A REVIEW OF THE LAND-SNAIL FAUNA OF SINGAPORE

Ho Wai Hoong

ABSTRACT. - À survey was conducted to determine the variety and distribution of land snails in Singapore. A total of 32 land-snail species, representing 26 genera and 12 families, were found during the present study. The largest family of land snails found in Singapore was the Ariophantidae, which comprised eight species. Twelve species of land snails were recorded for the first time in Singapore, bringing the total number of land snails recorded in Singapore to 39 species.

INTRODUCTION

Singapore land snails were recorded as early as 1843, when Sowerby (1843) documented the first occurrence of Cyclostoma aquilum [= Cyclophorus (perdix) aquila] in Singapore. Thereafter, Tenison-Woods (1888) listed species such as Helix naninoides [= Dyakia (Quantula) striata], Bulimus melanomma [= Amphidromus (Amphidromus) perversus], Bulimus mundus [= Amphidromus perversus], and Bulimus inversus [= Amphidromus inversus]. Thereafter, other species of land snails were recorded for the first time in Singapore, including Cyclophorus borneensis (Moellendorff, 1891), Semperula maculata [=Vaginula maculata], Opeas didyma (Laidlaw, 1933) and Hemiplecta humphreysiana (Rensch, 1934). Land snails that were also found in Singapore were Hemiplecta striata [= Dyakia (Quantula) striata], Dyakia sp., Achatina fulica (Jarrett, 1923, 1949), Cyclophorus (Litostylus) semisulcatus [= Cyclophorus semisulcatus] (Zilch, 1956) and Huttonella bicolor [= Gulella (Huttonella) bicolor] (van Benthem Jutting, 1961). However, the only comprehensive survey of the land snails in Singapore was undertaken by Lim (1969, unpublished). This paper is intended to summarise current information on the land snails of Singapore.

From December 1989 to July 1991, collecting trips were made by the author, the staff of Zoological Reference Collection (ZRC), National University of Singapore and visitors of ZRC to assess the variety and habitats of land snails. Additional surveys were undertaken in Singapore after July 1991 to uptake current records of land snails.

The snails of leaf litter and soil have largely escaped attention due to their minute size and highly effective camouflage. In fact, leaf litter that is moist and very deep through which the snails can crawl is a favourable snail habitat (Solem, 1984). Together with minimal human

Ho Wai Hoong - 3A Fort Road, Singapore 1543.

disturbance and the availability of calcium, snail populations build up rapidly so that their numbers are actually immense. Sites that satisfied these habitat requirements were examined. The sites included forests, public parks, private gardens, plant nurseries, wastelands and unkempt roadside vegetation. The results are presented in the present checklist. The species mentioned in the checklist include land molluscs without shells (slugs) and land molluscs with reduced shells (semi-slugs). The following listing is not exhaustive; and additional species can be expected to be found in the near future, especially those in forests, as forest snails usually tend to be so minute and well camouflaged that detection is difficult.

Detailed species descriptions have been documented by van Benthem Jutting (1950, 1952) and Lim (1969, unpublished). Collected specimens were deposited at the Zoological Reference Collection, National University of Singapore. Some comments on their habitats are also included in the text.

MATERIALS AND METHODS

Collecting sites of land snails were characteristically well-shaded, overgrown with vegetation and covered with a layer of damp leaf litter. A site that satisfied such requirements was checked for snails for at least ten minutes. Once snails were detected, a thorough search at that site was carried out for up to three hours. Several sites in Singapore were surveyed in this manner. Decaying plant material was routinely checked and leaf litter, particularly large brown leaves were sampled. When large deposits of leaves were found, soil debris and leaf litter were collected with a trowel and placed in polythene bags. The collected materials were sorted in the laboratory. Soil matter was also checked under the stereomicroscope for small shells.

The molluscs were drowned in dechlorinated water to facilitate partial or complete relaxation. The time required for complete relaxation varied with species, ranging from 17 hours to 41 hours. Completely relaxed animals became unpigmented or bleached in appearance. Snails drowned overnight were usually not completely relaxed, especially in oxygenated water. Pinching the antennae of the animals was not a reliable test for relaxation, because unreactive animals sometimes contracted rapidly when immersed in alcohol. To facilitate relaxation, animals were treated to a gradual increase in alcohol concentration, and finally preserved in 70% ethanol which was buffered to a pH of 8 to reduce shell damage as a result of preservation in alcohol.

The specimens were examined under the stereomicroscope (up to 60X) for species diagnoses. Measurements for each species were made for a minimum of ten shells (when available). In the text, shell width refers to the maximum diameter between the outer lip and opposite side, whereas shell height is the perpendicular distance between both extremities of the shell. Slugs were measured after they were relaxed. Radulae were prepared to facilitate identification according to Lim (1969). The specimens were catalogued and deposited at the Zoological Reference Collection, National University of Singapore.

The following taxonomic scheme used for the snails was proposed by Vaught (1989) and detailed historical records of the species have been provided by Lim (1969) and van Benthem Jutting (1959). The asterisk (*) is used to denote a new record. All specimens were collected by the author unless otherwise stated.

TAXONOMY

CLASS GASTROPODA

ORDER MESOGASTROPODA

SUPERFAMILY CYCLOPHOROIDEA

FAMILY CYCLOPHORIDAE

SUBFAMILY CYCLOPHORINAE

Genus Cyclophorus Montfort, 1810

Cyclophorus perdix (Broderip & Sowerby, 1829)

Cyclostoma perdix - Broderip & Sowerby, 1829: 50 (No locality).

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Cyclophorus perdix - Martens, 1867: 136 (Indonesia: Sumatra); Kobelt, 1902: 131 (Indonesia: Sumatra, Java); van Benthem Jutting, 1959 (Indonesia: Sumatra).

Material examined. - 1 ex. (ZRC 1990.1709), Bukit Timah Nature Reserve, forest, on rockface 1 m above ground, 26 May.90. — 1 ex., Bukit Timah Nature Reserve, Dec.1994. Shell width: 23.30-40.80 mm, shell height: 18.50-30.35 mm.

Diagnosis. - Shell dextral, umbilicate, low turbinate, apex sharp, last whorl large and keeled. Operculum brown, thin, horny and multi-spiral. Shell reddish-brown with irregular zig-zag pattern and numerous fine growth lines. Adult shell with oblique aperture as in *C. borneensis*, lip expanded and reflected which resembles the shell of *C. tuba*.

Remarks. - Identification of the first shell from Bukit Timah Nature Reserve to a subspecific level is difficult because the shell is a juvenile and does not have a thickened lip which facilitates identification. The second adult specimen that was collected from Bukit Timah Nature Reserve has intermediate shell characters of *C. borneensis* and *C. perdix tuba*, and warrants further study.

Cyclophorus (perdix) aquila (Sowerby, 1843)

Cyclostoma aquilum - Sowerby, 1843: 123, Pl. 27, Fig. 131 (Singapore).

Cyclophorus aquilus - Laidlaw, 1928: 29 (Singapore).

Cyclophorus perdix aquila van Benthem Jutting, 1949: 52 (Peninsular Malaysia).

Cyclophorus (Salpingophorus) perdix aquila - Zilch, 1956: 45 (Singapore).

Cyclophorus perdix aquila - Berry, 1963: 8 (Peninsular Malaysia); Basch & Solem, 1971: 93 (Peninsular Malaysia).

Material examined. - 1 ex., Nee Soon Freshwater Swamp Forest, Nov.1990.

Diagnosis. - Shell with reflected and thickened lip, upper edge of the peristome parallel to the keel. Shell width: 43.90 mm, shell height: 32.75 mm.

Cyclophorus borneensis (Metcalf, 1851)

Cyclostoma borneensis - Metcalfe, 1851: 71 (Borneo).

Cyclophorus borneensis - Stoliczka, 1872: 203-204 (Peninsular Malaysia, Singapore); Tenison-Woods, 1888: 249 (Borneo); Moellendorff, 1891: 341 (Peninsular Malaysia, Singapore); Kobelt, 1902: 126 (Borneo, Peninsular Malaysia); Habe, 1964: 122-123, Pl. 1, Fig. 3 (Sarawak).

Material examined. - Not found during the present study.

Cyclophorus (perdix) tuba (Sowerby, 1842)

Cyclostoma tuba - Sowerby, 1842: 83 (Peninsular Malaysia); Pfeiffer, 1846: 169 (Peninsular Malaysia). Cyclophorus tuba - Martens, 1867: 133 (Locality unknown); Tenison-Woods, 1888: 1065 (Peninsular Malavsia).

Cyclophorus perdix tuba - Kobelt, 1902: 131 (Indonesia: Sumatra; Peninsular Malaysia).

Cyclophorus (Salpingophorus) perdix tuba - Laidlaw, 1928: 29 (Peninsular Malaysia). Cyclophorus perdix tuba - Rensch, 1934: 316 (Singapore); van Benthem Jutting, 1949: 52 (Peninsular

Malaysia); van Benthem Jutting, 1959: 69 (Indonesia: Sumatra); Berry, 1963: 8 (Peninsula Malaysia). Cyclophorus perdix tuba - Lim, 1969: 22-26, Pl. 1 (Singapore).

Material examined. - Not found during the present study.

Cyclophorus semisulcatus (Sowerby, 1843)

Cyclostoma semisulcatus - Sowerby, 1843: 124, Pl. 25, Fig. 99 (Locality unknown). Cyclophorus semisulcatus - Moellendorff, 1886: 309 (Peninsula Malaysia); Tenison-Woods, 1888: 250 (Peninsular Malaysia). Cyclophorus (Litostylus) semisulcatus - Laidlaw, 1928: 29 (Peninsular Malaysia).

Cyclophorus semisulcatus - van Benthem Jutting, 1949: 53 (Peninsular Malaysia). Cyclophorus (Litostylus) semisulcatus - Zilch, 1956: 35 (Singapore).

Material examined. - Not found during the present study.

Genus Cyclotus Swainson, 1840

Cyclotus rostellatus (Pfeiffer, 1851)

Opisthoporus rostellatus - von Martens, 1867: 113 (Locality unknown). Cyclotus rostellatus - Kobelt, 1902: 217 (Singapore; Indonesia: Sumatra; Borneo). Opisthoporus rostellatus - Laidlaw, 1928: 32 (Singapore; Indonesia: Sumatra; Borneo). Cyclotus rostellatus - van Benthem Jutting, 1949: 53 (Peninsular Malaysia). Cyclotus (Opisthoporus) rostellatus - Lim, 1969: 26-28, Pl. 2 (Singapore).

Material examined. - 1 ex. (ZRC 1990.1712), Nee Soon Freshwater Swamp Forest, on ground, 25 Mar.1990. Shell width: 12.20 mm, shell height: 7.10 mm.

Diagnosis. - Shell dextral, operculate, flat with large umbilicus, shell brown radiating flames, rounded whorl and thickened lip. Shell with breathing tube near the aperture.

Genus Ditropis Blanford, 1869

*Ditropis cf. koperbergi Zilch, 1955

Ditropis koperbergi - Zilch, 1955: 194, Pl. 15, Fig. 78 (Indonesia).

Material examined. - 5 ex. (ZRC 1991.20413-20417), Botanic Gardens' Jungle, leaf litter, 24.Dec.1991. — 1 ex. (ZRC 1992.2952), Botanic Gardens' Jungle, leaf litter, 25 Sep.1990. — 1 ex. (ZRC 1992.2953), Bukit Timah Nature Reserve, Taban Valley, leaf litter, Feb.1990. Shell width: 1.60-2.85 mm, shell height: 1.20-2.90 mm.

Diagnosis. - Shell dextral, low conical, angular with strong wide keel and wide umbilicus. Operculum multi-spiral, dark brown with a central depression. Shell transparent and pale yellow.

Remarks. - Specimens collected in Singapore were sent to the Senckenberg Museum in Frankfurt but the identification was not verified to the specific level due to differences in the shell structure (embryonic whorl, spiral threads in the umbilical wall and growth lines) of the specimens and the holotype lodged at Senckenberg (Dr Ronald Janssen, pers. comm.).

Genus Japonia Gould, 1859

Japonia (Lagochilus) ciliocinctum (Martens, 1865)

Japonia ciliocincta - Kobelt, 1902: 551, Pl. 9, Figs. 6-8 (Indonesia: Java). Lagochilus ciliocinctum - van Benthem Jutting, 1948: 560-563, Fig. 18 (Indonesia: Java). Lagocheilus ciliocinctum - Zilch, 1955: 184 (Indonesia: Java); Lim, 1969: 29-31, Pl. 3 (Singapore).

Material examined. - 1 ex., Nee Soon Freshwater Swamp Forest, leaf litter, 3 May.94.

Diagnosis. - Shell dextral, high conical, whorls rounded with deep suture. Body whorl with short bristles that are easily detached. Aperture rounded, operculum thin, multi-spiral and horny.

FAMILY DIPLOMMATINIDAE

SUBFAMILY DIPLOMMATINAE

Diplommatina nevilli Crosse, 1879

Diplommatina nevilli - Laidlaw, 1928: 37 (Peninsular Malaysia); Tweedie, 1961: 54-57 (Peninsular Malaysia); Lim, 1969: 33, Fig. 1B (Singapore).

Material examined. - 40 ex. (ZRC 1990.14444-14483), Botanic Gardens' Jungle, leaf litter, 25 Sep.1990. Shell width: 1.20-1.55 mm, shell height: 3.05-3.60 mm.

Diagnosis. - Shell dextral, operculate, turreted, transparent with 20-22 well-defined ribs on the body whorl. Lip thickened and expanded with a single columellar tooth. Shell pale brown.

SUBCLASS GYMNOMORPHA

ORDER SOLEOIFERA

FAMILY VERONICELLIDAE

Genus Filicaulis Simroth, 1913

*Filicaulis alte (Ferussac, 1823)

Vaginulus alte - Ferussac, 1823: 96x, Pl. 8A, Fig. 8, Pl. 8B, Fig. 6 (India).

Meisenheimeria alte - Grimpe & Hoffman, 1925: 26-31, Fig. 1 (Locality unknown); Laidlaw, 1933: 213 (Peninsular Malaysia).

Laevicaulis alte - Rensch, 1932: 126 (Indonesia: Bali, Java).

Laevicaulis alte - van Benthem Jutting, 1952: 330, Fig. 15 (Indonesia: Java).

Material examined. - 19 ex. (ZRC 1991.20388-20406), Telok Kurau, Jalan Wakaff, private garden, coll. S.H. Chan, 9 Jul.1991. — 6 ex. (ZRC 1991.20407-20412), Jalan Wakaff, private garden, 24 Jun.1991. Slug width: 5.50-22.20 mm; slug length: 14.20-67.50 mm.

Diagnosis. - Shell absent, dorsal surface (notum) dark brown and granular, beige underneath (hypnotum). Mid-dorsal line may or may not be present. The notum is finely mottled with brown spots. *Filicaulis alte* resembles *Vaginula maculata* in its external appearance and *F. alte* is identified by its long and cylindrical penis with sub-basal collar (van Benthem Jutting, 1952, p. 333, fig. 15).

Genus Vaginula Ferussac, 1924

Vaginula maculata Templeton, 1858

Vaginula maculata - Templeton, 1858: 49, Pl. IIB, Figs. 1-5 (Sri Lanka).

Vaginulus sumatrensis - von Martens, 1892: 246 (Indonesia: Sumatra).

Semperula maculata - Rensch, 1932: 129 (Indonesia: Java).

8.65-36.05 mm.

Semperula maculata - Laidlaw, 1933: 213 (Peninsular Malaysia); van Benthem Jutting, 1952: 335-337, Fig. 18 (Indonesia: Java); van Benthem Jutting, 1959: 123 (Indonesia: Sumatra).

Material examined. - 1 ex. (ZRC 1990.1437), Fort Canning Park, under a rock, Jan.1990. — 1 ex. (ZRC 1990.1438), Bedok South Avenue, 3 Feb.1990. — 2 ex. (ZRC 1990.1440-1441), Hindhede Lane, near village, coll. H.K. Lua, 8 Feb.1990., — 2 ex. (ZRC 1990.1442-1443), Woodlands, beside railway track, 11 Jan.1990. — 2 ex. (ZRC 1990.1444-1445), Thomson Road, plant nursery, on ground, 23 Dec.1989. — 2 ex. (ZRC 1990.1446-1447), Sungei Tengah Road, 25 Dec.1989. — 1 ex. (ZRC 1990.1448), Tanjong Rhu, 17 Jan.1990. — 1 ex. (ZRC 1990.1449), Tanjong Rhu, 17 Jan.1990. — 1

ex. (ZRC 1990.1489), Hindhede Lane, coll. H.K. Lua, Dec.1989. Slug width: 3.65-12.90, slug length:

Diagnosis. - Shell absent, notum brown to dark brown with black mottling and a biege mid-dorsal line. Hypnotum beige. *Vaginula maculata* is distinguished from *Filicaulis alte* by the wide and compact penis (van Benthem Jutting, 1952, p. 335, fig. 18).

Remarks. - Mostly found in areas of human inhabitation, both in gardens, wastelands and farms. Not an uncommon species, usually found attached to wooden planks, but is also attracted to ripe fruits, decaying papaya leaves. So far, dissected specimens collected from Singapore

have been identified as this species only. No other species from the same genus has been found in Singapore.

Vaginula variegatula Simroth, 1918

Semperula variegatula - Rensch, 1932: 129 (Indonesia: Bali, Lombok).
Semperula variegatula - van Benthem Jutting, 1952: 337, Fig. 12 (Indonesia: Java); Lim, 1969: 38-40, Pls. 4A, B, Figs. 6-12 (Singapore).

Material examined. - Not found in the present study.

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SUBCLASS PULMONATA

ORDER STYLOMMATOPHORA

SUBORDER ORTHURETHRA

SUPERFAMILY ACHATINOIDEA

FAMILY SUBULINIDAE

SUBFAMILY SUBULININAE

Genus Subulina Beck, 1837

Subulina octona (Bruguière, 1789)

Stenothyra octona - Martens, 1892: 244 (Indonesia: Sumatra).

Subulina octona - Laidlaw, 1932: 39 (Peninsular Malaysia); Laidlaw, 1933: 215 (Peninsular Malaysia); van Benthem Jutting, 1952: 376-378, Figs. 52a,b,53 (Indonesia: Java); Berry, 1963: 12, Pl. VII, Fig. 45 (Peninsular Malaysia); Lim, 1969: 47-49, Pl. 6 (Singapore); Kerney & Cameron, 1987: 211 (Great Britain, Denmark, Germany); Solem, 1988: 521, Figs. 115,116 (Australia: Northern Territory).

Material examined. - 6 ex. (ZRC 1990.1001-1006), Bedok South Avenue 1, 3 Jan.1990. - 1 ex. (ZRC 1990.1007), Lim Chu Kang, 14 Jan.1990. - 12 ex. (ZRC 1990.1008-1019), East Coast Park, Bird Sanctuary, 29 Jan. 1990. — 8 ex. (ZRC 1990.1020-1027), Woodlands Road, beside railway track, 11 Jan.1990. - 1 ex. (ZRC 1990.1028), Thomson Road, plant nursery, on ground, 22 Dec. 1989. -3 ex. (ZRC 1990.1029-1031), Sungei Tengah Road, 25 Dec.1989. — 8 ex. (ZRC 1990.1034-1041), Pasir Ris Drive 6, 10 Mar.1990. — 11 ex. (ZRC 1990.1042-1052), Thomson Road, plant nurseries. 23 Dec.1989. — 5 ex. (ZRC 1990.1058-1062), Bukit Timah, plant nursery, 17 Feb.1990. — 8 ex. (ZRC 1990.1063-1070), Fort Canning Park, leaf litter, 24 Jan.1990. - 1 ex. (ZRC 1990.1080), Sungei Tengah Road, 12 Dec.1989. — 22 ex. (ZRC 1990.1081-1102), St John's Island, under rocks, leaf litter, 3 Mar.1990. — 15 ex. (ZRC 1990.1103-1117), Amber Road, wasteland, 24 Dec.1989. — 5 ex. (ZRC 1990.1118-1123), Amber Road, wasteland, 4 Feb.1990. - 12 ex. (ZRC 1990.1124-1135), Fort Road, flower pots, 9 Jan. 1990. — 38 ex. (ZRC 1990.1136-1173), East Coast Park, leaf litter, 12 Jan. 1990. - 5 ex. (ZRC 1990.2716-2720), East Coast Road, Holy Family Church, in flower pots, 14 Apr.1990. - 5 ex. (ZRC 1990.2721-2725), East Coast Park, leaf litter, Sep.1990. - 38 ex. (ZRC 1990.3060-3097), Jurong Lake, wasteland, leaf litter, coll. W.H. Ho and H.K. Lua, 21 Sep.1991. --- 13 ex. (ZRC 1990.14418-14430), Sungei Buloh, in soil with decaying plant matter, 18 Sep.1990. - 20 ex. (ZRC 1990.17099-17118), Amber Road, wasteland, soil debris, 24 Dec.1989. - 18 ex. (ZRC 1990.17122-17139), Kent Ridge, Pharmacology Block, National University of Singapore, in flower pots, coll. W.H. Ho and H.K Lua, 12 Mar. 1990. — 1 ex. (ZRC 1990.17609), Hindhede Drive, coll. H.K Lua, 7 Dec. 1989. - 3 ex. (ZRC 1992.3-5), Sungei Buloh, compost, Nov.1990. - 4 ex. (ZRC 1992.3134-3137), Sungei Buloh, near fish farms, coll. H.K Lua, 15 Nov.1990. — 3 ex. (ZRC 1992.3155-3157), Sungei Buloh, near fish pond, coll. H.K Lua, 15 Nov.1990. Shell width: 1.30-3.80 mm; shell height: 1.55-13.50 mm; shell width: 1.30-1.55 mm.

Diagnosis. - Shell dextral, non-operculate, turreted, translucent with fine vertical striation and rounded whorls. Calcareous eggs sometimes present in the body whorl. The columella is reflected and truncated at the base (van Benthem Jutting, 1952, p. 376, fig. 53c). Shell cream or yellow.

Genus Lamellaxis Strebel & Pfeffer, 1882

*Lamellaxis clavulinus (Potiez & Michaud, 1838)

Opeas clavulinum - Pilsbry, 1906: 135, Pl. 23, Figs. 17,21,22 (Mauritius, Seychelles); van Benthem Jutting, 1952: 381-384, Fig. 59 (Indonesia: Java).

Lamellaxis clavulinus - Berry, 1963: 12, Pl. VII, Fig. 47 (Peninsular Malaysia); Kerney & Cameron, 1987: 212 (Great Britain, Holland); Solem, 1989: 523, Figs. 121,122,128,129 (Australia: Northern Territory).

Material examined. - 1 ex. (ZRC 1990.1174), Lim Chu Kang, 29 km, ground, 14 Jan.1990. — 2 ex. (ZRC 1990.1175-1176), Lorong Gambas, off Jalan Ulu Sembawang, leaf litter, 10 Dec.1989. — 2 ex. (ZRC 1990.1177-1178), Sungei Tengah Road, resting on mud beside path, 25 Dec.1989. — 1 ex. (ZRC 1990.1179), Bukit Timah Nature Reserve, forest fringe, on palm leaf resting on ground at Taban Valley, 8 Feb.1990. — 2 ex. (ZRC 1990.1205-1206), Bukit Timah, near Institute of Education, 17 Feb.1990. — 15 ex. (ZRC 1990.1207-1221), Fort Canning Park, leaf litter, 24 Jan.1990. — 6 ex. (ZRC 1990.2684-2689), Hindhede Drive, village, in flower pots and under coconut husks, 15 Apr.1990. — 8 ex. (ZRC 1991.20094-20101), Jurong Lake, leaf litter and soil, Apr.1991. Shell width: 3.00-3.65 mm; shell height: 6.40-10.05 mm.

Diagnosis. - Shell dextral, turreted, translucent, smooth, glossy, straw-coloured or cream. The columella is reflected, not truncated, and extends to the base of the peristome.

Remarks. - Three specimens of Lamellaxis clavulinus (ZRC 1990.1511-1513), collected by Lim (1969) were mistaken as Subulina octona.

*Lamellaxis gracilis (Hutton, 1834)

Bulimus gracilis - Hutton, 1834: 84-85, 93 (India).
Stenogyra gracilis - von Martens, 1867: 375, Pl. 22, Fig. 13, Pl. 19, Fig. 5 (Indonesia: Sumatra).
Opeas gracile - Laidlaw, 1932: 39 (Peninsular Malaysia); van Benthem Jutting, 1949: 64 (Peninsular Malaysia); van Benthem Jutting, 1952: 378-381. Figs. 55, 56a (Indonesia: Java).

Lamellaxis gracilis - Berry, 1963: 12, Pl. VII, Fig. 46 (Peninsular Malaysia); Solem, 1964: 31 (Sabah); Solem, 1989: 521-522, Figs. 117-120 (Australia: Western Australia, Northern Territory, Queensland).

Material examined. - 2 ex. (ZRC 1990.1642-1643), Fort Canning Park, 24 Jan.1990. — 17 ex. (ZRC 1990.1684-1700), East Coast Park, leaf litter, 12 Jan.1990. — 1 ex. (ZRC 1992.2683), Thomson Road, plant nursery, 23 Dec.1989. — 1 ex. (ZRC 1992.2690), Pasir Ris Drive 6, on ground, 10 Mar.1990. — 8 ex. (ZRC 1992.2691-2698), Jurong Lake, leaf litter and soil, coll. H.K. Lua and W.H. Ho, Apr.1991. — 5 ex. (ZRC 1992.2706-2710), Hindhede Lane, village, 15 Apr.1990. — 5 ex. (ZRC 1992.2711-2715), East Coast Road, Holy Family Church, flower pots, 14 Sep.1990. Shell width: 1.20-2.55 mm; shell height: 2.00-7.50 mm.

Diagnosis. - Shell dextral, non-operculate, turreted, translucent, yellowish-white with slightly rounded whorls. Shell sculpture consists of distinct vertical striae which is also arcuate with faint spiral striae. The columella is reflected, not truncated, but extends to the base of the peristome (van Benthem Jutting, 1952, p. 377, fig. 56a). The details of shell sculpture can be seen in Solem (1989), figs. 132-134.

Genus Opeas Albers, 1850

Opeas didyma Westerlund, 1887

Opeas didyma - Laidlaw, 1933: 216 (Singapore).

Material examined. - Not found in the present study.

*Opeas pumilum (Pfeiffer, 1840)

Opeas pumilum - Kerney & Cameron, 1987: 212 (Great Britain, France, Holland, Germany, Denmark, Sweden); Solem, 1989: 524-525, Figs. 125, 132-134 (Australia).

Material examined. - 11 ex. (ZRC 1990.1622-1632), Kent Ridge, National University of Singapore, flower pots, coll. W.H. Ho and H.K. Lua, Mar.1990. 9 ex. (ZRC 1990.1633-1641), Amber Road, wasteland, 24 Dec.1990. — 5 ex. (ZRC 1990.1644-1648), Kent Ridge, National University of Singapore, Pharmacology Department, flower pots, 12 Dec.1990. — 7 ex. (ZRC 1990.1658-1664), Amber Road, wasteland, 4 Feb.1990. — 9 ex. (ZRC 1990.1665-1673), Amber Road, wasteland, 4 Feb.1990. — 9 ex. (ZRC 1990.1665-1673), Amber Road, wasteland, 4 Feb.1990. — 10 ex. (ZRC 1990.1674-1683), Amber Road, wasteland, 23 Feb.1990. — 2 ex. (ZRC 1990.2736-2737), Amber Road, wasteland, leaf litter, 24 Dec1989. Shell width: 1.20-1.60 mm; Shell height: 2.20-5.00 mm.

Diagnosis. - Shell dextral, non-operculate, slender, turreted, translucent, shell sculpture with numerous fine vertical striae. Columella reflected, not truncated, but extends to the base of the peristome. *Opeas pumilum* is the smallest subulinid species collected in Singapore. The main collecting site for the species, i.e., the wasteland at Amber Road was destroyed and converted into a plant nursery.

Genus Prosopeas Morch, 1876

*Prosopeas tchehelense (De Morgan, 1885)

Stenothyra (Subulina) tchehelensis - Moellendorff, 1887: 304-305 (Peninsular Malaysia).

Stenothyra tchehelensis - Tenison-Woods, 1888: 235 (Peninsular Malaysia).

Opeas dimorpha - Ghosh, 1929: 336-337, Fig. 4 (Peninsular Malaysia).

Prosopeas tchehelense - Laidlaw, 1932: 39 (Peninsular Malaysia); van Benthem Jutting, 1949: 63 (Peninsular Malaysia); Berry, 1963: 12, Pl. VII, Fig. 48 (Peninsular Malaysia).

Material examined. - 22 ex. (ZRC 1990.1222-1243) Fort Road, flower pot, 9 Jan.1990. Shell width: 1.45-2.55 mm; shell height: 2.50 - 6.95 mm.

Diagnosis. - Shell dextral, opaque, dull creamy white with coarse ribbing. The whorls are evenly rounded, and sutures are well-impressed, apex truncated. Columella reflected, not truncated, and extends to the base of the peristome.

Remarks. - The specimens found in the present study are smaller than specimens collected from Batu Caves, Selangor in Peninsular Malaysia (ZRC 1975.4.23.65-76), leg. E. Seimund, and the snails from Singapore may be a dwarf form of *Prosopeas tchehelense*.

FAMILY ACHATINIDAE

Genus Achatina Lamarck, 1799

Achatina fulica Bowdich, 1822

Achatina fulica - Jarrett, 1923: 73-76 (Peninsular Malaysia); Jarrett, 1949: 5 (Singapore); van Benthem Jutting, 1952: 391-396, Fig. 60 (Indonesia: Java); Berry, 1963: 12, Pl. VII, Fig. 49 (Peninsular Malaysia); Laidlaw, 1933: 215 (Peninsular Malaysia); Mead, 1961: 15 (Singapore); Lim, 1969: 51-55 (Singapore); Berry, 1974: 154-157, Fig. 22 (Peninsular Malaysia).

Material examined. - 4 ex. (ZRC 1990.1246-1249), Woodlands Road, near railway track, 11 Jan.1990. — 1 ex. (ZRC 1990.1257), Woodlands Road, near Bukit Panjang Road, 11 Jan.1990. — 1 ex. (ZRC 1990.1258), St John's Island, in leaf litter, 3 Mar. 1990. — 4 ex. (ZRC 1990.1259-1262), East Coast Park, Bird Sanctuary, 29 Jan.1990. — 1 ex. (ZRC 1990.1263), Woodlands Road, beside railway track, 11 Jan.1990. — 1 ex. (ZRC 1990.3030), Woodlands Road, 11 Jan.1990. — 1 ex. (ZRC 1990.15114), Sungei Buloh, under plastic shelter near fish pond, 18 Nov.1990. — 1 ex. (ZRC 1990.17002), Ayer Rajah Expressway, grass patch, coll. H.K. Lua, 31 Dec.1990. — 1 ex. (ZRC 1990.17097), outside Botanic Gardens, near decaying leaves of cocoyam, 19 Jan.1990. — 1 ex. (ZRC 1990.17098), St John's Island, on grass patch, 3 Mar.1990. — 2 ex. (ZRC 1990.17171-17172), Lower Peirce Reservoir, scrub, 11 Aug.1990. — 1 ex. (ZRC 1992.176), Sungei Buloh, fish farm, coll. H.K. Lua, 15 Nov.1990. — 1 ex. (ZRC 1992.238), Lower Peirce Reservoir, grassland, coll. H.K. Lua, 11 Aug.1990. Shell height: 6.65-100.95 mm; shell width: 4.85-56.80 mm.

Diagnosis. - Commonly known as the Giant African Snail, Achatina fulica is easily recognised by its large size. It is the largest land snail that is found in Singapore. Shell shape is ovate, apex pointed. The ground colour of the shell is straw or yellowish-brown with irregular dark brown streaks. The streaks are clearly visible in larger specimens (shell height > 20 mm), whereas smaller shells are irregularly mottled with black pigment spots and faint reddishbrown streaks that extend from the suture to the shell periphery on the last whorl.

SUPERFAMILY STREPTAXOIDEA

FAMILY STREPTAXIDAE

Genus Gulella Pfeiffer, 1856

Gulella (Huttonella) bicolor (Hutton, 1834)

Gulella (Huttonella) bicolor - van Benthem Jutting, 1950: 504-505, Figs. 106-107 (Indonesia: Java). Huttonella bicolor - van Benthem Jutting, 1961: 8 (Peninsular Malaysia). Gulella bicolor - Berry, 1963: 15, Pl. X, Fig. 73 (Peninsular Malaysia).

Material examined. - 6 ex. (ZRC 1990.1266-1271), Amber Road, wasteland, soil debris, 22 Feb.1990. — 37 ex. (ZRC 1990.144381-14417), Amber Road, wasteland, soil debris, 25 Nov. 1990. — 1 ex. (ZRC 1990.18000), Amber Road, wasteland, 4 Feb. 1990. — 2 ex. (ZRC 1992.2581-2582), Sungei Buloh, soil compost and in leaf litter, 10 Mar.1991. — 1 ex. (ZRC 1992.2583), Hindhede Lane, village,

under coconut husk, 13 Apr. 1990. — 2 ex. (ZRC 1992.2584-2585), Chapel Road, Holy Family Church, on ground, 14 Apr.1990. — 1 ex. (ZRC 1992.2586), Sungei Buloh, soil heap, 23 Nov.1991. Shell width: 1.25-2.40 mm; shell height: 2.80-6.85 mm.

Diagnosis. - Shell dextral, turreted with a blunt apex, shell aperture with four columellar teeth. The shell is cream but appears pink when the animal is alive.

Remarks. - This is the only known predatory land snail in Singapore. Gulella bicolor feeds on subulinids and helixarionids, e.g., Subulina octona and Microcystina sp. In captivity, this species is also capable of cannibalism.

SUPERFAMILY SUCCINOIDEA

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FAMILY SUCCINEIDAE

Genus Succinea Draparnaud, 1801

*Succinea minuta Martens, 1867

Succinea minuta - van Benthem Jutting, 1952: 342-343, Figs. 19, 21, 23 (Indonesia: Java); Smith & Djajasasmita, 1988: 388 (Indonesia: Krakatau Islands).

Material examined. - 6 ex. (ZRC 1990.14157-14162), Tanjong Rhu, wasteland, on dead leaves and mud, 25 Jan.1990. — 10 ex. (1990.14163-14172), Thomson Road, plant nursery, 23 Dec. 1989. — 2 ex. (ZRC 1990.14173-14174), Bukit Timah, plant nursery, flower pot, 17 Feb.1990. — 1 ex. (ZRC 1990.14175), East Coast Park, leaf litter, Sep.1990. — 17 ex. (ZRC 1990.14176-14192), East Coast Park, leaf litter, 12 Jan.1990.

Diagnosis. - Shell dextral, non-operculate, oval, glossy, golden brown and transparent, very thin and fragile. Body whorl very large and inflated, egg-shaped. Animal cannot be retracted into the shell.

Remarks. - Ground-dwelling, also found resting on leaf litter and in flower pots. Succinea minuta is well-camouflaged and the snail is not easily sighted.

SUPERFAMILY HELIXARIONOIDEA

FAMILY HELIXARIONIDAE

SUBFAMILY HELIXARIONINAE

Genus Helixarion Ferussac, 1821

Helixarion perfragilis (Moellendorff, 1897)

Helicarion perfragilis - van Benthem Jutting, 1950: 419, Fig. 36 (Indonesia: Java); van Benthem Jutting, 1959: 158 (Indonesia: Sumatra); Lim, 1969: 62-63, Pls. 7A,B (Singapore).

Material examined. - 5 ex. (ZRC 1990.1295-1299), Sembawang, farm, on banana leaf, 1.5-2.0 m above ground, 10 Dec.1989. — 4 ex. (ZRC 1990.1300-1303), Lorong Atong, off Lim Chu Kang Road,

on leaves, 25 Dec.1989. — 1 ex. (ZRC 1990.1308), Lim Chu Kang, on banana leaf, 14 Jan.1990. — 4 ex. (ZRC 1990.1309-1312), Pasir Ris Drive 6, on leaf, 11 Mar.1990. — 7 ex. (ZRC 1990.17542-17548), Hindhede Drive, coll. H.K. Lua, 24 Oct.1990. Shell height: 2.40-5.60 mm; shell width: 4.10-7.50 mm.

Diagnosis. - Shell dextral, non-operculate, low conical, very thin, transparent and broad with rapidly increasing whorls, smooth. Shell straw-coloured. Animal cannot retract completely into the shell.

Remarks. - An arboreal species found mostly on the underside on large leaves such as *Heliconia* spp., sometimes with clusters of four to six gelatinous eggs.

Genus Wilhelminaia Preston, 1913

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*Wilhelminaia mathildae Preston, 1913

Disconulus cf. sinapidium - Baker, 1941: 226-228, Pl. 40, Figs. 1, 2: Pl. 60, Fig. 14 (Caroline Islands).
Microcystina gratilla - van Benthem Jutting, 1950: 448, Fig. 68 (Indonesia: Java).
Wilhelminaia sp. (?mathildae) - Solem, 1959: 92-94, Pl. 33, Figs. 1-3 (New Hebrides, Florida Island, Solomon Islands, Batjan Island, Moluccas).

Material examined. - 1 ex. (ZRC 1990.13819), Botanic Gardens, on a decaying leaf in flower bed, 19 Jan.1990. Shell width: 1.85 mm; shell height: 1.00 mm.

Diagnosis. - Shell dextral, depressedly turbinate, polished shining, pale brown with regular hair-like growth striae and delicate spiral striae. The single live specimen corresponds to the description, and as Solem (1959) suggested, it is likely that all varieties will eventually be recognised as this species.

SUBFAMILY MICROCYSTINAE

Genus Liardetia Gude, 1913

*Liardetia doliolum (Pfeiffer, 1846)

Kaliella doliolum - Laidlaw, 1932: 40 (Peninsular Malaysia); van Benthem Jutting, 1949: 64-65 (Peninsular Malaysia).

Liardetia doliolum - van Benthem Jutting, 1950: 410, Figs. 9, 28 (various islands in the Malay Archipelago); van Benthem Jutting, 1959: 138 (Indonesia: Sumatra); Berry, 1963: 14, Pl. VIII, Fig. 57 (Decimal on Malay Society and Disinguesticity and

57 (Peninsular Malaysia); Smith and Djajasasmitha, 1988: 391 (Indonesia: Krakatau Islands).

Material examined. - 11 ex. (ZRC 1990.13820-13830), Amber Road, wasteland, leaf litter, 24 Dec.1989. — 15 ex. (ZRC 1990.13831-13845), Bedok South Avenue 1, wasteland, leaf litter, 3 Feb.1990. — 5 ex. (ZRC 1990.13846-13850), Botanic Gardens, on leaves, Jan.1990. — 2 ex. (ZRC 1990.13851-13852), East Coast Park, Bird Sanctuary, 9 Jan.1990. — 1 ex. (ZRC 1990.13853), Lorong Gambas, off Jalan Ulu Sembawang, on banana leaf, 10 Dec.1989. — 13 ex. (ZRC 1990.13854-13866), Hindhede Drive, ground, 2 Dec.1989. — 5 ex. (ZRC 1990.13867-13871), Amber Road, wasteland, Dec.1989. — 37 ex. (ZRC 1990.13872-13908), Kent Ridge, National University of Singapore, behind Department of Zoology, leaf litter, 28 Dec.1989. — 1 ex. (ZRC 1990.13909), Thomson Road, leaf litter beside footpath, 24 Dec.1989. — 6 ex. (ZRC 1990.13910-13915), Lim Chu Kang, leaf litter, 14 Jan.1990. — 2 ex. (ZRC 1990.13916-13917), Tanjong Rhu wasteland, leaf litter opposite bus terminus,

17 Jan.1990. — 1 ex. (ZRC 1990.13918), Pasir Ris Drive 6, on leaves of wild shrub, 1 m above ground, 11 Mar.1990. Shell width: 1.70-3.30 mm; shell height: 1.20-2.15 mm.

Diagnosis. - Shells golden-brown, low conical, apical whorls well-rounded, last whorl slightly rounded at the periphery. Very coarse ribbing on the upper shell surface.

Remarks. - The genus Liardetia was not recorded previously in Singapore. Mixed species of this genus were found at the same location, although the species distribution was not always homogeneous. Of the four members listed, L. doliolum was the most widespread and abundant. The species was most often attached to decaying leaf leaves of *Plumeria* and *Acacia*.

*Liardetia samoensis (Mousson, 1865)

Nanina samoensis - Mousson, 1865: 165 (Samoa). Helix ardua - Cox, 1870: 82 (New Hebrides). Helix antelata - Cox, 1870: 83-84 (New Hebrides). Guppya papuana - Thiele, 1928: 113, Pl. 5, Fig. 20 (New Britain). Liardetia (Liardetia) striolata - Baker, 1938: 158. Liardetia samoensis - Solem, 1959: 96-97, Pl. 33, Figs. 4-6 (New Hebrides, New Caledonia).

Material examined. - 1 ex. (ZRC 1990.14066) Lorong Gambas, off Jalan Ulu Sembawang, on banana leaf, 10 Dec.1989. — 3 ex. (ZRC 1990.14067-14069), Bedok South Avenue 1, 3 Feb.1990. — 9 ex. (ZRC 1990.14080-14088), Hindhede Drive, grass hedge, 2 Dec. 1989. — 3 ex. (ZRC 1990.14089-14091), Botanic Gardens, 2 Dec.1989. — 3 ex. (ZRC 1990.14092-14094), Lorong Malai, wasteland, leaf litter, 11 Jan.1990. — 4 ex. (ZRC 1990.14095-14098), Hindhede Drive, village, leaf litter, 11 Jan.1990. — 6 ex. (ZRC 1990.14099-14104), Pasir Ris Drive 6, wasteland, on leaves, 11 Mar.1990. — 2 ex. (ZRC 1990.14105-14106), Lim Chu Kang, leaf litter, 14 Jan.1990. — 4 ex. (ZRC 1990.14111-14114), Hindhede Drive, village, leaf litter. Shell width: 1.90-3.25 mm; shell height: 1.30-2.30 mm.

Diagnosis. - The shell is moderately conical, sutures shallow, gently sloping and angulated at the periphery. Growth striae are dense and closely spaced. Shell pale horny brown in preserved specimens, with irregular black patches.

Remarks. - Two shells of Liardetia samoensis (ZRC 1990.1502-1503) were previously identified as *Microcystina* sp. in Lim's collection.

*Liardetia indifferens (Boettger, 1891)

Kaliella indifferens - Boettger, 1891: 256, Pl. 3, Figs. 4, 4a, 4b (Indonesia).

Liardetia indifferens - van Benthem Jutting, 1950: 408-409, Fig. 25,26 (Indonesia: Java, Bali, Sumba, Timor, Kalao, Ambon, Saparua); van Benthem Jutting, 1959: 138 (Indonesia: Sumatra); Berry, 1963: 14, Pl. VIII, Fig. 57 (Peninsular Malaysia); Smith and Djajasasmitha, 1988: 391 (Indonesia: Krakatau Islands).

Material examined. - 5 ex. (ZRC 1990.14018-14022), Bedok South Avenue 1, wasteland, 3 Feb.1990. — 14 ex. (ZRC 1990.14023-14036), East Coast Park, on leaves lying on lawn, 12 Jan.1990. — 2 ex. (ZRC 1990.14043-14040), East Coast Park, on leaves lying on lawn, 12 Jan.1990. — 2 ex. (ZRC 1990.14041-14042), Lim Chu Kang, leaf litter along path, 14 Jan.1990. — 3 ex. (ZRC 1990.14043-14045), Tanjong Rhu, leaf litter, 17 Jan.1990. — 12 ex. (ZRC 1990.14046-14057), East Coast Park, leaf litter, after heavy rain, Sep.1990. — 2 ex. (ZRC 1990.14058-14059), Lorong Gambas, Sembawang, leaf litter, 10 Dec.1989. Shell width: 1.60-2.60 mm; shell height: 1.05-2.05 mm.

Diagnosis. - Shell low conical with slightly rounded whorls. On the upper surface the shell is sculptured with fine growth striae and intersected with less distinct radial striae. Shell colour is reddish-brown in living animals.

*Liardetia convexoconica (Moellendorff, 1897)

Kaliella convexoconica - Moellendorff, 1897: 60 (Indonesia: Java).
 Liardetia convexoconica - van Benthem Jutting, 1950: 396, Figs. 12, 13 (Indonesia: Java); van Benthem Jutting, 1959: 138 (Indonesia: Sumatra).

Material examined. - 3 ex. (ZRC 1990.14115-14117), Lorong Atong, on leaves of cocoyam, roadside plant, 25 Dec.1989. — 14ex. (ZRC 1990.14118), Hindhede Drive, village, 27 Dec.1989. — 4 ex. (ZRC 1990.14119-14122), Amber Road, wasteland, leaf litter and soil debris, 4 Feb.1990. — 2 ex. (ZRC 1990.14123-14124), Fort Canning Park, on ground, 24 Jan.1990. — 4 ex. (ZRC 1990.14125-14128), Lim Chu Kang, leaf litter, 14 Jan.1990. — 1 ex. (ZRC 1990.14129), East Coast Park, leaf litter, Sep.1990. — 1 ex. (ZRC 1990.14130), East Coast Park, on leaf, 1990. — 26 ex. (ZRC 1990.14131-14156), Bedok South Avenue 1, leaf litter, i.e., on bamboo leaves, 3 Feb.1990. Shell width: 1.80-3.70 mm; shell height: 1.30-3.15 mm.

Diagnosis. - Shell almost perfectly conical, suture shallow and acutely keeled at the periphery. Shell colour of live specimens yellowish-brown to dark brown.

FAMILY ARIOPHANTIDAE

SUBFAMILY ARIOPHANTINAE

Genus Hemiplecta Albers, 1850

Hemiplecta cymatium (Pfeiffer, 1856)

Hemiplecta cymatium Laidlaw, 1933: 217 (Peninsular Malaysia); Berry, 1963: 14, Fig. 62 (Peninsular Malaysia); van Benthem Jutting, 1949 (Peninsular Malaysia): 69 (Peninsular Malaysia); Lim, 1969: 79-81, pl. 13 (Singapore).

Material examined. - Not found in the present study. The specimens of Hemiplecta cymatium obtained by Lim (1969) were probably Hemiplecta humphreysiana.

Hemiplecta humphreysiana (Lea, 1841)

Nanina humphreysiana - Martens, 1867: 233-235, Pl. 10, Figs. 3,4,6 (Singapore); Tenison-Woods, 1888: 1020 (India, Singapore, Sumatra).

 Hemiplecta humphreysiana - Collinge, 1899-1900: 78-81, Pl. iv, Figs. 16-23 (Locality unknown); Laidlaw, 1932: 87-89 (Peninsular Malaysia); van Benthem Jutting, 1949: 69 (Peninsular Malaysia); Rensch, 1934: 322-327 (Singapore); van Benthem Jutting, 1950: 444-446, Figs. 63,64 (Indonesia: Java); Lim, 1969: 81-85, Pl. 14 (Singapore); Basch & Solem, 1971: 94 (Peninsular Malaysia).

Material examined. - 1 ex. (ZRC 1990.1710), Botanic Gardens' Jungle, beside concrete path, 16 Jul.1990. — 2 ex. (ZRC 1990.15103-15104), Nee Soon Freshwater Swamp Forest, coll. Y.H. Koo and K. Synder, 28 Dec.1989. — 1 ex. (ZRC 1990.15105), Sime Road, 17 Apr.1990. — 1 ex. (ZRC 1990.16996), Nee Soon Freshwater Swamp Forest, coll. H.K. Lua, 7 Jun.1990. — 1 ex. (ZRC 1990.17462), Bukit Timah Nature Reserve, 28 Aug.1990. Shell width: 22.20-48.60 mm; shell height: 13.65-32.90 mm.

Diagnosis. - Shell dextral, low conical, translucent in small specimens and opaque in large shells. Distinct radial striae intersected by faint, irregular spiral striae. Dark red or brown ring at the shell periphery but is sometimes not observed in small specimens (shell width < 27 mm). Shell acutely keeled in small specimens but angulation is reduced in larger specimens.

Remarks. - The type locality of *Hemiplecta humphreysiana* is Singapore. A common and abundant species that is restricted to Singapore forests. Often found on logs covered with algae.

SUBFAMILY PARMARIONINAE

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Genus Microparmarion Simroth, 1893

Microparmarion strubelli Simroth, 1893

Microparmarion strubelli - van Benthem Jutting, 1950: 441-442, Figs. 59-61 (Indonesia: Java); Lim, 1969: 77-78, Pl. 12, Fig. 5 (Singapore).

Material examined. - 1 ex., Seletar Reservoir, forest, coll. Quek Kian Chye, 27 May.94.

Diagnosis. - Shell reduced to a small yellow horny plate into which the animal cannot withdraw. Shell comprises one whorl.

Remarks. - Only one juvenile *M. strubelli* was found during the present study and was preserved by the collector before the animal was studied alive. Identification of the animal was based on the shell.

Genus Parmarion Fischer, 1855

Parmarion martensi Simroth, 1893

Parmarion martensi - van Benthem Jutting, 1950: 438, Fig. 54 (Indonesia: Java); Lim, 1969: 74-75, Pls. 11A, B (Singapore); Berry, 1974: 159, Pl. 2b (Peninsular Malaysia).

Material examined. - 3 ex. (ZRC 1990.1394-1396), Lim Chu Kang, on banana leaves, 14 Jan.1990. — 2 ex. (ZRC 1990.1397-1398), Fort Canning Park, Jan.1990. — 6 ex. (ZRC 1990.1380-1385), Lim Chu Kang, on banana and cocoyam leaves, 14 Jan.1990. — 1 ex. (ZRC 1990.1399), Fort Canning Park, under rock, 24 Jan.1990. — 1 ex. (ZRC 1990.1402), Sungei Tengah Road, 25 Dec.1989. — 1 ex. (ZRC 1990.1404), Tanjong Rhu, on papaya stem, 17 Jan.1990. Slug width: 5.70-7.25 mm, slug length: 21.15-39.00 mm.

Diagnosis. - Shell reduced to a yellow oval plate into which the animal cannot withdraw. Shell is surrounded by a mantle lobe on the dorsal surface of the animal and has no trace of a spiral whorl. Notum greyish-brown. As the external features of *Parmarion pupillaris* and *P. martensi* are similar, *P. martensi* is identified by its long dart gland and short dart (van Benthem Jutting, 1952, p. 439, fig. 54).

Remarks. - Parmarion martensi is a common slug that is both ground-dwelling and arboreal. Often shelters under decaying leaves and fruits of banana, jackfruit and papaya. Also found on tree-trunks and leaves of similar trees in plant nurseries, wasteland and gardens.

Parmarion pupillaris Humbert, 1864

Parmarion pupillaris - Paravinci, 1922: 26, Fig. 3 ('Deli').
Parmarion reticularis - van der Meer Mohr, 1928: 3-5, Pl. 1, Fig. 3 ('Deli').
Parmarion pupillaris - van Benthem Jutting, 1950: 435-438, Figs. 48-53 (Indonesia: Java); van Benthem Jutting, 1959: 159 (Indonesia: Sumatra); Lim, 1969: 70-74, Pl. 10 (Singapore).

Material examined. - Not found in the present study.

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SUBFAMILY GIRASIINAE

Genus Mariaella Gray, 1855

Mariaella dussumieri Gray, 1855

Mariaella dussumieri - Webb, 1898: 153, Pl. 9, Figs. 1-6 (India, Sri Lanka); Blandford & Godwin-Austen, 1908: 205-206, Figs. 71A-C (India, Sri Lanka); Lim, 1969: 91-93, Pl. 16 (Singapore).

Material examined. - 4 ex. (ZRC 1990.17006-17009), Ayer Rajah Expressway, grass patch, 31 Dec.1990, coll. H.K. Lua.—1 ex. (ZRC 1990.17010), Ayer Rajah Expressway, grass hedge, coll. H.K Lua, 31 Dec.1990. — 1 ex. (ZRC 1990.17011), Ayer Rajah Expressway, grass hedge, coll. H.K. Lua, 26 Dec.1990. Slug length: 28.05-40.30 mm; shell width: 6.15-9.45 mm.

Diagnosis. - Shell reduced to an oval calcareous plate that is completely embedded within the mantle. Ground colour dull ochre-brown with irregular black blotches.

SUBFAMILY DYAKIINAE

Genus Dyakia Godwin-Austen, 1891

Dyakia sp.

Material examined. - 1 ex. (ZRC 1990.17398), Nee Soon Freshwater Swamp Forest, coll. H.K. Lua, 23.Nov.1990. Shell width: 29.40 mm, shell height: 17.40 mm.

Diagnosis. - Shell sinistral, low conical, sutures shallow, keel prominent. Shell colour brown.

Remarks. - This species was described by Lim (1969) as Dyakia janus. However, more work needs to be done on this species as D. janus is restricted to Borneo (Laidlaw, 1963).

Dyakia (Quantula) striata (Gray, 1834)

Nanina naninoides - Tenison-Woods, 1888: 201 (Singapore).
Xestina striata - Laidlaw, 1933: 226 (Peninsular Malaysia).
Hemiplecta striata - van Benthem Jutting, 1949: 70 (Singapore); van Benthem Jutting, 1950: 444-446, Figs. 63,64 (Indonesia: Java).
Quantula striata - van Benthem Jutting, 1960 (Singapore).
Nanina striata - Lim, 1969: 67-69, Pls. 9A,B (Singapore).
Quantula striata - Berry, 1974: 159, Fig. 26 (Peninsular Malaysia).

Material examined. - 6 ex. (ZRC 1990.1313-1318), Woodlands, near railway track, on the ground, 11 Nov.1990. - 2 ex. (ZRC 1990.1319-1320), Bukit Timah, plant nursery, near Institute of Education, 17 Feb.1990. — 1 ex. (ZRC 1990.1329), outside Botanic Gardens, grass hedge, 19 Jan.1990. — 1 ex. (ZRC 1990.1330), Lorong Malai, wasteland, on decaying leaf, 11 Jan.1990. - 3 ex. (ZRC 1990.1331-1333), Fort Canning Park, 24 Jan.1990. 3 ex. (ZRC 1990.1334-1336), Sembawang, Lorong Gambas, beneath banana leaves, 10 Dec. 1989. - 2 ex. (ZRC 1990.1337-1338), Kent Ridge, National University of Singapore, base of banana leaves, 28 Dec. 1989. - 4 ex. (ZRC 1990.1339-1342), Woodlands Road, near railway track, 11 Jan.1990. — 1 ex. (ZRC 1990.1344), Lim Chu Kang, 14 Jan.1990. — 1 ex. (ZRC 1990.1348), Fort Canning Park, 24 Jan.1990. — 2 ex. (ZRC 1990.1387-1388), Kent Ridge, National University of Singapore, base of banana trees, 28 Dec. 1989. - 2 ex. (ZRC 1990.14327-14328), Sungei Buloh, under plastic shelter beside fish ponds, coll. H.K. Lua, 18 Nov.1990. - 4 ex. (ZRC 1990 16800-16803), Hindhede Drive, coll. H.K. Lua, Dec. 1989. — 1 ex. (ZRC 1991.20052), Kent Ridge, coll. W.Y. Chang, Jan. 1991. - 1 ex. (ZRC 1992.7), Hindhede Lane, shrubs, coll. H.K. Lua, Jan.1990. — 9 ex. (ZRC 1992.1223-1231), Kent Ridge, National University of Singapore, coll. S.H. Chan, 12 Jun. 1991. — 2 ex. (ZRC 1992.1233-1234), Kent Ridge, National University of Singapore, coll. S.H. Chan, 12 Jun.1991. Shell width: 5.85-24.80 mm, shell height: 3.40-15.30 mm.

Diagnosis. - Shell dextral, low conical, whorls rounded with a keel, shell sculpture with numerous radial striae. Shell colour dull yellow to brown on the upper surface and off-white underneath.

Remarks. - A common species that inhabits gardens, roadside vegetation and wastelands. Dyakia (Quantula) striata is the only known land snail that is capable of bioluminescence (Haneda, 1946).

SUBFAMILY MACROCHLAMYDINAE

Genus Macrochlamys Benson, 1832

Macrochlamys resplendens (Philippi, 1846)

Macrochlamys (Sarika) resplendens - Laidlaw, 1933: 219 (Peninsular Malaysia).

Sarika resplendens - van Benthem Jutting, 1949: 65 (Peninsular Malaysia); Berry, 1963: 14, Fig. 60 (Peninsular Malaysia).

Macrochlamys resplendens - Lim, 1969: 86-88, Pls. 15A, B (Singapore).

Macrochlamys (Sarika) resplendens - Berry, 1974: 157-159, Pl. 2a, Fig. 24 (Peninsular Malaysia).

Material examined. - 1 ex. (ZRC 1990.1349), Sungei Tengah Road, off Choa Chu Kang Road, 25 Dec.1989. — 3 ex. (ZRC 1990.1350-1352), Lorong Malai, off Woodlands Road, 11 Jan.1990. — 1 ex. (ZRC 1990.1355), Tyersall Road, outside Botanic Gardens, among weeds, Jan.1990. — 1 ex. (ZRC 1990.1356), Woodlands Road, under a plank, 11 Jan.1990. — 1 ex. (ZRC 1990.1357), Woodlands Road, grass hedge, 3 Feb.1990. — 3 ex. (ZRC 1990.1358-1360), Pasir Ris Drive 6, 11 Mar.1990. — 1 ex. (ZRC 1990.1361), Bukit Timah, plant nursery, near Institute of Education, 17 Feb.1990. — 4 ex. (ZRC 1990.1362-1365), Amber Road, wasteland, in leaf litter, 4 Feb.1990. — 2 ex. (ZRC 1990.1366-1367), Labrador Villa Road, under banana leaf, 6 Jan.1990. — 1 ex. (ZRC 1990.1368), Woodlands Road, near railway track, 11 Jan.1990. — 2 ex. (ZRC 1990.1371-1372), Sungei Tengah Road, on cocoyam leaves, 5 Dec.1989. — 1 ex. (ZRC 1990.17180), Pasir Ris Drive 6, 11 Mar.1990. — 2 ex. (ZRC 1990.17195-17196), Woodlands Road, beside railway track. — 1 ex. (ZRC 1992.3024), Bedok South Avenue 1, wasteland, 3 Feb.1990. Shell width: 2.15-20.85 mm, shell height: 2.10-15.50 mm.

Diagnosis. - Shell dextral, non-operculate, low conical, almost flat, glossy, translucent. Shell with many fine radial striae. Shell brown.

Remarks. - Common in gardens, plant nurseries, wasteland and roadside vegetation.

Genus Microcystina Morch, 1872

Microcystina sp.

Material examined. - 8 ex. (ZRC 1990.1272-1279), Tanjong Rhu, wasteland, on decaying leaf litter, 17 Jan.1990. — 4 ex. (ZRC 1990.1280-1283), Bedok South Avenue 1, attached to dry bamboo leaves on the ground, 3 Feb.1990. — 1 ex. (ZRC 1990.1284), Hindhede Drive, resting beneath coconut husk, 8 Feb.1990. — 3 ex. (ZRC 1990.1285-1287), Woodlands Road, near Bukit Panjang, on decaying vegetation, 11 Jan.1990. — 5 ex. (ZRC 1990.1288-1292), Sungei Tengah Road, on leaf litter, 25 Dec.1989. — 2 ex. (ZRC 1990.1293-1294), Pasir Ris Drive 6, on decaying cocoyam leaves resting on ground, 11 Mar.1990. — 1 ex. (ZRC 1990.1461), Bedok, on dead bamboo leaf, 4 Feb.1990. — 2 ex. (ZRC 1990.14441-14442), Sungei Buloh, in decaying plant matter, coll. H.K. Lua, 18 Nov.1991. — 3 ex. (ZRC 1991.19258-19260); Airport Road, wasteland, leaf litter, Feb.1991. — 7 ex. (ZRC 1992.3102-3108), Jurong Lake, under coconut husks, 28 Apr.1991. Shell width: 3.00-5.70 mm; shell height: 1.90-5.60 mm.

Diagnosis. - Shell dextral, yellow to brown, glossy, thin and transparent. The shell is globose conic without any trace of a keel. On the upper and lower surfaces spiral striae are closely spaced and distinct at 24 times magnification.

Remarks. - Microcystina sp. was found throughout Singapore. The animals are extremely active and fast-moving; and they prefer the soft decaying leaves of papaya, cocoyam and banana. The specific status of *Microcystina* sp. was not verified by Lim (1969). However, her description of *Microcystina* sp. and the specimens found during the present survey appear to be similar.

SUPERFAMILY VITRINOIDEA

FAMILY TROCHOMORPHIDAE

Genus Trochomorpha

Trochomorpha sp.

Trochomorpha sp. - Lim 1969: 94, Pl. 17 (Singapore).

Material examined. - Not found in the present study.

Diagnosis. - The identity of *Trochomorpha* sp. was not verified by Lim (1969).

SUPERFAMILY CAMAENOIDEA

FAMILY CAMAENIDAE

Genus Amphidromus Albers, 1850

Amphidromus atricallosus (Gould, 1843)

Amphidromus atricallosus - Pilsbry, 1900: 165-166 (Mynamar, Peninsular Malaysia). Amphidromus atricallosus - Laidlaw & Solem, 1961: 530-531 (Peninsular Malaysia, Thailand). Amphidromus attricallous - Lim, 1969: 98-99, Pls. 18A,B (Singapore).

Amphidromus atricallosus - Basch & Solem, 1971: 94 (Peninsular Malaysia).

Material examined. - 1 ex. (ZRC 1990.10741), Nee Soon Freshwater Swamp Forest, leaf litter in open scrubland, coll. K. Lim, 9 May.1990.

Diagnosis. - Shell dextral or sinistral, thin, pyramidal with shallow sutures, polished with porcellaneous lustre in live specimens. Shell lemon-yellow to white, occasionally with a narrow white sub-sutural band. Small shells with angulation at shell periphery, larger specimens rounded. Lip white, thickened and reflected in large specimens but absent in small shells.

Remarks. - Amphidromus atricallosus is restricted to the forest at the Central Water Catchment. The species is said to be arboreal but the animals are usually sighted on artifacts such as concrete and pipelines, possibly due to better visibility. Amphidromus atricallosus has also been seen at Bukit Timah Nature Reserve.

Amphidromus inversus (Müller, 1774)

Helix inversus - Müller, 1774: 93 (No locality).

Bulimus inversus - Martens, 1867: 337 (Locality unknown); Tenison-Woods, 1888: 231 (Peninsular Malaysia, Singapore, Thailand).

Amphidromus inversus - Pilsbry, 1900: 167, Pl. 56, Figs. 91, 92 (Sumatra, Indonesia, Singapore); van Benthem Jutting, 1959: 163 (Sumatra, Indonesia).

Amphidromus inversus inversus - Laidlaw and Solem, 1961: 560 (near Singapore).

Amphidromus inversus - Lim, 1969: 99-102 (Singapore).

Material examined. - 1 ex. (ZRC 1994.4117), Botanic Gardens, coll. E.R. Alfred, 20 Oct.92. Shell width: 24.25 mm, shell height: 43.50 mm.

Diagnosis. - Shell dextral or sinistral, pyramidal, thick, beige with longitudinal brown bands of variable thickness. Peristome white, thickened and reflected with a white parietal callus. Lower half of the body whorl tinged brown.

Amphidromus perversus (Pfeiffer, 1852)

Amphidromus melanomma - de Morgan, 1885: 39 (Locality unknown).

Bulimus melanomma - Tenison-Woods, 1888: 231 (Singapore, Borneo).

Bulimus mundus - Tenison-Woods, 1888: 231 (Singapore).

Amphidromus melanomma - Moellendorff, 1891: 336 (Singapore, Peninsular Malaysia, Borneo).

Amphidromus perversus - Pilsbry, 1900: 179 (Peninsular Malaysia, Thailand, Singapore).

Amphidromus perversus melanomma - Laidlaw and Solem, 1961: 640 (Rhiu archipelago, Peninsular Malaysia, Singapore).

Material examined. - Not found in the present study.

Remarks. - Laidlaw et al. (1961) suggested that the species could have been introduced to Singapore.

SUPERFAMILY HELICOIDEA

FAMILY BRADYBAENIDAE

Genus Bradybaena Beck, 1837

Bradybaena similaris (Ferussac, 1821)

Bradybaena similaris - Laidlaw, 1933: 231 (Peninsular Malaysia); van Benthem Jutting, 1950: 501, Fig. 105 (Indonesia: Java); van Benthem Jutting, 1959: 166 (Indonesia: Sumatra); Berry, 1963: 14, Pl. X, Fig. 69 (Peninsular Malaysia); Lim, 1969: 103-107, Pl. 19 (Singapore); Berry, 1974: 161, Fig. 27 (Peninsular Malaysia).

Material examined. -6 ex. (ZRC 1990.1450-1455), Thomson Road, plant nurseries, in flower pots, 23 Dec.1989. — 2 ex. (ZRC 1990.1456-1457), East Coast Park, Bird Sanctuary, 29 Jan.1990. — 1 ex. (ZRC 1990.1458), Woodlands Road, near Bukit Panjang junction, 11 Nov.1990. — 5 ex. (ZRC 1990.1459-1463), Sungei Tengah Road, wasteland, leaf litter, 25 Dec.1990. — 2 ex. (ZRC 1990.1464-1465), Woodlands Road, near railway track, 11 Jan.1990. — 1 ex. (ZRC 1990.1466), Tanjong Rhu, wasteland, 17 Jan.1990. — 1 ex. (ZRC 1990.1467), Bedok, 3 Feb.1990. — 1 ex. (ZRC 1990.1466), Woodlands Road, 11 Jan.1990. — 4 ex. (ZRC 1990.1470-1473), Bedok South Avenue 1, 3 Feb.1990. — 3 ex. (ZRC 1990.1475-1477), Lorong Malai, Woodlands, 11 Jan.1990. — 3 ex. (ZRC 1990.1479-1481), St. John's Island, leaf litter, 3 Mar.1990. — 1 ex. (ZRC 1990.1482), Amber Road, wasteland, 4 Feb.1990. — 1 ex. (ZRC 1990.1483), Lim Chu Kang Road, 14 Jan.1990. — 2 ex. (ZRC 1990.1484-1485), Bukit Timah, plant nursery, Dec.1989. — 2 ex. (ZRC 1990.1486-1487), Pasir Ris Drive 6, on weeds, 10 Mar.1990. — 1 ex. (ZRC 1990.1491), Bedok South, 3 Feb.1990. Shell width: 2.85-13.45 mm, shell height: 1.80-7.95 mm.

Diagnosis. - Shell globular, with moderately elevated spire. Whorls increase regularly with size. Shell straw-coloured or brown, sometimes with a red or brown peripheral band.

Remarks. - A very common and abundant snail that is both ground-dwelling and arboreal.

DISCUSSION

Thirty-nine species of land snails are listed in the present checklist, comprising species that were recorded by Sowerby (1843), Tenison-Woods (1888), Moellendorff (1891), Jarrett (1923, 1949), Laidlaw (1928, 1933), Rensch (1934), van Benthem Jutting (1949, 1961), Zilch (1956), Mead (1961), Lim (1969) and species that were collected during the present study. A total of 32 land-snail species, representing 26 genera and 12 families, were found during the present survey.

Current results show that the Ariophantidae is the largest snail family recorded in Singapore with a total of seven species, followed by the Helixarionidae with six species. Twelve landsnail species from five families are recorded for the first time in Singapore. They are *Ditropis* cf. koperbergi Zilch (Cyclophoridae), Lamellaxis gracilis (Hutton), Lamellaxis clavulinus (Potiez & Michaud), Opeas pumilum (Pfeiffer), Prosopeas tchehelense (De Morgan) (Subulinidae), Filicaulis alte (Simroth) (Veronicellidae), Succinea minuta Martens (Succineidae), Liardetia doliolum (Pfeiffer), Liardetia samoensis (Mousson), Liardetia indifferens (Boettger), Liardetia convexoconica (Moellendorff) and Wilhelminaia mathildae Preston (Helixarionidae).

Nine land-snail species were previously recorded in Singapore but were not found in the present survey. The species include Cyclophorus semisulcatus (Sowerby), Cyclophorus borneensis (Metcalf), Cyclophorus (perdix) tuba (Sowerby) (Cyclophoridae), Vaginula variegatula Simroth (Veronicellidae), Opeas didyma Westerlund (Subulinidae), Parmarion pupillaris Humbert, Hemiplecta cymatium (Pfeiffer) (Ariophantidae), Trochomorpha sp. (Trochomorphidae) and Amphidromus perversus (Pfeiffer) (Camaenidae).

Singapore land snails were collected from forests, public parks, private gardens, plant nurseries, wastelands including unkempt roadside vegetation. The majority of species, e.g., Subulina octona (Bruguiere), Achatina fulica Bowdich (Achatinidae) and Bradybaena similaris (Ferussac) (Bradybaenidae) were found near human inhabitation such as East Coast Park and at a plant nursery at Bukit Timah. The remaining ten species were forest species that were located in the Botanic Gardens' Jungle and the Central Catchment Area (Bukit Timah Nature Reserve and Nee Soon Freshwater Swamp Forest). The species included Cyclophorus perdix (Sowerby), Cyclotus rostellatus (Pfeiffer), Ditropis cf. koperbergi Zilch and Japonia (Lagochilus) ciliocinctum (Martens) (Cyclophoridae), Diplommatina nevilli Crosse (Diplommatinidae), Microparmarion strubelli Simroth, Hemiplecta humphreysiana (Lea), Dyakia sp. (Ariophantidae), Amphidromus atricallosus (Gould) and Amphidromus inversus (Müller) (Camaenidae). Because land-snail species located near human inhabitation (urbanised species) are more accessible and readily sighted than their forest counterparts, the snails were therefore better known and documented. One such species, Subulina octona was found to be the most common and abundant land snail in Singapore. Other urbanised species such as Achatina fulica, Dyakia (Quantula) striata (Gray), Macrochlamys resplendens (Philippi) and Bradybaena similaris are also widespread and abundant in Singapore. In contrast, snails that were only found in forests are extremely restricted in distribution and exist as isolated pockets in Singapore. They are also extremely rare. For instance, only one specimen of Cyclotus rostellatus was found at Nee Soon Freshwater Swamp Forest during the present study.

Favourable snail habitats in Singapore are moist, decaying leaf litter with an underlying layer of soil in which snails can aestivate during dry weather. Huge numbers of *Subulina octona* (Subulinidae) can be found under such conditions. However, most species such as *Liardetia doliolum* (Helixarionidae) show no preference for any size or species of leaf, and most snails were only found on brown decaying leaves.

Endemic land-snail species are not known in Singapore. Land snails recorded in Singapore, e.g., Cyclotus rostellatus and Filicaulis alte are also found in neighbouring countries such as Indonesia and Peninsular Malaysia. Snail introductions were not observed in the Malay Peninsula in 1888 (Tenison-Woods, 1888). Achatina fulica was introduced in Singapore in 1922 (Jarrett, 1923). Recent introductions include four new records, i.e., Lamellaxis clavulinus, Opeas pumilum, Prosopeas tchehelense and Wilhelminaia mathildae. Lamellaxis clavulinus originated from tropical East Africa (Kerney et al., 1987), whereas Opeas pumilum originated from tropical Central America (Kerney et al., 1987). Prosopeas tchehelense was recorded in the limestone hills in West Malaysia (van Benthem Jutting, 1949), and the snail population in Singapore was almost certainly carried in with ornamental plants. Wilheminaia mathildae was first reported from Beilan-Beilan from Moluccas by Preston (1913). Subsequently, specimens were found in the Caroline Islands and Java (Baker, 1941; van Benthem Jutting, 1950) where it probably spread to Singapore through human introduction. Apart from Lamellaxis clavulinus, these species introductions were of small and isolated populations. Because of limited mobility, there is little likelihood that they will be readily dispersed.

The results of these surveys are obviously only preliminary and qualitative. Little is known about the biology and distribution of snails within the forest. More work is needed to provide information on the current status of these species, and field surveys are presently being undertaken by the staff of the National Parks Board and Zoological Reference Collection in the Central Catchment Area in Singapore to ascertain its forest fauna.

ACKNOWLEDGEMENTS

I thank Mrs C.M. Yang and her staff of the Zoological Reference Collection, National University of Singapore for providing facilities and assistance during the project. I thank Professor Fred G. Thompson of the University of Florida at Gainesville and Dr Ronald Janssen of the Senckenberg Museum at Frankfurt for identifying specimens. In addition, I am grateful to Dr Jon B. Sigurdsson of the Department of Zoology, National University of Singapore for reviewing the manuscript, and the National Parks Board for allowing specimens from the National Parks to be collected for this paper.

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Received 18 Jul 1994 Accepted 9 Dec 1994