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Diversity and biogeography of land snails (Mollusca, Gastropoda) in the limestone hills of Perak, Peninsular Malaysia

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Abstract

Limestone hills are now gaining global conservation attention as hotspots for short-range endemic species. Levels of land snail endemism can be high at limestone hills, especially at hill clusters that are geographically isolated. In the State of Perak, Peninsular Malaysia, limestone hills have been opportunistically surveyed for land snails in the past, but the majority have yet to be surveyed. To address this knowledge gap, we systematically surveyed the terrestrial malacofauna of 12 limestone hills that, based on our opinion, are a representation of the limestone land snail assemblages within the State. Our inventory yielded high sampling completeness (>85%). We found 122 species of land snails, of which 34 species were unique to one of the surveyed hills. We identified 30 species that are potentially new to science. The number of land snail species recorded at each hill ranged between 39 and 63 species. Four of the sampled limestone hills namely, Prk 01 G. Tempurung, Prk 55 G. Pondok, Prk 47 Kanthan, and Prk 64 Bt Kepala Gajah, have high levels of species richness and unique species, representing 91% of the total species recorded in this study. We identified two clusters of limestone hills in central Perak with distinct differences in land snail species composition – a northern hill cluster on elevated granite bedrock and southern hill cluster in a low-lying valley surrounded by alluvial soils. As limestone hills continue to be quarried to meet the cement demand, the four identified limestone hills, along with other hills from the two clusters, warrant urgent conservation attention in order to maintain high species diversity within Perak's terrestrial malacofauna.

Keywords
Biogeography, checklist, conservation, endemism, karst, Kinta River, mollusc, Perak River

Introduction

Limestone hills are popularly known as “arks of biodiversity” because they contain high levels of species endemism, especially in Peninsular Malaysia where these hills only cover 0.2 % of the total land area (Schilthuizen 2004; Clements et al. 2006; Chua et al. 2009; Liew et al. 2014).

To date, at least 445 limestone hills have been documented in Peninsular Malaysia, with the majority located in the States of Kelantan (149 hills), Pahang (124 hills) and Perak (93 hills) (Liew et al. 2016). The State of Perak has the third largest number of limestone hills, but it has the largest number of operating quarries (Liew et al. 2016). The majority of these hills can be found within the Kinta Valley, with some other hills scattered around the northern part of the Kinta Valley and Bintang Range (Figure 1). Over the past decade, the endemism of different plant and animal at the limestone hills of Perak has drawn attention from evolutionary biologists (Clements et al. 2008a), conservationists (Clements et al. 2008b) and concerned taxonomists (Kiew et al. 2014; Vermeulen and Marzuki 2014). Given the large number of limestone hills in Perak, it is not practical to spare every hill from quarrying. Thus, conservation prioritisation needs to be conducted, ideally based on the biogeographical patterns of endemic taxa such as land snails (Clements et al. 2008b).

The limestone hills in Perak form an important region because that was where the foundation for land snail knowledge in Peninsular Malaysia was laid. More than 50 land snail species have been described from this State alone; these species descriptions were the outputs of three main faunistic studies by separate groups of naturalists and malacologists. The first was an expedition to central Perak by de Morgan (1885a), who described 33 new land snail species from the area. Second was the work by von Möllendorff, who published a species checklist of around 60 species and described 15 new species based on the collection by R. Hungerford at Gunung Larut (von Möllendorff 1886, 1891). Third was the survey done by E. Townsend at Gunung Pondok, where around 13 new species were described (Godwin-Austen and Nevill 1879; Crosse 1879a, 1879b). Besides these faunistic surveys in Perak, at least 20 new species were described based on taxonomic studies of particular land snail taxa or random sampling (van Benthem Jutting 1952, 1954, 1961a, 1961b; Tomlin 1938, 1939, 1941; Fulton 1901, 1902; Sykes 1903; Godwin-Austen 1909). More recent studies suggest that about one-third on the known species from Peninsular Malaysia can be found in Perak, particularly around the Kinta Valley (Davison 1991; Chan 1998a, 1998b; Clements et al. 2008b; Maassen 2001). In Perak, land snail species richness on a hill can reach as high as 53 species (Clements et al. 2008b).

Despite intensive land snail research conducted in the State of Perak, the land snail inventory is far from complete. Most of the comprehensive surveys only report the name of the species, without illustrations of the species, or with provisional working species

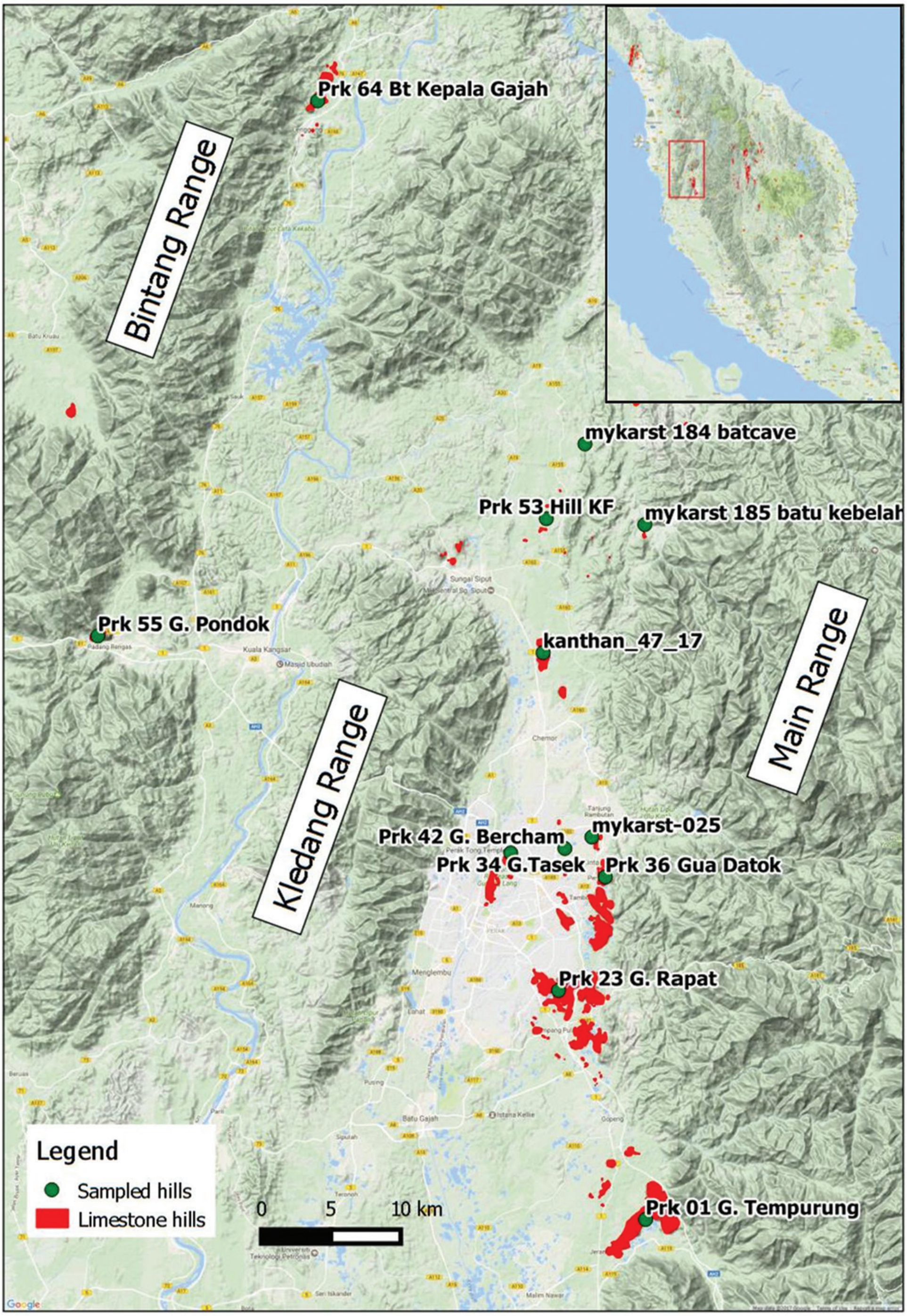

Figure 1. The 12 limestone hills sampled in and around the Kinta Valley of Perak, Peninsular Malaysia.

names, such as sp. 1, sp. 2. (e.g. Davison 1991; Clements et al. 2008b). This has made it difficult to update current checklists because species identities in previous reports cannot be used to compare with recently collected specimens. Furthermore, many of these unnamed species in previous reports are probably new species yet to be described or are doubtful species that require taxonomic revision. Hence, good annotated checklists of land snails with traceable specimens and high quality illustrations are key to improve the current knowledge of land snails in Perak and Peninsular Malaysia in general.

The biogeography of organisms on limestone hills in Perak is also poorly known. In Peninsular Malaysia, land snail communities on limestone hills can generally be divided into two groups, one on the hills along the east coast and the other on the hills along the west coast, both of which are separated by Main Range in the centre of the peninsula (van Benthem Jutting 1960; Clements et al. 2008b). Within the State of Perak, Davison (1991) noticed land snails on limestone hills can be further divided into two groups, one on the hills within Kinta Valley and the other one on the hills scattered in the area north of Kinta Valley, though based on an incomplete land snail inventory (Davison 1991: 6 – 35 species from 12 hills, averaging 17 species per hill, compared to Clements et al. 2008b: 32 – 53 species from 6 hills, averaging 42 species per hill). As such, further quantitative analysis on the biogeographical patterns of land snails with more comprehensive species inventories from limestone hills that are representative of Perak's terrestrial malacofauna can contribute to improved limestone conservation planning within the State.

Limestone hills have been recently highlighted as one of Malaysia's vulnerable ecosystems due to surrounding forest degradation and quarrying activities (Ministry of Natural Resources and Environment Malaysia 2016). Many land snail species that are endemic to limestone hills in Peninsular Malaysia are already extinct or on the brink of extinction (http://www.iucnredlist.org/search/link/57e5b1fd-2bc5b54c). In order to prevent further species extinctions, limestone hills that are currently being quarried or intact must be urgently assessed for land snail diversity.

Here, we conduct a land snail inventory in and around the Kinta Valley of Perak to: (1) provide an annotated checklist of land snail species for the State, along with photographic images for each species; and (2) elucidate land snail diversity and biogeographical patterns across 12 limestone hills within the State. For the second objective, we specifically examined relationships between limestone hill parameters (size and isolation) and species richness and biogeographical patterns of land snails. Finally, we discuss the conservation implications of our study for limestone hills in Perak.

Methodology

Sampling design and sites

In addition to six limestone hills previously surveyed by Clements et al. (2008b), six other limestone hills were included in this study. Among the six previously sampled hills, only one (i.e. Gunung Bercham) was resampled because of the low sampling

Table 1. The geographical coordinates, size, isolation of 12 limestone hills sampled in this study in and around the Kinta Valley of Perak. The names of the limestone hills follow a standardized national code developed by Liew et al. (2016).

No.	Limestone hills	Longitude	Latitude	Size (km^2)	Degree of Isolation[@]	Species richness	Unique species
1	Gunung Kanthan*	4.761388	101.1210	0.827	5	63	6
2	mykarst-025*	4.653244	101.1539	0.122	13	40	1
3	Prk 1 G. Tempurung*	4.415082	101.1877	8.722	6	54	9
4	Prk 23 G. Rapat^	4.552856	101.1311	5.379	17	45	3
5	Prk 34 G. Tasek^	4.643467	101.0998	0.114	13	45	1
6	Prk 36 Gua Datok^	4.627492	101.1581	0.644	16	49	1
7	Prk 53 Hill KF^	4.854229	101.1225	0.038	8	44	1
8	Prk 55 G. Pondok^	4.786687	100.8402	0.662	1	50	5
9	Prk 64 Bt Kepala Gajah*	5.118655	100.9727	1.075	7	45	7
10	mykarst-184 Bat Cave*	4.906175	101.1467	0.014	6	50	0
11	mykarst-185 Batu Kebelah*	4.853657	101.1864	0.022	4	39	0
12	Prk 42 G. Bercham #	4.644832	101.1338	0.059	16	45	0

* This study, ^ Clements et al. (2008), # combined data of this study and Clements et al. (2008)

[@] Degree of isolation of each limestone hill – number of other hills within its 10 km radius (see Liew et al. 2016).

completeness reported by Clements et al. 2008b. Sampling was conducted between 16/8/2016 and 24/8/2016. Our sampling approach consisting of 12 limestone hills will (1) result in the sampling of more hills in clusters that have a larger number of limestone hills; and (2) provide wider geographical coverage of limestone hills across the Kinta Valley (Table 1; Figure 1).

Land snails sampling and processing

In each of the seven limestone hills, four 2 m × 4 m plots were established (Clements et al. 2008b; Liew et al. 2008; Suppl. material 1). In each plot, a total of five litres of top soil and leaf litter were collected for extraction of micro-snails (< 5 mm) and the plot was searched for macro-snails. Upon returning to the laboratory, all macro-snails were cleaned with running water and then dried in an oven.

After that, shells were extracted from soil samples by manually picking up the shells under a stereomicroscope (Liew et al. 2008). For species identification, a complete literature of Malay Peninsular terrestrial mollusca was consulted, with emphasis on the most recent species compilation and overview by Maassen (2001). All specimens from recent sampling and previous studies (Clements et al. 2008b) were identified to morphospecies based on a combination of photographs, illustrations and description of types. Morphospecies that could not be assigned to an available name were given working morphospecies names (for example, *Acmella* 'Kanthan 1'). Species reported to be present in our study sites in the literature, but not found during our sampling, were not included in our results. All specimens were catalogued in the *BORNEENSIS* Mollusca collection database and were deposited in the *BORNEENSIS* collection of Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah.

Data analysis

A species checklist was compiled for the 12 limestone hills and was arranged according to the classification of Maassen (2001). Under species or subspecies, four subsections were provided: (1) Reference to figures; (2) Materials examined, which includes only species sampled from this study (with the exception of some species where poor shell preservation warranted a substitute specimen from other studies for photographic purposes); (3) Distribution, which is separated into distribution within Peninsular Malaysia and distribution elsewhere; (4) Remarks, which includes brief diagnosis, comparison with conspecifics and note on new records. All species are considered native unless noted as synantropic in Remarks.

For our analysis of land snail diversity patterns, we first assessed species diversity in terms of (1) species richness – total number of species for each hill; and (2) unique species – species found only in one of the twelve limestone hills in this study. Next, we assessed whether there was a correlation between the species richness and the number of unique species for the twelve hills. We also examined relationships between species diversity and limestone hill parameters (i.e. size and degree of isolation). Depending on the normality test of data for each parameter, Spearman or Pearson correlation coefficients were used to test for correlations. Analysis was conducted using built-in function in the R statistical environment v. 3.3.1 (R Core Team 2016).

For our analysis of land snail biogeographical patterns, land snail data were tabulated into a data matrix of 122 species × 12 limestone hills that consisted of absence (0)/presence (1) data for each species on each of the twelve hills. We evaluated sampling completeness for all 12 hills and compared their species composition to determine their degree of similarity. A cluster analysis was performed to objectively assign limestone hills into clusters so that hills within each cluster are similar to one another with respect to overall land snail composition. In our analysis, a dissimilarity distance matrix was calculated using the Jaccard similarity coefficient (i.e. Jaccard index) based on the data matrix. Next, hierarchical clustering on the 12 sites based on the dissimilarity matrix was performed using the method of complete linkage. Analysis was conducted using package 'vegan' (Dixon 2003) and 'iNEXT' (Hsieh et al. 2016) in the R statistical environment v. 3.3.1 (R Core Team 2016).

Results

Diversity and biogeography of land snails

We achieved high sampling completeness (> 85 %) for all seven limestone hills sampled in our study (Suppl. material 3). The species richness and number of unique species that can be found only in a single hill is listed in Table 1. The number of land snail species recorded in each hill ranges between 39 species and 63 species. Gunung Kanthan has the highest number of species – 63 species with 6 unique species, and followed by Gunung Tempurung – 54 species with 9 unique species. The list of 34 unique species

Table 2. Unique species for each of 12 limestone hills (and species richness [SR]) in and around the Kinta Valley of Perak, Peninsular Malaysia.

Prk 01 G. Tempurung (SR = 54)	**Prk 55 G. Pondok (SR = 50)**
Glyptaulax ‘tempurung 1’	*Chamalycaeus microconus* (von Möllendorff, 1886)
Macrochlamys ‘tempurung 1’	*Chamalycaeus oligopleuris* (von Möllendorff, 1886)
Macrochlamys ‘tempurung 2’	*Lagochilus* ‘pondok 1’
Microcystina ‘tempurung 2’	*Microcystina* ‘pondok 1’
Microcystina ‘tempurung 3’	*Sinoennea perakensis* (Godwin-Austen & Nevill, 1879)
Opisthostoma cf. *vermiculum*	
Opisthostoma ‘tempurung 1 detached’	
Paraboysidia ‘tempurung 1’	**Prk 23 G. Rapat (SR = 45)**
Rahula ‘tempurung 1’	*Arinia* (*Notharinia*) *micro* Marzuki & Foon, 219
	Opisthostoma megalomphalum van Benthem Jutting, 1955
Prk 47 Kanthan (SR = 63)	*Opisthostoma vermiculum* Clements & Vermeulen, 2008
Chamalycaeus ‘Kanthan 1’	
Chamalycaeus ‘kanthan 2’	
Diplommatina cf. *diminuta*	**Prk 36 Gua Datok (SR = 49)**
Lagochilus townsendi Crosse, 1879a	*Pupina arula perakensis* von Möllendorff, 1896
Opisthostoma cf. *gittenbergeri*	
Opisthostoma cf. *subconicum*	
	Prk 34 G.Tasek (SR = 45)
	Arinia (*Notharinia*) ‘tasek 1’
Prk 64 Bt Kepala Gajah (SP = 45)	**mykarst-025 (SR = 40)**
Diplommatina lenggongensis Tomlin, 1941	*Opisthostoma* ‘mykarst-25 1’
Microcystina ‘guatokgiring 1’	
Microcystina ‘guatokgiring 2’	**Prk 53 Hill KF (SR = 44)**
Opisthostoma castor van Benthem Jutting, 1961	*Sinoennea* ‘prk53 1’
Sinoennea ‘guatokgiring 1’	
Sinoennea lenggongensis Tomlin, 1948	**mykarst-184 Bat Cave (SP = 50)**
Sinoennea tweediei Tomlin, 1941	None.
Prk 42 G. Bercham (SP = 45)	**mykarst-185 Batu Kebelah (SP = 39)**
None.	None.

found in each limestone hills is listed in Table 2. The species richness and number of unique species of each hill were also mapped to understand land snail diversity patterns among the limestone hills in and around the Kinta Valley of Perak (Table 1)

Species richness and the number of unique species were not correlated among the 12 hills ($p = 0.052$, Figure 2A). There appears to be no relationship between the species richness and limestone hill size ($p = 0.12$) and isolation ($p = 0.5$) (Figure 2B, C). On the other hand, the number of unique species was strongly correlated with limestone hill size ($r_s = 0.91$, $p = 0.0005$), but not isolation ($p=0.43$) (Figure 2D, E).

Cluster analysis identified two clusters of limestone hills based on land snail species composition: a northern cluster and southern cluster (Figure 3). The northern cluster comprises four limestone hills: Prk 64 Bt. Kepala Gajah, Prk 55 G. Pondok, mykarst-184 Bat Cave, and mykarst-185 Batu Kebelah. The Southern cluster consists of the remaining limestone hills in the Kinta Valley (Figure 3).

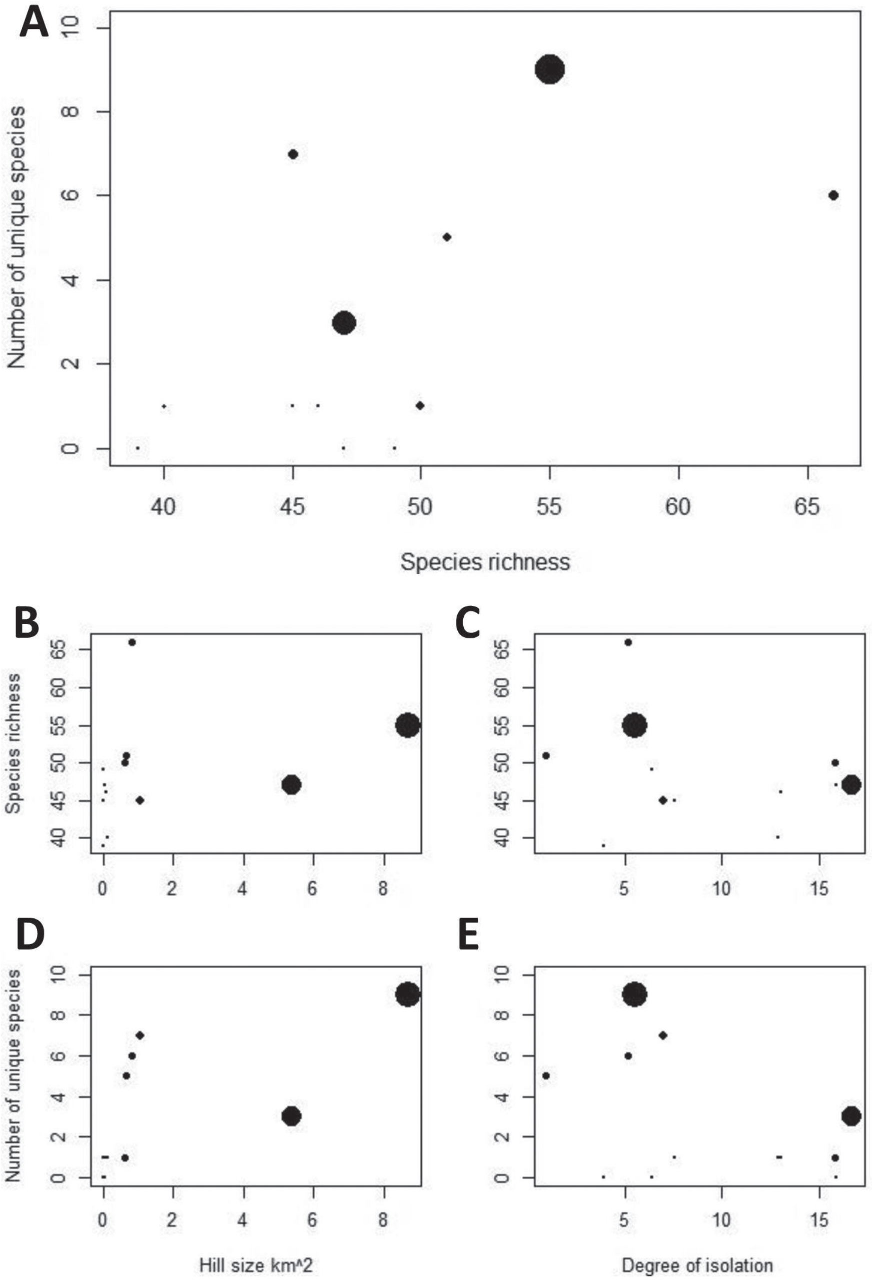

Figure 2. Relationships between limestone physical parameters and land snail species diversity of the 12 limestone hills in Perak, Malaysia. Limestone hills size indicated by relative point size in the plot. **A** Relationship between species richness and number of unique species **B** Relationship between species richness and limestone hills size (km^2) **C** Relationship between species richness and degree of isolation of the limestone hills **D** Relationship between number of unique species and limestone hills size (km^2) **E** Relationship between number of unique species and degree of isolation of the limestone hills.

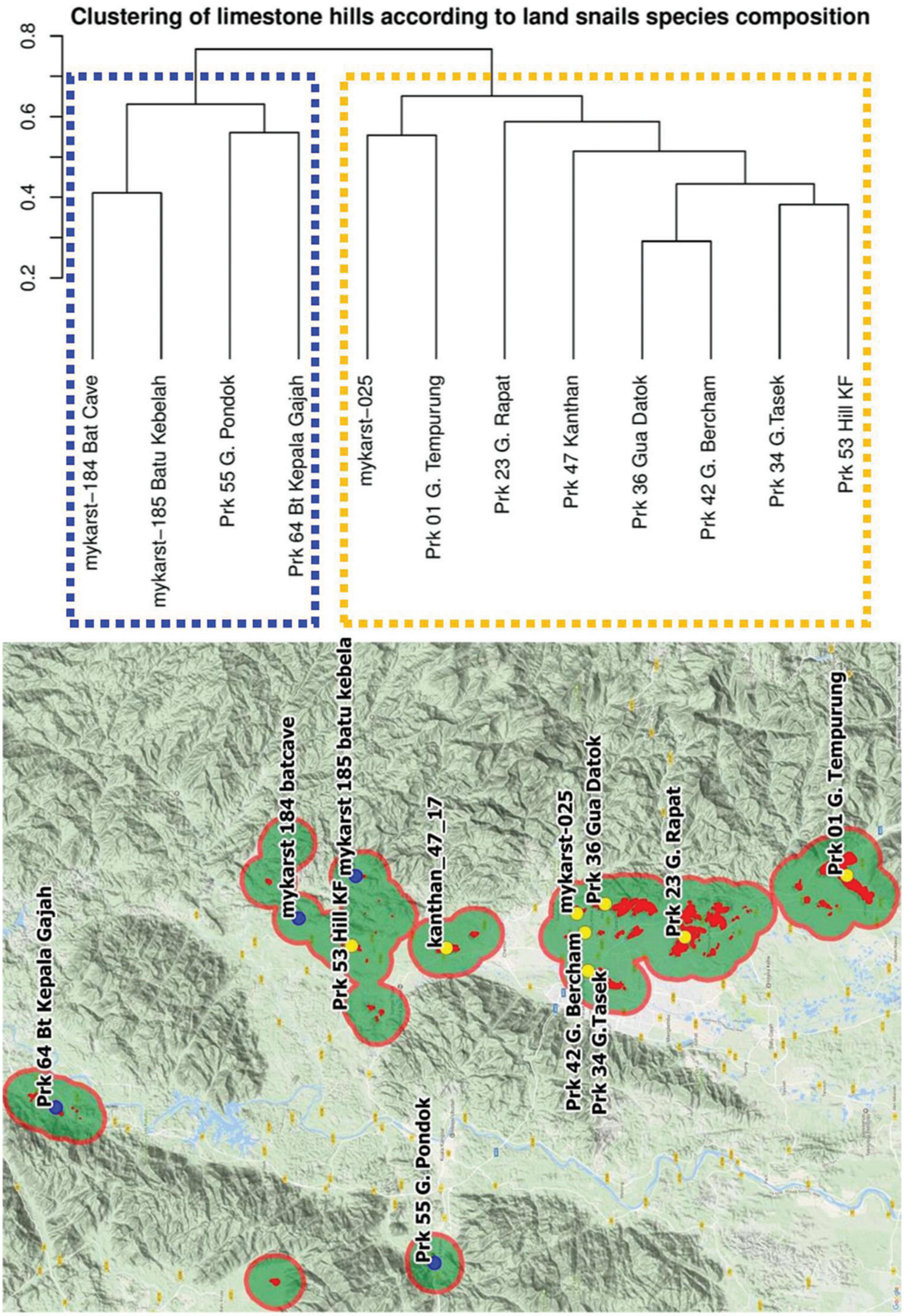

Figure 3. Cluster analysis of land snail species composition of 12 limestone hills in and around the Kinta Valley of Perak, Peninsular Malaysia. Two clusters were identified: a northern (blue dots) and southern cluster (yellow dots). Green polygons with red boundary refer to major clusters of limestone hills in Kinta Valley identified based on the 2.5 km buffer analysis (i.e. at least 2.5 km from the nearest cluster/hills). Red dots indicate limestone hills not sampled in this study.

Checklist

In total, we recorded 122 species from the 12 limestone hills sampled in and around the Kinta Valley of Perak (Suppl. material 2). This checklist consists of 23 families and 47 genera. There are 30 out of 122 species identified from this project which could not be assigned to scientific names that are currently published. Some of these unnamed species are potentially new to science but systematic taxonomic revisions need to be done as many of these groups have not been critically revised. The most diverse genera were *Opisthostoma* (13 species), *Microcystina* (10 species), and *Diplommatina* (9 species).

Class Gastropoda Cuvier, 1795
Clade Caenogastropoda Cox, 1960
Family Assimineidae Adams & Adams, 1856
Genus *Acmella* Blanford, 1869

Acmella 'Kanthan 1'
Figure 4A

Materials examined. Prk 47 Kanthan: BOR/MOL 9079, BOR/MOL 9157.mykarst-184 Bat Cave: BOR/MOL 9781, BOR/MOL 9839, BOR/MOL 12502. Prk 64 Bt Kepala Gajah: BOR/MOL 10192. Prk 23 G. Rapat: BOR/MOL 10237. Prk 36 Gua Datok: BOR/MOL 10453. Prk 42 G. Bercham: BOR/MOL 10583, BOR/MOL 12497, BOR/MOL 12498, BOR/MOL 12503. Prk 53 Hill KF: BOR/MOL 10784. Prk 01 G. Tempurung: BOR/MOL 11397, BOR/MOL 12501.

Distribution. Known from Kinta Valley and Lenggong, Perak only.

Remarks. Very small shell. Tall spire, conical shaped shell. Radial ribs prominent, chevron-shaped with the pointed end in the opposite direction of shell growth. *Acmella roepstorffiana* Nevill, 1878 from Pahang differs in radial rib shape.

Family Cyclophoridae Gray, 1847
Genus *Alycaeus* Baird, 1850

Alycaeus conformis Fulton, 1902
Figure 4B

Materials examined. Prk 23 G. Rapat: BOR/MOL 10057.

Distribution. In Peninsular Malaysia, known from Perak, Selangor and Kelantan (Maassen 2001). Elsewhere, in Tenasserim (=Tanintharyi), Myanmar and Salang (=Phuket), Thailand (Maassen 2001).

Remarks. Small shell. Globular, convex whorls. Very similar to *Alycaeus gibbosulus*, distinguished only by the less expanded penultimate whorl and clean operculum exterior.

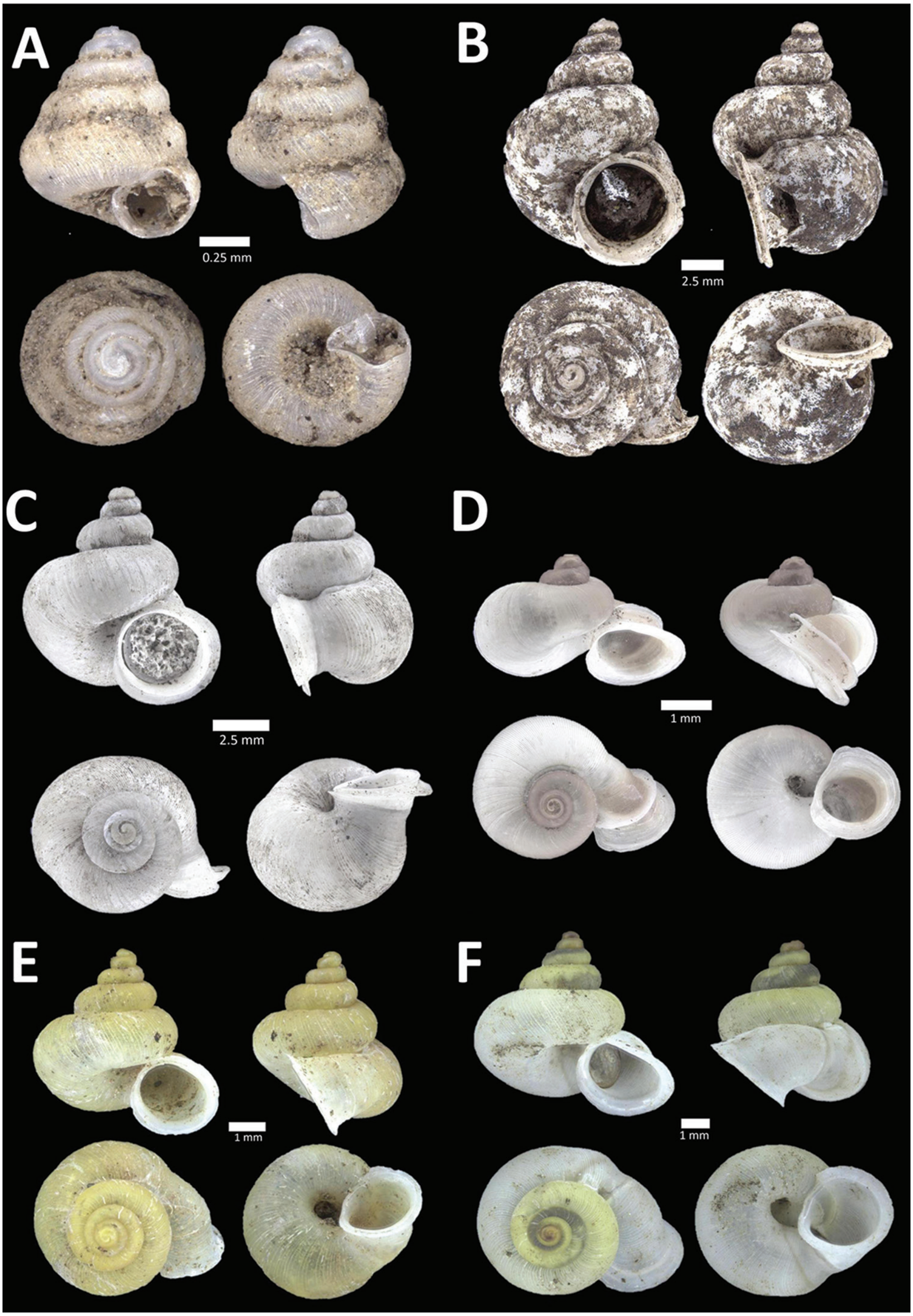

Figure 4. A. *Acmella* 'Kanthan 1' BOR/MOL 9781. Perak, Ipoh, Bat Cave Hill Plot 1 **B** *Alycaeus conformis* Fulton, 1902 BOR/MOL 10057. Perak, Ipoh, Gunung Rapat Plot C3 **C** *Alycaeus gibbosulus* (Stoliczka, 1872) BOR/MOL 9436. Perak, Ipoh, Mykarst-025 Plot 3 **D** *Alycaeus jousseaumei* (de Morgan, 1885a) BOR/MOL 11211. Perak, Ipoh, Gunung Tempurung Plot 3 **E** *Alycaeus kapayanesis* (de Morgan, 1885a) BOR/MOL 11385. Perak, Ipoh, Gunung Tempurung Plot 2 **F** *Alycaeus perakensis* (Crosse, 1879) BOR/MOL 11506. Perak, Ipoh, Gunung Pondok, plot 3.

Alycaeus gibbosulus (Stoliczka, 1872)

Figure 4C

Materials examined. mykarst-025: BOR/MOL 9382, BOR/MOL 9416, BOR/MOL 9436, BOR/MOL 9500. mykarst-027: BOR/MOL 9106. Prk 23 G. Rapat: BOR/MOL 10286. Prk 55 G. Pondok: BOR/MOL 11523, BOR/MOL 11538.

Distribution. Found throughout Peninsular Malaysia. Elsewhere, in southern Thailand (Maassen 2001).

Remarks. Small shell. Globular, convex whorls. Very similar to *Alycaeus conformis*, differs only by the more expanded penultimate whorl and calcrete-encrusted operculum exterior.

Alycaeus jousseaumei (de Morgan, 1885a)

Figure 4D

Materials examined. Prk 53 Hill KF: BOR/MOL 10717, BOR/MOL 10658, BOR/MOL 10689. Prk 47 Kanthan: BOR/MOL 9374, BOR/MOL 9053. mykarst-025: BOR/MOL 9383. mykarst-027: BOR/MOL 9101. Prk 23 G. Rapat: BOR/MOL 10228, BOR/MOL 10046, BOR/MOL 10202, BOR/MOL 10253. Prk 36 Gua Datok: BOR/MOL 10412, BOR/MOL 10441, BOR/MOL 10474, BOR/MOL 10494. Prk 42 G. Bercham: BOR/MOL 10593. Prk 34 G. Tasek: BOR/MOL 10788, BOR/MOL 11054. Prk 01 G. Tempurung: BOR/MOL 11136, BOR/MOL 11211, BOR/MOL 11408.

Distribution. Restricted to Kinta Valley.

Remarks. Small shell. Convex whorls. Easily distinguished from congeners by its flat and highly expanded penultimate whorl with double peristomal expansion.

Alycaeus kapayanesis (de Morgan, 1885b)

Figure 4E

Materials examined. Prk 47 Kanthan: BOR/MOL 9081, BOR/MOL 9161. mykarst-027: BOR/MOL 9041. mykarst-025: BOR/MOL 9425. Prk 23 G. Rapat: BOR/MOL 10230, BOR/MOL 10031, BOR/MOL 10259. Prk 53 Hill KF: BOR/MOL 10671, BOR/MOL 10696. Prk 36 Gua Datok: BOR/MOL 10482, BOR/MOL 10502. Prk 42 G. Bercham: BOR/MOL 10629. Prk 34 G. Tasek: BOR/MOL 10793, BOR/MOL 11028, BOR/MOL 11065. Prk 01 G. Tempurung: BOR/MOL 11142, BOR/MOL 11229, BOR/MOL 11385, BOR/MOL 11414.

Distribution. Restricted to Kinta Valley.

Remarks. Small shell. Tall spire, conical shell. Peristome expanded and reflected. Shell lemon yellow. Shell smaller and penultimate whorl less expanded than *Alycaeus perakensis*.

Alycaeus perakensis (Crosse, 1879a)

Figure 4F

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9877, BOR/MOL 9799, BOR/MOL 9833, BOR/MOL 9770. mykarst-185 Batu Kebelah: BOR/MOL 9546, BOR/MOL 9565, BOR/MOL 9573, BOR/MOL 9585. Prk 64 Bt Kepala Gajah: BOR/MOL 10088, BOR/MOL 10124, BOR/MOL 10136, BOR/MOL 10166. Prk 55 G. Pondok: BOR/MOL 11506, BOR/MOL 11479, BOR/MOL 11539, BOR/MOL 11563.

Distribution. Known from Upper Kinta Valley and Perak River Valley, Perak only.

Remarks. Shell larger than *Alycaeus kapayanensis*. Tall spire, conical shell. Penultimate whorl more expanded than *A. kapayanensis*. Peristome expanded and reflected. Shell lemon yellow.

Alycaeus thieroti de Morgan, 1885a

Figure 5A

Materials examined. mykarst-025: BOR/MOL 9415, BOR/MOL 12422. Prk 23 G. Rapat: BOR/MOL 10056, BOR/MOL 10258.

Distribution. Known from Perak, Selangor and Kelantan only (Maassen 2001).

Remarks. Small shell. Radial ribs prominent, at equidistant. Spiral sculpture fine, indistinct. Peristome expanded and reflected. Differs from other Perak congeners by its more globose whorls.

Genus *Chamalycaeus* Kobelt & von Möllendorff, 1897

Chamalycaeus diplochilus (von Möllendorff, 1886)

Figure 5B

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9885. Prk 47 Kanthan: BOR/MOL 9080, BOR/MOL 9150. mykarst-027: BOR/MOL 9038, BOR/MOL 9129. Prk 64 Bt Kepala Gajah: BOR/MOL 10098, BOR/MOL 10137, BOR/MOL 10175. Prk 42 G. Bercham: BOR/MOL 10586. Prk 55 G. Pondok: BOR/MOL 11522, BOR/MOL 11484.

Distribution. In Peninsular Malaysia, known from Perak and Kelantan (Maassen 2001). Elsewhere, in Jalor (=Yala), Thailand (Maassen 2001).

Remarks. Distinguished from congeners by its larger, low spired shell. Glossy surface. Periphery prominently keeled. Radial ribs prominent along the section of the whorl parallel to the pneumatophore, indistinct elsewhere. Shape similar but shell larger than *Chamalycaeus oligopleuris*.

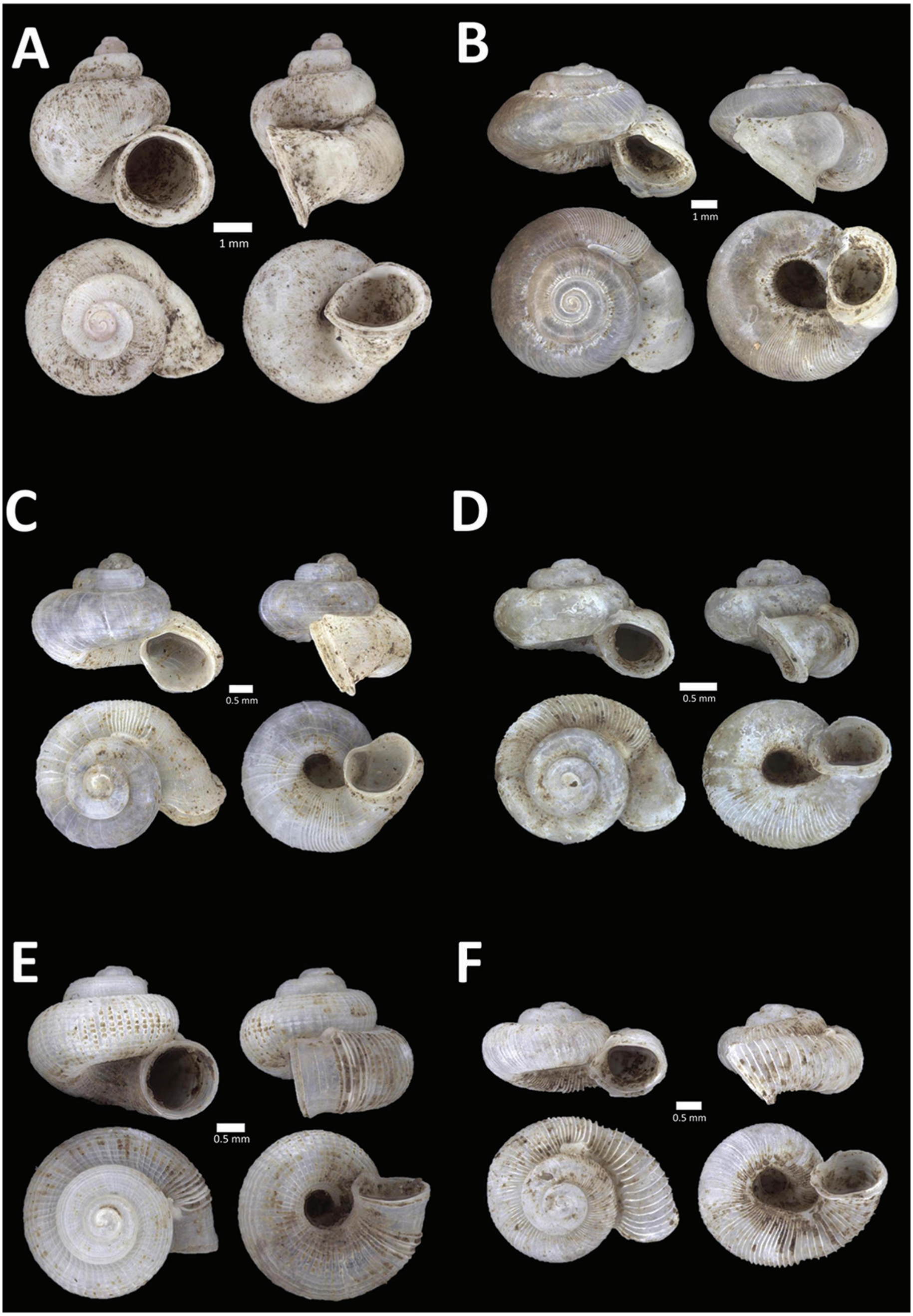

Figure 5. A *Alycaeus thieroti* de Morgan, 1885a BOR/MOL 10258. Perak, Ipoh, Gunung Rapat Plot C7 **B** *Chamalycaeus diplochilus* (von Möllendorff, 1886) BOR/MOL 10098. Perak, Ipoh, Gua Tok Giring **C** *Chamalycaeus* 'Kanthan 1' BOR/MOL 9127. Perak, Ipoh, Gunung Kanthan Plot 2 **D** *Chamalycaeus* 'kanthan 2' BOR/MOL 9160. Perak, Ipoh, Gunung Kanthan Plot 4 **E** *Chamalycaeus microconus* (von Möllendorff, 1886) BOR/MOL 11485. Perak, Ipoh, Gunung Pondok **F** *Chamalycaeus microdiscus* (von Möllendorff, 1886) BOR/MOL 10206. Perak, Ipoh, Gunung Rapat.

Chamalycaeus 'Kanthan 1'

Figure 5C

Materials examined. mykarst-027: BOR/MOL 9039, BOR/MOL 9127.

Distribution. Known from mykarst-027 only, but surrounding hills have yet to be adequately surveyed.

Remarks. Shell shares similar prominent, widely spaced-out radial and spiral ridges with *Chamalycaeus oligopleuris* but differs in having taller spire and rounder periphery.

Chamalycaeus 'kanthan 2'

Figure 5D

Materials examined. Prk 47 Kanthan: BOR/MOL 9082, BOR/MOL 9160.

Distribution. Known from Gunung Kanthan only, but surrounding hills have yet to be adequately surveyed.

Remarks. Distinguished from congeners by its arrangement of radial ribs, taller spire and the position of the pneumatophore.

Chamalycaeus microconus (von Möllendorff, 1886)

Figure 5E

Materials examined. Prk 55 G. Pondok: BOR/MOL 11617, BOR/MOL 11485.

Distribution. Known only from Bukit Pondok and Temengor, Perak only (Maassen 2001).

Remarks. Distinguished from all congeners by its tall spire, conical shell, penultimate whorl of constant width and the cross-hatching of radial and spiral ridges in post-apical whorls.

Chamalycaeus microdiscus (von Möllendorff, 1886)

Figure 5F

Materials examined. Prk 23 G. Rapat: BOR/MOL 10206.Prk 01 G. Tempurung: BOR/MOL 11236, BOR/MOL 11420.

Distribution. Known from Bukit Pondok (Maassen 2001) and Kinta Valley, Perak only.

Remarks. Shell small. Distinguished from congeners by its elongated shell at apical view, position of the pneumatophore and prominent spiral ribs at all whorls. New record for Kinta Valley.

Chamalycaeus oligopleuris (von Möllendorff, 1886)

Figure 6A

Materials examined. Prk 55 G. Pondok: BOR/MOL 11616.

Distribution. Known from Gunung Pondok only.

Remarks. Shell shape similar to *Chamalycaeus diplochilus* but differ by being smaller and have more prominent, wavy radial ribs.

Chamalycaeus parvulus (von Möllendorff, 1886)

Figure 6B

Materials examined. mykarst-025: BOR/MOL 9431, BOR/MOL 9514. Prk 42 G. Bercham: BOR/MOL 9467. Prk 36 Gua Datok: BOR/MOL 10506. Prk 53 Hill KF: BOR/MOL 10781. Prk 55 G. Pondok: BOR/MOL 11615, BOR/MOL 11587.

Distribution. Known from Bukit Pondok (Maassen 2001) and Kinta Valley, Perak only.

Remarks. Shell similar size to *Chamalycaeus microdiscus* but whorls differ in being rounder and radial ribs denser and less pronounced. New record for Kinta Valley.

Genus *Crossopoma* von Martens, 1891

Crossopoma albersi (Pfeiffer, 1847)

Figure 6C

Materials examined. mykarst-027: BOR/MOL 9134.

Distribution. In Peninsular Malaysia, known from Dindings (=Manjung) and Kinta Valley, Perak (Maassen 2001). Elsewhere, in Sumatra, Indonesia (van Benthem Jutting 1959).

Remarks. Shell distinguished from all other discoid cyclophorids by the presence of a deep, tunnel-like sutural canal which begins as a tube-like peristomal folding at the suture part of the aperture.

Genus *Cyclophorus* de Montfort, 1810

Cyclophorus malayanus (Benson, 1852a)

Figure 6D

Materials examined. Prk 64 Bt Kepala Gajah: BOR/MOL 10120, BOR/MOL 10086. mykarst-184 Bat Cave: BOR/MOL 9763, BOR/MOL 9874, BOR/MOL 9794, BOR/MOL 9829. Prk 53 Hill KF: BOR/MOL 10713, BOR/MOL 10738, BOR/MOL 10655, BOR/MOL 10685. mykarst-025: BOR/MOL 9380, BOR/MOL

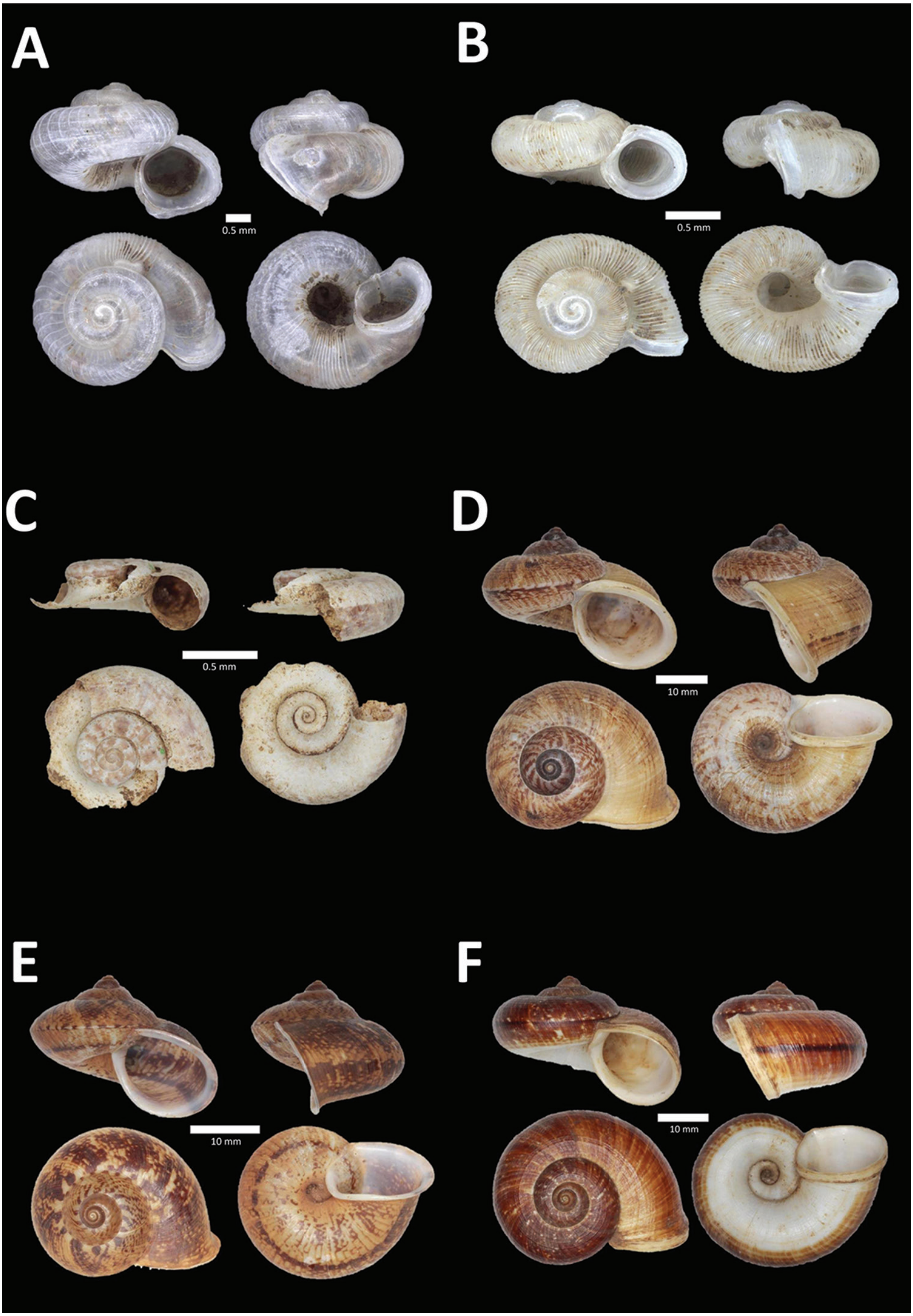

Figure 6. A *Chamalycaeus oligopleuris* (von Möllendorff, 1886) BOR/MOL 11616. Perak, Ipoh, Gunung Pondok **B** *Chamalycaeus parvulus* (von Möllendorff, 1886) BOR/MOL 11615. Perak, Ipoh, Gunung Pondok **C** *Crossopoma albersi* (Pfeiffer, 1847) BOR/MOL 9134. Perak, Ipoh, Gunung Kanthan Plot 2 **D** *Cyclophorus malayanus* (Benson, 1852a) BOR/MOL 9578. Perak, Ipoh, Batu Kebelah Plot 3 **E** *Cyclophorus perdix perdix* (Broderip & Sowerby, 1829) BOR/MOL 8274. Perak, Ipoh, Iron hill summit **F** *Cyclophorus semisulcatus* (Sowerby, 1843) BOR/MOL 9577. Perak, Ipoh, Batu Kebelah Plot 3.

9404, BOR/MOL 9437, BOR/MOL 9499, BOR/MOL 12433. mykarst-027: BOR/MOL 9047, BOR/MOL 9105. Prk 47 Kanthan: BOR/MOL 9066, BOR/MOL 9140. Prk 42 G. Bercham: BOR/MOL 9210, BOR/MOL 10568, BOR/MOL 10612, BOR/MOL 10628. mykarst-185 Batu Kebelah: BOR/MOL 9523, BOR/MOL 9560, BOR/MOL 9569, BOR/MOL 9578. Prk 36 Gua Datok: BOR/MOL 10414, BOR/MOL 10440. Prk 01 G. Tempurung: BOR/MOL 11130, BOR/MOL 11209, BOR/MOL 11240, BOR/MOL 11407. Prk 55 G. Pondok: BOR/MOL 11500, BOR/MOL 11476. Prk 34 G. Tasek: BOR/MOL 11059, BOR/MOL 11170.

Distribution. Known from Langkawi (Kedah), Penang, Kelantan and Perak only (Maassen 2001).

Remarks. Distinguished from congeners by its large shell, indistinct sculpture, rounded periphery and more thickened, expanded peristome. Colour pattern highly variable.

Cyclophorus perdix perdix (Broderip & Sowerby, 1829)

Figure 6E

Materials examined. Prk 23 G. Rapat: BOR/MOL 10226, BOR/MOL 10201. Prk 36 Gua Datok: BOR/MOL 10496. Prk 01 G. Tempurung: BOR/MOL 11131, BOR/MOL 11241.

Distribution. In Peninsular Malaysia, known from Pahang (Maassen 2001). Elsewhere, in Sumatra and Java, Indonesia (van Benthem Jutting 1941, 1959).

Remarks. Distinguished from congeners by its smaller shell, indistinct sculpture, somewhat keeled periphery and fine, complex brown mottled pattern.

Cyclophorus semisulcatus (Sowerby, 1843)

Figure 6F

Materials examined. Prk 64 Bt Kepala Gajah: BOR/MOL 10119, BOR/MOL 10085, BOR/MOL 10132, BOR/MOL 10163. mykarst-027: BOR/MOL 9048. Prk 23 G. Rapat: BOR/MOL 10224, BOR/MOL 10200, BOR/MOL 10248. Prk 47 Kanthan: BOR/MOL 9139. mykarst-185 Batu Kebelah: BOR/MOL 9524, BOR/MOL 9559, BOR/MOL 9577. Prk 36 Gua Datok: BOR/MOL 10448. Prk 42 G. Bercham: BOR/MOL 10588. Prk 55 G. Pondok: BOR/MOL 11501, BOR/MOL 11533, BOR/MOL 11475.

Distribution. In Peninsular Malaysia, known from Pahang, Kelantan, Selangor and Perak only (Maassen 2001).

Remarks. Distinguished from congeners by its small to large shell, pronounced spiral ridges and somewhat keeled periphery. Colour pattern highly variable.

Genus *Lagocheilus* Blanford, 1864

Lagocheilus 'kinta 1'

Figure 7A

Materials examined. Prk 53 Hill KF: BOR/MOL 10721, BOR/MOL 10677. mykarst-184 Bat Cave: BOR/MOL 9771, BOR/MOL 9813. Prk 36 Gua Datok: BOR/MOL 10421, BOR/MOL 10449, BOR/MOL 10481, BOR/MOL 10500. Prk 42 G. Bercham: BOR/MOL 10598. Prk 01 G. Tempurung: BOR/MOL 11238, BOR/MOL 11394, BOR/MOL 11427.

Distribution. Known from Kinta Valley only.

Remarks. Shell small, conical. Spire tall. Rounded dorsal whorls with numerous spiral ridges. Distinguished from *Lagocheilus kobelti* by its circular and flat peristome.

Lagocheilus kobelti Sykes, 1903

Figure 7B

Materials examined. Prk 64 Bt Kepala Gajah: BOR/MOL 10095, BOR/MOL 10138, BOR/MOL 10167. Prk 55 G. Pondok: BOR/MOL 11527, BOR/MOL 11482, BOR/MOL 11541, BOR/MOL 11575.

Distribution. Known from Gunung Pondok only. Elsewhere, in Jalor (=Yala), Thailand (Maassen 2001).

Remarks. Shell small, conical. Spire tall. Dorsal whorl angled at mid-distance between periphery and suture, in a region termed major spiral rib by Solem (1966). Differ from *Lagocheilus townsendi* in having a narrower penultimate whorl. New record for Perak.

Lagocheilus 'pondok 1'

Figure 7C

Materials examined. Prk 55 G. Pondok: BOR/MOL 11576.

Distribution. Known from Gunung Pondok only, but surrounding hills have yet to be adequately surveyed.

Remarks. Shell small, conical. Spire tall. Whorls convex, smooth with fine radial growth lines. Periphery keeled. Differ from congeners in the absence of spiral ridges.

Lagocheilus townsendi Crosse, 1879a

Figure 7D

Materials examined. Prk 47 Kanthan: BOR/MOL 9178, BOR/MOL 9052. mykarst-027: BOR/MOL 9095, BOR/MOL 9024.

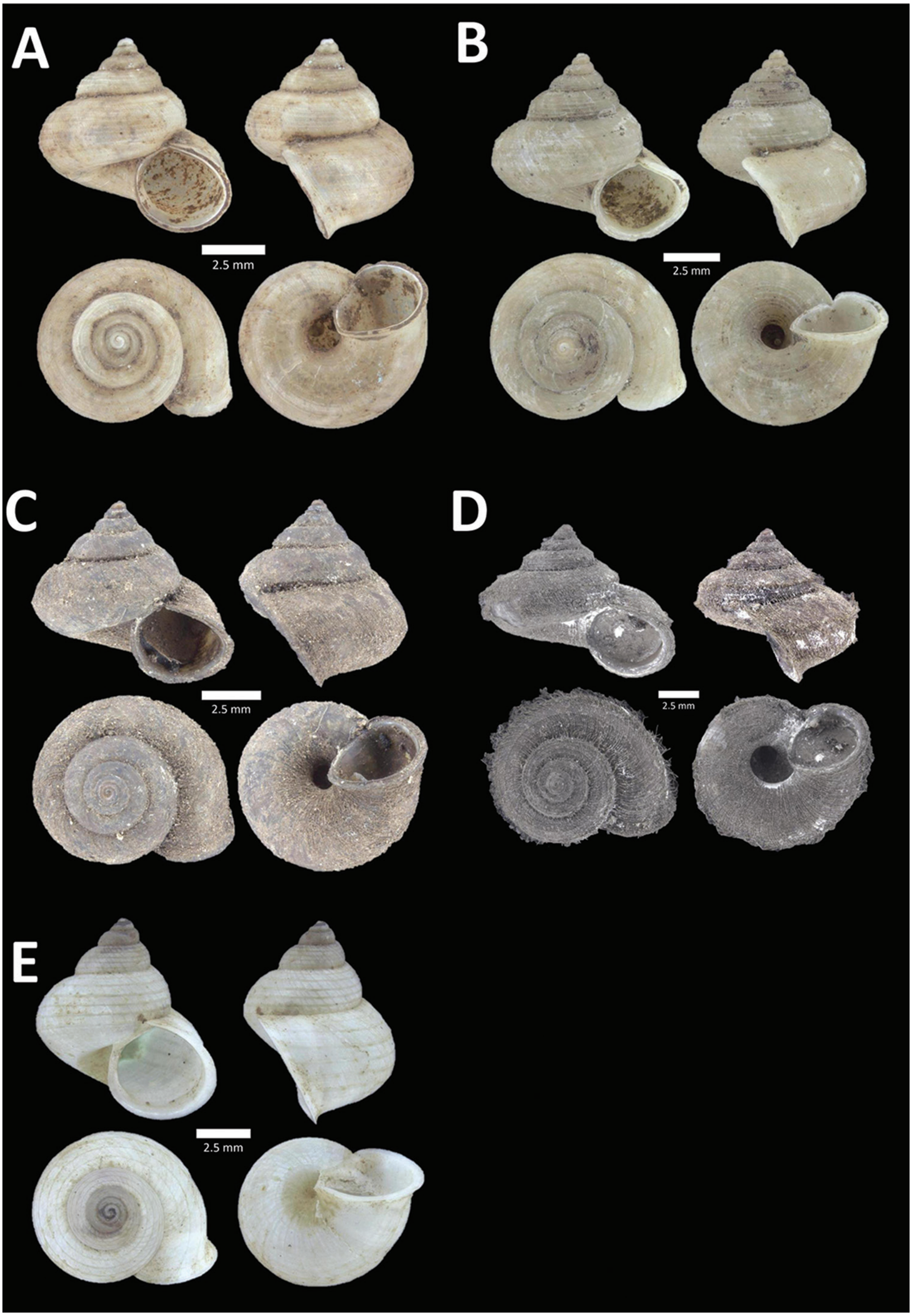

Figure 7. A *Lagochilus* 'kinta 1' BOR/MOL 10421. Perak, Ipoh, Gunung Datok Plot 2 **B** *Lagochilus kobelti* Sykes, 1903 BOR/MOL 10167. Perak, Ipoh, Gua Tok Giring Plot 4 **C** *Lagochilus* 'pondok 1' BOR/MOL 11576. Perak, Ipoh, Gunung Pondok, plot 6 **D** *Lagochilus townsendi* Crosse, 1879a BOR/MOL 9052. Perak, Ipoh, Gunung Kanthan Plot 3 **E** *Leptopoma aspirans* (Benson, 1856) BOR/MOL 8087. Perak, Ipoh, forested slope behind village at Gunung Pondok.

Distribution. Known from Perlis, Perak and Selangor only (Maassen 2001).

Remarks. Shell small, conical. Spire tall. Similar to *Lagocheilus kobelti* in the presence of angled dorsal whorls at major spiral rib but penultimate whorl is more expanded and shell larger (Sykes 1903).

Genus *Leptopoma* Pfeiffer, 1847

Leptopoma aspirans (Benson, 1856)

Figure 7E

Materials examined. Prk 55 G. Pondok: BOR/MOL 11537.

Distribution. In Peninsular Malaysia, known from Perlis and Perak (Maassen 2001). Elsewhere, in Tenasserim (=Tanintharyi), Myanmar and Jalor (=Yala), Thailand (Maassen 2001).

Remarks. Shell small, conical. Dorsal whorls with widely spaced, indistinct brown spiral ridges. Distinguished from *Leptopoma perlucidum* (de Grateloup, 1840) by its taller spire relative to shell width. This is an arboreal species.

Genus *Opisthoporus* Pfeiffer, 1851

Opisthoporus penangensis (Stoliczka, 1872)

Figure 8A

Materials examined. Prk 64 Bt Kepala Gajah: BOR/MOL 10101, BOR/MOL 10127, BOR/MOL 10134, BOR/MOL 10173. Prk 55 G. Pondok: BOR/MOL 11505, BOR/MOL 11478, BOR/MOL 11535.

Distribution. In Peninsular Malaysia, known from Penang, Perak and Kelantan (Maassen 2001). Elsewhere, in Pattani, Thailand (Maassen 2001).

Remarks. Distinguished from *Opisthoporus rostellatus* (Pfeiffer, 1851) by the pneumatophore being nearer to the aperture and the absence of a wing-like sutural extension at the peristome.

Opisthoporus rostellatus (Pfeiffer, 1851)

Figure 8B

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9834. Prk 36 Gua Datok: BOR/MOL 10416, BOR/MOL 10444, BOR/MOL 10475, BOR/MOL 10488. Prk 42 G. Bercham: BOR/MOL 10595. Prk 01 G. Tempurung: BOR/MOL 11132, BOR/MOL 11212, BOR/MOL 11410.

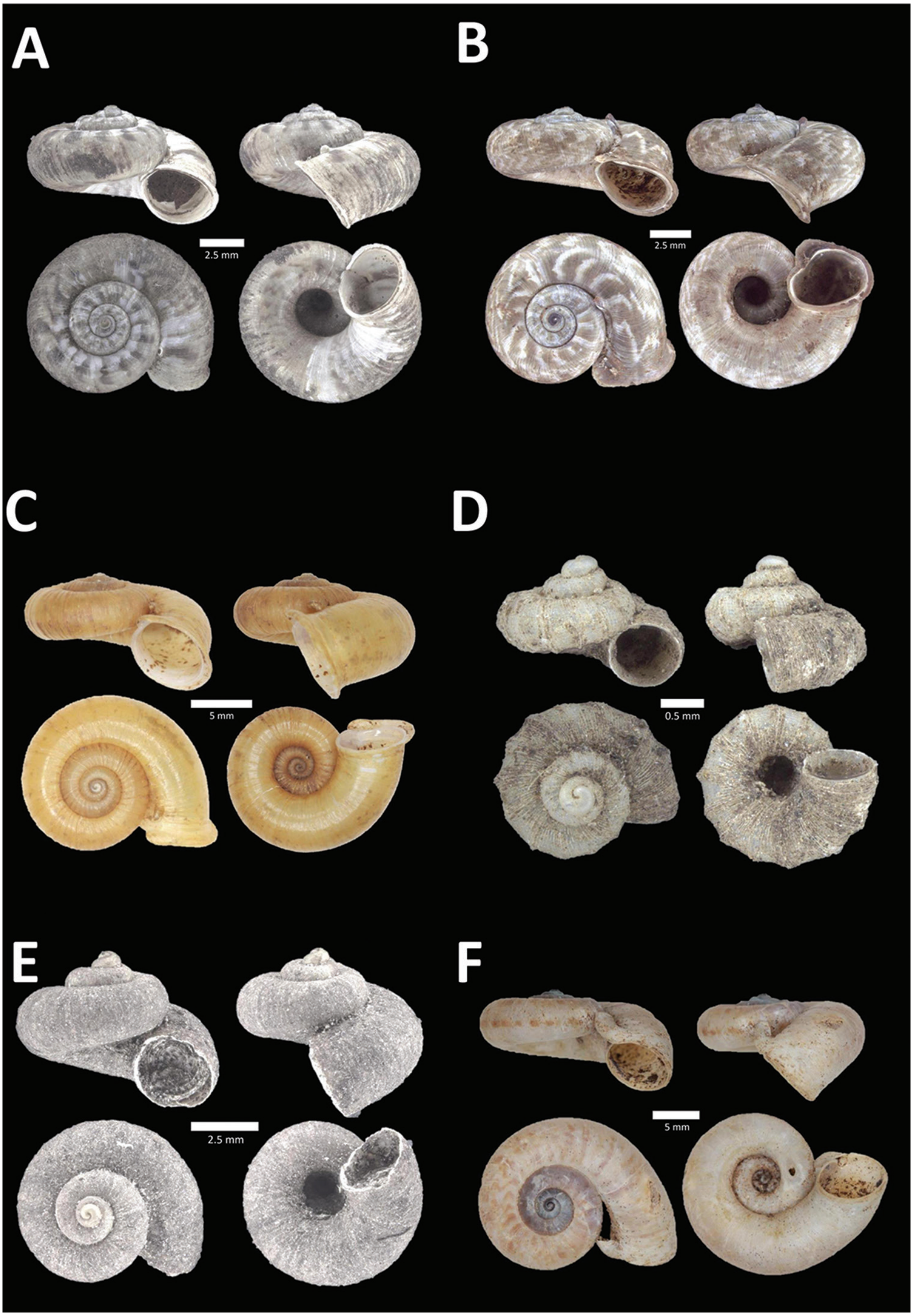

Figure 8. A *Opisthoporus penangensis* (Stoliczka, 1872) BOR/MOL 10101. Perak, Ipoh, Gua Tok Giring Plot 1 **B** *Opisthoporus rostellatus* (Pfeiffer, 1851) BOR/MOL 11410. Perak, Ipoh, Gunung Tempurung Plot 4 **C** *Opisthoporus solutus* (Stoliczka, 1872) BOR/MOL 11534. Perak, Ipoh, Gunung Pondok, plot 4 **D** *Platyraphe* 'BatuKebelah 1' BOR/MOL 10187. Perak, Ipoh, Gua Tok Giring Plot 4 **E** *Platyraphe lowi* (de Morgan, 1885a) BOR/MOL 9407. Perak, Ipoh, Mykarst-025 Plot 2 **F** *Rhiostoma jousseaumei* de Morgan, 1885b BOR/MOL 10225. Perak, Ipoh, Gunung Rapat Plot C6.

Distribution. In Peninsular Malaysia, known from Perak (Maassen 2001). Elsewhere, in Singapore (Maassen 2001).

Remarks. Distinguished from *Opisthoporus penangensis* (Stoliczka, 1872) by the pneumatophore being longer and further from the aperture and the presence of a wing-like sutural extension at the peristome.

Opisthoporus solutus (Stoliczka, 1872)

Figure 8C

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9892, BOR/MOL 9810. Prk 36 Gua Datok: BOR/MOL 10065, BOR/MOL 10473, BOR/MOL 10489. Prk 64 Bt Kepala Gajah: BOR/MOL 10107, BOR/MOL 10133, BOR/MOL 10164. Prk 55 G. Pondok: BOR/MOL 11504, BOR/MOL 11534, BOR/MOL 11477, BOR/MOL 11552, BOR/MOL 11566, BOR/MOL 11577.

Distribution. Known from Penang and Perak only (Maassen 2001).

Remarks. Differ from sympatric congeners by its patternless white shell and the yellow periostracum with equidistant spiral periostracal ridges.

Genus *Platyraphe* von Möllendorff, 1890

Platyraphe 'batukebelah 1'

Figure 8D

Materials examined. mykarst-185 Batu Kebelah: BOR/MOL 9752. Prk 64 Bt Kepala Gajah: BOR/MOL 10097, BOR/MOL 10146, BOR/MOL 10187.

Distribution. Known from Batu Kebelah and Bukit Kepala Gajah, Perak only, but surrounding hills have yet to be adequately surveyed.

Remarks. Very small shell at maturity compared to all congeners. Shell discoid. Medium spire. Fine spiral ridges and radial ridges interspersed with major radial ridges at regular intervals. Often encrusted with mud and plant debris.

Platyraphe lowi (de Morgan, 1885a)

Figure 8E

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9891. Prk 53 Hill KF: BOR/MOL 10711, BOR/MOL 10742, BOR/MOL 10661, BOR/MOL 10691. mykarst-025: BOR/MOL 9385, BOR/MOL 9407, BOR/MOL 9484, BOR/MOL 9506. Prk 47 Kanthan: BOR/MOL 9058, BOR/MOL 9136. mykarst-027: BOR/MOL 9094, BOR/MOL 9012. Prk 42 G. Bercham: BOR/MOL 9459, BOR/MOL

9462, BOR/MOL 9222, BOR/MOL 9233, BOR/MOL 10574, BOR/MOL 10592, BOR/MOL 10613, BOR/MOL 10624. Prk 23 G. Rapat: BOR/MOL 10207, BOR/MOL 10052, BOR/MOL 10238, BOR/MOL 10249. mykarst-185 Batu Kebelah: BOR/MOL 9530, BOR/MOL 9563, BOR/MOL 9751. Prk 64 Bt Kepala Gajah: BOR/MOL 10106, BOR/MOL 10126, BOR/MOL 10135, BOR/MOL 10172. Prk 36 Gua Datok: BOR/MOL 10420, BOR/MOL 10445, BOR/MOL 10476, BOR/MOL 10490. Prk 34 G. Tasek: BOR/MOL 10787, BOR/MOL 11030, BOR/MOL 11064. Prk 01 G. Tempurung: BOR/MOL 11140, BOR/MOL 11215, BOR/MOL 11244, BOR/MOL 11411. Prk 55 G. Pondok: BOR/MOL 11502, BOR/MOL 11459, BOR/MOL 11536, BOR/MOL 11578.

Distribution. In Peninsular Malaysia, found in Perlis, Perak and Selangor (Maassen 2001). Elsewhere, in Pattani, Thailand (Maassen 2001).

Remarks. Distinct from *Platyraphe* 'batukebelah 1' in being much larger and has fine radial growth lines. Shell discoid. Low to medium spire. Often encrusted with solidified mud in a consistent, angular fashion when alive.

Genus *Rhiostoma* Benson, 1860

Rhiostoma jousseaumei de Morgan, 1885b

Figure 8F

Materials examined. Prk 47 Kanthan: BOR/MOL 9179, BOR/MOL 9069, BOR/MOL 9059, BOR/MOL 9135.mykarst-027: BOR/MOL 9088, BOR/MOL 9109, BOR/MOL 9029, BOR/MOL 9031.Prk 53 Hill KF: BOR/MOL 10720, BOR/MOL 10662.mykarst-025: BOR/MOL 9386, BOR/MOL 9418, BOR/MOL 9490, BOR/MOL 9507, BOR/MOL 12423.Prk 42 G. Bercham: BOR/MOL 9470, BOR/MOL 9482, BOR/MOL 9208, BOR/MOL 9227, BOR/MOL 9229, BOR/MOL 9230, BOR/MOL 9232, BOR/MOL 10572, BOR/MOL 10594, BOR/MOL 10614, BOR/MOL 10625, BOR/MOL 10639.Prk 23 G. Rapat: BOR/MOL 10225, BOR/MOL 10055, BOR/MOL 10203, BOR/MOL 10250, BOR/MOL 10270. Prk 36 Gua Datok: BOR/MOL 10417, BOR/MOL 10442, BOR/MOL 10472, BOR/MOL 10491.Prk 34 G. Tasek: BOR/MOL 10786, BOR/MOL 11026, BOR/MOL 11010, BOR/MOL 11040, BOR/MOL 11053.

Distribution. Restricted to Kinta Valley.

Remarks. Shell small to medium-sized. Final whorl occasionally detached, with large upturned pneumatophore formed through peristomal folding. Shell patterns vary from dense zigzags and peripheral band over brown whorls to fugitive brown zigzags over white or purple whorls. *Rhiostoma macalpinewoodsi* (Laidlaw 1939) is synonymous with *Rhiostoma jousseaumei*, as intermediates were found in our study sites.

Family Diplommatinidae Pfeiffer, 1856
Genus *Arinia* Adams & Adams, 1856
Subgenus *Notharinia* Vermeulen, Phung & Truong, 2007

Arinia (*Notharinia*) *micro* Marzuki & Foon, 2016
Figure 9A

Materials examined. Prk 23 G. Rapat: BOR/MOL 10288.

Distribution. Known from Gunung Rapat only, but surrounding hills have yet to be adequately surveyed.

Remarks. Shell dextral, very small. Cylindrical, tall spire. Radial ribs dense, spiral ridges very fine. Differ from *Arinia* (*Notharinia*) 'tasek 1' in the final whorl being less detached.

Arinia (*Notharinia*) 'tasek 1'
Figure 9B

Materials examined. Prk 34 G. Tasek: BOR/MOL 11166, BOR/MOL 11193.

Distribution. Known from Gunung Tasek only, but surrounding hills have yet to be adequately surveyed.

Remarks. Shell dextral, very small. Cylindrical, tall spire. Radial ribs dense, spiral ridges very fine. Differ from *Arinia* (*Notharinia*) *micro* in that the final whorl is completely detached and coiled downwards.

Genus *Diplommatina* Benson, 1849

Diplommatina cf. *diminuta*
Figure 9C

Materials examined. mykarst-027: BOR/MOL 9113, BOR/MOL 9023.

Distribution. Known from mykarst-027 only, but surrounding hills have yet to be adequately surveyed.

Remarks. Shell sinistral. Shell very similar to *Diplommatina diminuta* von Möllendorff, 1891 but differ in having denser radial ribs.

Diplommatina crosseana Godwin-Austen & Nevill, 1879
Figure 9D

Materials examined. Prk 47 Kanthan: BOR/MOL 9087. mykarst-184 Bat Cave: BOR/MOL 9850. mykarst-027: BOR/MOL 9021.

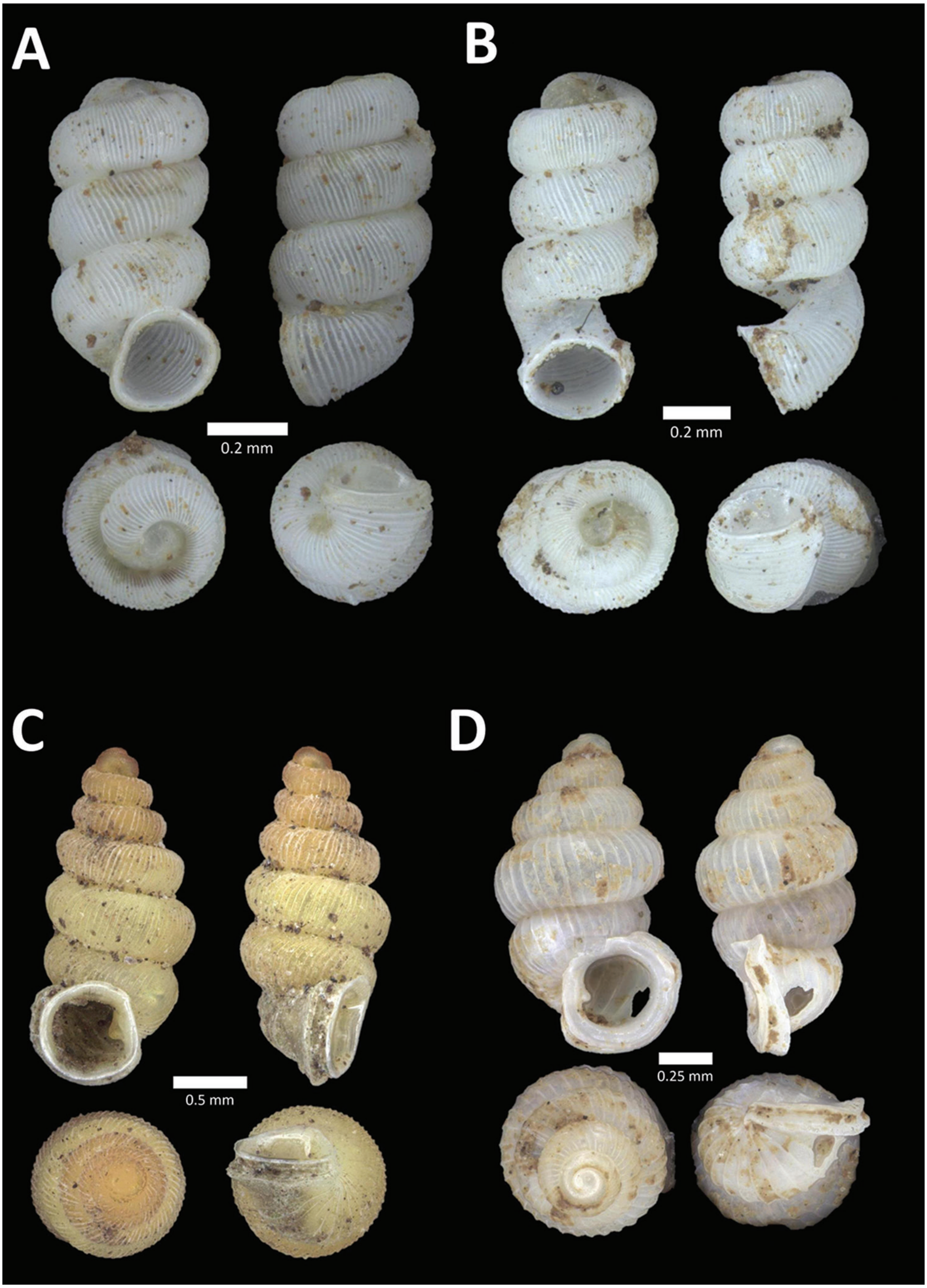

Figure 9. A *Arinia* (*Notharinia*) *micro* Marzuki & Foon, 2016 BOR/MOL 10288. Perak, Ipoh, Gunung Rapat **B** *Arinia* (*Notharinia*) 'tasek 1' BOR/MOL 11193. Perak, Ipoh, Gunung Tasek Plot 2 **C** *Diplommatina* cf. *diminuta* BOR/MOL 9023. Perak, Ipoh, Gunung Kanthan Plot 1.D. *Diplommatina crosseana* Godwin-Austen & Nevill, 1879 BOR/MOL 9021. Perak, Ipoh, Gunung Kanthan.

Distribution. Known from upper Kinta Valley and Perak River valley, Perak only (Maassen 2001).

Remarks. Shell dextral. Smallest shell of all congeners. Also differ from congeners by the peristome that is reflected and thickened multiple times, sharply angular at the base of the columella and slightly angular at the upper outer lip (Laidlaw 1949). Davison (1991) considers *D. crosseana* as possibly related to *Diplommatina maduana* Laidlaw, 1949.

Diplommatina lenggongensis Tomlin, 1941

Figure 10A

Materials examined. Prk 64 Bt Kepala Gajah: BOR/MOL 10111, BOR/MOL 10153, BOR/MOL 10191.

Distribution. Restricted to karsts in Lenggong, Perak only (Maassen 2001).

Remarks. Shell sinistral. Shell large among congeners. The characters distinguishing *Diplommatina lenggongensis* from congeners: Spire very tall, slender. Suture deep. Radial ribs pronounced, extending outwards as a triangular protrusion along the periphery.

Diplommatina nevilli Crosse, 1879a

Figure 10B

Materials examined. Prk 53 Hill KF: BOR/MOL 10698, BOR/MOL 10749, BOR/MOL 10732, BOR/MOL 10680, BOR/MOL 10783. mykarst-184 Bat Cave: BOR/MOL 9884, BOR/MOL 9783, BOR/MOL 9820, BOR/MOL 9848. Prk 64 Bt Kepala Gajah: BOR/MOL 10112, BOR/MOL 10113, BOR/MOL 10123, BOR/MOL 10155, BOR/MOL 10156, BOR/MOL 10190. mykarst-025: BOR/MOL 9389, BOR/MOL 9422, BOR/MOL 9423, BOR/MOL 9441, BOR/MOL 9442, BOR/MOL 9511. Prk 47 Kanthan: BOR/MOL 9062, BOR/MOL 9170. mykarst-027: BOR/MOL 9114, BOR/MOL 9020. Prk 42 G. Bercham: BOR/MOL 9481, BOR/MOL 9218, BOR/MOL 9235, BOR/MOL 10576, BOR/MOL 10609, BOR/MOL 10617, BOR/MOL 10640. mykarst-185 Batu Kebelah: BOR/MOL 9532, BOR/MOL 9744. Prk 23 G. Rapat: BOR/MOL 10033. Prk 36 Gua Datok: BOR/MOL 10068, BOR/MOL 10432, BOR/MOL 10463, BOR/MOL 10470. Prk 01 G. Tempurung: BOR/MOL 11154, BOR/MOL 11235, BOR/MOL 11402, BOR/MOL 11403, BOR/MOL 11429. Prk 34 G. Tasek: BOR/MOL 11159, BOR/MOL 11014, BOR/MOL 11015, BOR/MOL 11048, BOR/MOL 11049, BOR/MOL 11189. Prk 55 G. Pondok: BOR/MOL 11494, BOR/MOL 11495, BOR/MOL 11514, BOR/MOL 11584, BOR/MOL 11588, BOR/MOL 11555.

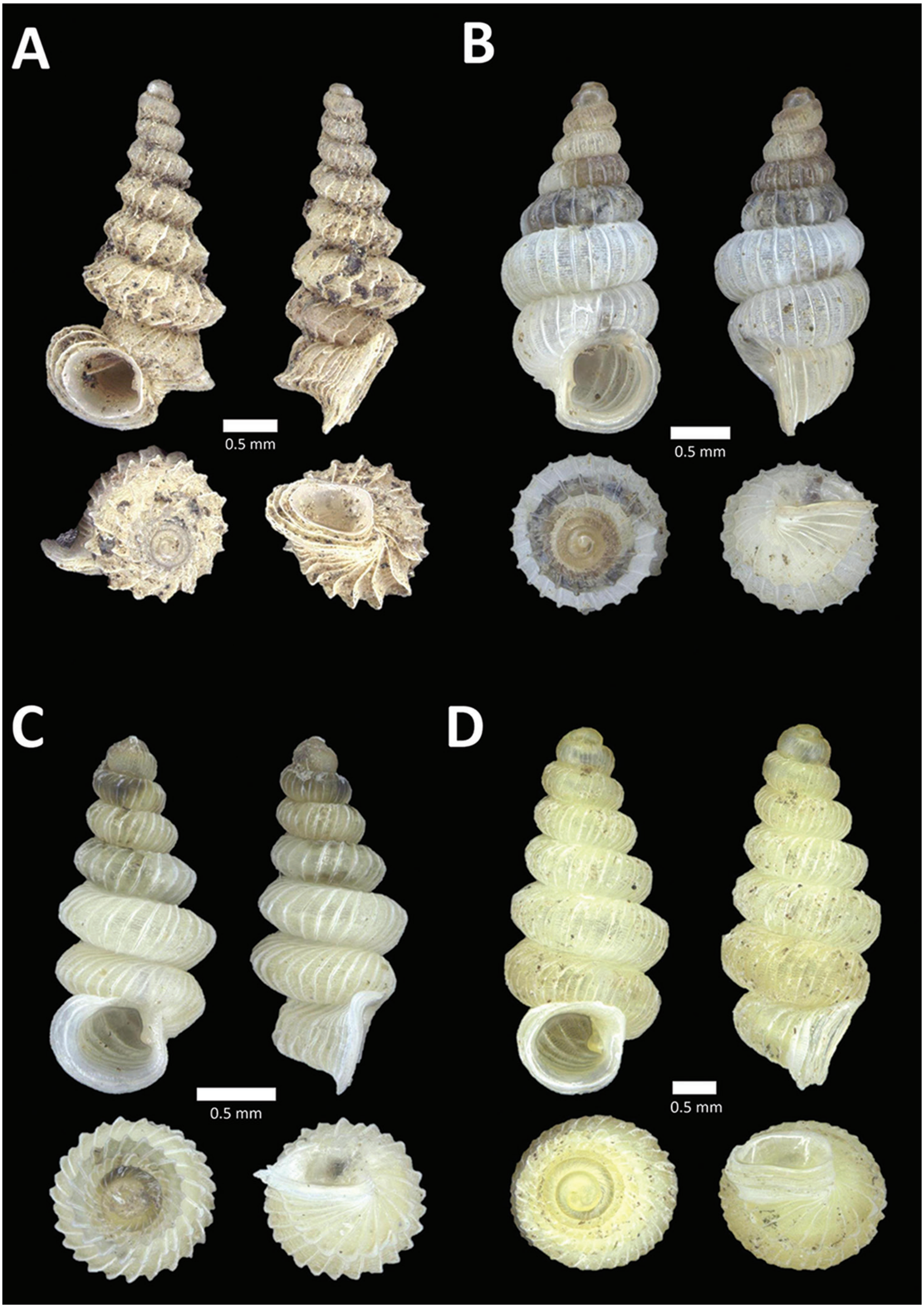

Figure 10. A *Diplommatina lenggongensis* Laidlaw, 1941 BOR/MOL 10111. Perak, Ipoh, Gua Tok Giring Plot 1 **B** *Diplommatina nevilli* Crosse, 1879a BOR/MOL 9532. Perak, Ipoh, Batu Kebelah Plot 1 **C** *Diplommatina parabates* Laidlaw, 1949 BOR/MOL 11556. Perak, Ipoh, Gunung Pondok, plot 4 **D** *Diplommatina sinistra* Tomlin, 1938 BOR/MOL 9074. Perak, Ipoh, Gunung Kanthan Plot 3.

Distribution. Found across Peninsular Malaysia (Maassen 2001). Elsewhere, in Singapore, Thailand and Indonesia (Ho 1995, Panha and Burch 2005, van Benthem Jutting 1941, 1959).

Remarks. Shell dextral, rarely sinistral. Shell vary greatly in height, rib density, number of whorls (7 to 8) and aperture thickness within and between populations. After examining large samples from our study sites, we concur with Tweedie in Laidlaw (1949) that it is not possible to separate *Diplommatina canaliculata* von Möllendorff, 1886 from *Diplommatina nevilli*. The specimens labelled as *Diplommatina mirabilis* in Davison (1991) are actually *Diplommatina nevilli*.

Diplommatina parabates Laidlaw, 1949

Figure 10C

Materials examined. Prk 64 Bt Kepala Gajah: BOR/MOL 10152. Prk 55 G. Pondok: BOR/MOL 11492, BOR/MOL 11515, BOR/MOL 11517, BOR/MOL 11585, BOR/MOL 11556.

Distribution. Known from Lenggong and Gunung Pondok, Perak only.

Remarks. Shell sinistral. Shell distinctly different from sympatric congeners by the rounder periphery, less pronounced spiral ribs and shallower suture. New record for Gunung Pondok.

Diplommatina sinistra Tomlin, 1938

Figure 10D

Materials examined. Prk 47 Kanthan: BOR/MOL 9074, BOR/MOL 9149. mykarst-184 Bat Cave: BOR/MOL 9893, BOR/MOL 9785, BOR/MOL 9847. Prk 42 G. Bercham: BOR/MOL 9456, BOR/MOL 10653. mykarst-185 Batu Kebelah: BOR/MOL 9754. Prk 34 G. Tasek: BOR/MOL 11018.

Distribution. Restricted to Upper Kinta Valley, Perak only.

Remarks. Shell sinistral. Differ from sympatric *Diplommatina diminuta* in having shorter spire, more widely spaced radial ribs and more slender shell. Previously known solely from Sungai Siput North (Maassen 2001).

Diplommatina streptophora Laidlaw, 1949

Figure 11A

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9882, BOR/MOL 9784. Prk 47 Kanthan: BOR/MOL 9061, BOR/MOL 9166. Prk 23 G. Rapat: BOR/MOL 10216, BOR/MOL 10037, BOR/MOL 10246, BOR/MOL 10263. mykarst-027: BOR/MOL 9120, BOR/MOL 9025. mykarst-185 Batu Kebelah: BOR/MOL 9533,

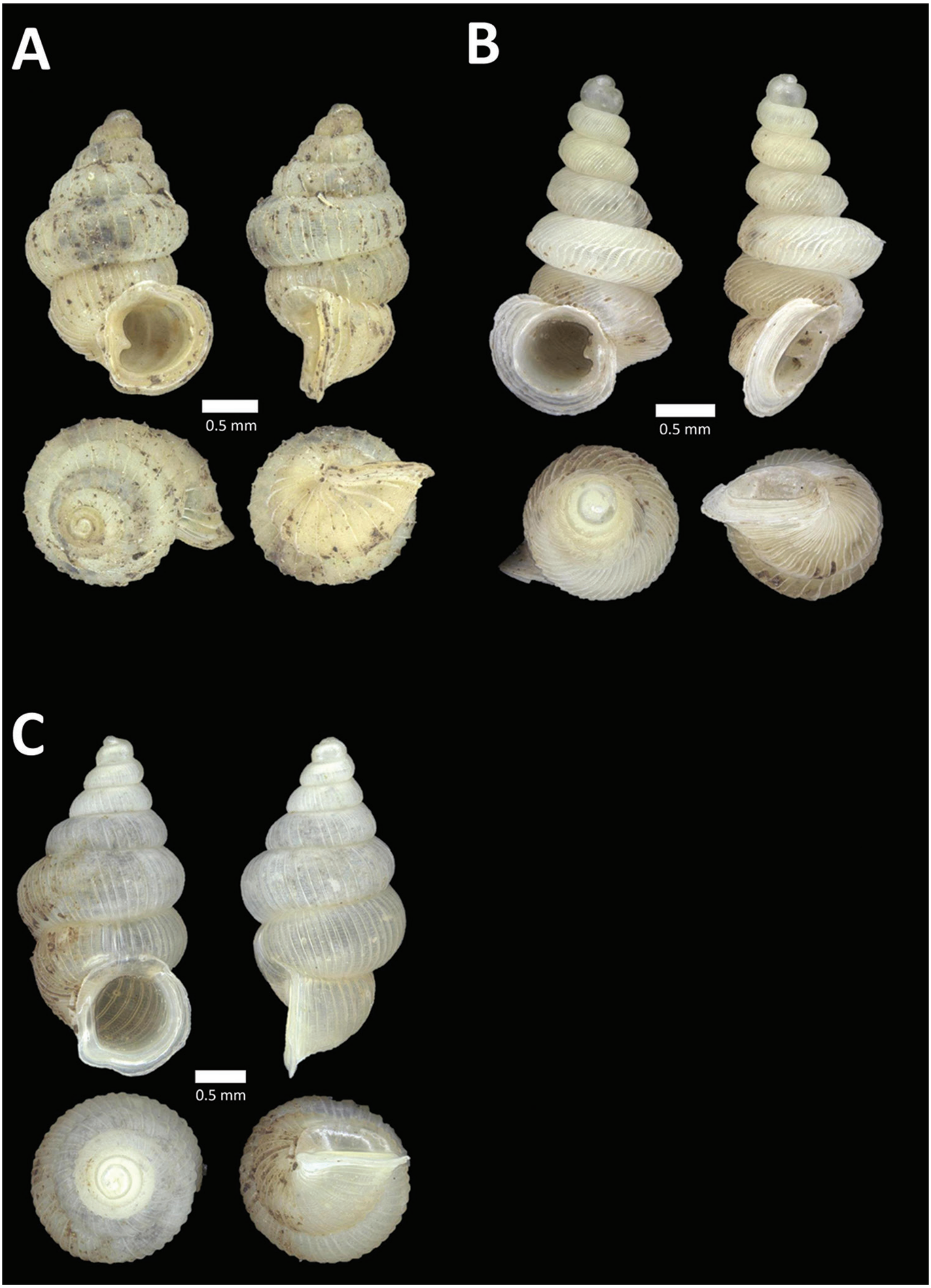

Figure 11. A *Diplommatina streptophora* Laidlaw, 1949 BOR/MOL 9061. Perak, Ipoh, Gunung Kanthan Plot 3 **B** *Diplommatina superba superba* Godwin-Austen & Nevill, 1879 BOR/MOL 11557. Perak, Ipoh, Gunung Pondok **C** *Diplommatina ventriculus* (von Möllendorff, 1891) BOR/MOL 9027. Perak, Ipoh, Gunung Kanthan.

BOR/MOL 9746. Prk 36 Gua Datok: BOR/MOL 10069, BOR/MOL 10468. Prk 64 Bt Kepala Gajah: BOR/MOL 10158.

Distribution. Found throughout Perak only (Maassen 2001).

Remarks. Shell dextral, rarely sinistral. Distinct from all sympatric congeners by its rather distended ultimate whorl and reflected aperture which extends to the right of the body whorl. Sinistral specimens of this species were labelled as *Diplommatina* sp. in Davison (1991).

Diplommatina superba superba Godwin-Austen & Nevill, 1879

Figure 11B

Materials examined. Prk 47 Kanthan: BOR/MOL 9181, BOR/MOL 9063. Prk 53 Hill KF: BOR/MOL 10709, BOR/MOL 10733, BOR/MOL 10747, BOR/MOL 10682. Prk 23 G. Rapat: BOR/MOL 10217, BOR/MOL 10039, BOR/MOL 10247, BOR/MOL 10272. mykarst-027: BOR/MOL 9123, BOR/MOL 9017. mykarst-185 Batu Kebelah: BOR/MOL 9745. Prk 64 Bt Kepala Gajah: BOR/MOL 10154. Prk 36 Gua Datok: BOR/MOL 10435, BOR/MOL 10464. Prk 42 G. Bercham: BOR/MOL 10611. Prk 01 G. Tempurung: BOR/MOL 11153, BOR/MOL 11233, BOR/MOL 11406, BOR/MOL 11428. Prk 34 G. Tasek: BOR/MOL 11165. Prk 55 G. Pondok: BOR/MOL 11516, BOR/MOL 11586, BOR/MOL 11557.

Distribution. Known from Gunung Pondok and Kinta Valley only (Maassen 2001).

Remarks. Shell sinistral. Shell vary greatly in height and width, rib density, rib height and aperture thickness within and between populations. Consistent features are keeled periphery and whorl shape. After examining large samples from our study sites, we conclude that it is not possible to separate *Diplommatina superba superba* from *Diplommatina superba brevior* Laidlaw, 1949.

Diplommatina ventriculus (von Möllendorff, 1891)

Figure 11C

Materials examined. Prk 53 Hill KF: BOR/MOL 10703, BOR/MOL 10745, BOR/MOL 10725, BOR/MOL 10681. mykarst-184 Bat Cave: BOR/MOL 9883, BOR/MOL 9821. Prk 47 Kanthan: BOR/MOL 9180, BOR/MOL 9086. Prk 23 G. Rapat: BOR/MOL 10219, BOR/MOL 10265. mykarst-027: BOR/MOL 9117, BOR/MOL 9018, BOR/MOL 9027. Prk 64 Bt Kepala Gajah: BOR/MOL 10157. Prk 55 G. Pondok: BOR/MOL 11493, BOR/MOL 11518, BOR/MOL 11554, BOR/MOL 11582. Prk 34 G. Tasek: BOR/MOL 11191. Prk 01 G. Tempurung: BOR/MOL 11234, BOR/MOL 11404.

Distribution. Found throughout Peninsular Malaysia (Maassen 2001). Elsewhere, in Sumatra, Indonesia (van Benthem Jutting 1959).

Remarks. Shell dextral, rarely sinistral. Distinguished from other sympatric dextral congeners by its large shell, more globular whorls and weak columellar tooth.

Genus *Opisthostoma* Blanford & Blanford, 1860

Opisthostoma castor van Benthem Jutting, 1952

Figure 12A

Materials examined. Prk 64 Bt Kepala Gajah: BOR/MOL 10115, BOR/MOL 10147, BOR/MOL 10193.

Distribution. Restricted to Lenggong, Perak only (Maassen 2001).

Remarks. See the Remarks section of *Opisthostoma fallax*.

Opisthostoma cf. *gittenbergeri*

Figure 12B

Materials examined. Prk 47 Kanthan: BOR/MOL 9151, BOR/MOL 12496.

Distribution. Known from Gunung Kanthan only, but surrounding hills have yet to be adequately surveyed.

Remarks. Similar to *Opisthostoma gittenbergeri* in the manner of coiling for the penultimate and ultimate whorls. Differ from *O. gittenbergeri* in wider whorl coiling and position of apical and antepenultimate whorls. Radial rib density is variable.

Opisthostoma cf. *subconicum*

Figure 12C

Materials examined. Prk 47 Kanthan: BOR/MOL 9183.

Distribution. Known from Gunung Kanthan only, but surrounding hills have yet to be adequately surveyed.

Remarks. Similar to *Opisthostoma subconicum* Vermeulen, 1994, in shell shape, differ in having a more depressed apical whorl, less expanded peristome, more pronounced parietalis at the lower aperture and tooth at the upper aperture.

Opisthostoma cf. *vermiculum*

Figure 12D

Materials examined. Prk 01 G. Tempurung: BOR/MOL 11400.

Distribution. Known from Gunung Tempurung only, but surrounding hills have yet to be adequately surveyed.

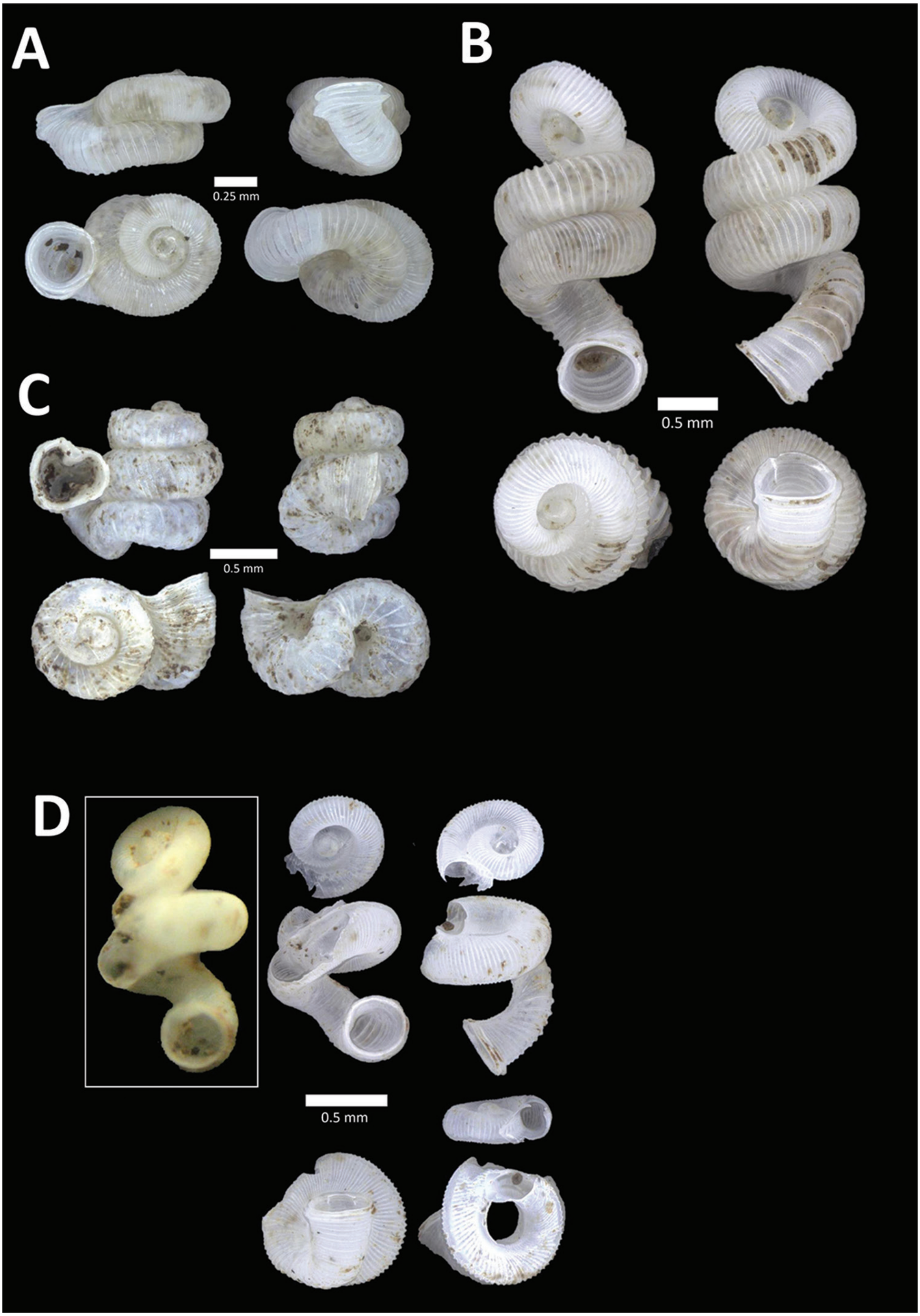

Figure 12. A *Opisthostoma castor* van Benthem Jutting, 1952 BOR/MOL 10115. Perak, Ipoh, Gua Tok Giring Plot 1 **B** *Opisthostoma* cf. *gittenbergeri* BOR/MOL 9151. Perak, Ipoh, Gunung Kanthan Plot 4 **C** *Opisthostoma* cf. *subconicum* BOR/MOL 9183. Perak, Ipoh, Gunung Kanthan Plot 4 **D** *Opisthostoma* cf. *vermiculum* BOR/MOL 11400. Perak, Ipoh, Gunung Tempurung Plot 2.

Remarks. Similar to *Opisthostoma vermiculum* in the manner of coiling for the penultimate and ultimate whorls. Differ from *O. vermiculum* in the coiling axis of apical and antepenultimate whorls.

Opisthostoma fallax van Benthem Jutting, 1961a

Figure 13A

Materials examined. mykarst-025: BOR/MOL 9420. mykarst-185 Batu Kebelah: BOR/MOL 9755, BOR/MOL 12519. Prk 01 G. Tempurung: BOR/MOL 11206, BOR/MOL 11231, BOR/MOL 12505. mykarst-184 Bat Cave: BOR/MOL 12499.

Distribution. Restricted to Kinta Valley.

Remarks. Similar to *Opisthostoma castor* in shell shape, differ in convexity of the whorl, larger umbilicus and the position of the ultimate whorl relative to the penultimate whorl (van Benthem Jutting 1961a).

Opisthostoma gittenbergeri Vermeulen & Clements, 2008

Figure 13B

Materials examined. Prk 36 Gua Datok: BOR/MOL 10452.Prk 42 G. Bercham: BOR/MOL 10604.

Distribution. Known from Gua Datok and Gunung Bercham only, but surrounding hills have yet to be adequately surveyed.

Remarks. Shell shape distinctive among congeners. Differ from *Opisthostoma* cf. *gittenbergeri* in whorl coiling being tighter and the position of apical and antepenultimate whorls.

Opisthostoma 'Kanthan 1'

Figure 13C

Materials examined. Prk 47 Kanthan: BOR/MOL 9182, BOR/MOL 9070, BOR/MOL 9060, BOR/MOL 9158, BOR/MOL 9168.mykarst-027: BOR/MOL 9115, BOR/MOL 9026. Prk 34 G. Tasek: BOR/MOL 11162, BOR/MOL 11007, BOR/MOL 11050, BOR/MOL 11187, BOR/MOL 11192.

Distribution. Known from Gunung Kanthan and Gunung Tasek only, but surrounding hills have yet to be adequately surveyed.

Remarks. Spire height, radial rib density and whorl shape variable. Differ from *Opisthostoma* cf. *subconicum* in having rounder whorls, finer but distinct radial ribs and the direction the aperture is facing.

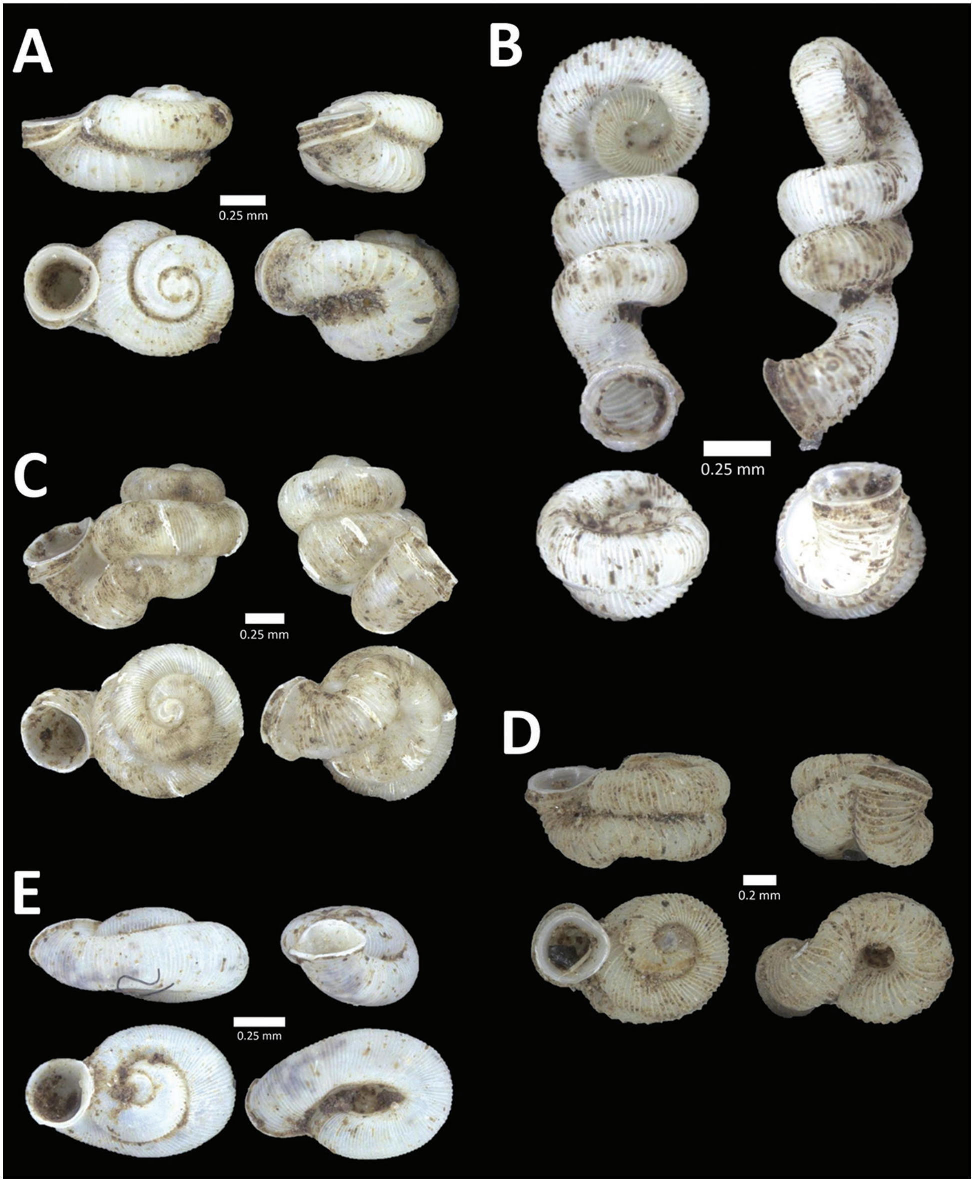

Figure 13. A *Opisthostoma fallax* van Benthem Jutting, 1961 BOR/MOL 9755. Perak, Ipoh, Batu Kebelah Plot 4 **B** *Opisthostoma gittenbergeri* Vermeulen & Clements, 2008 BOR/MOL 10452. Perak, Ipoh, Gunung Datok **C** *Opisthostoma* 'Kanthan 1' BOR/MOL 9182. Perak, Ipoh, Gunung Kanthan Plot 3 **D** *Opisthostoma megalomphalum* van Benthem Jutting, 1952 BOR/MOL 10271. Perak, Ipoh, Gunung Rapat Plot C7 **E** *Opisthostoma* 'mykarst-025 1' BOR/MOL 12506. Perak, Ipoh, Mykarst-025 Plot 4.

Opisthostoma megalomphalum van Benthem Jutting, 1952

Figure 13D

Materials examined. Prk 23 G. Rapat: BOR/MOL 10215, BOR/MOL 10035, BOR/MOL 10245, BOR/MOL 10271.

Distribution. Known from Kramat Pulai (van Benthem Jutting 1952) and Gunung Rapat only, but surrounding hills have yet to be adequately surveyed.

Remarks. Differ from other flat-shelled congeners by the convexity of the whorl, larger umbilicus, the position of apical and antepenultimate whorls and the direction the aperture is facing (van Benthem Jutting 1961a).

Opisthostoma 'mykarst-025 1'

Figure 13E

Materials examined. mykarst-025: BOR/MOL 9396, BOR/MOL 12506, BOR/MOL 12508, BOR/MOL 12520.

Distribution. Known from mykarst-025 only, but surrounding hills have yet to be adequately surveyed.

Remarks. Differ from other flat-shelled congeners by its much smaller shell and most distinctly, the coiling of the antepenultimate whorl.

Opisthostoma paulucciae (Crosse & Nevill, in Crosse 1879b)

Figure 14A

Materials examined. Prk 53 Hill KF: BOR/MOL 10697, BOR/MOL 10724, BOR/MOL 10683. mykarst-027: BOR/MOL 9130, BOR/MOL 9019. mykarst-184 Bat Cave: BOR/MOL 9849. Prk 36 Gua Datok: BOR/MOL 10082, BOR/MOL 10462. Prk 23 G. Rapat: BOR/MOL 10244. Prk 42 G. Bercham: BOR/MOL 10610. Prk 55 G. Pondok: BOR/MOL 11519, BOR/MOL 11558, BOR/MOL 11581. Prk 34 G. Tasek: BOR/MOL 11051. Prk 01 G. Tempurung: BOR/MOL 11205, BOR/MOL 11232, BOR/MOL 11401, BOR/MOL 11405.

Distribution. Known from Gunung Pondok and Kinta Valley, Perak only.

Remarks. Variable in spire height and the position of the apical whorls. Most similar to *Opisthostoma* 'Kanthan 1' but differ in the direction the aperture is facing as well as the less dense and more pronounced radial ribs.

Opisthostoma 'tempurung 1 detached'

Figure 14B

Materials examined. Prk 01 G. Tempurung: BOR/MOL 12500, BOR/MOL 12504.

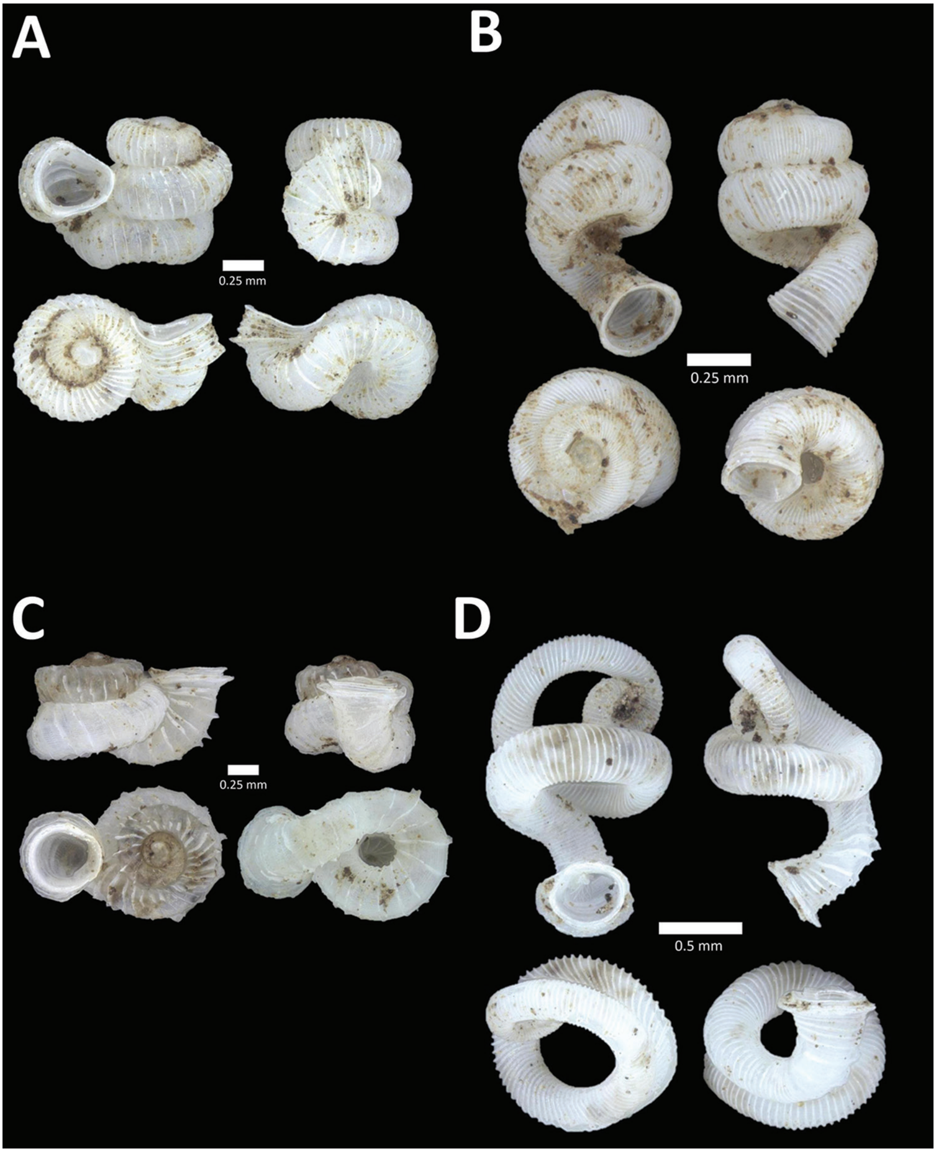

Figure 14. A *Opisthostoma paulucciae* ((Crosse and Nevill, in Crosse, 1879b)) BOR/MOL 9019. Perak, Ipoh, Gunung Kanthan **B** *Opisthostoma* 'tempurung 1 detached' BOR/MOL 12504. Perak, Ipoh, Gunung Tempurung Plot 4 **C** *Opisthostoma trapezium* van Benthem Jutting, 1952 BOR/MOL 9035. Perak, Ipoh, Gunung Kanthan **D** *Opisthostoma vermiculum* Clements and Vermeulen, in Clements et al., 2008 BOR/MOL 10242. Perak, Ipoh, Gunung Rapat.

Distribution. Known from Gunung Tempurung, but surrounding hills have yet to be adequately surveyed.

Remarks. Distinct from congeners in shell shape. Radial ribbing dense. *Opisthostoma* 'tempurung 1 detached' has a detached ultimate whorl similar to *Notharinia* 'tasek 1' but differ in having larger and less number of whorls.

Opisthostoma trapezium van Benthem Jutting, 1952

Figure 14C

Materials examined. Prk 47 Kanthan: BOR/MOL 9071, BOR/MOL 9164. mykarst-027: BOR/MOL 9035, BOR/MOL 9126. Prk 53 Hill KF: BOR/MOL 10780.mykarst-025: BOR/MOL 9397, BOR/MOL 9421, BOR/MOL 9489, BOR/MOL 9515.

Distribution. Restricted to central and upper Kinta Valley only.

Remarks. Distinguished from congeners by its box-like shell shape, pronounced but widely spaced radial ribs and the direction the aperture is facing is parallel to the coiling axis of the apical whorl. Previously known from Gunung Kanthan only (Maassen 2001).

Opisthostoma vermiculum Clements & Vermeulen, in Clements et al. 2008

Figure 14D

Materials examined. Prk 23 G. Rapat: BOR/MOL 10214, BOR/MOL 10242, BOR/MOL 10267.

Distribution. Known from Gunung Rapat only (Clements et al. 2008), but surrounding hills have yet to be adequately surveyed.

Remarks. Distinguished from congeners by its shell shape and the presence of four coiling axes. Differ from *Opisthostoma* cf. *vermiculum* only in the coiling axis of the apical and antepenultimate whorls.

Family Pupinidae Pfeiffer, 1853a

Genus *Pollicaria* Gould, 1856

Pollicaria elephas (de Morgan, 1885)

Figure 15A

Materials examined. mykarst-027: BOR/MOL 9089, BOR/MOL 9030. Prk 53 Hill KF: BOR/MOL 10714, BOR/MOL 10741, BOR/MOL 10657, BOR/MOL 10684. mykarst-025: BOR/MOL 9402, BOR/MOL 9432, BOR/MOL 9443, BOR/MOL 9498. mykarst-185 Batu Kebelah: BOR/MOL 9567, BOR/MOL 9579. Prk 01 G. Tempurung: BOR/MOL 11138.

Distribution. Known from Pluss (=Pelus) River Valley and Kinta Valley, Perak only (Maassen 2001).

Remarks. Shell large. Operculum hard, calcified, multilamella. Distinct from any sympatric land snail species in the structure and coiling of the whorls.

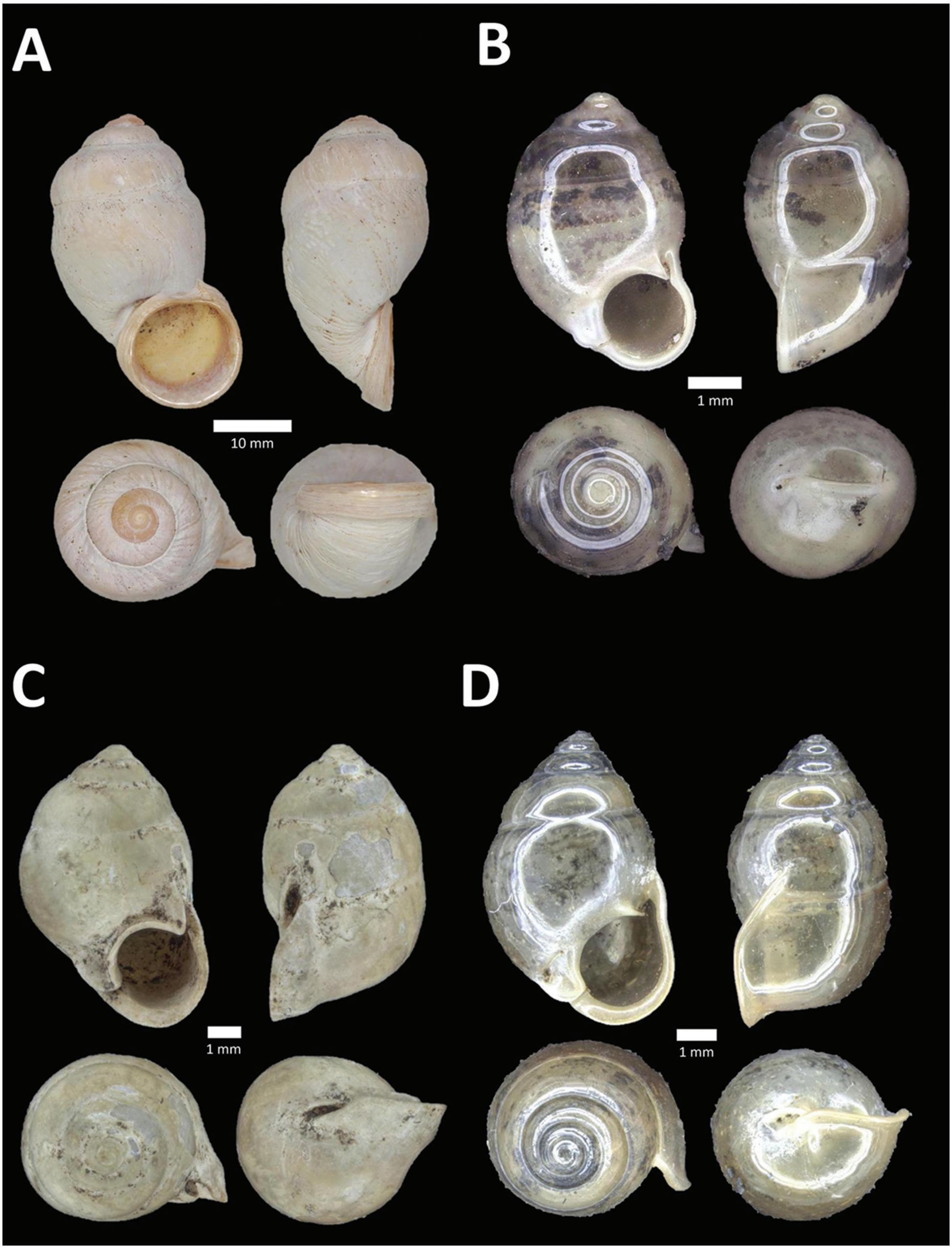

Figure 15. A *Pollicaria elephas* (de Morgan, 1885a) BOR/MOL 9443. Perak, Ipoh, Mykarst-025 Plot 1 **B** *Pupina artata* Benson, 1856 BOR/MOL 9803. Perak, Ipoh, Bat Cave Hill Plot 2 **C** *Pupina arula perakensis* von Möllendorff, 1891 BOR/MOL 10566. Perak, Ipoh, Gunung Datok Plot **D** *Pupina lowi* de Morgan, 1885a BOR/MOL 9873. Perak, Ipoh, Bat Cave Hill Plot 4.

Genus *Pupina* Vignard, 1829

Pupina artata Benson, 1856

Figure 15B

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9872, BOR/MOL 9803, BOR/MOL 9835, BOR/MOL 9777. mykarst-025: BOR/MOL 9413, BOR/MOL 9486, BOR/MOL 9505, BOR/MOL 12425. Prk 42 G. Bercham: BOR/MOL 9460, BOR/MOL 9474, BOR/MOL 9211, BOR/MOL 9234, BOR/MOL 10573, BOR/MOL 10622, BOR/MOL 10627. mykarst-185 Batu Kebelah: BOR/MOL 9534, BOR/MOL 9575, BOR/MOL 9580. Prk 64 Bt Kepala Gajah: BOR/MOL 10092, BOR/MOL 10139, BOR/MOL 10171. Prk 55 G. Pondok: BOR/MOL 11490, BOR/MOL 11525. Prk 01 G. Tempurung: BOR/MOL 11221.

Distribution. In Peninsular Malaysia, found in Perak and Selangor (Maassen 2001). Elsewhere, in Moulmein (=Mawlamyine), Myanmar and Ko Samui, Thailand (Maassen 2001).

Remarks. Shell colour varies from white to brown, glossy. Whorl convexity varies slightly but is always less expanded than congeners. Differ from all sympatric *Pupina* species in being small, whorls less expanded as well as the formation and curvature of the aperture and its narrow canals.

Pupina arula perakensis von Möllendorff, 1891

Figure 15C

Materials examined. Prk 36 Gua Datok: BOR/MOL 10566. Kampung Pahit limestone outcrop, Klian Intan, Perak: BOR/MOL 7091.

Distribution. Known from Perak only (Maassen 2001).

Remarks. Shell colour brown, glossy when alive. Whorl more convex and expanded than most congeners. Shell larger than most sympatric congeners. Distinguished from congeners by the formation and curvature of the aperture and its canals, as well as the peristome extension right of the penultimate whorl.

Pupina lowi de Morgan, 1885a

Figure 15D

Materials examined. Prk 53 Hill KF: BOR/MOL 10706, BOR/MOL 10718, BOR/MOL 10748, BOR/MOL 10666. mykarst-184 Bat Cave: BOR/MOL 9873, BOR/MOL 9780, BOR/MOL 9800. mykarst-185 Batu Kebelah: BOR/MOL 9535, BOR/

MOL 9566, BOR/MOL 9576, BOR/MOL 9581. Prk 64 Bt Kepala Gajah: BOR/MOL 10125.

Distribution. Known from Perlis, Perak and Kelantan only (Maassen 2001).

Remarks. Shell colour brown, glossy when alive. Radial striations of equal width occasionally present. Most similar to *Pupina arula perakensis* in its rounded whorls but differ by its taller spire, the open upper canal and the peristome extension right of the penultimate whorl.

Pupina tchehelensis de Morgan, 1885b

Figure 16A

Materials examined. Prk 47 Kanthan: BOR/MOL 9177, BOR/MOL 9072. mykarst-025: BOR/MOL 9387, BOR/MOL 9417, BOR/MOL 9491, BOR/MOL 9509. mykarst-027: BOR/MOL 9096, BOR/MOL 9028. Prk 23 G. Rapat: BOR/MOL 10208, BOR/MOL 10034, BOR/MOL 10051, BOR/MOL 10231, BOR/MOL 10261. Prk 42 G. Bercham: BOR/MOL 10654, BOR/MOL 10605. Prk 36 Gua Datok: BOR/MOL 10450, BOR/MOL 10480, BOR/MOL 10499. Prk 34 G. Tasek: BOR/MOL 11024, BOR/MOL 11063. Prk 01 G. Tempurung: BOR/MOL 11141, BOR/MOL 11216, BOR/MOL 11393, BOR/MOL 11419. Prk 55 G. Pondok: BOR/MOL 11510.

Distribution. Known from Perak only (Maassen 2001).

Remarks. Shell colour brown, glossy when alive. Variable in shell size. Whorls slender. Spire tall. Distinguished from congeners by the peristomal thickening and curvature of the aperture and its canals in mature shells.

Genus *Schistoloma* Kobelt, 1902

Schistoloma sectilabrum (Gould, 1844)

Figure 16B

Materials examined. Prk 47 Kanthan: BOR/MOL 9184. mykarst-184 Bat Cave: BOR/MOL 9765, BOR/MOL 9798.

Distribution. In Peninsular Malaysia, known from Penang, Perak and Pahang (Maassen 2001, Tumpeesuwan and Panha 2008). Elsewhere, in Petchaburi, Thailand as well as Tavoy (=Dawei) and Tenasserim (=Tanintharyi), Myanmar (Tumpeesuwan and Panha 2008).

Remarks. Shell colour brown. Spire tall. Peristome thin, reflected and expanded. Differ from *Pupina* species in the lack of apertural canals. Differ from *Pollicaria* species in its smaller size and straighter coiling axis.

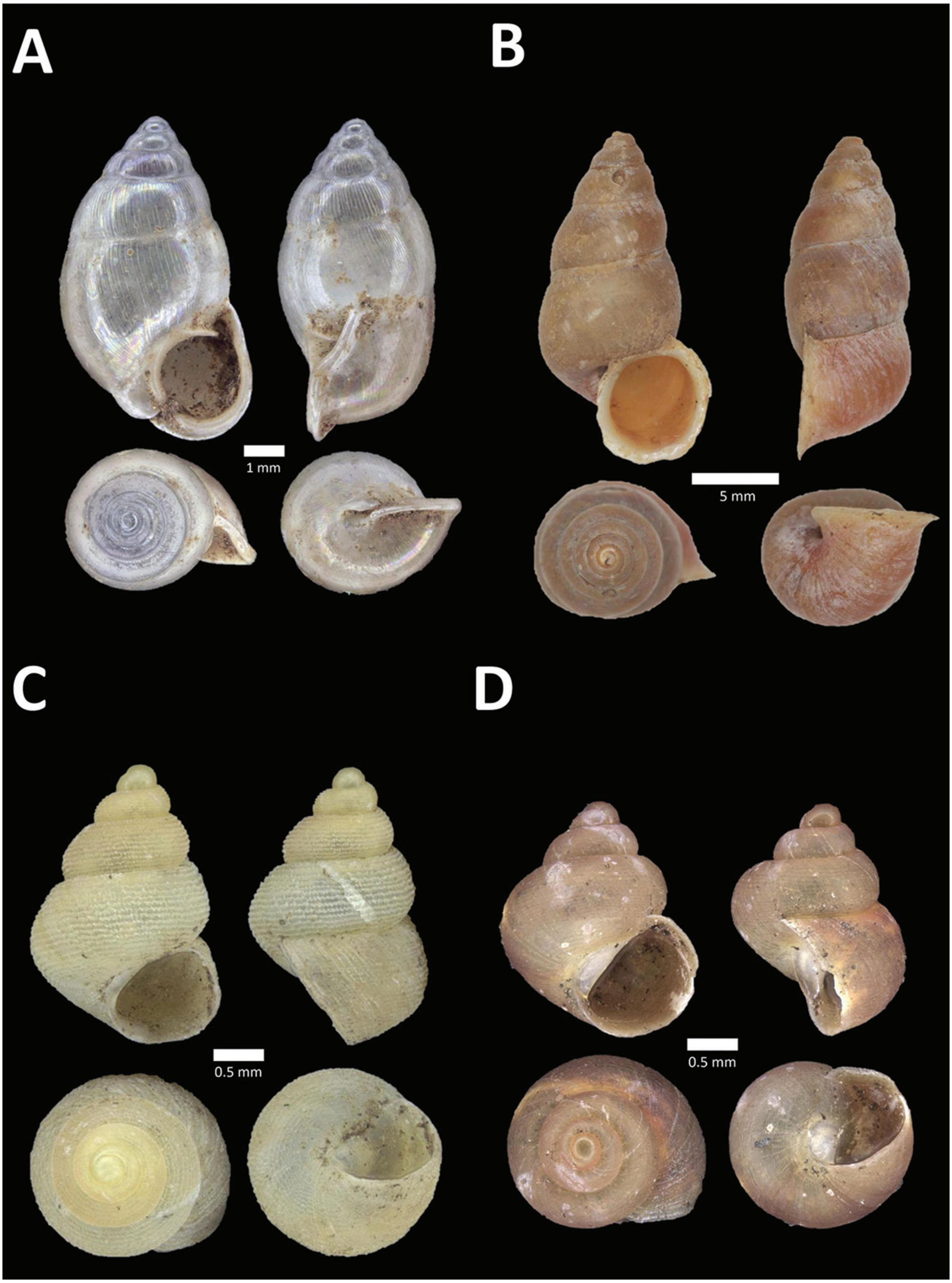

Figure 16. A *Pupina tchehelensis* de Morgan, 1885b BOR/MOL 11393. Perak, Ipoh, Gunung Tempurung Plot 2 **B** *Schistoloma sectilabrum* (Gould, 1844) BOR/MOL 8103. Perak, Ipoh, forested slope behind village at Gunung Pondok **C** *Georissa monterosatiana* Godwin-Austen & Nevill, 1879 BOR/MOL 11524. Perak, Ipoh, Gunung Pondok **D** *Georissa semisculpta* Godwin-Austen & Nevill, 1879 BOR/MOL 11047. Perak, Ipoh, Gunung Tasek.

Unranked clade: Neritimorpha
Family Hydrocenidae Troschel, 1857
Genus *Georissa* Blanford, 1864

Georissa monterosatiana* Godwin-Austen & Nevill, 1879
Figure 16C

Materials examined. Prk 53 Hill KF: BOR/MOL 10704, BOR/MOL 10754, BOR/MOL 10730, BOR/MOL 10669. Prk 47 Kanthan: BOR/MOL 9084, BOR/MOL 9156. mykarst-184 Bat Cave: BOR/MOL 9868, BOR/MOL 9816, BOR/MOL 9838, BOR/MOL 9776. mykarst-027: BOR/MOL 9044, BOR/MOL 9132. mykarst-185 Batu Kebelah: BOR/MOL 9547, BOR/MOL 9591. Prk 23 G. Rapat: BOR/MOL 10043, BOR/MOL 10240, BOR/MOL 10264. Prk 36 Gua Datok: BOR/MOL 10066, BOR/MOL 10430, BOR/MOL 10459. Prk 64 Bt Kepala Gajah: BOR/MOL 10189. Prk 42 G. Bercham: BOR/MOL 10606. Prk 01 G. Tempurung: BOR/MOL 11152, BOR/MOL 11228, BOR/MOL 11396, BOR/MOL 11423. Prk 55 G. Pondok: BOR/MOL 11499, BOR/MOL 11524, BOR/MOL 11544, BOR/MOL 11569. Prk 34 G. Tasek: BOR/MOL 11178.

Distribution. In Peninsular Malaysia, known from Perak, Kelantan, Pahang, Perlis and Selangor (Maassen 2001). Elsewhere, in Jalor (=Yala), Thailand (Maassen 2001).

Remarks. Shell small. Differ from the sympatric *Georissa semisculpta* by its taller spire, pronounced and crenulated spiral ridges as well as less obtuse whorls. Shell colour yellow to red.

Georissa semisculpta* Godwin-Austen & Nevill, 1879
Figure 16D

Materials examined. Prk 36 Gua Datok: BOR/MOL 10067. Prk 64 Bt Kepala Gajah: BOR/MOL 10105, BOR/MOL 10149, BOR/MOL 10188. Prk 01 G. Tempurung: BOR/MOL 10670, BOR/MOL 11151, BOR/MOL 12083. Prk 23 G. Rapat: BOR/MOL 10241, BOR/MOL 12092. Prk 42 G. Bercham: BOR/MOL 10580. Prk 34 G. Tasek: BOR/MOL 11001, BOR/MOL 11047, BOR/MOL 11058, BOR/MOL 11177. mykarst-184 Bat Cave: BOR/MOL 12082, BOR/MOL 12084, BOR/MOL 12085, BOR/MOL 12091. Prk 47 Kanthan: BOR/MOL 12086. mykarst-185 Batu Kebelah: BOR/MOL 12087. mykarst-027: BOR/MOL 12088, BOR/MOL 12090. Prk 53 Hill KF: BOR/MOL 12089.

Distribution. Known from Perak and Pahang only (Maassen 2001).

Remarks. Shell small. Differ from the sympatric *Georissa monterosatiana* by its lower spire, indistinct spiral sculpture over radial growth lines and very obtuse whorls. Shell colour pink to red. New record for Kinta Valley. Prior to this study, *G. semisculpta* was thought to be extinct because it was presumed endemic to Gunung Pondok, where it has not been detected ever since its original description (Davison 1991).

Clade Heterobranchia
Informal group Pulmonata Cuvier, in de Blainville 1814
Family Achatinellidae Gulick, 1873
Genus *Elasmias* Pilsbry, 1910

Elasmias terrestris (Brazier, 1876)
Figure 17A

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9790, BOR/MOL 9817, BOR/MOL 9840. Prk 64 Bt Kepala Gajah: BOR/MOL 10186. Prk 55 G. Pondok: BOR/MOL 11528.

Distribution. In Peninsular Malaysia, found in Kedah and Perak (Maassen 2001). Elsewhere, New Guinea and Australia (Maassen 2001, Solem 1988).

Remarks. Small shell. Distinguished from others by its oviform shell and truncated columella with two lamella teeth (one more pronounced than the other). This is a new record for Perak.

Family Achatinidae Swainson, 1840
Genus *Achatina* Lamarck, 1799

Achatina fulica (Bowdich, 1822)
Figure 17B

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9860. mykarst-025: BOR/MOL 9378, BOR/MOL 9438, BOR/MOL 9497. mykarst-027: BOR/MOL 9046, BOR/MOL 9102. Prk 47 Kanthan: BOR/MOL 9049, BOR/MOL 9141. Prk 42 G. Bercham: BOR/MOL 9207, BOR/MOL 10570. mykarst-185 Batu Kebelah: BOR/MOL 9525, BOR/MOL 9558, BOR/MOL 9568, BOR/MOL 9582. Prk 64 Bt Kepala Gajah: BOR/MOL 10176. Prk 34 G. Tasek: BOR/MOL 10785, BOR/MOL 11025, BOR/MOL 11061, BOR/MOL 11171. Prk 01 G. Tempurung: BOR/MOL 11208, BOR/MOL 11239.

Distribution. Widespread in Peninsular Malaysia (Maassen 2001). Elsewhere, native to tropical Africa but now pantropical (Fontanilla et al. 2014).

Remarks. Large shell. Tall-spired with distinct stripes or flammulations. This is a synanthropic species.

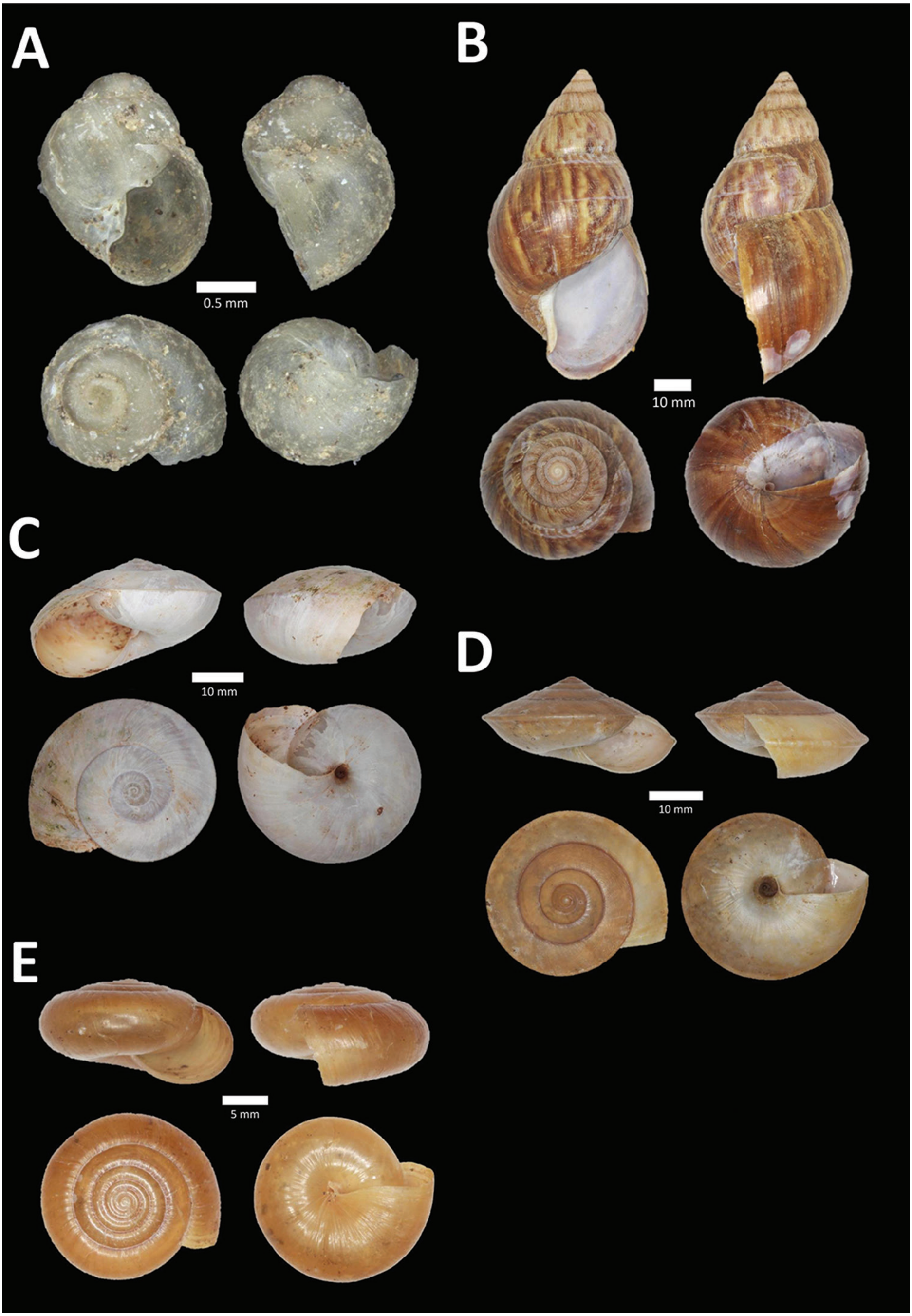

Figure 17. A *Elasmias terrestre* (Brazier, 1876) BOR/MOL 10186. Perak, Ipoh, Gua Tok Giring Plot 4 **B** *Achatina fulica* (Bowdich, 1822) BOR/MOL 11208. Perak, Ipoh, Gunung Tempurung Plot 3 **C** *Ariophanta lahatensis* de Morgan, 1885a BOR/MOL 8275. Perak, Ipoh, Iron hill summit trail **D** *Hemiplecta cymatium* (Pfeiffer, 1856) BOR/MOL 11611. Perak, Ipoh, Gunung Pondok, plot 5 **E** *Macrochlamys* 'Batu Kebelah 1' BOR/MOL 9528. Perak, Ipoh, Batu Kebelah Plot 1.

Family Ariophantidae Godwin-Austen, 1888
Genus *Ariophanta* Desmoulins, 1829

Ariophanta lahatensis (de Morgan, 1885a)
Figure 17C

Materials examined. Prk 47 Kanthan: BOR/MOL 9067, BOR/MOL 9173. mykarst-027: BOR/MOL 9099. mykarst-025: BOR/MOL 9434, BOR/MOL 9504. Prk 23 G. Rapat: BOR/MOL 10054, BOR/MOL 10204, BOR/MOL 10274. Prk 36 Gua Datok: BOR/MOL 10454. Prk 01 G. Tempurung: BOR/MOL 11137, BOR/MOL 11214, BOR/MOL 11247, BOR/MOL 11382, BOR/MOL 11409.

Distribution. Restricted to Kinta Valley (Maassen 2001).

Remarks. Medium-sized shell. Sinistral. Keeled periphery. Colour off-white to translucent brown. Shell surface has gentle radial growth lines overlaid with short spiral crenulations. The species group comprising of *Nanina salangana* von Martens, 1883, *Helix retrosa* Gould, 1844 and *Helix lahatensis* de Morgan, 1885a, was reassigned from Dyakiidae to Ariophantidae based on shell and anatomy (Sutcharit et al. 2012).

Genus *Hemiplecta* Albers, 1850

Hemiplecta cymatium (Pfeiffer, 1856)
Figure 17D

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9855, BOR/MOL 9795, BOR/MOL 9825. Prk 53 Hill KF: BOR/MOL 10740, BOR/MOL 10656, BOR/MOL 10686. mykarst-027: BOR/MOL 9104. Prk 55 G. Pondok: BOR/MOL 11611.

Distribution. In the states of Kedah, Penang, Perak, Kelantan and Pahang in Peninsular Malaysia (Maassen 2001). Elsewhere, in Jalor (=Yala), southern Thailand (Maassen 2001).

Remarks. Large shell. Perak shells differ from Penang shells only by their flatter spire. Whorls brown with darker periphery. Peripheral keel pronounced. Shell surface has numerous short spiral crenulations.

Genus *Macrochlamys* Godwin-Austen, 1883

Macrochlamys 'Batu Kebelah 1'
Figure 17E

Materials examined. Prk 64 Bt Kepala Gajah: BOR/MOL 10114, BOR/MOL 10118, BOR/MOL 10128, BOR/MOL 10129, BOR/MOL 10130, BOR/MOL 10168. mykarst-184 Bat Cave: BOR/MOL 9859. mykarst-185 Batu Kebelah: BOR/MOL 9528, BOR/MOL 9561, BOR/MOL 9571. Prk 55 G. Pondok: BOR/MOL 11612, BOR/MOL 11508, BOR/MOL 11564.

Distribution. Known from upper Kinta Valley and Perak River Valley, Perak only.

Remarks. Medium-sized shell. Whorls more tightly coiled than congeners, spire flat. Reddish brown shell with pronounced undulations of radial growth lines along the suture.

Macrochlamys 'Bercham 1'

Figure 18A

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9861, BOR/MOL 9828, BOR/MOL 9775, BOR/MOL 9806. Prk 53 Hill KF: BOR/MOL 10737, BOR/MOL 10771, BOR/MOL 10777, BOR/MOL 10676. Prk 42 G. Bercham: BOR/MOL 9468, BOR/MOL 9477, BOR/MOL 9212, BOR/MOL 9239, BOR/MOL 10645. Prk 23 G. Rapat: BOR/MOL 10223, BOR/MOL 10281, BOR/MOL 10283. mykarst-027: BOR/MOL 9199. Prk 47 Kanthan: BOR/MOL 9203. mykarst-185 Batu Kebelah: BOR/MOL 9556, BOR/MOL 9572, BOR/MOL 9588. Prk 36 Gua Datok: BOR/MOL 10081, BOR/MOL 10466, BOR/MOL 10483. Prk 34 G. Tasek: BOR/MOL 11011.

Distribution. Known from Kinta Valley, Perak only.

Remarks. Shell small relative to congeners. Rounded periphery, spire relatively tall, whorls wide. Overall, shell looks glossy. Radial sculpture indistinct, spiral grooves distinct but very fine. Suture indistinct. Most similar to *Macrochlamys malayana* (von Möllendorff, 1891), which differs in being more globose and has less whorls.

Macrochlamys malaccana (Pfeiffer, 1854)

Figure 18B

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9858. mykarst-185 Batu Kebelah: BOR/MOL 9762, BOR/MOL 9527, BOR/MOL 9562, BOR/MOL 9570. Prk 53 Hill KF: BOR/MOL 10712, BOR/MOL 10736, BOR/MOL 10765, BOR/MOL 10690. Prk 42 G. Bercham: BOR/MOL 9228. Prk 36 Gua Datok: BOR/MOL 10415, BOR/MOL 10465, BOR/MOL 10485. Prk 55 G. Pondok: BOR/MOL 12093.

Distribution. Known from Kedah and Perak only.

Remarks. Medium-sized shell. Whorls more expanded than *Macrochlamys* 'batu kebelah 1'. Suture has distinct dark brown line. Spiral striations are very fine. This species was previously known from Kedah only (Maassen 2001).

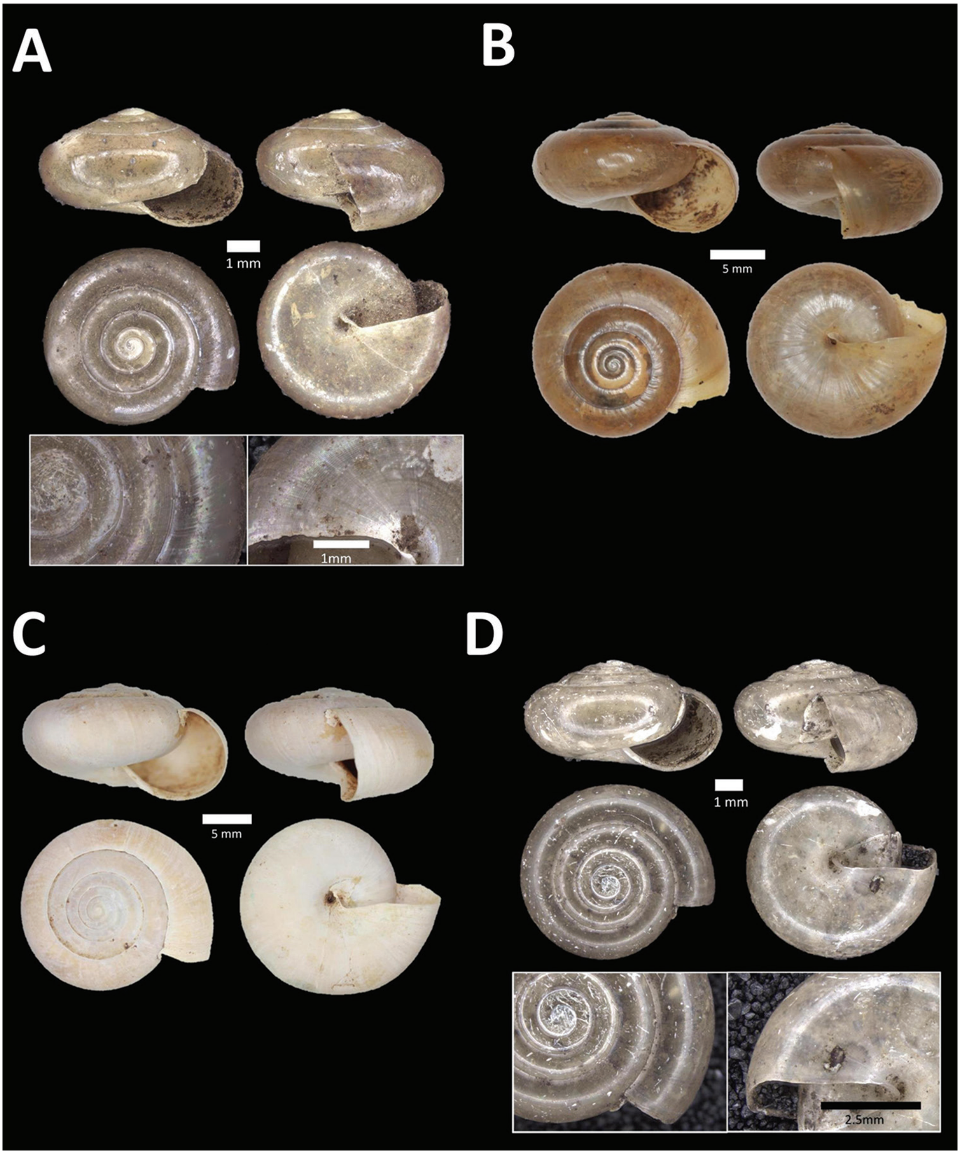

Figure 18. A *Macrochlamys* 'Bercham 1' BOR/MOL 9477. Perak, Ipoh, Gunung Bercham Plot 3 **B** *Macrochlamys malaccana* (Pfeiffer, 1854) BOR/MOL 9570. Perak, Ipoh, Batu Kebelah Plot 4 **C** *Macrochlamys* 'tempurung 1' BOR/MOL 11134. Perak, Ipoh, Gunung Tempurung Plot 1 **D** *Macrochlamys* 'tempurung 2' BOR/MOL 11449. Perak, Ipoh, Gunung Tempurung Plot 2.

Macrochlamys 'tempurung 1'

Figure 18C

Materials examined. Prk 01 G. Tempurung: BOR/MOL 11134, BOR/MOL 11436.

Distribution. Known from Gunung Tempurung only, but surrounding hills have yet to be adequately surveyed.

Remarks. Small shell. Spire flat and whorl coiling tight like *Macrochlamys* 'batukebelah 1' but shell more bulbous than *Macrochlamys* 'batukebelah 1'.

Macrochlamys 'tempurung 2'

Figure 18D

Materials examined. Prk 01 G. Tempurung: BOR/MOL 11440, BOR/MOL 11443, BOR/MOL 11449, BOR/MOL 11456.

Distribution. Known from Gunung Tempurung, but surrounding hills have yet to be adequately surveyed.

Remarks. Shell small relative to congeners. Rounded periphery, spire relatively tall, whorls wide. Overall, shell looks glossy. Radial sculpture more indistinct than *Macrochlamys* 'Bercham 1', spiral grooves indistinct and very fine. Suture distinct, each whorl distinguished by its convexity. Most similar to *Macrochlamys* 'Bercham 1'.

Genus *Microcystina* Mörch, 1872

Microcystina clarkae Maassen, 2000

Figure 19A

Materials examined. Prk 47 Kanthan: BOR/MOL 9186, BOR/MOL 9193. mykarst-184 Bat Cave: BOR/MOL 9852, BOR/MOL 9887, BOR/MOL 9792, BOR/MOL 9812. mykarst-185 Batu Kebelah: BOR/MOL 9760, BOR/MOL 9555. Prk 53 Hill KF: BOR/MOL 10758, BOR/MOL 10764, BOR/MOL 10768, BOR/MOL 10774. mykarst-025: BOR/MOL 9399, BOR/MOL 9428, BOR/MOL 9495. mykarst-027: BOR/MOL 9453, BOR/MOL 9201. Prk 42 G. Bercham: BOR/MOL 10650, BOR/MOL 9237. Prk 36 Gua Datok: BOR/MOL 10072, BOR/MOL 10080, BOR/MOL 10438. Prk 64 Bt Kepala Gajah: BOR/MOL 10108, BOR/MOL 10159, BOR/MOL 10195. Prk 55 G. Pondok: BOR/MOL 11602, BOR/MOL 11606, BOR/MOL 11593, BOR/MOL 11594. Prk 34 G. Tasek: BOR/MOL 11122, BOR/MOL 11127, BOR/MOL 11198, BOR/MOL 11199. Prk 01 G. Tempurung: BOR/MOL 11442, BOR/MOL 11445.

Distribution. In Peninsular Malaysia, only known from Perak. Elsewhere, in Sumatra, Indonesia (Maassen 2000).

Remarks. Very small shell. Easily distinguished from congeners by its white shell, tight whorls, fine radial ribs and finer spiral pits. This is a new record for Peninsular Malaysia.

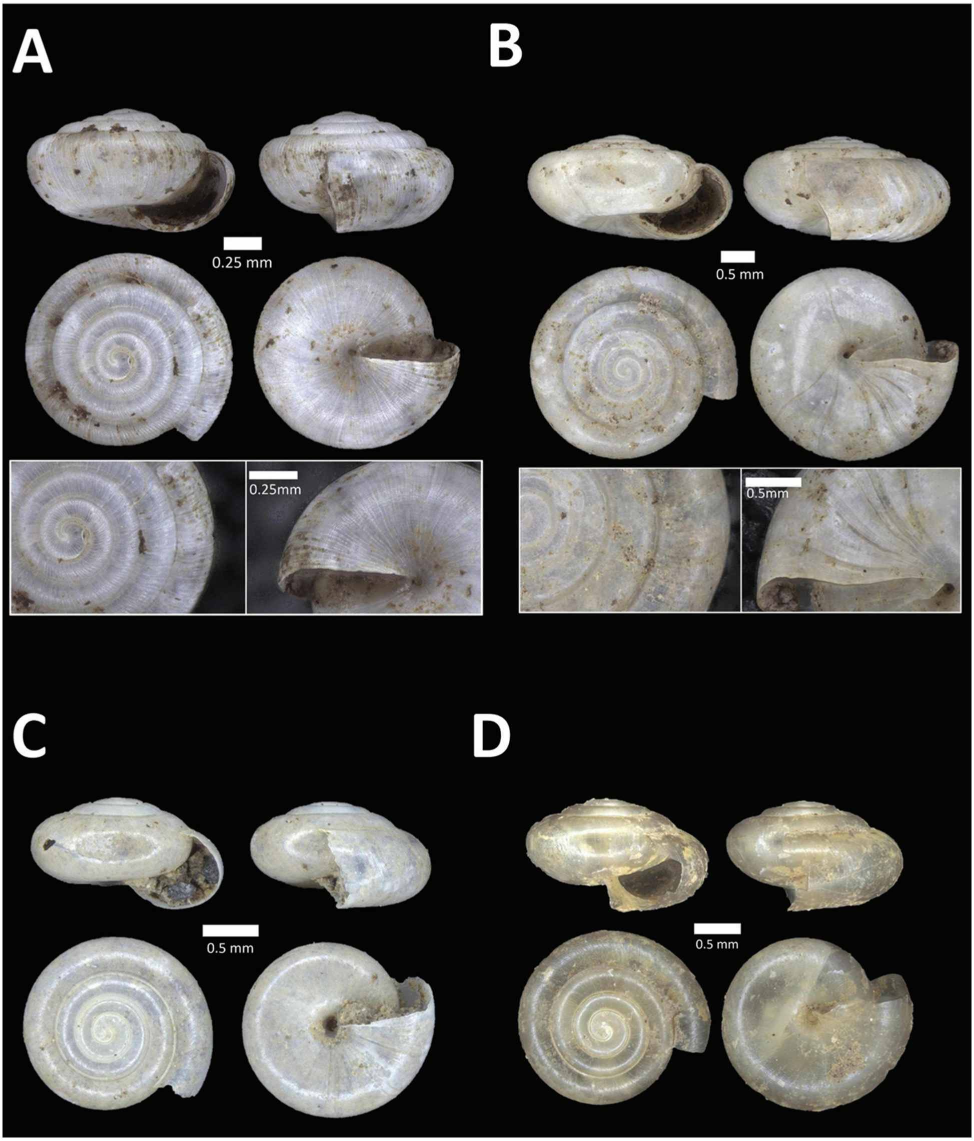

Figure 19. A *Microcystina clarkae* Maassen, 2000 BOR/MOL 9186. Perak, Ipoh, Gunung Kanthan Plot 4 **B** *Microcystina* 'guatokgiring 1' BOR/MOL 10109. Perak, Ipoh, Gua Tok Giring Plot 1 **C** *Microcystina* 'guatokgiring 2' BOR/MOL 10116. Perak, Ipoh, Gua Tok Giring Plot 1 **D** *Microcystina* 'Kanthan 1' BOR/MOL 9761. Perak, Ipoh, Batu Kebelah Plot 4.

Microcystina 'guatokgiring 1'

Figure 19B

Materials examined. Prk 64 Bt Kepala Gajah: BOR/MOL 10117, BOR/MOL 10109, BOR/MOL 10110, BOR/MOL 10160, BOR/MOL 10197.

Distribution. Known from Bukit Kepala Gajah, Perak only, but surrounding hills have yet to be adequately surveyed.

Remarks. Small shell. Whorls convex but tight, spire relatively low, dome shaped. Radial sculpture fine, spiral sculpture absent. Shell white.

Microcystina 'guatokgiring 2'

Figure 19C

Materials examined. Prk 64 Bt Kepala Gajah: BOR/MOL 10116, BOR/MOL 10161, BOR/MOL 10196.

Distribution. Known from Bukit Kepala Gajah, Perak only, but surrounding hills have yet to be adequately surveyed.

Remarks. Small shell. Whorls flat and denser than *Microcystina* 'guatokgiring 1'.

Microcystina 'Kanthan 1'

Figure 19D

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9888, BOR/MOL 9793. mykarst-185 Batu Kebelah: BOR/MOL 9758, BOR/MOL 9761, BOR/MOL 9553, BOR/MOL 9554. Prk 53 Hill KF: BOR/MOL 10757, BOR/MOL 10770, BOR/MOL 10775, BOR/MOL 10778. mykarst-025: BOR/MOL 9401, BOR/MOL 9429, BOR/MOL 9494, BOR/MOL 9519. Prk 42 G. Bercham: BOR/MOL 10652, BOR/MOL 10587, BOR/MOL 10641, BOR/MOL 10643. Prk 47 Kanthan: BOR/MOL 9189, BOR/MOL 9191, BOR/MOL 9206. mykarst-027: BOR/MOL 9197, BOR/MOL 9202. Prk 36 Gua Datok: BOR/MOL 10079, BOR/MOL 10084. Prk 64 Bt Kepala Gajah: BOR/MOL 10198, BOR/MOL 10199. Prk 55 G. Pondok: BOR/MOL 11596, BOR/MOL 11603, BOR/MOL 11605, BOR/MOL 11589. Prk 34 G. Tasek: BOR/MOL 11123, BOR/MOL 11022, BOR/MOL 11128, BOR/MOL 11032, BOR/MOL 11195, BOR/MOL 11200. Prk 01 G. Tempurung: BOR/MOL 11434, BOR/MOL 11438, BOR/MOL 11446, BOR/MOL 11457, BOR/MOL 11458.

Distribution. Known from Perak only.

Remarks. Small shell. Apical whorls with dense, spiral pits. Subsequent whorls spiral lined. Suture line brown. Radial sculpture indistinct. Shell brown.

Microcystina 'pondok 1'

Figure 20A

Materials examined. Prk 55 G. Pondok: BOR/MOL 11597.

Distribution. Known from Gunung Pondok only.

Remarks. Dome shaped spire, netted sculpture.

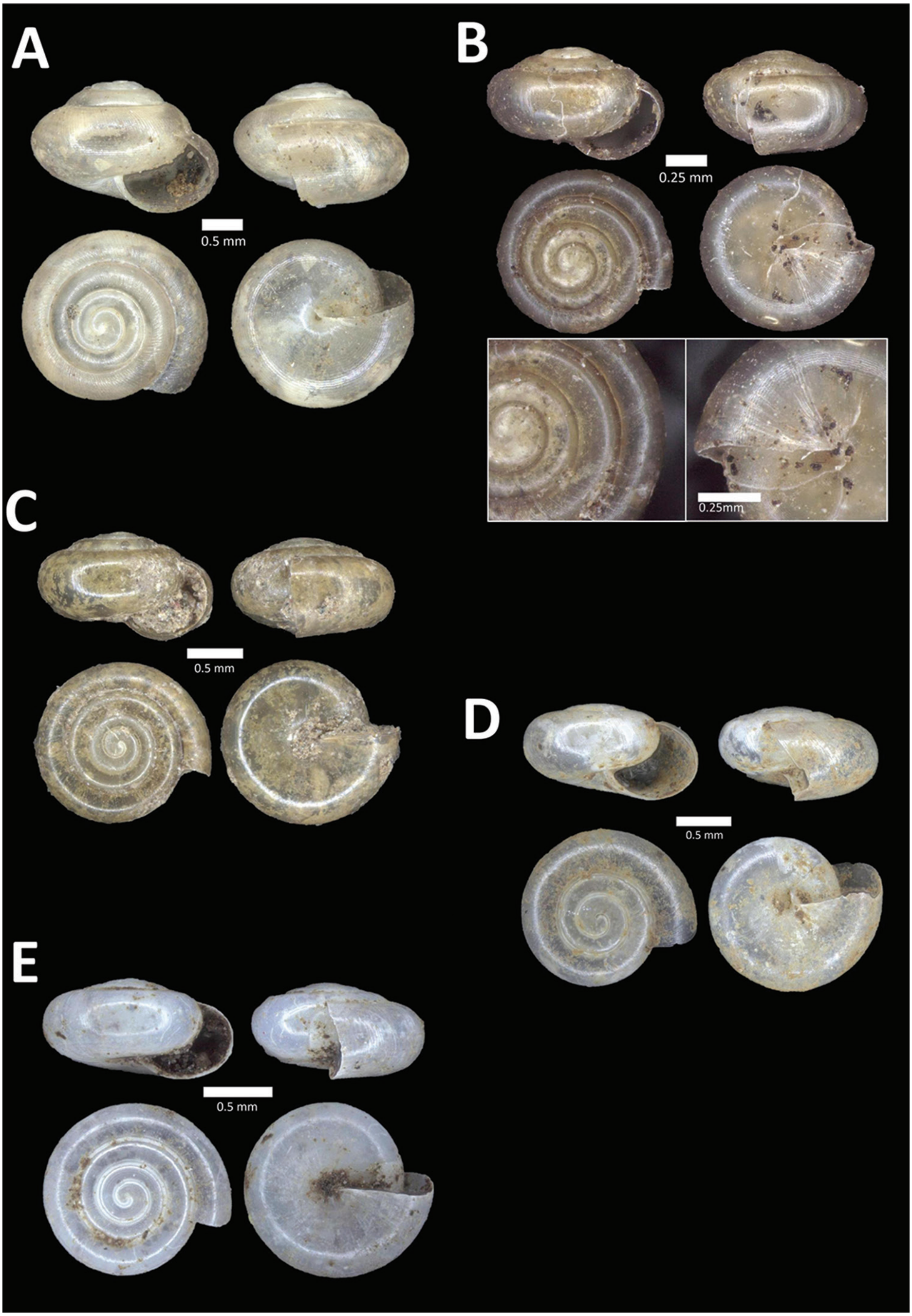

Figure 20. **A** *Microcystina* 'pondok 1' BOR/MOL 11597. Perak, Ipoh, Gunung Pondok, plot 1 **B** *Microcystina sinica* von Möllendorff, 1885 BOR/MOL 9192. Perak, Ipoh, Gunung Kanthan Plot 4 **C** *Microcystina* 'tempurung 2' BOR/MOL 11450. Perak, Ipoh, Gunung Tempurung Plot 2 **D** *Microcystina* 'tempurung 3' BOR/MOL 11451. Perak, Ipoh, Gunung Tempurung Plot 2 **E** *Microcystina townsendiana* Godwin-Austen & Nevill, 1879 BOR/MOL 9187. Perak, Ipoh, Gunung Kanthan.

Microcystina sinica (von Möllendorff, 1885)

Figure 20B

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9886, BOR/MOL 9851, BOR/MOL 9787, BOR/MOL 9823. mykarst-185 Batu Kebelah: BOR/MOL 9757, BOR/MOL 9549. Prk 53 Hill KF: BOR/MOL 10756, BOR/MOL 10772. mykarst-025: BOR/MOL 9398, BOR/MOL 9427, BOR/MOL 9493, BOR/MOL 9518. mykarst-027: BOR/MOL 9455, BOR/MOL 9204. Prk 42 G. Bercham: BOR/MOL 9472, BOR/MOL 9223, BOR/MOL 10646, BOR/MOL 10648. Prk 23 G. Rapat: BOR/MOL 10222, BOR/MOL 10279. Prk 47 Kanthan: BOR/MOL 9192, BOR/MOL 9205. Prk 36 Gua Datok: BOR/MOL 10073, BOR/MOL 10077, BOR/MOL 10439. Prk 64 Bt Kepala Gajah: BOR/MOL 10194. Prk 55 G. Pondok: BOR/MOL 11595, BOR/MOL 11610, BOR/MOL 11592. Prk 34 G. Tasek: BOR/MOL 11126, BOR/MOL 11201. Prk 01 G. Tempurung: BOR/MOL 11437, BOR/MOL 11453, BOR/MOL 11452, BOR/MOL 11454.

Distribution. In Peninsular Malaysia, known from Perak only (Maassen 2001). Elsewhere, south China and island Southeast Asia to western New Guinea (Vermeulen et al. 2015).

Remarks. Very small shell. Easily distinguished from congeners by its brown shell, domed spire, tight whorls, fine spiral lines and dark brown suture line.

Microcystina 'tempurung 2'

Figure 20C

Materials examined. Prk 01 G. Tempurung: BOR/MOL 11450.

Distribution. Known from Gunung Tempurung, Perak only, but surrounding hills have yet to be adequately surveyed.

Remarks. Shell shape similar to *Microcystina sinica*, differ in the absence of spiral sculpture.

Microcystina 'tempurung 3'

Figure 20D

Materials examined. Prk 01 G. Tempurung: BOR/MOL 11451.

Distribution. Known from Gunung Tempurung, Perak only, but surrounding hills have yet to be adequately surveyed.

Remarks. Shell somewhat similar to *Microcystina townsendiana* but differ in having wider whorls and the different manner of spiral and radial sculpture.

Microcystina townsendiana Godwin-Austen & Nevill, 1879

Figure 20E

Materials examined. Prk 47 Kanthan: BOR/MOL 9187, BOR/MOL 9174, BOR/MOL 9190, BOR/MOL 9194. mykarst-184 Bat Cave: BOR/MOL 9853, BOR/MOL 9890, BOR/MOL 9788, BOR/MOL 9822, BOR/MOL 9844. mykarst-185 Batu Kebelah: BOR/MOL 9756, BOR/MOL 9550. Prk 53 Hill KF: BOR/MOL 10759, BOR/MOL 10761, BOR/MOL 10766, BOR/MOL 10776. mykarst-025: BOR/MOL 9400, BOR/MOL 9430, BOR/MOL 9496, BOR/MOL 9521. mykarst-027: BOR/MOL 9454, BOR/MOL 9200. Prk 23 G. Rapat: BOR/MOL 10220, BOR/MOL 10041, BOR/MOL 10273, BOR/MOL 10277, BOR/MOL 10278. Prk 42 G. Bercham: BOR/MOL 10651, BOR/MOL 9224, BOR/MOL 9226, BOR/MOL 9238, BOR/MOL 10585, BOR/MOL 10642, BOR/MOL 10644, BOR/MOL 10647. Prk 36 Gua Datok: BOR/MOL 10070, BOR/MOL 10074, BOR/MOL 10078, BOR/MOL 10437. Prk 55 G. Pondok: BOR/MOL 11598, BOR/MOL 11600, BOR/MOL 11601, BOR/MOL 11608, BOR/MOL 11609, BOR/MOL 11591. Prk 34 G. Tasek: BOR/MOL 11121, BOR/MOL 11023, BOR/MOL 11129, BOR/MOL 11197, BOR/MOL 11202. Prk 01 G. Tempurung: BOR/MOL 11435, BOR/MOL 11439, BOR/MOL 11447, BOR/MOL 11448.

Distribution. Known from Perak and Pahang only (Maassen 2001).

Remarks. Small shell. Flat spire. Spiral sculpture fine, widely spaced. Whorls narrower than *Microcystina* 'tempurung 3'.

Family Bradybaenidae Pilsbry, 1939

Genus *Bradybaena* Beck, 1837

Bradybaena similaris (Férussac, 1821)

Figure 21A

Materials examined. mykarst-025: BOR/MOL 9376. Prk 64 Bt Kepala Gajah: BOR/MOL 10090. Prk 34 G. Tasek: BOR/MOL 11003.

Distribution. Widespread in Peninsular Malaysia (Maassen 2001). Native to East and Southeast Asia but now pantropical (de Winter et al. 2009).

Remarks. Medium-sized shell. Globular shell. Spire height low to medium. Umbilicus present. Periphery reflected when mature. Shell white to brown, occasionally with dark brown peripheral band. This is a synanthropic species.

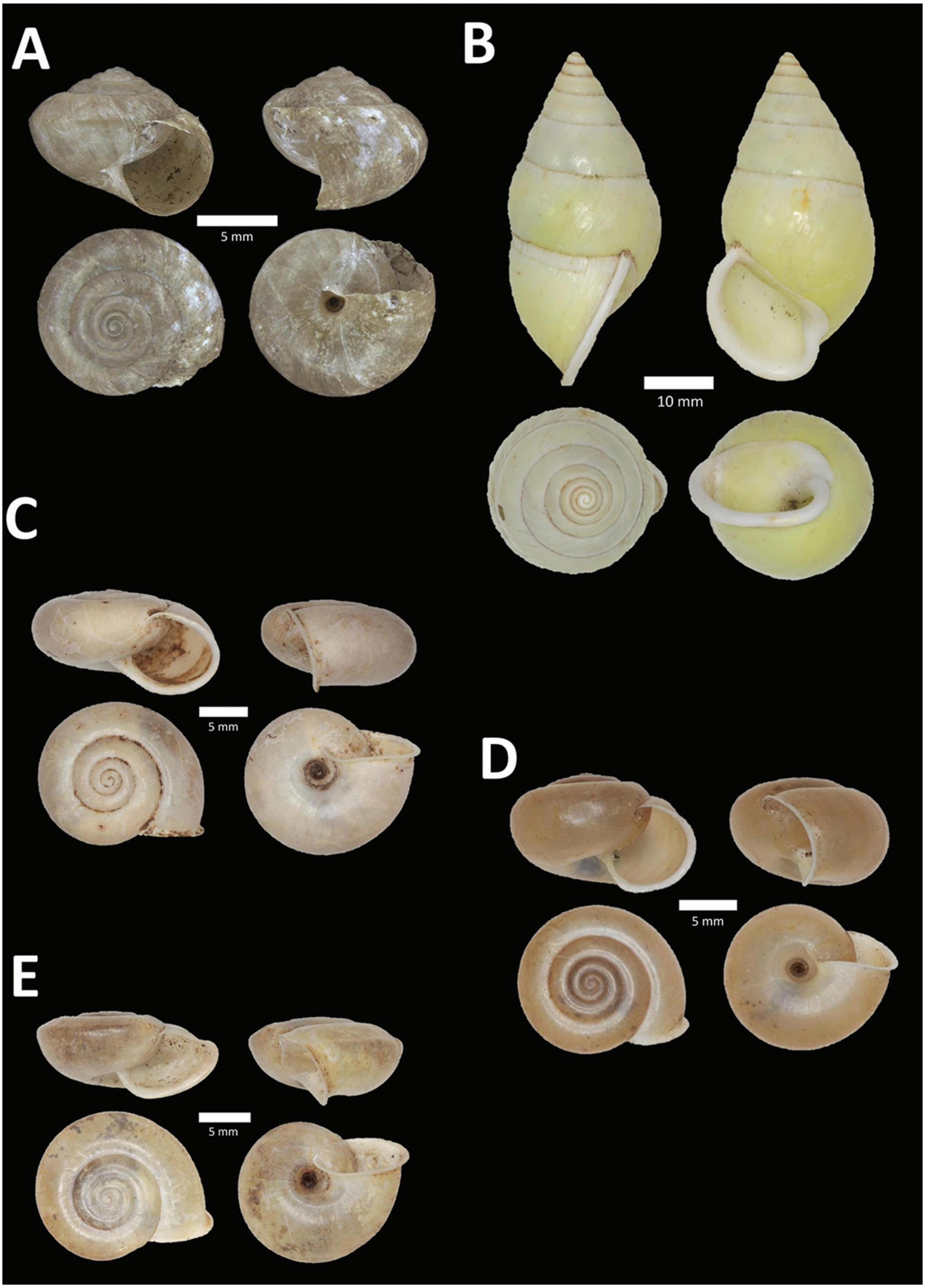

Figure 21. A *Bradybaena similaris* (Férussac, 1821) BOR/MOL 9376. Perak, Ipoh, Mykarst-025 Plot 1 **B** *Amphidromus atricallosus perakensis* (Fulton, 1901) BOR/MOL 8285. Perak, Ipoh, outcrop 500m **C** *Chloritis breviseta* (Pfeiffer, 1862) BOR/MOL 9091. Perak, Ipoh, Gunung Kanthan Plot 2 **D** *Chloritis penangensis* (Stoliczka, 1873) BOR/MOL 11562. Perak, Ipoh, Gunung Pondok, plot 6 **E** *Trachia wrayi* (de Morgan, 1885b) BOR/MOL 9381. Perak, Ipoh, Mykarst-025 Plot 1.

Family Camaenidae Pilsbry, 1895
Genus *Amphidromus* Albers, 1850

Amphidromus atricallosus perakensis (Fulton, 1901)

Figure 21B

Materials examined. Prk 47 Kanthan: BOR/MOL 9051.mykarst-027: BOR/MOL 9103. Prk 23 G. Rapat: BOR/MOL 10028. Prk 01 G. Tempurung: BOR/MOL 11139, BOR/MOL 11210, BOR/MOL 11243.

Distribution. Widespread in Peninsular Malaysia (Maassen 2001, Tan et al. 2011).

Remarks. Large shell. Tall spire. Dimorphic coiling within populations, with dextral and sinistral individuals. Shell lemon yellow throughout, with white sub-sutural line. Prior to this, among Kinta Valley limestone hills, Davison (1991) reported *A. atricallosus perakensis* from Gunung Kanthan only.

Genus *Chloritis* Beck, 1837

Chloritis breviseta (Pfeiffer, 1862)

Figure 21C

Materials examined. mykarst-027: BOR/MOL 9091, BOR/MOL 9016. Prk 47 Kanthan: BOR/MOL 9054, BOR/MOL 9137.

Distribution. In Peninsular Malaysia, known from Kelantan and Perak (Maassen 2001). Elsewhere, in Thailand (Maassen 2001).

Remarks. Medium-sized shell. Spire almost flat. Peristome reflected, more outwardly elongated than *Chloritis penangensis*. Shell flatter than *C. penangensis*.

Chloritis penangensis (Stoliczka, 1873)

Figure 21D

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9881. Prk 53 Hill KF: BOR/MOL 10715, BOR/MOL 10659. mykarst-025: BOR/MOL 9379, BOR/MOL 9405, BOR/MOL 9433, BOR/MOL 9501. mykarst-027: BOR/MOL 9093. Prk 42 G. Bercham: BOR/MOL 9469, BOR/MOL 9209, BOR/MOL 10589, BOR/MOL 10615, BOR/MOL 10637. Prk 23 G. Rapat: BOR/MOL 10229, BOR/MOL 10038, BOR/MOL 10050, BOR/MOL 10252. Prk 36 Gua Datok: BOR/MOL 10075, BOR/MOL 10413, BOR/MOL 10447, BOR/MOL 10477, BOR/MOL 10493. Prk 55 G. Pondok: BOR/MOL 11503, BOR/MOL 11543, BOR/

MOL 11562. Prk 34 G. Tasek: BOR/MOL 11062, BOR/MOL 11190. Prk 01 G. Tempurung: BOR/MOL 11380.

Distribution. Known from Penang and Perak only (Maassen 2001).

Remarks. Medium-sized shell. Spire almost flat. Peristome reflected, more rounded than *Chloritis breviseta*. Shell more globular than *C. breviseta*.

Genus *Trachia* Albers, 1860

Trachia wrayi (de Morgan, 1885b)

Figure 21E

Materials examined. mykarst-025: BOR/MOL 9381. Prk 34 G. Tasek: BOR/MOL 10789. Prk 01 G. Tempurung: BOR/MOL 11246.

Distribution. Known from Kinta Valley only (Maassen 2001).

Remarks. Medium-sized shell. Spire almost flat. Periphery keeled. Peristome reflected. Reflected upper peristome slightly distended towards the periphery.

Family Charopidae Hutton, 1884

Genus *Charopa* von Martens, 1860

Charopa 'Kanthan 1'

Figure 22A

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9889, BOR/MOL 9774, BOR/MOL 9807, BOR/MOL 9843. mykarst-185 Batu Kebelah: BOR/MOL 9759, BOR/MOL 9552. Prk 53 Hill KF: BOR/MOL 10760, BOR/MOL 10762, BOR/MOL 10767, BOR/MOL 10773. Prk 23 G. Rapat: BOR/MOL 10221, BOR/MOL 10042, BOR/MOL 10275, BOR/MOL 10280. Prk 42 G. Bercham: BOR/MOL 10649, BOR/MOL 9225. Prk 47 Kanthan: BOR/MOL 9188, BOR/MOL 9196. mykarst-027: BOR/MOL 9198.mykarst-025: BOR/MOL 9520. Prk 36 Gua Datok: BOR/MOL 10071, BOR/MOL 10076, BOR/MOL 10083, BOR/MOL 10436. Prk 55 G. Pondok: BOR/MOL 11599, BOR/MOL 11604, BOR/MOL 11607, BOR/MOL 11590. Prk 34 G. Tasek: BOR/MOL 11120, BOR/MOL 11125, BOR/MOL 11021, BOR/MOL 11196. Prk 01 G. Tempurung: BOR/MOL 11441, BOR/MOL 11444, BOR/MOL 11455.

Distribution. Known from Gunung Pondok and Kinta Valley, Perak only.

Remarks. Small shell. Whorls lesser than congeners. Dense nodules in all whorls. Latter whorls sometimes have nodules fused into wavy radial ridges. Shell white.

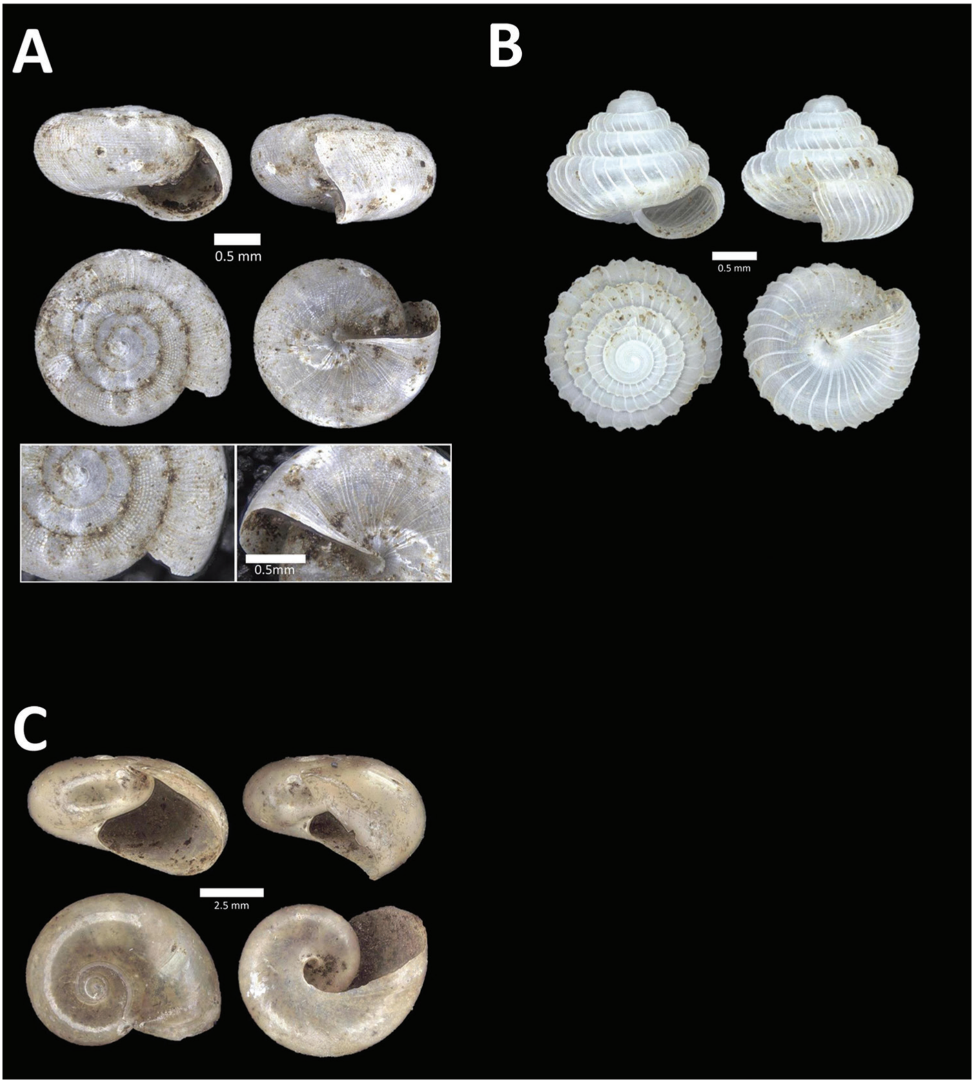

Figure 22. A *Charopa* ‘Kanthan 1’ BOR/MOL 9188. Perak, Ipoh, Gunung Kanthan Plot 4 **B** *Charopa lafargei* Vermeulen & Marzuki, 2014 BOR/MOL 9033. Perak, Ipoh, Gunung Kanthan Plot 1 **C** *Vitrinopsis nucleata* (Stoliczka, 1873) BOR/MOL 10150. Perak, Ipoh, Gua Tok Giring Plot 3.

‘*Charopa*’ *lafargei* Vermeulen & Marzuki, 2014
Figure 22B

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9854, BOR/MOL 9863, BOR/MOL 9778, BOR/MOL 9811. mykarst-027: BOR/MOL 9033, BOR/MOL 9124. Prk 47 Kanthan: BOR/MOL 9147. mykarst-185 Batu Kebelah: BOR/MOL 9529, BOR/MOL 9589. Prk 64 Bt Kepala Gajah: BOR/MOL 10179.

Distribution. Known from upper Kinta Valley only.

Remarks. Small shell. Spire tall. Periphery rounded, almost keeled. Radial ribs pronounced, spaced out and equidistant from each other. Spiral ridges distinct but not as pronounced as radial ribs. This species was previously presumed endemic to Gunung Kanthan (Vermeulen and Marzuki 2014).

Family Chronidae Thiele, 1931

Genus *Vitrinopsis* Semper, 1873

Vitrinopsis nucleata (Stoliczka, 1873)

Figure 22C

Materials examined. Prk 47 Kanthan: BOR/MOL 9057. Prk 64 Bt Kepala Gajah: BOR/MOL 10150, BOR/MOL 10174. Prk 36 Gua Datok: BOR/MOL 10567.

Distribution. In Peninsular Malaysia, known from Penang and Perak (Maassen 2001). Elsewhere, in Salanga (=Phuket), Thailand (von Martens, 1883).

Remarks. Flat spire. Whorls rapidly widened. Shell brown, glossy. This is a new record for Kinta Valley.

Family Clausiliidae Gray, 1855

Genus *Phaedusa* Adams & Adams, 1855

Phaedusa filicostata kapayanensis (de Morgan, 1885b)

Figure 23A

Materials examined. Prk 23 G. Rapat: BOR/MOL 10029, BOR/MOL 10236, BOR/MOL 10256. Prk 36 Gua Datok: BOR/MOL 10469, BOR/MOL 10498. Prk 01 G. Tempurung: BOR/MOL 11149, BOR/MOL 11412. Prk 34 G. Tasek: BOR/MOL 11005, BOR/MOL 11194.

Distribution. Known from Perlis, Kedah, Penang, Perak, Kelantan and Pahang (Maassen 2001).

Remarks. Shell Spire very tall, slender. Aperture small. Shell smaller and lamella more pronounced than *Phaedusa filicostata tenuicosta* (Loosjes 1953).

Phaedusa filicostata tenuicosta (Nevill, 1878)

Figure 23B

Materials examined. Prk 64 Bt Kepala Gajah: BOR/MOL 10122, BOR/MOL 10091, BOR/MOL 10170. mykarst-184 Bat Cave: BOR/MOL 9791, BOR/MOL 9824. Prk 53 Hill KF: BOR/MOL 10782. Prk 55 G. Pondok: BOR/MOL 11553.

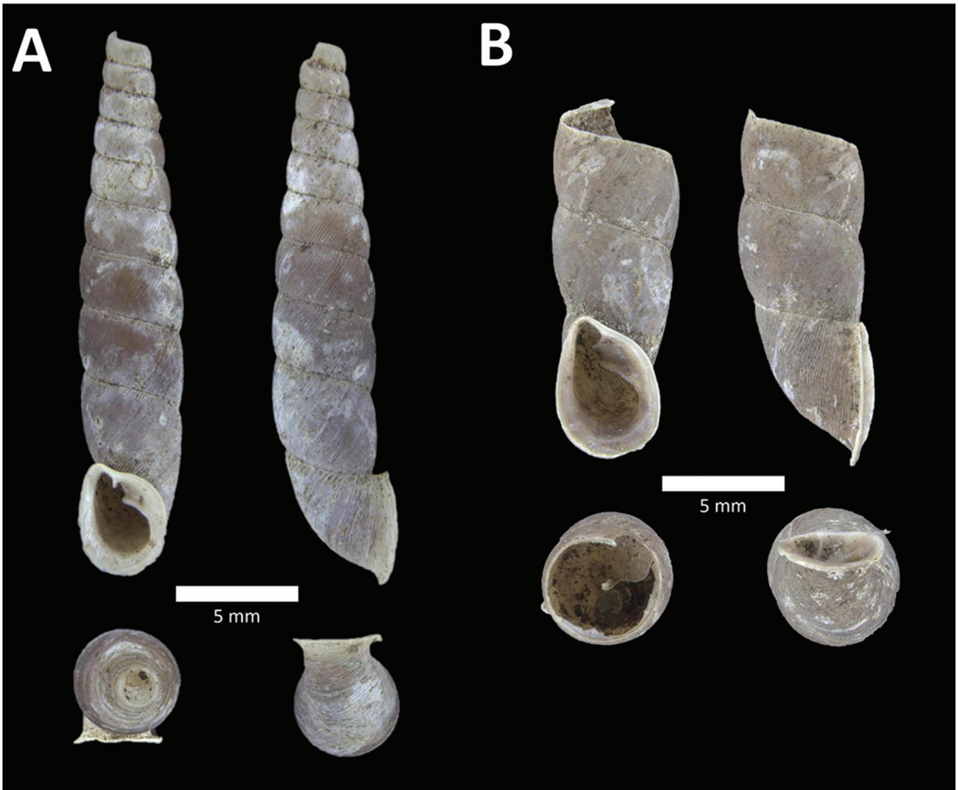

Figure 23. A *Phaedusa filicostata kapayanensis* (de Morgan, 1885b) BOR/MOL 10236. Perak, Ipoh, Gunung Rapat **B** *Phaedusa filicostata tenuicosta* (Nevill, 1878) BOR/MOL 10122. Perak, Ipoh, Gua Tok Giring Plot 2 **C** *Sinoennea* 'guatokgiring 1' BOR/MOL 10183. Perak, Ipoh, Gua Tok Giring Plot 4 **D** *Sinoennea hungerfordiana* (von Möllendorff, 1886) BOR/MOL 11009. Perak, Ipoh, Gunung Tasek.

Distribution. In Peninsular Malaysia, known from Perak and Selangor (Maassen 2001). Elsewhere, in Pattani, Thailand (Maassen 2001).

Remarks. Medium-sized shell, larger in all aspects compared to *Phaedusa filicostata kapayanensis* (Loosjes 1953). Lamella less pronounced compared to *P. filicostata kapayanensis*.

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

Genus *Sinoennea* Kobelt, 1904

Sinoennea 'guatokgiring 1'

Figure 23C

Materials examined. Prk 64 Bt Kepala Gajah: BOR/MOL 10183.

Distribution. Known from Bukit Kepala Gajah, Perak only, but surrounding hills have yet to be adequately surveyed.

Remarks. Radial rib sculpture distinct. Distinguished from congeners by the arrangement of lamella, its gradually inflated antepenultimate and penultimate whorls and an ultimate whorl aligned to the right of the previous whorls. Davison (1991) labelled this species as "*Sinoennea* sp. cf. *chrysallis*".

Sinoennea hungerfordiana (von Möllendorff, 1886)

Figure 23D

Materials examined. Prk 53 Hill KF: BOR/MOL 10707, BOR/MOL 10719, BOR/MOL 10752, BOR/MOL 10665. mykarst-025: BOR/MOL 9395. Prk 34 G. Tasek: BOR/MOL 11158, BOR/MOL 11009, BOR/MOL 11045. Prk 55 G. Pondok: BOR/MOL 11497, BOR/MOL 11520, BOR/MOL 11559.

Distribution. Known from Gunung Pondok, Perak and Bukit Baling, Kedah only (Maassen 2001, Tanmuangpak et al. 2015).

Remarks. Distinguished from congeners by its widely-spaced radial ribs, less number of whorls and arrangement of the lamella (van Benthem Jutting 1961b).

Sinoennea lenggongensis Tomlin, 1939

Figure 24A

Materials examined. Prk 64 Bt Kepala Gajah: BOR/MOL 10099, BOR/MOL 10141, BOR/MOL 10182.

Distribution. Known from Lenggong and Kramat Pulai, Perak only (Maassen 2001).

Remarks. Distinguished from congeners by its very cylindrical, tall spire shell, dense radial ribbing and slightly concaved central whorls (van Benthem Jutting 1961b).

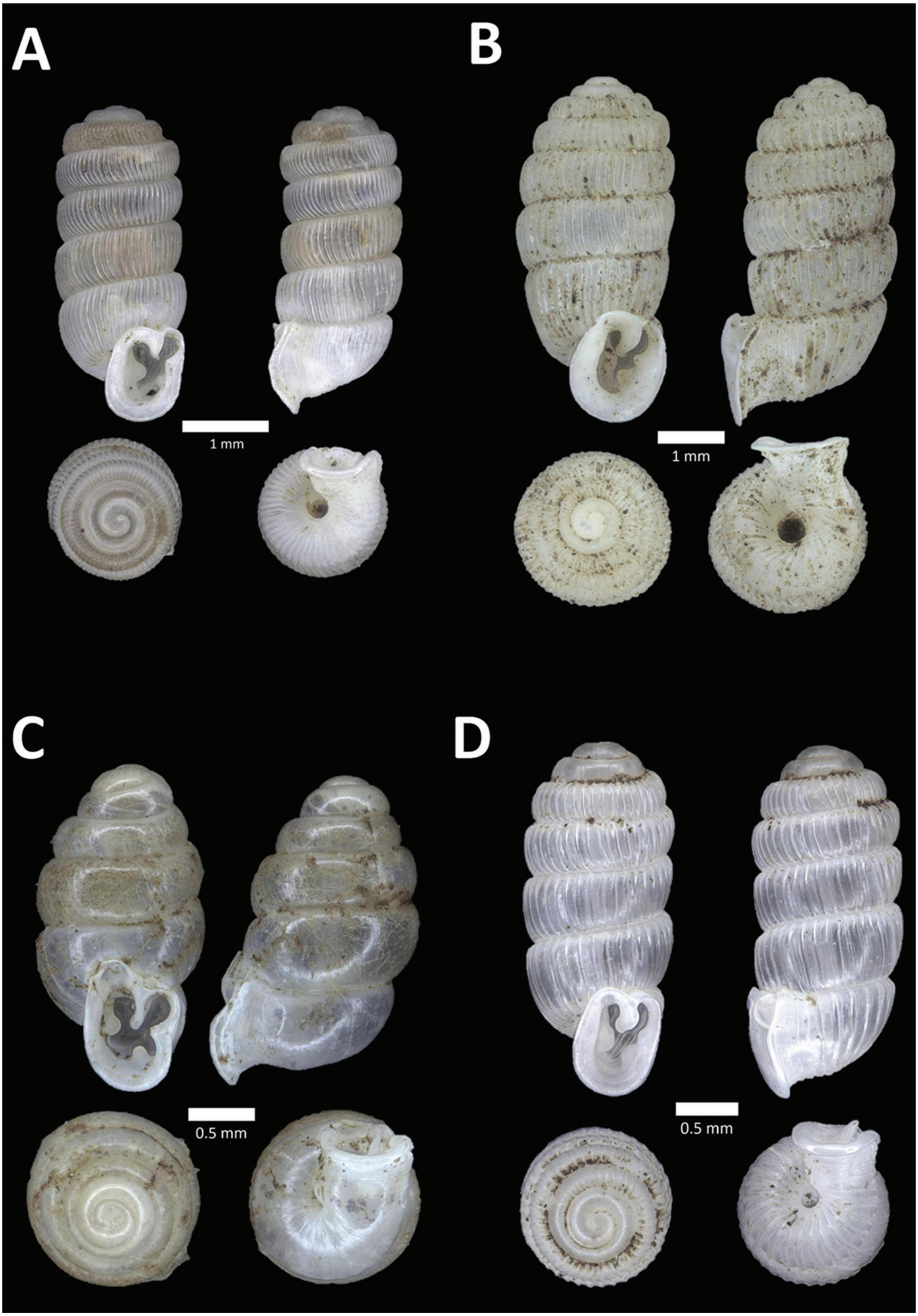

Figure 24. **A** *Sinoennea lenggongensis* Tomlin, 1939 BOR/MOL 10099. Perak, Ipoh, Gua Tok Giring Plot 1 **B** *Sinoennea perakensis* (Godwin-Austen & Nevill, 1879) BOR/MOL 11512. Perak, Ipoh, Gunung Pondok **C** *Sinoennea* 'prk53 1' BOR/MOL 10779. Perak, Ipoh, "Prk 53 Hill KF" plot 4 **D** *Sinoennea subcylindrica* (von Möllendorff, 1891) BOR/MOL 9779. Perak, Ipoh, Bat Cave Hill Plot 1

Sinoennea perakensis (Godwin-Austen & Nevill, 1879)

Figure 24B

Materials examined. Prk 55 G. Pondok: BOR/MOL 11498, BOR/MOL 11512, BOR/MOL 11561, BOR/MOL 11580.

Distribution. In Peninsular Malaysia, known from Gunung Pondok and Gapis Pass, Perak (Maassen 2001). Elsewhere, in Jalor (=Yala), Thailand (Maassen 2001).

Remarks. Differ from sympatric *Sinoennea hungerfordiana* by its taller, straight, cylindrical shell, more whorls, more expanded peristome, lamella arrangement and denser radial ribs (but not as dense as *Sinoennea lenggongensis*).

Sinoennea 'prk53 1'

Figure 24C

Materials examined. Prk 53 Hill KF: BOR/MOL 10735, BOR/MOL 10779.

Distribution. Known only from Prk 53 Hill KF only, but surrounding hills have yet to be adequately surveyed.

Remarks. Shell smallest among Perak congeners. Distinguished from Perak cogeners by its smooth whorls, absence of radial ribs and unique lamella arrangement.

Sinoennea subcylindrica (von Möllendorff, 1891)

Figure 24D

Materials examined. Prk 47 Kanthan: BOR/MOL 9075, BOR/MOL 9165, BOR/MOL 9169. mykarst-027: BOR/MOL 9034, BOR/MOL 9116. mykarst-184 Bat Cave: BOR/MOL 9866, BOR/MOL 9779, BOR/MOL 9814, BOR/MOL 9846. Prk 23 G. Rapat: BOR/MOL 10213. Prk 42 G. Bercham: BOR/MOL 9236. mykarst-185 Batu Kebelah: BOR/MOL 9545, BOR/MOL 9750. Prk 36 Gua Datok: BOR/MOL 10423, BOR/MOL 10455. Prk 55 G. Pondok: BOR/MOL 11496, BOR/MOL 11521, BOR/MOL 11560, BOR/MOL 11579.

Distribution. Known from Gunung Pondok, central and upper Kinta Valley, Perak only.

Remarks. Most similar to *Sinoennea lenggongensis* but differ in apical whorl shape, less dense radial ribs and lamella arrangement.

Sinoennea tweediei Tomlin, 1941

Figure 25A

Materials examined. Prk 64 Bt Kepala Gajah: BOR/MOL 10100, BOR/MOL 10140, BOR/MOL 10184.

Distribution. Known from Lenggong and Temengor, Perak only (Maassen 2001).

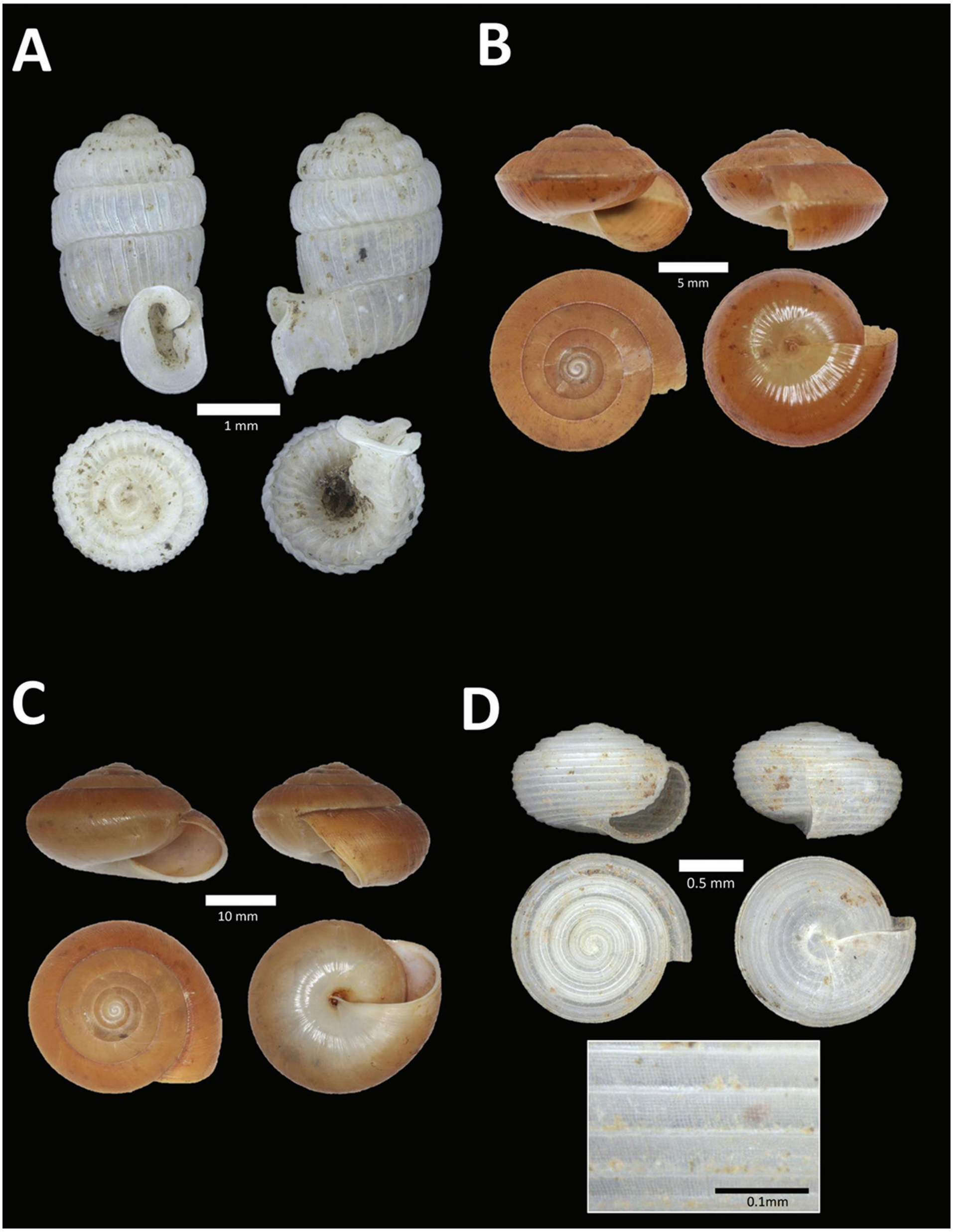

Figure 25. A *Sinoennea tweediei* Tomlin, 1941 BOR/MOL 10100. Perak, Ipoh, Gua Tok Giring Plot 1 **B** *Pseudoplecta bijuga* (Stoliczka, 1873) BOR/MOL 11213. Perak, Ipoh, Gunung Tempurung Plot 3 **C** *Quantula striata* (Gray, 1834) BOR/MOL 9857. Perak, Ipoh, Bat Cave Hill Plot 4 **D** *Glyptaulax* 'tempurung 1' BOR/MOL 11147. Perak, Ipoh, Gunung Tempurung Plot 1.

Remarks. Distinguished from Perak congeners by the box-like shell shape, fewer whorls of gradually increasing height, widely spaced radial ribs, flared peristome and peristomal structures.

Family Dyakiidae Gude & Woodward, 1921
Genus *Pseudoplecta* Laidlaw, 1932

Pseudoplecta bijuga (Stoliczka, 1873)
Figure 25B

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9856, BOR/MOL 9764, BOR/MOL 9796, BOR/MOL 9826. Prk 53 Hill KF: BOR/MOL 10710, BOR/MOL 10739, BOR/MOL 10660, BOR/MOL 10687. mykarst-025: BOR/MOL 9375, BOR/MOL 9403, BOR/MOL 9435, BOR/MOL 9502. Prk 47 Kanthan: BOR/MOL 9065, BOR/MOL 9138. mykarst-027: BOR/MOL 9100. Prk 23 G. Rapat: BOR/MOL 10227, BOR/MOL 10044, BOR/MOL 10049, BOR/MOL 10251. Prk 42 G. Bercham: BOR/MOL 9213, BOR/MOL 9231, BOR/MOL 10571, BOR/MOL 10590, BOR/MOL 10616. Prk 36 Gua Datok: BOR/MOL 10431, BOR/MOL 10443, BOR/MOL 10478, BOR/MOL 10495. Prk 34 G. Tasek: BOR/MOL 10790, BOR/MOL 11168, BOR/MOL 11052. Prk 01 G. Tempurung: BOR/MOL 11133, BOR/MOL 11213, BOR/MOL 11242, BOR/MOL 11418. Prk 55 G. Pondok: BOR/MOL 11507, BOR/MOL 11480, BOR/MOL 11540.

Distribution. In Peninsular Malaysia, found in Kedah (Langkawi), Penang, Perak, Selangor and Pahang (Cameron Highlands) (Laidlaw 1932, Maassen 2001). Elsewhere, in Nawngchik (=Pattani) and Rhaman (=Yala), Thailand (Maassen 2001).

Remarks. Shell medium-sized, brown. Periphery strongly keeled. Dorsal whorls have dense and pronounced sradial ribbing while the umbilical side is glossy with fine radial growth lines.

Genus *Quantula* Baker, 1941

Quantula striata (Gray, 1834)
Figure 25C

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9857, BOR/MOL 9827. mykarst-027: BOR/MOL 9092. mykarst-185 Batu Kebelah: BOR/MOL 9122, BOR/MOL 9526, BOR/MOL 9557. Prk 47 Kanthan: BOR/MOL 9142. mykarst-025: BOR/MOL 9503. Prk 42 G. Bercham: BOR/MOL 10569.

Distribution. Found throughout Peninsular Malaysia (Maassen 2001). Elsewhere, on Sundaland and the Philippines (Maassen 2001, Brodie and Barker 2012). Also, introduced into Fiji (Brodie and Barker 2012).

Remarks. Shell medium-sized. Brown and non-glossy at dorsal whorls, white and glossy at umbilicus. Periphery keeled but less pronounced than *Pseudoplecta bijuga.* Whorls have dense and fine radial growth lines. This is a synanthropic species.

Family Endodontidae Pilsbry, 1895
Genus *Glyptaulax* Gude, 1914

Glyptaulax 'tempurung 1'
Figure 25D

Materials examined. Prk 01 G. Tempurung: BOR/MOL 11147, BOR/MOL 11220, BOR/MOL 11391, BOR/MOL 11424.

Distribution. Known from Gunung Tempurung only, but surrounding hills have yet to be adequately surveyed.

Remarks. Shell small. Spire low, shell discoid. Distinguished from other discoid snails by the presence of strong spiral ridges of equal width. In between these spiral ridges, fine round pits are deposited in a neat matrix. Differs from *Glyptaulax artificiosa* (Benson, 1856) by its less expanded aperture and smaller umbilicus. First record of *Glyptaulax* in Peninsular Malaysia.

Genus *Philalanka* Godwin-Austen, 1898

Philalanka kusana (Aldrich, 1889)
Figure 26A

Materials examined. Prk 53 Hill KF: BOR/MOL 10702, BOR/MOL 10755, BOR/MOL 10769, BOR/MOL 10729, BOR/MOL 10672. Prk 36 Gua Datok: BOR/MOL 10060. Prk 23 G. Rapat: BOR/MOL 10284, BOR/MOL 10285. Prk 42 G. Bercham: BOR/MOL 10578. Prk 34 G. Tasek: BOR/MOL 11161, BOR/MOL 11017, BOR/MOL 11041, BOR/MOL 11174. Prk 55 G. Pondok: BOR/MOL 11488, BOR/MOL 11530, BOR/MOL 11546, BOR/MOL 11572. Prk 01 G. Tempurung: BOR/MOL 11223, BOR/MOL 11399.

Distribution. In Peninsular Malaysia, known from Pahang (Maassen 2001) and Perak. Elsewhere, ranges from Sumatra to Maluku, in Indonesia (Vermeulen and Whitten 1998).

Remarks. Distinguished from *Philalanka pusilla* by the white shell, taller spire, two to three major spiral ridges with many minor spiral lines and less changes in the angularity of whorls. New record for Perak.

Philalanka pusilla Maassen, 2000
Figure 26B

Materials examined. Prk 53 Hill KF: BOR/MOL 10705, BOR/MOL 10750, BOR/MOL 10673. mykarst-184 Bat Cave: BOR/MOL 9865.mykarst-027: BOR/MOL 9045, BOR/MOL 9128. Prk 47 Kanthan: BOR/MOL 9452, BOR/MOL 9154. Prk

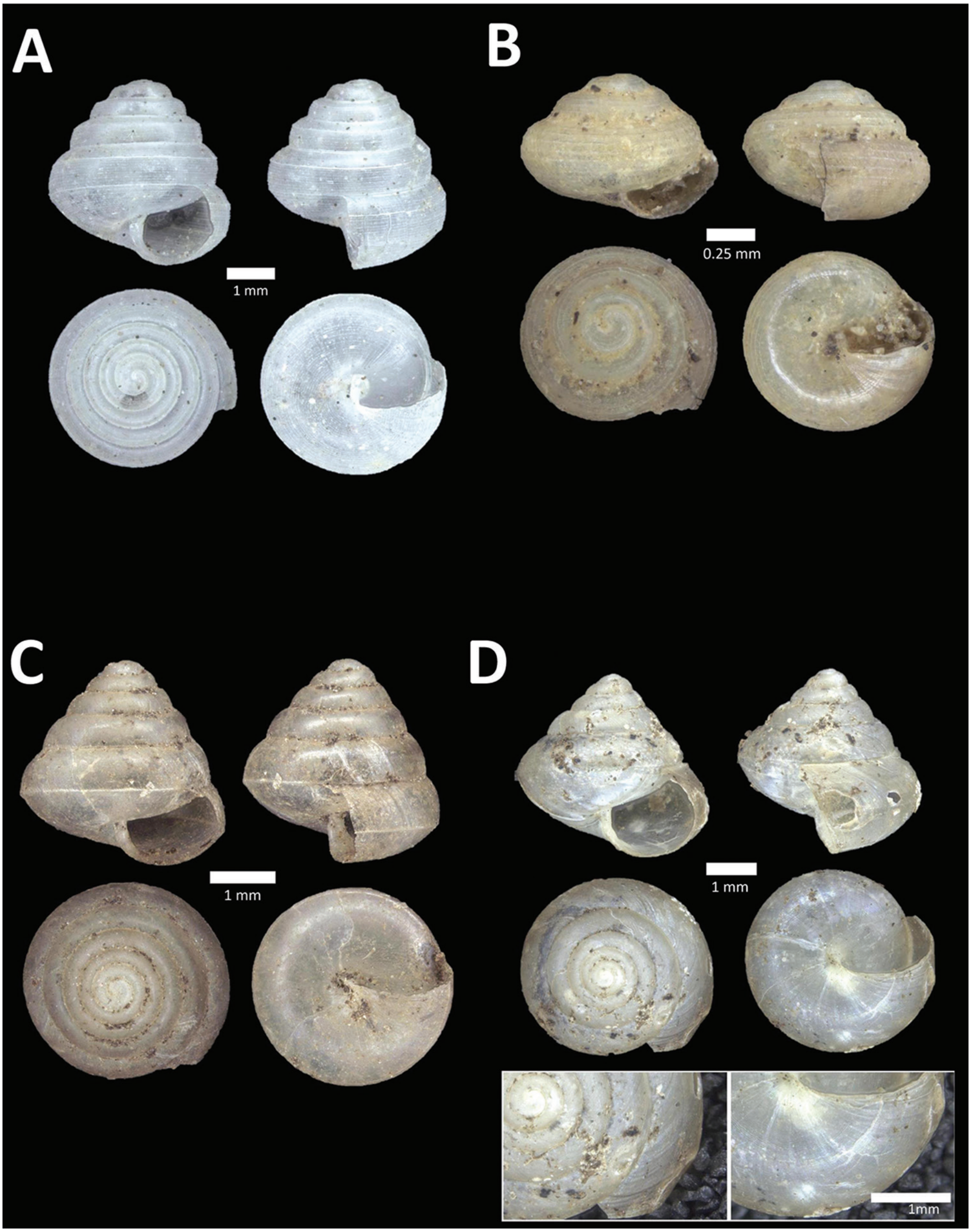

Figure 26. A *Philalanka kusana* (Aldrich, 1889) BOR/MOL 11174. Perak, Ipoh, Gunung Tasek Plot 5 **B** *Philalanka pusilla* Maassen, 2000 BOR/MOL 9865. Perak, Ipoh, Bat Cave Hill Plot 4 **C** *Kaliella barrakporensis* (Pfeiffer, 1852) BOR/MOL 9032. Perak, Ipoh, Gunung Kanthan Plot 1 **D** *Kaliella calculosa* (Gould, 1852) BOR/MOL 10053. Perak, Ipoh, Gunung Rapat Plot C3.

36 Gua Datok: BOR/MOL 10063, BOR/MOL 10424, BOR/MOL 10460. Prk 23 G. Rapat: BOR/MOL 10266. Prk 34 G. Tasek: BOR/MOL 11124, BOR/MOL 11188. Prk 01 G. Tempurung: BOR/MOL 11219.

Distribution. In Peninsular Malaysia, known from Kinta Valley, Perak. Elsewhere, in Sumatra, Indonesia (Maassen 2000).

Remarks. Shell smaller and flatter than *Philalanka kusana*, spire low. Shell yellow to light brown. Five or more major spiral ridges and more changes in angularity of whorls. New record for Peninsular Malaysia.

Family Euconulidae Baker, 1928

Genus *Kaliella* Blanford, 1863

Kaliella barrakporensis (Pfeiffer, 1852)

Figure 26C

Materials examined. mykarst-027: BOR/MOL 9032, BOR/MOL 9107. Prk 53 Hill KF: BOR/MOL 10744, BOR/MOL 10728, BOR/MOL 10679, BOR/MOL 10694. mykarst-184 Bat Cave: BOR/MOL 9869, BOR/MOL 9830, BOR/MOL 9773, BOR/MOL 9808. mykarst-025: BOR/MOL 9388, BOR/MOL 9411, BOR/MOL 9485, BOR/MOL 9510, BOR/MOL 12432. Prk 47 Kanthan: BOR/MOL 9111, BOR/MOL 9153. Prk 42 G. Bercham: BOR/MOL 9471, BOR/MOL 9475, BOR/MOL 9220, BOR/MOL 10579, BOR/MOL 10600, BOR/MOL 10619, BOR/MOL 10626. Prk 23 G. Rapat: BOR/MOL 10210, BOR/MOL 10030, BOR/MOL 10243, BOR/MOL 10268. mykarst-185 Batu Kebelah: BOR/MOL 9531, BOR/MOL 9587. Prk 36 Gua Datok: BOR/MOL 10062, BOR/MOL 10433, BOR/MOL 10456. Prk 64 Bt Kepala Gajah: BOR/MOL 10102, BOR/MOL 10143, BOR/MOL 10178. Prk 55 G. Pondok: BOR/MOL 11489, BOR/MOL 11532, BOR/MOL 11547, BOR/MOL 11573. Prk 34 G. Tasek: BOR/MOL 11016, BOR/MOL 11034, BOR/MOL 11056, BOR/MOL 11172. Prk 01 G. Tempurung: BOR/MOL 11203, BOR/MOL 11218, BOR/MOL 11388, BOR/MOL 11432.

Distribution. In Peninsular Malaysia, known from Perak only although it is likely widespread. Elsewhere, distributed from Africa in the west to Flores, Indonesia in the east (Vermeulen et al. 2015).

Remarks. Shell small, conical. Differ from congeners in its fine but distinct radial sculpture, less dense coiling of whorls and slightly convex whorls.

Kaliella calculosa (Gould, 1852)

Figure 26D

Materials examined. Prk 47 Kanthan: BOR/MOL 9185, BOR/MOL 9163. mykarst-027: BOR/MOL 9036, BOR/MOL 9108. mykarst-184 Bat Cave: BOR/MOL

9772, BOR/MOL 9809. Prk 23 G. Rapat: BOR/MOL 10053. Prk 64 Bt Kepala Gajah: BOR/MOL 10096. Prk 55 G. Pondok: BOR/MOL 11574.

Distribution. In Peninsular Malaysia, currently known from Penang, Perak and Selangor although it is likely widespread. Elsewhere, distributed from India in the west to Australia and Tahiti in the east (Vermeulen et al. 2015).

Remarks. Shell slightly larger than *Kaliella barrakporensis*. Differs from sympatric congeners in its fewer but more convex whorls, especially obvious in the ultimate whorl. Radial sculpture fine but distinct. Spiral sculpture usually present.

Kaliella microconus (Mousson, 1865)

Figure 27A

Materials examined. Prk 53 Hill KF: BOR/MOL 10746, BOR/MOL 10692. mykarst-025: BOR/MOL 9516. mykarst-185 Batu Kebelah: BOR/MOL 9551. Prk 36 Gua Datok: BOR/MOL 10061, BOR/MOL 10467, BOR/MOL 10486. Prk 42 G. Bercham: BOR/MOL 10577, BOR/MOL 10601, BOR/MOL 10633. Prk 34 G. Tasek: BOR/MOL 11155, BOR/MOL 11012, BOR/MOL 11036, BOR/MOL 11055, BOR/MOL 11173. Prk 55 G. Pondok: BOR/MOL 11531, BOR/MOL 11583. Prk 01 G. Tempurung: BOR/MOL 11387, BOR/MOL 11433.

Distribution. In Peninsular Malaysia, known from Perak, Johor (Pulau Aur) and Kelantan although it is likely widespread (Maassen 2001). Elsewhere, from Sundaland to Australia, Fiji and Samoa (Vermeulen et al. 2015).

Remarks. Distinguished from *Kaliella barrakporensis* by its straighter spire, less convex whorls and predominant spiral sculpture.

Kaliella scandens (Cox, 1871)

Figure 27B

Materials examined. Prk 47 Kanthan: BOR/MOL 9076, BOR/MOL 9155, BOR/MOL 9167. mykarst-027: BOR/MOL 9040, BOR/MOL 9131. Prk 53 Hill KF: BOR/MOL 10751, BOR/MOL 10763, BOR/MOL 10731, BOR/MOL 10668, BOR/MOL 10693. mykarst-184 Bat Cave: BOR/MOL 9870, BOR/MOL 9786, BOR/MOL 9819, BOR/MOL 9836. mykarst-025: BOR/MOL 9392, BOR/MOL 9424, BOR/MOL 9517. Prk 42 G. Bercham: BOR/MOL 9480, BOR/MOL 9221, BOR/MOL 10582, BOR/MOL 10603, BOR/MOL 10618, BOR/MOL 10638. Prk 23 G. Rapat: BOR/MOL 10211, BOR/MOL 10045, BOR/MOL 10276, BOR/MOL 10282. mykarst-185 Batu Kebelah: BOR/MOL 9536, BOR/MOL 9590. Prk 36 Gua Datok: BOR/MOL 10058, BOR/MOL 10425. Prk 64 Bt Kepala Gajah: BOR/MOL 10103, BOR/MOL 10151, BOR/MOL 10177. Prk 34 G. Tasek: BOR/MOL 11019, BOR/MOL 11164, BOR/MOL 11004, BOR/MOL 11035, BOR/MOL 11043, BOR/MOL 11044, BOR/MOL 11057, BOR/MOL 11175, BOR/

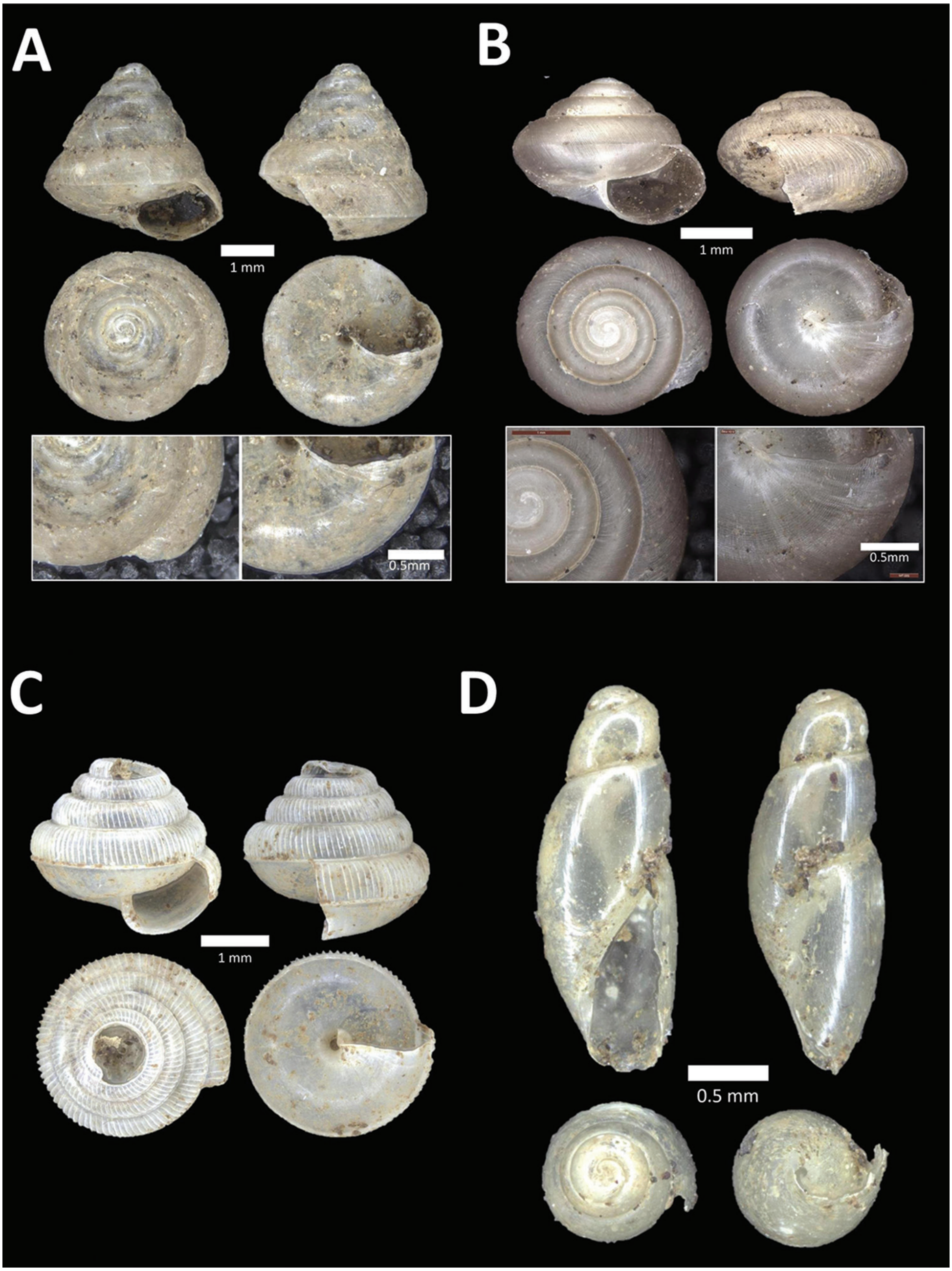

Figure 27. A *Kaliella microconus* (Mousson, 1865) BOR/MOL 9551. Perak, Ipoh, Batu Kebelah Plot 1 **B** *Kaliella scandens* (Cox, 1871) BOR/MOL 11043. Perak, Ipoh, Gunung Tasek Plot 1 **C** *Rahula* 'tempurung 1' BOR/MOL 11392. Perak, Ipoh, Gunung Tempurung Plot 2 **D** *Cecilioides caledonica* (Crosse, 1867) BOR/MOL 9748. Perak, Ipoh, Batu Kebelah Plot 4.

MOL 11184, BOR/MOL 11185. Prk 55 G. Pondok: BOR/MOL 11491, BOR/MOL 11529, BOR/MOL 11545, BOR/MOL 11571. Prk 01 G. Tempurung: BOR/MOL 11204, BOR/MOL 11225, BOR/MOL 11390, BOR/MOL 11425.

Distribution. Widespread in Peninsular Malaysia (Vermeulen et al. 2015). Elsewhere, from Sundaland to Australia and the Pacific islands (Vermeulen et al. 2015).

Remarks. Shell shape similar to *Kaliella doliolum* (Pfeiffer, 1846). Radial rib density highly variable, from very fine growth lines to coarse ribs. Distinguished from *K. doliolum* by the presence of fine spiral lines and absent or indistinct radial ribs at the umbilical section of the whorls. This is a synanthropic species.

Genus *Rahula* Godwin-Austen, 1907

Rahula 'tempurung 1'

Figure 27C

Materials examined. Prk 01 G. Tempurung: BOR/MOL 11207, BOR/MOL 11222, BOR/MOL 11392, BOR/MOL 11422.

Distribution. Known from Gunung Tempurung only, but surrounding hills have yet to be adequately surveyed.

Remarks. Distinguished from other Southeast Asian congeners by its convex whorls at both dorsal and umbilical sides, sharp peripheral keel, dense and pronounced radial ribs as well as glossy, spiral lined umbilical whorls. First record of *Rahula* in Peninsular Malaysia.

Family Ferussaciidae Bourguignat, 1883

Genus *Cecilioides* Férussac, 1814

Cecilioides caledonica (Crosse, 1867)

Figure 27D

Materials examined. mykarst-185 Batu Kebelah: BOR/MOL 9748. Prk 01 G. Tempurung: BOR/MOL 11421.

Distribution. In Peninsular Malaysia, known from Perlis and Perak (Maassen 2001). Elsewhere, in Indonesia (Java), New Guinea and New Caledonia (Maassen 2001).

Remarks. A distinctive species with a thin, bullet-shaped shell. Spire tall, suture indistinct, whorls smooth and glossy. Aperture elongated and narrow.

Family Helicarionidae Bourguignat, 1877
Genus *Helicarion* Férussac, 1821

Helicarion permolle Stoliczka, 1873
Figure 28A

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9766, BOR/MOL 9805. Prk 53 Hill KF: BOR/MOL 10734, BOR/MOL 10664. mykarst-025: BOR/MOL 9377, BOR/MOL 9414, BOR/MOL 9492. Prk 47 Kanthan: BOR/MOL 9055, BOR/MOL 9152. mykarst-027: BOR/MOL 9097. Prk 42 G. Bercham: BOR/MOL 9240, BOR/MOL 10597. Prk 36 Gua Datok: BOR/MOL 10434, BOR/MOL 10484. Prk 01 G. Tempurung: BOR/MOL 11148, BOR/MOL 11230, BOR/MOL 11248. Prk 34 G. Tasek: BOR/MOL 11179. Prk 55 G. Pondok: BOR/MOL 11542, BOR/MOL 11567.

Distribution. Known from Penang and Perak only (Maassen 2001).

Remarks. Shell small. Periphery rounded, whorls few, spire low. Surface glossy with very fine spiral lines. Sutural line distinct and white.

Family Streptaxidae Gray, 1860
Genus *Discartemon* Pfeiffer, 1856

Discartemon leptoglyphus van Benthem Jutting, 1954
Figure 28B

Materials examined. mykarst-027: BOR/MOL 9110, BOR/MOL 9013.mykarst-025: BOR/MOL 9412. Prk 42 G. Bercham: BOR/MOL 9466, BOR/MOL 10596. Prk 47 Kanthan: BOR/MOL 9143. Prk 23 G. Rapat: BOR/MOL 10048, BOR/MOL 10205, BOR/MOL 10232, BOR/MOL 10254. Prk 36 Gua Datok: BOR/MOL 10418, BOR/MOL 10446, BOR/MOL 10479, BOR/MOL 10492. Prk 34 G. Tasek: BOR/MOL 10794.

Distribution. Restricted to central Kinta Valley, Perak (Maassen 2001, Siriboon et al. 2014).

Remarks. Shell size varies. Differs from *Discatemon plussensis* in the prominence of lamella, presence of a peripheral keel and flatter shell.

Discartemon plussensis (de Morgan, 1885a)
Figure 28C

Materials examined. Prk 47 Kanthan: BOR/MOL 9056. Prk 42 G. Bercham: BOR/MOL 9458, BOR/MOL 9473, BOR/MOL 9476, BOR/MOL 9217, BOR/MOL 10620, BOR/MOL 10630. Prk 53 Hill KF: BOR/MOL 10695. Prk 23 G. Rapat: BOR/MOL 10260. Prk 34 G. Tasek: BOR/MOL 10795, BOR/MOL 11167, BOR/

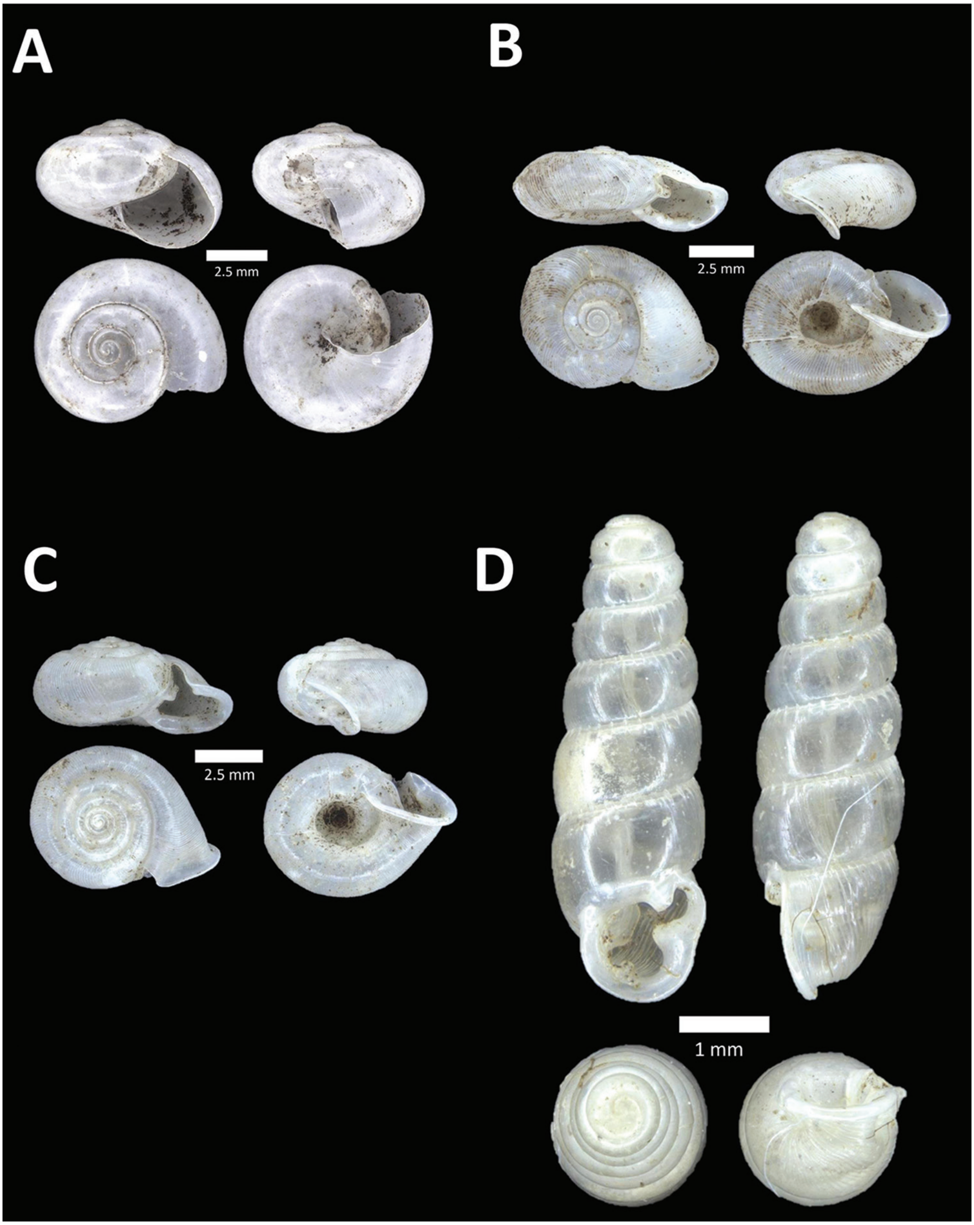

Figure 28. A *Helicarion permolle* Stoliczka, 1873 BOR/MOL 9152. Perak, Ipoh, Gunung Kanthan Plot 4 **B** *Discartemon leptoglyphus* van Benthem Jutting, 1954 BOR/MOL 10479. Perak, Ipoh, Gunung Datok **C** *Discartemon plussensis* (de Morgan, 1885a) BOR/MOL 11031. Perak, Ipoh, Gunung Tasek

MOL 11031, BOR/MOL 11176. mykarst-027: BOR/MOL 9015. Prk 01 G. Tempurung: BOR/MOL 11145, BOR/MOL 11381, BOR/MOL 11413.

Distribution. Known from Perak only (Maassen 2001, Siriboon et al. 2014).

Remarks. Shell size varies. Differs from *Discatemon leptoglyphus* in the prominence of lamella, the absence of a peripheral keel and having more bulbous whorls. Prior to this, Davison (1991) reported *D. plussensis* from Gunung Tchehel and a few hills near Sungai Siput North only.

Genus *Gulella* Pfeiffer, 1856

Gulella bicolor (Hutton, 1834)

Figure 28D

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9879. Prk 47 Kanthan: BOR/MOL 9159, BOR/MOL 9195. mykarst-185 Batu Kebelah: BOR/MOL 9540, BOR/MOL 9586.

Distribution. Found throughout Peninsular Malaysia (Maassen 2001). Elsewhere, pantropical (Simone 2013).

Remarks. Radial ribs faint to distinct. Distinguished from confamilals by its tall spire, cylindrical shell, compact whorls without detachment and its lamella arrangement. This is a synanthropic species.

Family Subulinidae Fischer & Crosse, 1877

Genus *Allopeas* Baker, 1935

Allopeas clavulinum (Potiez & Michaud, 1838)

Figure 29A

Materials examined. Prk 53 Hill KF: BOR/MOL 10700, BOR/MOL 10753, BOR/MOL 10722, BOR/MOL 10674. mykarst-184 Bat Cave: BOR/MOL 9876, BOR/MOL 9878, BOR/MOL 9801, BOR/MOL 9832, BOR/MOL 9769. Prk 47 Kanthan: BOR/MOL 9083, BOR/MOL 9145. mykarst-027: BOR/MOL 9037, BOR/MOL 9119. mykarst-025: BOR/MOL 9393, BOR/MOL 9409, BOR/MOL 9487, BOR/MOL 9512. Prk 42 G. Bercham: BOR/MOL 9465, BOR/MOL 9479, BOR/MOL 9215, BOR/MOL 10634, BOR/MOL 10635, BOR/MOL 10636. mykarst-185 Batu Kebelah: BOR/MOL 9539, BOR/MOL 9544, BOR/MOL 9583. Prk 64 Bt Kepala Gajah: BOR/MOL 10169. Prk 36 Gua Datok: BOR/MOL 10419, BOR/MOL 10487, BOR/MOL 10505. Prk 55 G. Pondok: BOR/MOL 11614. Prk 34 G. Tasek: BOR/MOL 11020, BOR/MOL 11160, BOR/MOL 11033, BOR/MOL 11038, BOR/MOL 11183. Prk 01 G. Tempurung: BOR/MOL 11150, BOR/MOL 11237, BOR/MOL 11386, BOR/MOL 11395, BOR/MOL 11430, BOR/MOL 11431.

Distribution. In Peninsular Malaysia, found in Perak and Kelantan but likely more widespread (Maassen 2001). Elsewhere, possibly native to tropical East Africa but now pantropical (Ho 1995, Vermeulen and Whitten 1998).

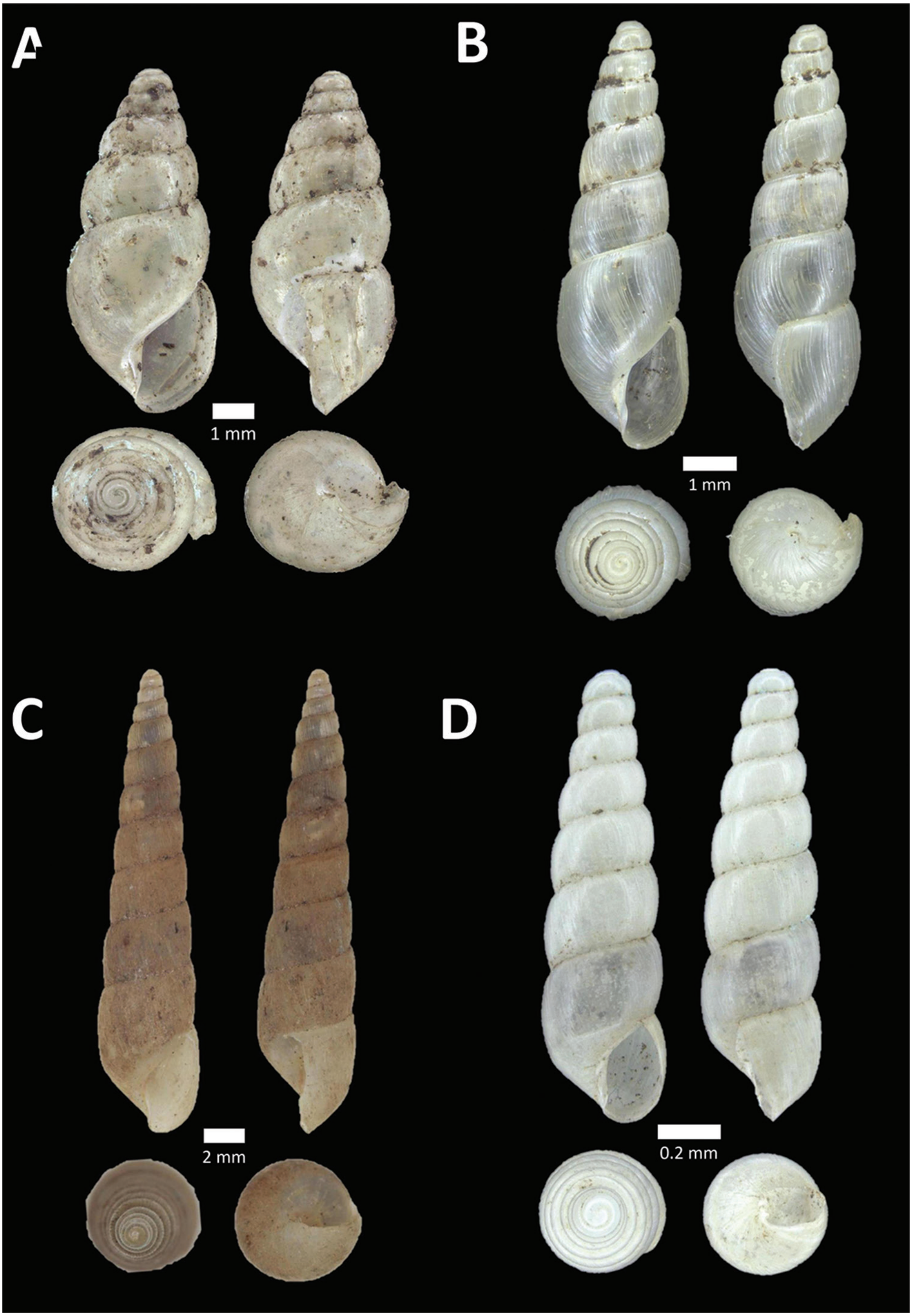

Figure 29. A *Allopeas clavulinum* (Potiez & Michaud, 1838) BOR/MOL 9409. Perak, Ipoh, Mykarst-025 Plot 2 **B** *Allopeas gracile* (Hutton, 1834) BOR/MOL 9112. Perak, Ipoh, Gunung Kanthan Plot 3 **C** *Prosopeas tchehelense* (de Morgan, 1885b) BOR/MOL 9098. Perak, Ipoh, Gunung Kanthan Plot 2 **D** *Subulina octona* (Bruguière, 1792) BOR/MOL 11227. Perak, Ipoh, Gunung Tempurung Plot 3.

Remarks. Shell small, spire tall. Whorls more obtuse than *Allopeas gracile*. Spiral growth lines fine. This is a synanthropic species.

Allopeas gracile (Hutton, 1834)

Figure 29B

Materials examined. Prk 53 Hill KF: BOR/MOL 10699, BOR/MOL 10678. mykarst-027: BOR/MOL 9085, BOR/MOL 9121. mykarst-184 Bat Cave: BOR/MOL 9867, BOR/MOL 9802, BOR/MOL 9837, BOR/MOL 9768. mykarst-025: BOR/MOL 9394, BOR/MOL 9408, BOR/MOL 9440, BOR/MOL 9513. Prk 47 Kanthan: BOR/MOL 9112, BOR/MOL 9146. Prk 42 G. Bercham: BOR/MOL 9214, BOR/MOL 10607. mykarst-185 Batu Kebelah: BOR/MOL 9541, BOR/MOL 9749. Prk 64 Bt Kepala Gajah: BOR/MOL 10089, BOR/MOL 10144, BOR/MOL 10145, BOR/MOL 10181. Prk 36 Gua Datok: BOR/MOL 10427, BOR/MOL 10461, BOR/MOL 10501. Prk 55 G. Pondok: BOR/MOL 11613. Prk 01 G. Tempurung: BOR/MOL 11143, BOR/MOL 11226, BOR/MOL 11398, BOR/MOL 11415. Prk 34 G. Tasek: BOR/MOL 11157, BOR/MOL 11006, BOR/MOL 11037, BOR/MOL 11180.

Distribution. Found throughout Peninsular Malaysia (Maassen 2001). Elsewhere, pantropical (Raheem et al. 2014).

Remarks. Shell small, spire tall. Whorls slender than *Allopeas clavulinum*. Spiral growth lines fine. This is a synanthropic species.

Genus *Paropeas* Pilsbry, 1906

Paropeas tchehelense (de Morgan, 1885b)

Figure 29C

Materials examined. Prk 64 Bt Kepala Gajah: BOR/MOL 10121, BOR/MOL 10087, BOR/MOL 10131, BOR/MOL 10165. mykarst-184 Bat Cave: BOR/MOL 9767, BOR/MOL 9797, BOR/MOL 9831. mykarst-025: BOR/MOL 9384, BOR/MOL 9406, BOR/MOL 9439, BOR/MOL 9508, BOR/MOL 12430. Prk 47 Kanthan: BOR/MOL 9050, BOR/MOL 9144. mykarst-027: BOR/MOL 9098, BOR/MOL 9014. Prk 23 G. Rapat: BOR/MOL 10209, BOR/MOL 10032, BOR/MOL 10047, BOR/MOL 10233, BOR/MOL 10257. mykarst-185 Batu Kebelah: BOR/MOL 9162, BOR/MOL 9543. Prk 42 G. Bercham: BOR/MOL 9216, BOR/MOL 10581, BOR/MOL 10591. Prk 36 Gua Datok: BOR/MOL 10059, BOR/MOL 10428, BOR/MOL 10451. Prk 53 Hill KF: BOR/MOL 10675. Prk 34 G. Tasek: BOR/MOL 10792, BOR/MOL 11029, BOR/MOL 11186. Prk 01 G. Tempurung: BOR/MOL 11146, BOR/MOL 11383, BOR/MOL 11416. Prk 55 G. Pondok: BOR/MOL 11511, BOR/MOL 11483, BOR/MOL 11550, BOR/MOL 11565.

Distribution. In Peninsular Malaysia, known from Perak, Selangor, Pahang and Kelantan (Maassen 2001). Elsewhere, in Jalor (=Yala), Thailand (Maassen 2001).

Remarks. Distinguished from all confamilials by its large shell, rounded apical whorls, fine but pronounced radial ribs and angular lower periphery.

Genus *Subulina* Beck, 1837

Subulina octona (Bruguière, 1792)

Figure 29D

Materials examined. mykarst-184 Bat Cave: BOR/MOL 9875. mykarst-025: BOR/MOL 9410. mykarst-185 Batu Kebelah: BOR/MOL 9542, BOR/MOL 9564, BOR/MOL 9574, BOR/MOL 9584. Prk 23 G. Rapat: BOR/MOL 10255. Prk 34 G. Tasek: BOR/MOL 10791, BOR/MOL 11027. Prk 01 G. Tempurung: BOR/MOL 11227, BOR/MOL 11389.

Distribution. Found throughout Peninsular Malaysia (Maassen 2001). Elsewhere, pantropical (Raheem et al. 2014).

Remarks. Distinguished from all confamilials by its glossy, large shell, very convex whorls, fine radial growth lines and truncated columella.

Family Trochomorphidae von Möllendorff, 1890

Genus *Videna* Adams & Adams, 1855

Videna castra (Benson, 1852b)

Figure 30A

Materials examined. Prk 47 Kanthan: BOR/MOL 9077, BOR/MOL 9172. mykarst-027: BOR/MOL 9090. Prk 53 Hill KF: BOR/MOL 10716, BOR/MOL 10663, BOR/MOL 10688. Prk 64 Bt Kepala Gajah: BOR/MOL 10093, BOR/MOL 10162. Prk 23 G. Rapat: BOR/MOL 10287. Prk 36 Gua Datok: BOR/MOL 10422, BOR/MOL 10457, BOR/MOL 10497. Prk 42 G. Bercham: BOR/MOL 10608. Prk 01 G. Tempurung: BOR/MOL 11135, BOR/MOL 11245, BOR/MOL 11384, BOR/MOL 11417. Prk 34 G. Tasek: BOR/MOL 11169. Prk 55 G. Pondok: BOR/MOL 11509, BOR/MOL 11481, BOR/MOL 11549, BOR/MOL 11570. mykarst-025: BOR/MOL 12429.

Distribution. Found throughout Peninsular Malaysia (Maassen 2001). Elsewhere, in Darjiling (=Darjeeling), India and Salang (=Phuket), Thailand (Maassen 2001).

Remarks. Distinguished from Peninsular Malaysian congeners by its distinct spiral lines at apical whorls, becoming less at post-apical whorls. Radial sculpture more prominent at post-apical whorls.

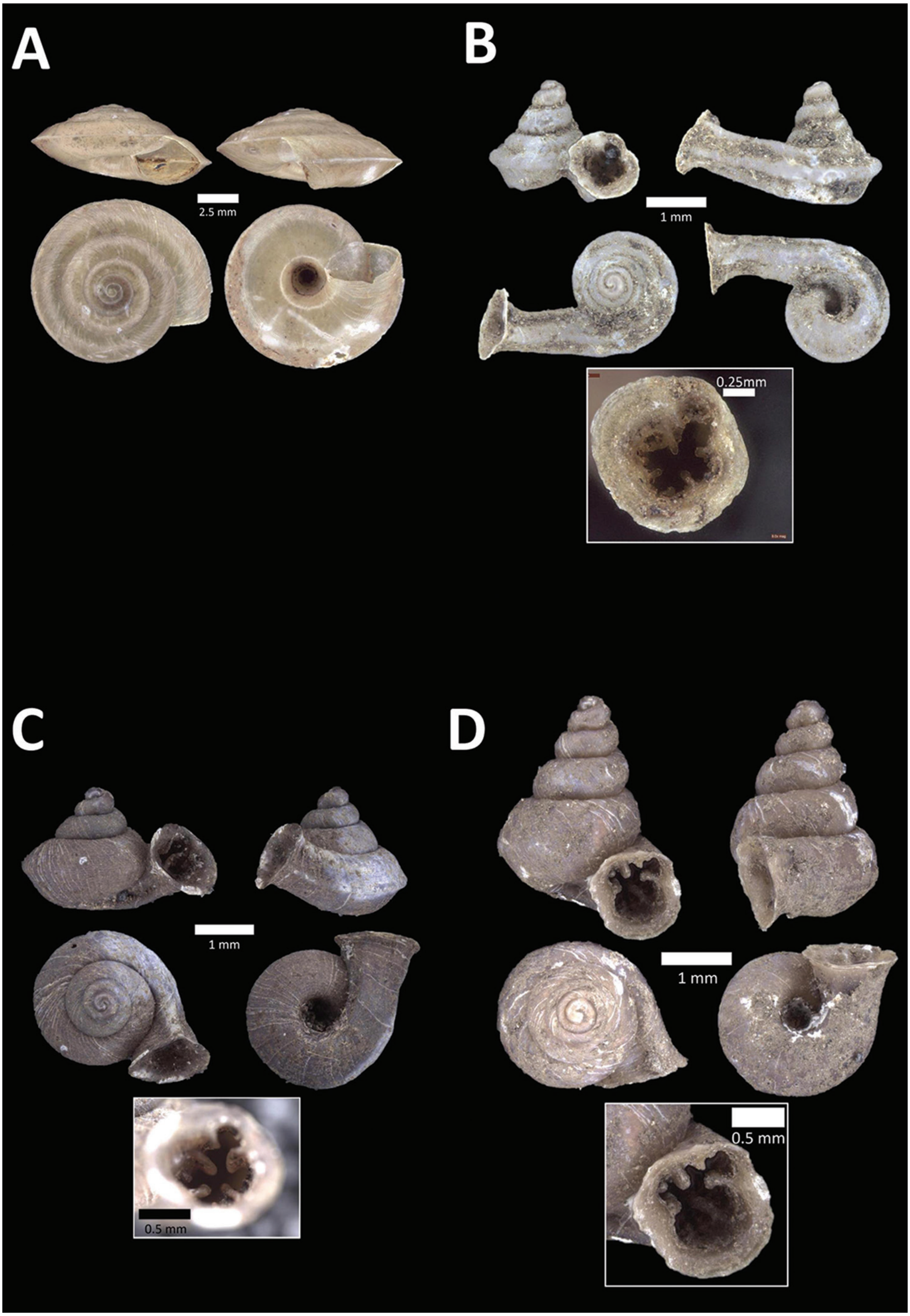

Figure 30. A *Videna castra* (Benson, 1852b) BOR/MOL 11135. Perak, Ipoh, Gunung Tempurung Plot 1 **B** *Gyliotrachela hungerfordiana* (von Möllendorff, 1886) BOR/MOL 9133. Perak, Ipoh, Gunung Kanthan **C** *Gyliotrachela luctans* van Benthem Jutting, 1950 BOR/MOL 10064. Perak, Ipoh, Gunung Datok **D** *Paraboysidia oreia* van Benthem Jutting, 1961 BOR/MOL 10504. Perak, Ipoh, Gunung

Family Hypselostomatidae Zilch, 1959
Genus *Gyliotrachela* Tomlin, 1930

Gyliotrachela hungerfordiana (von Möllendorff, 1886)
Figure 30B

Materials examined. Prk 53 Hill KF: BOR/MOL 10701, BOR/MOL 10743, BOR/MOL 10726, BOR/MOL 10667. Prk 47 Kanthan: BOR/MOL 9073, BOR/MOL 9148. mykarst-184 Bat Cave: BOR/MOL 9871, BOR/MOL 9789, BOR/MOL 9804, BOR/MOL 9845. mykarst-025: BOR/MOL 9390, BOR/MOL 9419. Prk 42 G. Bercham: BOR/MOL 9461, BOR/MOL 9464, BOR/MOL 9483, BOR/MOL 10575, BOR/MOL 10602, BOR/MOL 10623. mykarst-027: BOR/MOL 9133, BOR/MOL 9241. mykarst-185 Batu Kebelah: BOR/MOL 9538, BOR/MOL 9747. Prk 23 G. Rapat: BOR/MOL 10040, BOR/MOL 10234, BOR/MOL 10262. Prk 64 Bt Kepala Gajah: BOR/MOL 10094, BOR/MOL 10142, BOR/MOL 10180. Prk 36 Gua Datok: BOR/MOL 10426, BOR/MOL 10458, BOR/MOL 10507. Prk 34 G. Tasek: BOR/MOL 11156, BOR/MOL 11002, BOR/MOL 11046, BOR/MOL 11181. Prk 55 G. Pondok: BOR/MOL 11513, BOR/MOL 11486, BOR/MOL 11548, BOR/MOL 11568.

Distribution. Found on limestone karsts across Peninsular Malaysia (Maassen 2001). Elsewhere, in southern Thailand (Maassen 2003).

Remarks. Distinct among congeners in its tall spire, keeled periphery, very long trumpet-shaped ultimate whorl and apertural teeth arrangement. Shell colour varies from dark to light brown.

Gyliotrachela luctans van Benthem Jutting, 1950
Figure 30C

Materials examined. Prk 36 Gua Datok: BOR/MOL 10064.

Distribution. Known from Gunung Pondok (van Benthem Jutting 1950) and Gua Datok, Perak only.

Remarks. Spire tall but fewer than *Gyliotrachela hungerfordiana*. Penultimate whorl very expanded and periphery keeled, giving a depressed shell shape. Ultimate whorl trumpet-shaped, with aperture face at 45 degrees of the plane perpendicular to the coiling axis. Apertural teeth arrangement unique.

Genus *Paraboysidia* Pilsbry, 1917

Paraboysidia oreia van Benthem Jutting, 1961a
Figure 30D

Materials examined. Prk 53 Hill KF: BOR/MOL 10727. Prk 47 Kanthan: BOR/MOL 9064, BOR/MOL 9175. mykarst-027: BOR/MOL 9125, BOR/MOL 9022.

Prk 36 Gua Datok: BOR/MOL 10504. Prk 34 G. Tasek: BOR/MOL 11013, BOR/MOL 11039, BOR/MOL 11060.

Distribution. Known from Gunung Batu Kurau (van Benthem Jutting 1961) and Kinta Valley, Perak only.

Remarks. Shell small, dark brown. Spire tall. Whorls rather convex. Distinguished from Perak congeners by the slightly keeled periphery and apertural teeth arrangement.

Paraboysidia **'tempurung 1'**

Figure 31A

Materials examined. Prk 01 G. Tempurung: BOR/MOL 11217.

Distribution. Known from Gunung Tempurung, Perak only, but surrounding hills have yet to be adequately surveyed.

Remarks. Differ from *Paraboysidia kelantanensis tenuidentata* van Benthem Jutting, 1950, of Kramat Pulai by its gradually flatter and more expanded whorls, periphery rounded, shallow suture, short trumpet-like extension of ultimate whorl and apertural teeth arrangement.

Family Vallonidae Morse, 1864

Genus *Ptychopatula* Pilsbry, 1889

Ptychopatula orcula **(Benson, 1850)**

Figure 31B

Materials examined. Prk 53 Hill KF: BOR/MOL 10708, BOR/MOL 10723. mykarst-184 Bat Cave: BOR/MOL 9862, BOR/MOL 9782, BOR/MOL 9815, BOR/MOL 9842. Prk 47 Kanthan: BOR/MOL 9078, BOR/MOL 9171. mykarst-027: BOR/MOL 9043, BOR/MOL 9118. mykarst-025: BOR/MOL 9391, BOR/MOL 9426, BOR/MOL 9488, BOR/MOL 9522. Prk 42 G. Bercham: BOR/MOL 9457, BOR/MOL 9463, BOR/MOL 9478, BOR/MOL 9219, BOR/MOL 10584, BOR/MOL 10599, BOR/MOL 10621, BOR/MOL 10631, BOR/MOL 10632. Prk 23 G. Rapat: BOR/MOL 10218, BOR/MOL 10036, BOR/MOL 10235, BOR/MOL 10269. mykarst-185 Batu Kebelah: BOR/MOL 9537, BOR/MOL 9743. Prk 64 Bt Kepala Gajah: BOR/MOL 10104, BOR/MOL 10148, BOR/MOL 10185. Prk 36 Gua Datok: BOR/MOL 10429, BOR/MOL 10471, BOR/MOL 10503. Prk 01 G. Tempurung: BOR/MOL 11144, BOR/MOL 11224, BOR/MOL 11426. Prk 34 G. Tasek: BOR/MOL 11163, BOR/MOL 11008, BOR/MOL 11042, BOR/MOL 11182. Prk 55 G. Pondok: BOR/MOL 11487, BOR/MOL 11526, BOR/MOL 11551.

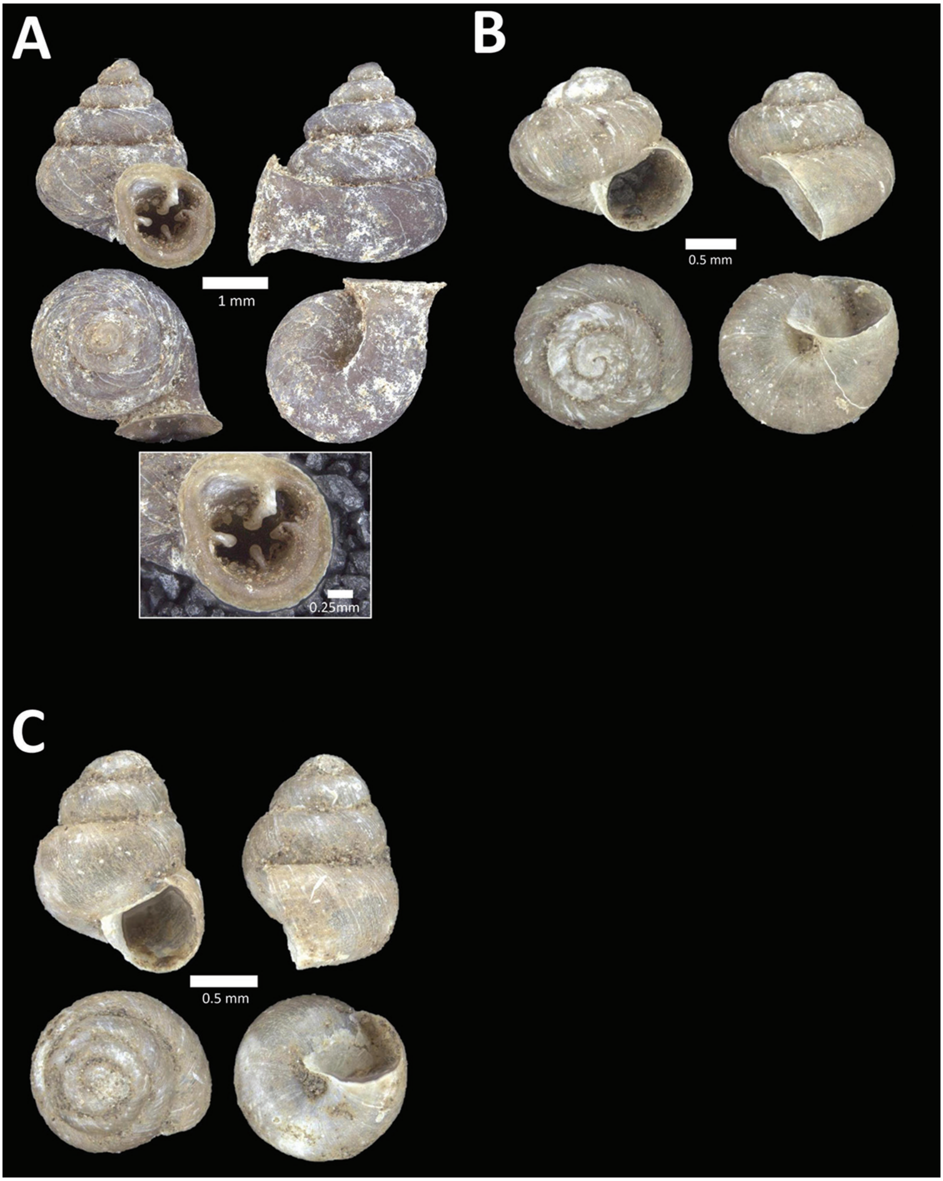

Figure 31. **A** *Paraboysidia* 'tempurung 1' BOR/MOL 11217. Perak, Ipoh, Gunung Tempurung Plot 3 **B** *Ptychopatula orcula* (Benson, 1850) BOR/MOL 9043. Perak, Ipoh, Gunung Kanthan Plot 1 **C** *Ptychopatula solemi* Maassen, 2000 BOR/MOL 9042. Perak, Ipoh, Gunung Kanthan Plot 1.

Distribution. In Peninsular Malaysia, known from Perlis and Perak (Maassen 2001). Elsewhere, in the tropical regions of the Indian Ocean and the Pacific Islands (Seddon 2000).

Remarks. Distinguished from sympatric congener *Ptychopatula solemi* by its larger shell, wider whorls, wide umbilicus and lower spire.

Ptychopatula solemi Maassen, 2000

Figure 31C

Materials examined. Prk 47 Kanthan: BOR/MOL 9176, BOR/MOL 9068. mykarst-027: BOR/MOL 9042. mykarst-184 Bat Cave: BOR/MOL 9864, BOR/MOL 9818, BOR/MOL 9841. mykarst-185 Batu Kebelah: BOR/MOL 9548, BOR/MOL 9753. Prk 23 G. Rapat: BOR/MOL 10239. Prk 34 G. Tasek: BOR/MOL 11000.

Distribution. In Peninsular Malaysia, known from Perak only (Maassen 2001). Elsewhere, in Sumatra and Sulawesi, Indonesia (Maassen 2000).

Remarks. Distinguished from sympatric congener *Ptychopatula orcula* by its smaller shell, tighter whorls, narrower umbilicus and tall spire.

Discussion

Apart from providing a comprehensive assessment of land snail diversity for the limestone hills in and around the Kinta Valley of Perak, our study has also elucidated interesting biogeographical patterns to assist in conservation planning. Our study has also paved the way for more in-depth land snail taxonomy studies to be conducted. For instance, many of the land snail species recorded by Davison (1991) and Clements et al. (2008b) could not be assigned to scientific names that have been published, until now. Speciose genera such as *Microcystina*, *Diplommatina* and *Opisthostoma*, require critical taxonomic revisions that need considerable effort. We hope unnamed species in these genera, now with traceable reference specimens collected from our study, can be described in the near future.

Land snail species diversity and biogeographical patterns

Correlation tests initially suggested no statistically significant relationship between the number of unique species and the degree of limestone hill isolation. However, when examined closely within a geographical context, the number of unique species for each hill could also be associated with the degree of isolation of major limestone clusters of each hill (Table 1). For example, Prk 55 G. Pondok, Prk 64 Bt Kepala Gajah, and Prk 01 G. Tempurung all located in the limestone clusters at the periphery of Kinta Valley and at least 50 km away from other limestone clusters outside of Kinta Valley (see Figure 6 in Liew et al. 2016).

At this point in time, our assignment of unique species should be considered “unique” to a particular hill in the context of hills that have been surveyed systematically in our study. The degree of endemism of a species depends on the geographical context, e.g. endemic to Malaysia, Perak, Kinta Valley, hill clusters or a single hill. For example, *Charopa lafargei* which previously presumed as endemic to Gunung Kanthan (Vermeulen and Marzuki 2014), is shown in our study to also occur on the limestone hills at the north of Kinta Valley. Also, *Hydrocena semisculpta* which was thought be endemic to Gunung Pondok (Davison 1991), is a relatively widespread species – can be found in 11 out of the 12 hills surveyed in our study.

Our comprehensive inventory has corroborated Davison's (1991) hypothesis that land snail assemblages on limestone hills in Perak can be divided into two groups, one comprising of hills within Kinta Valley and the other comprising of hills scattered in the area north of Kinta Valley. This biogeographical pattern cannot be explained by geographical distance between different limestone hills alone. For example, although Bat Cave Hill and Batu Kebelah Hill (northern cluster) are closest to Prk 53 Hill KF, the land snail assemblage of Prk 53 Hill KF is more similar to the land snail assemblages in the southern cluster hills.

It seems that biogeographical patterns of land snail assemblages at limestone hills in and around the Kinta Valley of Perak were influenced by the geology and topography of the area. For instance, all the hills in the southern cluster are located in the low-lying floodplains of the Kinta valley, while the hills of the northern cluster are located on hilly granitic areas north of the Kinta valley floodplain. As such, this biogeographical pattern could be a result of geological isolation (de Morgan 1885a; van Benthem Jutting 1960; Davison 1991).

The rocks in Perak (including limestone) first emerged in the Mesozoic – the Late Jurassic period (van Benthem Jutting 1960; Metcalfe 2013). After that, limestone hills in Perak became isolated due to two different processes that produced the two biogeographical regions (i.e. limestone hill clusters) (Paton 1961). For the northern hill cluster, the isolation of hills was likely to be caused by structural deformity with intrusion of granite and these hills were probably never contiguous from the start (Paton 1961). For the southern hill cluster, the isolation of hills was probably caused by limestone erosion, recent marine incursion and alluvial deposition (Paton 1961). However, our hypothesis of geological isolation being the main determinant of biogeographical patterns observed in our study requires further tests using phylogeographic approaches, where the divergence time of a particular land snail species can be estimated (by sampling populations from different limestone hills) and matched with historical geological events, including the more recent local geological events or climate changes in the Pleistocene.

Conservation implications

Despite containing the second highest number of limestone hills in Peninsular Malaysia after the State of Kelantan (see Liew et al. 2016), the State of Perak appears to be experiencing the greatest threat from limestone quarrying with 45 out of 78 limestone quarries in the peninsula being located in this State as of 2014 (Minerals and Geoscience Department Malaysia 2014). As such, there is an urgent need to identify limestone hills with high levels of species endemism for conservation prioritisation within this State. Four hills, namely Prk 01 G. Tempurung, Prk 55 G. Pondok, Prk 47 Kanthan, and Prk 64 Bt Kepala Gajah, were found to collectively contain 91% of the total land snail species occurring at 12 hills sampled in our study. In order to prevent the extinction of unique land snail species, these hills require immediate attention from conservation practitioners to mitigate ongoing threats from quarrying and surrounding forest loss.

Conclusion

Our study has updated the state of knowledge of land snail diversity and biogeography on limestone hills in Perak, Peninsular Malaysia. Larger limestone hills seem to have more unique species, of which several could be site endemic. In addition, we have shown that land snail assemblages can be divided into two groups that occupy limestone hills at two different areas in Perak – this was likely caused by different geological processes that separated the limestone hills. Most importantly, our findings can be used to assist in limestone conservation planning, especially within the Kinta Valley of Perak.

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Supplementary material 1

Sample completeness curve for all the seven limestone hills sampled in our study.

Authors: Junn Kitt Foon, Gopalasamy Reuben Clements, Thor-Seng Liew

Data type: Text and figures in Microsoft Word file.

Explanation note: Data and figure outputs from species richness and sampling completeness analysis.

Link: https://doi.org/10.3897/zookeys.682.12999.suppl1

Supplementary material 2

Data matrix for absence/presence of 122 land snail species at 12 limestone hills.

Authors: Junn Kitt Foon, Gopalasamy Reuben Clements, Thor-Seng Liew

Data type: Microsoft Excel datasheet.

Explanation note: Data matrix for absence/presence of 122 land snail species at 12 limestone hills.

Link: https://doi.org/10.3897/zookeys.682.12999.suppl2

Supplementary material 3

Location of sampling plots for each of the seven hills sampled in our study.

Authors: Junn Kitt Foon, Gopalasamy Reuben Clements, Thor-Seng Liew

Data type: Text in Microsoft Word file.

Explanation note: A list of the location names and coordinates of sampling plots for each of the seven hills sampled in our study.

Link: https://doi.org/10.3897/zookeys.682.12999.suppl3

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RESEARCH ARTICLE

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A new species of *Aleuromarginatus* Corbett, 1935 with a key and checklist of Chinese species (Hemiptera, Aleyrodidae)

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Abstract

A new whitefly species, *Aleuromarginatus dielsianae* Wang & Xu, **sp. n.** collected from *Millettia dielsiana* Harms (Rosales: Fabaceae) in Jiangshan (28°40'N, 118°40'E, 512 m) and Xinchang (29°22'N, 120°46'E, 308 m), Zhejiang, China, is described and illustrated. This new species is characterized by the dark brown lateral margin area and a pair of longitudinal furrows extending from the cephalothorax to the vasiform orifice. The submargin has an elongate-oval fold at the base of each marginal tooth and with 3-4 rows of irregular shaped papillae, nine pairs submedian setae and 13 pairs submarginal setae. Thoracic and caudal tracheal folds and pores discernible. An identification key and checklist of species of *Aleuromarginatus* known from China are provided.

Keywords

Aleyrodidae, *Aleuromarginatus*, China, new taxa, taxonomy

Introduction

The genus *Aleuromarginatus* (Hemiptera: Aleyrodidae) was established by Corbett (1935) with *A. tephrosiae* Corbett as the type species by monotypy. *Aleuromarginatus* is very distinct; based on the special characteristics of the puparium it unlikely to be confused with other whitefly genera. It is an Old World genus, recorded from the Afrotropical, Palearctic, Oriental, and Australasian regions. Only 14 species of this genus have been described, almost all of them are known only from leguminous plants (Fabaceae) (Bink-Moenen 1983; Cohic 1968, 1969; Corbett 1935a; David 1976, 1988; David and Subramaniam 1976; Jesudasan and David 1991; Ko et al. 1995; Martin 1985, 1999; Martin and Mound 2007; Mound and Halsey 1978; Takahashi 1955).

This genus was unknown from East Asian region until Ko et al. (1995) described *Aleuromarginatus shihmensensis* Ko on *Millettia seiculata* from Taiwan. In addition, *A. thirumurthiensis* David is known to occur in Taiwan (Chiun-Cheng Ko personal collection) and Wang et al. (2016) recorded *A. corbettiaformis* Martin from Hainan Island of China. In this paper, the fourth species of *Aleuromarginatus* from China is described.

Material and methods

Puparia of the new species were collected from *Millettia dielsiana* Harms (Rosales: Fabaceae) in Shuangxikou village, 28°40'N, 118°40'E, 512 m, Jiangshan and Jingling town, 29°22'N, 120°46'E, 308 m, Xinchang, Zhejiang, China. The puparia were mounted following the method suggested by Dubey and David (2012). The terminology for morphological structures follows Bink-Moenen (1983), Martin (1985) and Gill (1990). The habitus images were taken using the digital camera Canon IXUS 105 and LEICA M125 stereo-microscope (Leica, Wetzlar, Germany) attached with a LEICA DFC290 (Leica, Wetzlar, Germany). Puparial measurements and microphotographs were taken using a Zeiss (Carl Zeiss, Gottingen, Germany) from ZAFU. The scanning electron microscope images were taken by Hitachi TM-1000 Scanning Electron Microscope (Hitachi, Japan) from Center of Electron Microscopy, Zhejiang University (Life Sciences Division). Adobe Photoshop software was used to make small adjustments and to assemble the plates. The holotype is deposited in the Insect Collection of Zhejiang Agriculture & Forestry University, Lin'an, China (ZAFU).

Taxonomy

Aleuromarginatus Corbett, 1935

Aleuromarginatus Corbett 1935: 246. Type species. *Aleuromarginatus tephrosiae*, by monotypy.

Diagnosis. Puparia elongate to broadly oval, often slightly indented anteriorly and posteriorly and/ or at thoracic tracheal openings at margin (Martin 1999); margin with two rows of teeth and surrounded by a waxy palisade and fringe of wax-hairs; submarginal area not separated from dorsal disc. Dorsal with a subdorsal and submedian row of short setae including the cephalic, first and eighth abdominal setae; vasiform orifice cordate, operculum filling about half of orifice, lingula knobbed, exposed; caudal furrow faint (Jesudasan and David 1991; Ko et al. 1995). This genus resembles *Aleurotrachelus* in the two- teethed margin, and resembles *Crenidorsum* with the submedial furrow or papillae, but can be distinguished by the characters of the vasiform orifice and the absence of spine-like setae on the medial region of the dorsum.

Aleuromarginatus dielsianae Wang & Xu, sp. n.

http://zoobank.org/4CDE85C3-0F93-4B91-AB73-871F7613AEB9
Figures 1–16

Type locality. China, Zhejiang, Jiangshan, Shuangxikou village, 28°40'N, 118°40'E, 512 m, on *Millettia dielsiana* Harms, 8. viii. 2016, leg. JR Wang.

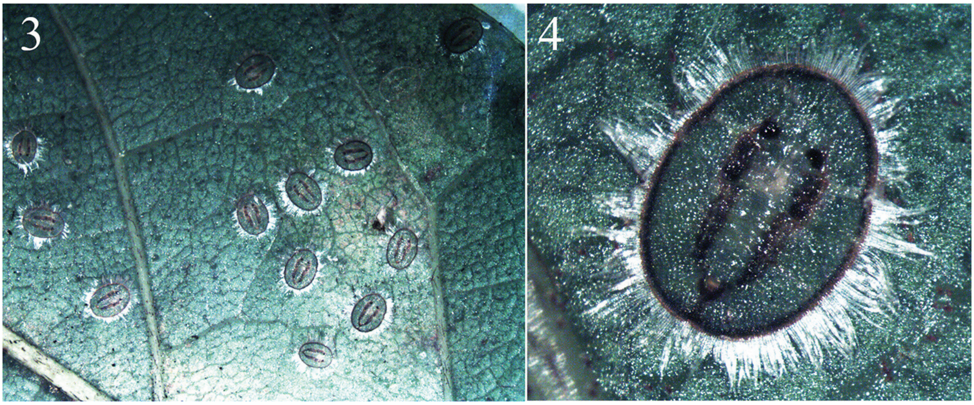
Type material. Holotype. China, Zhejiang, Jiangshan, Shuangxikou village, 28°40'N, 118°40'E, 512 m, 1 puparium on slide, on *Millettia dielsiana* Harms, 8. viii. 2016, leg. JR Wang, deposited in Insect Collection of Zhejiang Agriculture & Forestry University (ZAFU), Lin'an, China.

Paratypes. 35 paratypes of which: 28 are puparia on 20 slides, data same as holotype and 7 are puparia on 5 slides collected in Jingling town, 29°22'N, 120°46'E, 308 m, Xinchang, Zhejiang, China, on *Millettia dielsiana* Harms, 12. xi. 2016, leg. JR Wang, deposited in ZAFU. 68 dry puparia on *Millettia dielsiana* Harms leaves with above collection data available at ZAFU.

Diagnosis. This species is characterized by the dark brown margin area (Figs 4, 11, 12), in life with a pair of longitudinal submedian lines (Fig. 4) and microscopically with a pair of longitudinal submedian furrows (Figs 5, 7, 8, 11) from cephalothorax to the vasiform orifice. Submargin with an elongate-oval fold at the base of each marginal tooth and with 3-4 rows of irregularly shape papillae (Figs 9, 12). Nine pairs submedian setae (Fig. 14), minute, blunt - one pair of cephalic setae (cs), two pairs of thoracic setae (ts), six pairs of abdominal segment I and III-VI, VIII (as1, 3-6, 8); 13 pairs submarginal setae (sms) (Fig. 14) - three cephalic pairs, five thoracic pairs, one abdominal pair, and four posterior pairs. Vasiform orifice cordate (Figs 10, 13, 16); operculum broadly trapezoidal, covering nearly half the orifice; lingula exposed, setose, knobbed. Paired posterior marginal setae present while anterior marginal setae absent. Thoracic and caudal tracheal folds and pores discernible (Figs 6, 14).

Description. Puparium. Puparia have highly characteristic secretions in the form of a broad, laterally directed, white fringe on each side of the body, the fringe about 0.24-0.29 mm long; body light yellowish, transparent, margin dark brown; two longitudinal pigmented bands encompassing the submedian zone on either side of the body lines from cephalothorax to vasiform orifice; elliptical, 1.08-1.12 mm long, 0.75–0.82 μm wide, broadest at the abdominal segments I region. The presence of a colony can be easily ascertained by the dense bumps on the upper surface of the leaves caused by the puparia which embed themselves into the under surface of leaves, pushing the top surface of the leaf upward (Fig. 1).

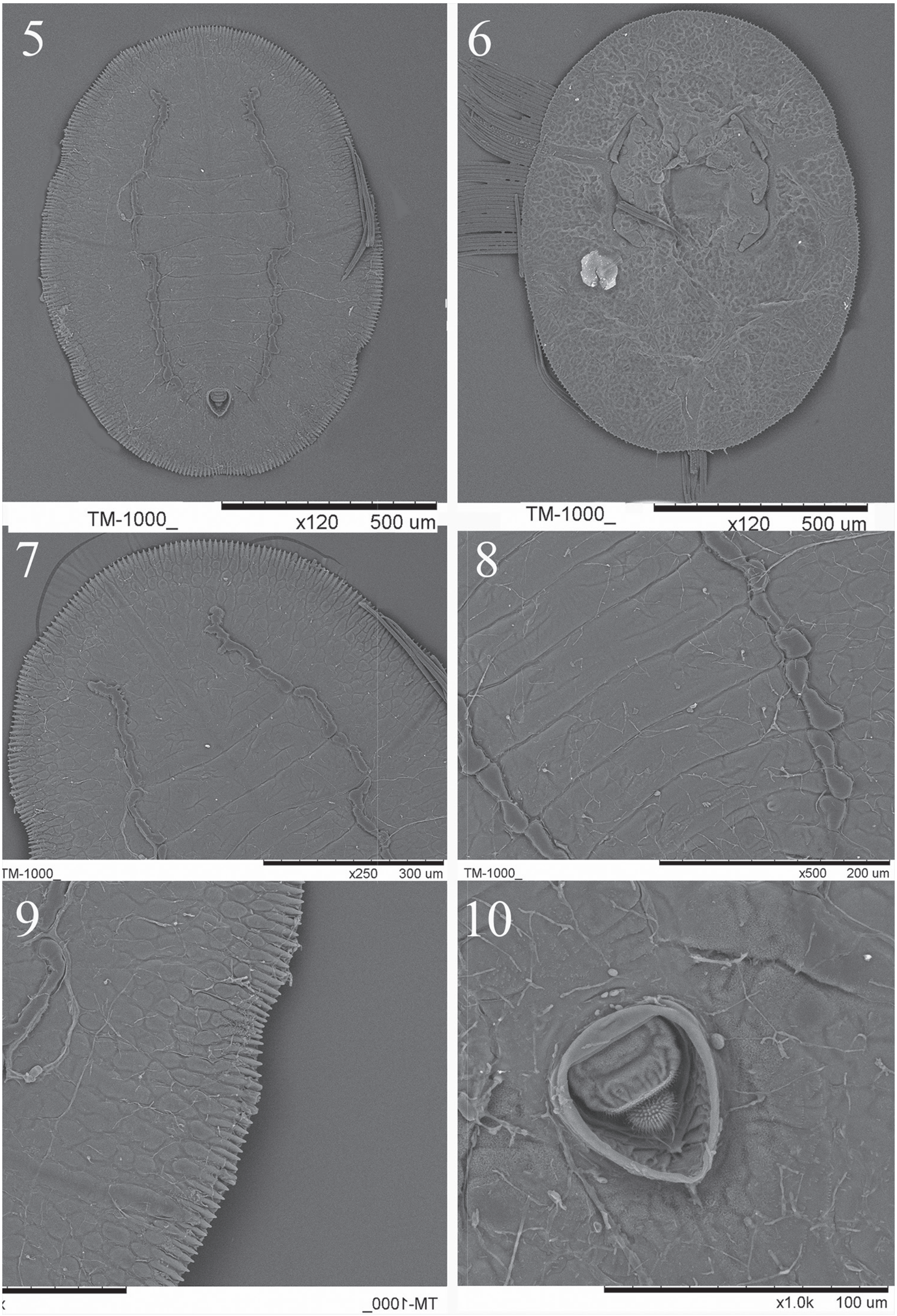
Figures 1–2. The host plant *Millettia dielsiana* Harms. **1** upper side of leaves infested by *Aleuromarginatus dielsianae* sp. n. **2** colony of *Aleuromarginatus dielsianae* sp. n. on the lower surface of leaves.



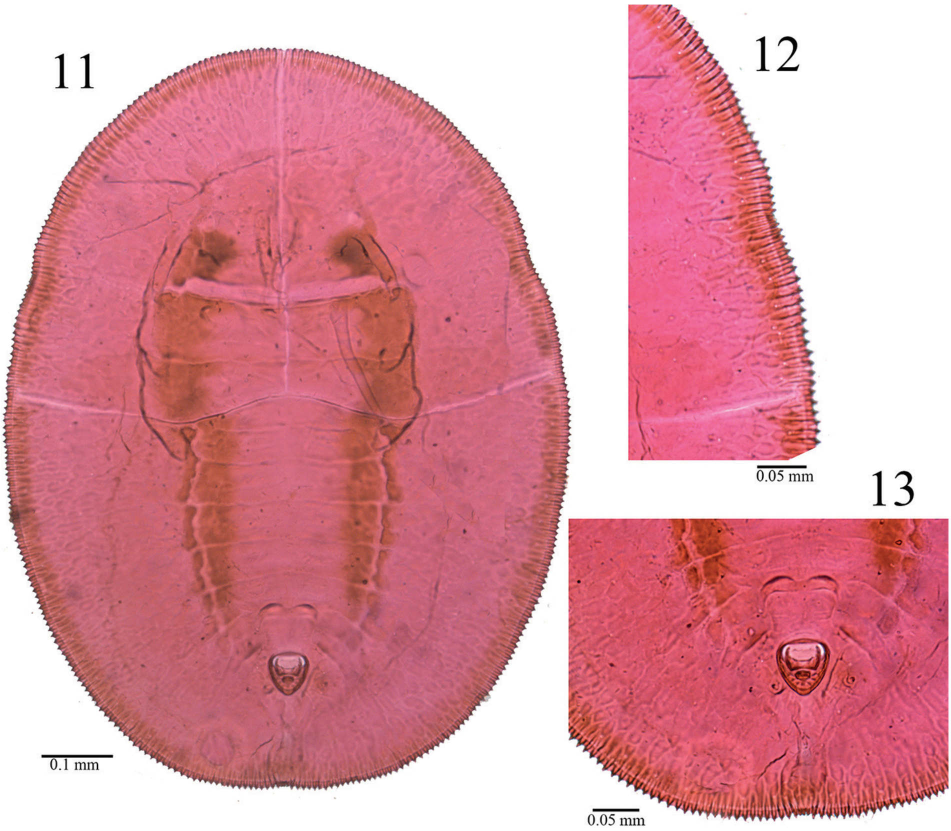
Figures 3–4. Images of pupaira of *Aleuromarginatus dielsianae* sp. n., on *Millettia dielsiana* leaves.

Margin (Figs 9, 12, 15) strongly toothed, with a pore at the base of each 3–4 teeth, 13–15 crenulations in 0.1 mm. The thoracic and caudal tracheal areas slightly recessed and differentiated from margin. Paired posterior marginal setae (pms) present, about 35.1 µm long, anterior marginal setae absent.

Dorsum almost flat, without tubercle, sparsely scattered with pores. Submarginal area not clearly separated from dorsal disk. A pair of dark brown longitudinal furrows

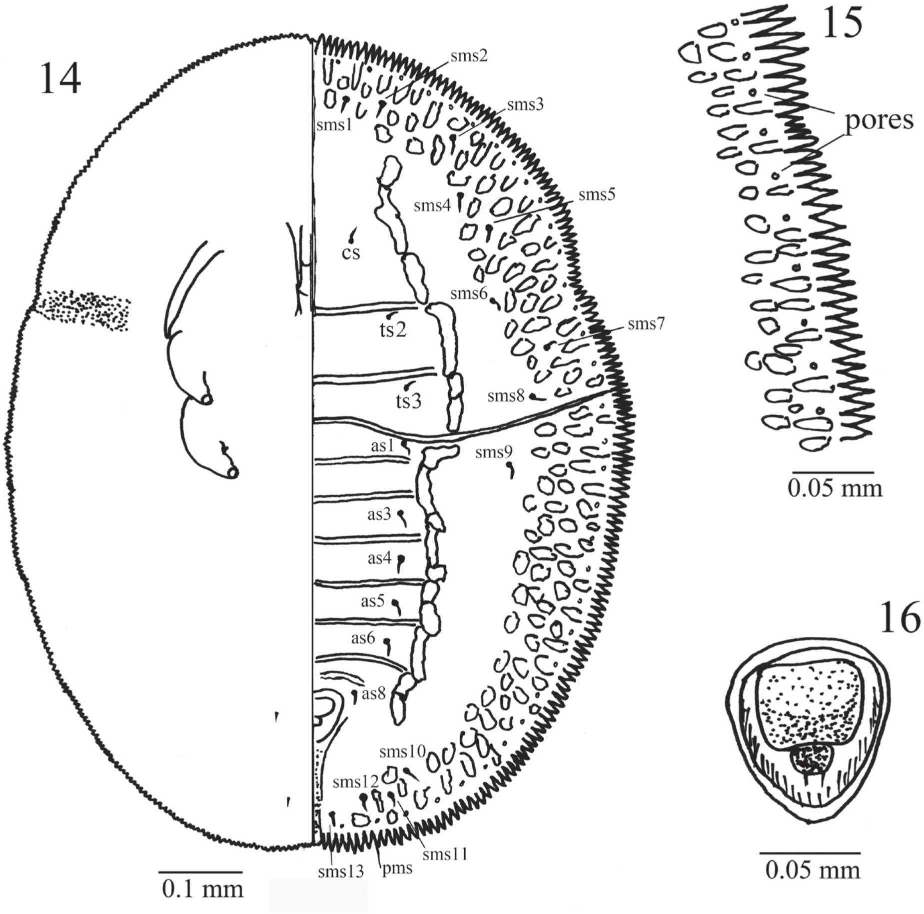


Figures 5–10. Scanning Electron Microscope photographs of *Aleuromarginatus dielsianae* sp. n. **5** puparium, dorsal view. **6** puparium, venter view **7** the longitudinal furrows on cephalothorax **8** the longitudinal furrows on abdomen and the abdomen segments **9** margin **10** vasiform orifice, operculum and lingula.



Figures 11–13. *Aleuromarginatus dielsianae* sp. n., slide mounted specimen. **11** puparium, dorsal view **12** margin **13** vasiform orifice, operculum and lingula.

(Figs 4, 5, 7, 8, 11) extending from the cephalic region to the vasiform orifice, the longitudinal furrows consist of some short longitudinal furrows. Submargin with an elongate-oval fold at the base of each marginal tooth and with 3–4 rows of irregular shape papillae (Figs 9, 12). Nine pairs submedian setae, minute, blunt - one pair of cephalic setae (cs), two pairs of thoracic setae (ts2, 3) which are on the 2nd and 3rd thoracic segments; six pairs of abdominal setae, one pair on each segments I and III-VI, VIII (as 1, 3–6, 8). Thirteen pairs submarginal setae (sms) - 3 cephalic pairs, 5 thoracic pairs, 1 abdomen pair and 4 posterior pairs. The submedian setae and submarginal setae each arising from a small tubercle and are subequal in length, about 6.1–6.7 µm. Longitudinal and transverse molting sutures reaching the anterior and lateral margin, respectively. The transverse molting suture slightly protruding forming a transverse ridge (Fig. 7). Thorax and abdominal segment sutures well defined, midline of abdominal segments I-II each about 44.5 µm in length; abdominal segments III-IV each about 54.8 µm in length; abdominal segments V about 47.3 µm



Figures 14–16. *Aleuromarginatus dielsianae* sp. n., holotype puparium, China (Zhejiang). **14**puparium, dorsal (right) and ventral (left) views **15** margin and minute pores **16** vasiform orifice.

in length; abdominal segments VI about 35.6 μm in length; abdominal segments VII about 12.7 μm in length.

Vasiform *orifice* (Figs 10, 13, 16) cordate, longer than wide, 65.5–68.3 μm long, 60.2–62.3 μm wide; operculum broadly trapezoidal, covering nearly half the orifice, 29.5–34.8 μm long, 39.2–41.2 μm wide. Lingula exposed, setose, knobbed, 9.1–12.2 μm long, 13.6–16.4 μm wide, with a pair of apical setae, about 7.4 μm in length.

Venter. Thoracic and caudal tracheal folds and pores discernible (Fig. 6). Ventral abdominal setae placed on either side of anterior angles of vasiform orifice, finely pointed and 5.7–7.8 μm long, 53.1 μm apart. Antenna slender, long, extending slightly beyond the prothoracic spiracular furrow but not reaching base of mesothoracic leg.

Host plant. *Millettia dielsiana* Harms (Figs 1, 2) (Rosales: Fabaceae).

Distribution. China (Zhejiang).

Biology. Specimens were found on the leaves in colonies from 20 - 60 individuals, distributed throughout the under surface of leaves (Fig. 2). No parasitoids were obtained from the puparia and no ants were observed attending the whiteflies.

Etymology. The species name takes its name of host plant *Millettia dielsiana* Harms.

Remarks. The new species resembles *A. millettiae* Cohic but differs in that the longitudinal furrows extend from the submendian region of the cephalic to the vasiform orifice while they are only present on the abdomen for *A. millettiae* and differs in the number and postion of the submarginal setae. The new species also resembles *A. kallarensis* David & Subramaniam but can be easily distinguished by the shape and the size of the puparia.

Key to the puparia of Chinese species of *Aleuromarginatus*

(Characters are obtained from original descriptions)

1 Puparia elongate-oval in shape 2

– Puparia elliptical or roundish in shape 3

2 Dorsum cuticle brownish. Vasiform orifice cordate, anterior and posterior margin straight, lateral margins almost rounded, operculum roundly trapezoidal; lingula setose, knobbed, exposed but included. Pupal case ♀1.44–1.68mm long, 0.45–0.52mm wide; ♂ 1.04–1.28mm long, 0.38–0.4mm wide; on average 2.7–3.2 times as long as wide. Known only feeding on plant *Millettia reticulata* .... ***A. shihmensensis* Ko**

– Dorsum cuticle pale, but many specimens with a brown median stripe. Vasiform orifice subcordate, anterior and posterior margin rounded, lateral margins almost straight, operculum trapezoidal with rounded lateral margins; lingula with large spinulose head, occupying most of the remaining area of the orifice. Pupal case ♀1.40–1.55mm long, 0.65–0.7mm wide; ♂ 1.10–1.2mm long, 0.47–0.5mm wide; on average 2.3 times as long as wide. Known only to feed on *Desmodium umbellatum*..................... ***A. corbettiaformis* Martin**

3 Puparia elliptical, dorsum with a pair of the longitudinal furrows extending from the cephalus to the vasiform orifice region. Margin with numerous, long, pointed teeth, with a pore at the base of each set of 3–4 teeth, 13–15 crenulations in 0.1 mm; anterior marginal setae absent. Thoracic and caudal tracheal folds and pores discernible .... ***A. dielsianae* Wang & Xu, sp. n.**

– Puparia oval to roundish, a row of papillae-like markings evident on subdorsum laterally from the posterior end of cephalic region to level of eighth abdominal segment. Margin strongly toothed with a pore at the base of each tooth, 24–27 crenulations in 0.1 mm; anterior marginal setae present. Thoracic and caudal tracheal folds and pores indiscernible..................... ***A. thirumurthiensis* David**

Checklist of Chinese species of *Aleuromarginatus*

1. *Aleuromarginatus corbettiaformis* Martin, 1985

Reported from China (Hainan Island) by Wang et al. (2016), voucher material in YZU from an unidentified Leguminosae plant.

2. *Aleuromarginatus dielsianae* Wang & Xu, sp. n.

Jiangshan and Xinchang, Zhejiang Province, China on *Millettia dielsiana*.

3. *Aleuromarginatus shihmensensis* Ko, 1995

Described from Taiwan by Ko (1995), holotype on *Millettia reticulata* in National Taiwan University (NTU).

4. *Aleuromarginatus thirumurthiensis* David, 1988

This species was first described on *Bauhinia racemosa* from India by David (1976) as "*Aleuromarginatus bauhiniae* David". However, David (1988) transferred *Trialeurodes bauhinae* Corbett (Corbett 1935b) to the genus *Aleuromarginatus* thus making his 1976 species a junior homonym of *Aleuromarginatus bauhinae* (Corbett). Since the two species are clearly distinct species, a replacement name, *Aleuromarginatus thirumurthiensis*, was proposed by David (1988) for his 1976 species.Ken-Ching Chou collected this species from *Millettia reticulata* and *Bauhinia championii* in Taiwan in 1995, voucher material in NTU. (Chiun-Cheng Ko, pers. comm.).

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RESEARCH ARTICLE

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Systematics and biology of *Cotesia typhae* sp. n. (Hymenoptera, Braconidae, Microgastrinae), a potential biological control agent against the noctuid Mediterranean corn borer, *Sesamia nonagrioides*

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Abstract

Many parasitoid species are subjected to strong selective pressures from their host, and their adaptive response may result in the formation of genetically differentiated populations, called host races. When environmental factors and reproduction traits prevent gene flow, host races become distinct species. Such a process has recently been documented within the *Cotesia flavipes* species complex, all of which are larval parasitoids of moth species whose larvae are stem borers of Poales. A previous study on the African species *C. sesamiae*, incorporating molecular, ecological and biological data on various samples, showed that a particular population could be considered as a distinct species, because it was specialized at both host (*Sesamia nonagrioides*) and plant (*Typha domingensis*) levels, and reproductively isolated from other *C. sesa-*

miae. Due to its potential for the biological control of *S. nonagrioides*, a serious corn pest in Mediterranean countries and even in Iran, we describe here *Cotesia typhae* Fernandez-Triana **sp. n.** The new species is characterized on the basis of morphological, molecular, ecological and geographical data, which proved to be useful for future collection and rapid identification of the species within the species complex. Fecundity traits and parasitism success on African and European *S. nonagrioides* populations, estimated by laboratory studies, are also included.

Keywords

Cotesia, *Sesamia*, biological control, species complex, Africa, Mediterranean

Introduction

Although the concept of species is questioned in situations characterized by a continuum of genetic differentiation and reproductive isolation between populations (The Marie Curie Speciation Network 2012), well described and identified species are still useful tools in many situations. For instance, in biological control the use of such species, with a defined host range and showing no gene flow with closely related species, limits the risk of confusion and guarantees the stability of its host range. The purpose of this paper is to describe a new species of parasitoid wasp, first considered as a host race of *Cotesia sesamiae* Cameron (Hymenoptera, Braconidae) (Branca et al. 2011; Kaiser et al. 2015). It is a potential candidate for the biological control of the Mediterranean maize stem borer, *Sesamia nonagrioides* (Lefèbvre, 1827) (Lepidoptera, Noctuidae).

Cotesia is one of the most diverse genera of the subfamily Microgastrinae (Hymenoptera, Braconidae), with almost 300 species already described (Yu et al. 2016), and probably over 1,000 species worldwide (e.g., Mason 1981). *Cotesia* was originally considered as a genus by Cameron in the 19th century, and definitively split from the genus *Apanteles* by Mason (1981) in his generic reclassification of the Microgastrinae, wherein many *Apanteles* species were transferred to *Cotesia*. Microgastrine wasps are koinobiont endoparasitoids of lepidopteran larvae, and species attacking large larval hosts are often gregarious (Whitfield 1997, Quicke 2015). Females emit sex-pheromones that attract males and can mate upon emergence (Xu 2014). They locate their host at a distance and initiate oviposition upon recognition of chemical cues (Turlings and Fritsche 1999, Jembere et al. 2003, Obonyo et al. 2010). The microgastrine wasps use a domesticated virus (called a bracovirus, Polydnaviridae) to inhibit the immune response of host larva. Bracoviruses are produced in the wasps' ovaries by genes integrated in the wasp genome and injected in the host body together with the eggs (Asgari 2006, Gitau et al. 2007, Herniou et al. 2013). Within the host, the viral particles infect the host cells, which produce the viral proteins, which in turn inactivate the host immune cellular response and regulate the host metabolism to the benefit of wasp larvae (Herniou et al. 2013). Fully developed larvae egress from the host body and spin their cocoons to undergo metamorphosis. Host resistance processes can manifest at all these steps of the life cycle, among which encapsulation of the parasitoid eggs has been often reported and well described (Beckage 1998). Evolution of virulence mechanisms by the parasitoid may have driven the radiation of species within the genus *Cotesia* (Herniou et al. 2013).

The *Cotesia flavipes* species-group is a monophyletic complex made up of (until now) four allopatric sister species, all gregarious endoparasitoids of a few families of lepidopteran stem borers (Crambidae, Pyralidae, and Noctuidae) in monocot Poales (Poaceae, Typhaceae and Cyperaceae). The species-group comprises *Cotesia chilonis* (Munakata, 1912) from eastern Asia, including China, Japan and Indonesia; *Cotesia flavipes* (Cameron, 1891), from the Indian sub-continent, but also released and established in east Africa and the New World for the purpose of biological control; *Cotesia nonagriae* (Olliff, 1893), an Australian endemic recently removed from synonymy with *C. flavipes* (Muirhead et al. 2008, 2012), and *Cotesia sesamiae* (Cameron, 1906), from sub-Saharan and Southern Africa (Kimani-Njogu and Overholt 1997). Members of this species complex are economically important worldwide as biocontrol agents of cereals and sugarcane stem borer pests (Kfir et al. 2002, Lou et al. 2014, Mindigoyi et al. 2016, Polaszek and Walker 1991, Simões et al. 2012), and their presence in their native settings help regulate populations of important pests (Kfir et al. 2002, Liu et al. 2000).

Additional, cryptic species have been suspected within this complex and several papers have explored this possibility, especially in regard to *C. flavipes* (e.g., Muirhead et al. 2012) and *C. sesamiae.* In the latter species, studies made from samples collected in maize fields on a few pest species showed that local adaptation to host resources and environmental factors were major drivers of intra-species genetic diversity (Dupas et al. 2008, Gitau et al. 2007, 2010). Subsequently, Branca et al. (2011) analysed a large sample of *C. sesamiae* covering most of the species' distribution area and a large range of host and plant species. They provided evidence that variations of host range were associated with sequence variation of a virulence gene, CrV1, which could be used as a marker of host races. Analysis of microsatellite markers revealed gene flow between the host races, except for one population specialized on the noctuid *Sesamia nonagrioides* (Branca et al. in prep.). One method to get an insight into the evolutionary stability of host-parasitoid associations is to characterize phylogenetic relationships between so-called host races. Kaiser et al. (2015) performed a phylogenetic analyses of the *C. sesamiae* samples based on mitochondrial, viral and non-viral nuclear markers, and demonstrated that the samples from the *S. nonagrioides* host race formed a highly supported monophyletic lineage showing all the hallmarks of a cryptic species. The authors confirmed the species status of this lineage by showing that it was reproductively isolated from the other lineages of *C. sesamiae* and from *C. flavipes.* Furthermore they showed that it was the only lineage being virulent against *S. nonagrioides*, and specifically so. Combined evidence for ecological specialization, selection for divergent host adaptation and for reproductive isolation, allowed them to conclude that this lineage was formed by ecological (adaptive) speciation. In addition, some morphological differences were readily identifiable.

Based on a wealth of information – morphological, molecular, biological, and ecological – we describe this new species of *Cotesia* from Africa, the fifth member of the *flavipes* complex, and present the first data showing that it is a successful parasitoid of European populations of *S. nonagrioides*, a major maize pest in West Africa and in Mediterranean countries.

Materials and methods

Morphological description

We studied 175 specimens from six different countries, representing ten populations from four out of the five known species within the *flavipes* complex (Table 1). We could not examine specimens of *Cotesia nonagriae*, but this Australian species has recently been redescribed and illustrated (Muirhead et al. 2008, 2012).

We evaluated a number of morphological characters proposed in previous studies (Kimani-Njogu and Overholt 1997, Muirhead et al. 2008), and others characters are explored for the first time in this species complex. Morphological terms and measurements of structures are mostly those used by Mason (1981), Huber and Sharkey (1993), Whitfield (1997), Karlsson and Ronquist (2012), and Fernandez-Triana et al. (2014). All characters used in this paper are illustrated in Figs 1–8.

In the species description, body ratios and measurement values are presented for the holotype first, followed by the range within the species in parentheses.

Photos were taken with a Keyence VHX-1000 Digital Microscope, using a lens with a range of 10–130 ×. Multiple images were taken of a structure through the focal plane and then combined to produce a single in-focus image using the software associated with the Keyence System. Plates were prepared using Microsoft PowerPoint 2010.

Institution acronyms used:

CBGP	Centre de Biologie pour la Gestion des Populations, Montpellier, France.
CNC	Canadian National Collection of Insects, Ottawa, Canada.

Table 1. Specimens studied for this paper. F- female specimen, M- male specimen.

Species	Country of origin	Collecting year	# of Specimens	Host caterpillar/host plant
C. flavipes	Trinidad	1972 & 1980	4 F, 3 M	*Diatraea lineolata* /unknown
C. flavipes	Colombia	1978	2 F, 7 M	Unknown/unknown
C. flavipes	Barbados	1977	2 F	Unknown/sugar cane
C. flavipes	India	1954	3 F	Unknown/unknown
C. flavipes	Kenya	2010	25 F, 5 M	*Chilo partellus*/maize
C. sesamiae	Kenya (Mombasa)	2010	25 F, 5 M	*Sesamia calamistis* /maize
C. sesamiae	Kenya (Kitale)	2012	25 F, 5 M	*Busseola fusca*/maize
C. chilo	Japan	2008	2 F, 2 M	Unknown/rice
C. typhae sp. n.	Kenya (Makindu)	2013	25 F, 5 M	*Sesamia nonagrioides*/ *Typha domingensis*
C. typhae sp. n.	Kenya (Kobodo)	2013	25 F, 5 M	*Sesamia nonagrioides*/ *Cyperus dives*

Molecular characterization

In order to check the molecular-specific characterization of *Cotesia typhae*, we used the COI (*cytochrome oxydase I*) sequences from Kaiser et al. (2015) (listed in Appendix 1) to calculate the divergence between pairs of *Cotesia* species and populations. The divergence corresponds to the number of nucleotide differences divided by the total number of nucleotides. Since there are several samples for each species and population, the minimum and maximum divergence is given for all pairs.

Distribution, ecology and abundance

Knowing that the new *Cotesia* species was found exclusively on *S. nonagrioides* on two plant families, Typhaceae and Cyperaceae (Kaiser et al. 2015), its distribution, ecology and abundance are characterized here from a collection of *S. nonagrioides* larvae on these two plant families, collected in 13 countries in sub-Saharan Africa between 2004 and 2013. *Sesamia nonagrioides* larvae were sampled from wild plants on banks of streams or rivers and in swamps, the favorite habitat of this species, which is rarely recorded from maize in East Africa. Plants were carefully inspected for stem borer infestations. Symptoms of infestation included scarified leaves, dry leaves and shoots (dead hearts), frass or holes bored. Infested plants were cut and dissected in the field; larvae collected were reared on an artificial diet (Onyango and Ochieng-Odero 1994) until pupation or emergence of parasitoid larvae. *Sesamia nonagrioides* were identified at the adult stage by dissection of the genitalia. After emergence, adult *Cotesia* were stored in absolute ethanol and identified by genotyping CrV1 sequence.

Life history traits and parasitoid success in European host populations

Insect material

The *C. typhae* laboratory-reared strains were collected initially from Kenya localities (Kobodo: 0.68°S; 34.41°E or Luanda: 0.48°S; 34.30°E, depending on the availability of the strains). They were reared on a Kenyan *S. nonagrioides* strain (collected initially from Makindu: 2.28°S; 37.82°E), according to the method described by Overholt et al. (1994). Parasitoid success was tested on this Kenyan strain and on two *S. nonagrioides* European strains collected respectively in France (Longage, 43.37°N; 1.19°E) and Italy (Monterotondo scalo, 42.06°N; 12.60°E). The Kenyan and French strains were reared as described above. The Italian larvae were sent from the University of Perugia.

Longevity experiments

Clusters of cocoons were each placed in a 0.5L disposable plastic box with a 1.5 cm diameter opening clogged with a foam cork. One of the three following food sources was placed in the box to test their effects on longevity: honey droplets and a tap water-imbibed cotton ball; a cotton ball imbibed with a 2% saccharose solution or a 20% solution. These small cages were placed at 21°C, with internal relative humidity around 75%. Dead insects were counted every day for the 2% sugar solution and at least every two days for the two other food sources, from 24h following emergence.

Realized fecundity

One-day-old wasps were taken from the cages as above and allowed to oviposit in one host larva per day, for four days. Parasitized larvae were kept individually in Petri dishes (2 cm high) with approximately 10cm^3 piece of diet, until emergence of the parasitoid larvae or pupation. The diet was replaced by a piece of toilet paper 12 days after parasitism to facilitate cocoon formation.

Parasitoid success

Four weeks after hatching, i.e. when reaching the 5th- 6th stadium, larvae were exposed each to one wasp, then kept fed with the diet, in the conditions described above, until emergence of the parasitoid larvae, or pupation. Recorded traits are specified in Table 8. Individual cocoon weight was calculated by dividing the weight of the cocoon cluster by the number of emerged adults and dead nymphs.

Data analyses

Kaplan Meyer tables from XLSTAT were used to estimate daily mortality and median longevity. The procedure included three tests of equality of the survival curves (Wilcoxon, Log-rank and Tarone-War) that gave identical P-values, so only Wilcoxon's result is given in this study. Comparisons of traits of parasitoid success on the three host strains were performed with the R package. As some of the traits did not follow a normal distribution (Shapiro statistic) or did not fulfill homoscedasticity (Bartlett statistic), the Kruskal-Wallis statistic was used to compare the quantitative traits recorded for the three host strains, followed by the Dunn post-hoc multiple comparison test. Chi-square was used to compare the issue of parasitism. Sample sizes are given in Table 8. The percentage of females in the cluster was not included in the analyses when pupal mortality was equal to or exceeded 30%. This occurred for 11 clusters obtained from the French host strain and two clusters obtained from the Kenyan strain.

Results

Morphological study

Cotesia typhae Fernandez-Triana, sp. n.

http://zoobank.org/EC4B19D5-9087-4698-A67D-E53EAE5E532E
Figs 1, 2

Holotype. Female (CBGP).

Type locality. Kenya, Makindu, 2.28°S, 37.82°E.

Holotype label details. Kenya, Makindu, xi.2010, ex *Sesamia nonagrioides* on *Typha domingensis* Pers. Voucher code: CNC634434. Other code on label: F78.

Paratypes. CBGP, Montferrier s/Lez, France; CNC, Canada; International Centre of Insect Physiology and Ecology, Nairobi, Kenya; Natural History Museum London, UK; Smithsonian National Museum of Natural History, Washington DC, USA. 24 female, 5 male specimens, same locality as holotype; 25 female, 5 male specimens from Kenya, Kobodo, 0.41°S, 34.25°E. iii.2013, ex *Sesamia nonagrioides* on *Cyperus dives* Delile.

Previous records. This species has been referred to as the *C. sesamiae* population, harbouring Cs Snona haplotype on CrV1 locus (Branca et al. 2011), as the *C. sesamiae* lineage 2 analysed by Kaiser et al. (2015) and as the sample CsBV G4675 sequenced for 3 viral genes in Jancek et al. (2013).

Diagnosis. The new *Cotesia* is relatively distinct from other members of the *flavipes* complex (Table 2). The most distinctive diagnostic characters are the median projection present between the base of the antennae, the punctures on the anteromesoscutum, the length and shape of the paramere, and the relative length of the antennal flagellomere. The median projection between the base of the antennae is depressed (compared to the rest of the face), usually paler than the rest of the face, and has a strongly excavated median longitudinal sulcus (Figs 1B, 2B); all other species within the *flavipes* complex have a less depressed median projection on the face, usually the same color (or at most slightly lighter) as the rest of the face, and the median sulcus is not defined (*nonagriae*) or is less strongly excavated (Figs 5B, 6B, 7B, 8B). The anteromesoscutum punctures (Figs 1G, 2E) are the largest, densest, and most widely distributed (present near the posterior margin of the anteromesoscutum) among all species within the *flavipes* complex (compare against Figs 5G, 6F, 7G, 8H). The paramere length (Figs 3A, B, 4C, F, G) is intermediate compared to the other species (longer than in *chilonis/sesamiae* and shorter than in *flavipes/nonagriae*; compare Figs 3D, F, H, 4D, E), and its shape seems to be distinctive, with a somewhat widened part near the apex (Fig. 4F, G). The antennal flagellomeres (Figs 1A, D, 2A, B) are the longest among the entire *flavipes* complex (compare versus Figs 5A, B, D, 6A, B, 7A, B, 8A, D). The color of metasoma laterally and ventrally (laterotergites, sternites and hypopygium) is light yellow-orange (Figs 1A, F, 2A, F). This character is useful in recognizing *typhae*, at least in Africa, as all other *Cotesia* species within this complex generally have a much darker metasoma latero-ventrally (e.g. Figs 5A, F, 6A, E, 7A, F, 8G); however, some populations of *C. flavipes* we have examined have a light-colored metasoma, so this character is not absolutely diagnostic.

Description. Head and mesosoma mostly dark brown to black (except for scape, pedicel, wing base and tegula yellow; antennal flagellomeres brown; mandibles and labrums orange-yellow, and face projection between antennal base usually light brown); legs mostly yellow (except for metafemur with brown dorsal tip on posterior 0.1, and metatarsus light brown to brown); metasoma mostly yellow-brown to yellow-orange (except for mediotergites 1 and 2 dark brown to black, and mediotergites 3+ usually

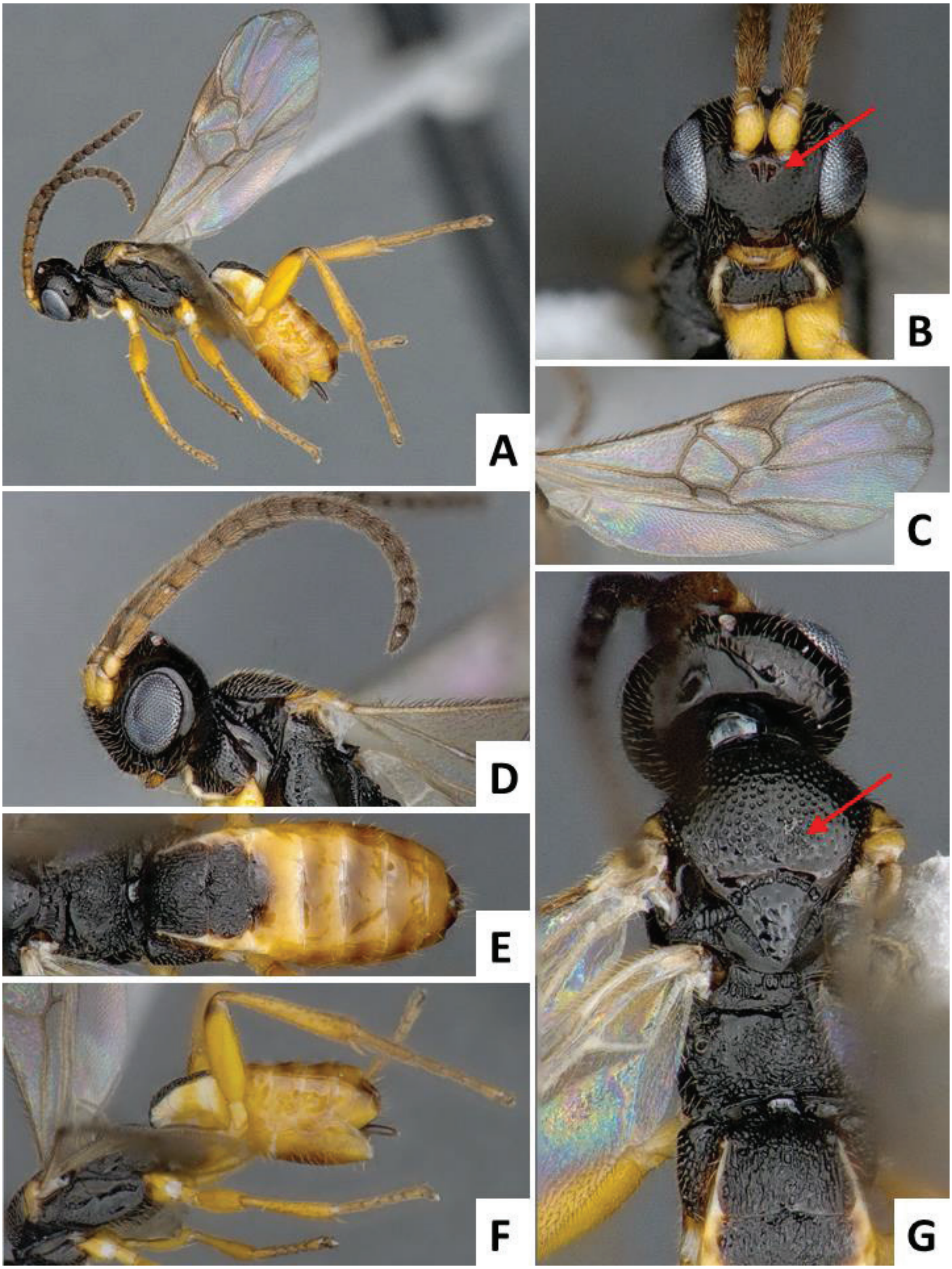

Figure 1. *Cotesia typhae*, holotype, female specimen from Makindu, Kenya. **A** Habitus, lateral view **B** Head, frontal view (arrow shows face projection between antennal base) **C** Wings **D** Head and mesosoma (partially), lateral view **E** Propodeum and metasoma, dorsal view **F** Mesosoma and metasoma, lateral view **G** Head, mesosoma and tergites 1-2, dorsal view (arrow shows anteromesoscutum punctures).

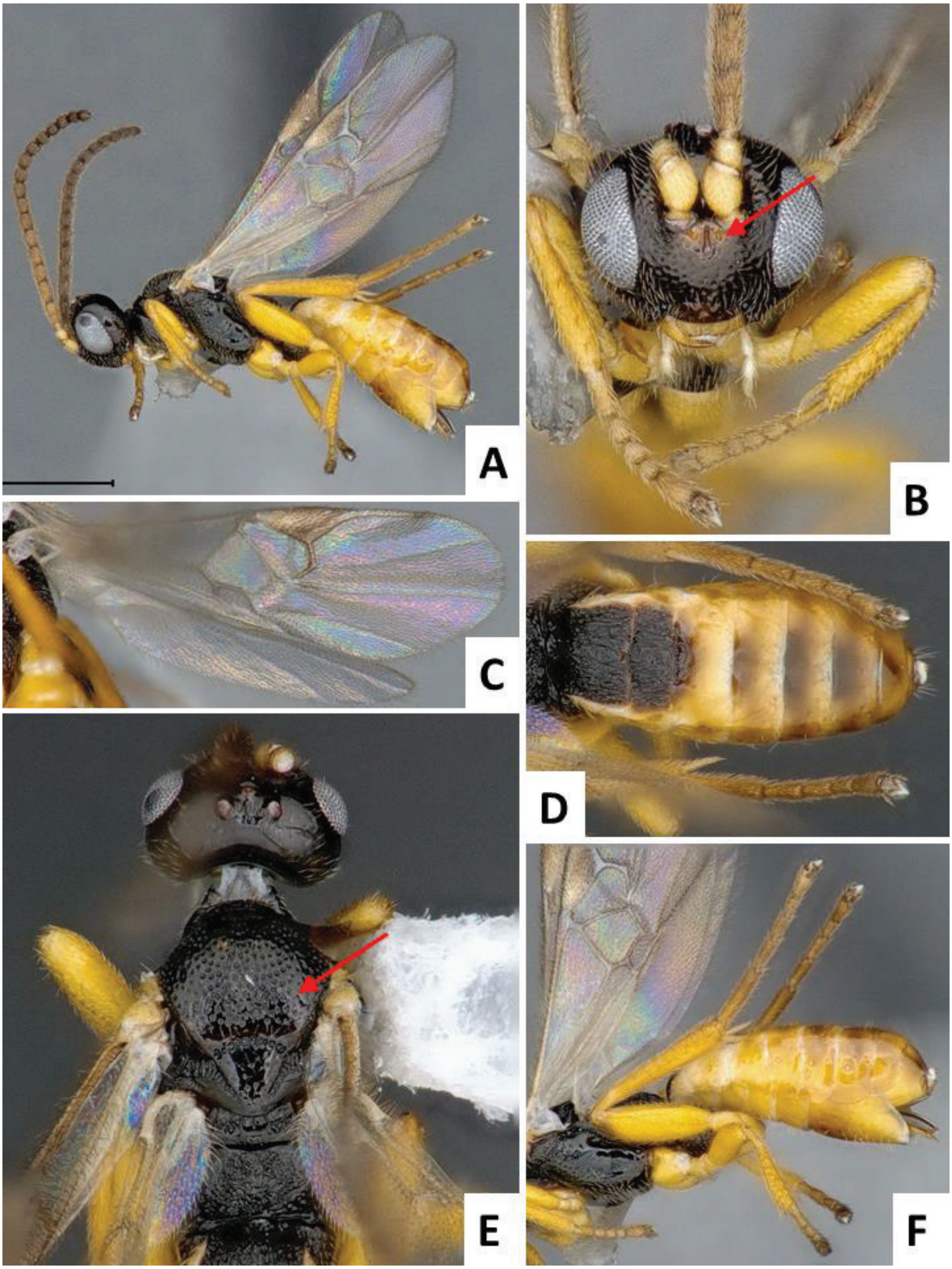

Figure 2. *Cotesia typhae*, paratype, female specimen from Kobodo, Kenya. **A** Habitus, lateral view **B** Head, frontal view (arrow shows face projection between antennal base) **C** Wings **D** Metasoma, dorsal view **E** Head and mesosoma, dorsal view (arrow shows anteromesoscutum punctures) **F** Metasoma, lateral view.

Table 2. Diagnostic characters within the *Cotesia flavipes* complex. Data on host caterpillar species from Branca et al. (2011), Muirhead et al. (2012), Sallam (2006), and Kaiser et al. (2015).

	Cotesia chilonis	***Cotesia flavipes***	***Cotesia nonagriae***	***Cotesia sesamiae***	***Cotesia typhae***
Scutoscutellar sulcus	Straight (Fig. 8H)	Curved (Fig. 7E)	Curved	Curved (Fig. 5F)	Curved (Figs 1G, 2E)
Antero-mesoscutum (AMS) punctures	Large punctures (diameter larger than distance between punctures) in most of AMS, including most of the posterior half (Fig. 8H)	Relatively small punctures on anterior half of AMS, posterior half almost entirely smooth (Fig. 7E, G)	Relatively small punctures on anterior half of AMS, posterior half almost entirely smooth	Relatively small punctures on anterior half of AMS, posterior half almost entirely smooth (Figs 5G, 6F)	Large punctures (diameter larger than distance between punctures) in most of AMS, including most of the posterior half (Fig. 2G, E)
Face projection between antennal base	Acute, triangular projection with clearly impressed median longitudinal sulcus (Fig. 8B)	Acute projection (sometimes projection less acute, margin almost straight) with clearly impressed median longitudinal sulcus (Fig. 7B)	More or less straight margin, with no clearly impressed, median longitudinal sulcus	Acute projection (sometimes projection less acute, margin almost straight) with clearly impressed median longitudinal sulcus (Figs 5B, 6B)	Acute, triangular projection with clearly impressed median longitudinal sulcus (Fig. 1B, B)
Paramere length (observed externally, without removing genitalia from specimen)	Short, around 1.0 × as long as median length of sternite 8 (partially visible in Fig. 3G, H)	Large, clearly more than 1.5 × (usually up to 2.0x) as long as median length of sternite 8 (Fig. 4A, D)	Large, clearly more than 1.5 × (usually up to 2.0x) as long as median length of sternite 8	Short, around 1.0 × as long as median length of sternite 8 (Fig. 4b, E)	Relatively large, around 1.5 × as long as median length of sternite 8 (Fig. 4C)
Paramere shape	Rather uniformly narrowing from base to rounded apex	Rather uniformly narrowing from base to rounded apex (Fig. 4D)	Rather uniformly narrowing from base to rounded apex	Rather uniformly narrowing from base to rounded apex (Fig. 4E)	With a broad, widened area near apex (Fig. 4F, G)
Antennal flagellomeres	Relatively short (3+ about as long as wide)	Relatively short (2+ about as long as wide)	Relatively short (2+ about as long as wide)	Relatively short (3+ about as long as wide)	Relatively long (1–4 much longer than wide)
Natural known hosts	*Chilo supressalis, C. partellus* (Crambidae)	More than 7 species (Crambidae & Noctuidae)	*Bathytricha truncata* (Noctuidae)	More than 34 species (mostly Noctuidae & Crambidae)	*Sesamia nonagrioides* (Noctuidae)

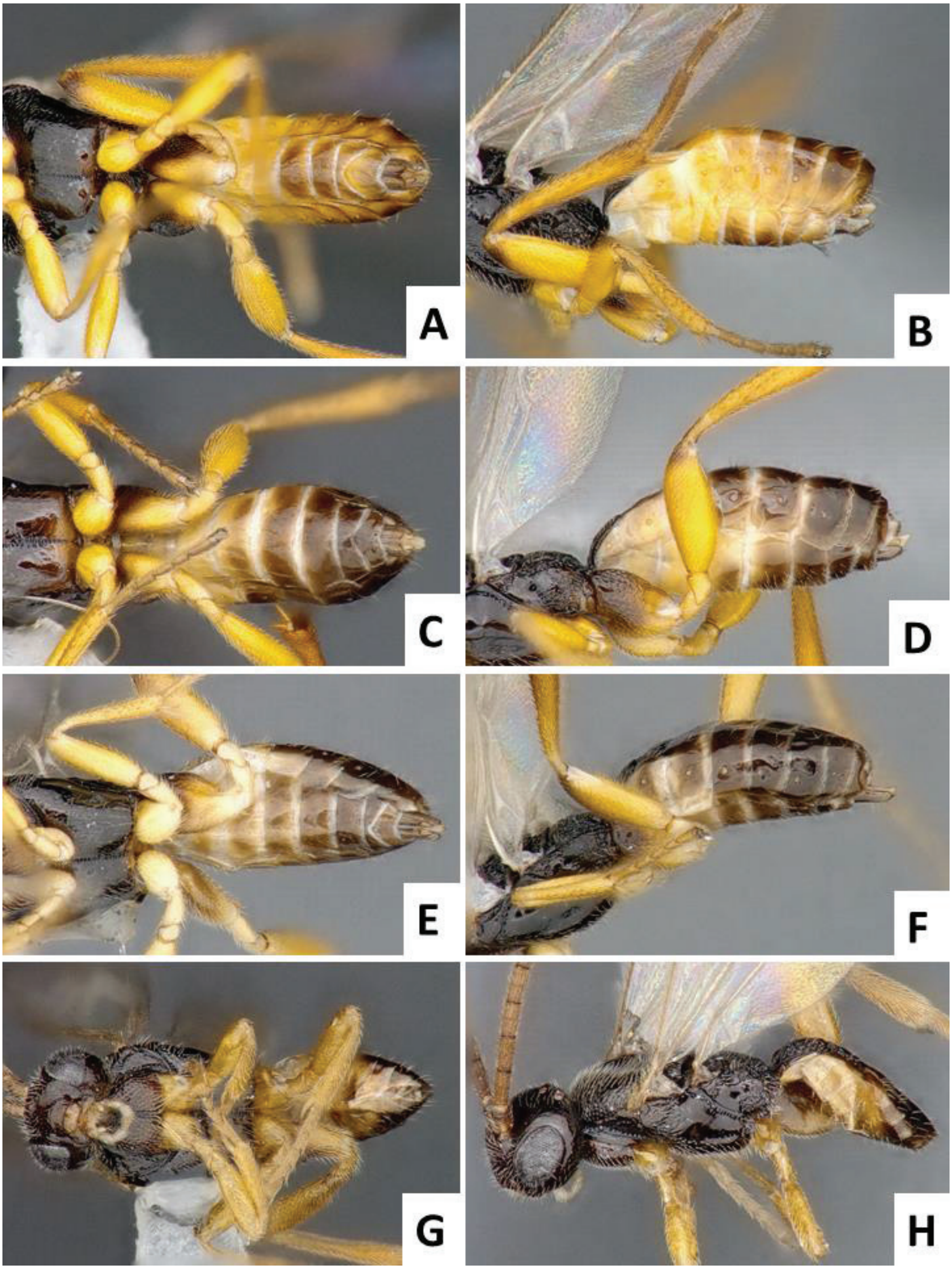

Figure 3. Male metasoma in ventral and lateral view. **A, B** *Cotesia typhae*, paratype specimen from Kenya **C, D** *Cotesia sesamiae*, specimen from Kenya **E, F** *Cotesia flavipes*, specimen from Kenya **G, H** *Cotesia chilonis*, specimen from Japan.

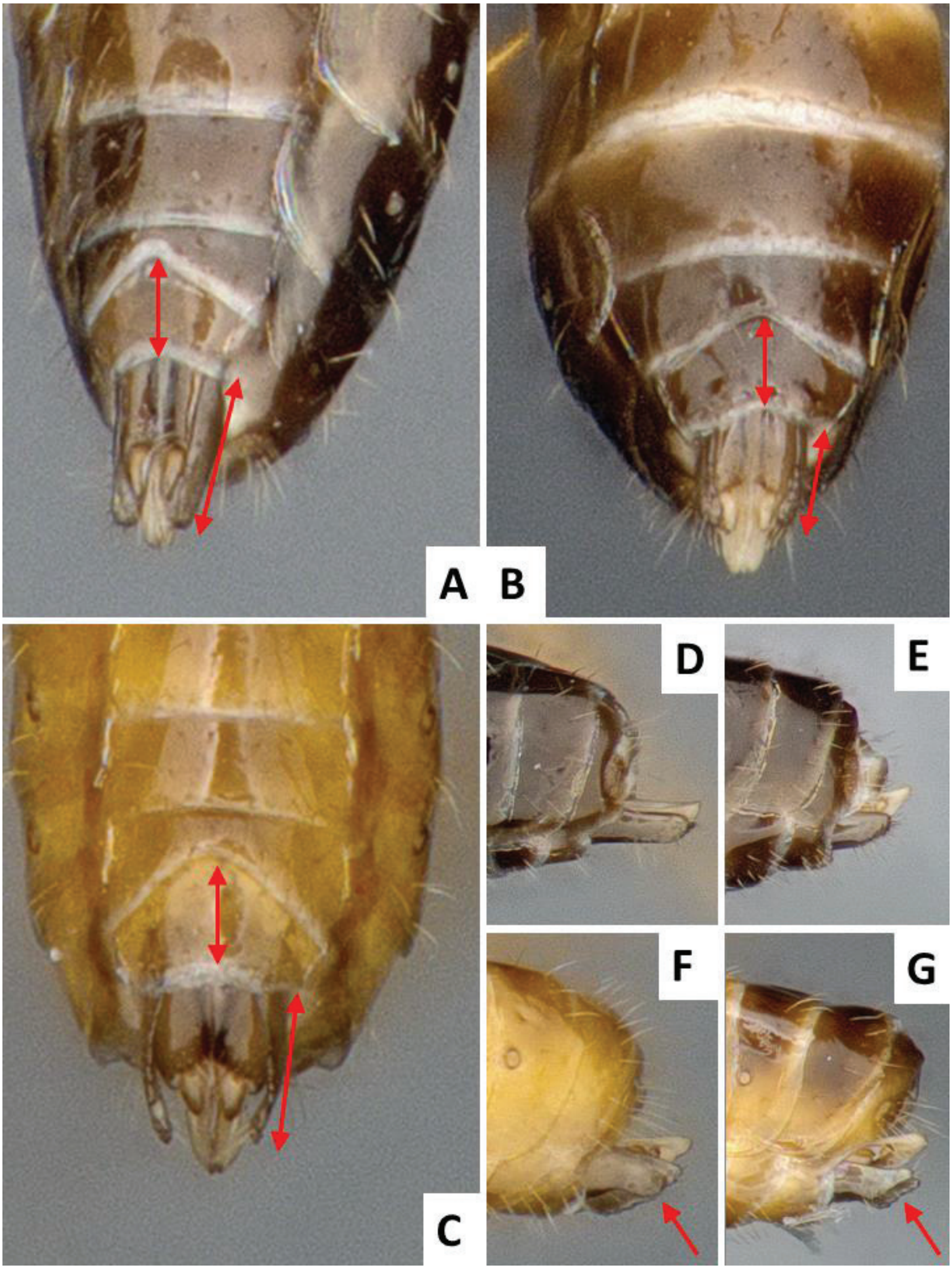

Figure 4. External male genitalia in ventral and lateral view; arrows show length of paramere and sternite 8. **A, D** *Cotesia flavipes* specimen from Kenya **B, E** *Cotesia sesamiae*, specimen from Kenya **C, F, G** *Cotesia typhae*, paratype specimen from Kenya.

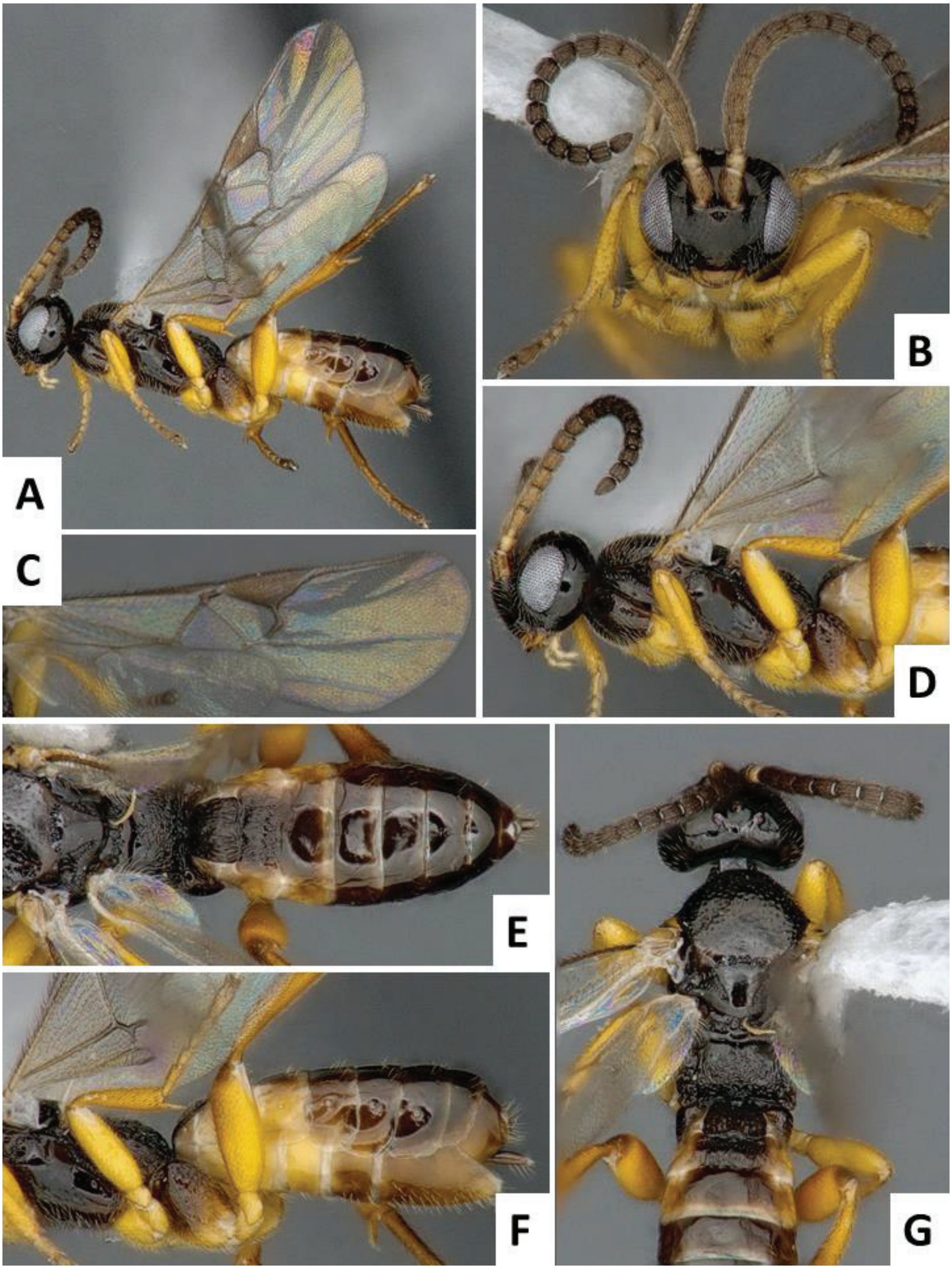

Figure 5. *Cotesia sesamiae*, female specimen from Kitale, Kenya. **A** Habitus, lateral view **B** Head, frontal view **C** Wings **D** Head and mesosoma, lateral view **E** Scutellar disc, propodeum and metasoma, dorsal view **F** Mesosoma and metasoma, lateral view **G** Head, mesosoma and tergites 1-4, dorsal view.

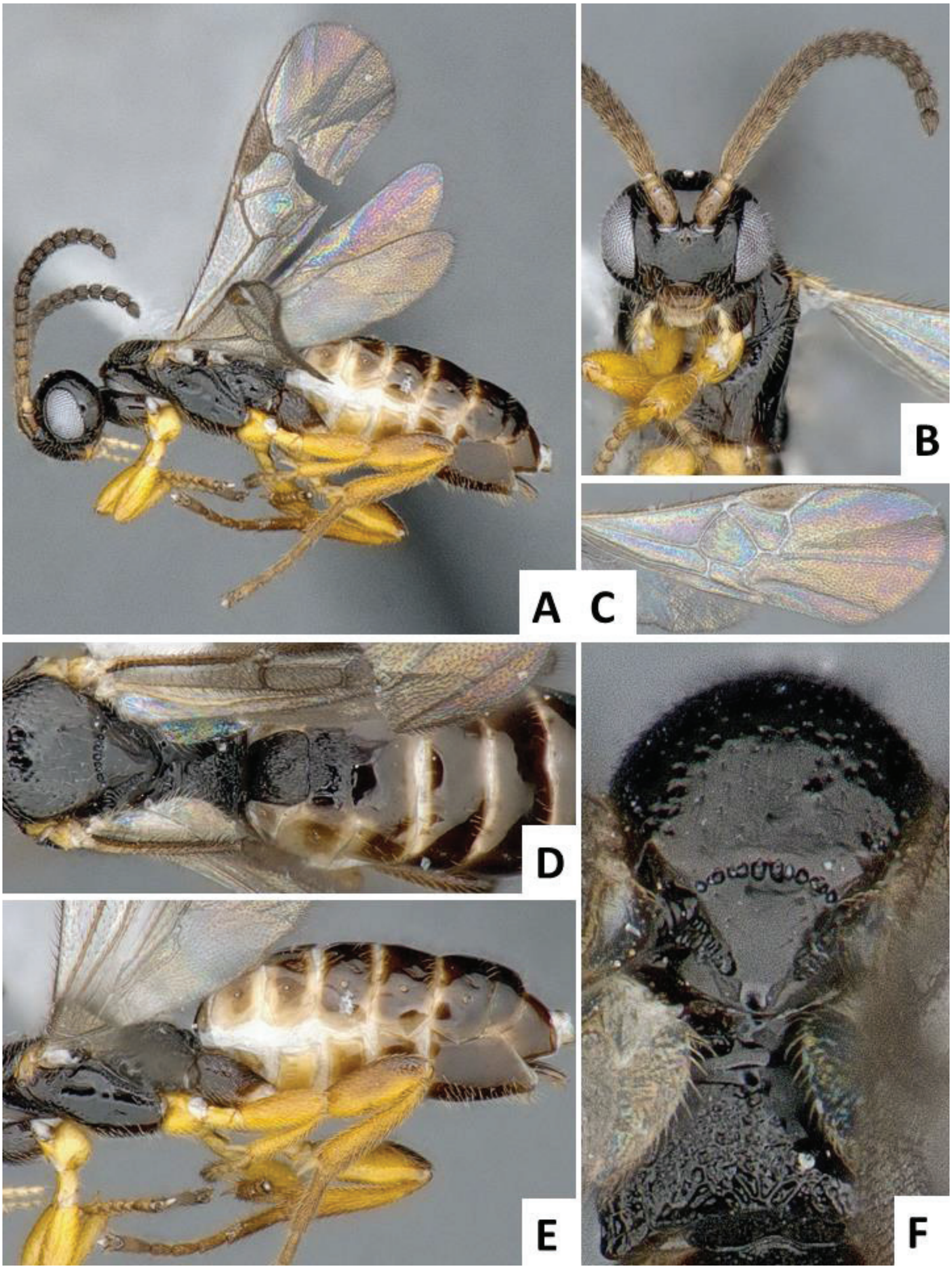

Figure 6. *Cotesia sesamiae*, female specimen from Mombasa, Kenya. **A** Habitus, lateral view **B** Head, frontal view **C** Wings **D** Mesosoma and metasoma (partially), dorsal view **E** Mesosoma and metasoma, lateral view **F** Anteromesoscutum, scutellar disc and propodeum, dorsal view.

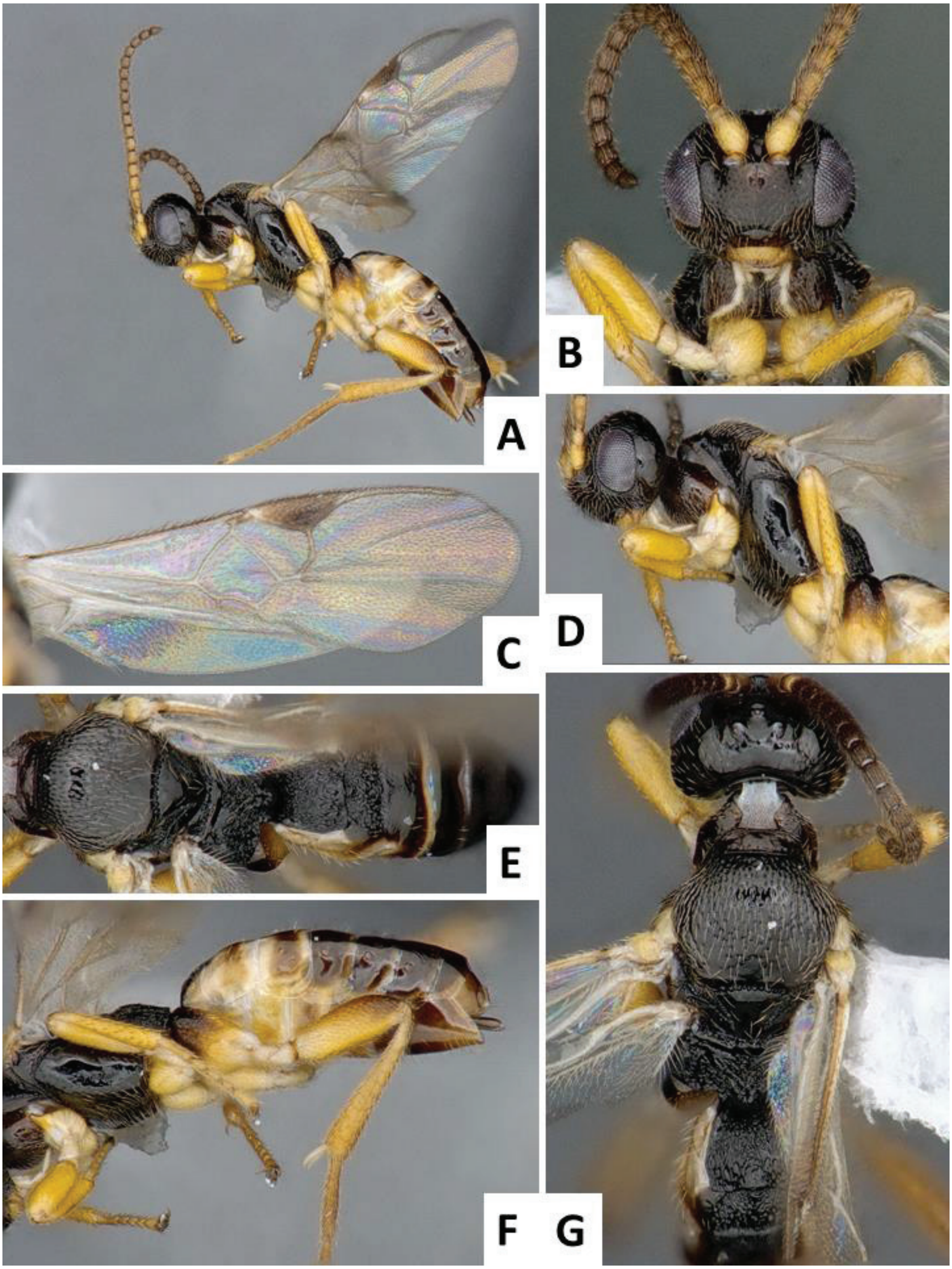

Figure 7. *Cotesia flavipes*, female specimen from Mombasa, Kenya. **A** Habitus, lateral view **B** Head, frontal view **C** Wings **D** Head and mesosoma, lateral view **E** Mesosoma and metasoma, dorsal view **F** Mesosoma and metasoma, lateral view **G** Head, mesosoma and tergites 1-2, dorsal view.

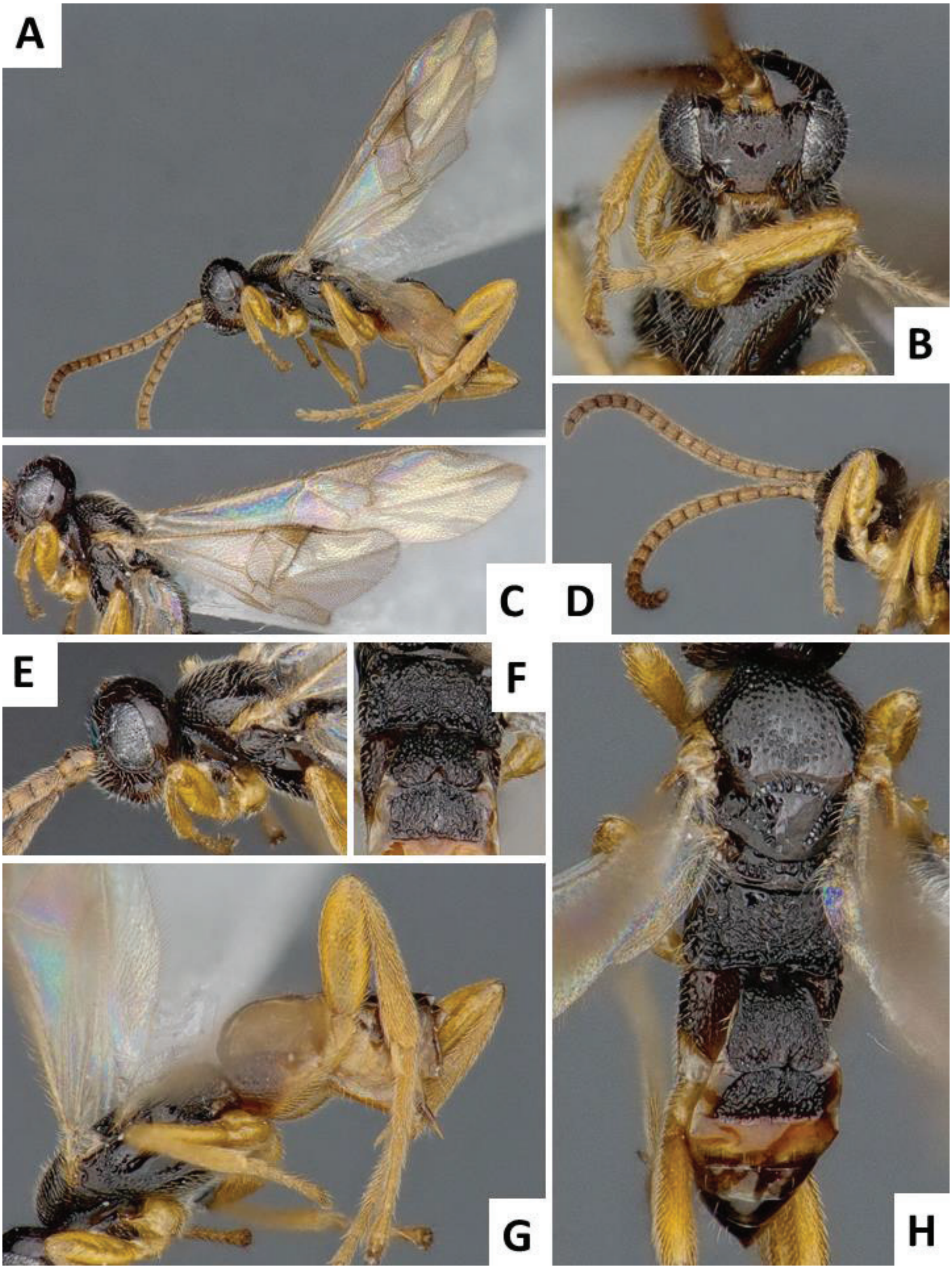

Figure 8. *Cotesia chilonis*, female specimen from Takatsuki, Japan. **A** Habitus, lateral view **B** Head, frontal view **C** Wings **D** Antennae, front and middle legs, lateral view **E** Head, lateral view **F** Propodeum, tergites 1-2, dorsal view **G** Mesosoma and metasoma, lateral view **H** Mesosoma and metasoma, dorsal view.

with brown spot centrally, near anterior margin). Wings with veins mostly brown, pterostigma brown with pale spot on anterior 0.3.

Head wider than high; face with acute, triangular projection between antennal base, the projection with clearly impressed median longitudinal sulcus; head dorsally smooth; gena laterally and dorsally as wide or wider than eye width; anteromesoscutum with relatively deep, coarse and large punctures (puncture diameter larger than distance between punctures), puncture density similar on most of the anteromesoscutum, including posterior half; scutoscutellar sulcus strongly curved, with 10-12 impressions; scutellar disc mostly smooth, with shallow and sparse punctures; propodeum mostly sculptured with an irregular pattern of strong carinae; mediotergites 1-2 mostly covered by strong longitudinal striae, mediotergites 3+ mostly smooth; hypopygium relatively small, apical tip in lateral view shorter than apical tip of tergites; paramere with broad, widened area near apex; paramere relatively large, around 1.50 × as long as median length of sternite 8.

Body ratios. Length of flagellomere 2/length of flagellomere 14: 1.71 × (1.50–1.86). Metafemur length/width: 3.06 × (2.92–3.25). Length of inner spur of metatibia/length of first segment of metatarsus: 0.48 × (0.46–0.52). Length of inner spur of metatibia/length of outer spur of metatibia: 1.07 × (1.07–1.18). Pterostigma length/width: 2.81 × (2.61–2.88). Length of fore wing vein r/length of fore wing vein 2RS: 0.82 × (0.82–1.00). Mediotergite 1 length/mediotergite width at posterior margin: 1.07 × (0.93–1.20). Length of mediotergite 2/length of mediotergite 3: 0.89 × (0.83–1.00).

Body measurements (all in mm). Body length: 2.40 (2.20–2.50). Fore wing length: 2.10 (2.10–2.20). Length of antennal flagellomere (F), F1: 0.15 (0.14–0.17), F2: 0.12 (0.12–0.13), F3: 0.11 (0.10–0.11), F14: 0.07 (0.06–0.08), F15: 0.07 (0.06–0.08), F16: 0.10 (0.09–0.11). Metafemur length: 0.55 (0.51–0.56). Metafemur width: 0.18 (0.16–0.19). Metatibia length: 0.71 (0.66–0.74). First segment of metatarsus length: 0.31 (0.28–0.31). Length of inner spur of metatibia: 0.15 (0.13–0.16). Length of outer spur of metatibia: 0.14 (0.11–0.14). Ovipositor sheaths length: 0.18 (0.15–0.18). Pterostigma length: 0.45 (0.145–0.49). Pterostigma width: 0.16 (0.16–0.18). Length of fore wing vein r: 0.09 (0.09–0.11). Length of fore wing 2RS: 0.11 (0.10–0.12). Length of mediotergite 1: 0.30 (0.27–0.31). Width at posterior margin of mediotergite 1: 0.28 (0.25–0.32). Length of mediotergite 2: 0.16 (0.14–0.20). Length of mediotergite 3: 0.18 (0.15–0.20).

Etymology. Named after the main host plant on which the wasp parasitizes its host caterpillar, Kaiser et al. (2015).

Notes. *Cotesia typhae* occurs sympatrically with *C. sesamiae* and *C. flavipes* (the latter introduced into Africa). Among these three species, *typhae* is the largest (body and fore wing lengths usually 0.2–0.3 mm longer than the two others), it also has a more sculptured anteromesoscutum and a longer antenna (especially flagellomeres 1–4 which are significantly longer).

Table 3. Minimum and maximum divergence of COI sequences between all pairs of species.

	C. typhae	*C. sesamiae*	*C. flavipes*	*C. chilonis*
C. typhae	0–0.002			
C. sesamiae	0.026–0.035	0–0.028		
C. flavipes	0.033–0.035	0.031–0.042	0	
C. chilonis	0.035	0.030–0.037	0.037	0

Table 4. Minimum and maximum divergence of COI sequences between *C. typhae* and two populations of *C. sesamiae*.

	C. typhae	*C. sesamiae* Kitale	*C. sesamiae* Mombasa
C. typhae	0–0.002		
C. sesamiae Kitale	0.03–0.035	0–0.014	
C. sesamiae Mombasa	0.026–0.03	0.019–0.028	0–0.003

Molecular characterization

Between species, pairwise divergence of COI sequences ranged from 2.6% to 4.2%, and distances observed between *C. typhae* and the other *C. sesamiae* species fell in this range Table 3). Within species, divergence was close to zero for *C. typhae*, *C. chilonis* and *C. flavipes*, and ranged from zero to 2.8% in *C. sesamiae*. The higher within-species values in *C. sesamiae* are explained by the divergence between the Kitale and Mombassa populations, reflecting their affiliation with different lineages, as shown by Kaiser et al. (2015) (Table 4).

Distribution, ecology and abundance

Among the ten sampled countries and 65 sampled localities hosting *S. nonagrioides* on Typhaceae and Cyperaceae, larvae parasitized by *C. typhae* were found in the three most sampled countries (highest numbers of localities and collected larvae), Ethiopia, Kenya and Tanzania (Table 5), in a total of 12 localities (Table 6). This showed that the probability of discovering *C. typhae* depended on the sampling effort, so this species may well be present in other sub-Saharan Africa areas inhabited by *S. nonagrioides* (Kergoat et al. 2015).

We then estimated the percentage of parasitized *S. nonagrioides* in the localities where the parasitoid was present. It varied from less than five to more than 70 % (Table 6), with a mean value of 20.3 % (standard error 4.0 %, n=18). All values, except the highest, ranged between 3.4 and 33.3% of parasitized larvae. Among the 660 parasitized larvae, 5 were parasitized by *Cotesia* other than *C. typhae* (4 *C. sesamiae* and 1 *C. flavipes*). Repeated findings of *C. typhae* in different years in the same locality, as seen in two Kenyan localities (Mbita Lwanda, 4 collections over 9 years; Makindu, 3 collections over 4 years), showed that locality and plant-host combination were good criteria for finding this new species.

Table 5. Presence of *Cotesia typhae* in the sampled countries. Results of collections of *S. nonagrioides* in sub-Saharan Africa from 2004 to 2013. For each country the Table shows the number of localities containing Typhaceae and Cyperaceae plants, the total number of *S. nonagrioides* larvae collected there during the period, and whether some were parasitized by *C. typhae*.

Country	Number of sampled localities with Typhaceae & Cyperaceae	Number of *S. nonagrioides* larvae	presence of *Cotesia typhae*
Benin	1	26	no
Botswana	1	2	no
Cameroun	1	1	no
Ethiopia	5	167	YES
Kenya	26	1253	YES
R. Congo	2	38	no
R.D.C.	2	26	no
Rwanda	1	7	no
Tanzania	18	463	YES
Tanzania, Pemba	1	1	no
Tanzania, Zanzibar	3	25	no
Uganda	4	26	no

Life history traits and parasitoid success on different host strains

Adult longevity

The median longevity was close to three days when adults were fed honey, but equal to two days or less when they were fed with 20% or 2% saccharose solution respectively (Fig. 9). The survival curves were significantly different ($W_{2df} = 129.78$; $P < 10^{-4}$). They showed that about 90% adults were dead six days after emergence when fed honey or 20% saccharose, and three days after emergence when fed 2% saccharose (Fig. 9).

Realized fecundity

Females were given the opportunity to parasitize a maximum of four larvae, but they actually parasitized a mean number of only 2.3 larvae (Table 7), either because they died before the end of the experiment (almost half of them were dead on the third day, Fig. 10), or because they refused to oviposit, as observed for a few females on day 3, and for most of the surviving ones on day 4 (Fig. 10). About 2/3 of the stung larvae allowed successful parasitoid development (Table 7). Finally, females produced about 100 offspring during their lifetime, from two host larvae.

In the next experiment, the possibility for *C. typhae* to develop in European populations was estimated by the incidence of the first oviposition, which ensured more than half of the wasp's reproductive success.

Parasitoid success in European host populations

Susceptibility of European *S. nonagrioides* strains to the parasitoid was equal or even higher than that of the Kenyan strain, with for instance almost 90% of successfully

Table 6. Percentage of parasitism of *S. nonagrioides* larvae in the localities where *C. typhae* was found.

Country	Locality	Latitude	Longitude	EDate	Plant species	Nbr *S.n.* larvae	% parasitism
ETHIOPIA	Awasa	7.05°N	38.47°E	Nov.-04	*T. domingensis*	64	6.3%
ETHIOPIA	Chamoleto	5.93°N	37.53°E	Nov.-04	*T. domingensis*	16	18.8%
ETHIOPIA	Omolante	6.16°N	37.67°E	Nov.-04	*T. domingensis*	27	22.2%
KENYA	Kabuto	0.35°S	34.96°E	May-12	*C. dives*	6	33.3%
KENYA	Kobodo	0.86°S	34.57°E	March-13	*C. dives*	42	7.1%
KENYA	Makindu	2.28°S	37.82°E	Nov.-10	*T. domingensis*	65	10.8%
KENYA	Makindu	2.28°S	37.82°E	Feb.-11	*T. domingensis*	64	4.7%
KENYA	Masimba	2.15°S	37.58°E	Dec.-06	*T. domingensis*	10	30.0%
KENYA	Masimba	2.15°S	37.58°E	Apr.-08	*T. domingensis*	13	15.4%
KENYA	Mbita Lwanda	0.89°S	34.67°E	Feb.-05	*T. domingensis*	68	27.9%
KENYA	Mbita Lwanda	0.89°S	34.67°E	Oct.-08	*T. domingensis*	147	10.2%
KENYA	Mbita Lwanda	0.89°S	34.67°E	June-07	*T. domingensis*	18	72.2%
KENYA	Mbita Lwanda	0.89°S	34.67°E	March-13	*T. domingensis*	59	8.5%
KENYA	Rabuor	0.43°S	34.91°E	March-13	*C. dives*	10	20.0%
KENYA	Rabuor	0.43°S	34.91°E	March-13	*T. domingensis*	6	33.3%
KENYA	Sori	0.97°S	34.28°E	March-13	*T. domingensis*	13	7.7%
TANZANIA	Arusha	3.37°S	36.87°E	July-04	*T. domingensis*	29	3.4%
TANZANIA	Ruvu	6.70°S	38.71°E	March-07	*C. exaltatus*	3	33.3%

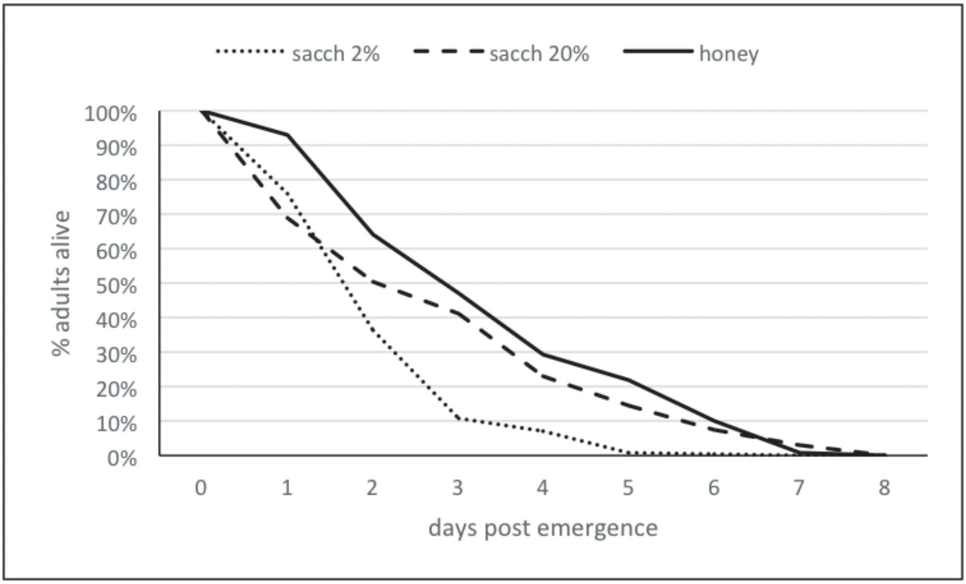

Figure 9. Survival curves of *C. typhae* adults fed honey (number of wasps: n=497), or 20% (n=742) or 2% (n=534) saccharose solutions in collective cages at 21°. Median lifespan is the time value observed at 50% survival.

Table 7. Realized fecundity of *C. typhae* on Kenyan *S. nonagrioides*.

	adult lifetime (days)	stung larvae (nbr)	successfully parasitized larvae (nbr)	Offspring (total nbr)
Mean (N=40)	2.83	2.3	1.63	102.93
Standard error	1.17	0.11	0.11	6.2

parasitized Italian larvae. Several other traits differed between the host strains, with a trend for better performances in the Italian strain, which ranked "a" for the five progeny traits showing significant differences: faster larval and pupal development, resulting in a development time of 20 days; high offspring number per cluster, showing the lowest pupal mortality and highest ratio of females. Highest immature developmental time (22 days) was observed in the Kenyan host strain, and highest pupal mortality and lowest female ratio was observed in the French strain. From these traits, it is possible to estimate a reproductive rate, i.e. the expected number of viable adults per mother, by multiplying the proportion of successful parasitism (probability of host larvae successfully parasitized) by the mean number of produced cocoons and by the proportion of viable adults (1-proportion of pupal mortality). This approach indicated that a female *C. typhae* would produce 56 viable offspring from a host larva of the Italian population, and only 37 from the host larvae of the French or Kenyan populations. As discussed hereafter, most differences could be explained by the effect of rearing conditions on host larvae quality.

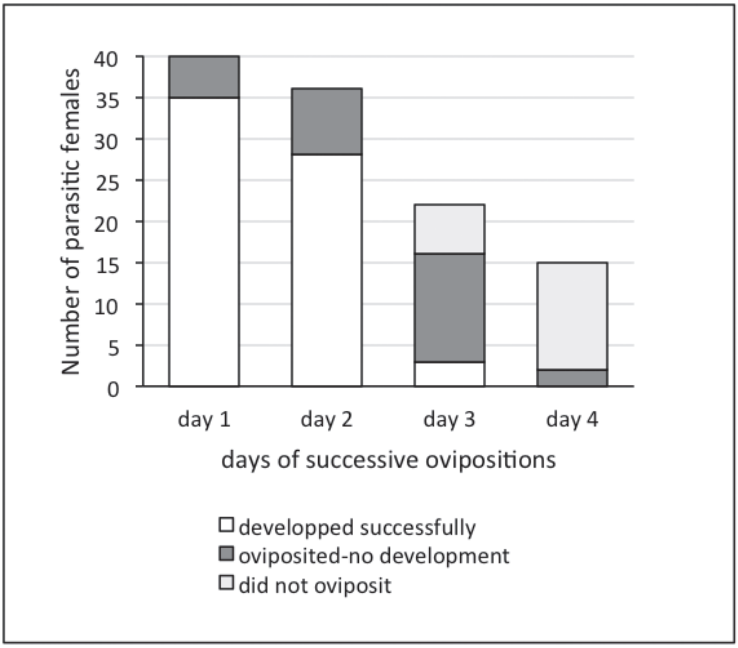

Figure 10. Issue of successive presentations of host larvae to *C. typhae* (one host per day for four days or less for wasps that died).

Table 8. Development of *C. typhae* in Kenyan and European hosts. Bold characters indicate significant differences between host strains.

***S. nonagrioides* populations:**	**Kenya**	**France**	**Italy**	**Statistical analyses**
N: Nbr parasitized host larvae	*58*	*58*	*47*	–
Host larval weight at time of parasitism (mg)	295 ± 11	272 ± 12	283 ± 12	$KW_{2df} = 1.28$ $P = 0.331$
% successful parasitism % host pupae % host larva mortality	69.0 (b) 12.1 19.0	67.2 (b) 13.8 19.0	89.4 (a) 2.1 8.5	**$\chi^2_{2df} = 7.95$** **$P = 0.019$**
N: Nbr of cocoon clusters analyzed below	38	32	33	–
Cotesia larval development	14.2 ± 0.4 b	14.4 ± 0.2 b	12.9 ± 7.1 a	**$KW_{2df} = 18.29$** **$P = 10^{-4}$**
Cotesia pupal development (days)	8.2 ± 0.3 b	6.8 ± 0.2 a	7.1 ± 0.1 a	**$KW_{2df} = 19.60$** **$P < 10^{-4}$**
Cocoon number	60.3 ± 4.6 b	75.0 ± 5.5 a	64.6 ± 4.5 ab	**$KW_{2df} = 7.67$** **$P = 0.022$**
Individual cocoon weight (mg)	1.3 ± 0.04	1,3 ± 0.05	1,2 ± 0.02	$KW_{2df} = 4.20$ $P = 0.122$
% *Cotesia* pupal mortality	10.4 ± 2.7 a	25.8 ± 4.6 b	3.0 ± 0.7 a	**$KW_{2df} = 16.54$** **$P < 10^{-3}$**
% females in the cluster	43.9 ± 5.4 c	35.0 ± 8.2 b	72 ± 3.8 a	**$KW_{2df} = 17.98$** **$P < 10^{-3}$**
Estimated Reproductive Rate (expected viable adults/mother)	37	37	56	–

Discussion

The morphological analysis conducted in this study, as well as the divergence of the CO1 sequences, confirmed the species status of the *C. sesamiae* lineage specialized on the noctuid *S. nonagrioides*. The CO1 divergence fell within the range of values observed between species of the *flavipes* complex. Morphological traits differentiated in this lineage included those used to distinguish species of the *flavipes* complex. This constitutes evidence for the existence of a fifth species in the *flavipes* complex. We named this new species *C. typhae*, based on the main host plant where it is found on its host. Whereas the first four species are allopatric in their endemic range, *C. typhae* is sympatric with *C. sesamiae* and may have differentiated from this species through divergent selection for adaptation on *S. nonagrioides* in Typhaceae and Cyperaceae, a permanent resource, and divergent selection for reproductive isolation (possibly facilitated by *Wolbachia*) (Kaiser et al. 2015).

It is likely that more species may be found in this complex. For instance, a relatively large CO1 divergence was also observed between *C. sesamiae* populations from Kitale (inland Kenya) and Mombassa (coastal Kenya), which are two host races with limited gene flow due to *Wolbachia* infection (Mochiah et al. 2002). Additional studies on the phylogenetic and biological relationships among those lineages, in particular the strength of bidirectional cytoplasmic incompatibilities related to *Wolbachia* strains, may reveal, in the future, the presence of an additional species.

Male genitalia were one of the differentiated morphological traits. This explains mating abnormalities observed by Kaiser et al. (2015) when crossing males of *C. typhae* with females of *C. sesamiae*, i.e. difficulties of males to disengage from females. It is one component of pre-zygotic barriers. In most animal species with internal fertilization, male external genitalia are the most rapidly evolving organs and are usually the first organs to diverge morphologically following speciation (Eberhard 2010; Yassin and Orgogozo 2013). Because of their rapid evolution and species-specificity, their illustration is a common feature in taxonomic literature to discriminate closely related species, particularly in insects (Yassin and Orgogozo 2013), including species of the *flavipes* complex (Kimani-Njogu and Overholt 1997).

The larger size of *C. typhae* relatively to the other species of the *flavipes* complex could result from an adaptation to host size, *S. nonagrioides* being a rather large noctuid relative to other Poales stem borer hosts for the *flavipes* complex. The size of a solitary parasitoid has been often reported as a plastic trait varying with host size; in gregarious parasitoids, the clutch size can be plastic and varies with host size (Godfray 1994). An evolutionary relationship between the size of gregarious parasitoids and the host size can exist if there is a genetic constraint on the clutch size, which is very likely, at least due to limits in the number of mature oocytes. The differentiation of other morphological traits may result from selective sweep or genetic correlation with other adaptive traits exposed to differential selection.

The morphological identification of species of the *flavipes* complex relies on a combination of slight differences, and their observation requires specific expertise, so a molecular diagnoses using CO1 or the virulence gene CrV1 (Dupas et al. 2006; Branca et al. 2011) remains the easiest identification method.

The geographic distribution and ecology of *C. typhae* have been reported by Kaiser et al. (2015). Here we provide evidence that the probability of collecting *S. nonagrioides* parasitized by *C. typhae* depended on the number of collected larvae. In several visited countries, this number was not sufficient to assess the presence of the wasp, so it may well be present over the sub-Saharan distribution of its noctuid host. The percentage of parasitized larvae was highly variable between localities, and even between periods of sampling in the same locality. Abundance of *C. typhae* within a locality may vary depending on the rainy season. Indeed Mailafiya et al. (2010) found that *C. sesamiae* was more abundant during the rainy season, and here (Table 6), the highest values of *C. typhae* abundance were observed in the middle of the rainy season (December), whereas lower values corresponded to the beginning of the season (Makindu-Masimba area, rainy season from November to January, Mailafiya et al. 2010). Other localities in western Kenya with rainy seasons from March to August and October to December had the highest parasitism observed in June. Regarding mean parasitism rates, about 20% of *S. nonagrioides* larvae were successfully parasitized by *C. typhae*. The same mean value or range of parasitism rates were observed in stem borers parasitized by *C. sesamiae,* and by *C. flavipes*, in maize and sorghum in Kenya (Mailafiya et al. 2010), and by *C. chilonis* in rice in China (Lou et al. 2014), but lower values were also observed (Jiang et al. 2006). This mean value is much lower than that observed in laboratory conditions. One limiting factor of parasitism success in natural conditions may be the behavior of host larvae, which hide inside the stem galleries with entrances that are naturally plugged with residues from boring, and move about mostly during the night, whereas the wasps are diurnal. Larvae also defend themselves by biting to death the wasps attempting to oviposit, killing 30-40% of them (Potting et al. 1997). Dispersion of these small parasitoids may also limit their efficiency, and would explain why mass releases of *C. flavipes* performed in sugarcane fields in Brazil successfully raised the parasitism rate to a range of 40-60% (Botelho and Macedo 2002; Dinardo-Miranda et al. 2014). Our data on *C. typhae* also show that parasitism rates as high as 70% can occur, although this rates was observed only once, and the next closest value was half lower. Even higher seasonal peaks were also reported in the case of the noctuid stem borer *Busseola fusca* parasitized by *C. sesamiae* on sorghum in South Africa (Kfir and Bell 1993), and of the crambid rice stem borer *C. suppressalis* in China (Lou et al. 2014).

Presence of *C. typhae* in different years in the same place showed that locality and plant-host combination was a good criterion for finding this new species. Very rare occurrence of parasitism of *S. nonagrioides* by *C. sesamiae and C. flavipes*, observed in less than 1% of the larvae, means that species identity has to be checked systematically.

The longevity of *C. typhae* and reproduction dynamics resemble those observed for the other species of the *flavipes* complex, which are typical short lived pro-ovogenic parasitoid wasps (Quicke 1997), i.e. females emerge with mostly mature oocytes and oviposit shortly after being mated, until egg-depletion. A literature review allows comparisons with three other species of the complex. *C. typhae* adult longevity was close to that of *C. sesamiae*, i.e. a mean longevity of about three days when fed honey at 25° and 60% RH (Sallam et al. 2002), but shorter than the longevity recorded in similar conditions for *C. flavipes* (about 5-6 days, Potting et al. 1997) and for *C. nonagriae* (about 12 days, Muirhead et al. 2008). Longevity in outdoor conditions may be longer due to cooler temperatures at night and the opportunity to rest in favorable micro-niches provided by plants. In the *flavipes* complex the dynamic of female reproduction follows their longevity, since most offspring are produced from the first two ovipositions in *C. typhae,* as in *C. sesamiae* (Sallam et al. 2002), and along 4-5 ovipositions in *C. flavipes* (Potting et al. 2007), with the exception of *C. nonagriae* which produces most offspring during the first two ovipositions, although it can live for several days. This behavior may have been selected in response to the defense behavior of stem borer noctuid larvae, which threatens female survival at each oviposition. With regard to realized fecundity, data available for the species complex were mostly the number of offspring produced from the first oviposition, which can be estimated at 60 offspring in *C. typhae*. This value is intermediate between higher value observed for *C. nonagriae* (about 90 offspring from one oviposition, Muirhead et al. 2008), and lower value observed for *C. sesamiae* and *C. flavipes* (from 25 to 45, depending on both parasitoid strain and host species, Jiang et al. 2004, Mochiah et al. 2001, NgiSong et al. 1998, Sallam et al. 2002). Altogether, these data indicate an evolution of the reproduction strategy within the *flavipes* complex. Considering longevity and oviposition dynamic, *C. typhae* appeared to be closer to *C. sesamiae* than to *C. flavipes* and *C. nonagriae*, which is in accordance with the estimated phylogenetic proximity (Muirhead et al. 2012; Kaiser et al. 2015).

The parasitism success of *C. typhae* in European host populations, assessed in the present work, was initially questioned because European *S. nonagrioides* are genetically well differentiated from African populations (Moyal et al. 2011), and they may have evolved immune responses adapted to European parasitoids and pathogens. However, the variation of reproductive success of *C. typhae* in the different host populations did not depend on the continental origin of the host, because *C. typhae* performed globally better in the Italian population than in the French and the Kenyan ones. A genetic differentiation of the Italian host population is unlikely because a recent study based on the analysis of micro-satellite markers showed an absence of genetic structure of *S. nonagrioides* collected in Europe, and in the Near and Middle East (Kader et al., unpublished data). We are more inclined to suspect that the laboratory rearing conditions of the noctuids had an effect on *C. typhae* parasitism success. Indeed, Italian larvae tested in the present work had been reared in a different laboratory than larvae from the French and the Kenyan populations. The Italian laboratory uses a different diet (Giacometti 1995), and larval food is known to influence immune response of Lepidoptera larvae (Smilanich et al. 2009; Vogelweith et al. 2015). Comparison of diets on susceptibility of the three host populations to *C. typhae* will allow this hypothesis to be tested.

In the areas where *C. typhae* have been found, in eastern sub-Saharan Africa, *S. nonagrioides* is rarely seen on maize, sorghum or sugarcane, whereas this is the case in more western parts of Africa and in Europe and the Near and Middle East. However *C. typhae* would probably parasitize *S. nonagrioides* at least on maize, if introduced for biological control, because in laboratory conditions host larvae are readily accepted when fed on maize stem and fecal pellets and eaten stem tissues are highly attractive, triggering intense behavioral examination of the host with antennal tapping.

In conclusion, this study adds a fifth species to the *Cotesia flavipes* complex. Despite the number of individual studies that illustrate the diversity of ecological adaptations in this complex, a comprehensive analysis of the *flavipes* species group is still needed. It will require the joint study of all populations across the geographical and ecological range of the *Cotesia flavipes* complex. The use of an integrative taxonomic approach (combining morphological, molecular, biological and geographical data) will be of paramount importance in recognizing and characterizing this economically important complex of parasitoid wasps. The new *C. typhae* species is an interesting potential biological control agent of the Mediterranean corn borer *S. nonagrioides*, because of its strict host-specificity to that species, at least in its native area, precluding potential negative impact on non-target host species populations.

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Appendix

Genebank accession numbers of CO1 sequences

Species	Genbank accession nbr	Sample name
Cotesia chilonis	KJ882549	P6679
	KJ882550	P6680
	KJ882551	P6681
Cotesia flavipes	KJ882544	P0433
	KJ882545	P0434
	KJ882546	P0435
	KJ882547	P2541
	KJ882548	P4706
Cotesia sesamiae Kitale	KJ882497	G4540
	KJ882501	G4594
	KJ882512	G4636
	KJ882527	G4701
	KJ882528	G4703
	KJ882529	G4708
	KJ882530	G4907
	KJ882532	G4915
	KJ882537	G5778
	KJ882543	CsK
Cotesia sesamiae Mombasa	KJ882495	G4511
	KJ882496	G4512
	KJ882500	G4572
	KJ882513	G4652
	KJ882533	G5699
	KJ882538	G7338
	KJ882541	Mhk
Cotesia typhae	KJ882502	G4608
	KJ882503	G4609
	KJ882507	G4614
	KJ882508	G4615
	KJ882510	G4618
	KJ882511	G4619
	KJ882514	G4655
	KJ882515	G4656

Species	Genbank accession nbr	Sample name
Cotesia typhae	KJ882516	G4664
	KJ882518	G4666
	KJ882519	G4667
	KJ882521	G4675
	KJ882522	G4676
	KJ882523	G4677
	KJ882531	G4909
	KJ882534	G5726
	KJ882535	G5773
	KJ882539	Mbita
	KJ882540	MbL
	KJ882542	Mkd

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RESEARCH ARTICLE

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A new species of the genus *Capoeta* Valenciennes, 1842 from the Caspian Sea basin in Iran (Teleostei, Cyprinidae)

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Abstract

A new species of algae-scraping cyprinid of the genus *Capoeta* Valenciennes, 1842 is described from the Kheyroud River, located in the southern part of the Caspian Sea basin in Iran. The species differs from other members of this genus by a combination of the following characters: one pair of barbels; predorsal length equal to postdorsal length; maxillary barbel slightly smaller than eye's horizontal diameter and reach to posterior margin of orbit; intranasal length slightly shorter than snout length; lateral line with 46–54 scales; 7–9 scales between dorsal-fin origin and lateral line, and 6–7 scales between anal-fin origin and lateral line.

Keywords

Algae-scraping cyprinid, Caspian Sea, inland freshwater, Iran, taxonomy

Introduction

Cyprinid fishes of the genus *Capoeta* Valenciennes, 1842 have a wide distribution throughout western Asia from Anatolia to the Levant, Transcaucasia, the Tigris and Euphrates basins, Turkmenistan, and northern Afghanistan (Bănărescu 1999; Levin et al. 2012; Ghanavi et al. 2016; Jouladeh-Roudbar et al. 2016). This genus has at least 28 species, of which the following 15 species are present in Iran: *Capoeta aculeata* (Valenciennes, 1844); *C. alborzensis* Jouladeh-Roudbar, Eagderi, Ghanavi & Doadrio, 2016; *C. anamisensis* Zareian, Esmaeili & Freyhof, 2016; *C. barroisi* Lortet, 1894; *C. buhsei* Kessler, 1877; *C. capoeta* (Güldenstaedt, 1773); *C. coadi* Alwan, Zareian, & Esmaeili, 2016; *C. damascina* (Valenciennes, 1842); *C. fusca* Nikolskii, 1897; *Capoeta gracilis* (Keyserling, 1861); *C. heratensis* (Keyserling, 1861); *C. mandica* Bianco & Bănărescu, 1982; *C. saadii* (Heckel, 1847), *C. trutta* (Heckel, 1843), and *C. umbla* (Heckel, 1843) (Jouladeh-Roudbar et al. 2015a,b; Alwan et al. 2016; Zareian et al. 2016; Jouladeh-Roudbar et al. 2016). Of these species, eight are endemic to Iran and three have been described recently based on the results of molecular studies (Alwan et al. 2016; Jouladeh-Roudbar et al. 2016; Zareian et al. 2016).

Capoeta species mainly inhabit fast flowing streams and rivers, but some species may also be found in lakes and springs (Turan et al. 2006). The members of this genus possess a fusiform body with small to moderately large scales and an inferior mouth (Coad 2017). Their lower lip bears a keratinized edge and lower lip is restricted to the corner of mouth (Howes 1982; Turan et al. 2006; Coad 2017). The dorsal fin is short with the last unbranched ray thickened, and has serrations posteriorly (serrations sometimes reduced to absent).

The populations of the genus *Capoeta* from the southern Caspian Sea basin are considered as belonging to two different species: *C. gracilis* and *C. capoeta* (Esmaeili et al. 2010; Jouladeh-Roudbar et al. 2015b). *Capoeta gracilis* was originally described from rivers near Esfahan, central Iran (Esfahan basin) and *C. capoeta* from Tiflis (Caspian Sea basin), Georgia (the Caspian Sea basin) (Güldenstädt 1773; Temminck and Schlegel 1843; Coad 2017). Several authors have considered *C. gracilis* as subspecies of *C. capoeta*, both with allopatric distribution. *Capoeta c. gracilis* was restricted to rivers between the Sefid and Atrak rivers in the southern part of the Caspian basin in Iran and *C. c. capoeta* to the Kura-Aras basin in western part of the Caspian basin (Bianco and Banarescu 1982). Furthermore, Bănărescu (1999) restricted the distribution of *C. c. gracilis* to the Urmia Lake basin and the Sefid River in southern part of the Caspian basin (and also to the lower Kura River in Azerbaijan) while *C. capoeta* aff. *gracilis* (an unnamed subspecies related to *C. c. gracilis*) was considered to inhabit the rest of the Iranian Caspian shore (Jouladeh-Roudbar et al. 2015). Posterior works have considered *C. gracilis* as a valid species but its distribution has been controversial (Esmaeili et al. 2014).

Currently, molecular studies have shown a high genetic differentiation in the populations of southern Caspian basins considered previously as *C. gracilis* or *C. c.* aff. *gracilis* and this led to the consideration of these populations as an undescribed species (Levin et al. 2012; Ghanavi et al. 2016). The presence of *C. capoeta* in both the Caspian Sea and Urmia Lake basins was also confirmed based on molecular and morphological data (Ghasemi et al. 2015; Ghanavi et al. 2016).

Previous phylogenetic and phylogeographic studies based on molecular mitochondrial data recognized three main clades within the genus *Capoeta*, Mesopotamian clade, Aralo-Caspian clade, and Anatolian-Iranian clade (Levin et al. 2012; Ghanavi et al. 2016). The Aralo-Caspian clade is composed by four valid species i.e. *C. capoeta*, *C. heratensis*, *C. fusca* and *C. alborzensis* in the Iranian freshwater basins (Ghanavi et al. 2016; Jouladeh-Roudbar et al. 2016). A detailed study of the populations of Aralo-Caspian clade in Iran, found some populations of the genus *Capoeta*, which were not identified as any described species (Ghanavi et al. 2016). Among them were populations distributed in the southern Caspian Sea basin, traditionally identified as *C. gracilis* (Jouladeh-Roudbar et al. 2015b). Our collection of the genus *Capoeta* from the southern Caspian Sea basin revealed the presence of two species, i.e. *C. capoeta* and an undescribed species (considered as *Capoeta* sp.1 in Ghanavi et al. 2016) that differ molecularly and morphologically from other described *Capoeta* species including species from the Esfahan basin (Alwan et al. 2016; Ghanavi et al. 2016). According to our intensive samplings from the Esfahan basin, only two species i.e. *C. aculeata* and *C. coadi* were found. Therefore, the main goal of this work is to study morphologically the populations of the collected *Capoeta* specimens from the southern Caspian Sea basin, north of Iran, previously assigned to *C. gracilis*, and to compare them with the remaining species of this genus from Iran, and based on differences found, they are described as a new species herein.

Materials and methods

Approximately 150 specimens of the genus *Capoeta* were collected by electrofishing at 14 sites covering most of its distribution area in southern Caspian Basin (Figure 1, Table 1). Fin clips stored in 96% ethanol and deposited in the Tissue and DNA Collection of the Ichtyological Museum of Natural Resources Faculty – University of Tehran (IMNRF-UT). The fish were killed with overdoses of MS222, were fixed in 10% formalin, and were later preserved in the Ichthyology collection of IMNRF-UT, Iran. For morphometric purposes and to have a base for molecular studies 23 individuals of *C. capoeta* and *C. fusca* from the Urmia Lake and Hari River basins, respectively, were also analysed.

Morphological examinations. Thirty morphometric measurements and thirteen meristic character countings were performed using a digital caliper to the nearest 0.1 mm and stereomicroscope, respectively (Tables 4–8). Measurements follow Kottelat and Freyhof (2007). Fin ray counts separate unbranched and branched rays. The last two branched rays articulated on a single pterygiophore in dorsal and anal-fins are noted as “1”.

An allometric method was used to remove size-dependent variation in morphometric characters using following formula (Elliott et al. 1995): $M_{adj} = M(L_s/L_0)^b$, where

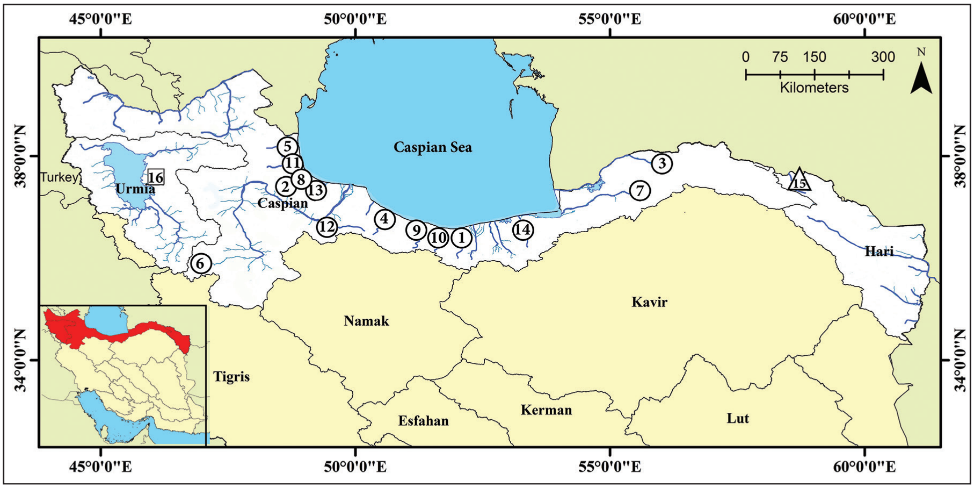

Figure 1. Map of the southern Caspian Sea basin and sampling points. Numbers of the sampling sites correspond to the numbers of sampling sites in Table 1, circle: *Capoeta razii* sp. n., triangle: *C. fusca*, square: *C. capoeta.*

Table 1. Sampling sites and coordinates. Numbers in the first column (Loc) correspond to numbers on the sampling map in Figure 1.

Loc.	River	Locality	Species	GPS Coordinates	Alt. (m)
1	Angueta Rud	Sangetab	*Capoeta razii* sp. n.	36°28'37"N, 42°13'31"E	44
2	Asalem	Asalem		37°42'53"N, 48°55'44"E	104
3	Atrak	Maraveh Tappeh		37°54'30"N, 55°57'10"E	198
4	Chalk Rud	Katalom		36°52'19"N, 50°46'17"E	-20
5	Choobar Rud	Choobar		38°10'36"N, 48°52'54"E	-7
6	Ghezel Ozan	Nesareh		35°52'12"N, 47°04'54"E	1732
7	Golestan	Tangrah		37°22'55"N, 55°51'12"E	564
8	Karrgan Rud	Talesh		37°48'02"N, 48°53'04"E	71
9	Kelar Abad Rud	Kelar Abad		36°42'05"N, 51°13'10"E	-15
10	Kheyr Rud	Chalos		36°36'35"N, 51°33'45"E	34
11	Khushavar Rud	Khushavar		38°01'51"N, 48°53'31"E	17
12	Sefid Rud	Lowshan		36°38'13."N, 49°29'17"E	307
13	Shafa Rud	Punel		37°31'52"N, 49°06'36"E	246
14	Tajan	Payin Hular (Sari)		36°29'12"N, 53°05'10"E	90
15	Ghale Chay	Ajab Shir	*C. capoeta*	37°29'25"N, 45°59'57"E	
16	Segonbadan	Farooj	*C. fusca*	37°14'46"N, 58°08'01"E	

M is the original measurement, M_{adj} the size adjusted measurement, L_0 the standard length of the fish, L_s the overall mean of the standard length for all fish from all samples in each analysis, and *b* was estimated for each character from the observed data as the slope of the regression of log M on log L_0 using all fish in any group. The adjusted morphometric characters of the studied populations were analysed using Principal

Table 2. List of species used for molecular analysis for *Cyt b* and GenBank accession number.

KU312380	*Capoeta anamisensis*	KU167903	*Capoeta razii* sp. n.	JF798266	*Capoeta aculeata*
KU312381		KU167905		KM459640	
JF798279	*Capoeta barroisi*	KM459627		KM459638	
KM459651	*Capoeta mandica*	KM459628		KM459637	
KM459649		KU167933		JF798267	
KM459650		KM459630		KM459631	*Capoeta saadii*
AF145949	*Capoeta trutta*	KU167922		KM459639	
KM459673		KU167934		KM459641	
JF798332		KU167932		KU167952	*Capoeta damascina*
KU167893	*Capoeta heratensis*	KU167913		KU167953	
JF798317		KU167911		KU167954	
JF798318		KU167912		KM459624	*Capoeta buhsei*
JF798319		KU167918		KM459623	
JF798316		KM459696	*Capoeta alborzensis*	JF798283	
KU167894		KY365754		KM459634	*Capoeta coadi*
KU167936	*Capoeta capoeta*	KY365752		JF798285	
KU167937		KY365753		KM459633	
KU167938		KM459695		AF145937	*Luciobarbus subquincunciatus*
KU312371	*Capoeta fusca*	KM459688		KP712171	*Luciobarbus capito*
KU312372		KM459687		AY004729	*Luciobarbus brachycephalus*

Component Analysis (PCA) and compared by Non-Parametric Multivariate Analysis of Variance (NPMANOVA) based on the *P*-values obtained from permutation test with 1000 replicates in PAST software (version 2.14). The meristic characters of the studied populations were analysed using Correspondence Analysis (CA), and compared by Non-Parametric Multivariate Analysis Of Variance (NPMANOVA) based on the Bonferoni-corrected *P*-values obtained from permutation test with 1000 replicates in PAST software (version 2.14).

Molecular data analysis. To analyse the molecular composition we studied the complete mitochondrial cytochrome *b* gene of all species of Aralo-Caspian group which include an unnamed population from Caspian Sea basin (Levin et al. 2012; Ghanavi et al. 2016). In this study, we considered sequences obtained from previous studies and deposited in GenBank (Table 2) (Levin et al. 2012; Ghanavi et al. 2016; Zareian et al. 2016; Jouladeh-Roudbar et al. 2016). Sequences were aligned using Geneious software (Geneious v. 10.0.2, Biomatters, http://www.geneious.com/), and visually verified to maximize positional homology. Sequences of *Luciobarbus capito* (Güldenstädt, 1773), *L. brachycephalus* (Kessler, 1872) and *L. subquincunciatus* (Günther, 1868) species were chosen as outgroup based on their phylogenetic relationship to genus *Capoeta* (Levin et al. 2012; Yang et al. 2015; Ghanavi et al. 2016). Uncorrected pairwise genetic distances (p-distances) between species (Table 3) were calculated with Mega 6 (Tamura et al. 2013). A bootstrapping process was implemented with 1000 repetitions. Jmodeltest 2.1.4 (Darriba et al. 2012) selected TrN+I as the best evolutionary model. RAxML (Stamatakis 2006) implemented in GENEIOUS software was used to estimate the

Table 3. Estimates of evolutionary divergence over sequence pairs between *Capoeta razii* sp. n. and other Iranian *Capoeta* species.

	species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	*L. subquincunciatus*	–															
2	*L. capito*	9.5	–														
3	*L. brachycephalus*	8.6	3.3	–													
4	*C. barroisi*	8.6	9.0	8.6	–												
5	*C. trutta*	9.7	9.3	9.2	1.2	–											
6	*C. mandica*	9.6	9.0	8.7	1.3	1.1	–										
7	*C. anamisensis*	9.2	8.4	8.6	1.6	1.4	1.5	–									
8	*C. saadii*	9.8	8.7	9.0	7.6	7.9	8.0	8.2	–								
9	*C. damascina*	9.2	8.3	8.8	7.5	7.9	7.9	8.3	2.8	–							
10	*C. buhsei*	9.6	8.6	9.3	8.1	8.4	8.4	8.7	2.6	2.2	–						
11	*C. coadi*	9.6	8.6	9.4	7.8	8.1	8.0	8.7	2.7	2.1	1.4	–					
12	*C. fusca*	8.8	8.9	8.5	8.5	8.9	9.1	8.9	6.5	6.4	5.7	6.3	–				
13	*C. alborzensis*	8.7	8.2	8.6	7.9	8.3	8.5	8.3	5.6	5.4	5.3	5.5	1.6	–			
14	*C. aculeata*	9.3	8.8	8.8	8.2	8.6	8.8	8.7	6.1	5.9	5.9	6.0	2.2	1.3	–		
15	*C. heratensis*	10.1	9.1	9.7	9.1	9.3	9.5	9.0	6.2	5.9	5.8	6.5	2.5	2.2	2.6	–	
16	*C. capoeta*	9.0	8.5	8.6	7.9	8.4	8.6	7.9	5.9	5.6	5.8	5.9	2.3	1.8	2.0	2.6	–
17	*C. razii* sp. n.	9.5	9.1	9.3	8.4	8.8	9.1	8.8	6.0	5.8	5.8	5.9	2.2	1.4	1.8	2.5	2.1

maximum-likelihood (ML) tree. Bayesian inference was conducted with MrBAYES v. 3.2.2 (Ronquist et al. 2012). Two simultaneous analyses were run on $2*10^7$ generations, each with four MCMC chains sampling tree every 2000 generations. Convergence was checked on Tracer 1.6 (Rambaut and Drummond 2013). After discarding the first 10% of generations as burn-in, we obtained the 50% majority rule consensus tree and the posterior probabilities. The species delimitation methodology used was Bayesian Poisson tree process (bPTP) model which is based on a distance-based tree (Zhang et al. 2013). bPTP were accessed at Exelixis Labs (http://sco.h-its.org/exelixis/web/software/PTP/index.html). Haplotype genealogies were visualized by HaploView v. 4.2 (Barrett et al. 2005).

Abbreviations

SL	standard length;
HL	lateral head length;
IMNRFI-UT	Ichtyological Museum of Natural Resources Faculty.

Results

Based on the results, from the 1040 bp of complete mitochondrial cytochrome *b* genes, 793 positions were conserved and 195 were parsimony informative. Genetic distances

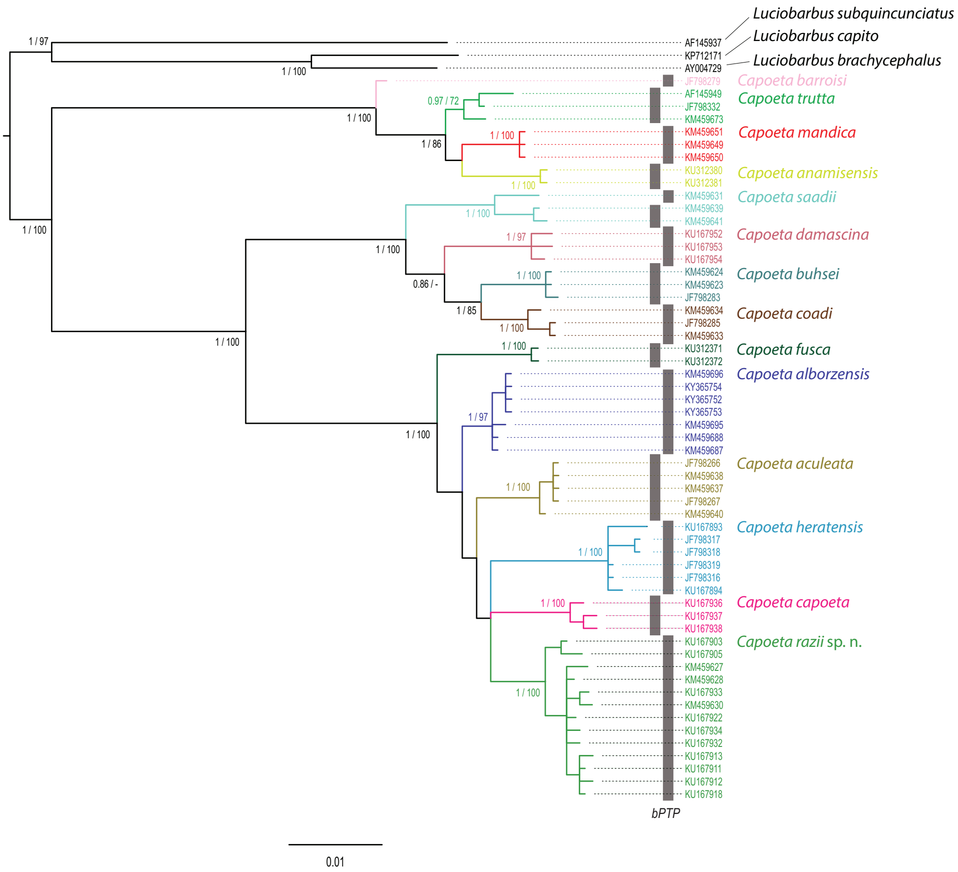

Figure 2. *Capoeta* genus; Values at nodes correspond to BI posterior probability/ML bootstrap. Grey bars represent the species delimitations performed with bPTP software.

between species are listed in Table 3. The Bayesian and ML analyses yielded similar topologies with well-supported nodes (Figure 2). The reconstructed topology was also in agreement with previously published higher-level phylogenies that included *Capoeta* and the three main clades, Aralo-Caspian, Anatolian-Iranian, and Mesopotamian were recovered (Levin et al. 2012; Ghanavi et al. 2016; Jouladeh-Roudbar et al. 2016). Based on molecular phylogeny, the differentiation of populations from Caspian Sea basin from the other described species is shown. The species delimitation methodology also supports these populations to be considered as a different species from the other populations included in the study (Figure 2). The haplotype network does not show any geographical patterns between the different populations of the suggested species in the closely located but independent rivers of the Caspian Sea basin (Figure 3).

The result of PCA analysis showed that all specimens explained 45.79% of morphometric variations by the first two PC axes extracted from the variance-covariance matrix (PC1=27.60% and PC2=18.19%). Plotting of first and second PCs displayed

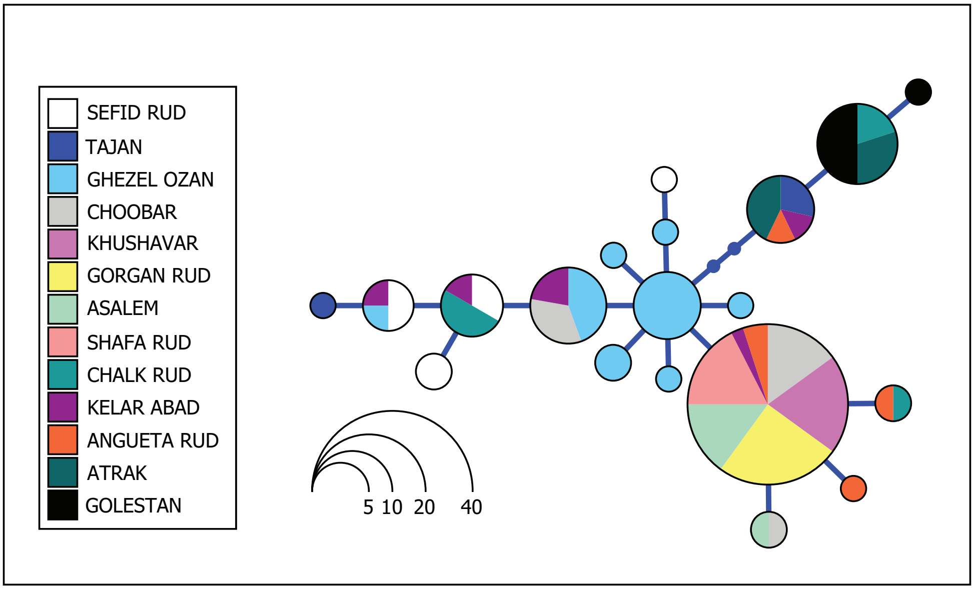

Figure 3. Haplotype networks of available specimens of Caspian Sea basin. Each independent river system is represented by a different colour. Data from Ghanavi et al. 2016.

a complete segregation of the three populations. In addition, NPMANOVA showed significant differences between all studied populations in terms of the morphometric characters (P<0.001) (Figure 11). The result of CA showed that all specimens explained 63.1% of morphometric variations by the first two CA (PCA1=35.82% and CA2=27.28%). Plotting of first and second CAs displayed a complete segregation of the three populations. In addition, NPMANOVA showed significant differences between all studied populations in terms of the morphometric characters (P<0.0001) (Figure 12).

Capoeta razii, sp. n.

http://zoobank.org/948BD913-A0DF-4371-97F6-B707CE56CFD6
Figures 4–7

Holotype. IMNRF-UT-1072-9, holotype, 142.6 mm SL. Iran: Mazandaran Prov., Chalus city, Kheyroud River (Figure 8), Caspian Sea basin, 36°36'35"N, 51°33'45"E, S. Eagderi & A. Jouladeh-Roudbar, November 2016.

Paratypes. IMNRF-UT-1072, 14 specimens, 90.7–184.2 mm SL; data same as holotype.

Diagnosis. *Capoeta razii* sp. n. is distinguished from the other species of *Capoeta* in Iran by a following combination of characters, none of them unique. One pair of barbels; pre-dorsal length equal to postdorsal length; maxillary barbel slightly smaller than eye's horizontal diameter and reach to posterior margin of orbit; intranasal length

Figure 4. *Capoeta razii* sp. n., IMNRF-UT-1072-9, holotype, SL: 142.6 mm, Iran: Mazandaran Prov., Chalos city, Kheyroud River, Caspian Sea basin.

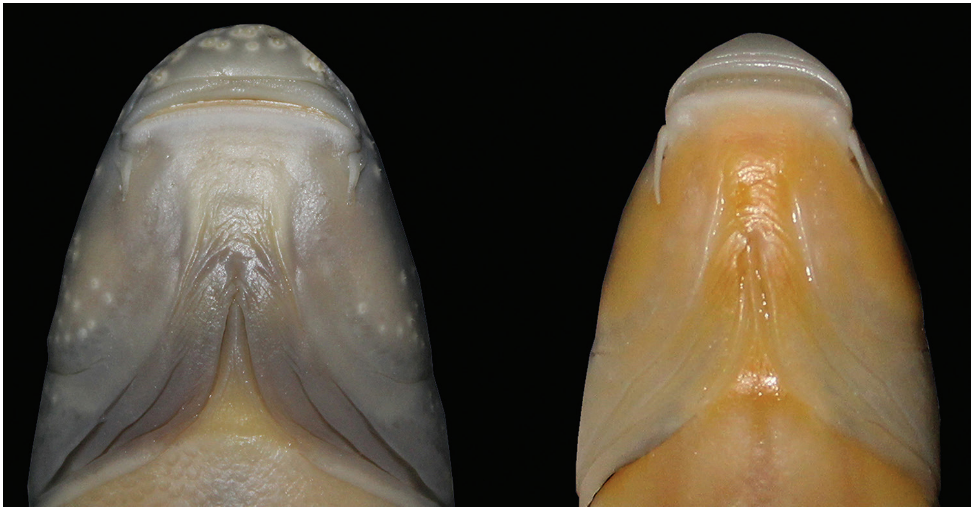

Figure 5. Ventral view of Head. *Capoeta razii* sp. n. (right, IMNRF-UT-1072-11, SL: 109 mm) and *C. capoeta* (left, IMNRF-UT-1067-6, SL: 110 mm).

slightly shorter than snout length; lateral line with 46–54 scales, 7–9 scales between dorsal-fin origin and lateral line and 6–7 scales between anal-fin origin and lateral line.

Description. See Figure 4 for general appearance and Tables 4–7 for morphometric and meristic data. Body is moderately deepened and compressed laterally. Greatest body depth occurs at the level of dorsal-fin origin. Dorsal profile of the head is convex. Predorsal length is equal to post-dorsal length. Dorsal profile of the body is convex without any keel in the front of dorsal-fin origin. Snout is rounded with a triangular view in ventral. Mouth is almost straight. Upper and lower lips are adnate to jaws. Lower jaw has a strong keratinized edge. Rostral cap is well developed and usually overlaps with upper lip. One set of maxillary barbels that are short, slightly smaller than eye's horizontal diameter, reaching to posterior margin of orbit. Intranasal length is slightly shorter than snout length. Pelvic axillary scales are triangular, well developed, and pointed. Dorsal

Table 4. Morphometric data of *Capoeta razii* sp. n. (holotype, IMNRF-UT-1072-9; paratypes, IMNRF-1072, 14 specimens) *C. capoeta* (IMNRF-UT-1067, 15 specimens) and *C. fusca* (IMNRF-UT-1065, 8 specimens).

Characters	Holotype	*C. razii* sp. n.			*C. capoeta*			*C. fusca*		
		Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
Standard length (mm)	142.6	90.7–184.2			66.5–157.3			47.2–124.2		
In percent of standard length (SL)										
Body depth maximal	23.7	23.1–25.5	23.9	0.7	23.4–26.9	25.2	1.0	24.4–27.1	26.0	0.9
Caudal peduncle depth	12.1	11.1–12.9	11.9	0.5	10.1–12.6	11.7	0.7	11.1–13.5	12.5	0.8
Predorsal length	52.3	50.2–53.1	51.8	0.9	50.8–55.5	52.9	1.2	52.6–55.0	53.8	0.9
Postdorsal length	51.8	49.9–54.2	51.7	1.2	47.6–55.1	51.9	2.1	48.9–52.3	50.6	1.2
Prepelvic length	55.1	55–58.7	56.1	1.1	54.3–61.3	57.1	1.9	55.2–58.6	57.3	1.2
Preanal length	75.9	76.4–79.6	77.6	1.0	74.9–79.7	77.5	1.4	76.7–79.9	78.4	1.3
Caudal peduncle length	18.9	16.1–19.4	17.4	1.1	14.7–20.0	17.2	1.4	14.2–17.9	16.1	1.3
Dorsal fin base length	11.3	12.1–15.4	13.6	0.9	12.7–16.7	14.5	1.4	14.9–18.0	16.5	0.9
Dorsal fin depth	17.7	16.2–21	18.9	1.2	18.5–22.2	20.5	0.9	18.7–26.1	22.3	2.2
Anal fin base length	7.3	6.8–8.3	7.5	0.4	6.0–9.1	7.7	0.8	8.1–10.1	9.1	0.7
Anal fin depth	16.8	15–20.4	17.7	1.4	14.4–18	16.2	1.0	17.1–19.9	18.7	0.8
Pectoral fin length	20.5	17.8–21.3	19.5	1.1	15.4–20.6	18.7	1.9	18.3–24.2	21.2	2.1
Pelvic fin length	16.7	14.1–17.5	16.0	1.0	14.2–17.3	16.0	0.9	15.9–19.9	18.1	1.2
Pectoral – pelvic-fin origin distance	32.3	30.6–36.1	32.8	1.4	31.4–37.0	34.2	1.7	29.5–34.5	32.3	1.8
Pelvic – anal-fin origin distance	20.6	21–24.2	22.2	1.0	18.7–23.0	21.5	1.2	20.1–23.9	22.1	1.4
Body width	16.3	15.1–17	16.0	0.6	16.3–18.4	17.2	0.6	16.6–18.7	17.6	0.7
Caudal peduncle width	3.6	2.8–4.1	3.4	0.5	3.1–4.2	3.7	0.3	5.5–7.0	6.3	0.5
Head length (HL)	22.5	20.5–24	23.0	1.0	19.8–25.9	22.6	1.8	25.0–28.6	26.2	1.7
As percentage of head length (HL)										
Snout length	26.2	26.2–31.6	28.7	1.4	24.7–29.8	27.1	1.6	28.2–33.1	30.6	1.9
Eye horizontal diameter	20.1	17.1–26.7	23.3	2.7	17.4–22.7	19.4	1.7	15.4–23.7	19.3	2.9
Postorbital distance	53.5	46.4–54.4	50.7	2.2	47.9–60.8	56.2	3.4	48.1–54.2	52.2	2.0
Head depth at nape	78.3	70.1–82.9	76.4	3.5	67.5–87.5	79.4	5.2	70.3–76.1	72.6	2.0
Head depth at eye	50.2	45.7–53	51.1	2.0	44.8–56.8	52.7	3.2	47.0–53.4	51.2	1.9
Head length at nape	90.1	88.9–97	92.2	2.4	83.8–98.6	92.9	3.9	87.9–96.3	91.5	3.1
Head width	67.6	61.6–73.1	65.9	3.1	62.3–77.3	70.0	5.4	54.9–69.7	60.7	4.7
Inter orbital	42.5	34.3–46	42.8	2.9	41.4–52.2	46.2	3.4	35.7–40.1	37.0	1.4
Inter nasal	26.1	20.2–26	24.7	1.8	24.0–31.3	28.0	2.2	17.1–23.6	20.7	1.8
Mouth width	35.6	28.7–37.9	34.2	2.9	31.4–41.3	36.0	2.9	26.6–38.9	31.3	4.7
Barbel length	13.0	14–21.6	17.2	2.4	9.3–16.2	13.2	1.8	9.9–17.3	13.6	2.9

Table 5. Number of scales above lateral line (ALL), below lateral line (BLL), Number Dorsal Soft Rays (DSR)/Hard (DHR), Anal Soft Rays (ASR)/Anal Hard Rays (AHR), pelvic (PLR) fin rays and Number Gill rakers on the lower limb (LOL) in *Capoeta razii* sp. n. and *C. capoeta*.

Species	3	4	5	6	7	8	9	10	Mod	Mean	SD
ALL											
Capoeta razii sp. n.					3	10	2		8	7.9	0.6
Capoeta capoeta						3	10	2	9	8.9	0.6
BLL											
Capoeta razii sp. n.				10	5				6	6.3	0.5
Capoeta capoeta					12	3			7	7.2	0.4
DHR											
Capoeta razii sp. n.	1	14							4	3.9	0.3
Capoeta capoeta	7	8							4	3.6	0.5
DSR											
Capoeta razii sp. n.					2	13			8	7.9	0.4
Capoeta capoeta					3	12			8	7.8	0.4
AHR											
Capoeta razii sp. n.	15								3	3.0	0.0
Capoeta capoeta	15								3	3.0	0.0
ASR											
Capoeta razii sp. n.				15					6	6.0	0.0
Capoeta capoeta				15					6	6.0	0.0
PLR											
Capoeta razii sp. n.						1	10	4	9	9.2	0.6
C. capoeta							9	6	9	9.3	0.6
LOL											
Capoeta razii sp. n.		4	12	1					5	4.9	0.5
Capoeta capoeta		2	11	2					5	5.0	0.5

Table 6. Number of pectoral (PFR), caudal fin rays (DFR), total gill rakers (TGR) and circum-pendicular scales (CPS) in *Capoeta razii* sp. n. and *C. capoeta*.

Species	15	16	17	18	19	20	21	Mod	Mean	SD
PFR										
Capoeta razii sp. n.		2	7	2	1			17	17.4	1.1
Capoeta capoeta				6	5	2	2	18	18.9	1.3
CFR										
Capoeta razii sp. n.				1	14			19	18.9	0.3
Capoeta capoeta					10	5		19	19.3	0.5
CPS										
Capoeta razii sp. n.			6	9				18	17.6	0.5
Capoeta capoeta				10	3	2		18	18.5	0.7
TGR										
Capoeta razii sp. n.	1		2	8	2	1	1	18	18.1	1.4
Capoeta capoeta					2	6	7	21	20.3	0.7

Figure 6. *Capoeta razii* sp. n., paratypes; **A** IMNRF-UT-4, SL: 130 mm **B** IMNRF-UT-12, SL: 115 mm **C** IMNRF-UT-3, SL: 99 mm.

fin has 3–4 unbranched and 7–8 branched rays, its outer margin is straight or slightly concave. Last unbranched dorsal-fin ray is thickened and serrated, distally flexible, and with 15–25 serrae on its posterior margin, with serrations along 50–70% of its posterior margin, denticles are long and narrowly spaced but not strongly developed. Last unbranched dorsal-fin ray slightly shorter than first branched ray, and the tip is soft. Pelvic fins are inserted under posterior of the first branched dorsal-fin base. Caudal fin is deeply forked with pointed and equal size of lobes. Pectoral fin has 16–19 branched rays. Pelvic fin has 1 unbranched and 9–10 branched rays. Anal fin has 2–3 unbranched rays, 6 branched rays and its outer margin is usually convex or straight. There are 15–21 gill rakers on the outer side of the first arch. There are 17–18 circum-peduncular scales. Lateral line is complete, with 46–54 scales. There are 7–9 scales between the dorsal-fin origin and lateral line and 6–7 are located between the anal-fin origin and lateral line.

Figure 7. Last simple dorsal-fin rays, *Capoeta razii* sp. n. (Below, IMNRF-UT-1066-9, SL: 116) and *C. capoeta* (Above, IMNRF-UT-1067-13, SL: 121 mm).

Table 7. Number of total lateral-line scales in *Capoeta razii* sp. n. and *C. capoeta*.

Species			Total lateral line Scales											Mod	Mean	SD
	46	47	48	49	50	51	52	53	54	55	56	57	58			
Capoeta razii sp. n.	2	1	4	2	2	-	2	-	2					48	49.1	2.3
Capoeta capoeta										4	5	4	2	56	56.3	1.0

Figure 8. Kheyroud River, near Chalos city, Caspian Sea basin, type locality of *Capoeta razii* sp. n.

Colouration. In life, the upper part of the body is golden brown, olive-green, or silver, and the belly is whitish up to the lateral line. The head is dark-brown or olive-green on top and the cheeks are pale brown to white (Figure 4). Anal, pelvic, and pectoral fins are hyaline or light brown, and dorsal and caudal fins have a narrow black line on rays. In specimen smaller than 50 mm SL, minute black spots are present on flanks.

Table 8. Range of meristic features of Iranian *Capoeta* species.

No.	Species	LL	ALL	BLL	CPS	TGR	Reference
1	*Capoeta alborzensis*	39–44	6–8	5–8	16–17	19–22	This study
2	*Capoeta aculeata*	39–43	7–8	5–7	16–20	19–23	This study
3	*Capoeta razii* sp. n.	46–54	7–9	6–7	17–18	15–21	This study
4	*Capoeta anamisensis*	56–67	11–12	6–8	–	21–25	Zareian et al. 2016
5	*Capoeta barroisi*	76–84	14–16	10–13	–	26–29	Turan et al. 2006
6	*Capoeta buhsei*	80–89	13–15	11–13	29–31	11–13	This study
7	*Capoeta capoeta*	51–58	9–11	7–8	19–23	17–29	This study
8	*Capoeta coadi*	68–75	12–15	9–10	25–29	15–18	This study
9	*Capoeta damascina*	64–82	12–17	8–12	23–30	17–25	Alwan, 2011
10	*Capoeta fusca*	46–54	8–10	8–9	19–26	16–18	This study
11	*Capoeta heratensis*	55–61	9–12	7–9	22–25	21–24	This study
12	*Capoeta mandica*	58–68	12–13	8–10	27–33	23–27	Alwan et al. 2016
13	*Capoeta saadi*	61–78	9–14	6–10	–	12–17	Alwan, 2011
14	*Capoeta trutta*	65–82	9–14	9–12	27–31	20–30	This study
15	*Capoeta umbla*	90–102	18–23	12–14	33–36	18–20	This study

Figure 9. Uncatalogued live specimen of *Capoeta capoeta*. Iran: Ajab Shir town, Ghale Chay River, Urmia basin.

When preserved, the dorsum is dark brown on back and flanks, and yellowish white on belly (Figure 6). Dorsum of the head is dark brown, and the cheeks beige. Fins are often light brown and pelvic and anal fins may be yellowish to hyaline. Dorsal and caudal fins are darker than lower fins. Peritoneum is black.

Distribution and habitat. *Capoeta razii* is found in many rivers and streams of the southern Caspian Sea basin. It is one of the most abundant species in the Caspian Sea basin along with the members of the genus *Alburnoides* Jeitteles, 1861. At the Kheyroud River (type locality), the current was medium to fast, river width was between 3–14 m and the maximum depth was around one meter, the stream bed was composed of cobbles and gravel, and the riparian vegetation type was deciduous forests. Following fish

Figure 10. Live specimen of *Capoeta fusca*, IMNRF-UT-1065-1, SL: 124 mm, Iran: North Khorasan prov.: Near Farooj town, at segonbadan village, Qanat-e Segonbadan, Hari basin.

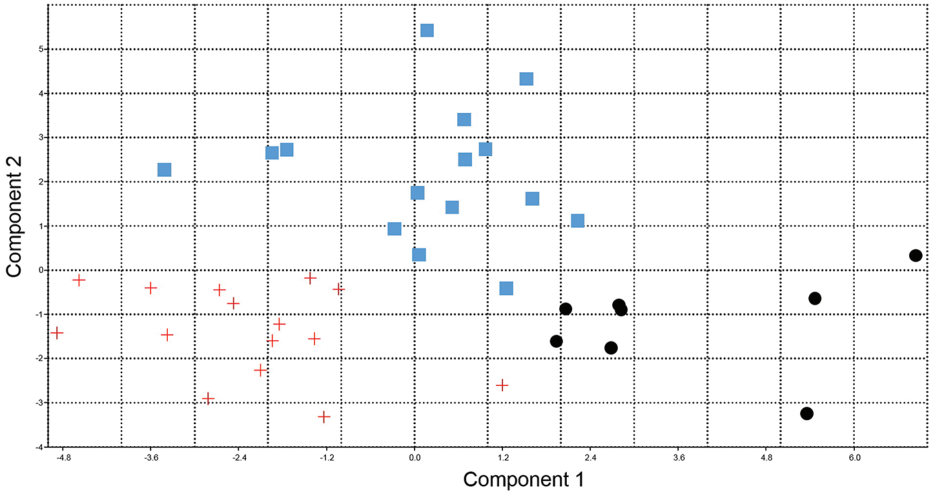

Figure 11. Principal component analysis of relative morphometric characters of the *Capoeta razii* sp. n. (+) *C. fusca* (•) and *C. capoeta* (■) populations.

species: *Poticola iranicus* Vasil'eva, Mousavi-Sabet & Vasil'ev 2015, *Alburnoides taberstanensis* Mousavi-Sabet, Anvarifar & Azizi, 2015, *Alburnus chalcoides* (Güldenstädt 1772), *Barbus cyri* De Filippi 1865, *Squalius turcicus* De Filippi 1865, *Luciobarbus capito* Güldenstädt 1773, *L. mursa* Güldenstädt 1773, *Cobitis faridpaki* Mousavi-Sabet, Vasil'eva, Vatandoust & Vasil'ev 2011, co-exist with *C. razii* in type locality. *Capoeta razii* is known from most of rivers and streams between Atrak and Kote komeh (Near Astara city) rivers in southern Caspian Sea basin.

Etymology. The new species is named in honour of Abū Bakr Muhammad ibn Zakariyyā al-Rāzī, a Persian polymath, physician, alchemist, and philosopher, for his

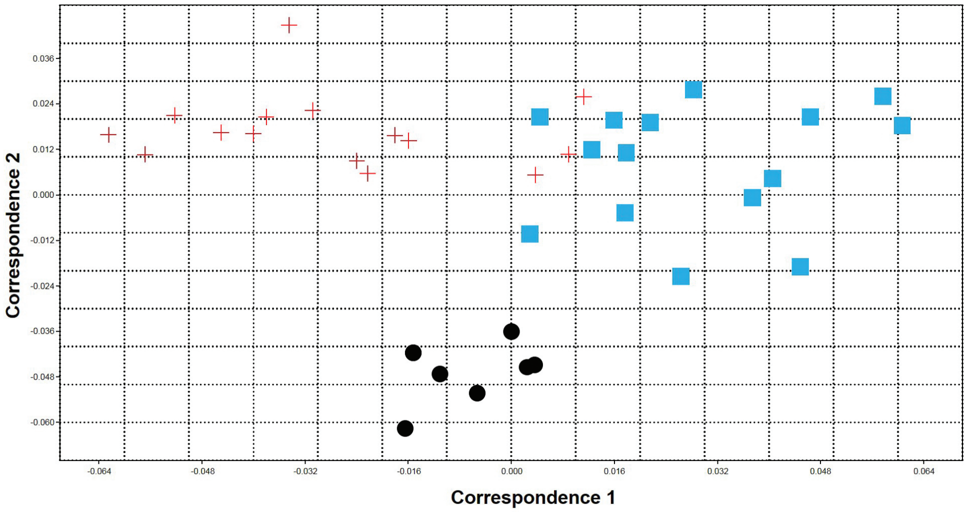

Figure 12. Correspondence analysis of meristic characters of the *Capoeta razii* sp. n. (+) *C. fusca* (•) and *C. capoeta* (■) populations.

important contributions in the history of medicine. He also discovered numerous compounds including Ethanol.

Remarks. *Capoeta razii* sp. n. is distinguished from *C. aculeata* and *C. alborzensis* by a smaller scale size and a higher number of total lateral line scales (46–54 vs. 39–44).

Capoeta razii sp. n. is distinguished from *C. fusca*, by a smaller caudal peduncle width (2.8–4.1 vs. 5.5–7.0 %SL), a smaller head length (20.5–24.0 vs. 25.0–28.6 %SL), and the presence of numerous minute scales on the caudal fin base extending distally onto the fin membranes for more than half the fin ray length (vs. absence of minute scales on the caudal fin base) (Figure 10).

Capoeta razii sp. n. is distinguished from *C. anamisensis*, *C. barroisi*, *C. buhsei*, *C. Capoeta*, *C. coadi*, *C. damascina*, *C. heratensis*, *C. mandica*, *C. saadi* and *C. umbla* by a larger scale size, a fewer number of total lateral line scales (46–54 vs. 55–102).

Comparative material. – *Capoeta aculeata*: IMNRF-UT-1058, 9. 53–116 mm SL, Iran: Fars prov.: Tange Boragh village, Kor River, Kor basin, 37°14'46"N, 58°08'01"E, Aug 2014, S. Eagderi & H. Mossavi-Sabet. – *Capoeta alborzensis.*: IMNRF-1063, 7. 50–153mm SL, Iran: Tehran prov.: Nam River, tributary of Hableh River, near Arjomand village, 35°48'00"N, 52°30'57"E; IMNRF-UT-2063, 23, 46–163mm SL, Iran: Tehran prov.: Nam River, tributary of Hableh River, Kavir basin, near Harandeh village, 35°42'41"N, 52°40'19"E, S. Eagderi & A. Jouladeh-Roudbar, September 2014. – *Capoeta buhsei*: IMNRF-UT-1075, 12. 103.9–211.8 mm SL, Iran: Markazi prov.: Tafresh town, at Khalife kandy village, Mazlaghan Chay River, Namak basin, 34°45'34"N, 49°56'50"E, Nov 2016, A. Rahmani, M. A. Jahazi, R. Rahbar-zare, A. Jouladeh-Roudbar. – *Capoeta capoeta*: IMNRF-UT-1067, 15. 66–157 mm SL, Iran: Tabriz prov.: Near Ajab shir city, Ghale Chay River, Urmia Lake basin, 37°29'25"N, 45°59'57"E, Nov 2016, T. Hosseinpour, M. Ahmadian & A. Jouladeh-Roudbar. – *Capoeta coadi*: IMNRF-UT- 1074, 15. 125.7–194.7 mm SL, Iran: Chaharmahal and Bakhtiari prov.: Near Joneghan town, at Darkesh varkesh village, Behesht Abad River, Tigris basin, 32°05'22"N, 50°39'54"E, Aug 2016, T. Hosseinpour, A. Soleymani & A. Jouladeh-Roudbar. – *Capoeta fusca*: IMNRF-UT-1065, 8. 46–121 mm SL, Iran: North Khorasan prov.: Near Farooj town, at segonbadan village, Qanat-e Segonbadan, Hari basin, 37°14'46"N, 58°08'01"E, Jun 2016, S. Eagderi & A. Jouladeh-Roudbar. – *Capoeta heratensis*: IMNRF-UT-1064, 15. 116–161 mm SL, Iran: Khorasan-e Razavi prov.: Near Sarakhs, at Pole-e Khaton, Hari River, Hari basin, 35°56'51"N, 61°08'51"E, Jun 2016, S. Eagderi & A. Jouladeh-Roudbar. – *Capoeta trutta*: IMNRF-UT- 1073, 15. 54.1–165.2 mm SL, Iran: Kermanshah prov.: Songhor to Satar road, Tape Esmail village, Gavehroud River, Tigris basin, 34°56'01"N, 47°12'49"E, Aug 2016, T. Hosseinpour, A. Soleymani & A. Jouladeh-Roudbar. – *Capoeta umbla*: IMNRF-UT-1077, 15. 107.3–175.9 mm SL, Iran: Kurdistan prov.: Near Sardasht town, Barisu village, Little Zab River, Tigris, 36°08'48"N, 45°32'17"E, May 2016, S. Eagderi, H. Porbagher, P. Jalili & A. Jouladeh-Roudbar.

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