Morphological analysis of the Chinese *Cipangopaludina* species (Gastropoda; Caenogastropoda: Viviparidae)

Hong-Fa LU\(^{1,†}\), Li-Na DU\(^{2,†}\), Zhi-Qiang LI\(^{1,*}\), Xiao-Yong CHEN\(^{3,*}\), Jun-Xing YANG\(^{3,*}\)

1. Zhejiang Normal University, Xiaoshan Campus, Hangzhou 311231, China
2. Kunming Natural History Museum of Zoology, Kunming Institute of Zoology, Chinese Academy of Sciences, Kunming 650223, China
3. State Key Laboratory of Genetic Resources and Evolution, Kunming Institute of Zoology, Chinese Academy of Sciences, Kunming 650223, China

**Abstract:** Viviparidae are widely distributed around the globe, but there are considerable gaps in the taxonomic record. To date, 18 species of the viviparid genus *Cipangopaludina* have been recorded in China, but there is substantial disagreement on the validity of this taxonomy. In this study, we described the shell and internal traits of these species to better discuss the validity of related species. We found that *C. ampulliformis* is synonym of *C. lecythis*, and *C. wingatei* is synonym of *C. chinensis*, while *C. ampullacea* and *C. fluminalis* are subspecies of *C. lecythis* and *C. chinensis*, respectively. *C. dianchiensis* should be palced in the genus *Margarya*, while *C. menglaensis* and *C. yunnanensis* belong to genus *Mekongia*. Totally, this leaves 11 species and 2 subspecies recorded in China. Based on whether these specimens’ spiral whorl depth was longer than aperture depth, these species or subspecies can be further divided into two groups, viz. *chinensis* group and *cathayensis* group, which can be determined from one another via the ratio of spiral depth and aperture depth, vas deferens and number of secondary branches of vas deferens. Additionally, Principal Component Analysis indicated that body whorl depth, shell width, aperture width and aperture length were main variables during species of *Cipangopaludina*. A key to all valid Chinese *Cipangopaludina* species were given.

**Keywords:** *Cipangopaludina*; Gastropoda; Bellamyinae; Anatomy; Taxonomy; Chinese

The freshwater gastropod Viviparidae is currently divided into three subfamilies (Bouchet & Rocroi, 2005): Viviparinae Gray, 1847, Bellamyinae Rohrbach, 1837 and Lioplacinae Gill, 1863, which together comprise approximately 150 species and 31 genera recognized to date (Franke et al, 2007). Typically, viviparid species inhabit lakes, ponds, and lentic rivers of temperate to tropical region (Strong et al, 2008; Ying et al, 2013), explaining their wide global distribution across every continent save for South America and Antartica (Brown, 1994). In China, the existing taxonomy for Viviparidae includes approximately 61 recognized species in 9 genera (Du et al, 2011; Liu, 1991; Wang & Xie, 2005; Yen, 1943): *Viviparus* Montfort, 1810, *Bellamy* Jousseaume, 1886, *Filopaudina* Habe, 1964, *Mekongia* Crosse et Fischer, 1876, *Angulya* Benson, 1836, *Margarya*Neill, 1877, *Rivularia* Heude, 1890 and *Trochotaia* Brandt, 1974, *Cipangopaludina* Hannibal, 1912. The last genus, *Cipangopaludina* is particularly interesting as a diverse genus mainly distributed in China, Japan, Korea, Thailand, Vietnam, Laos, India, Burma and Malaya (Brandt, 1974; Liu et al, 1993) that is comprising of 35 species and subspecies (Global Names Index; http://gni.Globalnames.org), there has been substantial debate on the taxonomy of *Cipangopaludina*. Hannibal (1912) had previously proposed *Cipangopaludina* as a subgenus of *Idiopoma*, based on invasive specimens collected in California which were identified as *Paludina malleata*

Received: 02 April 2014; Accepted: 20 July 2014

Foundation items: This research was funded by the National Natural Science Foundation of China (31301865); the Natural Science Foundation of Zhejiang Province of China (LY12C19006) and the Collection and Preparation of Display Specimens at Kunming Natural History Museum of Zoology (KSZD–EW–TZ–005)

*Corresponding authors, E-mail: hxlzq@zjou.edu.cn; chenxy@mail.kiz.ac.cn; yangjx@mail.kiz.ac.cn*

†Authors contributed equally to this work.
Reeve. Meanwhile, Annandale (1920) proposed Lecythoconcha as a distinct genus for Paludina lecythis Benson while Prashad (1928) argued that Lecythoconcha was invalid and adopted the name Cipangopaludina.

Even within China, there is no clear verdict on the validity of each species or how many are even distributed in the area. Heude (1890) listed 9 species from China, viz. C. chinensis (Benson (non Gray)), C. lecythoides (Heude), C. diminuta (Heude), C. longispira (Heude), C. fluminalis (Heude), C. leucostoma (Heude), C. cathayensis (Heude), C. ventricosa (Heude) and C. aubryana (Heude). Later, comprehensive work by Kobelt (1909) revised Viviparidae, including practically all the forms of the family known at the time, which was one species and 12 subspecies in China, with most of species being designated varieties of the species C. chinensis (Gray): cathayensis (Heude), compacta (Nevill), ventricosa (Heude), longispira (Heude), fluminalis (Heude), hainanensis (Kobelt), diminuta (Heude), leucostoma (Heude), aubryana (Heude), patris (Kobelt), wingatei (Smith), lecythoides (Benson) and its form latissima (Dautzenberg et H. Fischer). Several decades later, Yen (1943) revised species of Chinese Viviparidae, and pointed out that leucostoma and diminuta were synonyms of chinensis and that lecythoides (Heude, non Benson) distributed in Zhoushan Island, compacta (Kobelt, non Nevill) distributed in Hainan, and lecythis crassior (Annandale) distributed in western Yunnan were all synonyms of patris (Kobelt), and longispira (Heude) was argued to be synonymous with haasi. Liu (1991) later clarified the distribution and taxonomy of Cipangopaludina and raised 15 of the subspecies to the species level, viz. C. chinensis, C. cathayensis, C. fluminalis, C. aubryana, C. latissima, C. lecythoides, C. ussuriensis (Gerstfeldt), C. yunnanensis, C. dianchiensis, C. ampullacea, C. haasi, C. lecythis, C. longispira, C. ventricosa and C. menglaensis. Finally, Wang & Xie (2005) evaluated the extinction risk of Cipangopaludina species, listing 14 distinct species: Cipangopaludina hainanensis, C. leucostoma, C. menglaensis, C. latissima, C. dianchiensis, C. lecythis, C. lecythoides, C. haasi, C. ampullacea, C. ventricosa, C. ampulliformis, C. aubryana, C. longispira and C. ussuriensis. Curiously, these latest works by Liu (1991) and Wang & Xie (2005) made no mention of two species, C. patris and C. wingatei, and ignored some of the earlier work done by Yen (1943).

Despite discrepancies and arguments as well as the elevation and demotion of species to subspecies and vice versa, the existing literature names 18 potential species of Cipangopaludina distributed in China: C. ampullacea, C. ampulliformis, C. aubryana, C. cathayensis, C. chinensis (synopsis C. leucostoma and C. diminuta), C. dianchiensis, C. fluminalis, C. haasi (synopsis C. longispira), C. hainanensis (synopsis C. compacta), C. latissima, C. lecythoides, C. lecythis, C. menglaensis, C. patris, C. ussuriensis, C. ventricosa, C. wingatei and C. yunnanensis. Similarly, the disparate results of the previous studies on the topic also highlight how difficult and complex the identification of Cipangopaludina is, largely due to intraspecific variations in shell shape. This has left the taxonomic position and phylogenetic relationships of these species largely unknown. In this study, we opted to perform a fresh check on the morphology and anatomy of Chinese Cipangopaludina species currently being held at repositories in Beijing and Kunming in order to arrive at a more complete species list. Morphometric analyses of shell variations were conducted on Cipangopaludina species through a Principal Component Analysis.

**MATERIALS AND METHODS**

**Sample collection and identification**

Four hundred and ninety-six, including 11 Cipangopaludina species were collected from Jilin, Jiangxi, Zhejiang, Guangxi and Yunnan Provinces. These specimens were preserved in Kunming Institute of Zoology, Chinese Academy of Sciences (KIZ). Additionally, 145 Cipangopaludina specimens, including 18 Cipangopaludina species or its synonyms listed in the existing literature preserved in the Invertebrate Museum of the Institute of Zoology, Chinese Academy of Sciences, Beijing (IOZ) were measured. A morphological analysis was conducted on these specimens and the validity of the currently identified species was determined. Specimens were identified mainly based on original description, type specimens, Liu et al (1979, 1993), Kobelt (1909) and Prashad (1928).

**Characters selected for morphometric analysis**

To select characters for use in morphometric analysis, we reviewed the available taxonomic descriptions from literature (Liu et al, 1979). Five shell characters were measured with callipers accurate to 0.1 mm: Shell depth (D), the maximum dimension parallel to the axis of coiling; Shell width (W) the maximum dimension
perpendicular to D; Length of the aperture (LA), the maximum dimension from the junction of the outer lip with the penultimate whorl to the anterior edge of the aperture (oblique to coiling axis); width of the aperture (WA), the maximum dimension perpendicular to LA; depth of the body whorl (BW), the dimension from the lower margin of the aperture to the upper suture delimiting the first whorl; and N, the number of whorls.

Embryonic shells were measured to 0.1 mm using an ocular micrometer. Anatomy was studied using a microscope with drawing apparatus. Radulae and embryonic shells were studied via scanning electron microscopy (SEM). The radulae were cleaned enzymatically with proteinase K, as described by Holznagel (1998), then sonicated and mounted on aluminium specimen stubs with adhesive pads. Embryonic shells were cleaned mechanically, sonicated, and mounted on adhesive carbon-coated pads. Both radulae and embryonic shells were coated with gold-palladium and studied on AMRAY 1000B scanning electron microscope at 30 kV. The description of shell features and visceral hump follows the general terminology suggested by Simone (2004).

Allometric shell growth

Due to ontogenetic effect of allometric growth have usually caused confusion in morphometric analyses, these individuals within the range of allometric growth were eventually excluded before multivariate analyses (Armbruster, 1995; Chiu et al, 2002; Valovirta & Vaisanen, 1986). However, in the present-day study, it is difficult for us to obtain snails of all size classes from each population per species and examine the allometric shell growth. Under this circumstance, the consequence of Chiu et al (2002) was followed that excluded individuals with aperture lengths of less than 1.0 cm. Morphometric data was explored through a Principal Component Analysis by SPSS 10.0 (SPSS for Windows, Chicago, IL, USA).

RESULTS

Systematics Cipangopaludina Hannibal, 1912

Idiopoma (Cipangopaludina) Hannibal 1912, Proceedings of the Malacological Society of London 10: 194 (type species, Paludina malleata Reeve, original designation)

Lecythoconcha Annandale 1920, Records of the Indian Museum. 19: 111 (type species, Paludina lecythis Benson, monotypic); Annandale 1921, Records of the
<table>
<thead>
<tr>
<th>Species/subspecies</th>
<th>D</th>
<th>W</th>
<th>LA</th>
<th>WA</th>
<th>BW</th>
<th>N</th>
<th>Apex</th>
<th>Kidney</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. lecithodes (n=5)</td>
<td>27.3±38.8 (33.1±4.93)</td>
<td>23.4±32.6 (27.7±3.93)</td>
<td>16.3±23.2 (19.5±2.99)</td>
<td>21.6±30.5 (26.3±3.74)</td>
<td>11.4±16.4 (13.9±2.04)</td>
<td>4-5</td>
<td>pointed</td>
<td>unknown</td>
</tr>
<tr>
<td>C. haasi (n=20)</td>
<td>41.8±64.7 (55.5±6.31)</td>
<td>30.4±45.8 (39.8±4.34)</td>
<td>22.4±35.5 (29.8±3.33)</td>
<td>31.3±48.8 (41.8±4.85)</td>
<td>15.7±24.8 (20.6±2.23)</td>
<td>6-7</td>
<td>pointed</td>
<td>Triple-shape</td>
</tr>
<tr>
<td>C. leucostoma (n=12)</td>
<td>27.4±48.8 (43.0±5.85)</td>
<td>23.6±39.3 (34.0±4.11)</td>
<td>21.4±28.4 (24.6±3.28)</td>
<td>22.3±37.0 (32.9±4.11)</td>
<td>11.5±19.3 (17.4±2.17)</td>
<td>7</td>
<td>obtuse</td>
<td>Arch-shape</td>
</tr>
<tr>
<td>C. chinensis fluminalis (n=25)</td>
<td>34.8±62.9 (49.8±7.32)</td>
<td>26.2±47.8 (38.0±4.81)</td>
<td>18.3±33.7 (26.9±3.84)</td>
<td>25.5±47.0 (37.2±5.17)</td>
<td>12.3±33.9 (19.3±4.62)</td>
<td>6</td>
<td>pointed</td>
<td>Triple-shape</td>
</tr>
<tr>
<td>C. aurivara (n=28)</td>
<td>29.7±53.0 (41.3±5.85)</td>
<td>23.6±41.0 (33.2±4.23)</td>
<td>17.2±29.8 (24.1±3.01)</td>
<td>22.4±40.1 (31.9±4.29)</td>
<td>12.3±22.9 (17.3±2.42)</td>
<td>5-7</td>
<td>pointed</td>
<td>Triple-shape</td>
</tr>
<tr>
<td>C. lecithis amphilacea (n=11)</td>
<td>31.6±64.2 (55.8±8.17)</td>
<td>27.3±50.2 (45.3±6.01)</td>
<td>18.3±38.4 (31.5±4.80)</td>
<td>24.4±49.0 (41.7±6.04)</td>
<td>13.4±25.4 (22.4±3.07)</td>
<td>5</td>
<td>eroded</td>
<td>Arch-shape</td>
</tr>
<tr>
<td>C. ventricosa (n=23)</td>
<td>31.6±62.2 (46.9±9.46)</td>
<td>26.5±49.2 (38.0±6.71)</td>
<td>19.5±35.2 (26.4±4.81)</td>
<td>24.7±45.3 (35.2±6.49)</td>
<td>13.3±24.2 (19.0±3.30)</td>
<td>6-7</td>
<td>pointed</td>
<td>Triple-shape</td>
</tr>
<tr>
<td>C. chinensis (n=23)</td>
<td>37.3±63.5 (52.6±7.56)</td>
<td>28.5±47.9 (40.2±5.61)</td>
<td>20.3±34.2 (28.3±4.07)</td>
<td>27.8±46.8 (38.3±5.42)</td>
<td>15.2±24.4 (20.3±2.75)</td>
<td>6-7</td>
<td>pointed</td>
<td>Triple-shape</td>
</tr>
<tr>
<td>C. cathayensis (n=25)</td>
<td>27.7±58.5 (41.0±7.45)</td>
<td>24.3±50.5 (34.2±5.91)</td>
<td>16.9±33.3 (23.7±4.09)</td>
<td>21.5±45.7 (31.3±5.80)</td>
<td>12.5±24.4 (17.3±2.9)</td>
<td>5-6</td>
<td>pointed</td>
<td>Triple-shape</td>
</tr>
<tr>
<td>C. menglaensis (n=10)</td>
<td>16.7±29.5 (24.3±3.42)</td>
<td>13.3±22.9 (19.2±2.57)</td>
<td>8.6±15.1 (12.7±1.80)</td>
<td>12.0±21.3 (17.3±2.61)</td>
<td>6.4±10.6 (9.1±1.17)</td>
<td>5-6</td>
<td>pointed</td>
<td>unknown</td>
</tr>
<tr>
<td>C. yunnanensis (n=31)</td>
<td>15.7±28.3 (20.7±3.13)</td>
<td>14.2±23.5 (18.0±2.65)</td>
<td>9.4±16.7 (11.9±2.00)</td>
<td>12.2±22.2 (16.0±2.42)</td>
<td>6.5±13.0 (9.0±1.60)</td>
<td>3-5</td>
<td>eroded</td>
<td>unknown</td>
</tr>
<tr>
<td>C. latissima (n=12)</td>
<td>35.0±52.8 (42.2±4.89)</td>
<td>30.4±47.5 (38.0±4.71)</td>
<td>20.8±33.2 (25.6±4.41)</td>
<td>26.7±43.4 (33.5±4.17)</td>
<td>14.3±23.5 (18.2±2.27)</td>
<td>6</td>
<td>pointed</td>
<td>unknown</td>
</tr>
<tr>
<td>C. diachnealis (n=11)</td>
<td>44.1±63.3 (53.6±5.76)</td>
<td>31.8±47.2 (40.2±5.00)</td>
<td>23.0±33.7 (28.9±3.73)</td>
<td>32.4±45.2 (39.0±4.43)</td>
<td>16.5±23.1 (20.3±2.14)</td>
<td>6-7</td>
<td>pointed</td>
<td>Triple-shape</td>
</tr>
<tr>
<td>C. lecithis (n=6)</td>
<td>42.0±51.8 (46.4±3.37)</td>
<td>32.7±39.3 (36.0±2.79)</td>
<td>24.0±29.5 (26.6±2.19)</td>
<td>32.5±39.0 (35.3±2.97)</td>
<td>16.2±19.8 (18.0±1.52)</td>
<td>6</td>
<td>pointed</td>
<td>Triple-shape</td>
</tr>
<tr>
<td>C. hainanensis (n=5)</td>
<td>30.8±38.9 (33.0±3.33)</td>
<td>24.8±30.4 (26.2±2.13)</td>
<td>16.3±22.1 (18.4±2.19)</td>
<td>23.9±29.2 (25.3±2.57)</td>
<td>12.8±15.1 (14.0±1.30)</td>
<td>4-5</td>
<td>eroded</td>
<td>unknown</td>
</tr>
<tr>
<td>C. assuriensis (n=1)</td>
<td>54.1</td>
<td>42.5</td>
<td>41.3</td>
<td>21.3</td>
<td>29</td>
<td>5</td>
<td>eroded</td>
<td>unknown</td>
</tr>
</tbody>
</table>

Note: Measurement values in parentheses denote mean±SE.
Figure 1  Shell of Cipangopaludina
A: C. lecythis ampullacea, KIZ 000453; B: C. lecythis, KIZ000284; C: C. leucostoma, KIZ 000270; D: C. chinensis, IOZ–FG166277; E: C. chinensis fluminalis, KIZ 000443; F: C. haasi, KIZ 000101; G: C. dianchiensis, KIZ 000536; H: C. hainanensis, IOZ–FG168161; I: C. latissima, IOZ–FG84656; J: C. lecythoides, IOZ–FG166538; K, L: C. menglaensis, IOZ–FG0142 (Holotype); M: C. yunnanensis, IOZ–FG0152 (Holotype); N: C. aubryana, IOZ–FG 170556; O: C. ussuriensis, IOZ–FG84819; P: C. ventricosa, KIZ000227. Scale bars=1 cm.

Figure 2  Anatomy and genital system of Cipangopaludina
A: Shell removed showing external features of animal; B: Male with mantle cavity opened mid–dorsally; C: Two type of kidney, I triple shape and II arch shape.
Abbreviations: aa — anterior aorta; ag — albumen gland; an — anal papilla; au — auricle; bp — brood pouch; cm — columnellar muscle; ct — ctenidium; df — dorsal fold of buccal mass; eg — egg-shell gland; es — esophagus; ey — eye; ft — foot; int — intestine; jw — jaw; kd — kidney; l — liver; me — mantle edge; mo — mouth; ne — nephrostome; op — operculum; pa — posterior aorta; pe — penis; pg — prostate gland; re — rectum; sn — snout; te — tentacle; ur — ureter; ve — ventricle; vd — vas deferens.

Distribution: Southwest of China, Yunnan, Sichuan provinces and Macao (Liu, 1991).
Remarks: Cipangopaludina ampullacea can be distinguished from C. chinensis, C. fluminalis, C. haasi, C. menglaensis, C. dianchiensis and C. ussuriensis by spiral depth shorter than aperture depth. Cipangopaludina ampullacea can be distinguished from other species by the following characters: osphradium length shorter or equal with length from anterior tip of osphradium to mantle border, vs. longer in C. ventricosa, C. patris and C. aubryana; shell larger, apex eroded vs. shell medium and apex pointed in C. yunnanensis; umbilicus small or closed vs. big and round in C. latissima; apex obtused vs. pointed in C. cathayensis and C. lecythoides. Cipangopaludina ampullacea can be distinguished from C. lecythis by apex eroded vs. pointed;
the upper angle of aperture acute vs. straight. However, the anatomy of *C. ampullacea* and *C. lecythis* are not obviously different, so it is suitable to treat *C. ampullacea* as a subspecies of *C. lecythis.*

**Cipangopaludina aubryana** (Heude, 1890) (Figure 1N)

Paludina aubryana Heude, 1890, Memoires concernant *L’Histoire naturelle e L’empire chinois par des peres de la compagnie de Jesus*, 175, pl. 39.


Materials: 20 ex. (4 females and 4 males were anatomy). IOZ–FG166735, IOZ–FG166737, from Wang County, Sichuan Province in June 1964; IOZ–FG170556, IOZ–FG170553, IOZ–FG170551, IOZ–FG 170549, from Hanshou County, Hunan province in March 1963; KIZ 000087–100, from Pu’er City, Yunnan in April 2011 by Zheng LP.

Diagnosis: shell medium, brown green, with 5 whorls. Body whorl inflated, but other whorls not, without shoulders. Apex pointed. Spiral whorl depth less than aperture depth. Osphradium ridge-like, longer than length from anterior tip of osphradium to mantle border. The base of gill filaments wide and apex narrow and pointed, does not curve to right. Kidney triple-shape, the dorsal length of kidney right plane about 1.2 times than ventral left plane, 2 times than posterior plane, the left plane and posterior plane do not curve much (Figure 2C-1). Vas deferens with 3 main branches and the first anterior branch with 4 parallel secondary branches. Vas deferens opens in last 1/3 of testis. Pouch filled with less than 10 embryos in various stages of development.

Embryos with 4 whors, body whorl with 3 chaeta and other whors have 2 rows of chaetae.

Distribution: Sichuan, Hunan, Guangdong, Guizhou and Yunnan Provinces, China (Liu, 1991).

Remarks: *Cipangopaludina aubryana* can be distinguished from *C. chinensis*, *C. haasi*, *C. fluminalis*, *C. dianchiensis*, *C. ussuriensis* and *C. menglaensis* by spiral depth less than aperture length and shell medium. *Cipangopaludina aubryana* can be distinguished from other species by the following characteristics: kidney triple-shape vs. arch-shape in *C. ampullacea*, *C. patris* and *C. ventricosa*; acute spiral whorl and without shoulder (vs. spiral whorl inflated and form shoulder in *C. lecythoides* and *C. yunnanensis*); shell medium and body whorl not very inflated vs. shell larger and body whorl very inflated in *C. latissima*; apex pointed, not eroded vs. apex eroded, with only 4 whors in *C. hainanensis*; vas deferens opens in last 1/3 of testis vs. 1/4 in *C. lecythis* and *C. l. ampullacea*.

**Cipangopaludina cathayensis** (Heude, 1890) (Figure 1C)

Paludina cathayensis Heude, 1890, Memoires concernant *L’Histoire naturelle e L’empire chinois par des peres de la compagnie de Jesus*, 175, pl. 39.


Materials: 34 ex. (2 males and 2 females were anatomy) KIZ000016–17, collected from Lake Xingyun, Yunnan in July 2008 by Du LN; KIZ000422–434, collected from Lake Dianchi, Guangxi in August 2009 by Yu GH and Li Y; KIZ000190–196, collected from Liaoyuan City, Jilin in October 2012 by Du LN.

Diagnosis: shell shin, medium, up to 60 mm, with 6 whorls. Kidney triple-shape. Vas deferens opens in last 1/3 of testis vs. arch-shaped in *C. ampullacea*, *C. patris* and *C. ventricosa*; acute spiral whorl and without shoulder (vs. spiral whorl inflated and form shoulder in *C. lecythoides* and *C. yunnanensis*); shell medium and body whorl not very inflated vs. shell larger and body whorl very inflated in *C. latissima*; apex pointed, not eroded vs. apex eroded, with only 4 whors in *C. hainanensis*; vas deferens opens in last 1/3 of testis vs. 1/4 in *C. lecythis* and *C. l. ampullacea*.

Kunming Institute of Zoology (CAS), China Zoological Society
ens with 3 main branches and the first anterior branch with 3–4 parallel secondary branches. Vas deferens opens in last 1/3 of testis. Female pouch filled with more than 60 embryos in various stages of development. Embryos with 3 whors, body whorl with 3 chaeta and other whors have 2 rows of chaetae.


Remarks: In the original description, this species was spelt *catayensis*, but later reviewers all spelt it *cathayensis*, according to the International Code of Zoological Nomenclature (1999). *Catayensis* is then treated as an inadvertent error, and thus this spelling is incorrect. *Cipangopaludina cathayensis* can be distinguished from *C. chinensis*, *C. haasi*, *C. fluminalis*, *C. dianchiensis* and *C. menglaensis* by spiral depth less than aperture depth. *Cipangopaludina cathayensis* can be distinguished from other species by the following characteristics: anterior 2/3 of osphradium ridge-like and posterior 1/3 inflated; female’s pouch with more than 60 embryos, and embryo’s have 3 whors.

**Cipangopaludina chinensis (Gray, 1834)** (Figure 1D)


**Material**: 40 ex. (1 males and 2 females were anatomy). IOZ–FG166277, Shangsi Co. Guangxi Province in 19th April 1974; IOZ84521, Zhaotong City, Yunnan Province in May 1932; IOZ166773, IOZ166777, Qionghai Lake, Xichang County, Sichuan Province in 4th July 1964; IOZ166733, Luofang village, Guangdong Province in March 1982; KIZ000164–165, Lake Erhai, Yunnan, collected by Du LN, Jiang YE and David Aldridge in 14 April 2006; KIZ 000294–310, Lake north mountain, Jilin City, Jilin Province, collected by Du LN on 13 October 2012; KIZ 000132–133, KIZ 000149–150, West Lake, Dali City, Yunnan, collected by Du LN in 13 April 2006, Jiang YE and Aldridge D; KIZ 000157–158, Lake Xinyun, Jiangchuan County, Yunnan, collected by Du LN, Jiang YE and Cui GH in September 2009; KIZ 00013015, KIZ 000038040, KIZ 0000363–366, KIZ 00421, Lake Dianchi, Kunming City, Yunnan, collected by Du LN and Aldridge D in March 2006.

**Description**

Shell: large (up to 70 mm), oval, brown or greenish in colour, with 6–7 whors. Apex pointed. Suture narrow. Umbilicus narrow or closed. Sculpture lacking except growth lines and axial undulations. Aperture subcircular, inner lip whitish blue and outer lip black in colour, easily brown. Young specimens (from brood pouch) with up to 4 whors; protoconch smooth, three primary rows of chaetae on last whorl and other whors have two rows of chaetae.

**Operculum**: Occupying entire shell aperture. Centre is brown and outer parts greenish. Nucleus sub-central, located closer to inner margin. Sculptured with concentric growth lines. Inner surface glossy; scar sub-circular, close to inner margin, occupying about 2/3 of operculum area.

**External morphology** (Figure 2B): head and foot black. Snout cylindrical, anterior margin flat. Length of tentacles about 1.3 times longer than snout length, base at side of snout base. Ommatophore short, located between basal and middle third of outer surface of each tentacle. Foot large, sole simple. Opercular pad larger than its base in dorsal foot surface. Columellar muscle thick.

**Radula**: Central tooth with wide rounded major denticles and 4 smaller triangular denticles on each side. Lateral tooth with tongue-shaped major denticles and 3 minor denticles on each side. Inner marginal tooth with
tongue-shape major denticles and 3 minor denticles and marginal teeth with 10 almost equal-sized denticles.

Mantle organs (Figure 2A-B): Mantle border simple and thick. Osphradium ridge-like, very close to ctenidium, about same length from anterior tip of osphradium to mantle border. Ctenidium long and narrow, about same length as pallial cavity, anterior end at mantle border. Gill filaments very tall and narrow, arched towards right and apex slightly pointed, close to food groove.

Hypobranchial gland lies on left of gill margin. Right margin of mantle cavity filled by oviduct in females. Ureter runs along mantle cavity right margin in males or edging oviduct in females. Rectum on dorsal and left sides of ureter. At right end of mantle border, in females, presenting three openings, most posterior and smaller is ureter pore, anus most anterior, and female pore larger, located between anus and ureter pore.

Alimentary canal: Oval mouth, bounded by fleshy lips, ventral at anterior end of snout. Jaw plates ridge-like (Figure 2A). Esophagus with pair of dorsal, longitudinal folds, about 1.5 times of buccal mass length. Esophagus runs along the hypobranchial gland to posterior of columnellar muscle, and then turns right and passes upwards in floor of pericardial chamber to reach digestive gland in upper part of visceral hump where it curves round to open into stomach. Stomach located halfway posterior to pallial cavity, posterior half immersed in digestive gland. Esophagus is inserted in posterior gastric extremity, and as gradually enlarges curves towards left. After this curve, stomach abruptly expands becoming almost as wide as whorl, posterior narrowing, without clear separation with intestine. Intestine forms loop overlying pericardial cavity and makes loop. Oviduct increases in size and runs to capsule gland on dorsal and posterior surface and opens to brood pouch. Walls of brood pouch thin, semi-transparent, smooth. Pouch filled with about 45–84 embryos in various stages of development.

Genital system.

Male (Figure 2A): Testis compact, semi-lunar, on right of mantle cavity. Extends to upper end of mantle cavity, where apex close to pericardial cavity also connected by thin fold of membrane with lower surface of digestive gland. Testis flattened laterally, right surface abuts columnellar muscle while left surface abuts right wall of ureter. Vas deferens very narrow, running on columnellar and inferior ventral margin of testis, with 2 main branches, and in the anterior branch with 5–6 parallel secondary branches, the branches with many very narrow branches from different portions of testis. Vas deferens opens in last 1/3 of testis and runs to prostate gland in mantle cavity along mantle cavity floor for about 3/4 of its length; left 1/4 length of vas deferens abruptly narrows and is surrounded by very thick, muscular walls. Vas deferens runs all along the right cephalic tentacle, its inner surface relatively broad, with some inner, longitudinal folds. Vas deferens opens in tentacle tip as broad papilla with rounded tip. Right tentacle possesses deep concavity located at right from genital papilla. Papilla can retract into its concavity.

Female. Ovary grey, located in same position as testis. Ovary in close contact with posterior wall of cardiac region of stomach and along course of hepatic artery. Oviduct very narrow; from albumen gland it runs to posterior end of columella, and then turns left, making a loop. Oviduct increases in size and runs to capsule gland along brood pouch. Brood pouch located in dorsal of oviduct. Albumen gland tongue-shaped, slightly curved, capsule gland on dorsal and posterior surface and opens to brood pouch. Walls of brood pouch thin, semi-transparent, smooth. Pouch filled with about 45–84 embryos in various stages of development.

Ecology and habitat: it lives in slow-moving water such as lakes, pond, irrigation canals, ditches and slow moving stream (Pace, 1973). It is a benthic grazer and filter feeder, feeding on benthic and epiphytic diatom (Plinski et al, 1978), often found on sandy to muddy substrates.

Distribution: original range in China (including Taiwan), Korea, and Japan, but has also been introduced
in freshwater ponds and lakes in Canada, the north-eastern USA, and Europe (Soes et al, 2011).

Remarks: Although Yen (1943) mentioned that *C. leucostoma* (Heude) and *C. diminuta* (Heude) are synonymous with *C. chinensis* (Gray), the authors thought these two species are synonymous with *C. patris* (Kobelt) according to apex obtuse and less than 6 whorls. Additionally, *Cipangopaludina wingatei* (Smith) could be synonymous with *C. chinensis* according to shell size, spiral depth longer than length of aperture, and number of whorls. *Cipangopaludina chinensis*, *C. dianchiensis*, *C. fluminalis*, *C. haasi*, *C. ussuriensis* and *C. menglaensis* share the characteristic that spiral depth is longer than length of the aperture. However, *C. chinensis* can be distinguished from *C. dianchiensis* and *C. ussuriensis* by its shell smooth rather than having a shell with a ridge; female’s pouch has more than 80 embryos vs. less than 10 embryos in *C. dianchiensis*; embryo with three primary rows of chaetae on last whorl vs. 3 ridges in *C. dianchiensis*. *Cipangopaludina chinensis* can be distinguished from *C. fluminalis* by the following characters: shell thin vs. thick, umbilicus close vs. big and deeply.

**Cipangopaludina dianchiensis** Zhang, 1990 (Figure 1F)


Materials: 34 ex. (2 males and 3 females were anatomy). KIZ 000233, collected in November 2002 by Cui GH; KIZ 000001–KIZ 000004, collected in June 2008 by Du LN, Jiang YE and Barclay H; KIZ 000005–KIZ 000012, collected in September 2005 by Du LN and Aldridge D; KIZ 000212–KIZ 000217, KIZ 000287–KIZ 000293; KIZ 000311–KIZ 000316, collected in January 2006 by Du LN and Yuan C; KIZ 000373, KIZ 000231 collected in June 2006 by Du LN. All specimens were from Lake Dianchi.

Diagnosis: shell thick. Body whorl with 7–12 ridges (3–4 ridges clearly). Apex pointed. Osphradium ridge–like, shorter than length from anterior tip of osphradium to mantle border. Gill filaments and jaw plate are the same as *C. chinensis*. The size of ventricle is the same as the auricle. Vas deferens has 3 main branches and the first anterior branch has 4 “V” shaped secondary branches. Vas deferens opens in last 1/3 of testis. Pouch filled with about 6–8 embryos in various stages of development. Embryos with 5 whorls, body whorl with 3 ridges and other whorls with 1 ridge.

Distribution: only known to live in Lake Dianchi, Yunnan.

Remark: Morphology characteristics, such as shell thickness, body whorl with clear ridges, female’s pouch with few (6–8) embryos and embryo shell with ridges can be distinguished clearly from other species of genus *Cipangopaludina*. Additionally, phylogenetic analysis indicated that *C. dianchiensis* clustered with species of *Margarya* in Lake Dianchi (Du et al, 2013). The morphology and molecular results indicated that *C. dianchiensis* should be placed into the genus *Margarya*.

**Cipangopaludina fluminalis** (Heude, 1890) (Figure 1E)


Materials: 21 ex (1 male and 1 female were anatomy). KIZ 000181 collected from Jinping County, Honghe prefecture, Yunnan in December 2004 by Du LN; KIZ 000181–KIZ 000184, collected from Songming County, Kunming prefecture, Yunnan in December 2005 by Du LN. All specimens were from Lake Dianchi.

Diagnosis: shell is thick, larger, up to 60 mm, with 7 slightly inflated whorls. Apex pointed. Spiral whorl depth longer than aperture depth. Umbilicus big and deep. Osphradium length similar with length from anterior tip of osphradium to mantle border. Gill filaments same as *C.
Morphological analysis of the Chinese Cipangopaludina species (Gastropoda; Caenogastropoda: Viviparidae)  

Cipangopaludina latissima (Dautzenberg et H. Fischer, 1905) (Figure 11)


Materials: 15 shell specimens. IOZ–FG84653–84667, collected from Mengzi County, Yunnan in March 1927.

Diagnosis: shell is large, round, up to 53 mm, with 6 whorls. Apex pointed. Body whorl very inflated, shell width is about 85%–95% of shell depth. Due to the body whorl inflated, the upper of body whorl has a flat shoulder. Aperture ellipse. Umbilicus very big, round. Anatomy characteristics unknown.

Distribution: only known to be from Mengzi County, Yunnan.

Remarks: Cipangopaludina latissima can be distinguished from other species of Cipangopaludina by the body whorl special inflated, and the upper of body whorl with a flat shoulder.

Cipangopaludina lecythoides (Benson, 1842) (Figure 1J)

Paludina lecythoides Benson, 1842, The Annals and Magazine of Natural History; Zoology, Botany and Geology 9, 488; Philippi, 1846, Abbildungen und Beschrei-bungen neuer oder wenig gekannter Conchylien herausgegeben, II. p.133, pl 2, fig 1; Küster, 1852, In Abbildungen nach der Natur mit Beschreibungen. Systematisches Conchylien-Cabinet 2ed, p. 23, pl. 5, fig 1, 2; Reeve, 1862, Conchologia iconica, or, illustrations of the shell of mollusous animals, pl. 4, fig 21; Dautzenberg et H. Fischer, 1905, Journal de Conchyliologie, p417–418.


Vivipara (chinesis var.) lecythoides (Benson), Kobelt, 1909, Abbildungen Nach de Natur mit Beschreibungen, p 119, pl. 23, fig 8.

Cipangopaludina chinensis lecythoides (Benson), Prashad, 1928, Memoirs of the Indian Museum, Calcutta, 8: 168.


Materials: 1 ex. KIZ 000507, collected from Hangzhou City, Zhejiang Province in April 2013 by Lu HF;

Diagnosis: shell depth 55 mm, with 6 inflated whorls. Shell dark brown, with clearly growth lines. Apex pointed. Spiral whorl depth shorter than aperture depth. Umbilicus small, nearly closed. Vas deferens has 2 main branches and the first anterior branch with 3 parallel secondary branches. Vas deferens opens in last 1/3 of testis. Vas deferens opens in various stages of development. Embryos with 4 whorls, body whorl with 3 chaeta and other whorls have 2 rows of chaetae.


Remarks: Although Wang & Xie (2005) mentioned that this species is distributed in Yunnan, it was not collected during field excursions undertaken between 2003–2008 by authors Du LN and Chen XY. Generally, the validity of this species is unclear, as it is difficult to distinguish C. lecythoides and C. cathayensis by shell morphology alone. Further anatomic characteristics are required to determine the validity of this species.

Cipangopaludina lecythis (Benson, 1836) (Figure 1B)


Paludina ampullacea Reeve (not Charpentier), 1862, Conchologia iconica, or, illustrations of the shell of...
molluscan animals, 12.


Materials: 25 ex. (1 female and 2 males). KIZ 000018–000030 collected from Songming County, Kunming City, Yunnan in April 2006 by Du LN and Yuan C; KIZ 000044 collected from Lake Dianchi, Yunnan in April 2006 by Du LN and Yang J; KIZ 000144 collected from Lake Erhai in April 2006 by Du LN, Yang YE and Aldridge D; KIZ 000151–156 collected from Lake Xingyun, Yunnan in September by Du LN, Jiang YE and Cui GH; KIZ 000224 collected from Lake Xingyun, Yunnan in April by Du LN; KIZ 000284–286 collected from Lake Dianchi, Yunnan in March 2006 by Du LN.

Diagnosis: shell larger, up to 60 mm, brown gree-nish, with 7 whorls. Apex pointed. Spiral whorl depth shorter than aperture depth. Whorls inflated, with a shoulder. Aperture ellipse, the upper of aperture form a straightgth shoulder. Umbilicus small or closed. Osphradium ridge-like, shorter than length from anterior tip of osphradium to mantle border. Gill filaments same with C. chinensis. Vas deferens with 3 main branches and the first anterior branch with 4 parallel secondary branches. Vas deferens opens in last 1/3 of testis. Pouch filled with 96–109 embryos in various stages of development. Embryos with 3–4 whorls, body whorl with 2 chaetae and other whorls with 1 chaetae.


Remarks: Cipangopaludina lecythis can be distinguished from other species of this genus by the special aperture shape, the upper of aperture straight and form a flat shoulder. Kobelt (1909) list C. lecythis ampulliformis (Souleyet) as a subspecies of C. lecythis, which are distributed in both Burma and Yunnan, China. According to Kobelt (1909) it is difficult to distinguish between these two species, so we opted to treat C. lecythis ampul-liformis as synonymous with C. lecythis.

Cipangopaludina patris (Kobelt, 1906) (Figure 1C)


Cipangopaludina chinensis patris (Kobelt), Prashad, 1928, Memoirs of the Indian Museum, Calcutta, 8: 168.


Materials: 28 ex (2 females and 2 males were anatomy). KIZ 000268–000279, collected from Yuanjiang County, Yunnan in January 2010 by Du LN; KIZ 000369–000372, collected from Jinning County, Yunnan in August 2006 by Du LN; KIZ 000391–000402, collected from Yuanjiang County, Yunnan in January 2013 by Du LN.

Diagnosis: shell medium, up to 50 mm, brownish, with 6 whorls. Apex obtuse. Whorls inflated, especially last two whorls, upper three whorls slightly inflated and always eroded. Spiral whorl depth shorter or equal with aperture depth. Aperture ellipse. Umbilicus closed. The shape of the kidney is similar with C. amplulacea. Osph-radum ridge-like, longer than length from anterior tip of osphradium to mantle border. Gill filaments same with C. chinensis. Vas deferens with 3 main branches and the first anterior branch with 1 “V” shape and 3 parallel secondary branches. Vas deferens opens in last 1/3 of testis. The loop of oviduct exceeds the posterior margin of columnellial muscle. Pouch filled with 96–109 embryos in various stages of development. Embryos with 3 whorls, body whorl with 3 chaetae and other whorls with 2 chaetae.

Distribution: Yunnan, Guangdong and Zhejiang provinces, China.

Remarks: Cipangopaludina patris can be distinguished from C. chinensis, C. haasi, C. dianchiensis, C. u ssuriensis and C. menglaensis by a spiral depth shorter than aperture length and a medium shell. Cipangopaludina patris can be distinguished from other species by the following characteristics: larger shell, up to 50 mm (vs. medium, up to 26 mm in C. yunnanensis); the kidney arch-shape is similar with C. amplulacea, (vs. triple-shape in C. cathayensis, C. aubryana and C. lecythoides); medium shell and body whorl are not very inflated (vs. shell larger and body whorl very inflated in C. latissima); shell with 6 whorls (vs. only with 4 whorls in C. hainanensis); the upper of aperture without straight shoulder (vs. with straight shoulder in C. lecythis).

Cipangopaludina haasi (Prashad, 1928) (Figure 1F)

Cipangopaludina chinensis haasi Prashad, 1928,
Morphological analysis of the Chinese *Cipangopaludina* species (Gastropoda; Caenogastropoda: Viviparidae)


- **Paludina longispira** Heude, 1890, *Memoires concernant L’Histoire naturelle e L’empire chinois par des peres de la compagnie de Jesus*, 175, pl. 39.

**Viviparus chinensis longispira** (Heude), Yen, 1939, *Diese Arbeit erscheint gleichzeitig in den Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft Abhandlung*, 444, p. 35, taf. 3.

**Viviparus chinensis longispira** (Heude), Yen, 1942, *Proceedings of the Malacological Society of London*, 190, 200, pl. 13, fig 32.


**Cipangopaludina longispira** (Heude), Liu, 1991, *Proceeding Tenth International Malacological Congress*, 590.

Materials: 44 ex (2 females and 2 males were anatomy). KIZ 000197–000198, KIZ 000280–000282, collected from Black dragon spring, Songming Town, Kunming, Yunnan in December 2004 by Cui GH and Chen XY; KIZ 000122–131, collected from Xiayu Village, Zhangshu City, Jiangxi Province in February 2006 by Yu GH; KIZ 00101–00108, collected from Lake Yilong, Yunnan in February 2008 by Du LN and Jiang YE; KIZ 000477–000497, collected from Hangzhou City, Zhejiang Province in April 2013 by Lu HF.

Diagnosis: shell larger, up to 65 mm, greenish, with 7 whorls. Apex pointed. Suture shallow. Spiral whorl depth higher than aperture depth. Shell width less than body whorl depth. Whorls slightly inflated, do not form shoulder. Umbilicus small. Aperture ellipse. Osphradium ridge-like, longer than the length from anterior tip of osphradium to mantle border. Gill filaments same as *C. chinensis*. Esophagus has pair of dorsal, longitudinal folds, about 2 times of buccal mass length. Stomach elliptical, spoon-shape. Heart located anterior ventral of kidney. Ventricule is about 2 or 3 times larger than auricle. Kidney triple-shape. Nephrostome round, small pore, located in posterior 1/5 of ventral surface of kidney. Vas deferens with 2 main branches and the first anterior branch has 8 to 9 parallel secondary branches. Vas deferens opens in last 1/4 of testis. Female’s pouch length is about 4 times longer than egg gland. Pouch filled with 128–188 embryos in various stages of development. Embryos with 4 whorls, body whorl with 3 chaetae and other whorls with 2 chaetae.

**Cipangopaludina hainanensis** (Möllendorff, 1909) (Figure 1H)


Diagnosis: shell medium, up to 40mm. Apex eroded, left 4–5 inflated whorls. Suture deeply. Umbilicus big and deep.

Distribution: only known from Hainan Island.

Remarks: this species was evaluated as being extinct by Wang and Xie (2005). Existing specimens can be distinguished from other species by medium shell, apex eroded, with 4–5 inflated whorls and umbilicus big and deep.

**Cipangopaludina menglaensis** Zhang, Liu et Wang, 1981 (Figure 1L)


Materials: 10 ex. IOZ–FG 0142 (holotype), IOZ–FG 00143–151 (Paratypes) from Manzhazai Village,
Pu’er City, Yunnan in March 1965 by Zhang WZ and Liu YY.

Diagnosis: shell dark brown, small, up to 30 mm, with 6 whorls. Apex pointed. Suture deeply. Central tooth with wide rounded major denticles and 3 or 4 smaller triangular denticles on each side. Lateral tooth with tongue-shaped major denticles and 4 or 5 minor denticles on each side. Inner marginal tooth with tongue-shape major denticles and 3 or 4 minor denticles and marginal teeth with 20 almost equal sized denticles.

Distribution: only known from type locality.

Remarks: Without anatomized specimens, the anatomy characteristics remain unknown. However, this species can be distinguished from other species of *Cipangopaludina* by a smaller shell, up to 30 mm and marginal teeth with 20 almost equal sized denticles.

*Cipangopaludina ussuriensis* (Gerstfeldt, 1859) (Figure 1O)

*Paludina ussuriensis* Gerstfeldt, 1859, *Memoires des savants Strangers*, 9: 507, fig 1–4; *Reeve*, 1862, *Conchologia iconica, or, illustrations of the shell of molluscous animals*, pl. 8, fig 1–4;


Material: 24 ex. (1 female and 2 males were anatomy). KIZ 000031 collected from Yangguang County, Yunnan in February 2006 by Du LN; KIZ 000036–38, KIZ 000174, KIZ 000227–228, KIZ 000230 collected from Lake Dianchi, Yunnan in March 2006 by Du LN; KIZ 000143 collected from Lake Erhai, Yunnan in April 2006 by Du LN, Jing YE and Aldridge A; KIZ 000175–180 collected from Jiuzai dragon spring, Yunnan in March 2006 by Du LN; KIZ 000226 collected from Lake Xingyun, Yunnan in April 2006 by Du LN; KIZ 000283 collected from Black dragon spring, Songming County, Yunnan in December 2005 by Cui GH and Chen XY; KIZ 000361–362 collected from Black dragon spring, Songming County, Yunnan in December 2005 by Du LN; KIZ 000437–441 collected from Black dragon spring, Songming County, Yunnan in April 2006 by Du LN.

Diagnosis: shell larger, medium thick, up to 65 mm, with 7 whorls. Body whorl inflated. Aperture inflated and round, but the upper angle does not forms a straight shoulder. Apex pointed. Umbilicus big and deep. Osphradium ridge-like, longer than length from anterior tip of osphradium to mantle border. Gill filaments same with *C. chinensis*. The dorsal length of kidney left plane about same length with ventral right plane, 1.5 times than posterior plane. Vas deferens with 3 main branches and the first anterior branch with 1 “V” shape and 3 parallel secondary branches. Vas deferens opens in last 1/4 of testis. Pouch filled with 33 embryos in various stages of development. Embryos with 3 whorls, body whorl with 3 chaetae and other whorls with 2 chaetae.

Distribution: Yunnan, Sichuan and Guizhou Provinces, China (Liu, 1991).

Remarks: *Cipangopaludina ventricosa* is similar to *C. cathayensis* and *C. ampullacea* with a slightly larger shell, apex pointed and whorls inflated. However, *C. ventricosa* can be distinguished from *C. cathayensis* by following characteristics: shell with 7 whorls vs. 6; aperture round vs. ellipse; Osphradium ridge-like, longer than length from anterior tip of osphradium to mantle border vs. anterior 2/3 part of osphradium ridge-like and posterior 1/3 part inflated, osphradium length similar.
with length from anterior tip of osphradium to mantle border; Vas deferens opens in last 1/4 of testis vs. 1/3. *Cipangopaludina ventricosa* can be distinguished from *C. ampullacea* by the following characteristics: upper aperture does not form straight shoulder vs. having a straight shoulder; umbilicus big and deep vs. closed; Osphradium longer than length from anterior tip of osphradium to mantle border vs. shorter; Vas deferens opens in last 1/4 of testis vs. 1/3.

**Cipangopaludina yunnanensis** Zhang, Liu et Wang, 1981 (Figure 1M)


Materials: 48 ex. IOZ–FG 0152 (holotype), IOZ–FG164354–164400 (Paratypes) from Maliping village, Pu’er City, Yunnan in May 1957 by Zhang WZ and Liu YY.

Diagnosis: shell greenish, small, up to 26 mm, with 5 whorls. Apex obtuse. Shell surface with conspicuous growth lines and irregular malleation. Central tooth with wide rounded major denticles and 3 or 4 smaller triangular denticles on each side. Lateral tooth with tongue-shaped major denticles and 3 or 5 minor denticles on each side. Inner marginal tooth with tongue-shape major denticles and 3 or 4 minor denticles and marginal teeth with 13 almost equal-sized denticles.

Distribution: only known from type locality.

Remarks: Without anatomized specimens, the anatomy characters remain unknown. However, it can be distinguished from other species of *Cipangopaludina* by a smaller shell, up to 30 mm and marginal teeth with 13 almost equal-sized denticles.

**Morphometric analysis by PCA**

The five shell characteristics are shown in Table 1. The first two factors PCA accounted for 85.4% of the total variance (Table 2). The first factor (55.9% of the variation of the selected variables) separated the ratios W/D, BW/D, BW/LA and BW/WA (factor loadings >0.80). The second factor (29.5% of the variation of the selected variables) separated the WA/D and WA/LA. A scatter map was made by averaging the first and second PCA factors per species (Figure 3). In PCA 1 axis (X-axis), W and BW are positively, D and LA negatively related to X-axis, respectively. In PCA 2 axis (Y-axis), WA is positive, D and LA negatively related to Y-axis, respectively. These variances are related to the shape of aperture and body whorl depth. The pot of *C. latissima* located in the right of region II, it indicated that this species has a taller body whorl and shell width, but has a shorter spiral whorl. To the contrary, *C. haasi* looks slimmer due to taller spiral whorl and smaller shell width.

**Figure 3 Scatterplots of scores on 1st and 2nd principle components of Chinese *Cipangopaludina***

<table>
<thead>
<tr>
<th>Table 2 Loadings of the first two principal components for 5 shell characteristics of Chinese <em>Cipangopaludina</em> species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PCA 1</strong></td>
</tr>
<tr>
<td>W/D</td>
</tr>
<tr>
<td>LA/D</td>
</tr>
<tr>
<td>WA/D</td>
</tr>
<tr>
<td>BW/D</td>
</tr>
<tr>
<td>WA/LA</td>
</tr>
<tr>
<td>BW/LA</td>
</tr>
<tr>
<td>BW/WA</td>
</tr>
<tr>
<td>Prp. Total</td>
</tr>
</tbody>
</table>

* loadings> 0.80.

Additionally, *C. haasi*, located in left bottom of region III, has an oval aperture. *Cipangopaludina hainanensis* and *C. cathayensis* located in the top of region I and II, they have a bigger WA and relatively smaller LA, indicating these two species have a round aperture.

**Key to species of Chinese *Cipangopaludina***

1 Shell with brown color band and ridge

- Shell without brown color band or ridge

2 Apex pointed

- Apex obtuse or eroded

3 The upper of body whorl form a flat shoulder

- .............................................................. *C. latissima*
– The upper of body whorl without a flat shoulder
4 Shell with 5 whorls, spiral whorl not inflated
– C. aubryana
– Shell with 6–7 whorls, spiral whorl inflated
5 Vas deferens opens in last 1/3 of testis
– C. chinensis
6 The first anterior branch of vas deferens with more
7 The first anterior branch of vas deferens with less than
8 Shell thin; umbilicus small, nearly closed
– C. leucostoma
– C. chinensis
– Shell thick; umbilicus big and deeply
– C. c. fluminalis
9 Vas deferens with 3 main branches
– C. cathayensis
– Vas deferens with 2 main branches
– C. lecythoides
10 Vas deferens with 2 main branches; kidney triple shape
– C. lecythis
– Vas deferens with 3 main branches; kidney arch shape
– C. ventricosa
11 Shell medium, with 4–5 whorls
– C. hainanensis
– Shell larger, with 6 whorls
12 Vas deferens with 2 main branches, opens in last 1/4 of testis
– C. lecythis
– Vas deferens with 3 main branches, opens in last 1/3 of testis
– C. leucostoma

DISCUSSION

Alongside numerous difficulties in determining the validity of numerous Cipangopaludina—lack of anatomy samples, discrepancies in the literature, or ambiguous morphological data—the genus itself is also problematic. Smith (2000) treated Cipangopaludina as subgenus of Bellamya, while Sengupta et al (2009) indicated that species of Bellamya from Asia could not belong to this genus. In China, there are currently seven recognized genera of Bellamyinae recorded, viz. Margarya Nevill, 1877, Cipangopaludina Hannibal, 1912, Bellamya Jousseau, 1886, Mekongia Crosse et Fischer, 1876, Filopaludina Habe, 1964, Angulyagrea Benson, 1836 and Trochotaia Brandt, 1974 (Liu et al, 1979, 1993; Du et al, 2011). Generally speaking, it is possible to distinguish these, as the shell of Cipangopaludina, Margarya, and Trochotaia tend to be larger, while other four genera species are more mid-sized. Similarly, species of Filopaludina and Mekongia have a color band, and Angulyagrea has ridges. For more detailed markers, Cipangopaludina can be distinguished from Trochotaia by shell round or oval vs. depressed pyramidal, last whorl with a sharp keel, and from Margarya by shell smooth vs. shell with ridges, nodules or spines; embryo with chaetae vs. ridges or nodules. Based on these criteria, we opted to treat Cipangopaludina as a valid genus.

Generally, the diagnostic characteristics of Cipangopaludina are shell median to large, sculpture lacking except growth lines and axial undulations. Aperture subcircular. Young specimens (from brood pouch) with up to 3–4 whorls; protoconch smooth, three primary rows of chaetae on last whorl and other whorls have two rows of chaetae. However, C. menglaensis and C. yunnanensis are small, up to 30 mm, smooth and solid, suggesting that C. menglaensis and C. yunnanensis belong to the genus Mekongia. It is also possible that C. dianchiensis could belong to the genus Margarya due to several characteristics: shell thick with ridges, female pouch with few big embryos and embryos shell with ridges (not chaetae). Similarly, Cipangopaludina ampullacea and C. lecythis, C. fluminalis and C. chinensis can be distinguished by shell characteristics, but they do not appear to possess any obviously distinctive anatomy, placing C. ampullacea and C. fluminalis as a subspecies of C. lecythis and C. chinensis, respectively. Our analysis also placed C. leucostoma (Heude) and C. diminuta (Heude) as synonymous with C. patris (Kobelt) according to apex obtuse and less than 6 whorls. However, according to the International Code of Zoological Nomenclature (ICZN, 1999), C. leucostoma should be valid due to its publication earlier than C. patris. Finally, Cipangopaludina wingatei and C. amphuliformis were found to be synonyms of C. chinensis and C. lecythis, respectively.

Totally, our analysis of 18 Cipangopaludina species resulted in a revised taxonomy that includes 11 species and 2 subspecies recorded in China, viz. C. aubryana, C. cathayensis, C. chinensis, C. haasi, C. hainanensis, C. latissima, C. lecythis, C. lecythoides, C. leucostoma, C. ussuriensis, C. ventricosa and C. chinensis fluminalis, C. lecythis ampullacea. Based on whether or not the spiral whorl depth was longer than aperture depth, Chinese
Cipangopaludina species could be divided to two groups, the *chinensis* group with spiral whorl depth longer than aperture depth that includes *C. chinensis*, *C. haasi*, *C. ussuriensis* and *C. c. fluminalis*, and the other the *cathayensis* group with spiral whorl depth being shorter than aperture depth, including *C. aubryana*, *C. cathayensis*, *C. hainanensis*, *C. latissima*, *C. lecythis*, *C. lecythoides*, *C. leucostoma*, *C. ventricosa* and *C. l. ampullacea*. Several anatomical characteristics can also help distinguish between the two groups. For example, the *chinensis* group can be distinguished from *cathayensis* group by vas deferens: *chinensis* group species with more than 5 (*C. haasi* with 8) parallel secondary branches in anterior branch, while *cathayensis* group species always with 4 secondary branches. The number of secondary branches of vas deferens are in connection with size of body whorl. The shell of *chinensis* group species was taller, with body whorl depth being the same or longer than body width, making the vas deferens longer and with more secondary branches, especially in *C. haasi*. However, the body whorl of *cathayensis* group species is inflated, with body whorl depth shorter than body width, resulting in vas deferens being short and fat, and the secondary branch with many tiny branches, looking rather similar to a lush tree.

Within each group, there are further defining characteristics of individual species. In *chinensis* group, *C. ussuriensis* can be easily distinguished from other species by body whorl with 4 ridges and colour band. *Cipangopaludina haasi* can be distinguished from other species by body whorl not inflated, vas deferens with 8 secondary branches in anterior branch and vas deferens opens in last 1/4 of testis. *Cipangopaludina chinensis fluminalis*, however, is quite similar with *C. chinensis*, except for the shell thick vs. thin; umbilicus big and deeply vs. small or closed. In *cathayensis* group, *C. latissima* could be distinguished from other species by its markedly enlarged aperture while *C. hainanensis* can be distinguished from other species by apex eroded, left 4 whorls. According to kidney shape, the other species could be divided to two subgroups. Triple shape, including *C. cathayensis*, *C. aubryana* and *C. lecythis*, and arch shape, including *C. l. ampullacea*, *C. leucostoma* and *C. ventricosa*. *Cipangopaludina lecythis* can be distinguished from *C. cathayensis* and *C. aubryana* by vas deferens with 2 branches and opens in last 1/4 of testis vs. 3 branches and 1/3, and *C. cathayensis* can be distinguished from *C. aubryana* by the anterior 2/3 part of osphradium ridge-like and posterior 1/3 part inflated. *Cipangopaludina leucostoma* can be distinguished from *C. l. ampullacea* and *C. ventricosa* by vas deferens opening in last 1/3 vs. 1/4, and *C. ventricosa* can be distinguished from *C. l. ampullacea* by vas deferens with 3 branches vs. 2 branches.

Similar to our study, most viviparids are primarily delineated by their shells, though a few observations on the anatomy have also been made. Vail (1977) for example mentioned that the reproductive system was a useful characteristics to delineate viviparid subfamilies and genera by anatomical studies of mature male and female *Campeloma geniculum* (Conrad, 1834), *Lioplax pilsbryi* Walker, 1905 and *Viviparus georgianus* (Lea, 1834). Simone (2004) and Rao (1925) also reported intergeneric differences in the central nervous system, stomach lining and form of the ctenidial filaments in the five Asian genera. Du et al (2011) later reported a difference in kidney shape and the number of embryos present in the uterus of four Chinese viviparids, *Angulygra*, *Cipangopaludina*, *Margarya* and *Trochotaia*. In this study, the size of osphradium, location of vas deferens opens and the number of secondary branches, kidney shape were useful anatomical characteristics to identify interspecies of *Cipangopaludina*. The allometric growth or environmental effects could result in intraspecific variations in shell morphology and operculum (Chiu et al, 2002), but these anatomical characteristics could be used to identify young specimen.

Given the difficulties in identifying species solely by shell characters, further description of such species anatomical characteristics of both young and mature individuals may prove useful in further refining the taxonomy and identifying species and determining their validity. Unfortunately, until further studies are undertaken that more accurately characterize the anatomy or even underlying genetic differences, there will remain a variety of unanswered or unanswerable questions. To date, the monophyly of *Cipangopaludina* is still unresolved. A recent study by Du et al (2013) on the phylogeny of *Margarya* based on combined COI and 16S rRNA sequences indicated that *Cipangopaludina* is not a monophyly, since species cluster with *Margarya*; however, the specimens of *Cipangopaludina* and *Margarya* are from Lake Dianchi. Likely further studies into the phylogeny and ecology of the *Cipangopaludina* in different environments and distributions will further enhance our understanding of these organisms.
Acknowledgments: We thank Jiang YE, Cui GH, Zheng LP, Jiang WS, Yuan C, Li Y and Yu GH of Kunming Institute of Zoology, CAS and Aldridge D of Cambridge University for collecting these specimens. We greatly thank Meng K and Jia LJ of Institute of Zoology, CAS for generous helping when first author check specimens at IOZ. We specially thank Liu YY for showing how to identify these species. We thank the anonymous reviewers for their helpful comments on the manuscript.

References


Benson WH. 1842. Mollusca, in Theodor Cantor’s general features of fresh-water shells, chiefly contained in the museum of the Asiatic Society; 33.


Philippi RA. 1846. Paludina Tab. II. Abbildungen und Beschreibungen neuer oder wenig gekannter Conchylien herausgegeben, 133.


