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Bivalves composition and ecological aspects of the Ba Lai River, an estuary of the Mekong Delta, Vietnam

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ABSTRACT

Benthic mollusk communities in the upper part of the Ba Lai River (the Mekong Delta), located upstream an irrigation dam, were investigated with respect to species composition, densities, biodiversity and some ecological aspects in 5 sampling stations. Densities of bivalve communities ranged from 21.5 ± 8.2 inds/10 cm^2 to 28.5 ± 3.3 inds/10 cm^2. In summary, 12 species from six Bivalvia families were recognised. Preliminary investigation on reproductivity of *Corbicula blandiana* showed the species is dioecious (specimens with separately female or male gonads were indicated), perhaps non-incubatory. Find of *Meretrix lyrata*, the most abundant commercial species in southern Vietnam, brings up a necessity on suitable policy and exploration in the Ba Lai to conserve valuable species for economic development and scientific purpose.

Key words: Bivalvia, ecology, distribution, Ba Lai River, Mekong Delta, Vietnam

INTRODUCTION

The Mekong Delta is located in southwestern Vietnam where the Mekong River approaches and empties into the East Sea (South China Sea) through a network of distributaries. The Mekong Delta, as a region, lies immediately to the west of Ho Chi Minh City, roughly forming a triangle stretching from My Tho in the east to Chau Doc and Hà Tiên in the northwest, down to Ca Mau at the southernmost tip of Vietnam, and including the Phu Quoc Island. The Mekong Delta of Vietnam includes two major branches that are the Mekong (named as Tien River in Vietnam) and Bassac (Hau) of Mekong River, tributaries and the interacting canal network connecting with Vam Co and Dong Nai river systems. The Mekong Delta begins from Phnom Penh City and ends up as a huge fertile flat plain in southern Vietnam where the largest tributary, the Bassac, branches away from the Mekong. The Tien and Bassac split into a number of smaller distributaries, forming an area known in Vietnam as the "Nine Dragons". Tien River flows to the East Sea by 6 tributaries: Cua Dai, Cua Tieu, Ba Lai, Ham Luong, Co Chien and Cung Hau.

The Mekong Delta is not strongly industrialized, but is still the third out of seven regions in terms of industrial gross output. The region is intensively cultivated for rice and for cage-cultured *Pangasius* catfish. As a result, it is facing serious chemical contamination and nutrient pollution, so that the anthropogenic pressure influences strongly the status of its environmental quality. Today, this abundant delta is one of the top three most threatened deltas in the world from the impacts of climate change, from

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reduction of Mekong sediment flows, and from human land use modification.

In addition to anthropogenic pressure, natural variability affects the Mekong estuarine system. The Mekong Delta region of Vietnam displays a variety of physical landscapes, but is dominated by flat flood plains in the south (+1.0 m ÷ +5.0 m, +2.0 m on average), with a few hills in the north and west. So the tidal flats are daily subjected to great fluctuations in salinity and humidity and the tidal regime is causing a heterogeneous and unstable biotope characterized by strong environmental gradients to which the biota is adapted. The Mekong estuarine system, as many tropical estuaries, is also characterized as a temporarily "negative estuary" in the dry season when evaporation from the surface exceeds the freshwater runoff entering the estuaries (McLusky and Elliott, 2004). Only Mekong Delta of Vietnam has a migrated phenomenon of marine originated species into the inland water bodies. The flooded season provide good conditions for the marine originated species enlarging widely the distribution area toward to the north part of the Mekong Delta, in addition, the acid sulfate water have limited the development and restricted the distribution of freshwater aquatic flora and fauna in many areas of the Mekong Delta in the dry season.

The combined impacts of natural and anthropogenic stressors on the estuarine system are responsible for a continuous change in the biochemical, physical and biological characteristics of the sediment including the distribution of aquatic animals along the estuarine gradient.

The Ba Lai River, one of the above mentioned tributaries of the Tien River, is a good example of the combined impacts to the river biota. The Ba Lai flows through Ben Tre Province, where the extensive irrigation makes it a major producer of rice, but also means that the area is prone to flooding. In 2002, an irrigation dam was built across the Ba Lai to stop the infiltration of salt water and preserve fresh water. However, after more than 10 years now, the construction of this dam is considered as an environmental failure for the originally connected estuarine and river ecosystem. Despite of dam construction, saltwater still can reach in the dry season the freshwater reserve from the An Hoa channel which connects with the Dai estuary. In addition, this dam resulted in a high silt deposition, since the water from upper stream was not strong enough to remove substrate and alluvium from the Dai estuary transported land inward by the tidal regime. Upstream the dam, fresh water also becomes enriched, low in oxygen and acidified because of its stagnation.

Studies on meiofauna from 8 estuaries including the Ba Lai River in the Mekong Delta were made (Ngo *et al*., 2013a, b; Ngo *et al*., 2016; Ngo and Ngo, 2014), and the data on mollusks collecting were first made for the Cung Hau and Tien rivers (Ngo *et al*., 2013b; Ngo and Ngo, 2014). This investigation is the next line survey on bivalve mollusks with their identification and distribution along the Ba Lai River (Raschepkina and Sayenko, 2017; Sayenko *et al*., 2017). Mollusks are known as indicators of environmental change and there are many examples of decline and modification of molluscan faunas and assemblages in heavily polluted south Asian coastal shallow waters, estuaries, mangrove ecosystems and lagoons (Di Geronimo *et al*., 2005; Meiji *et al*., 2009; Negri *et al*., 2015; Lutaenko, 2016). For instance, in the Gulf of Thailand, diversity indexes reveal a dramatic biodiversity decline of mollusks occurred from the 1960s onwards, and the responsibility for this is largely attributable to the high impact of human activities, such as the intensive sea bottom trawling, the wastewaters from aquaculture, dense coastal villages, and, the digging of edible molluscs from the tidal flat (Negri *et al*., 2015). Our study is an attempt to understand species composition and ongoing changes/impacts of a tropical estuarine molluscan community in Vietnam.

MATERIAL AND METHODS

Mollusks (dry shells and alive specimens) were collected in estuary of the Ba Lai River in September 2015 (Fig. 1). In total, 8 sampling stations (3 stations before and 5 after the dam) were selected from the river mouth downstream, representing a comparable

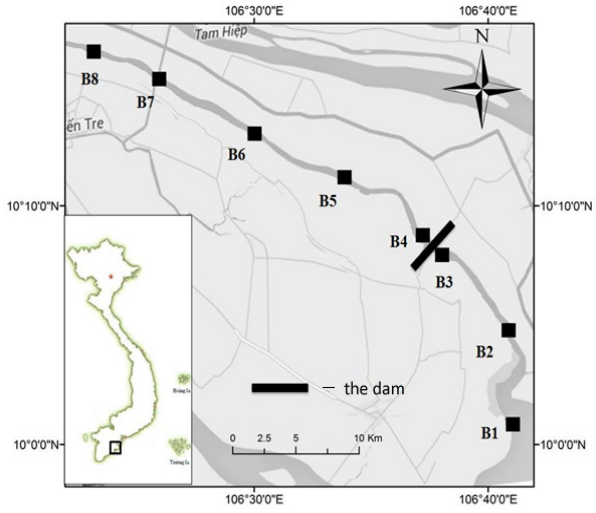

Fig. 1. Map of sampling stations in the Ba Lai River, Ben Tre Province (Mekong Delta, Vietnam).

salinity gradient and approximately equal distance between the stations. Per station, three replicate samples by river transect (left bank, middle and right bank) were collected and fixed in 75% ethanol. Mollusks collected are stored at the Laboratory of Freshwater Hydrobiology FSCEATB FEB RAS, Vladivostok, Russia.

Photographs of the shells were taken with stereomicroscope SteREO Discovery.V12 and stacked using CombineZM software at the Biology and Genetic Engineering Center for Collective Use of the FSCEATB FEB RAS. The final illustrations were post-processed for contrast and brightness using Adobe® Photoshop® software.

Salinity was determined from chloride concentration using the following formula:

$$\text{Salinity } (‰) = 0.0018066 \times Cl^{-} \text{ (mg/L)}.$$

Nitrate-nitrogen (NO_3-N) and ammonia-nitrogen (NH_3-N) were analyzed by methods of the TCVN 6643:2000 while total nitrogen (TN) was analyzed by Kjeldahl method (Total Kjeldahl Nitrogen) which is the sum of ammonia-nitrogen plus organically bound nitrogen but does not include nitrate-nitrogen or nitrite-nitrogen.

Coliform concentrations in sediments which indicate an organic pollution were identified based on the standard Most Probable Numbers (MPN) method.

Other water and sediment environmental variables such as dissolved oxygen, total suspended solids, total dissolved solids, total organic carbon and heavy metal concentration were also collected and measured together with bivalvia samples in each station.

RESULTS AND DISCUSSION

1. Environmental variables in the Ba Lai River

Salinity is an important measurement in estuaries where freshwater from rivers and streams mixes with salty ocean water. The salinity level in seawater (measured in ppt or ‰) is fairly constant, at about 35 ppt or ‰ (35000 mg/L), while brackish estuaries may have salinity levels between 1 and 10‰. In the Ba Lai River, the chloride concentration increased from 6292 mg/L at station B1 to 32 mg/L at station B8, so the salinity changed from 11.367 to 0.058‰, respectively. Thus, there were brackish waters along the investigated river part, where the salinity changed from mesohaline to oligohaline (Table 1).

Silt (grain size 0.05-0.002 mm) together with clay (< 0.002 mm) form the main part of sediments in the 5 upper part stations of the Ba Lai River while grain size in the range from 0.1-0.05 mm and larger than 0.1 mm had unsufficient percentage (Fig. 2). However, no significant difference between stations in grain size were recorded.

Water and benthic environmental characteristic have

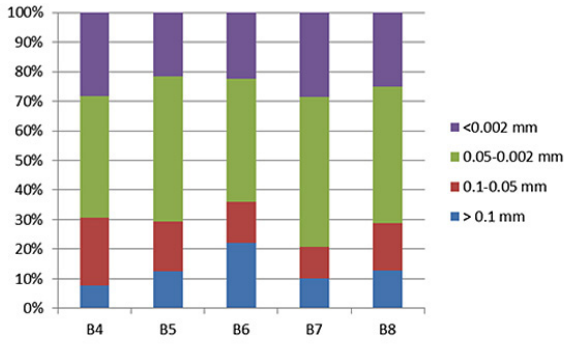

Fig. 2. Granulometrics percentage in the upper part of the Ba Lai River.

Table 1. Tested parameters of the Ba Lai River: dissolved oxygen (DO), total suspended solids (TSS), total dissolved solids (TDS), ammonia (NH_4), nitrate (NO_3^-), total organic carbon (TOC), total nitrogen (TN)

Stations	pH	DO (mg/L)	TSS (mg/L)	TDS (mg/L)	Salinity (mg Clo/L)
B1	6.9 ± 0.1	6.3 ± 0.4	70.0 ± 27.8	10506.7 ± 469.2	6380.7 ± 88.5
B2	6.8 ± 0.1	6.3 ± 0.2	127.7 ± 51.4	9343.3 ± 273.0	5347.0 ± 51.1
B3	6.7	6.0 ± 0.7	56.7 ± 15.0	6303.3 ± 97.1	3279.0 ± 234.5
B4	7.2 ± 0.1	8.0 ± 0.1	53.3 ± 9.6	1034.3 ± 12.9	431.3 ± 10.2
B5	7.9	3.3 ± 0.3	279.0 ± 67.1	1312.7 ± 44.8	525.3 ± 9.8
B6	7.6 ± 0.1	4.0 ± 0.4	301.3 ± 134.0	606.7 ± 89.6	218.5 ± 10.0
B7	7.9	4.5 ± 0.4	287.0 ± 156.6	252.0 ± 11.3	53.7 ± 1.2
B8	7.8 ± 0.2	4.0 ± 0.3	112.3 ± 10.7	179.5 ± 3.3	33.3 ± 1.2
Stations	NH_4 (µg/g)	NO_3^-(µg/g)	TOC (µg/g)	Coliform (MPN/g)	TN (µg/g)
B1	7.5 ± 2.9	3.9 ± 2.2	164.3 ± 152.5	1666.7 ± 1097.0	562.3 ± 58.8
B2	1.9 ± 3.2	3.9 ± 2.5	85.0 ± 34.0	8266.7 ± 13625.5	799.3 ± 427.1
B3	17.8 ± 17.5	5.3 ± 0.9	107.7 ± 14.6	15633.3 ± 26302.2	870.7 ± 74.4
B4	2.9 ± 5.1	6.5 ± 3.0	206.7 ± 61.1	5200.0 ± 5524.5	1168.3 ± 173.5
B5	3.9 ± 6.8	3.3 ± 0.8	151.7 ± 41.5	1733.3 ± 1530.8	962.3 ± 56.6
B6	15.6 ± 13.8	4.9 ± 2.0	138.0 ± 55.0	1000.0 ± 360.6	922.7 ± 89.7
B7	7.9 ± 7	4.6 ± 1.4	106.3 ± 30.1	1566.7 ± 2020.7	1029.0 ± 73.7
B8	10.2 ± 1.6	5.2 ± 0.8	92.0 ± 13.1	1666.7 ± 2307.2	934.3 ± 63.6

lots of alteration because of high deposition and silt accumulation in the Ba Lai River since the time of dam construction and operation. Environmental variables in the upper part of the Ba Lai River have been described in Tab. 1 showing changing values of dissolved oxygen (DO), total suspended solids (TSS), total dissolved solids (TDS), ammonia (NH_4), nitrate (NO_3^-), total organic carbon (TOC), total nitrogen (TN) and coliform. The values of pH is greater than 7 in all stations of the upper part of the Ba Lai River (B3-B8) that is charactersitic for subalkali waters while at stations before the dam (B1-B3) pH is less than 7 detecting the waters as weak acidic. The same subalkali waters with pH > 8 were recorded in all sampling stations for the other 4 Mekong estuaries: Cua Tieu, Cua Dai, Co Chien and Dinh An (Ngo *et al*., 2013b). Dissolved oxygen (DO) was found rather low (less than 4.5 ± 0.4 mg/L) with the only exception at station B4, the closest station to the river mouth. The threshold value of DO used for water quality assessment should be > 5 mg/L. Generally, 4-5 mg/L of dissolved oxygen content is a borderline concentration for an extended time period but for adequate ecosystem functioning it should be in a greater range. It was recorded very hight level of the total suspended solids (TSS) in all stations, exceeding the Vietnam National Standard Limitation from 6.9 to 11.3 times, especially in station B5. In comparison, according to the "2014 Lower Mekong Regional Water Quality Monitoring Report" (http://www.mrcmekong.org/assets/Publications/technical/Annual-Water-Quality-Report-2014-final-lowres.pdf), the average monthly concentration for TSS in the Mekong Delta was measured to be 76.5 mg/L. Total organic carbon was found to exceed 90 µg/g in all stations (from 92 ± 13.1 to 206.7 ± 61.1 µg/g). Nitrogen compounds such as ammonia, nitrate and total nitrogen were very high showing one of the highest concentrations among the investigated estuaries of the Mekong Delta (Ngo *et al*., 2013b). No significant differences in nitrogen along the entire studied part of the river upstream the irrigation dam were observed. Total nitrogen exceeded 600 mg/kg at all observed stations. The coliform bacteria concentrations show a wide variation between

Table 2. Dissolved trace elements of the Ba Lai River: common metal (Fe), potentially toxic metals (Cu, Pb) and metalloid (As), in μg/g

Stations	Fe	Cu	Pb	As
B1	28.7 ± 2.9	18.7 ± 0.5	11.1 ± 3.5	16.7 ±2.9
B2	30.5 ± 1.5	27.2 ± 1.7	9.4 ± 0.9	20.8 ± 1.1
B3	39.1 ± 1.2	38.7 ± 1.8	9.5 ± 0.9	29.2 ± 1.4
B4	39.6 ± 1.7	32.3 ± 1.5	8.9 ± 1.4	28.6 ± 2.5
B5	37.2 ± 1.2	32.7 ± 2.4	8.5 ± 1.9	33.0 ± 2.5
B6	30.7 ± 3.0	25.9 ± 1.6	8.6 ± 0.7	17.6 ± 1.9
B7	37.2 ± 1.4	33.4 ± 2.5	7.8 ± 0.4	19.0 ± 1.3
B8	37.0 ± 3.3	32.4 ± 3.8	7.6 ± 0.3	27.9 ± 3.9

sampling stations with the highest result in station B4 (5200 ± 5524.5 MPN/g). Large numbers of coliforms found in the Ba Lai indicate a high probability of other pathogenic bacteria or organisms that may be present.

Dissolved trace elements of the Ba Lai River such as common metal (Fe), potentially toxic metals (Cd, Cu, Pb) and metalloid (As) in the sediments were also analyzed (Table 2). Generally, heavy metal concentration in the upper part of the Ba Lai River were not so high. Cadmium was not detected in stations B2-B8 at all.

Decline of dissolved oxygen with sufficiently high level of total suspended solids, nitrogen compounds and the coliform bacteria concentrations along the river part upsteram the dam were associated mainly to anthropogenic activities rather than natural processes. Biochemical adaptations of bivalves including various mechanisms of metabolic regulations to anoxia (Fokina *et al*., 2011), their ability to accumulate microelements and heavy metals (Malakhov and Medvedeva 1991; Lavrinenko and Iljasova, 2010; Tran *et al*., 2016) are factors of bivalves survival in the conditions of the Mekong Delta and partly the Ba Lai River.

2. Bivalves assemblages.

Bivalvia were found only at five (B4-B8) stations from the dam to the river source (Sayenko *et al*., 2017). Average and standard deviation of bivalvia individual densities for 5 upstream stations of the Ba Lai River were illustrated in Fig. 3. Densities of bivalvia communities ranged from 21.5 ± 8.2 inds/10 cm^2 to 28.5 ± 3.3 inds/10 cm^2. There is no significant difference in densities between stations among the observed 5 stations. In total, 12 species from 6 families were identified (Table 3, Fig. 4).

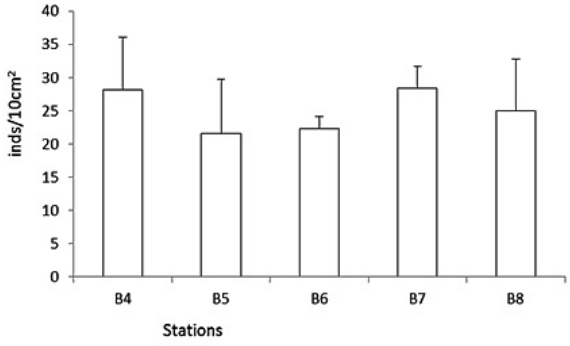

Fig. 3. Average and standard deviation of bivalvia densities in the upper part of the Ba Lai River.

Members of the marine genus *Meretrix* Lamarck, 1799 from the family Veneridae Rafinesque, 1815 are highly appreciated table food for internal and export markets. Because of the remarkable variation of shapes and patterns of shells of *Meretrix*, early researchers divided this genus into many species. Now between 3 and 14 species of the genus *Meretrix* are considered valid (Huber, 2010). The species *Meretrix lyrata* (G.B. Sowbery II, 1851) (known also as the *hard clam*) is quite variable in extent of liration, color and form and the only species of the genus with a lirate sculpture (Fig. 4A, B).

Species identification of *Potamocorbula* sp. (family Corbulidae Lamark, 1818) and *Mactra* sp. (family Mactridae Lamark, 1809) were impossible because of

Table 3. Bivalvia species identified from the samples of the Ba Lai Rive

Species	Stations					Remarks
	B4	B5	B6	B7	B8	
Family Veneridae						
Meretrix lyrata	+	–	–	–	–	1 dry valve
Family Corbulidae						
Potamocorbula sp.	+	–	–	–	–	1 dry valve
Family Mactridae						
Mactra sp.	+	–	–	–	–	1 dry valve
Family Mytilidae						
Brachidontes setiger	+	–	–	–	–	dry shells and living specimens
Limnoperna fortunei	+	–	–	+	+	
Limnoperna siamensis	–	–	–	–	+	dry shells and living specimens
Family Pharidae						
Novaculina siamensis	+	–	+	+	+	dry shells and living specimens
Family Corbiculidae						
Corbicula cyreniformis	+	+	+	–	–	characteristic trigonal, dorso-ventrally elongated shells
Corbicula solidula	–	–	+	+	+	small oval-trigonal shells with comparatively solid valves
Corbicula blandiana	+	+	+	+	+	rounded, solid shells with regular, raised, sharp ridges; valves with pale violet colour inside
Corbicula gubernatoria	+	+	+	–	–	equilateral shells; valves with reduced and unclear stirae
Corbicula tenuis	+	–	–	–	–	characteristic shells with elongated longitudinally, compressed valves; irregular ridges, purple colour inside

broken hinge of the only dry valves. Three species from the genus *Potamocorbula* Habe, 1955 are known from Vietnam: *P. fasciata* (Reeve, 1843), *P. laevis* (Hinds, 1843) and *P. ustulata* (Reeve, 1844) (Hylleberg and Kilburn, 2003). In literature at least 25 species of the genus *Mactra* Linnaeus, 1767 are recorded from Vietnam (Lutaenko, 2000; Hylleberg and Kilburn, 2003). Further investigation will help to solve the problems with species identification.

Records of empty shells of marine euryhaline and tolerant to salinity decrease bivalves (*Meretrix lyrata*, *Potamocorbula* sp., *Mactra* sp.) shows either episodic influence of marine waters or presence of these species in the past and historical change of environment. *M. lyrata* is cultured in the Mekong River estuarine area (Phu 1996) and it is the most abundant commercial species in southern Vietnam with yield of 54000-61000 tons per year (Phung *et al*., 2001). Representatives of the genus *Potamocorbula* are regarded now as non-marine species belonging to a group called "limnetic-euryhaline Corbulidae" (Hallan *et al*., 2013).

There are a few Indochinese mussel genera - *Arcuatula* Jousseaume in Lamy, 1919, *Brachidontes* Swainson, 1840, *Sinomytilus* Thiele, 1934 and *Limnoperna* Rochebrune, 1882 - with freshwater species of the mainly marine family Mytilidae Rafinesque, 1815 differing in respect to shell morphology, anatomy and life histories. The following 7 species of the mentioned 4 genera were previously listed by different authors from the Mekong Delta: *Sinomytilus harmandi* (Rochebrune, 1881), *S. morrisoni* Brandt, 1974, *Limnoperna supoti* Brandt, 1974, *L. siamensis* P.A. Morelet, 1866, *L. fortunei* (Dunker, 1856), *Arcuatula arcuatula* (Hanley, 1843), and *Brachidontes exustus* (Linnaeus, 1758) (Hylleberg and Kilburn, 2003; Sangpradub and Boonsoong, 2006; Kulabtong, 2011; Bogan, 2013; Ngo *et al*., 2013a, b; Ngo and Ngo, 2014; and others). In the Ba Lai River

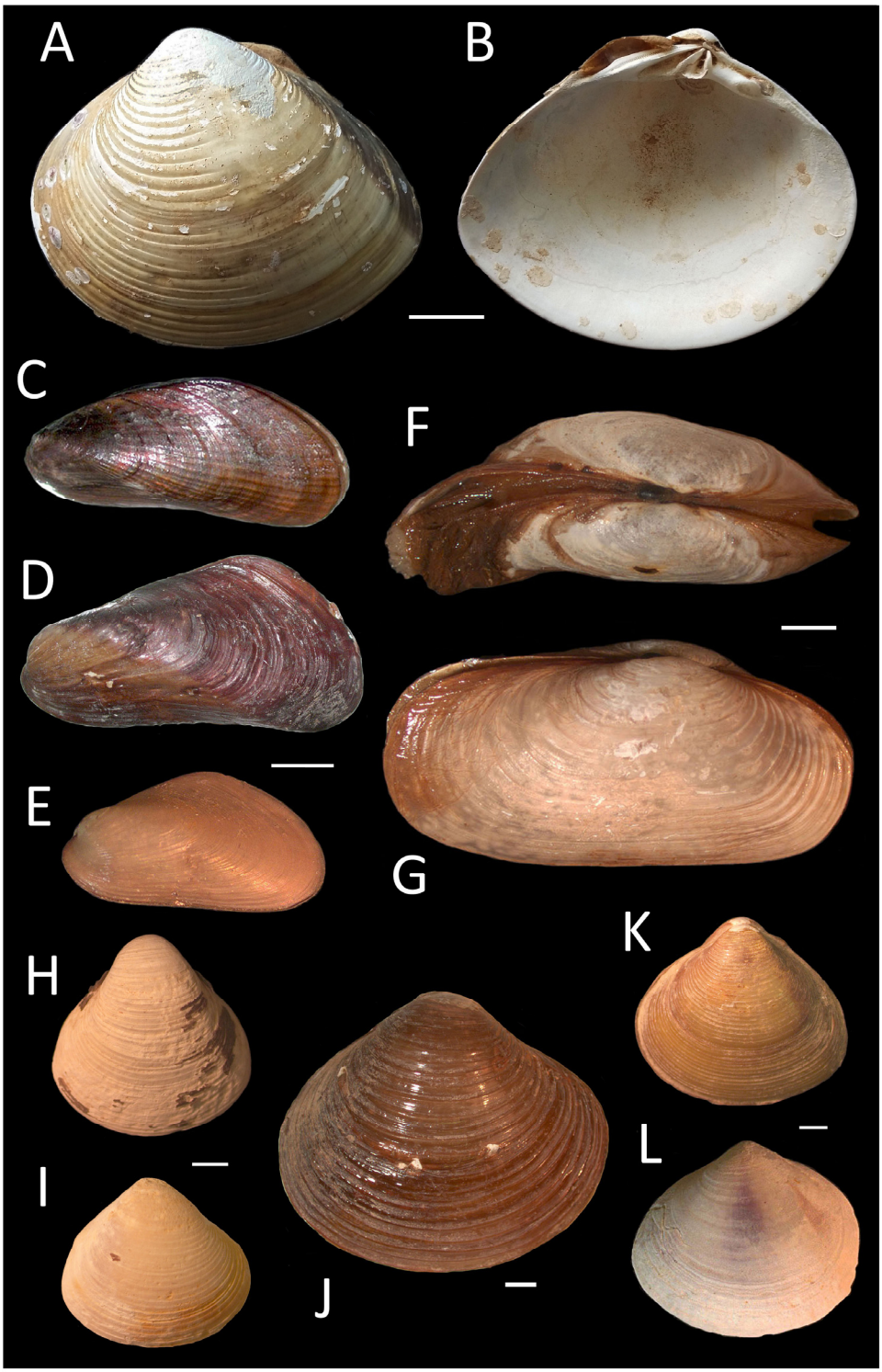

Fig. 4. Mollusks from the Ba Lai River (Mekong Delta, Vietnam): A, B - valve of *Meretrix lyrata*, exterior (**A**) and interior (**B**) views, scale bar 1 cm; **C**-**E** - mytilids *Brachidontes setiger*, juvenile shell (**C**), *Limnoperna siamensis* (**D**) and *L. fortunei* (**E**), scale bar 0.5 mm; **F**, **G** - shell of *Novaculina siamensis*, dorsal (**F**) and back (**G**) views, scale bar 2 mm; **H**-**L** - corbiculids *Corbicula cyreniformis* (**H**), *C. solidula* (**I**), *C. blandiana* (**J**), *C. gubernatoria* (**K**) and *C. tenuis* (**L**), scale bars 2 mm.

Limnoperna fortunei, *L. siamensis* and *Brachidontes setiger* (Dunker, 1856) were recorded (Table 3); species of the genera *Sinomythilus* and *Arcuatula* were not found (Sayenko *et al*., 2017).

All mytilid mussels including species from the Ba Lai have a similar fragile, trigonal-elongate shell, some with papery valves and often ventrally curbed texture, are medium sized and prefer shallow habitats in bays or in estuaries having a high tolerance to fluctuating salinities (Fig. 4C-E). The main difference is the extent of the dysodont denticles posterior and anterior to the long ligament line and shell texture.

Brachidontes exustus was noted for the Cung Hau and Tien River (Ngo and Ngo, 2014) and this species clearly differs from *B. setiger* by shell shape. *Brachidontes* differs from *Limnoperna* by shell sculpturing and ligament with denticles (Sangpradub and Boonsoong, 2006). Some authors consider *Limnoperna* as monospecific genus represented by the only golden mussel *L. fortunei* (Dunker, 1857) (Brandt and Temcharoen, 1971; Morton, 1973; Brandt, 1974; Ricciardi, 1991). The other consider up to 9 species (Kulabtong, 2011; Bogan, 2013; WoRMS, 2016). Specimens of *Limnoperna* are often confused in the literature with *Sinomytilus* (Morton and Dinesen, 2010). Because of an interior shell septum, a unique feature that differs this species from all other disscussed mytilids, *Sinomytilus harmandi* was originally assigned to the Dreissenidae Gray, 1840 (Bivalvia: Heterodonta), an anatomically distinct family naturally restricted to Europe and the Americas (Brandt, 1974; Bogan, 2008). Species *L. fortunei* and *Arcuatula arcuatula* are easily confounded in shape, color and commarginal sculpture; the hinge only shows the difference, denticles in the latter species, none in the former. Some subspecies of *L. fortunei* are shown to be a synonym of *Xenostrobus securis* (Lamarck, 1819) (Kimura *et al*., 1999). *Limnoperna siamensis* P.A. Morelet, 1866 differs from *L. fortunei* by shell features and distribution.

Mytilids found in the Ba Lai River differ by their tolerability to water salinity. If *Brachidontes setiger* is mesohaline species, *Limnoperna fortunei* is very tolerant to salinity decrease inhabiting the river from upstream to the lower part, while *L. siamensis* is a freshwater species only (Tables 1, 3).

The genus *Novaculina* Benson, 1830 is a freshwater member of the marine family Pharidae H. Adams and A. Adams, 1858 that was considered by some authors as a family Solenidae Lamark, 1809 (Bieler *et al*., 2010; WoRMS, 2016). The genus includes 4 species, where *Novaculina siamensis* Morlet, 1889 inhabits the Mekong Delta (Bogan, 2013). The characteristic of assymetrical or torsed shell development appears more than once in Asian unionaceans, and *Novaculina* is an example of such assymetry. The shells are subinequivalve, inequilateral, transversely elongated, with two cardinal teeth in the right valve and three in the left valve (Fig. 4F, G). The abundance of *N. siamensis* specimens in the Ba Lai River was enlarged with decreasing of water salinity (Tables 1, 3). *N. siamensis* were not noted for the Cung Hau and Tien River (Ngo *et al*., 2013a, 2014).

Bivalves of the family Corbiculidae Gray, 1847 were dominant clams and the most abundant (Table 3) in the Ba Lai, they were found in all stations from the dam to the river source (B4-B8), at least 5 species of the genus *Corbicula* Megerle von Mühlfeld, 1811 are recorded for the Ba Lai River: *C. cyreniformis* Prime, 1860, *C. solidula* Prime, 1861, *C. blandiana* (Prime, 1864), *C. gubernatoria* Prime, 1870, *C. tenuis* Clessin, 1887 (Table 3, Fig. 4H-L). These species show different tolerability to water salinity: *C. tenuis*, *C. cyreniformis* and *C. gubernatoria* are mesohaline species inhabiting only the lower part of the river while *C. solidula* and *C. blandiana* are oligohaline and freshwater bivalves (Tables 1, 3).

Previous investigations on reproductive characters allowed categorizing *Corbicula* species into three major groups (Miyazaki, 1936). Species from the first group are monoecious, viviparous, and incubatory; they have non-swimming planktonic veliger larvae and live in freshwater. The second group has dioecious, non-incubatory species which also live in freshwater regions. The third group includes dioecious and oviparous species which do not incubate their young, have free-swimming planktotrophic larvae, and live in brackish waters only. Our preliminary investigations

on reproductivity of *C. blandiana* from the Ba Lai River (Raschepkina and Sayenko, 2017) allow to assume the species belongs to the second group as it is dioecious (specimens with separately female or male gonads were indicated), perhaps non-incubatory species (we didn't find any larvae in the gills) living in freshwater regions. Male and female gonads have an acinar structure and consisted of number of oogenic (female gonad) or spermatogenic (male gonad) follicles. In the beginning of September female gonads had oocytes in the stage of trophoplasmic growth (previtellogenic and vitellogenic oocytes); in the male gonads cross sections of the acini and gonad tube areas were occupied by spermatocytes with a rounded shape and spermatids, but the mature sperm cells were not observed. Further investigations will help to understand more clearly the reproductive strategy of all *Corbicula* species.

Generally, the bivalve species composition is rather poor but it is in accordance with environmental conditions of the area studied, especially salinity level. For example, the Red River (northern Vietnam) estuarine molluscan fauna (including all mollusk classes) consists of 30 species in fresh-water part, and 68 species in brackish-water and marine parts of the estuary (Thanh, 2003). However, in a tropical Pearl River estuary (southern China) in three different wetland types, only five bivalve mollusk species were found (Li *et al*. 2012): *Meretrix lusoria* (Rŏding, 1798), *Potamocorbula amurensis* (Schrenck, 1867), *Potamocorbula* sp., *Abra* sp., *Modiolus plicatus* (Lamarck), belonging to the same ecological groups (infauna and epifauna).

In summary, no significant correlation was found between species composition, densities and physical-chemical data in the investigated stations of the Ba Lai River.

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