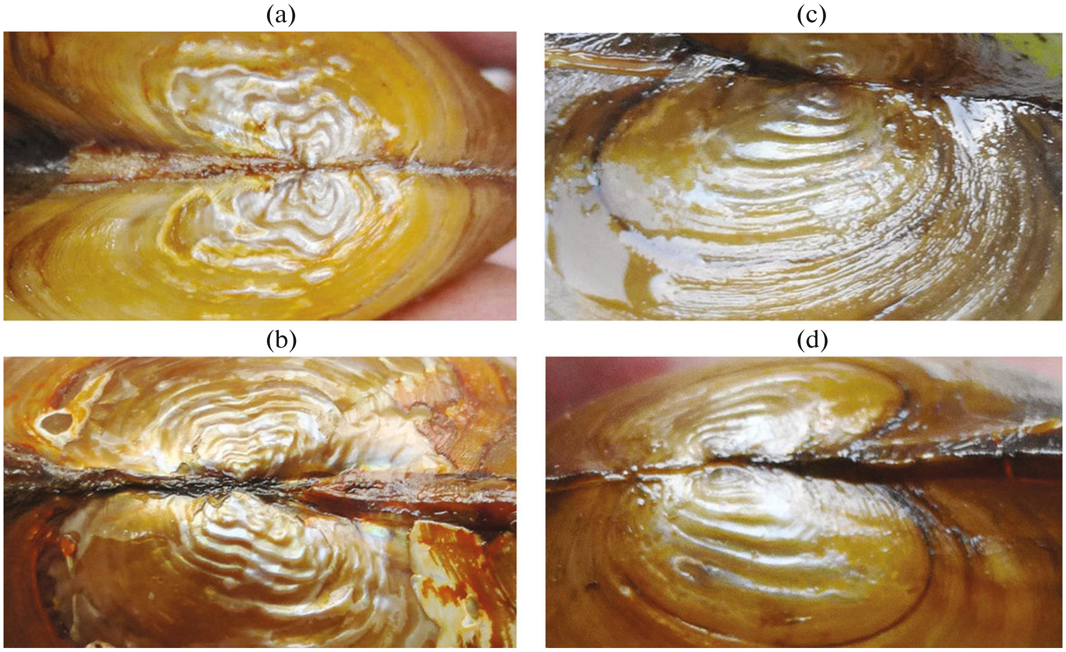

Fig. 4. Apex sculpture in the Anodontini representatives: *Kunashiria* (a, b), *Sinanodonta* (c, d).

but also representatives of the coastal and insular *Kunashiria*, in particular the Japanese *K. japonica* (Clessin 1874) and *K. haconensis* (Ihering 1893) with the exception of *K. iwakawai* (Suzuki 1939), the name of which, as was mentioned above, has become a synonym to *A. arcaeformis* (He and Zhuang, 2013, p. 29). In this view, it is necessary to recall that the species included within the genus *Kunashiria* differ from the true *Sinanodonta* not only by the relevant conchological characters and the apex sculpture pattern (Figs. 4a–4d), but also by the shape of their glochidia (in representatives of *Sinanodonta*, as well as in the closely related *Cristaria*, the glochidia are sharply asymmetric, while in *Kunashiria*, they are just slightly asymmetric) (Starobogatov et al., 2004).

To illustrate the "polymorphism" of *S. woodiana,* the authors of the catalog provided numerous images of the shells the valve shape of which varied from rounded to ovoid-triangular (He and Zhuang, 2013, "Figs. 257–284"). At the same time, our Chinese colleagues found it possible to describe a new species *S. qingyuani,* the distinguishing feature for which appeared to be the elongated ovoid shape of the shell. It should be noted that this character (elongated shell) was left out of the account by the authors of the catalog when they prepared the list of the *Anemina arcaeformis* synonyms; however, it was considered relevant in the case of the description of *Sinanodonta qingyuani.* In this regard we should mention that the character discussed may be considered taxonomically important only when the earlier shell outlines indicated by the growth rings are of the same shape as the successive ones. However, if we judge by the photograph provided by He and Zhuang (He and Zhuang, 2013, "Fig. 285," top view), the growth lines corresponding to the first years of life of the specimen depicted represent an ovoid-triangular shape, typical for the *Sinanodonta* shell (Figs. 5a–5d). Hence, the markedly elongated shell was formed in the later period of mollusk development under the action of external factors and, therefore, cannot be use as a diagnostic character (Bogatov, 2015), especially when it comes to the description of a new species. Because the authors did not provide any other distinguishing characters for *S. qingyuani,* it should be considered as an junior synonym to *S. woodiana*.

To this we should add that *S. woodiana* is indeed widely distributed across the territory of China, from the Xinjiang Uygur Autonomous Region in the West (Liu et al., 1981) to the Pacific coast in the East (Huang et al., 2003). Most findings of this species were recorded in the Yangtze River basin (Lin and Liu, 1863; Tchang et al., 1965; Liu et al., 1980; etc.), where apart from *S. woodiana*, *S. lucida* (Heude 1877) and *S. rivularia* (Heude 1877) were also detected (Prozorova et al., 2005; Liu et al., 1980). In the Chinese part of the Amur River basin, there occur the universal Amur *Sinanodonta* species closely related to *S. woodiana*, at least *S. likharevi* Moskvicheva 1973, detected in Beir Lake (Zatravkin and Bogatov, 1987) and *S. schrencki* Moskvicheva 1973 widespread in Khanka Lake and the Ussuri River basin. Another species, this time *S. fukudai* Modell 1945 from Primor'e and Korea, is likely to live in the Tumannaya River basin, since it was detected in the submouth part of the river (Prozorova and Kavun, 1999; Prozorova, 2001; Bogatov, 2007).

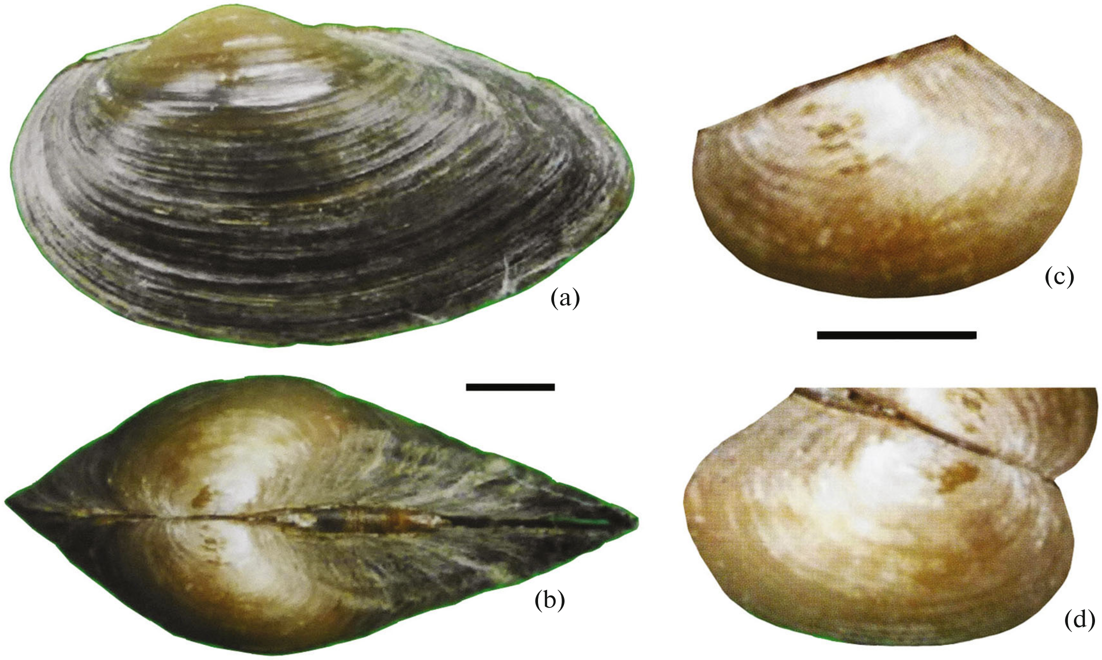

Fig. 5. *Sinanodonta qingyuani* He et Zhuang 2013 holotype: (a) lateral view; (b) top view; (c) subapical region of the left valve; (d) subapical region of the right valve (according to He and Zhuang, 2013, "Fig. 285"). Scale bar 1 cm.

To summarize, according to our data, the discussed genus in China includes no fewer than six valid species (*S. woodiana, S. lucida, S. rivularia, S. likharevi, S. schrencki,* and *S. fukudai*). The taxonomic status of other species in this genus, which were described for the adjacent Russian territories, namely, *S. manchurica* Bogatov et Starobogatov 1996, *S. crassitesta* Moskvicheva 1973, and *S. primorijensis* Bogatov et Zatravkin 1988 from the southern Primor'e Region and *S. amurensis* from the Amur River region, remains unresolved.

Tribe **Unionini**

Genus ***Lanceolaria*** Conrad 1853

The genus *Lanceolaria* is represented in the catalog by seven species: *L. cylindrica* (Simpson 1900), *L. eucylindrica* C. Lin 1962, *L. gladiola* (Heude 1877), *L. grayii* (Gray 1833), *L. oxyrhyncha* (Martens 1861), *L. triformis* (Heude 1877), and the new species *L. yueyingae* He et Zhuang (He and Zhuang, 2013, pp. 70–77). The names of four *Lanceolaria* species described for the territory of Russia, namely, *L. maacki* Moskvicheva 1973, *L. ussuriensis* Moskvicheva 1973, *L. chankensis* Moskvicheva 1973, and *L. bogatovi* Zatravkin et Starobogatov 1984, were reduced to the synonyms to *L. cylindrica* for no reason. The image of *L. chankensis* Moskvicheva 1973 from Saenko's report (2008) was provided as an example of this species ("Fig. 164"), a decision that proved to be unfortunate since the image of *L. chankensis* provided in the mentioned work was mistakenly inverted. Moreover, *L. chankensis* possesses the flattest shell among the Russian *Lanceolaria* species and, hence, by no means resembles a cylinder in shape (Fig. 6a). These facts point to the inaccuracy of the list of synonyms suggested by the Chinese authors.

The resulting imbalance in *Lanceolaria* diversity between the Amur basin (one species) and the Yangtze–Huang He basin (six species) also demands attention, especially if we consider the fact that only a single species from the genus *Nodularia* closely related to the genus *Lanceolaria* was listed for the Chinese malacofauna (He and Zhuang, 2013, pp. 82–85). The attempt at describing the new species, *L. yueyingae* He et Zhuang 2013, which in "Figs. 174 and 175" is compared with the shell of three different species, including *L. eucylindrica,* also seems unreliable. In the figures mentioned, the left valve of *L. eucylindrica* depicted in "Fig. 165" becomes the right valve in "Fig. 174," and again the left valve in "Fig. 175."

Unfortunately, the Chinese authors often utilize a rather inappropriate approach to comparing shells when specimens of different lengths are depicted as being of the same size in two views, the lateral view ("Fig. 174") and the top view ("Fig. 175"). As a result, the proportions of the valves compared appear to be significantly distorted. Using the size data available in the catalog, we tried to restore the actual relative sizes of *Lanceolaria* (Figs. 6b*,* 6c). It can be seen in the resulting figure that the new species differs from *L. eucylindrica* by the markedly slower growth rate. Another distinguishing feature of the new species,

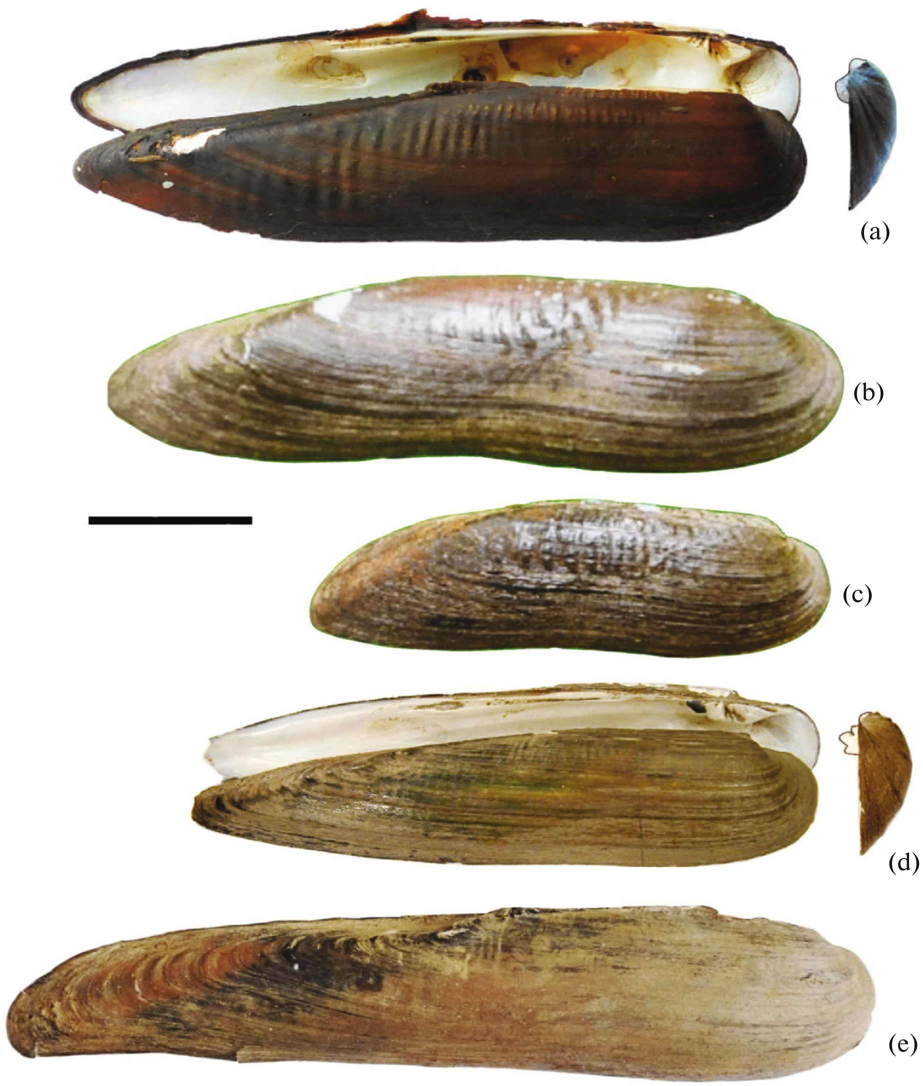

Fig. 6. *Lanceolaria* genus shells: (a) *L. chankensis* Moskvicheva 1973 from Khanka Lake, a waterway near the settlement of Astrakhanka (collection of the Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far East Branch, Russian Academy of Sciences); (b) inverted image of the left valve of *L. eucylindrica* C. Lin 1962 from Hubei (Shayang, Hubei Province) (according to He and Zhuang, 2013, "Fig. 174," third valve from the left); (c) right valve of the *L. yueyingae* holotype (according to He and Zhuang, 2013, "Fig. 174," fourth valve); (d) *L. bogatovi* holotype Zatravkin et Starobogatov 1984 (collection of the Zoological Institute, Russian Academy of Sciences); (e) right valve of the adult specimen of *L. bogatovi* from the Lower Amur, channel near the settlement of Mayak (collection of the Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far East Branch, Russian Academy of Sciences). Scale bar 2 cm.

which was considered relevant by our Chinese colleagues, the dropped posterior margin of the shell, cannot be considered a taxonomic character, since it is an age-related character in these mollusks. This characteristic feature of morphogenesis may as well be observed among the northern *L. bogatovi* populations (Figs. 6d, 6e). Thus, in this case, no relevant taxonomic characters that would allow distinguishing the new species were determined. It is evident that *L. yueyingae* represents a slow-growing variety of *L. eucylindrica,* and the new name should be considered as an junior synonym to the latter. It is possible for *L. eucylindrica* to be further reduced to a synonym to *L. triformis* (Heude 1987), the only difference between them being the bent posterior part of the shell of the latter species (He and Zhuang, 2013, "Figs. 171 and 172"). It seems rather doubtful that such anomaly, which is observed in other mollusk groups as well, should be taxonomically relevant.

Genus ***Middendorffinaia*** Moskvicheva et Starobogatov 1973

Accepting the validity of the genus *Middendorffinaia,* the authors of the catalog include two species within it (He and Zhuang, 2013, pp. 80, 81), namely,

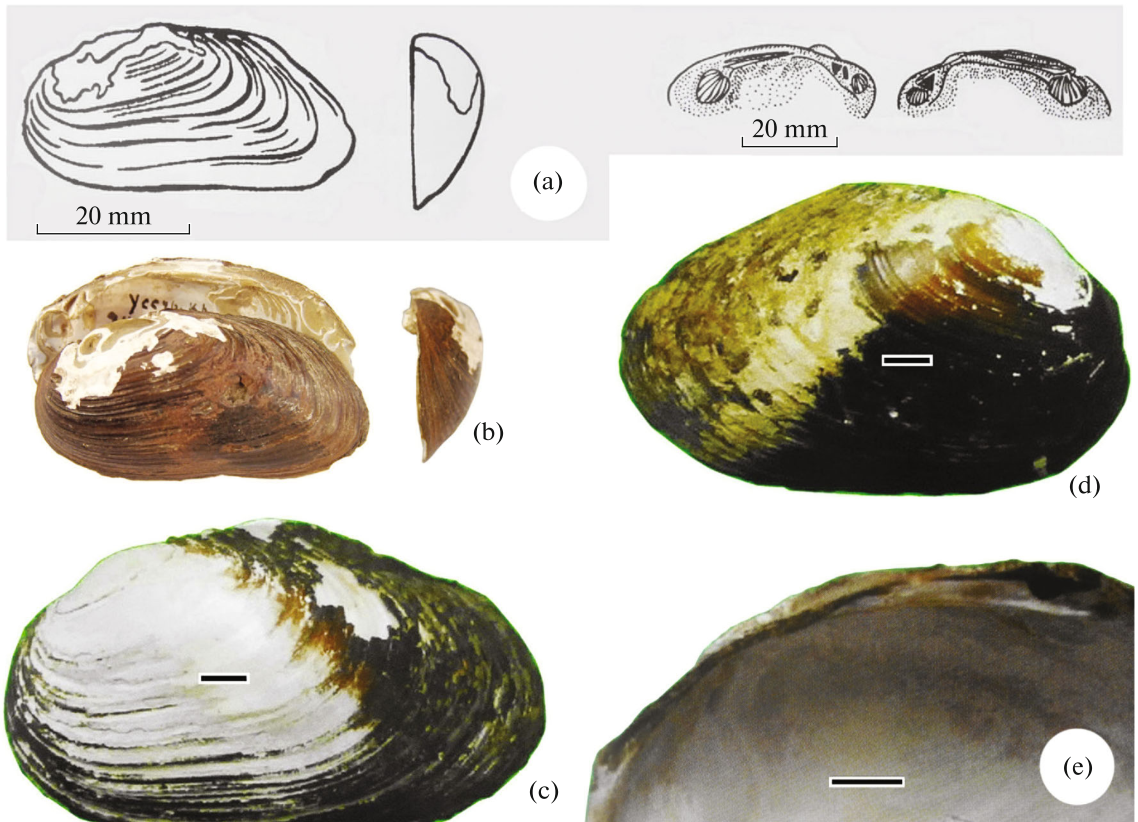

Fig. 7. Shells in the genus *Middendorffinaia*: (a) drawing of the *M. ussuriensis* Moskvicheva et Starobogatov 1973 holotype from the Arsen'evka River (Daubikhe) (according to Moskvicheva and Starobogatov, 1973, Figs. 3i–3k); the same according to He and Zhuang (2013, "Fig. 182"); (b) image of the *M. ussuriensis* holotype (collection of the Zoological Institute, Russian Academy of Sciences); (c, d, e) *M. beirensis* (Liu et Zhang 1982) from Beir Lake, Inner Mongolia: (c) left valve of the syntype, 245 mm (according to He and Zhuang, 2013, "Fig. 183"); (d, e) right valve of the paratype, 230 mm (according to He and Zhuang, 2013, "Fig. 184"). Scale bar 2 cm.

M. ussuriensis Moskvicheva et Starobogatov 1973 and *M. beirensis* (Liu et Zhang 1982). It should be noted that, while *M. ussuriensis* was initially ascribed to the genus *Middendorffinaia*, *M. beirensis* should be included in the genus *Cristaria* if we consider its first description (Liu and Zhang, 1982). Apparently, this unaccountable unification of the two taxonomically distant species was based on certain similarities of their shell outlines (Figs. 7a–7d) and on the observed reduction of the crest on the posterior part of the dorsal margin, which can often be found in old *Cristaria* specimens. It should be recalled here that the typical species of the genus *Middendorffinaia* is *Unio mongolicus* Middendorf 1851 (Moskvicheva and Starobogatov, 1973), which was considered as not worth mentioning by the authors of the book, along with two other Amur *Middendorffinaia* (Middendorff 1851) species, namely, *M. ochotica* Bogatov 2000 and *M. alimovi* Bogatov 2012, comprising a nominative subgenus (Bogatov, 2012). In recognizing the genus *Middendorffinaia,* it would be natural also to recognize the validity of the type species *M. mongolica* (Middendorff, 1851) commonly occurring across the entire Amur basin. Undoubtedly, this and some other Amur *Middendorffinaia* species occur in the Chinese part of the Amur basin as well. For this reason it would be useful to learn the opinion of our Chinese colleagues as to their taxonomic status. With respect to *M. beirensis*, it may be judged by the image provided in the catalog (He and Zhuang, 2013, "Fig. 184") that this species belongs to the genus *Cristaria* since it lacks the front hinge teeth and possess a single back tooth (Fig. 7e), while true *Middendorffinaia* possess well-developed both front and back teeth (see Fig. 7b).

Along with uniting *Middendorffinaia* with *Cristaria*, another obvious mistake made by the authors of the discussed catalog was to transfer the Southern Primor'e subgenus *Pseudopotomida* Moskvicheva et Starobogatov 1973, which includes four species, namely, *M. sujfunensis* Moskvicheva et Starobogatov 1973, *M. weliczkowskii* Moskvicheva et Starobogatov 1973 (syn. *M. hassanica* Moskvicheva et Starobogatov 1973; *M. maihensis* Moskvicheva 1973), *M. shadini* Moskvicheva et Starobogatov 1973 (syn. *M. martensi* Moskvicheva et Starobogatov 1973), and *M. dulkeitiana* Moskvicheva et Starobogatov 1973 from the genus *Middendorffinaia* to the genus *Inversidens* (He and Zhuang, 2013, p. 54). We also consider unjustifiable the transfer of the Amur *Middendorffinaia*, including *M. ussuriensis,* to the genus *Unio* which was performed previously by Graf (2007). The Amur and Southern Primor'e *Middendorffinaia* represent a single group, the subdivision of which into two subgenera, *Middendorffinaia* s. str. and *Pseudopotomida,* suggested by the Russian scientists (Bogatov and Starobogatov, 1992) was based on biogeographic features and may well be annulled in the near future.

Genus ***Nodularia*** Conrad 1853

The authors of the catalog included only a single species *Nodularia douglasiae* (Griffith et Pidgeon 1833) in the genus *Nodularia* (He and Zhuang, 2013, pp. 82–85), which corresponds to data from half-a-century ago, which is now out of date (Lin, 1962; Lin and Liu, 1963; Tchang et al., 1965) and is in good accordance with the unification concept of Graf and Cummings (Graf, 2007; Graf and Cummings, 2007). However, while American malacologists included only ten names of *Nodularia* inhabiting the Amur and Primor'e regions in the synonymy list for this species (Graf, 2007), the Chinese scientists also listed the names of endemic Japanese (for example, *Unio biwae* Kobelt 1879 and *U. nipponensis* von Martens 1877) and some subtropical species (He and Zhuang, 2013, p. 82). The authorship of the genus *Nodularia* is a matter of argument as well. While Graf along with the Russian malacologists attributes the authorship to Conrad, the Chinese scientists give preference to Cockerell with a reference to the unpublished work of Bogan (He and Zhuang, 2013, p. 82).

The authors of the catalog recognize that the species identification within the genus *Nodularia* is exceptionally difficult. Apparently, this was the reason behind the incorrect, in our view, generic identification of the new species *Acuticosta jianghanensis* He et Zhuang (He and Zhuang, 2013, "Figs. 47 and 48," pp. 22, 23) (Figs. 8a–8c). Seemingly, the basis for assigning this species to the genus *Acuticosta* was the slight similarity between the generally oval shape of the shell of *A. jianghanensis* and that of certain representatives of the genus discussed. However, the oval shell is also characteristic of the representatives of the genus *Nodularia.* If we shift our attention to the more important taxonomic characters such as the hinge structure and apical sculpture pattern, it appears that the new species is closer to representatives of the genus *Nodularia* possessing the laminar front teeth (Fig. 8d) and a weblike sculpture formed by thin transverse rolls near the ligament (Figs. 8e, 8f) typical for the representatives of Nodulariinae. The representatives of *Acuticosta* are characterized by the following hinge structure and the sculpture pattern: the low pyramidal front tooth, two–three rows of tuberous ridges radiating from the apex, and the absence of a weblike sculpture near the ligament. Thus, it seems that there is a need to reassign *A. jianghanensis* to the genus *Nodularia*. Moreover, the absence of any significant conchological differences between *A. jianghanensis* and *Nodularia douglasiae* allows us to consider the newly described species as not more than an intraspecific variety of *N. douglasiae*, or in other words, its junior synonym.

Genus ***Unio*** Philipsson in Retzius 1788

The catalog indicates the presence of the European *Unio pictorium* (Linnaeus 1758) and Chinese *Unio rufescens* Heude 1874, commonly included within the genus *Cuneopsis* Simpson 1900 (Liu et al., 1979; Prozorova et al., 2005; Graf and Cummings, 2007) in China (He and Zhuang, 2013, pp. 122–125). The list of synonyms to *U. pictorum* includes 111 mollusk names. There is obviously no need to discuss whether such an extended synonymy list is appropriate or not within the framework of the current work. However, since *U. pictorium* encompasses shells from both Europe ("Fig. 308") and northeastern China ("Figs. 309 and 310"), they undoubtedly belong to different genera, the genus *Unio* and the genus *Nodularia,* respectively. The authors of the catalog explain their position as follows: "Basically, *Unio* seems to be a western European taxon, somehow difficult to distinguish from *Nodularia*" (He and Zhuang, 2013, p. 122). Indeed, *Nodularia* and European *Unio* share some common features of their shells, but they can be very well distinguished from each other by the structure of the excurrent siphon. *Nodularia,* as well as *Middendorffinaia,* show distinct papillae around the edge of the excurrent siphon, while the European representatives of the *Unio* genus lack such papillae (Figs. 9a*,* 9b) (Bogatov, 2009). The additional examination of the siphon shape among the northeastern China representatives of the *Unio* genus is not a challenging task with the result of such study being quite a predictable one.

Subfamily **Gonideinae**

Genus ***Inversidens*** Haas 1911

The catalog contains data on the sole Chinese species *I. pantoensis* (Neumayr 1899), assigned to the Japanese genus *Inversidens* described first as *Unio* (He and Zhuang, 2013, pp. 54, 55). The validity of the name *Inversidens* was earlier confirmed by Graf and Cummings (Graff, 2007; Graf and Cummings, 2007), after whose manner, the authors of the catalog included *Nodularia continentalis* Haas 1910 along with the seven names of the species from the Southern Primor'e subgenus *Pseudopotomida* of the genus *Middendorffinaia* in the list of synonyms to *I. pantoensis,* the name *M. suifunensis* being erroneously listed twice (He and Zhuang, 2013, p. 54). It should be recalled here that the genus *Middendorffinaia* includes another

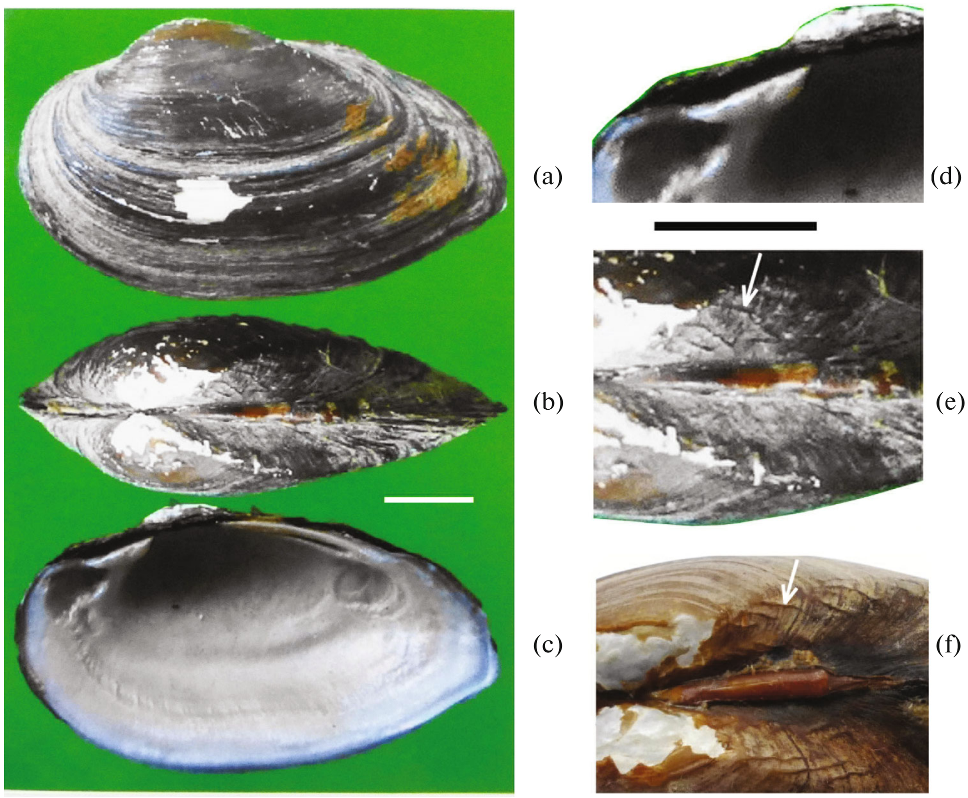

Fig. 8. *Acuticosta jianghanensis* He et Zhuang 2013 holotype from Hubei (Jingyang River, Hubei Province) (according to He and Zhuang, 2013, "Fig. 47"): (a) left valve; (b) top view; (c) right valve, inside view; (d) front tooth of the right valve; (e) rolls near ligament (indicated by an arrow); (f) rolls near ligament, *Nodularia schrencki* (Westerlund 1897) from the Mel'gunovka River, Ussuri River basin (collection of the Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far East Branch, Russian Academy of Sciences). Scale bar 1 cm.

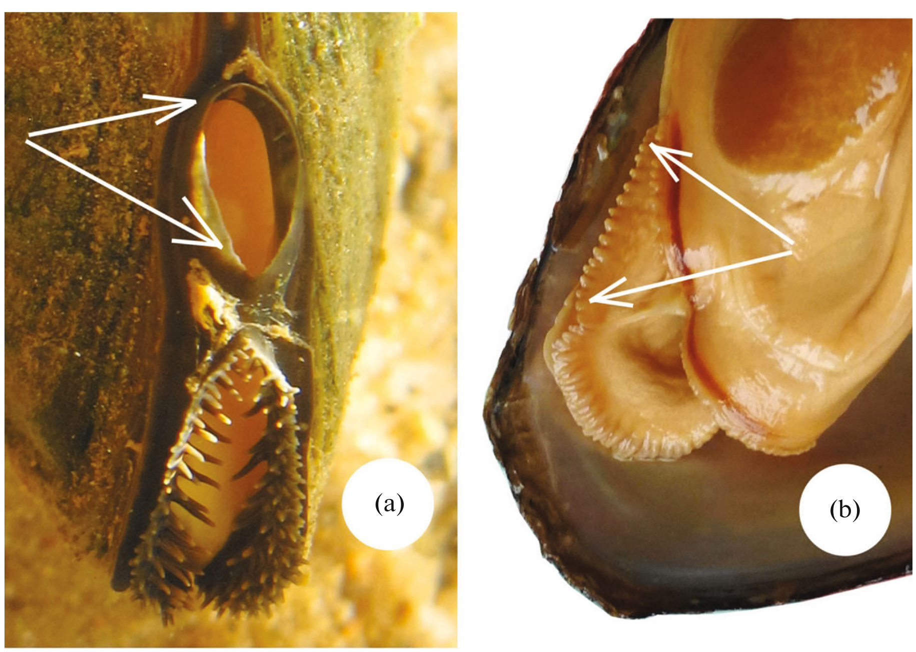

Fig. 9. Siphons in Unionini: (a) *Unio longirostris* Rossmaessler 1836 from Sapsho Lake, Smolensk oblast (image by E. Soldatenko); (b) *Nodularia schrencki* (Westerlund 1897) from the Mel'gunovka River, Ussuri River basin (collection of the Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far East Branch, Russian Academy of Sciences, image by V. Bogatov). Excurrent siphons are indicated by arrows.

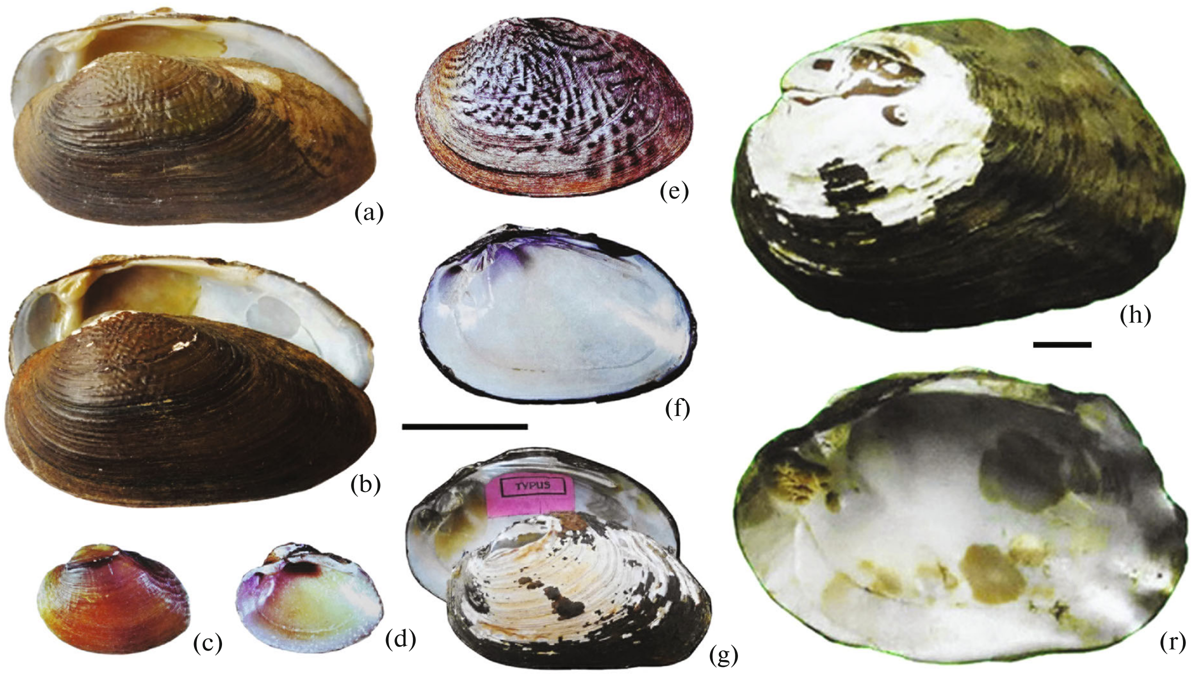

Fig. 10. Shells of some of the Unionidae species: (a, b) *Middendorffinaia sujfunensis* Moskvicheva et Starobogatov 1973 from Cherepash'e Lake (Artem) on the Murav'ev-Amurskii Peninsula (collection of the Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far East Branch, Russian Academy of Sciences); (c, d) *Inversidens brandti* (Kobelt 1879) from Japan (according to Matsuda and Ushiyama, 2009, p. 92); (e, f) *I. japanensis* (Lea 1859) from Japan (according to Matsuda and Ushiyama, 2009, p. 94); (g) *Nodularia continentalis* Haas 1910, type species from Hunan Province (according to He and Zhuang, 2013, "Fig. 126"); (h, r) *I. pantoensis* (Neumayr 1899) from Jiangxi (Duchang, Jiangxi Province) (according to He and Zhuang, 2013, "Fig. 127"). Scale bar 2 cm.

four species from the nominative subgenus, representatives of which occur in the Amur River basin (Moskvicheva and Starobogatov, 1973). It should be noted that all Amur *Middendorffinaia* were earlier reduced by Graf (2007) to synonyms to *Unio crassus mongolicus* Middendorff 1851. As has been demonstrated above, notwithstanding this fact, the authors of the catalog recognized the validity of the genus *Middendorffinaia* and included only *M. ussuriensis* of all the Amur *Middendorffinaia* in it failing to mention three other Amur species, thus causing even more confusion.

We cannot justify the transition of the Primor'e *Middendorffinaia* into the genus *Inversidens* and the reduction of their names to synonyms of *I. pantoensis* because of the considerable differences observed between *Middendorffinaia* (Figs. 10a, 10b) and the Japanese *Inversidens* (Figs. 10c–10f) in the shell morphology, hinge structure, apical sculpture pattern, etc., which indicate that they belong to at least different genera. Evidently, the Chinese authors were once more confused by the external phenotypic similarity, since *Middendorffinaia* from Primor'e often possess truncated shells similar to those of *Inversidens*. In general, the truncated shell of certain *Pseudopotomida* resulting from the slower growth of its posterior part is taxonomically irrelevant since is it determined by ecological factors, such as soil density and the effects of periphyton metabolites. Shell deformations of the same type may be observed in other Unionidae, namely *Buldowskia, Nodularia, Sinanodonta,* etc., with the earliest shell outlines shown by the growth lines being in these cases of the standard, typical for the certain taxon, shape (Bogatov, 2015). It should be further added that, on the basis of the data on the phylogeny of Unioniformes, the genus *Inversidens* and the most closely related to *Middendorffinaia* genus *Nodularia* were assigned to different taxa within the family group (Starobogatov, 1970; Starobogatov et al., 2004; Prozorova et al., 2005; Graf, 2013; etc.).

In the absence of molecular data, the presence of the representatives of the genus *Inversidens* in China (Graf and Cummings, 2007; He and Zhuang, 2013) may not be considered proven. The fact is that the Chinese malacologists consider the presence of two lateral teeth in the right valve as the most important conchological character for this genus (normally the *Unio* representatives are characterized by the presence of a single lateral tooth in the right valve) illustrating their statements with images of the type specimen of *Nodularia continentalis* ("Fig. 126") (Fig. 10g) and a surprisingly large shell (about 15 cm in length) under the name *I. pantoensis* ("Fig. 127") (Figs. 10h, 10r). Indeed, two long lateral plates are noticeable on the hinge plate of the right valve of the *N. continentalis* holotype (see Fig. 10g). However, a more thorough examination of the photograph reveals that the upper plate, which is taken for the lateral tooth by the authors of the catalog, is just a low roll on the upper part of the hinge plate, while the lower plate is a true lateral tooth. The development of low rolls at the margins of the hinge plate is common for different Unionidae groups, especially in adult mollusks. When viewed under side lighting, such rolls may look like true teeth. Regarding the shell in "Fig. 127" (see Figs. 10h, 10r), its identification as the representative of the genus *Inversidens* is an evident mistake since the size of this shell significantly exceeds the definitive size of the *Inversidens* shell. The presence of the broad wavelike longitudinal folds at the posterior margin of the shell and the single lateral tooth in the right valve characterized this mollusk as a representative of some other genus. It should be also noted here that all *Middendorffinaia* representatives possess one lateral tooth in the right valve (see Figs. 10a, 10b).

Order **Luciniformes**

Family **Sphaeriidae**

He and Zhuang subdivided Chinese Sphaeriidae into two genera, *Pisidium* and *Sphaerium* (He and Zhuang, 2013, pp. 161–171), according to the most simplified view on the taxonomy of this family (Graf and Cummings, 2015). The taxonomic structure of Sphaeriidae is a matter of discussion; however, the current morphological and molecular biology data (Korniushin and Glaubrecht, 2002, 2006; Lee and Foighil, 2003; Clewing et al., 2013; etc.) indicate that ovoviviparous small bivalves constitute no fewer than five large genera, which are *Sphaerium, Pisidium, Afropisidium, Odhneripisidium,* and *Euglesa = Cyclocalyx.* In accordance with this subdivision, we identified representatives of three genera, namely, *Sphaerium, Odhneripisidium,* and *Euglesa*, among the Sphaeriidae species listed in the catalog. In addition, our data suggest that true *Pisidium* can be found in northeastern China, while the species *Afropisidium* can be found in the southern regions of the country (Prozorova et al., 2005). The latter supposition was confirmed by recorded finds of two *Afropisidium* species in the Krasnaya River basin (Clewing et al., 2013) and in the northeastern regions of Vietnam adjacent to Southern China (Dang et al., 2002).

Род ***Sphaerium*** Scopoli 1777

According to the morphological taxonomy data (Starobogatov et al., 2004), which is supported by the molecular data (Lee and Foighil, 2003; Clewing et al., 2013), the genus *Sphaerium* may be subdivided into five subgenera, namely, *Sphaerium* s. str.*, Sphaerinova* Iredale 1943*, Amesoda* Rafinesque 1820*, Musculium* Link 1807, and *Paramusculium* Alimov et Starobogatov 1968 (*Sphaerium transversum* (Say 1829) species group). The catalog lists three *Sphaerium* species (He and Zhuang, 2013, pp. 168–171), including *Sph. lacustre* (Müller 1774), the type species of the subgenus *Musculium*, and *Sph. parvium* (Yen 1948) and *Sph. okinawaense* Mori 1937, which most likely belong to the subgenus *Paramusculium*.

All the names of the subgenus *Musculium* species previously described in central China together with the names of the Japanese and North American species (a total of 27 names) were reduced by He and Zhuang (He and Zhuang, 2013, p. 168) to synonyms to European *Sphaerium lacustre* ("Fig. 385"), the areal of which is often thought to be the holarctic region (Graf and Cummings, 2015). Our own data on the Russian *Musculium* fauna and morphology partly confirm this synonymy and the palearctic distribution of this species known in Siberia as *Musculium johanseni* Tscheremnov 1972 and in the Amur region as *M. amurense* Moskvicheva in Zatravkin et Moskvicheva 1986. Undoubtedly, *Sphaerium (Musculium) lacustre* occurs also in the north of China (Lie et al., 1979); however, the endemic *Sph. (M.) likharevi* Moskvicheva 1986 in Zatravkin et Moskvicheva (Fig. 11a) dominates the Ussuri River basin, Khanka Lake, and Primor'e rivers, including the Tumannaya River (Prozorova, 2001). This species is the sole representative of the discussed subgenus in the natural biotopes of Southern Primor'e. We also detected it in northeastern China when exploring the lower reaches of the Tumannaya River near Hunchun in 2015. *Sph. (M.) likharevi* differs from *Sph. (M.) lacustre* not only by the shape of the shell and the smaller size of the shell, but also by the hinge structure with hinge lateral teeth at both edges of the valve being short and of almost the same length (Zatravkin and Moskvicheva, 1986; Starobogatov et al., 2004). *Sph. (M.) likharevi* is the most closely related to the Japanese representatives of the subgenus *Musculium*, which were shown to differ from *Sph. (M.) lacustre* at the molecular level (Lee and Foighil, 2003). It should be noted that we observed similar cases in other groups of freshwater mollusks when Russian species from the southern Far East rather than Chinese and European species, as was previously considered, appeared to be the closest relatives of the Japanese species (Prozorova et al., 2014, 2015; Saito et al., 2015).

Another species in the subfamily *Musculium*, *Sph. (M.) kashmirensis* Prashad 1937, described from the upper reaches of the Indus River and widespread across the Tibetan Plateau, is mentioned in the catalog, but is not included in the faunistic list because of the "absence of clear morphological differences from *Sph. lacustre*" (He and Zhuang, 2013, p. 168). However, the data indicating its species identity and the occurrence on the Tibetan Plateau (including China) are beyond doubt and are supported by the results of molecular analysis (Clewing et al., 2013).

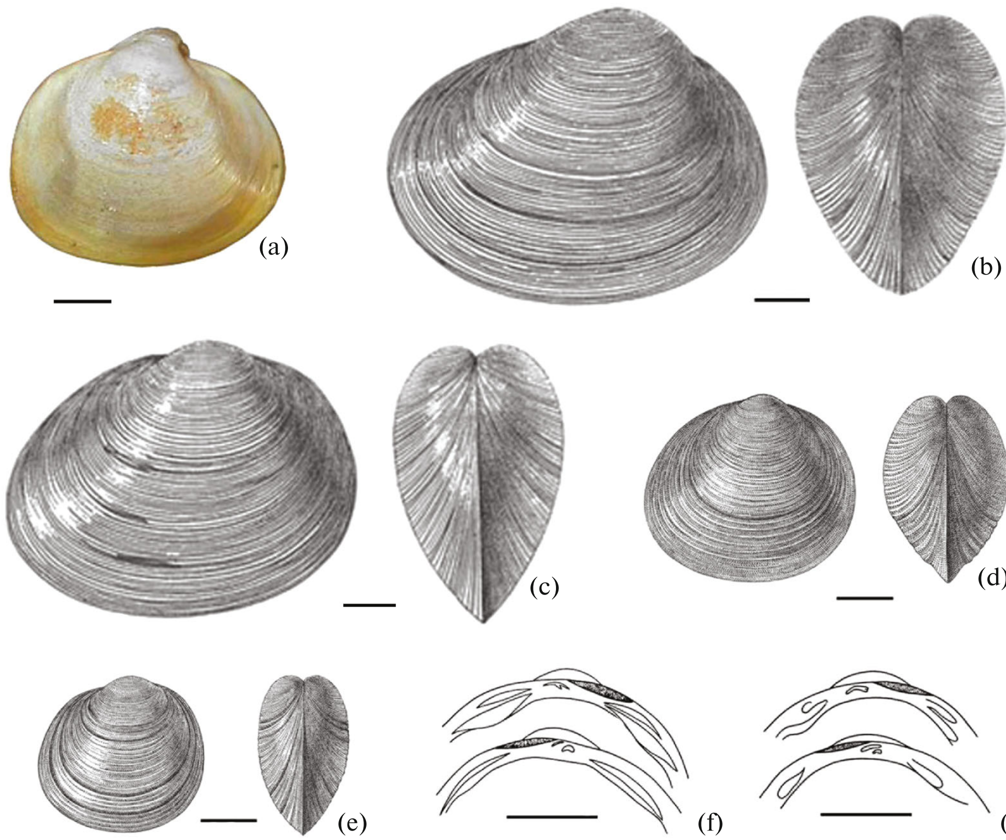

Fig. 11. Shells of some of the Luciniformes species: (a) *Sphaerium (M.) likharevi* Moskvicheva 1986 in Zatravkin et Moskvicheva 1986 from the south of Primorskii krai (collection of the Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far East Branch, Russian Academy of Sciences); (b) *Pisidium amnicum* (Müller 1774) from the Mel'gunovka River, a tributary of Khanka Lake (collection of the Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far East Branch, Russian Academy of Sciences); (c) *P. amurense* Moskvicheva in Zatravkin 1985 from the Ussuri River (collection of the Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far East Branch, Russian Academy of Sciences); (d) *Euglesa falsicorbicula* Prozorova in Prozorova, Starobogatov et Korniushin 1996 from the Ussuri River (according to Prozorova et al., 1996); (e) *E. chankensis* (Likharev in Shadin 1952) from Khanka Lake (according to Prozorova et al., 1996); hinges of *E. falsicorbicula* (f) and *E. chankensis* (g) (according to Prozorova et al., 1996). Scale bar 1 mm.

Sph. parvium from the lower reaches of the Yangtze River (He and Zhuang, 2013, p. 171), which is characterized by valves with a slightly elevated umbo, which is a little tilted forward, and the flattened shell, belongs, judging from its original description (Yen, 1948) and the images of the mollusk ("Figs. 388 and 389"), to the subgenus *Paramusculium,* one of the species in this subgenus, the Amur *Sph. (P.) limanicum* Moskvicheva in Zatravkin et Moskvicheva 1986, also occurring in Khanka Lake (Zatravkin and Moskvicheva, 1986; Prozorova, 2000; Starobogatov et al., 2004). Because the lake is located in part on the territory of China (as are the upper reaches of the Razdol'naya River), we consider it possible to include this species in the fauna list of neighboring countries as well. As opposed to *Musculium* s. str., the ligament in the species belonging to the subgenus discussed is external (Korniushin, 1996, 2000), but never protruding beyond the valve margin (Starobogatov et al., 2004). The representatives of the genus *Paramusculium* share similar ecology inhabiting large drainage lakes and rivers. However, the areals of the two indicated species do not overlap since the former occurs in the Yangtze basin, while the latter is not found beyond the Amur River basin and the basins of the large Southern Primor'e rivers (the Razdol'naya River).

Thus, the representatives of the genus *Sphaerium* in China include at least six species, namely, *Sph. (Musculium) lacustre, Sph. (M.) likharevi, Sph. (M.) kashmirensis*, *Sph. (M.) okinawaense, Sph. (Paramusculium) parvium,* and *Sph. (P.) limanicum*, and not three species as it is presented in the catalog (He and Zhuang, 2013).

Genera ***Pisidium*** Pfeiffer 1821, ***Odhneripisidium*** Kuiper 1962, ***Euglesa*** Leach in Jenyns 1832 = ***Cyclocalyx*** Dall 1905

The genus *Pisidium* in the catalog encompasses six species, namely, *P. appressum* Prashad 1933, *P. stewarti* Preston 1909, *P. casertanum* (Poli 1791), *P. obtusale* (Lamarck 1818), *P. zugmayeri* Weber 1910, and *P. uejii*

Mori 1938 (He and Zhuang, 2013, pp. 161–167). However, these species belong to other genera, which are distinct from the true *Pisidium* (*P. amnicum* (Müller 1774) species group) by both morphological (Korniushin, 1996, 2002; Starobogatov et al., 2004; Korniushin and Glaubrecht, 2002, 2006; etc.) and molecular features (Lee and Foighil, 2003; Clewing et al., 2013). The representatives of *Pisidium* s. str. can easily be identified by the strong relatively large shell which in shape resembles a right triangle with rounded corners. Among the true *Pisidium,* the Palearctic *P. amnicum* (Fig. 11b) and *P. amurense* Moskvicheva in Zatravkin, 1985 (Fig. 11c) from the Amur and Ussuri surely occur in northeastern China, since both species are common in the basins of Khanka Lake, the Amur, and the Ussuri (Prozorova, 2000; Starobogatov et al., 2004).

In China, the genus *Odhneripisidium* includes in addition to the type species *O. stewarti* the Tibetan species *O. appressum*, which is characterized by an introverted ligament deeply embedded in the shell and extending to the edges of the hinge plate ("Fig. 375"). Both species were described from Yarkand County of the Xinjiang Uygur Autonomous Region, where the closed-drainage system of the Tarim River is located (Starobogatov, 1970; Preston, 1909; Prashad, 1933). *O. appressum* is morphologically the closest to the Indian *O. annandalei* (Prashad 1925), which, in turn, is closely related, according to the molecular data, to the Japanese *O. japonicum* (Pilsbry et Hirase 1908) and *O. parvum* (Mori 1938) (Clewing et al., 2013). It seems justifiable to assign these species to a separate subgenus within the genus *Odhneripisidium.*

Regarding the small Sphaeriidae, which are included by foreign researchers in the *Cyclocalyx* group, for these mollusks there is a broader and older name *Euglesa,* the validity of which resulted from the selection of the neotype for *Euglesa henslowiana* Jenyns 1832, the type species for this genus (Korniushin, 2000; Falkner and Korniushin, 2000). Although the authors of the Chinese catalog under discussion expressed doubts about the accuracy of the species identification of *Euglesa casertana, E. obtusalis,* and *E. uejii,* they however provided long lists of synonyms to the first two species, including the Siberian, Amur, Southern Kuril, and Japanese names in them without any justification. Yet two names of species from the closed-drainage basin of the Tarim River in Yarkand oblast, namely *Pisidium yarkandense* Prashad 1933 and *P. stoliczkanum* Prashad 1933, were reduced by He and Zhuang to the synonyms to *Pisidium obtusale* quite rightly (He and Zhunag, 2013, p. 161), this having been done earlier by Kuiper based on study of the type materials (Kuiper, 1989 in Korniushin, 1996).

Recently two more *Euglesa*, *E. nitida* (Jenyns 1832) and *E. subtruncata* (Malm 1855) were detected on the Tibetan Plateau (Clewing et al., 2013), which should be added to the list of Chinese malacofauna. In addition, based on the data on the fauna of the bordering regions, we may speak about the presence of some more species of this genus in the water basins of Jílín and Heilongjiang Provinces. In particular, in Khanka Lake and the rivers of the Amur River basin from its upper reaches to the mouth, there may be found species of the *E. henslowana* (Sheppard 1825) group (Zhadin, 1952; Prozorova, 2000, 2006), which constitute a separate taxon within the *Henslowiana* Fagot 1892 subgenus (Korniushin, 1996; Prozorova et al., 1996), the latter often being elevated to the status of a genus (Starobogatov et al., 2004; Prozorova, 2013, 2013a; etc.). Two species from this group, namely, *E. falsicorbicula* Prozorova in Prozorova, Starobogatov et Korniushin 1996 (syn.: *E. costifera* Korniushin et Starobogatov in Prozorova, Starobogatov et Korniushin 1996) (Fig. 11d) and *E. chankensis* (Likharev in Shadin 1952) (Fig. 11e), were recorded in Khanka Lake (Zhadin, 1952; Prozorova, 2000, 2006). These species can be distinguished from other *Euglesa* species by a more flattened, rounded-quadrangular shell with regular ribs, as well as an elongated narrow ligament pit. The differences between *E. falsicorbicula* and *E. chankensis* lie in the width of the apex, the degree of rib development, and the hinge structure (Figs. 11f, 11g).

Therefore, in China, the genus *Euglesa* unrecorded in the catalog encompasses at least eight species, *Euglesa nitida, E. subtruncata, E. zugmayeri, E. falsicorbicula, E. chankensis*, *E.* cf. *uejii, E.* cf. *casertana,* and *E.* cf. *obtusalis.*

To summarize, small Luciniformes bivalves are represented in China by at least 16 species and not nine species as is indicated in the catalog (He and Zhuang, 2013). Taking into account that two *Afropisidium* species recorded in adjacent regions of northern Vietnam are likely to inhabit the southern China, the diversity of the order may be as high as 18 species.

Clearly, the names of many Chinese Bivalvia species have a considerable number of synonyms, which may be objectively connected with the long history of research and predominance of the conchological approach. Extensive data on the species composition of this mollusk group were first reported in the late 19th–early 20th centuries (Heude, 1875, 1877, 1883, 1885; Haas, 1910; etc.). These works, as well as the major part of the reports published in the mid and late 20th century (Lin, 1962; Liu et al., 1992; etc.), chiefly contained the species lists for various water basins and regions of China along with the conchological descriptions of the new species and subspecies based on the morphological properties of definitive shells. Later, the data on the morphology of their glochidia (Wu et al., 1999, 2000) and phylogeny of several Chinese Unioniformes (Huang et al., 2002) appeared in press. Regretfully enough, no data on the soft body morphology were used, with no special works concerned with the study of these taxonomically relevant features in the Chinese species ever having been reported. As a result, the taxonomic system of the Chinese Bivalvia lower than the family levels remains loose and the taxonomic status of certain groups without distinct conchological identity is still vague. Inadequate attention paid to labor-consuming morphological studies largely accounts for the incidents with generic identification observed by us in the catalog discussed (He and Zhuang, 2013), unjustifiably long synonymy lists for many species, and, as a consequence, overall underestimation of the richness of the freshwater bivalve fauna of China.

The generic and specific synonymy of Bivalvia used in the catalog is in good accordance with the data that were obtained based on the broad species concept and are available at the website of The MUSSEL Project North American (Graf and Cummings, 2015). Viewed in this way, the majority of the Russian bivalve species, including the endemic Amur and Primor'e species, are usually reduced to synonyms to the European names based on the similarity of the definitive conchological characters, without regard to the distinctness of the morphology of the embryonic shells and soft tissues (for example, Graf, 2007). The objective cause is that the taxon diagnoses in the Russian language published previously is not readily available and not yet digitized in Russian journals; the subjective cause is prejudice against the mollusk species that are allegedly described by the Russian scientists only on the basis of curvature of the shell frontal section (Bogatov, 2014, 2015). The confusion of views on the taxonomy and faunistics of Chinese bivalves is compounded by the fragmentary nature of molecular and morphological data, disregard of important morphological features, and obvious deficiency in the number of solid phylogenetics works involving complex genetic and morphological data. The current work illustrates the most critical issues, among those we have noted above, in the taxonomy of freshwater Chinese Bivalvia at the generic and specific levels by the example of analysis of the previously published catalog of Chinese Bivalvia (He and Zhuang, 2013).

Resolution of the problems identified will allow us to estimate more accurately the actual taxonomic diversity of freshwater Bivalvia inhabiting the vast territory of China. The territory of China is almost equally distributed between the Palearctic and Oriental biogeographic realms (Banarescu, 1990), or between the Palearctic and Sino-Indian zones, according to the zone division by Starobogatov (1970, 1986). The great variety of natural conditions and the presence of large river and lake basins determine the high diversity and endemism of the aquatic malacofauna of this country (Prozorova et al., 2005; Graf and Cummings, 2007; Bogan and Roe, 2008; Strong et al., 2008), which is only partially reflected in the catalog discussed (He and Zhuang, 2013). For example, cataloguing of the bivalve fauna of the basin of the Yangtze River, the largest and longest water course in Eurasia, which we performed together with Chinese malacologists from the Zoology Institute of the Chinese Academy of Sciences, revealed the presence of 80 species and subspecies of bivalves (Prozorova et al., 2005). Taking into account the data accumulated over the last decade, including the newly described species and taxonomic updates, we may state that there are now no fewer than 100 taxons of the species group. Malacofauna of the other two large water basins of southern China, the Xi River = Xun River (Pearl River) and the upper reaches of the Yuan River = Hong Hà (Red River), differs significantly from that of the Yangtze River at both the specific and generic levels (Starobogatov, 1970; He and Zhuang, 2013) thus increasing the diversity of the Chinese Bivalvia by no fewer than 30 species. In what regards the northeastern Jílín and Heilongjiang provinces, which share the Amur River, Ussuri River, Razdol'naya River, Tumannaya River, and Khanka Lake basins with Russia, among the ninety-five Unioniformes and Luciniformes species recorded in this region on the territory of the Russian Far East (Prozorova, 2000, 2001, 2013, 2013a), about thirty species occur also in the waters of China. The closed-drainage basins of the northwestern arid regions and the water basins of the Tibetan Plateau, which are characterized by impoverished palearctic malacofauna, may add no fewer than ten species of essentially the smallest representatives of the order Luciniformes to the Chinese bivalve fauna (Starobogatov, 1970; Prashad, 1933, 1937; Nesemann and Sharma, 2005; Nesemann et al., 2007; Clewing et al., 2013). Among the large Unioniformes, only single *Corbicula* Megerle von Mühlfeld 1811 species were described from the inner closed-drainage basins, Kokonor Lake, and, possibly, near-border water basins belonging to the Irtysh River and Balkhash Lake water systems.

To summarize, the most conservative estimate of the diversity of freshwater bivalve fauna in China is about 170 species. We hope that the comments and data provided in the current work will contribute to the study of the taxonomy of bivalves and their fauna in China and all of East Asia, which would finally allow us to assess adequately the diversity of the rich freshwater malacofauna of this unique region and its lake and river basins in particular.

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