

Sinoennea loeiensis, a new species of diapherid microsnail (Pulmonata: Streptaxoidea: Diapheridae) from Phu Pha Lom Limestone Hill, Loei Province, Northeastern Thailand

Kitti Tanmuangpak¹, Pongrat Dumrongrojwattana², Chanidaporn Tumpeesuwan¹ & Sakbaworn Tumpeesuwan^{1,3*}

Abstract. A new species of carnivorous microsnail is described from Phu Pha Lom Limestone Hill in Loei Province, Northeastern Thailand. *Sinoennea loeiensis*, new species, has a minute, ovoid-cylindrical shell. The external shell surface is rather smooth, glassy, transparent, and shiny. Six apertural teeth are present, including one parietal, two palatal, one basal, and two columellar teeth. Reproductive anatomy of the new species differs from *Sinoennea kanchingensis* by its shorter gametolytic sac, vas deferens entering the penis subapically, and vagina shorter than oviduct. The radula comprises 42 rows of teeth, which are arranged in V-shape rows, and contains 19–21 teeth each. This is the first record of a diapherid microsnail in northeastern Thailand.

Key words. Diapheridae, *Sinoennea*, microsnail, reproductive anatomy, limestone hill

INTRODUCTION

Carnivorous microsnails of the genus *Sinoennea* Kobelt, 1904, were formerly classified in the family Streptaxidae. Recently, both *Sinoennea* Kobelt, 1904 and *Diaphera* Albers, 1850 were placed in the Diapheridae Panha & Naggs in Sutcharit et al., 2010, based on their reproductive anatomy and molecular analysis (Sutcharit et al., 2010). *Sinoennea* has an elongate-ovate to clavate shell and is widely distributed within South, Southeast and East Asia (van Benthem Jutting, 1961; Panha & Burch, 2005; Zhou et al., 2006, 2009; Schileyko, 2011; Ouyang et al., 2012; Steiner, 2013; Dumrongrojwattana & Wongkumhaeng, 2013). The species described from the Peninsular Malaysia, Thailand, Laos, Vietnam, and southern China are herein listed (see Table 1). However, the reproductive anatomy and radula morphology of most species remain unknown. In Thailand, three *Sinoennea* species, from Doi Chiang Dao in Chiang Mai (*S. prima* Panha & Burch, 1999), Prakayang Cave in Ranong (*S. ranongensis* Panha, 2005), and Charakae Cave in Satun (*S. stunensis* Dumrongrojwattana & Wongkumhaeng, 2013), have been described (Fig. 1). A fourth *Sinoennea* was recently discovered from a limestone hill in Loei Province,

Northeastern Thailand, and is herein proposed as a new species. Its shell morphology, radula morphology, and reproductive anatomy are described in detail in this paper.

MATERIAL AND METHODS

Six specimens were collected in November and December 2012, September 2013, and March 2014 from Phu Pha Lom Limestone Hill (17°33'626"N, 101°52'311"E), at an elevation of about 384 meters above mean sea level (Fig. 1) in Mueang District, Loei Province, Northeastern Thailand. Four empty shells and two living snails were collected from the surface of leaf litter. Complete adult shells were counted for whorl number, and measured for shell height (SH), shell width (SW), aperture height (AH), and aperture width (AW) with digital vernier calipers (Electronic Digital Calliper S.H). Photomicrographs were taken by means of a Scanning Electron Microscope JEOL (JSM-6460 LV) at the Central Laboratory, Faculty of Science, Mahasarakham University.

Type material was deposited in the following institutions: Natural History Museum, Mahasarakham University, Maha Sarakham, Thailand (NHMSU); Natural History Museum of Loei Rajabhat University, Loei, Thailand (NHLRU); Zoological Research Collection of Burapha University, Chonburi, Thailand (ZRCBUU), and Zoological Reference Collection, Lee Kong Chian Natural History Museum, National University of Singapore (ZRC). Description of the new species herein is attributed to the first and fourth authors, Tanmuangpak & S. Tumpeesuwan, respectively.

Abbreviations. ag, albumin gland; at, atrium; eg, egg; fo, free oviduct; hd, hermaphroditic duct; p, penis; pr, penial retractor muscle; pro, prostate; gs, gametolytic sac; u, uterus; v, vagina; vd, vas deferens.

¹Department of Biology, Faculty of Science, Mahasarakham University, Kantharawichai District, Maha Sarakham 44150 Thailand

²Department of Biology, Faculty of Science, Burapha University, Mueang District, Chon Buri 20131 Thailand

³Palaeontological Research and Education Centre, Mahasarakham University, Kantharawichai District, Maha Sarakham 44150 Thailand; Email: stumpeesuwan@yahoo.com (*corresponding author)

Table 1. Known species of *Sinoennea* and their reported distribution (References: 1 = van Benthem Jutting (1961); 2 = Panha & Burch (2005); 3 = Dumrongrojwattana & Wongkamhaeng (2013); 4 = Maassen (2008); 5 = Schileyko (2011); 6 = Yen (1939); 7 = Zhou, et al. (2006); 8 = Zhou et al., (2009); and 9 = Ouyang et al., (2012).

S/N	Species name	Localities	Reference
1	<i>S. apicata</i> van Benthem Jutting, 1961	Gua Bama, Pahang, Malaysia Gua Sai, Pahang, Malaysia	1
2	<i>S. bacca</i> van Benthem Jutting, 1961	Gua CheYatin, Pahang, Malaysia	1
3	<i>S. glebula</i> van Benthem Jutting, 1961	Gua CheYatin, Pahang, Malaysia	1
4	<i>S. malaccana</i> (Möllendorff, 1902)	Kelantan, Malaysia	1
5	<i>S. callizonus</i> van Benthem Jutting, 1961	Gunong Sinyum, Pahang, Malaysia	1
6	<i>S. leucostolos</i> van Benthem Jutting, 1961	Ulu Kenyam Kechil, Pahang, Malaysia	1
7	<i>S. chintamanensis</i> Tomlin, 1941	Bukit Chintamani, Pahang, Malaysia	1
8	<i>S. crumenillavan</i> Benthem Jutting, 1961	Gua Nenek, Kelantan, Malaysia	1
9	<i>S. chrysalis</i> van Benthem Jutting, 1961	Gunong Kantang, Perak, Malaysia	1
10	<i>S. pagodellavan</i> Benthem Jutting, 1961	Gua Bama, Pahang, Malaysia	1
11	<i>S. charasensis</i> Tomlin, 1941	Bukit Charas, Pahang, Malaysia	1
12	<i>S. perakensis</i> (Godwin Austen & Nevill, 1879)	Bukit Pondok, Perak, Malaysia Cave near Biiserat, Jorlor (Pattani), Thailand Gunong Pondok, Perak, Malaysia	1
13	<i>S. hungerfordiana</i> (Möllendorff, 1886)	Bukit Pondok, Perak, Malaysia Gunong Pondok, Perak, Malaysia Bukit Baling, Kedah, Malaysia	1
14	<i>S. tweediei</i> Tomlin, 1941	Lenggong, Perak, Malaysia Gua Badak, Perak, Malaysia Gunong Tasek, Perak, Malaysia	1
15	<i>S. kanchingensis</i> Tomlin, 1948	Bukit Takun (= Bukit Kanching), Selangor, Malaysia	1
16	<i>S. lembingensis</i> Tomlin, 1941	Bukit Charas, Pahang, Malaysia Bukit Panching, Pahang (near Sungei Lembing), Malaysia	1
17	<i>S. ridleyi</i> (Peile, 1926)	Batu Cave, near Kuala Lumpur, Malaysia	1
18	<i>S. dactylus</i> van Benthem Jutting, 1961	Bukit Serdam, Pahang, Malaysia	1
19	<i>S. baculum</i> van Benthem Jutting, 1961	Bukit Serdam, Pahang, Malaysia Kota Gelanggi, Pahang, Malaysia Kota Tongkat, Pahang, Malaysia	1
20	<i>S. tiarella</i> van Benthem Jutting, 1961	Gunong Batu Kurau, Perak, Malaysia	1
21	<i>S. butleri</i> (Peile, 1929)	Batu Caves, Selangor, Malaysia Bukit Takun, Selangor, Malaysia	1
22	<i>S. lenggongensis</i> Tomlin, 1939	Lenggong, Perak, Malaysia North of Gua Badak, Lenggong, Perak, Malaysia Kramat Pulau, Perak, Malaysia	1
23	<i>S. subcylindrica</i> (Möllendorff, 1891)	Bukit Pondok, Perak, Malaysia Gunong Pondok, Perak, Malaysia Sungei Siput, Perak, Malaysia Gunong Kantang, Perak, Malaysia	1
24	<i>S. attenuate</i> van Benthem Jutting, 1961	Gua Musang, Kelantan, Malaysia Gua Madu, Kelantan, Malaysia	1
25	<i>S. lepida</i> van Benthem Jutting, 1961	Goa Siput, Pahang, Malaysia	1
26	<i>S. prima</i> Panha & Burch, 1999	Doi Chiang Dao, Chiang Mai, Thailand	2
27	<i>S. ranongensis</i> Panha, 2005	Prakayang Cave, Ranong, Thailand	2
28	<i>S. stunensis</i> Dumrongrojwattana & Wongkamhaeng, 2013	Charakae Cave, La-ngu, Satun, Thailand	3
29	<i>S. loeiensis</i> new species	Phu Pha Lom, Loei, Thailand	This study
30	<i>S. lizae</i> Maassen, 2008	Oung Pra Ngiene, Luang Namtha, Laos	4
31	<i>S. atomaria</i> (Dautzenberg, 1893)	Hai Phong, Vietnam	5
32	<i>S. calva</i> (Dautzenberg, 1893)	Hai Phong, Vietnam	5
33	<i>S. hippocrepis</i> (Bavay & Dautzenberg, 1912)	Phong-Tho District, Vietnam	5
34	<i>S. macrodonta</i> (Bavay & Dautzenberg, 1912)	Muong-Khong, Vietnam	5
35	<i>S. ovulum</i> (Bavay & Dautzenberg, 1912)	Than Khe, Lang Son, Vietnam	5
36	<i>S. plagiostoma</i> (Möllendorff, 1901)	Insula Bah-Mun, Halong Bay, Vietnam	5
37	<i>S. strophiodes</i> (Gredler, 1881)	Hunan, China	6
38	<i>S. micropleuris</i> (Möllendorff, 1887)	Heng-shan-hsien, Hunan, China	6

Table 1...continued

S/N	Species name	Localities	Reference
39	<i>S. larvula</i> (Heude, 1882)	Ning-kuo-fu, Hunan, China	6
40	<i>S. kwangsiensis</i> Yen, 1939	Guangxi, China	6
41	<i>S. fuchsi</i> (Gredler, 1885)	Kwei-dshou, Hubei, China	6
42	<i>S. microstoma</i> (Möllendorff, 1881)	Lo-fou-shan, Guangdong, China	6
43	<i>S. splendens splendens</i> (Möllendorff, 1882)	Lo-fou-shan, Guangdong, China	6
44	<i>S. splendens hongkongensis</i> (Möllendorff, 1885)	Hongkong	6
45	<i>S. fuzhouensis</i> Zhou, Chen & Guo, 2006	Fuzhou, Fujian, China	7
46	<i>S. pupoidea</i> Zhou, Zhang & Chen, 2009	Longkoutong, Fujian, China	8
47	<i>S. longtanensis</i> Ouyang, Liu & Wu, 2012	Longtan scenic spot, Jinggangshan City, Jianxi, China	9

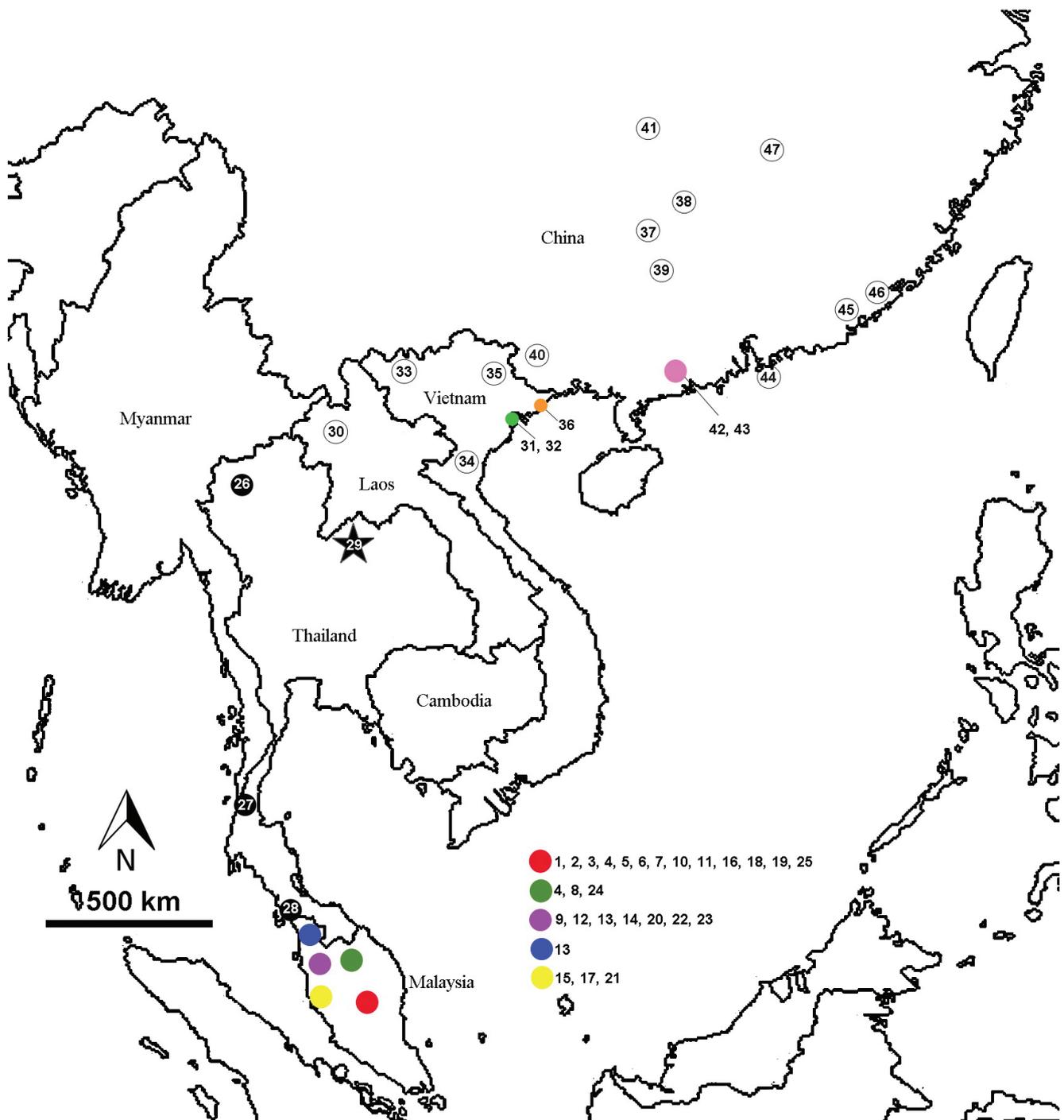


Fig. 1. Map of mainland Southeast Asia and South China showing the type locality of *Sinoennea loeiensis*, new species, from Phu Pha Lom, Mueang District, Loei Province (star); and type localities of some other species (number indicates species from Table 1).

Table 2. Shell dimensions of *Sinoennea loeiensis*, new species, shell height (SH), shell width (SW), aperture height (AH), and aperture width (AW).

Types	SH (mm)	SW (mm)	AH (mm)	AW (mm)
Holotype	4.10	2.00	1.34	1.00
Paratype				
1	4.17	2.18	1.57	0.96
2	4.92	2.27	1.85	1.12
3	4.62	2.17	1.93	0.86
Average	4.45	2.16	1.67	0.99
S.D.	0.39	0.11	0.27	0.11



Fig. 2. *Sinoennea loeiensis*, new species, from Phu Pha Lom Limestone Hill, Mueang District, Loei Province. Shell height about 3 mm. (Paratype NHLRU-0002)

SYSTEMATICS

Superfamily Streptaxoidea Gray, 1860

Family Diapheridae Panha & Naggs, in Sutcharit, Naggs, Wade, Fontanilla & Panha, 2010

Genus *Sinoennea* Kobelt, 1904

Type species. *Ennea strophioides* Gredler, 1881

Sinoennea loeiensis Tanmuangpak & S. Tumpeesuwan, new species

Figs. 2–5; Table 2

Type material. Holotype: NHMSU-0004 (Fig. 3). Measurements: shell height (SH) 4.10 mm, shell width (SW) 2.00 mm; type locality: Phu Pha Lom Limestone Hill in Mueang District, Loei Province, Northeastern Thailand, coll. K. Tanmuangpak, November 2012. Paratype: NHMSU-0005 (genital system and radula) (Figs. 4, 5); NHLRU-0002 (1 specimen in 70% alcohol and 1 shell); ZRCBUU 03396 (1 shell); ZRC.MOL.5794 (1 shell), coll. K. Tanmuangpak, November 2012–May 2014.

Etymology. The specific epithet “*loeiensis*” refers to Loei Province, Northeastern Thailand, where this species was discovered.

Diagnosis. Shell surface rather smooth, regular vertical ribs retained in the deep suture. The parietal side of the peristome is attached to the umbilical keel. The umbilicus is very wide with many transverse ribs. In the aperture, one basal tooth is present. Two columellar teeth present near the peristome, of which a plate-like columellar tooth is deeper within the aperture (Fig. 3F).

Description. Shell: minute, dextral, ovoid-cylindrical, shell height 4.10–4.92 mm (holotype 4.10 mm), shell width 2.00–2.27 mm (holotype 2.00 mm), aperture height 1.34–1.93 mm (holotype 1.34 mm), aperture width 0.86–1.12 mm (holotype 1.00 mm) (Table 2), glassy transparent and shiny (Figs. 2, 3A, B). Apex depressed and smooth (Fig. 3C). Middle part of each whorl convex and largely smooth, upper part of each whorl possesses regular vertical ribs (Fig. 3D), about 24–26 on the last whorl; suture deep. On the third to last whorl the ribs are rather distantly placed, the ribs bulge on the suture part and regularly attenuate towards the middle part of the each whorl. Umbilical ribs vertical, prominent, which continuously connect from the middle part of the last whorl. These ribs extend to the umbilicus (Fig. 3E). Whorls 6½, regularly increasing in size towards the last whorl of the shell. Last whorl is a little pinched around the rather wide umbilicus (Fig. 3E). Aperture almost vertical, irregularly quadrangular with rounded angles, peristome smooth, inner side of aperture possesses only small nodules (Fig. 3G). One large parietal tooth lies at the middle of parietal site, which its distal part points downward to the columellar tooth (C) direction (Fig. 3A, F). The palatal side comprises two unequal teeth (1st PL and 2nd PL), which lie deep inside the aperture (Fig. 3F). There is only one basal tooth (B) deep in aperture. On the columellar side there are two teeth, a low rounded knob (C) at the margin and a plate-like tooth (pC) that lies well inside aperture.

Body: Live specimens with a yellow foot and pale yellow tentacles (Fig. 2).

Genital system: Atrium (at) rather short. Penis (p) very long, central section cylindrical shape, distal section curved and bottom part narrow. Vas deferens (vd) very long and slender, entering penis subapically. Penial retractor muscle (pr) attached to flagellum apically. Vagina (v) short and rather stout. Free oviduct (fo) cylindrical shape and longer

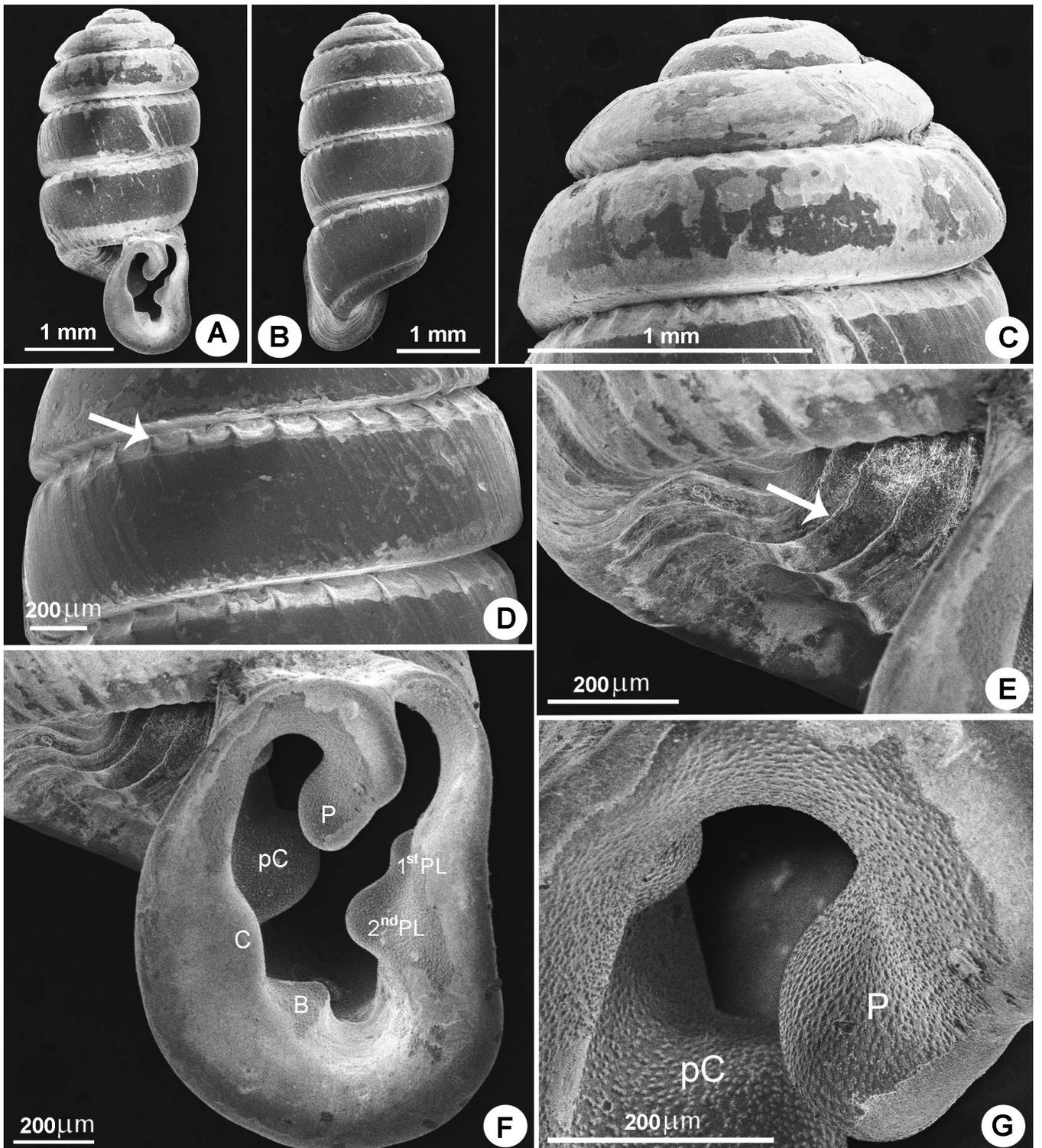


Fig. 3. Shell morphology of *Sinoennea loeiensis*, new species. Holotype (NHMSU-0004): A, apertural view; B, rear view; C, early whorls; D, regular vertical ribs in suture (arrow); E, ribs within umbilicus (arrow); F, apertural view of last whorl; and G, close up of inner side of aperture.

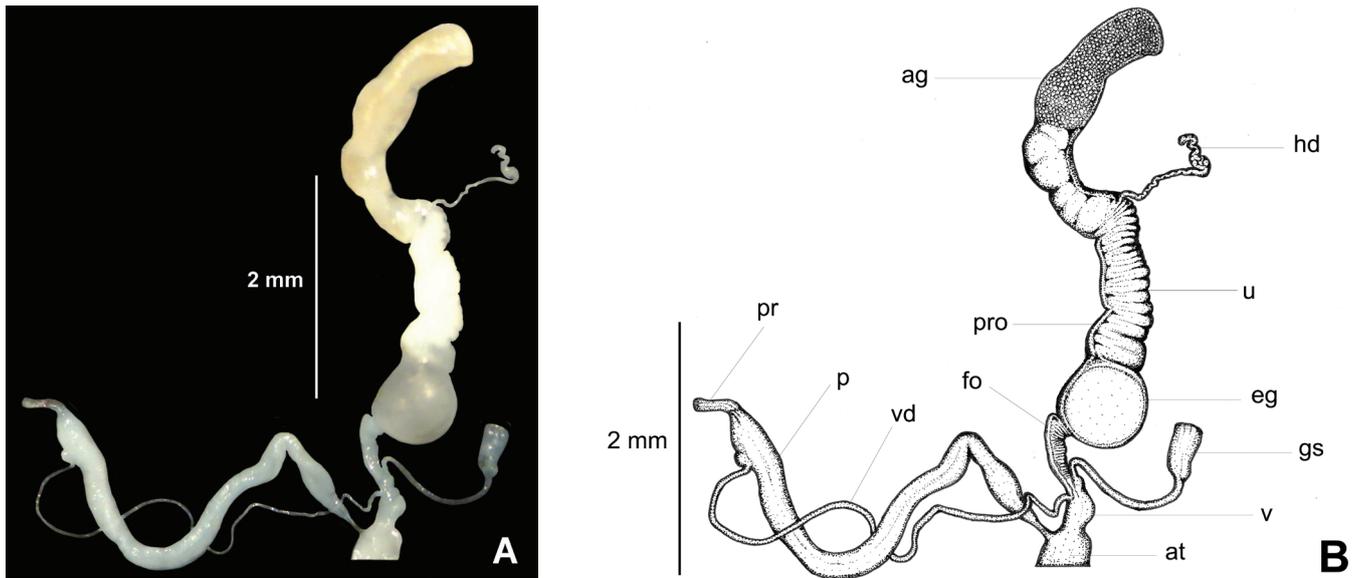


Fig. 4. *Sinoennea loeiensis*, new species, collected in March 2014. Genital system: Paratype (NHMSU-0005). A, genital system; and B, schematic drawing of genital system.

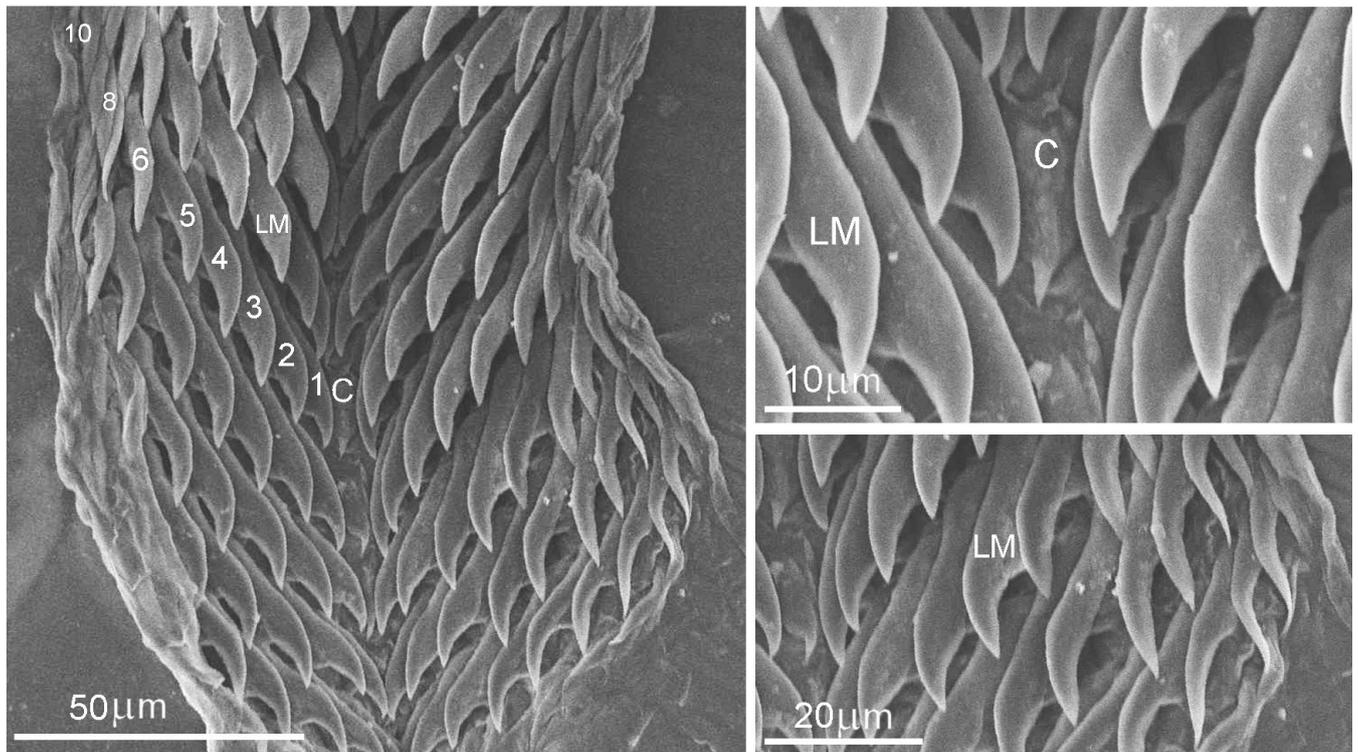


Fig. 5. Radula morphology of *Sinoennea loeiensis*, new species (Paratype NHMSU-0005). C = central tooth and LM = latero-marginal teeth.

than vagina. Gametolytic sac (gs) with narrow, long stalk, reservoir ovate. Prostate gland (pro) long. Hermaphroditic duct (hd) loosely convoluted. Albumin gland (ag) yellowish and rather long (Fig. 4).

Radula: Radula teeth arranged in V-shape rows; 42 rows of teeth ($n = 1$), each row contains 19–21 teeth, for which the dentition formula is (9-10) + C + (9-10). Central tooth unicuspid, elongate mesocone narrowly pointed, ectocones absent. Latero-marginal teeth (LM) unicuspid, gradual change

from elongate and long narrow pointed mesocone to more elongate and slender mesocone (Fig. 5).

Remarks. Reproductive anatomy of *S. loeiensis* was compared with that of *S. kanchingensis*, which is presently the only congener with its reproductive anatomy studied and known (see Berry, 1963). The gametolytic sac is shorter than *S. kanchingensis*; vas deferens entering penis subapically. Vagina shorter than free oviduct. Uterus (u) of each of the two live collected specimens contained one large egg (eg) (Fig. 4).

DISCUSSION

According to van Benthem Jutting (1961), Malayan *Sinoennea* can be divided into two groups with shells that are oviform (15 species) and cylindrical (nine species). The three known *Sinoennea* species (*S. prima*, *S. ranongensis*, *S. stunensis*, and *S. loeiensis*) described from Thailand and *S. loeiensis*, new species, belong to the group with cylindrical shells.

The new species differs from its Thai congeners by its shell sculpture, which is almost smooth and the presence of regular and delicate vertical ribs in the suture. Compared to closely related species of *Sinoennea* from Thailand (*S. prima*, *S. ranongensis*, and *S. stunensis*), China (*S. pupoidea* and *S. longtanensis*), and Laos (*S. lizae*), *S. loeiensis* possesses about $6\frac{1}{3}$ whorls, which is less than *S. prima*, *S. lizae*, and *S. stunensis*, but more than *S. ranongensis*, and equal with *S. pupoidea* and *S. longtanensis* from China. *Sinoennea loeiensis* displays more delicate ribs than other species from Thailand, Laos, and *S. pupoidea*, but the sculpture is similar to *S. longtanensis*. The peristome and aperture of *S. loeiensis* differ from all the other known species, the most similar being *S. lizae* from Laos.

Apertural teeth are an important character for identification of *Sinoennea* species. The number of apertural teeth in the new species differs from all other *Sinoennea* species described from Thailand and Laos. *Sinoennea loeiensis* has more apertural teeth than all Thai and Laos *Sinoennea* species; *S. loeiensis* possess two columellar teeth (a small round knob at the margin and a plate-like tooth that lies deep inside the aperture) and one basal tooth whereas the other species from Thailand and Laos possess only one columellar tooth and the basal tooth is absent.

The reproductive anatomy and radula morphology of *S. loeiensis* was studied and compared to anatomy and radula morphology of *S. kanchingensis* from the Peninsular Malaysia as described by Berry (1963). *Sinoennea loeiensis* possesses a shorter gametolytic sac and the vas deferens enters the penis subapically, whereas it enters the middle of the penis in *S. kanchingensis*. The radula of *S. loeiensis* has 9–10 latero-marginal teeth in each size, but *S. kanchingensis* possesses up to 20. In this study, living specimens collected in September 2013 and March 2014 were found to have one large egg in the uterus. The observations suggest that the breeding season of *S. loeiensis* occurs before September and March.

All Thai *Sinoennea* species have only been recorded in limestone areas. *Sinoennea prima* and *S. ranongensis* were collected from soil samples, whereas *S. stunensis* was collected from litter samples. All living snails and shells of *S. loeiensis*, new species were discovered under leaf litter on the soil layer deposit in a limestone crevice, suggesting a leaf litter dwelling habit.

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