

The land snail genus *Pterocyclos* Benson, 1832 (Caenogastropoda: Cyclophoridae) from Thailand and Peninsular Malaysia, with descriptions of two new species

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Abstract. Specimens of the operculated land snail genus *Pterocyclos* Benson, 1832, from Thailand and Peninsular Malaysia were investigated based on their shell characteristics. Type specimens and topotypic material were studied and compared with newly collected specimens. Two new species are described, viz. *Pterocyclos diluvium* Sutcharit & Panha, new species, from Tam Suman, Pathalung, Thailand, adjacent areas in Thailand, and Malaysia, and *Pterocyclos frednaggsi* Sutcharit & Panha, new species, collected from Bukit Chintamani, Pahang, Malaysia, and adjacent areas in Peninsular Malaysia. Two species that hitherto were included in *Pterocyclos*, viz. *P. blandi* Benson, 1851 and *P. subulatus* Sykes, 1903, were retained in this genus, while two other former *Pterocyclos* species were re-assigned to other genera, viz. *Pearsonia regelspergeri* (Morgan, 1885) and *Ptychopoma perrieri* (Morlet, 1889). Conversely, two previously described species in other genera (*Rhiostoma spaleotes* Tomlin, 1932, and *Cyclotus umbraticus* Benthem Jutting, 1949) are here transferred to *Pterocyclos*, viz. *P. spaleotes* (Tomlin, 1932) and *P. umbraticus* (Benthem Jutting, 1949). To stabilise the nomenclatural status, the lectotype of *Pterocyclos rupestris* Benson, 1832, and *Pterocyclos spaleotes* are designated herein.

Key words. Taxonomy, systematics, limestone, biodiversity, Gastropoda

INTRODUCTION

The operculate land snails of the superfamily Cyclophoroidea are one of the more diverse terrestrial gastropods and show a wide variety of lifestyles, ranging from ground dwelling species that live hidden in the soil to tree climbing, arboreal species that live in the canopy. It is a species-rich taxon with turbinate to discoidal shells in which the last whorl is sometimes disconnected (Kobelt, 1902; Wenz, 1938; Stanisic, 1998). In the Cyclophoroidea, the family Cyclophoridae Gray, 1847, is the largest taxon group containing about 35 nominal genera (Wenz, 1938; Vaught, 1989). Their classifications were established by Kobelt (1902, 1911) utilising shell characteristics and have remained largely unchanged since then. However, recent modern works on the diversity of land snails in Southeast Asia using various systematic characters, such as karyotypic and DNA sequence analyses, have suggested that many cyclophoroidid species and taxa at the generic level need to be largely revised (Vermeulen, 1999; Prasankok et al., 2009, 2011; Kongim et al., 2010, 2013; Marzuki & Clements, 2013; Nantarat et al., 2014). This applied, for example, to the genus *Pterocyclos* Benson, 1832, where additional new materials are now available from various localities in Thailand and Peninsular Malaysia for a taxonomic study.

Pterocyclos has a wide distribution from South and Southeast Asia to southern China (Kobelt, 1902, 1911; Gude, 1921; Wenz, 1938; Yen, 1939; Benthem Jutting, 1948). The current delimitation of species is still reliant on the classical works of Kobelt (1902, 1911), which are mainly based on the degree of the apertural lip expansion, the shape of the accessory breathing structures, and other shell characters, including the calcareous cup-shaped operculum. However, these characters do not provide a consistent and unambiguous basis for the separation of the currently recognised genera in the tribe Pterocyclini.

Currently, the genus *Pterocyclos* is comprised of about 45 nominal species of which about 20 have been described from South Asia and Burma, and about 10 from the Greater Sunda Islands. Some are known from Indochina and southern China. Only four nominal species are reported from Thailand and Peninsular Malaysia (Kobelt, 1902, 1911; Gude, 1921; Benthem Jutting, 1949; Hemmen & Hemmen, 2001; Maassen, 2001). This somewhat odd situation calls for a taxonomic study of the species in these regions. However, in order to do so it is necessary to investigate the type material of all relevant *Pterocyclos* species in the first step and to verify their distinct generic placement. Against this background, the present study aims to conduct a taxonomic study of the *Pterocyclos* species found in Thailand and Peninsular Malaysia, including a comparison of type material and topotypic specimens. In addition, two overlooked species from other genera are herein redescribed and assigned to the genus *Pterocyclos*. Unique name-bearing types are also designated to stabilise the names.

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MATERIAL AND METHODS

Several areas were surveyed in eastern to southern Thailand and in Peninsular Malaysia (Fig. 1). Specimens were collected and processed for classification and identification. The terminology used in the description of their shell characters, including the accessory respiratory structures and the apertural lip expansion, follow Bentheim Jutting (1949), Cox (1964), and Rees (1964). The type specimens and topotypic materials of all known nominal species that have been included in the genus *Pterocyclos* were examined and compared. The “shell” and “specimen in ethanol” mentioned in the examined material refer to the empty shells and preserved specimens respectively. Descriptions of the new species herein are attributed to the first and the third author, Sutcharit and Panha, respectively.

Museum collections are abbreviated as follows: CUMZ, Chulalongkorn University, Museum of Zoology, Bangkok; NHMUK, The Natural History Museum, London; NMW, National Museum of Wales, Cardiff; SMF, Forschungsinstitut und Naturmuseum Senckenberg, Frankfurt am Main.; UMZC, University Museum of Zoology Cambridge, Cambridge; ZMA, Zoological Museum, Amsterdam, The Netherlands.

RESULTS

This study recognised six nominal *Pterocyclos* species in Thailand and Peninsular Malaysia, two of which are new to science. Four nominal species, *Pterocyclos blandi* Benson, 1851, *P. regelspergeri* Morgan, 1885, *P. perrieri* Morlet, 1889 and *P. subalatus* Sykes, 1903 have previously been reported from Thailand and Peninsular Malaysia (Morgan, 1885; Morlet, 1889; Kobelt, 1902, 1911; Hemmen & Hemmen, 2001; Maassen, 2001). However, after examining the type material and topotypic specimens, only *P. blandi* and *P. subalatus* were retained in the genus *Pterocyclos*. In contrast, because “*Pterocyclos*” *regelspergeri* showed a deep sutural groove, a calcareous plate-shaped operculum, and a non-expanded apertural lip, this species was transferred to the genus *Pearsonia* Kobelt, 1902. Similarly, topotypic shells of “*Pterocyclos*” *perrieri* from Srakeo, Thailand, had a corneous multi-spiral operculum, and an upper peripheral-lip expansion near the suture, two characters typical of the genus *Ptychopoma* Möllendorff, 1885, and to which this species was hence assigned. In addition, two nominal species previously classified as *Rhiostoma spaleotes* Tomlin, 1932, and *Cyclotus umbraticus* Bentheim Jutting, 1949, were transferred to the genus *Pterocyclos*.

SYSTEMATIC ACCOUNT

Family Cyclophoridae Gray, 1847

Subfamily Cyclophorinae Gray, 1847

Tribe Pterocylini Kobelt & Möllendorff, 1897

Genus *Pterocyclos* Benson, 1832

Pterocyclos Benson, 1832: 11. Benson, 1836: 356. Troschel, 1848: 44. Benson, 1848: 345. Pfeiffer, 1849: 193. Adams & Adams, 1855: 277. Pfeiffer, 1858: 28. Pfeiffer, 1865: 41. Martens, 1867: 114. Wenz, 1938: 461. Bouchet & Rocroi, 2005: 146. *Steganostoma* Troschel, 1837: 163. Adams & Adams, 1855: 277. Wenz, 1938: 461.

Pterocylus Agassiz, 1848: 908 [unjustified emendation; ICZN, 1999: Art. 19.1 and 33.2.3]. Nevill, 1878: 260. Fischer, 1885: 745. Kobelt & Möllendorff, 1897: 113. Kobelt, 1902: 160, 161. Kobelt, 1911: 719. Gude, 1921: 97. Vaught, 1989: 15.

Type species. *Pterocyclos rupesiris* Benson, 1832 by monotypy. The specimen that matches best with the original description and figures (Benson, 1832: 13, pl. 2, fig. 1A–C) is here designated as the lectotype UMZC 2359.1 (Fig. 3A, no operculum) to stabilise the name. The other specimens become the paratypes UMZC 2359.2 (4 shells, Fig. 3B). The type locality is from “outlying rocks of the Rajmahal range of Hill, India”. Subsequently, based on differences in the shell colour, Benson (1832: 13) also recognised three varieties (var. 1–3) in the same lot of specimens. However, only the syntype UMZC 2359.3 of “var. 3” (1 shell, Fig. 3C) could be distinguished from the others.

Diagnosis. Apertural lip narrow to wide, wing-shaped and overhanging the accessory respiratory structure. This last

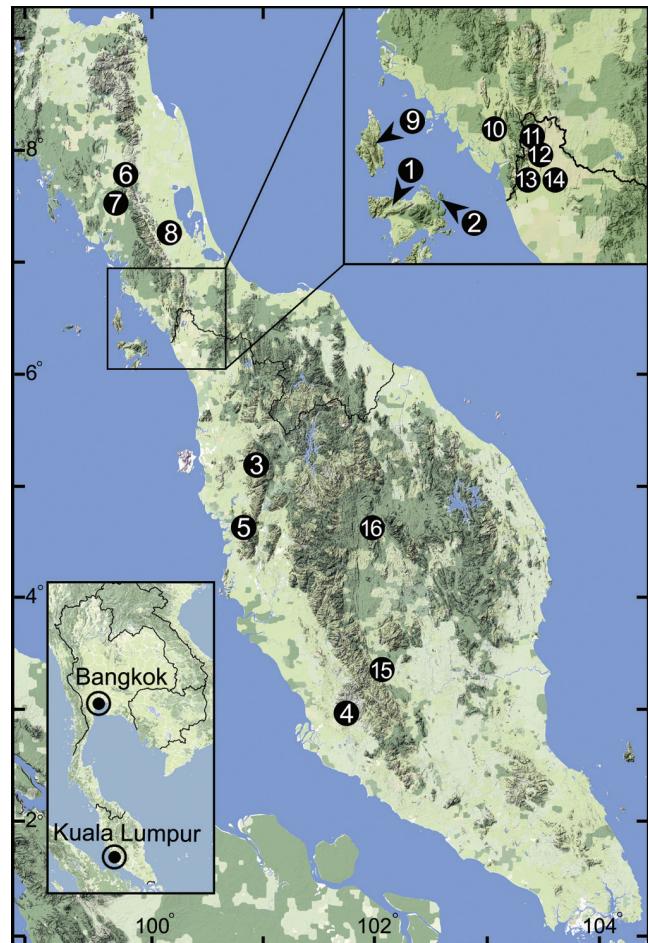


Fig. 1. Distribution map of *Pterocyclos* species examined in this study. The numbered locality names are detailed in Table 1. The approximate type locality of *Pterocyclos subalatus*, and *Pterocyclos umbraticus*, are indicated by locality numbers 3 and 5, respectively.

structure varies from notch-like to completely tubular in shape. The last whorl is usually completely attached to the penultimate whorl (only in a few species is the last whorl partly separated from the penultimate whorl). Operculum calcareous with a shallow to deep concave profile, inside covered with a corneous layer, and outside with many calcareous counterclockwise multilamellae. These characters made *Pterocyclos* s.s. different from the other known pterocyclini genera.

External features. Animal shows blackish patches and/or mottles scattered on a whitish body, faded near mantle cavity (Fig. 2A–C). Head with pair of long cephalic tentacles (ct), each containing dark eyespot at outer base (Fig. 2A). Anterior body short with genital groove on right side running downwards from anterior end of pallial cavity. Posterior body long, foot broad, with operculum attached dorsally

of posterior body. Animal dioecious, male has both long conical external penis (p) on right side below tentacles, and sperm groove (sg) passed along to tip of external penis (Fig. 2A); female shows only vaginal groove (vg) on right side (Fig. 2B). Lung cavity (lc) has large vein (v) and reticulated vessels. Ctenidium and osphradium absent. Mantle collar (mc) smooth and slightly thickened. Columellar muscle (cm) broad and thickened (Fig. 2B).

Genitalia. Testis (te) with branched tubules, bright orange, located around 2–3 whorls from apex. Vas deferens (vd) thin, straight tube, connected between testis and prostate gland (pg). Narrow sperm groove connected from genital opening on the right side of snail to tip of external penis. Long cylindrical shaped external penis situated posteriorly below tentacles (Fig. 2A).

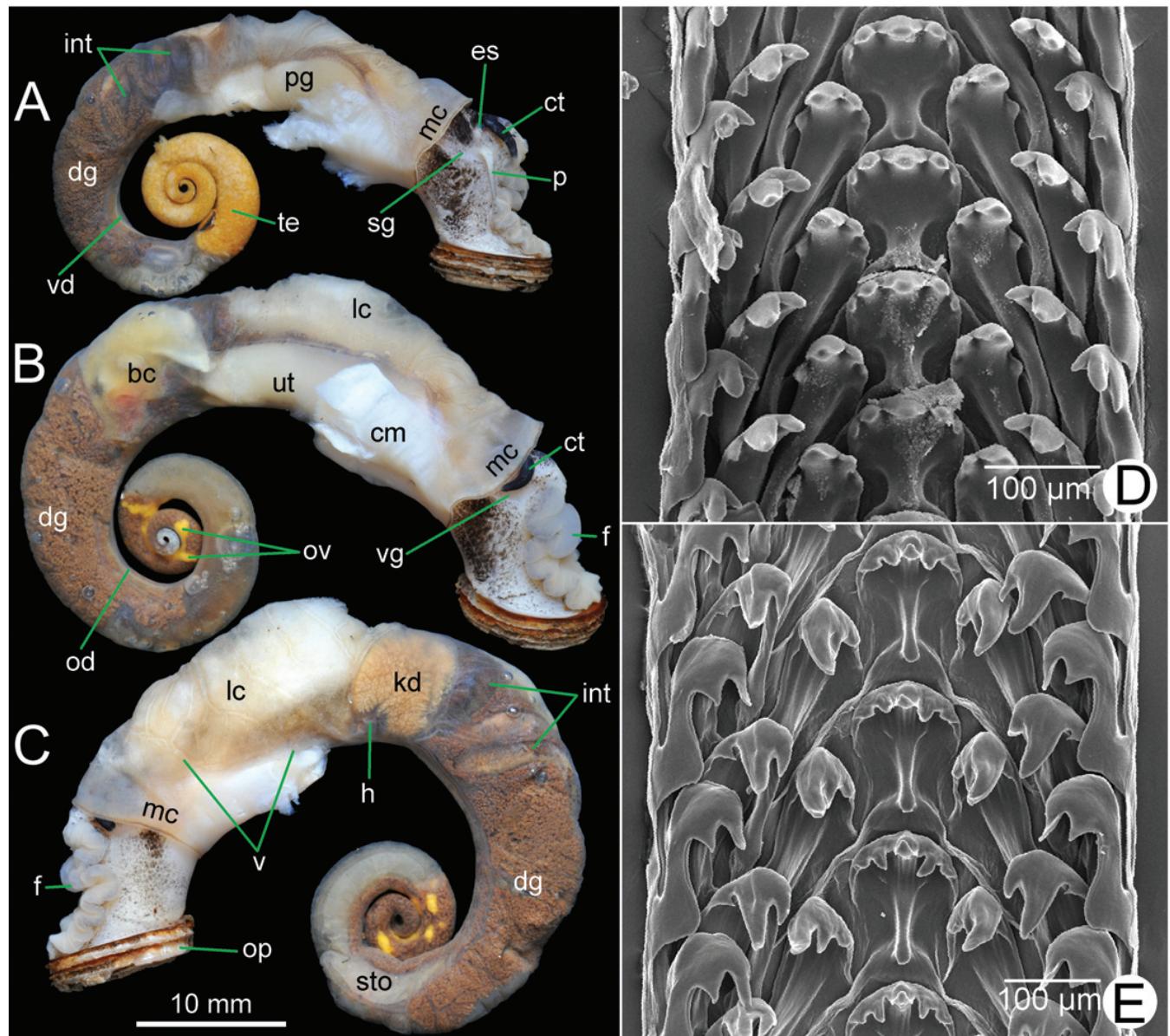


Fig. 2. A–C, General anatomy of *Pterocyclos frednaggsi* Sutcharit & Panha, new species, from Gua Musang, Kelantan, Malaysia CUMZ 4944, showing: A, right side of male with testis and external penis; B, right side of female with ovary and vaginal groove; C, left side of female with lung cavity and heart. D, E, Radula morphology of: D, *Pterocyclos spaleotes*, topotype specimen CUMZ 4585; E, *Pterocyclos frednaggsi* Sutcharit & Panha, new species, paratype CUMZ 4581.

Female: Ovary (ov) bright orange colour and multi-lobulate glands embedded with brownish digestive glands. Oviduct (od) with thin tube, connected between ovary and uterus (ut) (Fig. 2B).

Radula morphology. Typical taenioglossate radula were observed (Fig. 2D, E), teeth arranged in v-shaped row, each transverse row contained 7 teeth (2-1-1-1-2). Central tooth large, symmetrical triangular shape, with 2-4 well developed cusps on each side. Lateral and marginal teeth slightly slender, inclining to central tooth, with 3-4 cusps. Shape of teeth and number of cusps vary among species.

Remarks. Two different spellings, viz. *Pterocyclos* and *Pterocyclus*, are widely used in the literature and both attributed to Benson (1832). However, the name *Pterocyclus* is an unjustified emendation that has been erroneously used as a valid name (e.g., Nevill, 1878; Fischer, 1885; Kobelt & Möllendorff, 1897; Kobelt, 1902, 1911). Wenz (1938) was the first to place *Pterocyclus* in the synonymy of *Pterocyclos*. In addition, he attributed the authorship of *Pterocyclus* to Crosse (1868). However, it now seems that Agassiz (1848: 908) was responsible for this unjustified emendation. Hence, the proper authorship and date of the name *Pterocyclus* is “Agassiz, 1848” (ICZN, 1999: Art. 50.5).

Nomenclaturally, *Pterocyclus* Agassiz, 1848 [Mollusca, Gastropoda] is a junior homonym of *Pterocyclos* Gray, 1846 [Aves, Passeriformes, Tomaliidae]. Thus, it should not be used as valid generic name (ICZN, 1999, Arts. 23, 52), even if *Pterocyclos* Gray, 1846 is itself a junior subjective synonym of *Garrulax* Lesson, 1831 (Deignan et al., 1964; Sibley & Monroe, 1999).

Pterocyclos blandi Benson, 1851

(Figs. 1, 3E, F; Table 1)

Pterocyclos blandi Benson, 1851: 196, pl. 5 fig. 1. Type locality: Pulo Susson insulam prope Pulo Penang jacentem. Reeve, 1863: *Pterocyclos*, pl. 2 species 7. Morgan, 1885: 400. Kongim et al. 2013: 16, fig. 2B.

Pterocyclos blandi—Kobelt, 1902: 163. Laidlaw, 1928: 30. Maassen, 2001: 26.

Other material examined. Teluk Ewa, Pulau Langkawi, Kedah, Malaysia: CUMZ 3880 (64 shells), 4582 (44 shells, Fig. 3E, F), 4583 (70 shells), 4584 (3 shells). Gua Cerita, Northern Island, Pulau Langkawi, Kedah, Malaysia: CUMZ 3879 (9 shells).

Remark. *Pterocyclos blandi* was described by Benson (1851) in one of the two papers (out of nearly 60) in which Benson dealt with land snails and provided illustrations of specimens (Naggs, 1997). The species identification is unambiguous and there are no type specimens. The species differs from all other *Pterocyclos* species by its depressed and thick shell, and transparent periostracum. The shell colour is usually uniform brown to purplish, rarely with variegated brown zigzag pattern, apertural lip whitish; upper part of the apertural lip broadly expanded and wing-shaped; lower part of the apertural lip thickened and not expanded. Accessory respiratory structure triangular, overhanging by

the upper part of the apertural lip. Operculum calcareous, slightly concave inside, and multilamellae outside.

The species was not found in the limestone areas of Perlis, Kedah, Perak and Kelantan in Malaysia, and in southern Thailand. This suggests that *P. blandi* has a limited distribution and is possibly endemic to Langkawi Islands, Perlis, Malaysia, where the species seems to be declining due to exploitation of the limestone quarries.

Pterocyclos subalatus Sykes, 1903

(Figs. 1, 3G)

Pterocyclos subalatus Sykes, 1903: 195, 196, pl. 20, figs 21, 22.

Type locality: Gunong Inas, at 5000 feet.

Pterocyclos subalatus—Laidlaw, 1928: 30. Maassen, 2001: 27.

Type specimens. Holotype UMZC 1032 (height 8.8 × diameter 17.2 mm, Fig. 3G) (no other material was available).

Remark. *Pterocyclos subalatus* has been described in detail, based on two shells (Sykes, 1903). Because of its relatively small size (diameter about 15 mm), and its thick and brownish periostracum, this species superficially resembles the genus *Cyclotus*. However, the holotype clearly shows the typical characters of *Pterocyclos*, i.e., the expanded apertural lip, with thin channel and shortly expanded of apertural lip at suture area, operculum low cup shape, and multilamellae outside.

This species clearly differs from *P. spaleotes* and *P. umbraticus* because its last whorl is not disconnected from the penultimate whorl, while its accessory respiratory structure has a shallow channel. It further differs from *P. umbraticus* by having a smooth shell surface and much smaller shell size.

Pterocyclos spaleotes (Tomlin, 1932)

(Figs. 1, 2D, 3H–J; Table 1)

Rhiostoma spaleotes Tomlin, 1932: 227, pl. 26 text figure. Type locality: In a hole in the rock just outside the Batu Caves, near Kula Lumpur, Selangor. Laidlaw, 1932: 36. Maassen, 2001: 28.

Type specimens. The specimen herein designated as the lectotype NMW 1955.158.01107 (height 11.4 × diameter 22.8 mm; Fig. 3H, no operculum), to stabilise the name, is the shell figured in the original description (Tomlin, 1932, pl. 26 text figure). The other specimen from the same lot of the lectotype becomes the paralectotype NMW 1981.118.02705 (1 shell, Fig. 3I, no operculum).

Other material examined. Topotypes from Batu Cave, Kuala Lumpur, Malaysia (03°14.276' N, 101°41.079' E): CUMZ 4585 (35 specimens in ethanol, Fig. 3J), 4747 (52 shells).

Remark. *Pterocyclos spaleotes* is only known from its type locality, despite several surveys in nearby areas. Originally, it was described from two shells without an operculum, which leads Tomlin (1932) to assign it to the genus *Rhiostoma* Benson, 1860. However, after examining the types (Fig. 3G, H) and topotypic specimens (Fig. 3I), this generic placement seems untenable. The unique characters of *P. spaleotes* are: the small and thin shell, the corneous and transparent periostracum, and the surface with a variegated



Fig. 3. A–D, Shell and operculum of *Pterocyclus rupestris*: A, lectotype UMZC 2359.1; B, paralectotype UMZC 2359.2; C, syntype of var. 3 UMZC 2359.3; D, operculum from same lot of the paralectotype (showing top, side and bottom views). E, F, Specimens of *P. blandi* from Langkawi Island, Perlis, Malaysia CUMZ 4582. G, Holotype UMZC 1032 of *P. subalatus*. H–J, *Pterocyclus spaleotes*: H, lectotype NMW 1955.158.01107, I, paralectotype NMW 1981.118.02705; J, topotype specimen CUMZ 4585. K, Holotype ZMA Moll. 135622 of *P. umbraticus*. L–P, *Pterocyclus diluvium* Sutcharit & Panha, new species: L, holotype CUMZ 4595, M, paratype CUMZ 4588, N, specimen from Gua Cenderawasih, Perlis, Malaysia CUMZ 4592; and O, P, specimens from Tam Tone-din, Kuan-Don, Satun, Thailand CUMZ 4590 showing a: O, uniform whitish shell; and P, dark brown colour patterns. Q–S, *Pterocyclus frednaggsi* Sutcharit & Panha, new species: Q, holotype CUMZ 4594; R, paratype CUMZ 4581; S, specimen from Gua Pulai, Gua Musang, Kelantan, Malaysia CUMZ 4597.

Table 1. Shell size variation in *Pterocyclos* spp. Specimen collections and catalogue numbers are indicated in parentheses.

Species and Locality (CUMZ nos.)	No. of Specimens	Ranges, Mean \pm S.D. (mm) of the Shell			Number of Whorls
		Height (H)	Diameter (D)	H/D Ratio	
<i>Pterocyclos blandi</i>					
1. Pulau Langkawi, Malaysia (3880, 4582, 4583, 4584)	180	8.9–13.2 11.0 \pm 0.84	19.3–25.4 22.2 \pm 1.28	0.42–0.57 0.50 \pm 0.03	4 $\frac{3}{4}$ –5 $\frac{1}{2}$
2. Gua Cerita, Pulau Langkawi, Malaysia (3879)	9	8.9–10.6 9.7 \pm 0.67	18.9–25.6 22.4 \pm 1.85	0.40–0.47 0.44 \pm 0.02	4 $\frac{3}{4}$ –5
<i>Pterocyclos spaleotes</i>					
4. Batu Cave, Kuala Lumpur, Malaysia (4585, 4747)	71	8.3–12.1 9.7 \pm 0.92	15.6–20.7 17.8 \pm 1.16	0.48–0.68 0.55 \pm 0.04	4 $\frac{3}{4}$ –5 $\frac{1}{2}$
<i>Pterocyclos diluvium</i> Sutcharit & Panha, new species					
6. Tam Suman, Patthalung, Thailand (4588)	13	11.8–14.4 13.3 \pm 0.74	21.8–25.2 23.8 \pm 1.06	0.52–0.61 0.56 \pm 0.02	4 $\frac{3}{4}$ –5 $\frac{1}{2}$
7. Tam Puttha Kodome, Patthalung, Thailand (3812)	9	12.0–15.6 13.2 \pm 1.18	20.1–25.0 22.5 \pm 1.65	0.57–0.62 0.59 \pm 0.02	4 $\frac{3}{4}$ –5 $\frac{1}{2}$
8. Tam Phaya Hong, Kong Ra, Patthalung, Thailand (4870)	11	11.3–15.0 13.1 \pm 1.16	22.9–27.1 25.2 \pm 1.54	0.47–0.57 0.52 \pm 0.03	4 $\frac{3}{4}$ –5 $\frac{1}{2}$
9. Tarutao National Park, Satun, Thailand (4589, 4593, 4749, 4750)	54	9.8–14.4 11.9 \pm 0.95	18.6–27.2 21.7 \pm 1.50	0.49–0.61 0.55 \pm 0.03	4 $\frac{3}{4}$ –5 $\frac{1}{2}$
10. Tam Tone-din, Kuan-Don, Satun, Thailand (4590, 4591, 4866)	41	13.0–16.6 14.5 \pm 0.88	26.1–31.5 28.0 \pm 1.42	0.43–0.55 0.50 \pm 0.04	4 $\frac{1}{2}$ –5 $\frac{3}{4}$
11. Gua Kelam, Perlis, Malaysia (3877, 4587)	17	10.7–13.3 11.7 \pm 0.70	20.0–26.7 22.6 \pm 1.96	0.45–0.59 0.52 \pm 0.04	4–5 $\frac{1}{2}$
12. Perlis State Park, Malaysia (4586)	7	12.6–15.0 13.8 \pm 0.97	24.4–28.3 26.0 \pm 1.30	0.49–0.61 0.53 \pm 0.04	4 $\frac{1}{2}$ –5 $\frac{1}{2}$
13. Sungi Jenia, Perlis, Malaysia (3878)	26	9.9–14.2 11.9 \pm 0.99	18.7–24.0 21.9 \pm 1.49	0.47–0.62 0.54 \pm 0.03	4 $\frac{3}{4}$ –5 $\frac{1}{2}$
14. Gua Cenderawasih, Perlis, Malaysia (3881, 4592)	29	11.5–15.6 13.3 \pm 1.25	21.0–27.5 24.3 \pm 1.51	0.49–0.61 0.55 \pm 0.03	4 $\frac{3}{4}$ –5 $\frac{1}{2}$
<i>Pterocyclos frednaggsi</i> Sutcharit & Panha, new species					
15. Bukit Chintamanis, Pahang, Malaysia (4581, 4571)	47	10.8–14.8 13.1 \pm 0.78	21.8–32.0 25.6 \pm 1.64	0.43–0.60 0.51 \pm 0.03	4 $\frac{1}{2}$ –5 $\frac{1}{4}$
16. Gua Pulai, Gua Musang, Kelanta, Malaysia (4597)	9	13.4–16.8 14.8 \pm 1.17	26.6–31.3 28.6 \pm 1.80	0.49–0.56 0.52 \pm 0.02	4 $\frac{1}{2}$ –5 $\frac{1}{4}$

brown zigzag colour pattern and a dark brown peripheral band. The last whorl is usually partially disconnected from the penultimate whorl. Aperture rounded, with a white lip and a little expansion of the upper part. The accessory respiratory structure has a short, tubular shape. The operculum is calcareous, slightly concave inside and multilamellae outside.

Pterocyclos spaleotes clearly differs from any *Rhiostoma* species by the shape of its accessory respiratory structure located on the sutural area, and by its calcareous, low cup-shaped and multilamellae operculum. Moreover, *P. spaleotes* has been recorded (type locality) much further south than *Rhiostoma*, which does not occur south of the limestone karst in Perlis, Malaysia. Finally, preliminary analysis of the DNA sequence of a fragment of the cytochrome oxidase subunit I gene supports the transfer of *Rhiostoma spaleotes* to *Pterocyclos* (Tongkerd, unpublished data).

***Pterocyclos umbraticus* (Benthem Jutting, 1949)**
(Figs. 1, 3K)

Cyclotus umbraticus Benthem Jutting, 1949: 54, 55, pl. 1 fig. 1.
Type locality: Maxwell's Hill (700 feet). Maassen, 2001: 15.

Type specimens. Holotype ZMA Mol. 135622 (height 13.2 \times diameter 29.4 mm, Fig. 3K) (no other material was available).

Remarks. Benthem Jutting (1949) described this species based on a number of shells. We have examined the holotype, which clearly does not show the typical characters of *Cyclotus* and, therefore, we suggest transferring the species to *Pterocyclos*. The shell has a relatively large, short channel-like accessory respiratory structure at the apertural lip, and the upper part of the apertural lip is expanded near the suture. In contrast, *Cyclotus* usually has a relatively small shell (diameter 10–30 mm), no accessory respiratory structure or only a short sutural tube, and has a corneous or thin calcareous, plate-shaped operculum (Kobelt, 1902, 1911; Wenz, 1938). Because of these differences, we suggest the re-assignment of this species to *Pterocyclos*.

The characters by which *P. umbraticus* differs from the other *Pterocyclos* species are the chevron-shaped, zigzag sculpture on the upper shell surface, and the accessory respiratory structure that forms a nearly complete tube. In addition, this species tends to live in non-limestone forests of highland areas (altitude about 200–1600 m) in Pahang (Benthem Jutting, 1949).

***Pterocyclus diluvium* Sutcharit & Panha, new species**
(Figs. 1, 3L–P; Table 1)

Rhiostoma asiphon—Benthem Jutting, 1960: 11. [not Möllendorff, 1893].

Pterocyclus sp.—Kongim et al., 2013: 16: fig. 2A.

Type specimens. Holotype CUMZ 4595 (height 13.9 × diameter 25.4 mm; Fig. 3L). Type locality: Tam Sumano, Patthalung, Thailand (7°35'183" N, 99°52'80" E). Paratypes CUMZ 4588 (11 specimens in ethanol, Fig. 3M), NHMUK (2 shells), NMW (2 shells), SMF (2 shells) are from the type locality.

Other material examined. Gua Cenderawasih, Perlis, Malaysia CUMZ 3881 (44 shells), 4592 (7 shells, Fig. 3N). Sungi Jenis, Perlis, Malaysia: CUMZ 3878 (27 shells). Gua Kelam, Perlis, Malaysia: CUMZ 3877 (39 shells), 4587 (6 shells). Wang Kelian, Perlis, Malaysia: CUMZ 3875 (4 shells). Perlis State Park, Malaysia: CUMZ 4586 (10 shells). Khao Loop-chang, Padang Besar, Songkhla: CUMZ 3876 (4 shells). Tam Tone-din, Kuan-Don, Satun: CUMZ 4590 (19 shells; Fig. 3O, P), 4591 (16 shells), 4866 (4 shells). Tarutao National Park, Satun: CUMZ 4589 (14 shells), 4593 (3 shells), 4749 (6 shells), 4750 (43 shells). Tam Kantiphol, Tung Wa, Satun: CUMZ 4596 (6 shells). Tam Phaya Hong, Kong Ra, Patthalung: CUMZ 4870 (13 shells). Tam Puttha Kodome, Srinagarindra, Patthalung: CUMZ 3812 (9 shells).

Etymology. The specific epithet is from the Latin word “*diluvium*” meaning “inundation or flood”. This is a commemorative name referring to the most devastating flooding in the history of the Kingdom of Thailand in the year 2011.

Diagnosis. This new species differs from *P. blandi* by having a larger shell, a triangular shaped accessory respiratory device, an upper apertural-lip that is only slightly expanded, and a white to brown shell colour. It differs from the other newly described species, viz. *P. frednaggsi* Sutcharit & Panha, new species, by having a white to brown shell, a thin periostracum, a triangular shaped accessory respiratory device, and a narrow peripheral band. The differences from *Rhiostoma asiphon* Möllendorff, 1893, are the white to brownish shell colour, the low, cup-shaped operculum, and the triangular accessory respiratory structure.

Description. Shell medium to large, depressed, thickened, and widely umbilicated. Apex acute; spire nearly flat; suture wide; whorl 4–5 convex becoming increasingly regular. Shell surface with thin growth lines; periostracum thin, corneous to brownish colour. Last whorl rounded and stout, narrow dark brown peripheral band usually present. Shell colour monochrome white, brown or brown zigzag pattern. Aperture rounded with white lip; upper peripheral-lip is slightly expanded near suture. Apertural tube structure triangular shaped, connected with a radial ridge parallel to apertural lip margin. Operculum calcareous, slightly concave inside and multilamellae outside.

Distribution. *Pterocyclus diluvium* Sutcharit & Panha, new species, has only been located in limestone areas. It is mainly distributed in southern Thailand in Trang, Patthalung, Satun, Krabi, and Songkhla Provinces. In Malaysia, it was recorded from limestone hills in Perlis and Kedah.

Remarks. This new species is superficially similar to *R. asiphon* with which it could easily be misidentified. Under the name “*Rhiostoma asiphon*”, not in the sense of Möllendorff (1893, 1894), several specimens were reported from many localities from Peninsular Malaysia (Benthem Jutting, 1960). We examined those specimens and revisited all mentioned localities, and confirmed none of them could be identified as *R. asiphon* s.s. Moreover, the type specimens of *R. asiphon* (lectotype SMF 130509 and paralectotypes SMF 130510, 130511, 130512) are clearly distinct from this new species. Especially, with the purplish to black shell colour, the calcareous cup-shaped operculum, and notch shaped apertural tube structure.

Intraspecific variation was observed in the specimens from Tam Tone-din, Satun (CUMZ 4590). This population tended to show a wide range of shell colour variation from dark brown (Fig. 3P) to white (Fig. 3O). However, the unique accessory respiratory structure and the operculum suggest that the observed colour variation is likely to reflect intraspecific patterns, although this requires further corroboration, such as from molecular data, for confirmation.

***Pterocyclus frednaggsi* Sutcharit & Panha, new species**
(Figs. 1, 2A–C, E, 3Q–S; Table 1)

Type specimens. Holotype CUMZ 4594 (height 12.1 × diameter 27.8 mm; Fig. 3Q). Type locality: Bukit Chintamanis, Pahang, Malaysia (03°26.798' N, 102°00.987' E). Paratypes CUMZ 4581 (18 specimens in ethanol, Fig. 3R), 4571 (29 shells), NHMUK (2 shells), NMW (2 shells), SMF (2 shells) are from the type locality.

Other material examined. Gua Pulai, Gua Musang, Kelanta, Malaysia CUMZ 4597 (9 shells, Fig. 3S), 4944 (4 specimens in ethanol).

Etymology. The specific epithet “*frednaggsi*” comes from Fred Naggs, malacologist at the Natural History Museum, London, who has enthusiastically encouraged and continuously supported land snail research in Thailand and other Southeast Asian countries.

Diagnosis. *Pterocyclus frednaggsi* Sutcharit & Panha, new species, differs from *P. blandi* by having a thick and yellowish periostracum, a broad, dark brown peripheral band, a channel shaped accessory respiratory structure, and a slight expansion of the upper part of the apertural lip. It differs from *P. spaleotes* by having a larger shell, a thicker periostracum, and a broad, dark brown peripheral band. The differences from *P. diluvium* Sutcharit & Panha, new species, include the broad, dark brown peripheral band and the channel shaped accessory respiratory structure.

This new species is superficially similar to *P. umbraticus*, but differs from this latter species by its relatively smooth shell surface, the broad dark brown peripheral band, and the fact that its distribution is limited to the lowland limestone area (altitude less than 200 m amsl). In contrast, *P. umbraticus* has a chevron-shaped, zigzag shell sculpture and tends to live in non-limestone forests of highland areas (altitude about 200–1600 m amsl) at Maxwell's Hill and Gunung Brinchang, Pahang (Bentham Jutting, 1949).

Description. Shell medium sized, depressed, thickened, widely umbilicated. Apex acute; spire flattened to slightly elevated; suture wide; 4–5 convex and regularly increasing whorls. Shell surface with thin growth lines; periostracum brown and corneous. Last whorl rounded, stout, with a broad dark brown peripheral band. Shell colour brownish or with a variegated, dark brown zigzag pattern on early whorl. Aperture rounded. Apertural lip white, upper part slightly expanded near suture. Accessory respiratory structure channel-like to short tubular shaped. Operculum calcareous, slightly concave inside, and multilamellae outside.

Radula. Central tooth with well developed central cusp and two smaller lateral cusps on each side; central cusp small with pointed tip; four smaller lateral cusps on both sides with dull to pointed head. Lateral teeth have three cusps; outer cusp large, elongate shape, and two smaller inner lateral cusps with curved tips. Inner marginal teeth have three cusps; central cusp large and convex head, and flanked with smaller and pointed head of one inner and one outer lateral cusps. Outer marginal cusp bicuspid, each cusp with pointed head (Fig. 2E).

Distribution. This limestone dwelling species is known from the type locality and from Gua Musang, Kelantan, Malaysia.

Remarks. Specimens of this species from Gua Musang, Kelantan (Fig. 3S) have slightly larger and darker shells with a narrower peripheral band than typical shells. However, the unique shape of the short tubular accessory respiratory structure and the multilamellae operculum suggest that these atypical forms represent intraspecific geographic variation.

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