

TERRESTRIAL EARTHWORMS (OLIGOCHAETA) FROM SINGAPORE

Huei-Ping Shen

Habitat and Ecosystem Division, Taiwan Endemic Species Research Institute, Chichi, Nantou, Taiwan
Email: shenhp@tesri.gov.tw

Darren C. J. Yeo

Department of Biological Sciences, National University of Singapore, 10 Kent Ridge Crescent, Singapore 119260
Email: darrenyeo@nus.edu.sg

ABSTRACT. – In 2003, we conducted a field survey of terrestrial earthworms of the island of Singapore, and also examined the earthworm collections preserved in the Zoological Reference Collection (ZRC) of the Raffles Museum of Biodiversity Research, National University of Singapore. This paper describes a new species *Glyphidrilus singaporensis*, and adds four new records, *Glyphidrilus horsti* Stephenson, 1930, *Amyntas gracilis* (Kinberg, 1866), *Amyntas minimus* (Horst, 1893), and *Polypheretima taprobanae* (Beddard, 1892), and three unidentifiable *Drawida* species to Singapore's earthworm fauna. These make a total of 19 species of terrestrial earthworms that are now known from the island. In our survey, pheretimoid earthworms made up about half of the total number of the species, while the exotic *Pontoscolex corethrurus* (Müller, 1856) was the most dominant species. A key to terrestrial earthworm species from Singapore is included. The opportunity is also taken here to describe a new species from the Malay Peninsula, *Glyphidrilus gatesi*, based on preserved specimens in the historical collections of the ZRC.

KEY WORDS. – Earthworms, checklist, new species, new records, Singapore.

INTRODUCTION

Terrestrial earthworms of Singapore have been rarely investigated. Prior to this study, only three surveys were conducted in the 1930s (Stephenson, 1932; Gates, 1935, 1937). Stephenson (1932) first reported three species of terrestrial earthworms, *Lampito mauritii* Kinberg, 1866 [as a *Megascolex* species], *Amyntas morrisoni* (Beddard, 1892) [misidentified as "*Pheretima hawayana*"] and *Metaphire peguana* (Rosa, 1890) [as a *Pheretima* species], from the island. Gates (1935) subsequently listed seven species from the island, of which four were newly recorded: *Pheretima darnleiensis* (Fletcher, 1886) [as "*Pheretima indica*", an invalid name], *Dichogaster saliens* (Beddard, 1892), *Ocnodrilus occidentalis* Eisen, 1878, and *Pontoscolex corethrurus* (Müller, 1856). Gates (1937) added four more species: *Amyntas procerus* (Gates, 1937), *Metaphire arcuata* (Gates, 1937), and *Metaphire houlleti* (Perrier, 1872) [all as *Pheretima* species], and *Perionyx violaceus* Horst, 1893, collected from Bukit Timah, Singapore. Accordingly, a total of 11 species of earthworms were reported from Singapore from 1932 to 1937 (Table 1). They consisted of two native species, *A. procerus* and *M. arcuata*, and nine peregrine or exotic species. According to Gates (1972), the male terminalia of *M. arcuata* from Singapore and *Metaphire lorella* (Gates, 1936) from Burma [=Myanmar] are similar, and thus, the former might be a parthenogenetic morph of the latter, but

presently there is little reason for suspecting their relationship because both species were represented only by type specimens.

In 2003, together with staff of the Zoological Reference Collection (ZRC) of the Raffles Museum of Biodiversity Research, National University of Singapore, we conducted a survey of Singapore terrestrial earthworm fauna. Fresh material was collected from selected representative sites in Singapore (see Materials and Methods). This paper serves to report the findings of this survey in which 15 species belonging to seven genera, four families and two orders of terrestrial earthworms are recorded from Singapore (see Table 2). Of interest are the description of one new species, *Glyphidrilus singaporensis*, and four new records for Singapore, viz., *Glyphidrilus horsti* Stephenson, 1930, *A. gracilis* (Kinberg, 1866), *Amyntas minimus* (Horst, 1893) and *Polypheretima taprobanae* (Beddard, 1892). Pheretimoid earthworms made up about half of the total number of the species; while the exotic *P. corethrurus* was the most dominant species. Seven species previously reported from Singapore by Stephenson (1932) and Gates (1935, 1937) were not recorded in the present study. They are *A. procerus*, *L. mauritii*, *M. arcuata*, *M. houlleti*, *M. peguana*, *D. saliens*, and *O. occidentalis* (cf. Table 1). To date, therefore, a total of 16 nominal species and three unidentifiable *Drawida* species of terrestrial earthworms have been reported from Singapore.

Table 1. Terrestrial earthworms reported from Singapore.

Species	Stephenson (1932)	Gates (1935)	Gates (1937)	Present study
<i>Pontoscolex corethrurus</i> (Müller, 1856)		+	+	+
<i>Glyphidrilus horsti</i> Stephenson, 1930				+
<i>Glyphidrilus singaporensis</i> , new species				+
<i>Amyntas gracilis</i> (Kinberg, 1866)				+
<i>Amyntas minimus</i> (Horst, 1893)				+
<i>Amyntas morrissi</i> (Beddard, 1892)*	+	+		+
<i>Amyntas procerus</i> (Gates, 1937)			+	
<i>Lampito mauritii</i> Kinberg, 1866	+	+		
<i>Metaphire arcuata</i> (Gates, 1937)			+	
<i>Metaphire houlleti</i> (Perrier, 1872)			+	
<i>Metaphire peguana</i> (Rosa, 1890)	+	+	+	
<i>Perionyx violaceus</i> Horst, 1893			+	+
<i>Pheretima darnleiensis</i> (Fletcher, 1886)**		+	+	+
<i>Polypheretima taprobanae</i> (Beddard, 1892)				+
<i>Dichogaster saliens</i> (Beddard, 1892)		+		
<i>Ocnerodrilus occidentalis</i> Eisen, 1878		+		
<i>Drawida</i> sp. 1				+
<i>Drawida</i> sp. 2				+
<i>Drawida</i> sp. 3				+

* Listed by Stephenson (1932) and Gates (1935) as *Pheretima hawayana*.

** Listed by Gates (1935, 1937) as *Pheretima indica*.

In addition to the fresh specimens from our survey, the terrestrial earthworm collection in the Zoological Reference Collection (ZRC) of the Raffles Museum of Biodiversity Research was also examined and reappraised to supplement the present study. In the course of re-examining the preserved material, one historical lot of specimens collected in the 1930s from the Malay Peninsula was found to be a new species, named herein as *Glyphidrilus gatesi*. In addition, “*Pheretima hawayana*” listed by Stephenson (1932) is found to be a mis-identification, and the reported specimens are instead *A. morrissi*.

MATERIALS AND METHODS

The authors and ZRC staff conducted terrestrial earthworm surveys on the island of Singapore from 3-14 March 2003. The junior author and museum staff made two further collections on 18 March and 25 June 2003. In addition, two specimens of *P. darnleiensis* were collected from Bukit Timah by Benjamin Lee on 5 March 2003. A total of 329 specimens were collected from the following eight localities (see also Table 2):

Locality 1 – Jungle Fall Valley in Bukit Timah Nature Reserve: a small valley with muddy bottom saturated with water and surrounded by lowland evergreen forest. Most earthworms were collected from muddy soil in the valley, and a few were from a roadside slope surrounding the valley.

Locality 2 – Rifle Range Road opposite Murnane Reservoir: a grass field near forest margin. Earthworms were collected from soil under water pipeline.

Locality 3 – Upper Seletar Reservoir Park outside Nee Soon Rifle Range. Earthworms were collected from underbrush.

Locality 4 – Sungei Buloh Wetland Reserve: a nature park covered mainly with mangroves. Earthworms were collected from black, muddy soil under mangroves in the areas not flooded by sea water, and from gardening lots around houses.

Locality 5 – Kranji Wireless Station: a roadside ditch along the Turut Track.

Locality 6 – Kent Ridge Campus of National University of Singapore. Earthworms were collected from gardening lots alongside buildings.

Locality 7 – Singapore Botanic Gardens Jungle: a small area covered with tropical rainforest.

Locality 8 – Nee Soon freshwater swamp forest. Earthworms were collected from soil under water pipeline.

The earthworms collected were anesthetized in a 20% ethyl alcohol-water solution, fixed in a 10% formalin-water solution and preserved in a 70% ethyl alcohol-water solution. They were deposited at the Zoological Reference Collection (ZRC) of the Raffles Museum of Biodiversity Research, Department of Biological Sciences, National University of Singapore.

The following earthworm specimens were also examined: one catalogued lot (ZRC 1974.12.2.51-62), and one uncatalogued lot from ZRC; one *A. gracilis* specimen received by the senior author in 1999; and one *P. darnleiensis* specimen collected by H. H. Tan on 13 February 2003. All these specimens were from Singapore, except the catalogued ZRC material of 12 *Glyphidrilus* specimens that were collected from Malaysia in February 1937. The uncatalogued ZRC material was an amputated *P. violaceus* specimen collected from Bukit Timah, Singapore by H. K. Lua on 19 March 1989. Measurements

Table 2. Earthworms collected from Singapore, March and June 2003.

Species	Localities								Number	
	Bukit Timah Nature Reserve	Rifle Range Rd.	Upper Seletar Reservoir Park	Sungei Buloh Wetland Reserve	Kranji Wireless Station	Kent Ridge NUS Campus	Singapore Botanic Gardens	Nee Soon swamp forest	Localities	Specimens
Glossoscolecidae										
1. <i>Pontoscolex corethrurus</i>	2	59	33	41	21	5	33	25	8	219
Microchaetidae										
2. <i>Glyphidrilus horsti</i>					3				1	3
3. <i>Glyphidrilus singaporensis</i> , new species	12							4	2	16
4. <i>Glyphidrilus</i> sp. 1*			2						1	2
5. <i>Glyphidrilus</i> sp. 2*		2							1	2
Megascolecidae										
6. <i>Amyntas gracilis</i>		2							1	2
7. <i>Amyntas minimus</i>		1		1		22			3	24
8. <i>Amyntas morrisi</i>		21		5	1	2			4	29
9. <i>Amyntas</i> sp.*						1			1	1
10. <i>Perionyx violaceus</i>		1							1	1
11. <i>Pheretima darnleiensis</i>	2	12					2		3	16
12. <i>Polypheretima taprobanae</i>							1		1	1
Moniligastridae										
13. <i>Drawida</i> sp. 1*		9	1						2	10
14. <i>Drawida</i> sp. 2*		2							1	2
15. <i>Drawida</i> sp. 3*					1				1	1
Number of species	3	9	3	3	4	4	3	2	—	—
Number of specimens	16	109	36	47	26	30	36	29	—	329

* Anonymous accliteller.

are in millimeters. Terminology used essentially follows Gates (1972) and Chen (1933).

LIST OF SINGAPORE EARTHWORMS

The 19 species of terrestrial earthworms, consisting of 16 nominal species and three unidentifiable *Drawida* species, from Singapore, were classified according to Reynolds & Cook (1993) for families, and to Gates (1972), Sims & Easton (1972) and Easton (1979) for genera.

Order Haplotaxida

Suborder Lumbricina

Superfamily Glossoscolecoidae

Family Glossoscolecidae

1. *Pontoscolex corethrurus* (Müller, 1856)

Family Microchaetidae

2. *Glyphidrilus horsti* Stephenson, 1930

3. *Glyphidrilus singaporensis*, new species

Superfamily Megascolecoidae

Family Megascolecidae

4. *Amyntas gracilis* (Kinberg, 1866)

5. *Amyntas minimus* (Horst, 1893)

6. *Amyntas morrisi* (Beddard, 1892)

7. *Amyntas procerus* (Gates, 1937)

8. *Lampito mauritii* Kinberg, 1866

9. *Metaphire arcuata* (Gates, 1937)

10. *Metaphire houlleti* (Perrier, 1872)

11. *Metaphire peguana* (Rosa, 1890)

12. *Perionyx violaceus* Horst, 1893

13. *Pheretima darnleiensis* (Fletcher, 1886)

14. *Polypheretima taprobanae* (Beddard, 1892)

Family Octochaetidae

15. *Dichogaster saliens* (Beddard, 1892)

Superfamily Ocnerodriloidae

Family Ocnerodrilidae

16. *Ocnerodrilus occidentalis* Eisen, 1878

Order Moniligastrida

Family Moniligastridae

17. *Drawida* sp. 1

18. *Drawida* sp. 2

19. *Drawida* sp. 3

In addition to the species in the above list, there were other unidentifiable immature specimens collected from Singapore. They were *Glyphidrilus* sp. 1 (two specimens), *Glyphidrilus* sp. 2 (two specimens) and *Amyntas* sp. (one specimen).

TAXONOMY

ORDER HAPLOTAXIDA

FAMILY GLOSSOSCOLECIDAE

Pontoscolex Schmarda

Pontoscolex corethrurus (Müller, 1856)

Lumbricus corethrurus Müller, 1856: 113.

Urochaeta hystrix Perrier, 1872: 142.
Urochaeta dubia Horst, 1885: 7.
Urochaeta corethrura – Rosa, 1889: 125.
Pontoscolex arenicola – Beddard, 1892c: 126.
Pontoscolex corethrurus – Beddard, 1892c: 127; Horst, 1893a: 328; 1893b: 51; Michaelsen, 1896: 197; 1897: 250; 1900: 425; 1922: 8; 1928: 9; 1932: 599; 1935: 101; Ude, 1905: 495; Stephenson, 1916: 349; 1930: 3; 1931: 283; 1932: 51; Gates, 1926b: 472; 1935: 93; 1937: 197; 1938: 221; 1949: 38; 1972: 54; Easton, 1984: 120.
Pontoscolex hawaiiensis – Beddard, 1896: 196.

Material examined. – 2 specimens (ZRC), Bukit Timah, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 5 Mar.2003; 57 specimens (ZRC), Rifle Range Rd. opposite to Murnane Reservoir, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 5 Mar.2003; 33 specimens (ZRC), Upper Seletar Reservoir Park outside Nee Soon Rifle Range, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 5 Mar.2003; 5 specimens (ZRC), Kent Ridge Campus of National University of Singapore, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 6 Mar.2003; 41 specimens (ZRC), Sungei Buloh, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 7 Mar.2003; 21 specimens (ZRC), Turut Track, Kranji Wireless Station, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 7 Mar.2003; 33 specimens (ZRC), Singapore Botanic Gardens, coll. K. K. P. Lim & K. L. Yeo, 11 Mar.2003; 25 specimens (1 dissected)(ZRC), Nee Soon swamp forest along pipeline, coll. K. L. Yeo, K. K. P. Lim & David Nasir, 18 Mar.2003; 2 mature specimens (ZRC), Rifle Range Rd. opposite to Murnane Reservoir, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 25 Jun.2003.

Description. – Body length (mature) 92-148 mm. Segments numbering 167-232. Prostomium lacking. Dorsal pores absent. Clitellum XIV, XV-XXII, length 3.98-6.73 mm, width 2.93-4.08 mm, saddle-shaped, setae present. Tubercula pubertatis longitudinal bands in XVIII-XXI, lateral to b. Head segments wider, secondary segmentation in postclitellar segments with an anterior non-setal annulet and a posterior setal annulet. Setae present from segment I, lumbricin (eight setae per segment), aa > bc, dd 0.5 body circumferences in the anterior portion of the body, gradually irregular and becoming quincunx towards the posterior end. Nephropores longitudinal, paired laterally in intersegmental furrows medial to c. Female pores, male pores and spermathecal pores not visible. Preserved specimens white, greyish brown around clitellum. Live worms without pigments, head portion pink, three pairs of bright yellow spots (calciferous glands) on lateral dorsum in front of clitellum when the head portion extended.

Septa 6/7-9/10 muscular, posteriorly directed. Gizzard in VI. Intestine enlarged from XV. Caecum absent. Three pairs of calciferous glands in VII-IX, oval shaped. Esophageal hearts in X-XI. Nephridia holoic, with a slender duct and a slightly enlarged distal end. Testes large in XV. Seminal vesicles one pair, follicular, flattened, extending from posterior portion of XV to XVII or anterior portion of XVIII. Prostate and accessory glands absent. Spermathecae three pairs in VII-IX, small, tubular, duct long, slender, ampulla 0.35-0.65 mm long, less than 0.2 mm in width, diverticulum absent.

Remarks. – *Pontoscolex corethrurus* is the most dominant earthworm in Singapore. A total of 219 worms, about 66.6% of the total specimens, were collected during the surveys in

March and June 2003 (see Table 2). There was a record of 231 worms collected in Bukit Timah alone in February 1936 (Gates, 1937). This exotic species is native to tropical America and the West Indies, and its pantropical distribution is due to successful colonization resulted from human transportation (Gates, 1972, 1973). The species was about the commonest among worms brought to Kew Gardens according to Beddard (Gates, 1972: 55). It was also a dominant earthworm in rubber plantations in Malaysia and Burma (Gates, 1972). It is possible that the large scale introduction of Para Rubber in the late 19th century into Southeast Asia might have accelerated the expansion of its range. According to Horst (1893b), *P. corethrurus* was already present in Singapore in the early 1890s. This species occurs throughout the year (Gates, 1926b, c).

FAMILY MICROCHAETIDAE

Glyphidrilus Horst

Remarks. – Gates (1972) stated that glyphidrilid earthworms dwell in habitats saturated with fresh water, and no species of *Glyphidrilus* is known to be anthropochorous. Only 16 nominal species and one anonymous species, *Glyphidrilus* sp. (Gates, 1938), have been reported for this genus. All the *Glyphidrilus* species are found in South or Southeast Asia except for one species in Africa. Of these, *Glyphidrilus malayanus* (Michaelsen, 1902) and the anonymous *Glyphidrilus* sp. (Gates, 1938) are from the Malay Peninsula, and *Glyphidrilus horsti* (Stephenson, 1930) is from Pulau Berhala, Straits of Malacca.

Because the internal characters of the *Glyphidrilus* species tend to be conservative, locations of wings and clitellum, and position and arrangement of genital papillae are characters often used for species distinction (Michaelsen, 1910; Gates, 1958). However, Gates (1972) regarded external genital characters as being subject to considerable individual variation so that their systematic usefulness is doubtful, and considered that more attention should be paid to somatic anatomy. Although Gates (1972) adopted digestive and vascular systems as the important diagnostic characters, the positions of genital markings and wings remained as important characters for species identification.

The *Glyphidrilus* specimens from Peninsular Malaysia in the ZRC (ZRC 1974.12.2.51-62), previously described by Gates (1938) as *Glyphidrilus* sp., are identified as a new species in this study. The present study also includes one new species, one new record, and four unidentifiable acitellate specimens of *Glyphidrilus* from Singapore.

Glyphidrilus gatesi, new species (Fig. 1)

Glyphidrilus sp. Gates, 1938: 221.

Material examined. – Holotype – 1 mature (clitellate), amputated specimen (dissected)(ZRC 1974.12.2.51), Sungei Kayu, swamp forest near River Sedili, Johore, Malaysia, Feb.1937.

Paratypes – 9 mature and 2 immature specimens (7 mature and 1 immature specimens amputated; one of the amputated mature specimens dissected by Gates with parts of the digestive tract and blood vessels removed) together with three body fragments in the bottle (ZRC 1974.12.2.52-62).

Description. – Length 46+ mm, segments numbering 65+ for holotype. For two intact mature specimens (one nearly broken between segment 42/43, the other macerated), 95 mm and 83 mm in length, and 122 and 119 in segment number. For the other seven amputated mature specimens, 34–65 mm in length, and 42–90 in segment number. Wing width for mature specimens 2.1–3.0 mm. For two acitellate specimens, 115 mm and 70 mm in length, and 262 and 157 in segment number. Prostomium zygalobous. Dorsal pores absent. Clitellum from XVII, 1/2XVII or XVIII to XXV, 1/2XXVI or XXVII. Wings lateral to b, from posterior XVIII or 18/19 to 1/2 XXIV, or entire segment XXIV. Setae paired, preclitellum: $aa = 2ab$, $bc = 1.47cd$, $aa = 0.88dd$; postclitellum: $aa = 2.57ab$, $bc = 2cd$, $aa = 0.62dd$. Preserved specimens brown in colour with yellowish clitellum.

Female pores inconspicuous on XIV, in line with b near 13/14 segmental furrow. Male pores and spermathecal pores not visible. Genital papillae postsetal (except one mature specimen with presetal genital papillae in XXIV–XXVI); lateral series paired or asymmetrical, lateral to b or medial to c on XV–XVIII, in line with b or lateral to b or medial to c on XXIV–XXVI; unpaired median series between aa on XIII–XIX and XXIV–XXVII; number and position variable among specimens. For 10 mature type specimens examined, prewing lateral papillae on XVII for 1 specimen, XVII–XVIII

for 4 specimens, XVI–XVIII for 1 specimen, XV–XVIII for 3 specimens, not recognizable for 1 macerated specimen; prewing median papillae absent from 1 specimen, present on XIII–XVIII for 1 specimen, XIV–XVII for 1 specimen, XIV–XVIII for 1 specimen, XIV–XIX for 1 specimen, XV–XVIII for 2 specimens, XV–XIX for 1 specimen, XVI–XVIII for 2 specimens; postwing lateral papillae on XXIV for 2 specimens, XXV for 1 specimen, XXIV–XXV for 1 specimen, XXIV–XXVI for 5 specimens, not recognizable for 1 macerated specimen; postwing median papillae absent from 4 specimens, present on XXIV for 1 specimen, XXIV–XXVI for 1 specimen, XXIV–XXVII for 2 specimens, XXV–XXVI for 1 specimen, not recognizable for 1 macerated specimen. Each papilla round, prewing papillae 0.4–0.5 mm and postwing papillae 0.3–0.35 mm in diameter.

Gizzard mainly in VIII. Intestine enlarged from XVIII. Dorsal blood vessel aborted anterior to segment IX. Hearts IX–XI. Nephridia holoic. Seminal vesicles four pairs in IX–XII: smallest in X, large in XI, and largest in XII occupying two segments. Testes shiny in X and XI. Prostate and accessory glands absent. Spermathecae sessile, elongated oval or globular, 0.35–0.45 mm long, three on each side per segment in XV–XVII.

Etymology. – The name “*gatesi*” is given to this species in honor of Dr. Gordon Enoch Gates who made great contributions to taxonomy and systematics of earthworms, particularly of South and Southeast Asia, and described the collection (ZRC 1974.12.2.51–62) as an anonymous species (*Glyphidrilus* sp.)(Gates, 1938).

Remarks. – For mature *Glyphidrilus* specimens, genital papillae are always present on the segments or adjacent segments where wings begin and end. The presence of genital papillae in the middle of the wing region is rare. Therefore, the position of genital papillae shows some association with location of wings. The presence or absence of median (medio-ventral) papillae has been used as one of the key characters for species identification (Gates, 1958; Chen & Xu, 1977), but this character is highly variable among individuals. For example, four of the 10 mature specimens of *G. gatesi* lack postwing median papillae. The position of wings is less variable among specimens as compared to genital papillae (Gates, 1958), and is perhaps a more reliable external character for species distinction (see Table 3).

Glyphidrilus gatesi, new species, is similar to *Glyphidrilus spelaotes* (Stephenson, 1924) from Assam, India in the location of wings (see Table 3). The position and arrangement of genital papillae are highly variable in both species so that they are not used for the distinction between the two species. *G. gatesi* has a clitellum from XVII or XVIII to XXV or XXVI, three pairs of hearts in IX–XI, and three spermathecae on each side per segment in XV–XVII, whereas *G. spelaotes* has a longer clitellum in XVI–XXX, four pairs of hearts in VIII–XI, and four to five spermathecae on each side per segment in XIV–XVI (see Table 3).

Glyphidrilus gatesi differs from *Glyphidrilus malayanus*

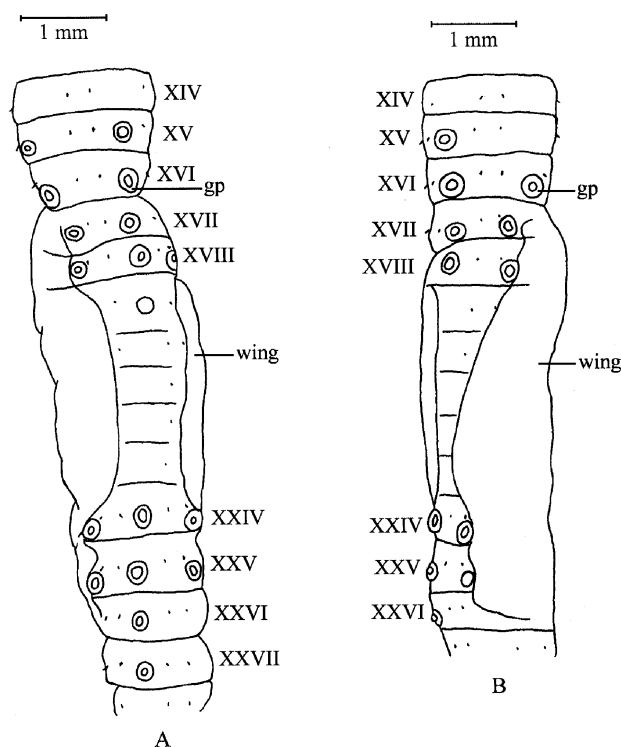


Fig. 1. *Glyphidrilus gatesi*, new species, holotype (46+ mm). A, right latero-ventral view of wings and genital papillae (gp); B, left lateral view of wings and genital papillae.

(Michaelsen, 1902), the only species of this genus reported from the Malay Peninsula, by having wings extending from XVIII or XIX to 1/2XXIV or XXIV, three spermathecae on each side in XV–XVII and four pairs of seminal vesicles in IX–XII, whereas the latter has wings from XVII or XVIII to 1/3XXI or 1/3XXII, spermathecae in XIV–XVI and two pairs of seminal vesicles in XI–XII (see Table 3).

Glyphidrilus horsti Stephenson, 1930

(Fig. 2)

Glyphidrilus horsti Stephenson, 1930: 4; 1931: 262.

Material examined. – 1 mature (clitellate) specimen (amputated and half-broken between segment 46/47, dissected) and 2 not fully matured specimens (1 amputated)(ZRC), Turut Track, Kranji Wireless Station, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 7 Mar.2003.

Description. – Length for amputated, dissected specimen 47.7 mm, and for the other two specimens 34.9 mm (amputated) and 53.3 mm. Wing width 2.1–3.3 mm. Segments numbering 125–232. Prostomium zygotobous. Dorsal pores absent. Clitellum from XVIII, 1/2XVIII or XIX to XXIX, XXX or 1/2 XXXI. Wings lateral to b, XXIII–XXVIII. Setae paired, preclitellum: $aa = 2.6ab$, $bc = 2.5cd$, $aa = 0.78dd$; postclitellum: $aa = 3.2ab$, $bc = 2.2cd$, $aa = dd$. Genital papillae present only for the dissected specimen, postsetal, lateral to or in line with b, asymmetrical on XVIII and XIX, paired on XXII and XXIX. No median papillae (Fig. 2). Each papilla small, round, vague, about 0.2 mm in diameter. Male pores, female pores, and spermathecal pores not visible. Preserved specimens pale grey.

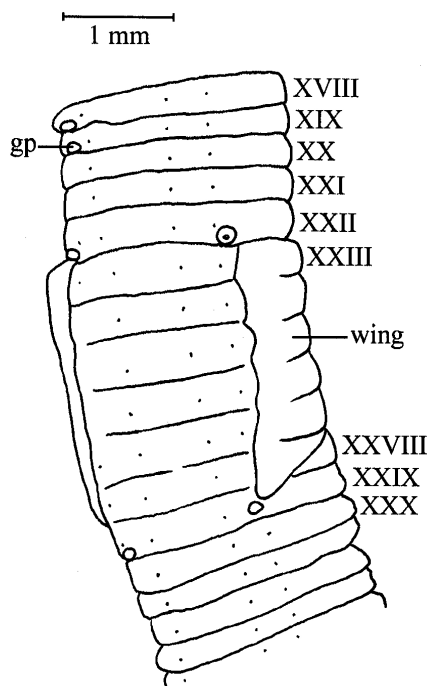


Fig. 2. *Glyphidrilus horsti* Stephenson, 1930. Left latero-ventral view of wings and genital papillae (gp).

Gizzard in VIII. Intestine enlarged from XV. Hearts VIII–XI. Nephridia holoic. Seminal vesicles in IX–XII, small, vestigial, last pair larger. Prostate and accessory glands absent. Spermathecae sessile, globular, transparent, underdeveloped, about 0.3 mm in diameter, two on each side per segment in XIV–XVII.

Remarks. – *Glyphidrilus horsti* from Pulau Berhala has clitellum in XVII–XXVIII, wings in 1/2XXIII–XXVII and the presence of median papillae (Stephenson, 1930). The specimens collected from Singapore in this study were slightly different from the original description by the positions of clitellum and wings one or two segments behind, and absence of median papilla. The differences might be considered as individual or geographical variation.

Glyphidrilus singaporensis, new species

(Fig. 3)

Material examined. – Holotype – 1 mature (clitellate) specimen (dissected)(ZRC), Jungle Fall Valley, Bukit Timah, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 5 Mar.2003.

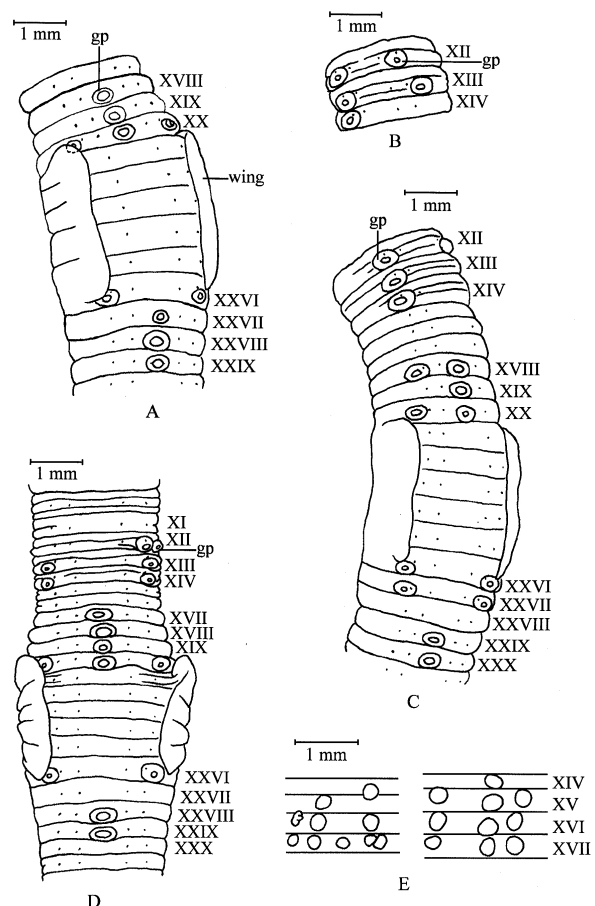


Fig. 3. *Glyphidrilus singaporensis*, new species. A, right latero-ventral view of wings and genital papillae (gp) of holotype; B, left latero-ventral view of genital papillae of a 140-mm paratype; C, right latero-ventral view of wings and genital papillae of a 140-mm paratype; D, ventral view of wings and genital papillae of a 112-mm paratype; E, dorsal view of spermathecae of holotype.

Table 3. A comparison of characters among *Glyphidrilus malayanus* Michaelsen, *G. gatesi*, new species, *G. spelaotes* Stephenson, *G. singaporensis*, new species, *G. jacobsoni* Michaelsen, and *G. horsti* Stephenson.

Characters	<i>G. malayanus</i> Michaelsen, 1902	<i>G. gatesi</i> new species	<i>G. spelaotes</i> Stephenson, 1924	<i>G. singaporensis</i> new species	<i>G. jacobsoni</i> Michaelsen, 1922	<i>G. horsti</i> Stephenson, 1930
Locality	Malay Peninsula	Malay Peninsula	Assam, India	Singapore	Sumatra	Pulau Berhala in Straits of Malacca
Length (mm)	90	34-115**	175	112-142	160	30 (maximum 35)
Segments	256	42-262**	310	163-220	274	145-167
Diameter (mm)	2.5	2.1-3	2-3	3.9-4.65	3-4	2
Clitellum	Some segments over the wings	From XVII, 1/2XVII or XVIII to XXV, 1/2XXVI or XXVI	XVI-XXX	From XVIII or XIX to XXVII or 1/2XXVIII	XVIII-XXX	XVII-XXVIII
Wing begin end	XVII or XVIII 1/3XXI or 1/3XXII 14/15-16/17	XVIII or XIX 1/2XXIV or XXIV Not visible	XVIII or XIX XXIV or 1/2XXV Absent	XXI XXV Not visible	XXI XXVI —	1/2XXIII XXVII —
Spermathecal pores						
Genital papillae lateral	XXI and XIV (1 specimen), or XXII and XV-XVII (the other)	Lateral to b on XV-XVIII and XXIV-XXVI	Lateral to b on XXV and between cd or bc on XIV-XVII	Lateral to b on XII-XIV, XVIII-XX and XXVI-XXVII	Lateral to b on XVIII-XX and XXVII-XXIX, asymmetrical on XIV-XV	Lateral to b on presetal XXIII and postsetal XXVII
medio-ventral	XII-XV (1 specimen), or XXI-XXV (the other)	XIII-XIX and XXIV-XXVII	Single on XVII-XVIII (1 specimen), or single on XI and paired on XIX, XXVII (the other)	Single on XVII-XX and XXVII-XXX	—	Single on XVI, XVII or XXIII to XX or XXII and XXVII-XXVIII
Gizzard	Mainly in VIII	Mainly in VIII	VIII	VIII	—	VIII
Intestinal origin	XVI*	Enlarged from XVIII	XV	XV	—	XVI
Hearts	IX-XI*	IX-XI	VIII-XI	IX-XI	—	—
Spermathecae	XIV-XVI, globular	XV-XVII, 3 on each side per segment	XIV-XVI, ovoid, 4-5 on each side per segment	XIV-XVII, globular, 1-5 on each side per segment	—	XIV-XVII, subspherical, 0-1 on each side of XIV, 2 on each side of XV-XVII
Seminal vesicles	2 pairs in XI-XII	4 pairs in IX-XII	4 pairs in IX-XII	4 pairs in IX-XII	—	4 pairs in IX-XII
Prostate glands	Absent	Absent	Absent	Absent	—	Absent

* Data of Gates (1972).

** Amputated specimens included.

Paratypes – 2 mature (clitellate) and 9 immature (aclitellate) specimens (ZRC), same collection data as for holotype.

Others – 2 not fully matured and 2 immature (aclitellate) specimens (all amputated)(ZRC), Nee Soon swamp forest along pipeline, coll. K. L. Yeo, K. K. P. Lim & David Nasir, 18 Mar.2003.

Description. – Length (mature) 112-142 mm, wing width 3.9-4.65 mm. Segments numbering 163-220. Prostomium zygalobous. Tail pointed. Dorsal pores absent. Clitellum from XVIII or XIX to XXVII or 1/2 XXVIII. Wings lateral to b, XXI-XXV; its anterior edge covered the posterior portion of XX and its posterior edge reached the anterior portion of XXVI. Setae paired, preclitellum: aa = 2ab, bc = 2cd, aa = 0.63dd; postclitellum: aa = 2.4ab, bc = 2.3cd, aa = 0.54dd. Genital papillae postsetal; lateral series paired or asymmetrical, lateral to or in line with b on XII-XIV, XVIII-XX and XXVI-XXVII; unpaired median series between aa on XVII-XX and XXVII-XXX; number and position variable among specimens (Figs. 3A-D). Each papilla round, 0.6-0.65 mm in diameter. Male pores, female pores, and spermathecal pores not visible. Specimens pale fleshy, darker around clitellum.

Gizzard in VIII. Intestine origin in XV, enlarged from XVII. Dorsal blood vessel aborted anterior to segment IX. Hearts IX-XI. Nephridia holoic. Seminal vesicles four pairs in IX-XII; last pair large to push septum 12/13 against septum 13/14. Testes shiny in X and XI. Prostate and accessory glands absent. Spermathecae sessile, globular, about 0.4 mm in diameter, one on each side of segment XIV, and one to five (usually three) on each side per segment in XV-XVII (Fig. 3E).

Etymology. – The name “*singaporensis*” is given to this species for its type locality in the Jungle Fall Valley in Bukit Timah, Singapore.

Remarks. – *Glyphidrilus singaporensis*, new species, is fairly similar to *Glyphidrilus jacobsoni* (Michaelsen, 1922) from Sumatra in the locations of wings and lateral genital papillae (see Table 3). However, *G. jacobsoni* has longer body length of 160 mm and higher segment number of 274 than *G. singaporensis*, which is 112-142 mm in length and 163-220 in segment number. Also, *G. singaporensis* has clitellum from XVIII or XIX to XXVII or 1/2 XXVIII, whereas *G. jacobsoni* has clitellum in XVIII-XXX (see Table 3). Michaelsen (1922) did not mention median papillae and the internal characters in the original description of *G. jacobsoni*.

Glyphidrilus singaporensis of Singapore differs from *G. gatesi* of Sungei Kayu swamp forest of Malay Peninsula by the former having wings in XXI-XXV and one to five (usually three) spermathecae on each side per segment in XIV-XVII, whereas the latter has wings from XVIII or XIX to 1/2XXIV or XXIV and three spermathecae on each side per segment in XV-XVII.

Glyphidrilus singaporensis is also similar to *G. horsti* in the positions of clitellum, wings and median genital papillae (see Table 3). However, *G. singaporensis* is larger, and has three pairs of hearts in IX-XI and one to five (usually three) spermathecae on each side per segment in XV-XVII, whereas *G. horsti* is much smaller, has four pairs of hearts in VIII-XI and two spermathecae on each side per segment in XV-XVII.

Glyphidrilus sp. 1

Material examined. – 2 immature (aclitellate) specimens (1 dissected)(ZRC), Upper Seletar Reservoir Park outside Nee Soon Rifle Range, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 5 Mar.2003.

Description. – Length 60.7-78 mm. Segments numbering 183-204. Widest diameter 2.09-2.23 mm. Prostomium zygalobous. Dorsal pores absent. Small worm with faint traces of a left wing from posterior XX to anterior XXIV and a right wing in segment XXI. No wing for the other specimen. Genital papillae, male pores, female pores, and spermathecal pores not visible. Preserved specimens pale fleshy.

Gizzard in VIII. Intestine enlarged from XVI. Slender, paired lateral longitudinal blood vessels extending over segments anterior to the first heart, visible from outside. Large blood vessels begin from segment IX. Hearts IX-XI. Nephridia holoic. Seminal vesicles vestigial in IX and XII, yellowish white, not visible in X and XI. Spermathecae, prostate and accessory glands absent.

Remarks. – The specimens were too small and immature for species identification. They might be conspecific to *G. singaporensis* according to the wing position. However, their anterior lateral longitudinal blood vessels were not observed for *G. singaporensis*.

Glyphidrilus sp. 2

Material examined. – 2 immature (aclitellate) specimens (1 dissected)(ZRC), Rifle Range Rd. opposite to Murnane Reservoir, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 25 Jun.2003.

Description. – Thin, slender worm, 52-85 mm in length, 126-182 in segment number, and 1.51-1.54 mm in widest diameter. Prostomium zygalobous. Dorsal pores absent. Wings, genital papillae, male pores, female pores, and spermathecal pores not visible. Preserved specimens pale fleshy.

Gizzard in VIII. Intestine enlarged from XVI. Dorsal blood vessel aborted anterior to segment IX. Hearts VIII-XI. Nephridia holoic. Seminal vesicles in IX-XII, vestigial and white in IX and X, not easily demarcated from blood vessels in XI, last pair largest and darker orange in colour. Spermathecae, prostate and accessory glands absent.

Remarks. – The specimens were immature for species identification.

FAMILY MEGASCOLECIDAE

Amyntas Kinberg*Amyntas gracilis* (Kinberg, 1866)

Nitocris gracilis Kinberg, 1866: 102.

Perichaeta hawayana Rosa, 1891: 396; Beddard, 1896: 201.

Perichaeta bermudensis Beddard, 1892a: 160.

Perichaeta barbadensis Beddard, 1892a: 167 (part).

Perichaeta pallida Michselsen, 1892: 227 (part).

Perichaeta mandhorensis Michaelsen, 1892: 241.

Amyntas mandhorensis – Michaelsen, 1899: 86.

Amyntas hawayanus – Beddard, 1900a: 645 (part).

Pheretima hawayana – Michaelsen, 1900: 271; 1928: 40; Ude, 1905: 457; Stephenson, 1912: 276; Gates, 1936b: 417; 1972: 189.

Pheretima mandhorensis – Michaelsen, 1900: 281.

Pheretima hawayana (Rosa) f. *typica* – Michaelsen, 1909: 187; Chen, 1931: 142; 1933: 238; Ude, 1932: 155.

Pheretima hawayana var. *typica* – Gates, 1931: 382; 1932: 433.

Amyntas hawayanus – Sims & Easton, 1972: 235.

Amyntas gracilis – Sims & Easton, 1972: 235; Easton, 1981: 50 (part); 1982: 728; 1984: 118.

Material examined. – 1 mature (clitellate) specimen (dissected)(ZRC), Kent Ridge Campus of National University of Singapore, coll. P. H. Ho, damaged and given to the senior author on 29 Dec.1999; 1 mature and 1 amputated, immature specimens (ZRC), Rifle Range Rd. opposite to Murnane Reservoir, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 25 Jun.2003.

Description. – Length (mature) 120-127 mm, weight 1.08-1.15 g. Segments numbering 92-94. Prostomium epilobous. First dorsal pore 10/11 or 11/12. Setal number 30-39 in VII, 54-60 in XX, 14-16 between male pores in XVIII. Clitellum XIV-XVI, 3.0-3.2 mm in length, 3.95-4.55 mm in width, dorsal pores absent, 6-12 setae on ventral XVI. Spermathecal pores three pairs in 5/6-7/8. Preclitellar genital papillae absent or widely paired, postsetal on VII near 7/8 segmental furrow, one additional postsetal papilla on medio-ventrum of VIII near 8/9 segmental furrow for one mature specimen. Each papilla small, round, about 0.25 mm in diameter. Female pore single, medio-ventral in XIV. Male pores paired in XVIII, 0.31-0.34 body circumferences ventrally apart, each on a small, round porophore surrounded by four or five circular folds. One or two postsetal papillae medial to each male porophore. Each papilla round, centre concave, 0.25-0.4 mm in diameter. Preserved specimens brown or yellowish grey, with grey ventrum and dark brown clitellum.

Septa 5/6-7/8 and 10/11-13/14 thickened, 8/9 and 9/10 absent. Gizzard in IX-X. Intestine enlarged from XIV. Intestinal caeca paired in XXVII-XXV, each simple with small indentations on the edge. Esophageal hearts XI-XIII. Meronephridia bush-

like mass in intersegmental spaces anterior to 6/7. Spermathecae three pairs in VI-VIII, ampulla oval, large with a long, stout stalk. Diverticulum long, slender, slightly twist at the end. Holandry: testis sacs paired in X and XI, round, smooth. Seminal vesicles paired in XI and XII, large, posterior pair extending into XIII. Prostate glands paired in XVIII, lobed, extending anteriorly to XVI and posteriorly to XXI. Prostatic ducts large, U-shaped. Accessory glands stalked.

Remarks. – *Amyntas gracilis* is a holandric and sixthelcal earthworm belonging to the *gracilis* (= *hawayanus*) species-group of the genus *Amyntas* (sensu Sims & Easton, 1972). According to Gates (1972) it is native to China, and was introduced to Hawaii and California before 1852. It is a cosmopolitan species, and has often been confused with *Amyntas morrisi* (see Gates, 1968).

Two nominal species, *Amyntas pallidus* (Michselsen, 1892) and *Amyntas barbadensis* (Beddard, 1892), are actually mixtures of specimens of *A. gracilis* and *A. morrisi* based on the original descriptions of individual specimen: the two type specimens of *A. pallidus* are in fact an *A. gracilis* specimen and an *A. morrisi* specimen; and the three type specimens of *A. barbadensis* consist of one *A. gracilis* (designated as individual *b* in original description) specimen and two *A. morrisi* (designated as individuals *a* and *c* in original description) specimens.

The differences between *A. gracilis* and *A. morrisi* are presented in the **Remarks** section of *A. morrisi*.

Amyntas minimus (Horst, 1893)
(Fig. 4)

Perichaeta minima Horst, 1893b: 66.

Perichaeta pusilla Ude, 1893: 63.

Amyntas minimus – Beddard, 1900a: 649.

Amyntas pusillus – Beddard, 1900a: 649.

Pheretima minima – Michaelsen, 1900: 284; Gates, 1961: 298; 1972: 201.

Pheretima enchytraeoides Michaelsen, 1916: 33.

Pheretima humilis Gates, 1942: 120.

Amyntas minimus – Sims & Easton, 1972: 236; Easton, 1979: 119; 1982: 728; 1984: 118.

Material examined. – 7 mature (1 dissected) and 15 immature specimens (ZRC), Kent Ridge Campus of National University of Singapore, 6 Mar.2003; 1 immature specimen (ZRC), Sungei Buloh, 7 Mar.2003; 1 mature specimens (ZRC), Rifle Range Rd. opposite to Murnane Reservoir, 25 Jun.2003. All the above specimens were collected by K. K. P. Lim, D. C. J. Yeo & K. L. Yeo.

Description. – Small worm, length (mature) 24-32 mm. Segments numbering 81-90. Prostomium epilobous. First dorsal pore 12/13. Setal number 58 in VII, 39 in XX, 6-9 between male pores in XVIII. Clitellum XIV-XVI, 1.03 mm in length, 1.64 mm in width, dorsal pores absent, setae absent or 1-3 on ventral XVI. Spermathecal pores one pair in 5/6, distance between paired pores 0.48 body circumferences ventrally apart. Female pore single, medio-ventral in XIV.

Male pores inconspicuous, paired in XVIII, about 0.26 body circumferences ventrally apart, each on a round, conical porophore about 0.3 mm in diameter (Fig. 4A). Genital papillae absent in both preclitellar and postclitellar regions. Preserved specimens whitish grey with yellowish tan clitellum.

Septa 5/6-7/8 and 10/11-13/14 thickened, 8/9 and 9/10 absent. Gizzard in IX-X. Intestine enlarged from XIV. Intestinal caeca paired in XXVII, simple, long, extending anteriorly to XVIII or XIX (Fig. 4D). Esophageal hearts X-XIII. Meronephridia bush-like mass in intersegmental spaces anterior to 7/8. Spermathecae one pair in VI, ampulla elongated oval, about 0.5 mm long, 0.27 mm wide, with a slender stalk about 0.45 mm in length. Diverticulum with a slender stalk about 0.4 mm long and an elongated oval seminal chamber about 0.28 mm in length (Fig. 4B). Holandry: testis sacs in X and XI. Seminal vesicles paired in XI and XII, vestigial, first pair included in testis sacs. Prostate glands paired in XVIII, smooth, extending anteriorly to XVI or XVII and posteriorly to XIX. Prostatic ducts large, U-shaped (Fig. 4C). Accessory glands absent.

Remarks. – *Amyntas minimus* is a small, holandric and bithecal earthworm belonging to the *minimus* species-group of the genus *Amyntas* (sensu Sims & Easton, 1972). Gates (1942) described *Amyntas humilis* a small earthworm with one pair of spermathecae in VI. It has 6-12 setae on ventral XVI (clitellum) but no genital markings. *Amyntas humilis* was only found in soil of flower pots in the Judson College campus, Rangoon, in spite of extensive collecting throughout Burma. It was probably imported from somewhere else (Gates, 1942). Gates (1961) later found that its spermathecal diverticula were similar to that of *A. minimus* figured by Horst (1893b). After examination of the Hawaii worms, Gates (1961: 301) considered that the indistinctness of some markings and the condition of associated tissues warrant a suspicion that glands as well as the markings may be

disappearing in some lineages, and individuals without genital markings can be expected. Therefore, Gates (1961, 1972) considered *A. humilis* as a synonym of *A. minimus*.

Easton (1981: 55) placed *Amyntas zoysiae* (Chen, 1933) and *Amyntas ishikawai* (Ohfuchi, 1941) in the brace of species synonyms of *A. minimus*. *Amyntas minimus* is fairly similar to *A. zoysiae* of China in external characters, such as body size, segment number (see Table 4), and male porophore structure. However, *A. minimus* has higher setal number and smaller prostate glands in XVI-XIX, whereas *A. zoysiae* has lower setal number and larger prostate glands occupying six to seven segments in XV-XXII (see Table 4). The prostate glands of *A. minimus* were described as well-developed in the original description (Horst, 1893b), but Gates (1961) stated that prostates appear to be confined within XVII-XIX after examining the type specimen. *Amyntas minimus* was described based on four specimens from Java (Horst, 1893b). Gates (1961) reported that three of the type specimens have been lost.

Amyntas zoysiae occurs in uncultivated land at the foot of hills in Zhejiang (= Chekiang), China (Chen, 1933). The presence of the *A. minimus* [as *A. humilis*] specimens from Burma and the *A. minimus* specimens from Singapore with the external characters so similar to *A. zoysiae* suggest a close relationship between *A. minimus* and *A. zoysiae*. In fact, both species were represented by bithecal, monothecal, and athecal morphs with more or less abnormal spermathecae (Gates, 1961).

Amyntas ishikawai was reported from a cave in Japan (Ohfuchi, 1941). It has one pair of spermathecae in VI, and its male porophore structure is similar to *A. minimus*. Gates (1961, 1972) and Easton (1981) considered it synonymous to *A. minimus*. However, *A. ishikawai* is of a larger size, and has lower setal number that shows a slightly increasing trend from anterior toward posterior region (see Table 4), whereas

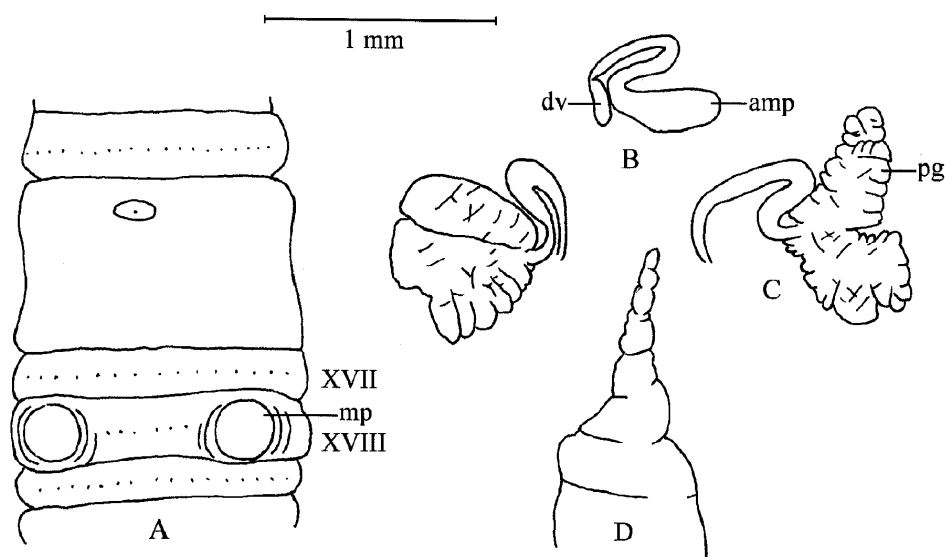


Fig. 4. *Amyntas minimus* (Horst, 1893). A, ventral view of male porophore (mp) region; B, dorsal view of right spermatheca (amp, ampulla; dv, diverticulum); C, dorsal view of prostate glands (pg); D, dorsal view of right intestinal caecum.

Table 4. A comparison of characters among *Amyntas minimus* (Horst), *A. humilis* (Gates), *A. zoysiae* (Chen), and *A. ishikawai* (Ohfuchi).

Characters	<i>A. minimus</i> (Horst, 1893)*	<i>A. humilis</i> (Gates, 1942)*	<i>A. minimus</i> (Gates, 1961)*	<i>A. zoysiae</i> (Chen, 1933)*	<i>A. ishikawai</i> (Ohfuchi, 1941)*
Locality	Java	Burma	Burma, Java, Hawaii	China	Japan
Length (mm)	≤ 25	20-23	20-28	20-45	47-65
Segments	about 80	75-80	75-89	70-108	60-72
Diameter (mm)	—	2	1.5-2	1.5-2.5	2.3-2.8
First dorsal pore	—	12/13	11/12-12/13	11/12	12/13
Setal number					
III	—	40-47	40-47	32-42	—
VI	—	—	75	42-52	39
VII	60	—	60	—	40
VIII	—	54-58	54-58	40-54	40-41
XII	44	46-52	46-52	34-43	—
XVI (clitellum)	10	6-12	3-12	0	0
XX	—	38-44	38-44	—	44-45
XXV	—	—	—	34-44	—
between male pores	—	6-8	6-10	5-10	1-2
Genital papillae					
preclitellar	1 pair on anterior margin of VII	Absent	Absent or paired presetal on VII-VIII or postsetal on VI	Absent	Absent
postclitellar	Medio-ventrum of XVII-XIX depressed	Absent	Absent or single median presetal on XX, XXI	Absent	Absent
Spermathecae	Ampulla tubular, diverticulum slender	Three ovoidal seminal chambers for each diverticulum	Large, 2 or 3 seminal chambers for each diverticulum	Absent in one or both sides; ampulla large, diverticulum coiled	Ampulla ovoid, diverticulum slender, straight with a round chamber
Seminal vesicles	—	Small	Small	Small	Well-developed
Prostate glands	Well-developed	XVI-XIX or XVII-XIX	XVI-XIX	XV-XXI or XVI-XXII	XV-XXI
Prostatic ducts	S-shaped	U-shaped	Looped	U-shaped	Straight, muscular
Accessory glands	—	Absent	Stalked and coelomic	Absent	Absent

* Reference in parenthesis after scientific name.

the setal number of *A. minimus* is higher in the preclitellar region and lower in the postclitellar region (see Table 4). Furthermore, *A. ishikawai* has well-developed seminal vesicles and large prostate glands (occupying seven segments) with straight, muscular ducts, whereas *A. minimus* has small, vestigial seminal vesicles and normal prostate glands (occupying three or four segments) with U-shaped ducts. Therefore, *A. ishikawai* is considered as a valid species different from *A. minimus* in this study.

Amyntas minimus probably has been transported by man as evidenced by its presence in flower pots in Rangoon, Burma (Gates, 1942) and in banana plantations in Hawaii (Gates, 1961). The original home of this species is unknown (Gates, 1972). This species is by far the smallest pheretimoid earthworm recorded in Singapore.

Amyntas morrisi (Beddard, 1892)

Perichaeta morrisi Beddard, 1892a: 166; Rosa, 1896a: 516.
Perichaeta barbadensis Beddard, 1892a: 167 (part).
Perichaeta pallida Michselsen, 1892: 227 (part).
Perichaeta amazonica Rosa, 1894: 14.
Perichaeta insulae Beddard, 1896: 204.
Perichaeta cupulifera Fedarb, 1898: 445.
Amyntas hawayanus – Beddard, 1900a: 645 (part).
Pheretima morrisi – Michaelsen, 1900: 287; Ude, 1905: 434; Chen, 1931: 148; 1933: 267; Gates, 1936b: 437; 1968: 253; 1972: 202.
Pheretima hawayana (Rosa) subsp. *barbadensis* (Beddard) – Michaelsen, 1909: 187; Ude, 1932: 155.
Pheretima hawayana var. *lineata* Gates, 1926a: 154; 1931: 385; 1932: 434.
Pheretima hawayana – Stephenson, 1932: 45; Gates, 1933: 529; 1935: 92.
Amyntas morrisi – Sims & Easton, 1972: 236; Easton, 1981: 55; 1982: 729.

Material examined. – 9 mature (clitellate) and 3 immature (a clitellate) specimens (ZRC), Rifle Range Rd. opposite to Murnane Reservoir, 5 Mar. 2003; 1 mature (dissected) and 1 immature specimens (ZRC), Kent Ridge Campus of National University of Singapore, 6 Mar. 2003; 3 mature and 2 immature specimens (ZRC), Sungei Buloh, 7 Mar. 2003; 1 mature specimen (ZRC), Turut Track, Kranji Wireless Station, 7 Mar. 2003; 7 mature (1 dissected) and 2 immature specimens (ZRC), Rifle Range Rd. opposite to Murnane Reservoir, 25 Jun. 2003. All the above specimens were collected by K. K. P. Lim, D. C. J. Yeo & K. L. Yeo.

Description. – Length 77–100 mm, weight 0.61–0.87 g. Segments numbering 74–95. Prostomium epilobous. First dorsal pore 10/11. Setae small, number 47–52 in VII, 45–59 in XX, 8–15 between male pores in XVIII. Clitellum XIV–XVI, 2.86–3.6 mm in length, 2.79–3.83 mm in width, anterior edge of XIV and posterior edge of XVI slightly coloured, not glandular, dorsal pores absent, 8–19 setae on ventral XVI. Spermathecal pores two pairs in 5/6/7, ventro-lateral, distance between paired pores 0.32–0.34 body circumferences ventrally apart. One or two papillae ventro-medial to each spermathecal pore at the anterior edge of VII, often an additional presetal papilla on medio-ventrum of VII, an additional presetal papilla on medio-ventrum of VIII for one mature specimen. Each papilla round, about 0.35 mm in diameter, with a conspicuous

dark centre. Female pore single, medio-ventral in XIV. Male pores paired in XVIII, about 0.36 body circumferences ventrally apart, each on a small, papilla-like protuberance which often the fusion of two. Two round genital papillae immediately medial to each male pore, one presetal and the other postsetal; the above papillae within porophore surrounded by five or six circular ridges. The whole male area sometimes slightly elevated. Often one to three presetal papillae on medio-ventrum of XVIII or additional papillae above and/or below male porophore adjacent to 17/18 or 18/19 segmental furrow. Each papilla round, centre concave, about 0.3 mm in diameter. Preserved specimens with dark grey dorsum, greyish ventrum and dark brown clitellum.

Septa 5/6–7/8 and 10/11–13/14 thickened, 8/9 and 9/10 absent. Gizzard in IX–X, large, round, yellowish white. Intestine enlarged from XIV or XV. Intestinal caeca paired in XXVII, each simple, short, extending anteriorly to XXV, with a white distal end. Esophageal hearts XI–XIII. Meronephridia bush-like mass in intersegmental spaces anterior to 6/7. Spermathecae two pairs in VI and VII, ampulla round, 0.97–1.4 mm long, 1.04–1.52 mm wide, with a long, slender stalk of 1.26–1.35 mm in length. Diverticulum vestigial or normally developed, stalk slender, straight or slightly bent, 0.88–2.09 mm long, seminal chamber absent, or in the form of an elongated end about 0.8 mm in length, or a normal oval-shaped seminal chamber of 0.25–0.52 mm in length. Accessory glands sessile, white, each in the form of an irregular tissue-like mass, 0.8–0.9 mm long, 0.55 mm wide. Holandry: testis sacs paired in X and XI, round, smooth, yellowish. Seminal vesicles paired in XI and XII, large, follicular, yellowish. Prostate glands paired in XVIII, racemose, follicular, extending posteriorly to XX or XXI. Prostatic ducts large at the middle, narrow and coiled at distal end. Accessory glands small, stalked or sessile, whitish and irregularly shaped.

Remarks. – *Amyntas morrisi* is a holandric and quadrithecal earthworm belonging to the *morrisi* species-group of the genus *Amyntas* (sensu Sims & Easton, 1972). It is a peregrine species and has often been considered conspecific to or a subspecies or variety of *A. gracilis* (see Beddard, 1900a; Michaelsen, 1909; Stephenson, 1912, 1932; Gates, 1926a, 1931, 1932, 1933). However, the two species are easily distinguishable by the number and position of spermathecae and genital papillae. *Amyntas morrisi* is quadrithecal with spermathecae paired in VI and VII, whereas *A. gracilis* is sexthecal with spermathecae paired in VI, VII and VIII. In addition, *A. morrisi* has one presetal and one postsetal papillae immediately medial to each male pore in the male porophore and presetal papillae in VII, whereas *A. gracilis* has a simple male pore with postsetal papillae in oblique row outside the male porophore and small postsetal papillae absent or present in VII. Ude (1905) and Chen (1931, 1933) have also made detailed comparisons between the two species.

All specimens of *A. morrisi* examined from Singapore exhibit the typical papilla arrangements in segment VII and within the male porophore except one mature worm collected from the NUS campus (6 March 2003), which has only two small

sunken papillae in the male porophore. In the Oligochaeta collection of the Raffles Museum, specimens of ZRC 1974.11.25.20 and ZRC 1974.11.25.21 identified by Stephenson (1932) as *P. hawayana* are actually *A. morrisi*. This species is the most common pheretimoid earthworm in Singapore (see Table 2).

Amyntas sp.

Material examined. – 1 immature (dissected) specimen (ZRC), Kent Ridge Campus of National University of Singapore, coll. K. K. P. Lim & D. C. J. Yeo, 6 Mar. 2003.

Description. – Length 62 mm, diameter 2.59 mm. Segments numbering 95. Prostomium epilobous. First dorsal pore 10/11. Number of incomplete annulets 4 in VII, 3 per segment in VIII and IX, 5 in X and XI, inconspicuous, visible in medio-ventrum only. Setal number 49 in VII, 57 in XX, 14 between male pores in XVIII. Spermathecal pores not visible. Male pores not visible, porophore round, small, about 0.25 mm in diameter. Genital papillae absent. Preserved specimen greyish with lighter colour in anterior thirteen segments.

Septa 6/7/8 and 10/11-12/13 thicker, 8/9 and 9/10 absent. Gizzard in IX-X, large, round, yellow. Intestine enlarged from XIV. Intestinal caeca paired in XXVII, each simple, stocky, coarsely granulated, extending anteriorly to XXIV. Esophageal hearts XI-XIII. Meronephridia bush-like mass in intersegmental spaces anterior to 6/7. Spermathecae not visible. Holandry: testis sacs paired in X and XI, rudimentary. Seminal vesicles paired in XI and XII, small, white, about 0.45 mm long. Pseudovesicles of XIII vestigial. Prostate glands confined in XVIII, small, lobed, underdeveloped, ducts short and straight, the entire length of duct and gland about 0.4 mm. Accessory glands absent.

Remarks. – The specimen is too young to permit species identification.

Perionyx Perrier

Perionyx violaceus Horst, 1893

Perionyx violaceus Horst, 1893b: 72; Michaelsen, 1900: 209; 1922: 22; 1923: 1; 1928: 10; 1932: 602; Stephenson, 1930: 3; 1931: 262; 1932: 51; Gates, 1935: 89; 1937: 197.

Material examined. – 1 mature (clitellate), amputated specimen (dissected)(ZRC), Hindehe Drive, Bukit Timah, coll. H. K. Lua, 19 Mar. 1989; 1 mature specimen (ZRC), Rifle Range Rd. opposite to Murnane Reservoir, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 5 Mar. 2003.

Description. – Length (amputated) 19+ mm. Segments numbering 33+. Prostomium epilobous. First dorsal pore 5/6. Setal number 44 in VII, 50 in XX. Clitellum XIII-XVII, 2.9 mm in length, 3.04 mm in width, setal ring present on each segment. Spermathecal pores two pairs in 7/8-8/9, medio-ventral. Female pore single, medio-ventral in XIV.

Male pores closely paired in medio-ventral XVIII, on round protuberances within a transversely depressed area with distinct anterior and posterior margins but indistinct lateral margins. Penial setae absent. Genital papillae absent in both preclitellar and postclitellar regions. Preserved specimens with purplish red dorsum, much lighter ventrum, and yellowish clitellum.

No septa specially thick. Gizzard invisible. Intestine enlarged from XV. Caeca absent. Last hearts in XII. Spermathecae two pairs in VIII and IX, large. Ampulla oval, 0.9-1.0 mm long, 0.75 mm wide, duct short and stout; two small, sessile lobes about 0.2 mm in diameter at the junction of the first ampulla and its duct, several tiny protuberances at the junction of the second ampulla and its duct. Diverticulum absent. Holandry: testis sacs in X and XI. Seminal vesicles in XI and XII, large, second seminal vesicle on the left occupying segments XII-XIV. Prostate glands confined to XVIII, compact. Prostatic ducts short and stout. Accessory glands absent.

Remarks. – According to Gates (1937), *Perionyx excavatus* Perrier, 1872 and *P. violaceus* were considered to be different species, owing to the presence or absence of diverticulum and penial setae. However, in the key to *Perionyx* species provided by Horst (1893b), neither one of the two species had penial setae; the only difference between them was that *P. excavatus* had no diverticulum while *P. violaceus* had small, stalked diverticula. According to Beddard (1892b), the group of setae of each male pore of *P. excavatus* might withdraw from the exterior of the body. This phenomenon might explain Horst's (1893b) observation, and while this happens, there is hardly any difference in the external appearance between *P. excavatus* and *P. violaceus*.

In Michaelsen's (1900) description, four to six setae were present between male pores for *P. excavatus*. Michaelsen (1900) also provided a key for the *Perionyx* species in which *P. excavatus* had very small diverticula while *P. violaceus* had round or club-shaped diverticula and had no penial setae. Michaelsen (1909: 176) noted that the appearance of diverticulum was very different in different states of spermathecae, and characteristic penial setae was a principal diagnostic feature for distinguishing species. However, Gates (1972: 140) stated that penial setae, to which so much systematic importance was attributed in the past, seemed to be of much less significance in *Perionyx* as well as in certain other genera.

According to Horst (1893b), *P. violaceus* was very common in Java and Sumatra. It was also found in Borneo (Michaelsen, 1928, 1932) and Pulau Berhala, Straits of Malacca (Stephenson, 1930). Gates (1935, 1937) described the *P. violaceus* specimens from Malay Peninsula and Bukit Timah, Singapore as having diverticula. However, the *Perionyx* specimen collected from Bukit Timah in 1989 had no diverticulum but only two small, sessile lobes at the junction of the first ampulla and its duct. Therefore, we agree with Michaelsen (1909) on the importance of penial setae for species identification.

***Pheretima* Kinberg**

***Pheretima darnleiensis* (Fletcher, 1886)**

Perichaeta cingulata – Vaillant, 1869: 4 (part).
Megascolex indicus Horst, 1883: 186 (part).
Perichaeta indica – Horst, 1885: 4; Beddard, 1886: 298.
Perichaeta darnleiensis Fletcher, 1886: 966.
Perichaeta vaillanti Beddard, 1890: 66.
Perichaeta martensi Michaelsen, 1892: 242; 1896: 240; Horst, 1893a: 324.
Perichaeta bosschae Horst, 1893a: 324; Michaelsen, 1896: 238.
Perichaeta padasensis Beddard & Fedarb, 1895: 73.
Perichaeta eoa Rosa, 1896a: 528; 1896b: 609.
Perichaeta floweri Benham, 1897: 217.
Perichaeta madelinae Benham, 1897: 219.
Perichaeta belli Rosa, 1898: 286.
Amyntas martensi – Michaelsen, 1899: 87.
Amyntas cingulatus – Beddard, 1900a: 615; 1900b: 892.
Amyntas padasensis – Beddard, 1900a: 624.
Amyntas bosschae – Beddard, 1900a: 625.
Pheretima belli – Michaelsen, 1900: 255.
Pheretima bosschae – Michaelsen, 1900: 256.
Pheretima darnleyensis – Michaelsen, 1900: 263.
Pheretima floweri – Michaelsen, 1900: 267; Gates, 1934: 258.
Pheretima indica – Michaelsen, 1900: 275 (part); 1922: 41; 1923: 2; 1932: 614; 1935: 108; Gates, 1935: 83; 1937: 193; 1940: 413; 1949: 26.
Pheretima martensi – Michaelsen, 1900: 282.
Pheretima padasensis typica – Michaelsen, 1900: 290.
Pheretima vaillanti – Michaelsen, 1900: 311.
Pheretima benguetensis Beddard, 1912: 183.
Pheretima kuchingensis Stephenson, 1916: 337.
Pheretima borneoensis Ude, 1925: 109; 1932: 131; Michaelsen, 1928: 55; 1934: 45.
Pheretima indica (Horst) subsp. *typica* – Michaelsen, 1928: 41; Ude, 1932: 146.
Pheretima indica (Horst) f. *typica* – Stephenson, 1930: 1; 1931: 273; 1932: 47.
Amyntas indicus – Sims & Easton, 1972: 235.
Pheretima darnleiensis – Sims & Easton, 1972: 260; Easton, 1982: 732; 1984: 119.

Material examined. – 1 mature (clitellate) specimen (dissected)(ZRC), Right bank near mouth of Sg. Khatib Bongsu, coll. H. H. Tan, 13 Feb.2003; 2 mature specimens (ZRC), Bukit Timah, coll. Benjamin Lee, 5 Mar.2003; 7 mature and 1 immature specimens (ZRC), Rifle Range Rd. opposite to Murnane Reservoir, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 5 Mar.2003; 2 mature specimens (ZRC), Singapore Botanic Gardens, coll. K. K. P. Lim & K. L. Yeo, 11 Mar.2003; 4 mature specimens (ZRC), Rifle Range Rd. opposite to Murnane Reservoir, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 25 Jun.2003.

Description. – Length 159 mm, weight 1.99 g. Segments numbering 107. Prostomium with a large everted buccal cavity. First dorsal pore 12/13. Setal number 35 in VII, 44 in XX, 9 between male pores in XVIII. Clitellum XIV-XVI, 4.27 mm in length, 4.75 mm in width, setae absent, dorsal pores absent. Spermathecal pores four pairs in 5/6-8/9, ventro-lateral, small transverse slits in the segmental furrows. Female pore single, medio-ventral in XIV. Male apertures paired in XVIII, about 0.26 body circumferences ventrally apart, each transverse slit with crenated margin on a white, round porophore. Genital papillae absent in both preclitellar and

postclitellar regions. Specimens brown with purplish iridescence, lighter coloured on ventrum and dark brown on clitellum.

Septa 5/6-7/8 and 10/11-13/14 thick, 8/9 membranous, 9/10 absent. Gizzard large in VIII-X. Intestine enlarged from XVII. Intestinal caeca paired in XXVII, each simple, slender, extending anteriorly to 23/24. Esophageal hearts XI-XIII. Spermathecae four pairs in VI-IX, small, ampulla oval, its upper part and junction with diverticulum covered by nephridia. Diverticulum with a slender stalk and an oval-shaped seminal chamber about 0.46 mm in length. Holandry: testis sacs small, paired in X and XI. Seminal vesicles paired in XI and XII, each small with a prominent dorsal lobe. Pseudovesicles paired in XIII. Prostate glands paired in XVIII, racemose, follicular, occupying two to three segments in XVII-XIX. Prostatic duct very short with terminal end enlarged into a bulb (copulatory chamber) in XVIII. Accessory glands absent.

Remarks. – *Pheretima darnleiensis* is a holandric and octothecal earthworm. It possesses copulatory chambers and has nephridia on spermathecal ducts. Numerous synonyms of *P. darnleiensis* have been erected (Gates, 1935). Sims & Easton (1972: 264) considered both names *cingulata* and *indica* are invalid as they have been wrongly applied (Article 49, Int. Code zool. Nomencl.), and the species should carry the first available name in the synonymy, which is *Perichaeta darnleiensis*. They regarded both *cingulata* (part) (Vaillant, 1869) and *indica* (Horst, 1885) as synonyms of *Pheretima darnleiensis* (Fletcher, 1886) under the genus *Pheretima* Kinberg, 1866 on page 239, but placed *indica* (Horst, 1883) as a member of the *diffringens* (= *corticis*) species-group of the genus *Amyntas* Kinberg, 1866 on page 235. Easton (1981: 49) subsequently regarded *indica* (Horst, 1883) as a synonym of *Amyntas corticis* (Kinberg, 1866). There was neither explanation on why *indica* (Horst, 1883) is considered a synonym of *A. corticis* nor explanation on why *cingulata* and *indica* had been wrongly applied.

The original description of *indica* (Horst, 1883: 186-189) is brief (not perfect), like most of the early specific descriptions in oligochaete taxonomy of the late 1800s. Nevertheless, it clearly mentions in the first sentence that “Cephalic lobe extending over two thirds of the length of the buccal segment, dilating at the anterior part”. This character is similar to the everted buccal cavity, a unique character illustrated for *indica* by Beddard (1890, Plate IV, Figs. 1-3). Simply based on this character, *indica* (Horst, 1883) is certainly not synonymous to *A. corticis* as Easton (1981) suggested. However, the footnote in the original description of *indica* (Horst, 1883) remarks that “The *Perichaeta*-specimen described in my paper ‘Niederl. Arch. f. Zool: Bd. IV’ belongs to this species”. “My paper” refers to the paper of Horst (1879), in which there is a detailed description and well-illustrated figures of an earthworm from Java without a name of the species, but obviously it is *A. corticis*. Chen (1935: 34-35) was the first one to point out this confusion, and clearly stated that *P. indica* consists of more than one species. Apparently, those from Sumatra (Alahan Pandjang, Silago, Soepajang) are *P. indica*,

and that from Java is *A. corticis*. Horst (1885: 4-5, Plate I, Fig. 1a, 1b and 1c) re-describes *indica* based on specimens from Sumatra, and attaches with figures (spermathecae, prostate gland and prostatic duct with male copulatory pouch) that have the legend of “*Perichaeta indica* Horst” on page 8. The muscular duct of prostate gland of *indica* in Horst (1883) might imply the male copulatory pouch of *indica* in Horst (1885). However, the name “*indica*” has been wrongly applied, because it denotes partly to the specimens of *P. indica* (Horst, 1883, 1885) from Sumatra and partly to the specimen of *A. corticis* from Java (Horst, 1879).

In the remarks of the original description of *indica*, Horst (1883: 189) also noted that “Probably some of the specimens of *P. cingulata*, examined by Vaillant, are identical with *M. indicus*; however Vaillant, as stated by Perrier, having confounded different species under this name,....”. The same statement was made by Beddard (1890: 57). Beddard (1892c) examined the type specimens of *P. cingulata* (Schmarda) and redefined it as *Megascolex cingulatus*, a different species from *P. darnleiensis*. Beddard (1892c) also found that none of the species confounded by Vaillant are identical with Schmarda’s specimens. Obviously, the name *cingulata* is invalid, because it has been wrongly applied (Article 49, ICZN) as Sims & Easton (1972: 264) indicated.

Among other synonyms mentioned by Gates (1935), the specific name, *Pheretima decipiens* (Beddard, 1912), is not considered a synonym of *P. darnleiensis* in this study because of its inadequate description. Sims & Easton (1972: 239) placed *decipiens* within the *planata* species-group of the genus *Metaphire*.

In the description by Sims & Easton (1972: 262) of *P. darnleiensis*, the setal number is 12-35 in VII and 38-45 in XX, much lower than those in the original descriptions of *P. darnleiensis* (60-66 per segment) from Darnley Island, *P. madelinae* (56 in V and 66 in XX) from Borneo and *P. belli* (48 in XII and 60 in XXV) from the Philippines. Apparently, the re-description of *P. darnleiensis* by Sims & Easton (1972) did not match the original description by Fletcher (1886). In spite of the setal differences of the specimens mentioned above, their other characters are not distinguishable from *P. darnleiensis*.

Pheretima darnleiensis is widely distributed in Southeast Asia: Sumatra, Java, Borneo (Horst, 1883, 1885, 1893a, b; Beddard & Fedarb, 1895; Rosa, 1896a; Benham, 1897; Michaelsen, 1899, 1922, 1928, 1932, 1934; Stephenson, 1916; Ude, 1925, 1932; Gates, 1940); North Celebes [=North Sulawesi] (Michaelsen, 1899); the Philippines (Beddard, 1890, 1912; Rosa, 1898; Gates, 1935); and the Malay Peninsula (Beddard, 1900b; Stephenson, 1931, 1932; Gates, 1935, 1937, 1949). It is also found on islands such as Mentawai (Rosa, 1896b), Christmas Island (Michaelsen, 1935; Gates, 1935), Molucca, Fiji (Gates, 1935), Darnley Island in the Torres Straits (Fletcher, 1886), New Caledonia (Beddard, 1886), and the Hawaiian Archipelago (Beddard, 1896). The numerous synonyms indicate the abundance and vast distribution of this species. The occurrence of geographical morphs or races

might be possible as supported by the setal difference mentioned previously.

Polypheretima Michaelsen

Polypheretima taprobanae (Beddard, 1892)

(Fig. 5)

Perichaeta taprobanae Beddard, 1892a: 163.

Perichaeta pauli Michaelsen, 1897: 243.

Amyntas taprobanae – Beddard, 1900a: 648.

Pheretima taprobanae – Michaelsen, 1900: 308; Gates, 1972: 220.

Pheretima taprobanae var. *pauli* – Michaelsen, 1900: 309.

Metapheretima taprobanae – Sims & Easton, 1972: 233.

Metapheretima pauli – Sims & Easton, 1972: 233.

Polypheretima taprobanae – Easton, 1979: 45; 1982: 734; 1984: 117.

Material examined. – 1 mature (clitellate) specimen (dissected)(ZRC), under a fallen log in the Singapore Botanic Gardens Jungle, coll. K. K. P. Lim & K. L. Yeo, 11 Mar.2003.

Description. – Stout worm, length 105 mm, weight 1.61 g. Segments numbering 122. Prostomium prolobous. First dorsal pore 12/13. Three annulets per segment from segment VI. Setae minute, closely spaced, not easily visible. Setal number 55 in V, 85 in VII, 82 in XII, 77 in XX, 71 in XXV, 14 between male pores in XVIII. Clitellum XIV-XVI, 3.5 mm in length, 5.11 mm in width, dorsal pores absent, three setal rings with setal number 63 in XIV, at least 55 in XV, 61 in XVI, pale in colour with an amorphous appearance. Spermathecal pores one pair in 7/8, ventro-lateral, each on a papilla-like porophore in the segmental furrow (Fig. 5A), distance between paired pores 0.34 body circumferences ventrally apart. Female pore single, medio-ventral in XIV. Male pores paired in XVIII, about 0.29 body circumferences ventrally apart, male aperture not visible; porophore round, white in color, indistinctly demarcated, about 0.5 mm in diameter (Fig. 5B). A white, indistinctly demarcated circular area immediately posterior to each male porophore in presetal annulet of XIX. Genital papillae absent in both preclitellar and postclitellar regions. Preserved specimen pale greyish on dorsum, light grey on ventrum, pale grey on clitellum, and white in the anterior five segments.

Septa 5/6-7/8 and 12/13/14 thickened, 8/9 membranous, 9/10 absent, 10/11/12 thin. Gizzard large in IX-X, yellowish white. Intestine enlarged from XIV. Caeca absent. Esophageal hearts XI-XII. Meronephridia bush-like mass in intersegmental spaces anterior to 6/7. Spermathecae one pair in VIII, small, ampulla oval, slightly wrinkled, about 0.6 mm long, 0.38 mm wide, with a stout stalk of about 0.57 mm long (Fig. 5C). Diverticulum transparent, stalk enlarged at proximal end and narrow, slender, twist at distal end with an oval seminal chamber of about 0.35 mm in length. Holandry: testis sacs in X and XI, annular, smooth, pink. Seminal vesicles paired in XI and XII, small, follicular, yellowish, first pair included in testis sacs. Prostate glands small, paired in XVIII, racemose, follicular, yellowish white (Fig. 5D). Prostatic ducts large, stout, looped (Fig. 5E), passing into the

parietes in the posterior portion of XVIII. Accessory glands absent.

Remarks. – *Polypheretima taprobanae* is a holandric and bi-thecal earthworm belonging to the *bifaria* species-group of the genus *Polypheretima* (sensu Easton, 1979). This species is known mostly from botanical gardens in India, Ceylon, Brazil, Hawaii (Gates, 1972); Madagascar (Michaelsen, 1897); Northeast Australia, Fiji, and Seychelles (Easton, 1979, 1984). It has never been recorded from the *Pheretima* domain (Gates, 1970). Gates (1972) postulated its original home perhaps to be New Guinea. However, the numerical studies by Easton (1979) suggested that the species might have originated in Southeast Asia.

ORDER MONILIGASTRIDA

FAMILY MONILIGASTRIDAE

Drawida Michaelsen

Remarks. – *Drawida* is widely distributed in India, Burma, Malay Peninsula, Borneo, the Philippines, China, Japan, Korea, and Manchuria (Gates, 1972). Three species, *Drawida*

sp. A (sensu Gates, 1935, 1936a), *Drawida* sp. B (sensu Gates, 1936a) and *Drawida malayana* (Gates, 1938)(= *Drawida* sp. C sensu Gates, 1936a), were reported from the Malay Peninsula. However, only one species, *D. malayana*, was named, and the others were considered as anonymous species due to immaturity of the specimens (Gates, 1935, 1936a, 1938). In this study, none of the *Drawida* specimens collected from Singapore was fully matured, but they may be separated into the following three anonymous species.

Drawida sp. 1

(Fig. 6)

Material examined. – 6 immature (acitellate) specimens (3 amputated, 1 dissected)(ZRC), Rifle Range Rd. opposite to Murnane Reservoir, 5 Mar.2003; 1 immature specimen (ZRC), Upper Seletar Reservoir Park outside Nee Soon Rifle Range, 5 Mar.2003; 3 immature (acitellate) specimens (ZRC), Rifle Range Rd. opposite to Murnane Reservoir, 25 Jun.2003. All the above specimens were collected by K. K. P. Lim, D. C. J. Yeo & K. L. Yeo.

Description. – Length 59-92 mm (amputated specimens not included), weight 0.35-0.61 g, diameter 2.7-3.8 mm. Segments numbering 119-168. Prostomium prolobous. Dorsal pores absent. Setae closely paired, $ab = cd$, $aa = 0.7 bc$, dd

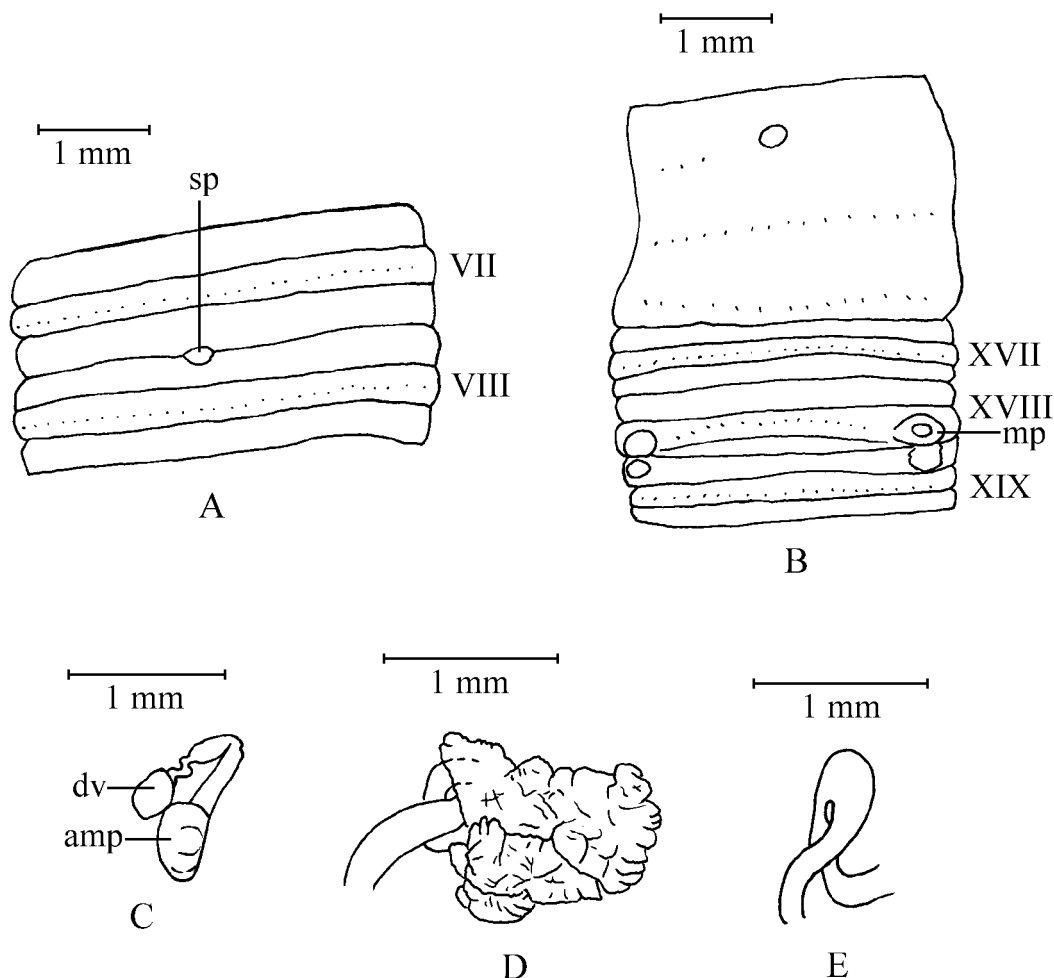


Fig. 5. *Polypheretima taprobanae* (Beddard, 1892). A, left lateral view of spermathecal region (sp, spermathecal porophore); B, ventral view of male porophore (mp) region; C, dorsal view of right spermatheca (amp, ampulla; dv, diverticulum); D, dorsal view of right prostate gland; E, right prostatic duct.

greater than 0.5 body circumferences. Clitellum not recognizable on any of the specimens. Spermathecal pores one pair in 7/8, medial to c, edge wrinkled (Fig. 6A). Male pores on teat-like protuberances from transversely oval areas across 10/11 (Fig. 6B). Female pores in 11/12. A pair of round epidermis thickening postsetal on segment X, lateral to b, each area about 0.55 mm wide, one transversely oval area often present between male porophores on XI, about 0.98 mm in width. Preserved specimens pale grey.

Septa 5/6-7/8 muscular, 8/9 thick. Gizzards five in XIV-XVIII, large, round, yellowish. Hearts VI-IX. Nephridia holoic. Testis sacs one pair, large, extending into IX and X, smooth, yellowish, elongated oval, 1.61-1.7 mm in length, about 0.95 mm in width. Sperm duct in form of a large mass of white twisted tubes (Fig. 6D). Male atrium tubular, coiled into a compact, circular shape about 0.85 mm in length and 0.75 mm in width, not bound to the body wall, ectal end finely granulated, connecting to outside male opening. Accessory glands absent. Ovaries not visible. One pair of ovisacs extending from septum 11/12 to segment XIII. Spermathecae lying on anterior face of septum 7/8, ampulla spindle-shaped and wrinkled, about 1.64 mm long, 0.95 mm wide, with a stout, wrinkled, slightly bent stalk connecting to the spermathecal atrium, the atrium about 0.65 mm in length (Fig. 6C).

Remarks. – *Drawida* sp. 1 is similar to *Drawida rara* (see Gates, 1925, 1926a, d) in structure of male protuberances. However, the structure and position of genital markings are different. *Drawida* sp. 1 has a pair of round epidermis thickenings lateral to b on segment X, whereas *D. rara* has a small, circular papilla slightly external to each male protuberance and/or a transversely crescent-shaped area

postsetal on VIII or presetal on IX, X, or XI (cf. Gates, 1925, 1926a, d). In addition, *Drawida* sp. 1 has sperm ducts in the form of large masses of twisted tubes, whereas *D. rara* has short, slender, slightly coiled sperm ducts (Gates, 1925, 1972).

The characters of the sperm duct (vas deferens) and male atrium (prostate) described for *Drawida* sp. A (see Gates, 1935, 1936a) from the Malay Peninsula are similar to *Drawida* sp. 1 of this study. However, the juvenile specimen of *Drawida* sp. A has small testis sacs, small spermathecal ampullae and no genital marking. These characteristics are probably due to its immaturity. *Drawida* sp. 1 has male pores on protuberant porophores whereas this is not observed for *Drawida* sp. B (see Gates, 1936a) and *D. malayana* (see Gates, 1938).

Drawida sp. 2

(Fig. 7)

Material examined. – 2 immature (aclitellate) specimens (1 dissected)(ZRC), Rifle Range Rd. opposite to Murnane Reservoir, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 5 Mar.2003.

Description. – Thin, slender worm, length 67-100 mm, diameter 1.2-1.7 mm. Segments numbering 178-208. Prostomium prolobous. Setae closely paired, ab = cd, aa slightly smaller than bc, dd greater than 0.5 body circumferences. Clitellum not distinguishable. Spermathecal pores one pair in 7/8, small, inconspicuous slits, medial to c. Male pores not visible. Female pores in 11/12. A pair of white, elongate and slightly diagonal areas with bluntly rounded ends across 10/11 (Fig. 7A). A pair of white elongate epidermis thickening extending from 9/10 to just behind the setal line on segment X, each area about 0.55 mm in length, 0.5-0.55 mm in width (Fig. 7A). Preserved specimens pale grey.

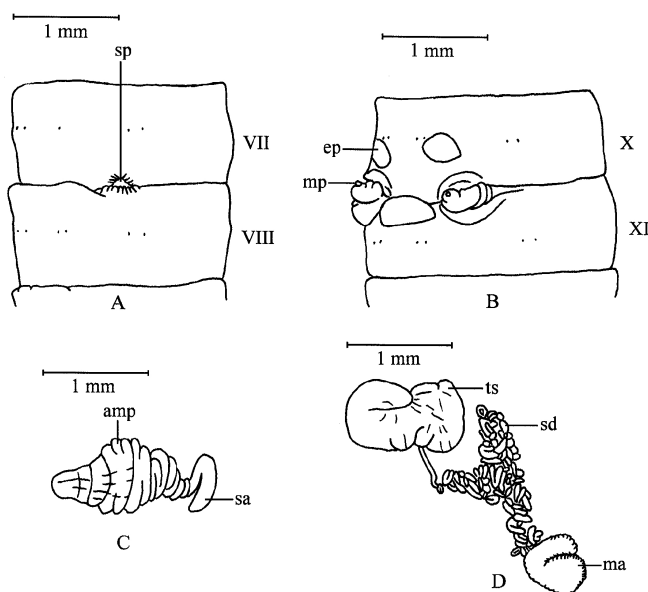


Fig. 6. *Drawida* sp. 1. A, left latero-ventral view of spermathecal pore (sp); B, left latero-ventral view of male pore (mp) region (ep, epidermis thickening); C, dorsal view of right spermatheca (amp, ampulla; sa, spermathecal atrium); D, dorsal view of right testis sacs (ts), sperm duct (sd), and male atrium (ma).

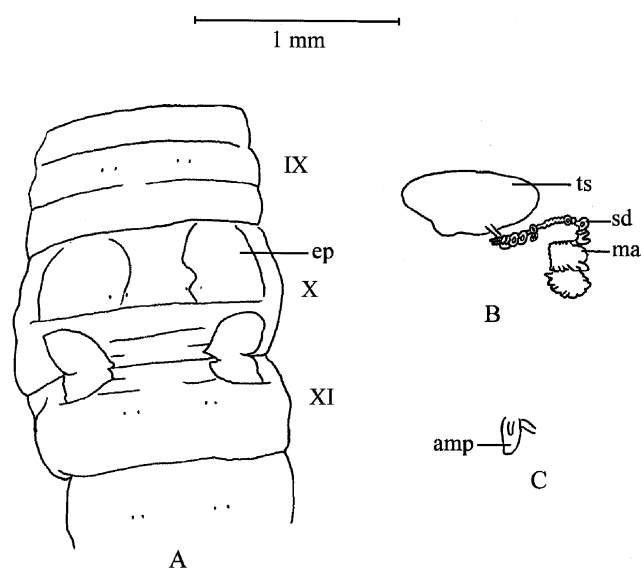


Fig. 7. *Drawida* sp. 2. A, ventral view of segment IX-XI (ep, epidermis thickening); B, dorsal view of right testis sacs (ts), sperm duct (sd), and male atrium (ma); C, dorsal view of right spermatheca (amp, ampulla).

Septa 5/6-8/9 thick. Gizzards five in XIX-XXIII, round, yellowish. Hearts VI-IX. Nephridia holoic. Testis sacs one pair, extending into X and XI, smooth, yellowish, elongated oval, 0.98-1.07 mm in length, about 0.45 mm in width. Sperm duct thin, twisted, consisting of several small coils (Fig. 7B). Male atrium small, about 0.35 mm in length and 0.18 mm in width. Accessory glands absent. Ovaries not visible. Ovisacs small, one pair extending from septum 11/12 and confined in segment XII, about 0.35 mm long. Spermathecae very small, lying on anterior face of septum 7/8, tongue-like, stick out from body wall, about 0.2 mm in length (Fig. 7C).

Remarks. – The thin, slender feature and the gizzard positions in more posterior segments distinguish *Drawida* sp. 2 from all other *Drawida* species of Burma and the Malay Peninsula.

***Drawida* sp. 3**
(Fig. 8)

Material examined. – 1 immature (aclitellate) specimen (dissected)(ZRC), Turut Track, Kranji Wireless Station, coll. K. K. P. Lim, D. C. J. Yeo & K. L. Yeo, 7 Mar.2003.

Description. – Small worm, length 40 mm, diameter 1.87 mm. Segments numbering 113. Prostomium prolobous. Setae closely paired, ab = cd, aa slightly smaller than bc, dd greater than 0.5 body circumferences. Spermathecal pores small slits in 7/8, medial to c. Male pores and female pores not visible. Paired white round areas lateral to ab, postsetal on segment X and presetal on segment XI, without distinctly demarcated margins. Other genital markings or protuberances not visible. Preserved specimen pale grey.

Septa 5/6-7/8 muscular. Gizzard in XV, round, yellowish. Hearts VI-IX. Nephridia holoic. Testis sacs one pair in X, small, oval, smooth, about 0.45 mm in length. Sperm duct compact and heavily twisted, with a short, slender, straight distal end connecting to male atrium (Fig. 8). Male atrium small, follicular portion about 0.35 mm in length, lower bulge round, white, about 0.3 mm in diameter, immediately adjacent to 10/11 segmental furrow. Accessory glands absent. Ovaries not visible. Two pairs of large, yellowish fat tissues present: anterior pair in X-XI and posterior pair asymmetrical (left

one in XII-XV and right one in XII-XIII). Spermathecae not visible.

Remarks. – The specimen is too small and immature for species identification.

DISCUSSION

Based on the literature (Stephenson, 1932; Gates, 1935, 1937), earthworm specimens preserved in the Raffles Museum of the National University of Singapore, and the results of our 2003 earthworm survey, there are a total of 16 nominal species and three unidentifiable *Drawida* species of terrestrial earthworms known from Singapore so far. Two anonymous species of the genus *Glyphidrilus* and one anonymous species of *Amyntas* described in the present study might be conspecific with one or more of the nominal species, and they are thus not included as the part of the earthworm biodiversity of Singapore.

Of the 16 nominal species from Singapore, there are three native species, *Amyntas procerus*, *Metaphire arcuata* and *Glyphidrilus singaporensis*, new species; one possibly native species, *Glyphidrilus horsti* found only in Pulau Berhala and Singapore; and 12 peregrine species. Based on the original home ranges suggested by Gates (1972), the peregrine species might be divided into the following four groups:

Group 1 consists of *Pontoscolex corethrurus*, which originated from the tropical America; *Dichogaster saliens*, from the tropics of either Africa or America; and *Ocnodrilus occidentalis*, possibly from somewhere between the United States and South America. Group 2 consists of *Amyntas gracilis* and *A. morrissi* from China. Group 3 consists of *Lampito mauritii*, which originated from South India; *Metaphire houlleti* from Southeast Asia and probably eastern Burma; *M. peguana* from Burma and presumably also in adjacent Thailand and the Malay Peninsula; and *Perionyx violaceus* from Southeast Asia. Group 4 is *Amyntas minimus* and *Polypheretima taprobanae* of unknown origin. The original home of *Pheretima darnleiensis* is probably somewhere in Southeast Asia, and thus, it belongs to Group 3. Species in Groups 1 and 2 are cosmopolitan, while those in Group 3 are widely distributed in South or Southeast Asia; and Group 4 shows scattered distribution (Gates, 1972).

Of the 16 nominal species, five were newly recorded to Singapore in 2003, while seven species reported in the 1930s (Stephenson, 1932; Gates, 1935, 1937) were not found in 2003 (Table 1). For the newly recorded species, two are native species, *G. singaporensis* and *G. horsti*, and three are peregrine species, *A. gracilis* of Chinese origin and *A. minimus* and *P. taprobanae* of unknown origin. Of the seven species not found in 2003, two are native species, *A. procerus* and *M. arcuata*, and five are common peregrine earthworms: *L. mauritii*, *M. houlleti*, *M. peguana*, *D. saliens*, and *O. occidentalis*. The former three species belonging to Group 3 are from South or Southeast Asia (Gates, 1972), and thus, they might be the original residents of Singapore or introduced

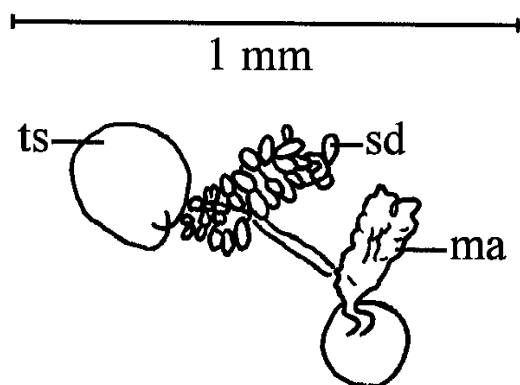


Fig. 8. *Drawida* sp. 3. Dorsal view of right testis sacs (ts), sperm duct (sd), and male atrium (ma).

to the island long time ago. The latter two species belonging to Group 1 are from tropical America or Africa. Like *P. corethrurus* they might be introduced to the island perhaps a few centuries ago. The above difference in the species composition of Singapore's earthworm fauna between the 1930s and 2003 suggests the presence of species shift. As Singapore rapidly became highly urbanized in the past decades, local earthworm species that once prevailed in the forest and lowland habitats were replaced by species more adapted to man-made habitats, such as those belonging to Groups 1 and 2.

Key to species of terrestrial earthworms reported from Singapore

1. Setae 8 per segment 2
 - Setae numerous, more than 10 per segment 8
2. Caudal setae in irregular, quincunx arrangement
 - *Pontoscolex corethrurus*
 - Caudal setae in regular rows 3
3. Dorsal pores present *Dichogaster saliens*
 - Dorsal pores absent 4
4. Segment number less than 100; calciferous glands paired in IX *Ocnodrilus occidentalis*
 - Segment number more than 100; calciferous glands absent ... 5
5. Spermathecal pores not visible; wings present at maturity ... 6
 - Spermathecal pores one pair in 7/8; wings absent 7
6. Body length longer than 100 mm *Glyphidrilus singaporensis*
 - Body length shorter than 60 mm *Glyphidrilus horsti*
7. Diameter about 3 or 4 mm; gizzards in XIV-XVIII
 - *Drawida* sp. 1
 - Diameter less than 2 mm; gizzards in XIX-XXIII
 - *Drawida* sp. 2
 - Diameter about 2 mm; gizzard in XV *Drawida* sp. 3
8. Male pores closely paired in medio-ventral XVIII
 - *Perionyx violaceus*
 - Male pores widely paired in ventral XVIII 9
9. Gizzard in V *Lampito mauritii*
 - Gizzard behind 7/8 10
10. Intestinal caeca absent *Polypheretima taprobanae*
 - Intestinal caeca present 11
11. Copulatory pouches absent 12
 - Copulatory pouches present 14
12. One thecal segment *Amyntas minimus*
 - More than one thecal segment 13
13. Two thecal segments *Amyntas morrisi*
 - Three thecal segments *Amyntas gracilis*
 - Four thecal segments *Amyntas procerus*
14. Nephridia on spermathecal ducts *Pheretima darnleiensis*
 - Nephridia absent from spermathecal ducts 15
15. Zero or one thecal segment *Metaphire arcuata*
 - Three thecal segments 16
16. Post-clitellar genital markings absent *Metaphire houlleti*
 - Post-clitellar genital markings paired in 17/18 and 18/19
 - *Metaphire peguana*

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