Biodiversity Data Journal 11: e105444
doi: 10.3897/BDJ.11.e105444

Taxonomy & Inventories

Checklist of the micromolluscs in the intertidal zone of the Yellow Sea and Bohai Sea, China

Lu Qi[‡], Biyang Xu[‡], Lingfeng Kong[‡,§,|], Qi Li[‡,§,|]

‡ Key Laboratory of Mariculture, Ministry of Education, Ocean University of China, Qingdao, China
§ Sanya Oceanographic Institution, Ocean University of China, Sanya, China
| Laboratory for Marine Fisheries Science and Food Production Processes, Laoshan Laboratory, Qingdao, China

Corresponding author: Lingfeng Kong (klfaly@ouc.edu.cn)

Academic editor: Sérgio Ávila

Received: 25 Apr 2023 | Accepted: 22 Jun 2023 | Published: 07 Jul 2023

Citation: Qi L, Xu B, Kong L, Li Q (2023) Checklist of the micromolluscs in the intertidal zone of the Yellow Sea and Bohai Sea, China. Biodiversity Data Journal 11: e105444. https://doi.org/10.3897/BDJ.11.e105444

Abstract

Background

The diversity of the sedimentary environment and molluscs is rich in the intertidal zone of the Yellow Sea and Bohai Sea. At present, many of the investigations focus on macromolluscs, while the diversity of micromolluscs is seriously underestimated.

New information

In this study, the survey of micromolluscs was carried out in the intertidal zone of the Yellow Sea and Bohai Sea. The collection and preservation of micromolluscs, as well as the preparation methods of morphological characteristic structures by scanning electron microscopy (SEM) were explored. A total of 20 species were described in this survey. These can be assigned to 16 families, four orders (Vetigastropoda (1), Caenogastropoda (10), Heterobranchia (5) and Autobranchia (3)) and two classes (Gastropoda (17), Bivalvia (3)).

Keywords

biodiversity, description, mollusca, morphology

Introduction

Molluscs are one of the largest groups of marine benthos, with a huge variety of life strategies. In marine ecosystems, molluscs occupy different trophic levels, from filtrators and phytophages to predators and parasites. Due to their high diversity and widespread distribution, they have been widely recorded in taxonomic monographs. Recent examples of taxonomic monographs from the Western Pacific Region included Liu (2008), Zhang et al. (2016), Okutani (2017), and Li et al. (2019). These monographs recorded a large number of taxa, but most of them are macromolluscs, while micromolluscs are not fully understood, especially in China.

Micromolluscs are important components of molluscs and play an important role in biodiversity assessments. As micromolluscs usually require specific collecting/sorting attention and have a reputation for presenting formidable taxonomic difficulties, they are often overlooked in biodiversity surveys, resulting in a gross underestimation of mollusc diversity. In a biodiversity survey of New Caledonia, the micromolluscs account for approximately one-third (33.5%) of all identified mollusk species, with the largest size class being 1.9–4.1 mm (Bouchet et al. 2002). Therefore, it is of great significance to carry out micromolluscs' surveys to assess the diversity of molluscs.

The diversity of the sediment environment and molluscs is rich in the intertidal zone of China. However, much of the literature focuses on macromolluscs that can be collected by hand-picking in the field. Only Liu (2013) investigated the small gastropods in the *Zostera marina* in Swan Lake, Rongcheng Bay China. Here, we carried out the survey of micromolluscs in the intertidal zone along the coasts of the Yellow Sea and Bohai Sea, established methods for sample collection and preservation, used morphological and molecular data to identify the species and performed morphological descriptions based on SEM.

Materials and methods

Taxon sampling and processing

Sampling was carried out in the intertidal zone of the Yellow Sea and Bohai Sea from September 2017 to December 2019 (Fig. 1, Table 1). Sample collection was performed with reference to the handbook by Li et al. (2019). Field collection of micromolluscs requires some specialised techniques depending on the likely habitats of the target organisms and a range of microhabitats.

Table 1.

Details on collection sites (Fig. 1).

Name	Abbreviation	Area and Geographic Data	Date of Collection
Tangshan	TS	38°54′47″N, 118°29′35″E	20.10.2017
Dongying	DY	37°48′49″N, 119°18′57″E	24.06.2018
Yantai	YT	37°33′34″N, 121°30′58″E	12.08.2018
Weihai	WH	37°21′35″N, 122°34′38″E	03.06.2019
Qingdao	QD	36°03′18″N, 120°19′47″E	09.07.2019
Ganyu	GY	34°51′00″N, 119°13′17″E	20.09.2019

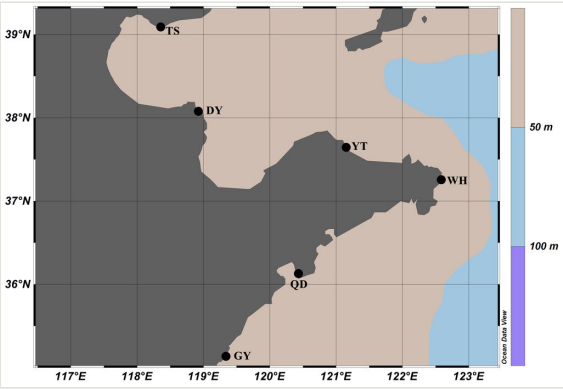

Figure 1. doi

Map of sampling site. For details on collection sites, see Table 1.

Shell grit or shell sand

The sediments usually contain mainly empty shells and certain species should be divided into size fractions by using graded sieves (e.g. 10, 5, 2.5, 1.0 and 0.4 mm mesh size). If there is a need to collect all adult species, the 0.4 mm sieve is suitable.

Algal samples

Algae are one of the most important habitats for micromolluscs. After the algae are collected on-site, it should be placed in a bucket or ‘zip-lock’ bag and then the bucket or bag should be shaken violently. The algal material is then removed and the sample is allowed to settle briefly. The water can then be gently decanted, being run through a sieve to catch any floating molluscs.

Rock

The upper and undersides of rocks are very different environments. Some micromolluscs may be attached to the algal films or turf on the rock surface. These rocks can be scrubbed with a brush in a bucket. Then the residue in the bucket is collected into the sample bottle.

Specimens for anatomical study were stored in formalin, whereas for molecular work, strong (> 95%) ethanol or RNALater are the best preservatives. All samples were brought back to the laboratory for further processing. All the material collected has been deposited in the Laboratory of Shellfish Genetics and Breeding (LSGB), Fisheries College, Ocean University of China, Qingdao, China. Morphological identification of the species was carried out mainly through the identification book from Okutani (2017) and original literature, as well as WoRMS (http://www.marinespecies.org).

Molecular analyses

Traditional barcoding gene COI was analysed for most specimens to verify identification. Total genomic DNA was extracted from entire animals with the TIANamp Marine Animals DNA Kit (Tiangen Biotech, Beijing, China), according to the manufacturer's protocol and stored at -4°C for short-term use. Amplification of partial sequences of mitochondrial COI was amplified by a polymerase chain reaction using the primers from Folmer et al. (1994), LCO1490 (5'-GGTCAACAAATCATAAAGATATTGG-3') and HC02198 (5'-TAAACTT CAGGGTGACCAAAAAATCA-3'). PCR reactions were made in a volume of 25 µl, using the following: 19.3 µl distilled H_2O (sterile MilliQ), 0.5 µl dNTPs (2.5 mM), 2.5 µl 10×buffer (Mg^{2+} plus) , 0.2 µl TakaRa Taq DNA polymerase, 1 µl of each primer (10 µM) and 0.5 µl genomic DNA (50-100 ng). Thermal cycling conditions were: 94°C for 3 min, followed by 37 cycles of 94°C for 45 s, 48°C for 45 s, 72°C for 60 s and a final extension of 72°C for 10 min. PCR products were run in a 1.5% agarose gel to corroborate the success of the amplifications and sequenced by Shanghai Bioengineering Co., Ltd (China). DNA sequences were assembled using SeqMan (Swindell and Plasterer 1997). The obtained sequences were compared to sequences of molluscs in both GenBank and BOLD databases. Sequences have been deposited in GenBank (Table 2).

Table 2.

Species used in this study, species name and taxonomic ranks, GenBank accession numbers, locality of collection and Date of Collection.

		Family	Species name	Genbank	Locality	Date of Collection
Gastropoda	Vetigastropoda	Trochidae	*Lirularia iridescens* (Schrenck, 1863)	MT254075	Weihai	2018
	Caenogastropoda	Litiopidae	*Alaba picta* (A. Adams, 1861)	MT254074	Qingdao	2018
		Barleeiidae	*Barleeia angustata* (Pilsbry, 1901)	MT254076	Weihai	2018
			Barleeia sp.	MT254077	Qingdao	2017
		Iravadiidae	*Iravadia elegantula* (A. Adams, 1861)	MT240257	Dongying	2017
		Stenothyridae	*Stenothyra glabra* A. Adams, 1861	MN548735	Ganyu	2019

		Family	Species name	Genbank	Locality	Date of Collection
		Assimineidae	*Assiminea estuarina* Habe, 1946	MT240258	Weihai	2019
		Rissoidae	*Alvania concinna* A. Adams, 1861	MT240259	Weihai	2018
		Tornidae	*Pseudoliotia pulchella* (Dunker, 1860)	-	Tangshan	2018
		Littorinidae	*Peasiella habei* D. Reid & Mak,1998	MT823260	Qingdao	2019
			Lacuna carinifera (A. Adams, 1853)	MT823257	Weihai	2018
	Heterobranchia	Tornatinidae	*Acteocina fusiformis* (A. Adams, 1850)	-	Tangshan	2019
		Retusidae	*Pyrunculus tokyoensis* Habe, 1950	-	Tangshan	2019
		Pyramidellidae	*Brachystomia bipyramidata* （Nomura,1936）	MT823256	Qingdao	2018
			Odostomia subangulata A. Adams, 1860	MT254072	Qingdao	2018
			Turbonilla osyuensus Nomura, 1936	-	Tangshan	2018
		Rissoellidae	*Rissoella elatior* (Golikov, Gulbin & Sirenko, 1987)	-	Tangshan	2019
Bivalvia	Autobranchia	Lasaeidae	*Lasaea undulata* (A. A. Gould, 1861)	MT254080	Weihai	2018
		Kelliellidae	*Alveinus ojianus* (Yokoyama, 1927)	-	Tangshan	2019
		Arcidae	*Bentharca* sp.	-	Tangshan	2019

Preparation of micromollusc shells for SEM

Specimens can be immersed for one to two minutes in strong commercial bleach to remove the periostracum. The soaked shells were placed in a centrifugal tube with neutral detergent and cleaned by ultrasound. The cleaning time depends on the amount of dirt on the shell surface. After sonication, shells should be washed in distilled water preferably two or three times. After the last wash, the water drops should be removed with a paper towel and the specimen air-dried. The clean shells were attached to conductive glue in the direction of the standardized views and then sputtered with gold. The thickness of the metal coating is 1-10 nm; however, even excessive coating will not interfere with the detail in a normal shell. The operating tool was TESCAN VEGA3 scanning electron microscope (SEM).

Checklist of the micromolluscs in the Yellow Sea and Bohai Sea, China

Lirularia iridescens Schrenck, 1863

Diagnosis: Shell minute (2.5±0.26 mm in width, 2.2±0.15 mm in length), ovato-conica. Whorls 4-5, spire low, body whorl rather ventricose (Fig. 2). Suture distinct. Every whorl is striated by about 9-10 distinct spiral ribs and the distance between the spiral ribs is not uniform. Reddish-brown spiral ribs contrasting with iridescent interspaces; lines on ribs occasionally broken by white spots, with crater-like pitted microsculpture on protoconch. Aperture ovate, outer lip thin, with small notches, inner lip simple and slightly convex. Umbilicus circular deep. Basal surface flat, with 9-10 circular spiral ribs.

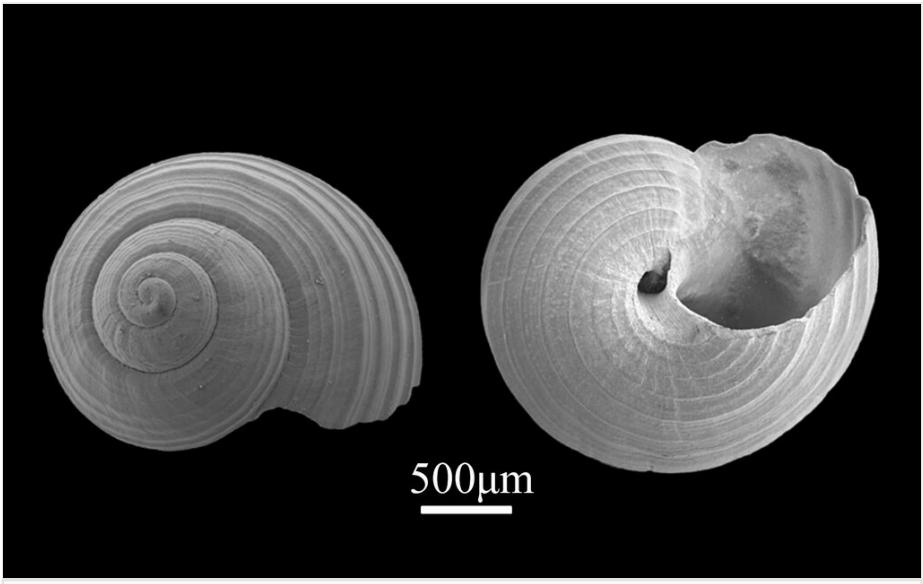

Figure 2. doi

Lirularia iridescens Schrenck, 1863.

Native status: Found on seagrass between tidal and shallow waters.

Distribution: Yellow Sea of China; Japan Sea, South Kurile Islands.

Notes: *L. iridescens* was recorded by Kantor and Sysoev (2006). Okutani (2017) described and illustrated in detail *L. iridescens*. In this study, the species was re-described, based on the SEM. Crater-like pitted microsculptures on the protoconch were first discovered here. At present, there are very few morphological studies on this genus *Lirularia*. Many studies have shown that *L. iridescens* are phytal gastropods inhabiting seaweeds (Toyohara et al. 1999, Agatsuma et al. 2005).

Alaba picta A. Adams, 1861

Diagnosis: Shell small (8.5±0.34 mm in height, 4.5±0.18 mm in width), ovate-conica, thin, fragile, translucent, whorls about 8, less inflated, spire high, body whorl inflated (Fig. 3). Suture shallow. Shell surface smooth, varices on whorls here and there. Yellowish-brown in colour, with red-brown fine spiral striae and irregularly red-brown longitudinal striae and with thin periostracum. The aperture wide and large, outer lip thin, simple, columella concave, without umbilicus.

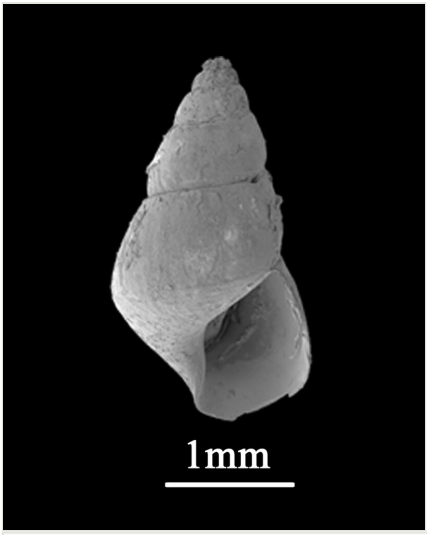

Figure 3. doi

Alaba picta A. Adams, 1861.

Native status: Found on seagrass between tidal and shallow waters.

Distribution: From Liaoning to Shandong coasts of China; Japan; Australia.

Notes: *Alaba picta* with obvious morphological variance in colour, aperture, shell length and sculpture (Liu 2013). *Diala vitrea* G. B. Sowerby, 1915 is the name given to a phenotype lacking a colour-pattern (Okutani 2017). *Diala picta* A. Adams, is the original name of *A. picta*, which is from the Shandong coast of China (Adams 1861).

Lacuna carinifera (A. Adams, 1853)

Diagnosis: Shell minute (4.3±0.76 mm in length, 1.2±0.26 mm in width), conical, depressed or auricular (Fig. 4). Whorls 4, inflated. Spire low; body whorl large, sudden expansion of width, slightly tilted. Shell thin, smooth, except for weak growth lines, with tawny periostracum. Keel round the body whorl, with grooved suture. Aperture large, pyriform, oblique, with angulate periphery on the underside of the outer lip, inner lip thick. Umbilicus open. Protoconch usually eroded.

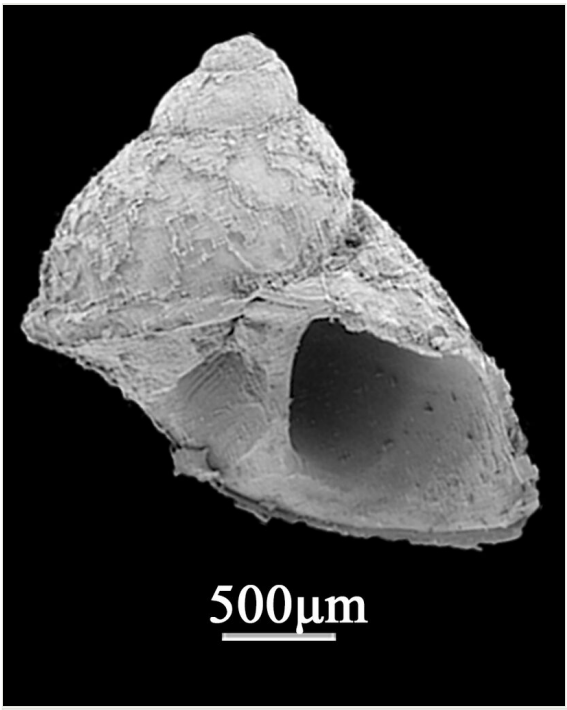

Figure 4. doi

Lacuna carinifera (A. Adams, 1853).

Native status: Lives on intertidal sandy mud, algae.

Distribution: China, Japan.

Notes: *Stenotis lois* (Yen, 1936) is very similar to *Lacuna carinifera* (A. Adams, 1853), but the aperture is wider, with angulate periphery on the underside of the outer lip, the umbilicus more open. This study thinks *Stenotis lois* (Yen, 1936) is the larva of *Lacuna carinifera* (A. Adams, 1853) and is a synonym.

Barleeia angustata Pilsbry, 1901

Diagnosis: Shell minute (2.5±0.18 mm in length, 1.3±0.09 mm in width), elongate conical, solid (Fig. 5). Whorls about 5, with high spire, periphery weakly angulate in immature individuals, round when matured. Suture distinct. Shell glossy and smooth, colour uniformly reddish-brown in northern localities. Protoconch with several pits on the surface. Aperture small, peristome simple, rounded-ovate, outer lip thin, the columellar and parietal margins somewhat thickened. No umbilicus.

Native status: Lives on algae in intertidal and sublittoral zones.

Distribution: China, Japan, Australia.

Notes: The species originally belonged to Rissoidae. *Rissoina dunedini* Grabau & S. G. King, 1928 and *Rissoina nelsoni* Grabau & S. G. King, 1928 were the synonyms of this species (Zhang et al. 2016). There are shell colour variations, lightly coloured forms with distinct brown spiral bands in warm waters.

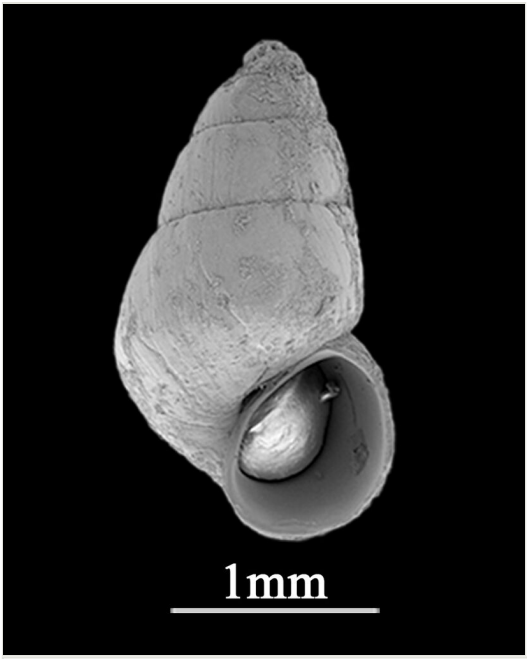

Figure 5. doi

Barleeia angustata (Pilsbry, 1901).

Barleeia sp.

Diagnosis: Shell minute (1.2±0.42 mm in width, 1.8±0.13 mm in length), conic to ovate-conic, dark brown, smooth or with weak axial microsculptures and rather solid, periphery weak convex to angled (Fig. 6). Whorls 4, suture prominent and deep. Protoconch dome-shaped, smooth, with a diameter of about 300 μm, some sediment attached to it, with several pits on the surface. Apical angle around 45°. Aperture oval with a simple peristome, the posterior of outer lip in contact with the body whorls. Operculum, not a canal; inner lip attaching to the previous whorl, but not contacted with outer lip, not umbilicate and anterior canal; outer lip thin, anterior prosocline.

Native status: Lives on algae in intertidal and sublittoral zones.

Distribution: China

Notes: *Barleeia* sp. very similar to *Barleeia angustata* (Pilsbry, 1901), but the aperture is open.

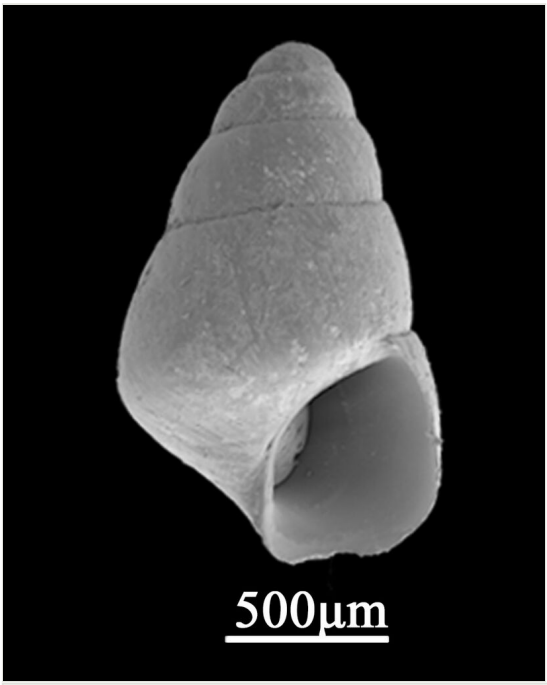

Figure 6. doi

Barleeia sp.

Iravadia elegantula A. Adams, 1861

Diagnosis: Shell minute (3.0±0.22 mm in length, 1.6±0.14 mm in width), elongate conical, stout (Fig. 7). Whorls 5, inflated, with deeply impressed suture. Whorls increasing gradually in size. Surface of shell glossy dark brown at apical and yellowish-brown at abapical part, sculptured with many fine spiral lirae and fine growth lines. Periphery of body whorl rounded, base of whorl gradually curved. Protoconch is small, depressed dome-shape. Aperture oval and weakly angled both up and down, peristome somewhat thickened and broad down region, outer lip rounded. Umbilicus narrow and very shallow.

Native status: Brackish water, on muddy flats and under rocks in estuary at river mouth.

Distribution: Korea, China, Japan.

Notes: The *Iravadia* includes the subgenera *Fluviocingula* Kuroda & Habe, 1954, *Pseudomerelina* Ponder, 1984 and *Pseudonoba* O. Boettger, 1902. The original description from the species *Onoba elegantula* A. Adams, 1861. At present, the *Iravadia elegantula* (A. Adams, 1861) has been accepted as *Fluviocingula elegantula* (A. Adams, 1861).

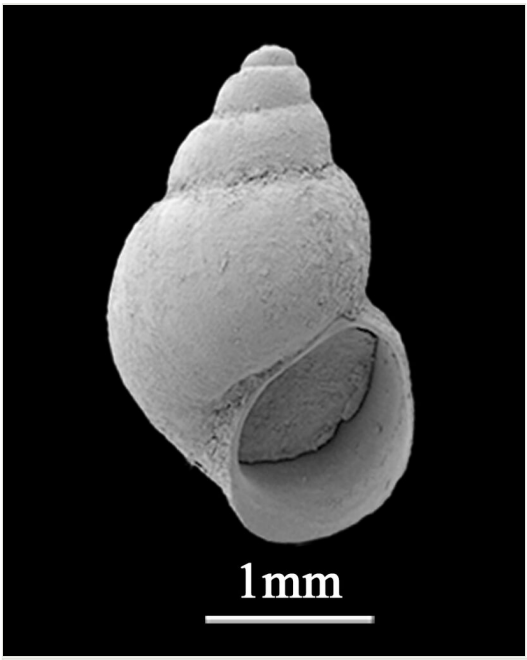

Figure 7. doi

Iravadia (*Fluviocingula*) *elegantula* A. Adams, 1861.

Stenothyra glabra A. Adams, 1861

Diagnosis: Shell minute (2.1±0.14 mm in length, 1.5±0.07 mm in width), ovate-conic, rather thick, dorso-ventrically compressed, with rounded to angled inflation of last whorl (Fig. 8). Up to 5 whorls including protoconch, with less convex whorls and sutures moderately deep. Surface smooth, yellowish-brown, sculpture not dotted lines, but continuous spiral grooves. The aperture abruptly descending, contracted and near circular; peristome continuous, showing a weak triangular area above; outer lip round with marked grooves. Operculum ovate, yellowish, translucent, with very weak angulation aligning with posterior apex of aperture; exterior surface with central paucispiral nucleus close to the inner lip. Protoconch dome-shaped, smooth, 1-3/4-2 whorls; some pits in the first whorl.

Native status: Inhabiting the surface of mud flats or attaching to the under surface of floating leaves in freshwater estuaries.

Distribution: Yellow Sea and Bohai Sea of China, Korea and Japan.

Notes: The type locality of *Stenothyra glabra* A. Adams, 1861 is “estuary of the Pei-ho, North China”, which is on the coast of the Bohai Sea. One of the localities in this study, Yellow River Estuary, is adjacent to the type locality. Moreover, the shells exhibit remarkable similarity in terms of size, shape, and microsculpture when compared to the

descriptions provided by Adams (1861), Yen (1939), Yen (1942), and Kantor and Sysoev (2006), although the available photograph of the holotype is lacking (Agatsuma et al. 2005). We believe that specimens collected in this study belong to common species from the coasts of the Yellow Sea and Bohai Sea in China and are conspecific with the type material.

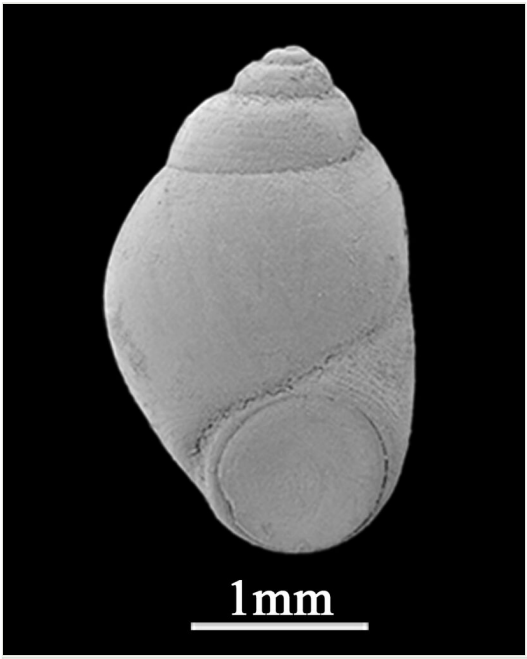

Figure 8. doi

Stenothyra glabra A. Adams, 1861.

Assiminea estuarina Habe, 1946

Diagnosis: Shell minute (2.2±0.36 mm in length, 1.5±0.08 mm in width), globose-conic, solid (Fig. 9). Whorls 5, spire low, each whorl weakly convex in spire, body whorl large and more convex, with impressed suture. Surface smooth, with many fine axial growth threads, yellowish, with 2 brown bands on body whorl. Aperture large, simple, ovate, columellar lip of aperture pale brown, but inner lip dark purplish-brown. Early whorls of teleoconch without spiral ribs.

Native status: Lives on mud bottoms in brackish water areas of estuaries.

Distribution: China, Japan.

Notes: The genus *Assiminea* H. & A. Adams, 1865 is cosmopolitan, but most of them are from the Indo-pacific Region. *A. estuarina* is rarely found in China. The shell of this species is similar to *A. hiradoensis* Habe, 1942, but there are some differences

between them. Each whorl of *A. estuarina* is more convex than *A. hiradoensis*. The height of the spire of *A. hiradoensis* is higher.

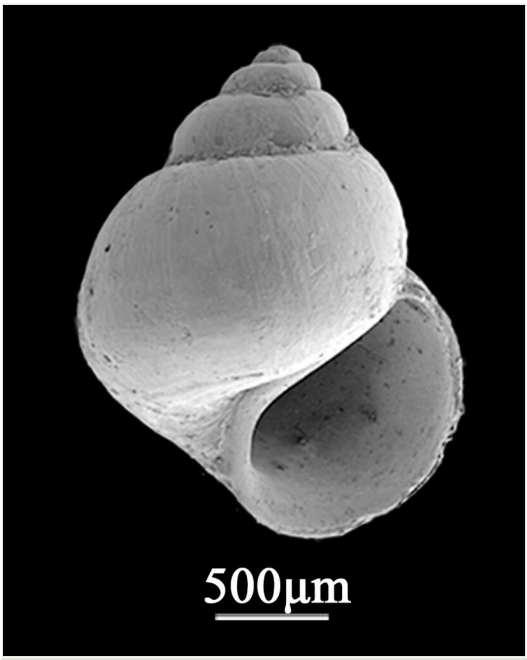

Figure 9. doi

Assiminea estuarina Habe, 1946.

Alvania concinna A. Adams, 1861

Diagnosis: Shell minute (4.5±0.41 mm in length, 2.4±0.11 mm in width), elongate conical (Fig. 10). Whorls about 6, slightly convex, with elevated spire, deeply sutured. Shell surface reddish-brown, sculptured with many spiral ribs and strong axial ribs; axials tend to weaken on body whorls in populations in temperate waters. Aperture simple, ovate, outer lip thin, without varix, the upper part of outer lip slightly angular. Apex generally not strongly tilted in species with paucispiral protoconch. No umbilicus.

Native status: Lives in intertidal areas in sheltered bays on seaweed.

Distribution: China, Japan and Korea.

Notes: The trait of the genus *Alvania* Risso, 1826 is that the teleoconch is ovate-conic to elongate-conic, with clathrate sculpture or spiral sculpture (Adams 1850). The changes of morphological characteristics and surface colour are relatively large, the synonym *Hydrobia plicosa* E. A. Smith, 1875 is a northern form of this species (Okutani 2017).

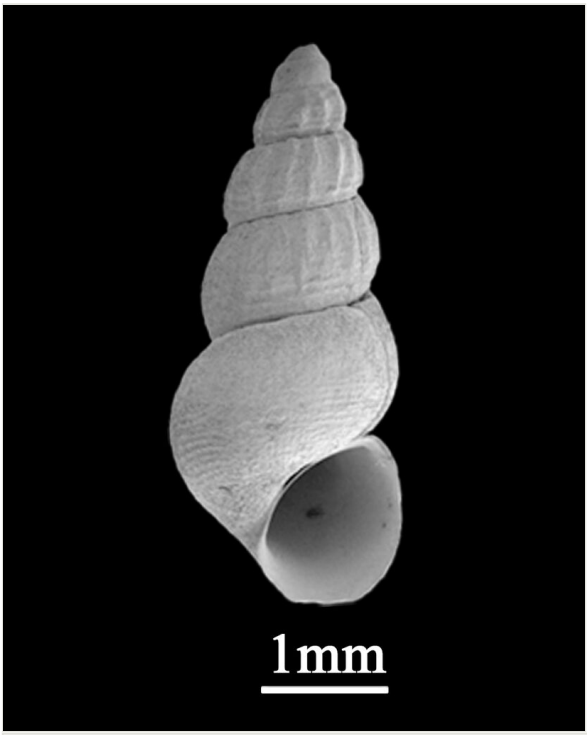

Figure 10. doi

Alvania concinna A. Adams, 1861.

Pseudoliotia pulchella Dunker, 1860

Diagnosis: Shell minute (1.3±0.19 mm in length, 3.1±0.16 mm in width), depressed conical, round pie, solid (Fig. 11). Whorls about 5, spire very low, body whorl large, the spiral layers are almost in the same plane, whorl periphery appears markedly truncate with a deep concave sulcus between the two peripheral keels. Suture distinct, grooved. Surface sculptured with thick spiral cords and many strong axial ribs, white or covered with yellow crust, thin sculpture lines on the sides of the whorl. Protoconch smooth. Aperture thickened, ovate, declining. Umbilicus deep.

Native status: Under rocks on sandy gravel bottoms in intertidal zones in sheltered areas.

Distribution: China, Japan.

Notes: *Pseudoliotia* Tate, 1898 is characterised by a depressed conical shell with strong axial and spiral ribs on its surface. *P. pulchella* is similar to *P. astericus*, but much larger, lower in shell height and with relatively weak axial ribs.

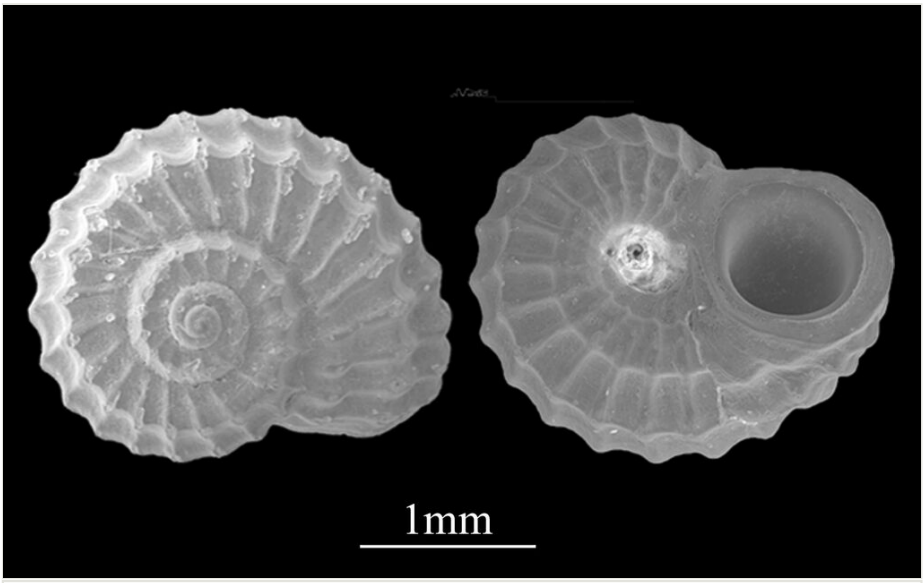

Figure 11. doi

Pseudoliotia pulchella (Dunker, 1860).

Peasiella habei D. Reid & Mak,1998

Diagnosis: Shell minute (3.0±0.28 mm in length, 2.4±0.09 mm in width), depressed conical, thick, stout; outline domed (Fig. 12). Whorls 3, whorls almost flat-sided or rounded or slightly shouldered; body whorl large with sharply angulate periphery; teleoconch whorls usually smooth, with spiral microstriae. Base flat to slightly rounded, with about 4 spiral ribs. Dark brown with irregular white spots. Suture impressed; peripheral keel prominent, often a projecting flange, rarely slightly undulating. Umbilicus usually narrow; columella narrow, curved at base. Protoconch usually eroded. Aperture ovate, outer lip thin and bottom angular, inner lip slightly thick and the upper part not connected with outer lip.

Native status: The species is abundant in crevices and amongst barnacles in the middle and upper eulittoral zone, on sheltered and moderately exposed rocky shores; on exposed shores, it shows a preference for surfaces protected from wave action.

Distribution: China, Korea, Taiwan, Japan.

Notes: This species is variable in conspicuous features of the shell including colour, spire profile and sculpture, but consistent characteristics are the row of dark spots above the periphery, which extend on to the pale peripheral keel, the darker and often black spire whorls and the prominent keel at the periphery.

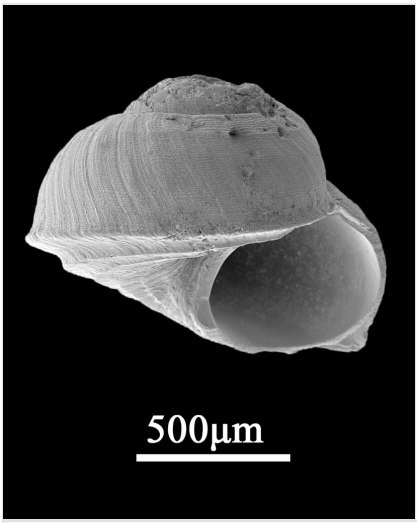

Figure 12. doi

Peasiella habei D. Reid & Mak,1998.

Acteocina fusiformis A. Adams, 1850

Diagnosis: Shell minute (2.5±0.15 mm in length, 0.9±0.08 mm in width), cylindrical to fusiform, thick, solid, with fine and indistinct spiral grooves (Fig. 13). Surface white, smooth, slightly corroded. Whorls about 3, spire small, body whorl was slightly constricted on the upper part. Shoulder acutely angulated. Protoconch prominently projecting. Suture oblique. Columella stout, with a fold above.

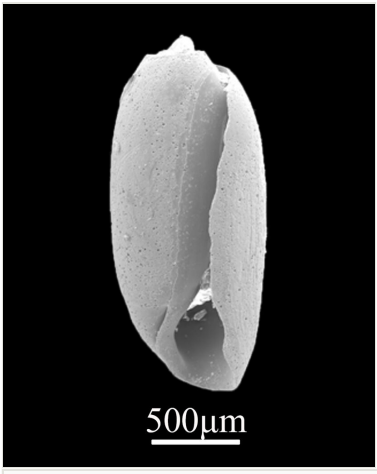

Figure 13. doi

Acteocina fusiformis A. Adams, 1850.

Native status: Found on sandy and mud bottoms in intertidal seagrass bed.

Distribution: Bohai Sea in China, Japan, South African.

Notes: Shell cylindrical or fusiform, spire conspicuous, apex papillated, suture channelled, columella callous, with a single fold in the genus *Acteocina* Gray, 1847 (Adams 1850). The division of the genus *Acteocina* is problematic in systematics. Okutani (2017) divided it into the family Cylichnidae, but it was divided into Tornatinidae in WoRMS.

Pyrunculus tokyoensis Habe, 1950

Diagnosis: Shell minute (3.0±0.34 mm in length, 1.3±0.11 mm in width), pyriform, thin, white, polished (Fig. 14). Apex narrowly perforated with rounded margin. The upper end of the body spiral shrinking and the lower end expanding, covered with spiral grooves overall, axial grooves distinct on upper extremity. Columella with fold. Outer lip thin.

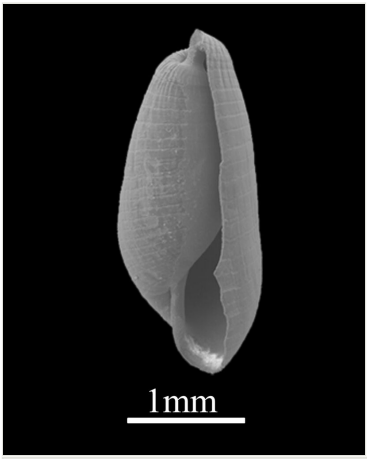

Figure 14. doi

Pyrunculus tokyoensis Habe, 1950.

Native status: Found on sandy and mud bottoms in intertidal seagrass beds.

Distribution: China and Japan.

Notes: *P. tokyoensis* is similar to *P. phiala*, but differs from *P. phiala* in having distinct spiral grooves overall.

Brachystomia bipyramidata Nomura, 1936

Diagnosis: Shell minute (3.2±0.27 mm in height, 1.5±0.34 mm in width), oval conical, moderately thick, translucently milky-white, solid (Fig. 15). Whorls about 5, each spiral

slightly convex, the height of the body whorl is larger than spire. Surface covered with yellowish-brown periostracum. Suture distinct, grooved. Growth lines coarse and flexuous. Aperture ovate. Columella with a weak fold. Outer lip margin with a shallow posterior sinus.

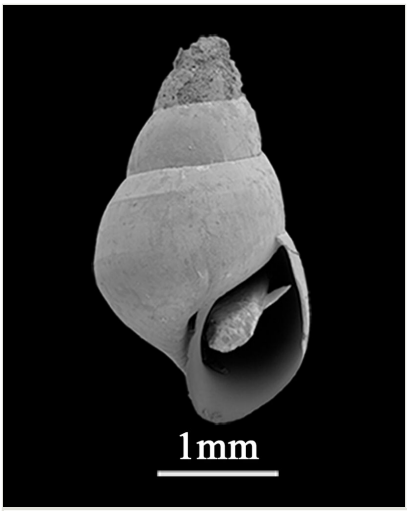

Figure 15. doi

Brachystomia bipyramidata (Nomura, 1936).

Native status: Sucking body fluid of *Crassostrea gigas* on rocks in intertidal zones.

Distribution: North of China, Japan.

Notes: The genus *Brachystomia* Monterosato, 1884 is very similar to *Odostomia* spp. in shell characters, but differs in the protoconch turning down on the teleoconch apex, attaching to other molluscs when alive (Okutani 2017).

Odostomia subangulata A. Adams, 1860

Diagnosis: Shell minute (5.0±0.12 mm in height, 2.3±0.03 mm in width), conical, milky-white, moderately thick, solid (Fig. 16). Whorls about 6, each whorl nearly flat-sided, shoulder of each whorl feebly angulate. Sutures distinct, grooved. Protoconch immersed in first teleoconch whorl, rotated right. Umbilicus narrowly opened. Aperture simple, long-ovate, columella with fold, outer lip thin, curved.

Native status: Sucking body fluid of *Crassostrea gigas* on rocks in intertidal zones.

Distribution: North of China, Japan.

Notes: *Megastomia tenera* (A. Adams, 1860) very similar to *Odostomia subangulata* A. Adams, 1860 in shell characters, but differs in having palatal ridges in the inner lip.

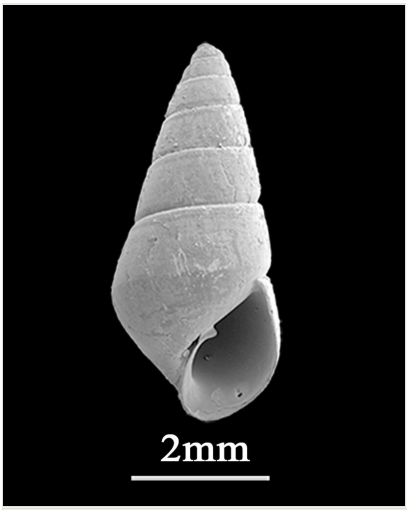

Figure 16. doi

Odostomia subangulata A. Adams, 1860.

Turbonilla osyuensus Nomura, 1936

Diagnosis: Shell minute (3.8±0.13 mm in height, 1.0±0.21 mm in width), towered, moderately solid, white (Fig. 17). Whorls about 10, each whorl with convex sides. Sutures constricted. Axial ribs oblique and straight, terminating at periphery. Interspaces of axial ribs twice as wide as ribs, the axial rib of the upper whorl is aligned with the interspace of the lower whorl. Aperture simple, upper of the outer lip with angular, columella with no folds, basal lip circle. The apex of the protoconch is composed of two parts of different sizes.

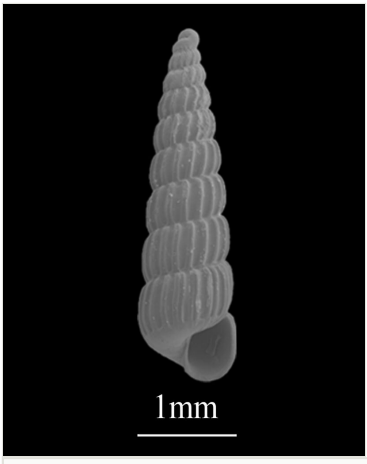

Figure 17. doi

Turbonilla osyuensus Nomura, 1936.

Native status: Found on sandy mud bottoms of seagrass beds.

Distribution: Bohai Sea of China, Japan.

Notes: *Chemnitzia osyuensis* (Nomura, 1936) is the type specimen and a synonym. Very similar to *T. gracilenta*, but differs in the protoconch rotated right (Higo and Goto 1993).

Rissoella elatior Golikov, Gulbin & Sirenko, 1987

Diagnosis: Shell minute (1.5±0.12 mm in height, 0.88±0.06 mm in width), elongate oval, thin, vitreous, fragile, translucent (Fig. 18). Whorls about 4, each whorl rather convex, spire about 25% of shell height. With deep sutures. Surface almost smooth, the axial growth lines of body whorl shrinking at base. Protoconch smooth, low. Aperture simple, ovate. With narrow umbilicus.

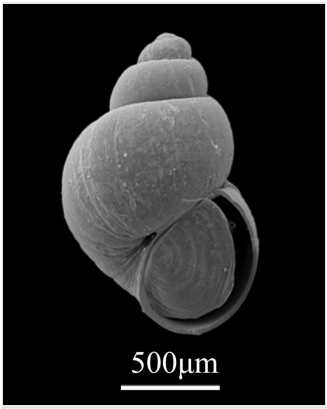

Figure 18. doi

Rissoella elatior (Golikov, Gulbin & Sirenko, 1987).

Native status: Living on seagrass.

Distribution: China, Japan, Russia.

Notes: The shell characteristics of the genus *Rissoella* are thin; vitreous and soft parts can be seen through it. As some species are similar in morphology, many species are misidentified or undescribed. In this study, our sampled material agrees with the original description of this species (Golikov et al. 1987), as well as the study from Siaden et al. (2019).

Lasaea undulata A. A. Gould, 1861

Diagnosis: Shell small (2.7±0.15 mm in length, 1.9±0.11 mm in height), elongate-ovate, thin, fragile (Fig. 19). Surface purplish-red, ornamented with concentric growth striae.

Umbo prominent, situated slightly behind the mid-point of the dorsal margin. Break located near posterior margin. Hinge plate very strong, with one cardinal socket, with one anterior lateral cardinal tooth and two posterior lateral cardinal teeth of different sizes in right valve.

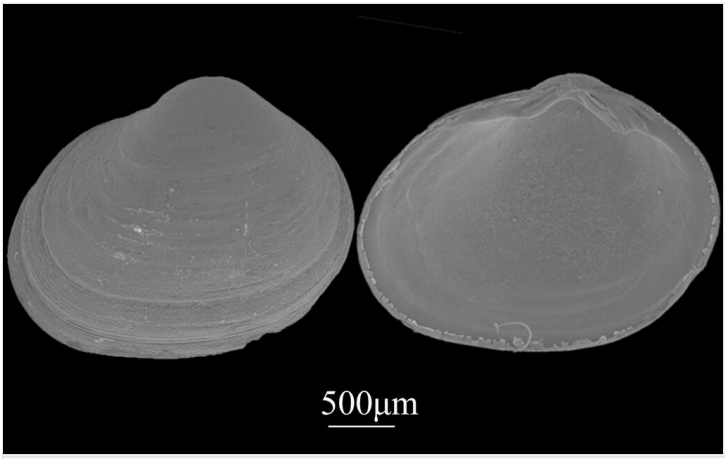

Figure 19. doi

Lasaea undulata (A. A. Gould, 1861).

Native status: Attached to the byssus of the septifer and the roots of seaweeds between tidal marks.

Distribution: Yellow Bay (Shandong Province) of China, Japan.

Notes: *Lasaea* consists of small pelecypod species, the largest of which attains a size of about 8 mm in length; adult specimens of the smaller species are about 2 mm long. In general, these shells are quadrangular in outline; they are equivalved, but inequilateral, the anterior end being the longer (Keen 1938). Most, if not all, species of *Lasaea* are nestlers, finding shelter in dead barnacle tests and amongst the holdfasts of seaweeds. It is cosmopolitan, but only *L. undulata* is found in China.

Alveinus ojianus Yokoyama, 1927

Diagnosis: Shell minute (1.1±0.17 mm in length, 1.0±0.22 mm in height), triangular-ovate, inflated, equivalved (Fig. 20). Umbo prominent, almost situated at the middle of the dorsal margin. Anterior and posterior ends round. Surface smooth and yellowish, ornamented by densely-spaced co-marginal lamellae. Hinge plate with one anterior and one posterior cardinal tooth in the left valve and one cardinal tooth in the right ligament external parivincular, with small resilium.

Native status: Found on sandy mud bottoms in upper sublittoral zones.

Distribution: Yellow Sea and Bohai Sea of China, southern Japan.

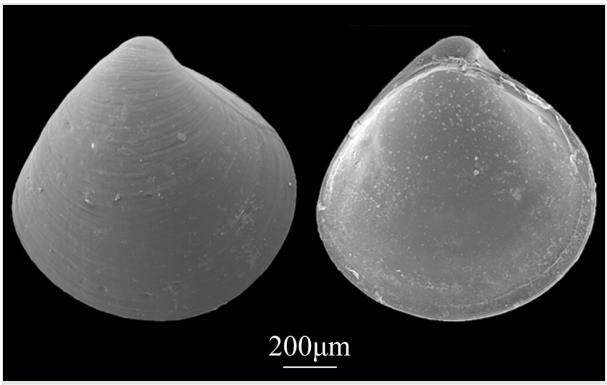

Figure 20. doi

Alveinus ojianus (Yokoyama, 1927).

Notes: *Spaniodon* Reuss, 1867 was considered a senior synonym of *Alveinus* Conrad, 1865, containing only *Alveinus miliaceus* (Issel, 1869) and *Alveinus ojianus* (Yokoyama, 1927) in WoRMS. *A. miliaceus* is very similar to *A. ojianus* in shell characters, but differs in the cardinal tooth. The cardinal teeth bifurcate into two lamellae (Conrad 1865).

Bentharca sp.

Diagnosis: Shell minute (2.3±0.02 mm in length, 1.5±0.04 mm in height), elongate squarish, thin, moderately inflated (Fig. 21). Antero-posterior margin round, anterior narrower and shorter than posterior; posterior hardly oblique, sides weakly angulated at upper part. Umbo corroded, situated in front of dorsal margin. Surface with 33 radial riblets of various prominence and strong concentric ribs near the umbo; covered with lamellate epidermis at interstices; inner surface margin is toothed. With a depression at the ventral margin. Cardinal plate with 3 teeth on anterior arc and 4 on posterior arc.

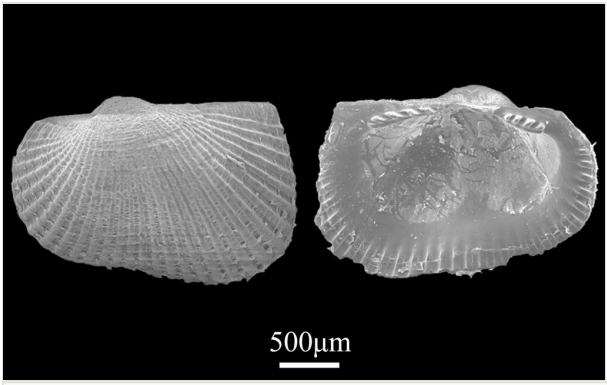

Figure 21. doi

Bentharca sp.

Native status: Found on sandy mud bottoms in upper sublittoral zones.

Distribution: Bohai Sea of China.

Notes: This species is very similar to *Bentharca* spp. in shell characters including radial riblets and is covered with lamellate epidermis at interstices, cardinal plate and umbo.

Analysis

A total of 20 species were described in this survey (Table 2). Out of the 20 specimens, identification was verified by barcoding for 13 specimens whose sequences have been deposited in GenBank. These can be assigned to 16 families, four orders (Vetigastropoda (1), Caenogastropoda (10), Heterobranchia (6) and Autobranchia (3)) and two classes (Gastropoda (17), Bivalvia (3)).

Discussion

This study described the diversity of common micromolluscs from the Yellow Sea and Bohai Sea in China. A total of 20 species were collected, belonging to 16 families and 16 genera of Gastropoda and 3 families and 3 genera of Bivalve, respectively. The statistics show that Caenogastropoda has the highest species diversity, which should be attributed to two essentially micromollusc groups, Rissooidea and Truncatelloidea (Fig. 22A). However, Vetigastropoda have the least diversity. This was due to the micromolluscs of Vetigastropoda being difficult to collect, as many in the families, Solariellidae, Liotinidae, Crosseolidae, Skeneidae, Anatomidae and Scissurellidae inhabited the subtidal zone (10-500 m depth).

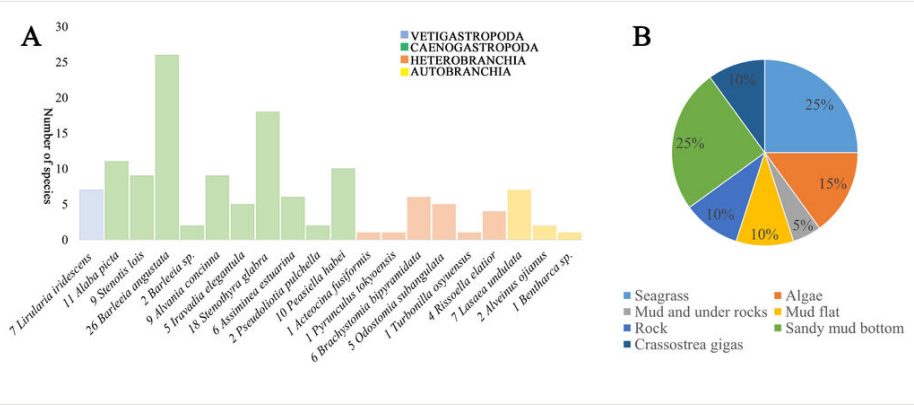

Figure 22. doi

The statistical chart of micromolluscs diversity and habitat. **A** The numbers in front of the species names indicate the number of collected specimens. Different colours represent different orders. **B** The percentage of species in different habitats. Different colours represent different habitats.

In terms of morphology, this study analysed the surface characteristics of the shells in detail by taking SEM images of the shells and carried out morphological identification and description, but there are still many undetermined species and, due to the limited amount of sample, a further morphological study could not be carried out. Meanwhile, this also means that there are still many micromolluscs to describe.

According to the survey, it is found that most of the micromolluscs inhabit seagrass (25%), sandy mud bottom (25%), algae (15%), mud and under rocks (5%) and others habitats (respectively 10%) (Fig. 22B). A total of about 40% of them living on seagrass and algae may be associated with their feeding and further refuging habits to reduce predation pressure (Holthuis 1995). Interestingly, *B. bipyramidata* and *O. subangulata* from Pyramidellidae were associated with *Crassostrea gigas*, which are often considered parasites or symbionts of bivalves (Fretter and Graham 1986), while some Pyramidellidae species, such as *Odostomia turrita*, *Odostomia acuta* and *Spiralinella spiralis*, were confirmed to associate with tubeworms from polychaetes (Høisæter 2014). Some 25% of collected samples were from sandy mud bottoms, because most of them contained only a shell. There are also fewer micromolluscs inhabiting mud flat and rocks, which may indicate that shellfish like to choose the best habitat in terms of habitat space and this selectivity is related to the geography of the sea area. Factors such as location, bottom deposition type, wave disturbance, abundance of food and seasonal changes are closely related.

Acknowledgements

This study was supported by the Hainan Provincial Joint Project of Sanya Yazhou Bay and Technology City Grant 320LH019, the National Natural Science Foundation of China under Grant 31772414, and the Fundamental Research Funds for the Central Universities under Grant 201964001. We thank Dr. Takenori Sasaki from the University of Tokyo, for his advice on the morphological research.

Author contributions

All authors were involved in collecting the animals. L. Q. analysed the material, designed the figure and wrote the manuscript. All authors read and approved the final manuscript.

References

- Adams A (1850) Monograph of the family Bullidae Privately. In: Sowerby G (Ed.) Thesaurus conchyliorum, or monographs of genera of shells. Privately published, London, England, 553-608 pp.
- Adams A (1861) On some new genera and species of Mollusca from the North of China and Japan. Annals and Magazine of Natural History 8 (3): 243.

- Agatsuma Y, Kuwahara Y, Taniguchi K (2005) Life cycle of *Dilophus okamurae* (Phaeophyceae) and its associated invertebrate fauna in Onagawa Bay, Japan. Fisheries Science 71 (5): 107-111. https://doi.org/10.1111/j.1444-2906.2005.01070.x
- Bouchet P, Lozouet P, Maestrati P, Heros V (2002) Assessing the magnitude of species richness in tropical marine environments: exceptionally high numbers of molluscs at a New Caledonia site. Biological Journal of the Linnean Society 75: 421-436. https://doi.org/10.1046/j.1095-8312.2002.00052.x
- Conrad TA (1865) Descriptions of new Eocene shells from Enterprise, Mississippi. American Journal of Conchology 1: 137-141.
- Folmer O, Black M, Hoeh W, Lutz R, Vrijenhoek R (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology 3 (5): 294-299.
- Fretter V, Graham A (1986) The prosobranch molluscs of Britain and Denmark. Part 9. Pyramidellacea. Journal of Molluscan Studies 16: 557-649.
- Golikov AN, Gulbin VV, Sirenko BI (1987) Prosobranch from Moneron Island shelf (Sea of Japan). I. Orders Patelliformes Calyptraeiformes. In: Kafanov A (Ed.) Fauna and distribution of molluscs, North Pacific and Polar Basin. Far Eastern Science Center of the USSR Academy of Science, Moscow, Russia, 20-44 pp.
- Higo S, Goto Y (1993) A systematic list of molluscan shells from the Japanese Islands and the Adjacent Areas. Erukairuishupankyoku, Yao, Japan, 69 pp.
- Høisæter T (2014) The Pyramidellidae (gastropoda, heterobranchia) of Norway and adjacent waters. A taxonomic review. Fauna Norvegica 34: 7-78. https://doi.org/10.5324/fn.v34i0.1672
- Holthuis BV (1995) Evolution between marine and freshwater habitats: a case study of the gastropod Neritopsina. University of Washington, Seattle, Washington.
- Kantor YI, Sysoev A (2006) Marine and brackish-water Gastropoda of Russia and adjacent countries: an illustrated catalogue. KMK Scientific Press Ltd, Moscow, Russia, 33 pp.
- Keen AM (1938) New pelecypod species of the genera lasaea and crassinella. Journal of Molluscan Studies 23: 18-32. https://doi.org/10.1093/oxfordjournals.mollus.a064332
- Li Q, Kong LF, Zheng XD (2019) Mollusks of Intertidal Zone in China. Science press, Beijing, China, 1516 pp.
- Liu J (2013) Investigation and molecular research of small gastropods in *Zostera marina* in the Swan Lake, Rongcheng, Shandong. Qingdao university, Qingdao, Shandong, China, 66 pp.
- Liu RY (2008) Checklist of Marine Biota of China Seas. Science Press, Beijing, China, 456-597 pp.
- Okutani T (2017) Marine mollusks in Japan. Tokai University Press, Tokyo, Japan, 771 pp.
- Siaden LE, Wakeman KC, Webb SC, Hasegawa K, Kajihara H (2019) Morphological and molecular diversity of rissoellids (Mollusca, Gastropoda, Heterobranchia) from the Northwest Pacific island of Hokkaido, Japan. Zootaxa 4551 (4): 415-431. https://doi.org/10.11646/zootaxa.4551.4.2
- Swindell S, Plasterer T (1997) SEQMAN. In: Swindell S (Ed.) Sequence Data Analysis Guidebook. 75-98 pp. https://doi.org/10.1385/0-89603-358-9:75

- Toyohara T, Nakaoka M, Aioi K (1999) Population dynamics and reproductive traits of phytal gastropods in seagrass bed in Otsuchi Bay, North-Eastern Japan. Marine Ecology 20 (3-4): 273-289. https://doi.org/10.1046/j.1439-0485.1999.2034082.x
- Yen TC (1939) Die Chinesischen Land-und Süßwasser-Gastropoden des Natur-Museums Senckenberg. Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft, Frankfurt am Main, Germany, 234 pp.
- Yen TC (1942) A review of Chinese gastropods in the British Museum. Journal of Molluscan Studies 24 (5-6): 170-289. https://doi.org/10.1093/oxfordjournals.mollus.a064412
- Zhang SP, Zhang JL, Chen ZY, Xu FS (2016) Mollusks of the Yellow Sea and Bohai Sea. Science Press, Beijing, China, 421 pp.