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The Semi-Aquatic Freshwater Earthworm Genus *Glyphidrilus* Horst, 1889 from Myanmar (Oligochaeta: Almidae) with Description of a New Species

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ABSTRACT.– After the publication of the comprehensive monograph on Burmese earthworms by Gordon E. Gates in 1972, there has only been one recent publication by Csuzdi et al. (2015), which reported seven species records belonging to the families Moniligastridae, Benhamiidae, Octochaetidae and Megascolecidae, but did not include any species in the family Almidae. During 2015–2016, we collected *Glyphidrilus* samples (family Almidae) from some parts of Myanmar under the Fauna and Flora International (FFI) program, resulting in the discovery of *Glyphidrilus tonywhitteni* Chanabun and Panha, new species. It differs from its congeners by having clitellar wings at 21–25, ½26, clitellum location at 14, 15–30, 31, genital markings paired on bc at 13, 14–20 and 26 and on aa at 11–13, 14, and spermathecae at 13/14–15/16.

KEY WORDS: *Glyphidrilus*, earthworm, Almidae, new species, Myanmar

INTRODUCTION

The earthworms of Myanmar have rarely been investigated. The total of 13 species was firstly presented by Rosa (1888, 1890a, b). After that, there were several reports by Michaelsen (1907, 1908, 1918), Stephenson (1912, 1916, 1923) and Gates (1972). Blakemore (2006) updated the earthworm numbers from Myanmar and reported the total of 195 species. After Gates (1972) work, no further earthworm records were reported from Myanmar until very recently, Wang et al. (2015) reported the full mitochondrial genome of *Tonoscolex birmanicus* (Gates, 1927) from National Kandawgyi garden, Mandalay and Csuzdi et al. (2015) reported seven species from the families Moniligastridae, Benhamiidae, Octochaetidae and Megascolecidae. However, the report contained only the data of the terrestrial species without data on the semi-aquatic earthworms in the family Almidae.

The semi-aquatic freshwater earthworm genus *Glyphidrilus* Horst, 1889 is comprised of earthworms that live in the ecotone habitat between freshwater and terrestrial ecosystems. They could be found along the muddy banks of rivers, streams, canals, ponds, lakes, waterfalls and in paddy fields (Chanabun et al., 2013). These earthworms belong to the family Almidae, whose distribution range covers wide areas from Central and South America, tropical Africa

and the Nile Valley, to India and Southeast Asia (Jirapatrasilp et al., 2016). Earthworms in this family are notable for their quadrangular body at the posterior and round body at the anterior. The earthworm presents the unique extensions of the epidermis in the clitellar region called wings (Jamieson, 2006). The genus *Glyphidrilus* has a widespread occurrence in the Oriental region and East Africa (Jirapatrasilp et al., 2016). In recent years, several surveys and investigations have revealed a high species diversity of *Glyphidrilus* in Southeast Asia, which has led to the recognition of a total of 46 morphospecies and one subspecies (Shen and Yeo, 2005; Chanabun et al., 2011, 2012a, b, 2013; Chanabun and Panha, 2015; Jirapatrasilp et al., 2016; Chanabun et al., 2017). However, a recent molecular analysis revealed that twelve nominal morphospecies belong to the same clade as some other older morphospecies (Jirapatrasilp et al., 2019), in which the status of those doubtful morphospecies will be reinvestigated and revised in future study.

Myanmar is bordered by India and Bangladesh to its west, Thailand and Laos to its east and the People's Republic of China to its north and northeast. Myanmar has a contiguous coastline along the Bay of Bengal and Andaman Sea to the southwest and the south, which forms one quarter of its total perimeter. In the north, the Hengduan Mountains form the border with China and include Hkakabo Razi, located in Kachin State, the (likely) highest peak in Myanmar. Myanmar has six river basins including Ayeyarwady (Irrawaddy)-Chindwin River basin, Sittaung river basin, Thanlwin (Salween in Thailand, Nu in China) River basin, Mekong (Lankang in China) River basin, Rakhine (Arakan) coastal basin and Tanintharyi (Tenasserim) coastal basin (Frenken, 2012).

Knowledge of the country's biodiversity is currently scarce but increasing due to the recent assistance of Fauna and Flora International (FFI) to conduct biodiversity surveys. The fauna inventories of Myanmar have mainly focused on vertebrates and some large groups of invertebrates near limestone mountain areas, including earthworms. However, the diversity of semi-aquatic freshwater earthworms in Myanmar has been totally neglected since the Gates' report in 1958, and has still received no attention from local researchers, in contrast to the neighboring Singapore (Shen and Yeo, 2005), Thailand (Chanabun et al., 2012a, b, 2013, 2017), Laos (Chanabun et al., 2011; 2017), Malaysia (Chanabun et al., 2012b; Chanabun and Panha, 2015) and Cambodia (Jirapatrasilp et al., 2016). Until now, there has still been no update on the semi-aquatic earthworm diversity in Myanmar.

During 2015–2016, together with members of the Animal Systematics Research Unit, Chulalongkorn University and staff of the FFI, Myanmar, we conducted a survey of Myanmar invertebrates, including the semi-aquatic earthworm fauna which were collected from selected river basins in Myanmar. This paper serves to report the findings of this survey for the semi-aquatic freshwater earthworms. Of interest is the description of one new species, *Glyphidrilus tonywhitteni*, which was previously recognized based on molecular data as an undescribed species (sp. 14) in Jirapatrasilp et al. (2019). In addition, we reported a new record of *Glyphidrilus horsti* Stephenson, 1930 and obtained new specimens of *Glyphidrilus papillatus* (Rosa, 1890a). *Glyphidrilus birmanicus* Gates (1958) was also reported here. To date, therefore, a total of four nominal *Glyphidrilus* species have been reported from Myanmar, including the new species reported here (Table 1).

TABLE 1. Comparison of the morphological characters of *Glyphidrilus tonywhitteni*, new species, *G. papillatus* (Rosa, 1890), *G. birmanicus* Gates, 1958, *G. horsti* Stephenson, 1930 and *G. wararamensis* Chanabun and Panha, 2013.

Characters	*G. tonywhitteni*, new species	*G. papillatus*		*G. horsti*		*G. birmanicus*	*G. wararamensis*
		*	**	*	**	*	*
Length	52–120	100	41–78	30 (max: 35)	47–112	95–103	18+–120
Segments	156–284	330	129–267	145–167	148–277	?	46+–279
Clitellum	14, 15–30, 31	14–40	14, 15–35, 36, 37, 38, 39	17–28	16, 18–29, 30, 31	12, 13–43, 44	11, 12, 13–33, 34, 35
Wings	21–25, ½26	18–23, 24, 25, 26	18, 19–25, 26	½23–27	21, 22, 23–26, 27, 28, 29	21–29	20, 21–26, 27
Genital markings							
On bc	13, 14–20, 26	12–18	16, 17, 18	23, 27	13–15, 17, 18, 21, 22	12–21, 22, 23, and 30–31, 33, 34	14, 15, 17–19, 20, 27
On aa	11–13, 14	11–21, 23–32, 33	12, 13, 18	16, 17, 18–20, 22, 27, 28	18, 19, 29–31	Absent	11–13, 14, 15, 17, 18, 19, 20, 28, 29, 30
Hearts	7–11	7–11	7–11	?	9–11	7–11	8–11
Seminal vesicles	9–12	9–12	9–12	9–12	9–12	9–12	9–12
Intestinal origin	15	15	15	16	15 (16)	15	14
Gizzard	7–8	7–8	7–8	7–8	7–8(8)	7–8	6–8
Spermathecae	13/14–15/16	14–17	13/14–16/17	14–17 (14/15–16/17)	13/14 (14/15)–16/17 (17/18)	14–18	13/14–17/18

*original descriptions, **this study

MATERIALS AND METHODS

Earthworms were collected by digging up the topsoil from the banks of freshwater habitats where casts were apparent. The GPS coordinates of each locality was recorded, and the habitat type photographed. All specimens were cleaned and then killed in 30% (v/v) ethanol, photographed and fixed in 95% (v/v) ethanol for morphological and molecular studies. Species identification and nomenclature for the taxonomic characters was based on Chanabun et al. (2013). Further comparative studies of *Glyphidrilus* type specimens were conducted at Chulalongkorn University, Museum of Zoology, Bangkok (CUMZ). The new species was described from observations under an OLYMPUS SZX16 stereomicroscope. The following external and internal morphological structures were recorded: body length and segment number; the positions of clitellum and clitellar wings, genital markings, intestinal origin, gizzard and spermathecae. The hearts and seminal vesicles were also critically searched for and studied. Drawings were made for the anterior body segments and the distinct external characters and internal organs, as mentioned above, and are shown in the Figures.

The holotype and paratypes were deposited in Chulalongkorn University, Museum of Zoology (CUMZ), The Natural History Museum, London, UK (NHMUK), Biozentrum Grindel und Zoologisches Museum, University of Hamburg, Germany (ZMH) and Lee Kong Chian Natural History Museum, National University of Singapore, Singapore (LKCNHM). The collection localities of the specimens in this study are shown in Figure 1.

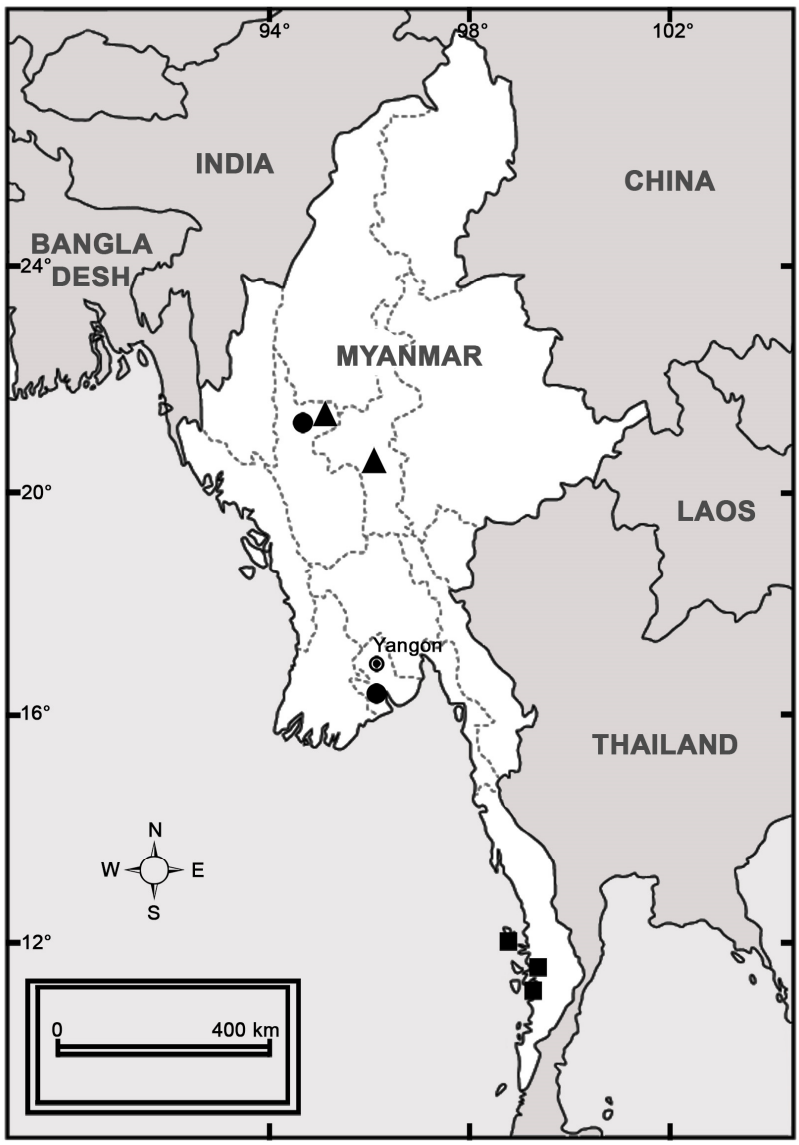

FIGURE 1. Distribution map of the *Glyphidrilus* species from Myanmar. Filled triangle: *G. tonywhitteni*, new species, filled circle: *G. papillatus* (Rosa, 1890), filled square: *G. horsti* Stephenson, 1930

Comparative studies of *Glyphidrilus* type specimens were made at the same four natural history museums: CUMZ, LKCNHM, NHMUK, and ZMH.

Anatomical abbreviations: The following abbreviations used in the figures are as appeared in Chanabun et al. (2013): wi, wings; gm, genital markings; he, hearts; sv, seminal vesicles; sc, spermathecae; np, nephridia.

RESULTS

TAXONOMY

Family ALMIDAE Duboscq, 1902

Genus *Glyphidrilus* Horst, 1889

Type species *Glyphidrilus weberi* Horst, 1889, by monotypy

***Glyphidrilus tonywhitteni* Chanabun and Panha, new species**

urn:lsid:zoobank.org:act:C77B7899-E11B-460E-AE3B-C74C0226E014

(Figs. 1, 2, 3)

Material examined.– Holotype: One adult (CUMZ 3801), Myanmar, bank of Paalaung River at Mandalay (20° 49' 05.5" N, 96° 23' 06.9" E), coll. S. Panha, C. Sutcharit, W. Siriwut, R. Srisonchai, A. Pholyotha and T. Seesamut (7 October 2016). 55 paratypes: 43 adults and 12 juveniles (CUMZ 3812), 2 adults (LKCNHM), 2 adults (ZMH 14585), and 2 adults (NHMUK), all with the same collection data as for holotype.

Other material examined.– 10 juveniles (CUMZ 3802), Myanmar, Bahin Village, Pakkoku, Magway (21° 43' 34.0"N, 94° 40' 39.6" E), coll. W. Siriwut (12 February 2014).

Diagnosis.– *Glyphidrilus tonywhitteni*, new species, small semi-aquatic freshwater earthworm with body size both adults and late juveniles ranged from 52–120 mm, with 156–284 segments. The distinct expanded tissues of clitellar wing organs on the lateral sides of the body in 21–25, ½26. Clitellum location at 14, 15–30, 31. Female pores, male pores and spermathecal pores not visible. Genital markings paired on bc at 13, 14–20 and 26 and on aa at 11–13, 14. Four pairs of seminal vesicles in 9–12, with the pair in segment 12 largest. Intestinal origin in 15. Ovaries in 13–14. Prostate and accessory glands absent. Spermathecae at 13/14–15/16.

Etymology. – The species was named after FFI's Dr. Tony Whitten, who has been a passionate advocate for the conservation of biodiversity.

Description of Holotype. – Dimensions: Body length 82 mm by 2.9 mm wide at the anterior body region in segment 8, 3.1 mm wide before the clitellar wings in segment 20, 3.2 mm wide after the wings in segment 27 within the clitellum, body cylindrical in the anterior part but quadrangular in transverse section after the clitellum, with 174 segments. Body colour pale brown with variation from red to pink coloration at tissues adjacent to the wing portion in different individuals based upon newly collected specimens after placement in 30% (v/v) ethanol for narcotization. Dorsal surface considerably broader than ventral surface at the posterior end. Clitellar wings on the ventro-lateral part of the clitellum in 21–½26, 1.5 mm long, and about 0.5 mm wide on both sides. Prostomium zygolobous. Dorsal pores absent. Clitellum annular shape in 14–30. Four pairs of setae per segment from segment 2, setae formula aa:ab:bc:cd:dd = 1.0:0.5:1.5:0.5:2.0 in segment 8 and 1.0:0.5:1.5:0.5:1.5 in postclitellar segments. Female pores, male pores and spermathecal pores not visible. Genital markings: paired on bc in 14–20 and 26.

Septa 7/8–11/12 thicker than the other segments, 12/13–13/14 thick and 14/15 to the last segment thin. Gizzard small, globular within segments 7–8. Intestine enlarged from 15. Dorsal blood vessel anterior to 7. Hearts from 7–11. No nephridia distinguishable in the first twelve segments. Four pairs of seminal vesicles in 9–12, with the pair in segment 12 larger than the others. Ovaries in 13–14. Prostate and accessory glands absent. Spermathecae sessile, elongated oval in 13/14–15/16,

FIGURE 2. Photographs showing the **(A)** type locality of *Glyphidrilus tonywhitteni*, new species, in the bank of the Paalaung River at Mandalay, Myanmar, with **(B)** casts of *G. tonywhitteni*, new species. **(C, D)** coloration of the newly collected paratype (CUMZ 3812) as **(C)** after the first preservation step in 30% (v/v) ethanol and **(D)** the living paratype (CUMZ 3812)

about 0.3 mm in diameter, one to four on each side per segment.

Variation. – Body lengths of adult (n = 50) ranged from 57–92 mm (74.2 ± 13.0), with 156–284 segments; and juvenile (n = 22) ranged from 52–120 mm (84.33 ± 19.5), with 194–228 segments. Wing begin in 21 and end in 25 or ½26, the most frequent position is 21–25. Clitellum begin in 14 or 15 and ends in 30 or 31. The most specimens have genital markings paired or asymmetrical on aa in 11, 12, 13, 14. Genital markings paired or asymmetrical on bc start in 13, 14 and end in 20 some in 26.

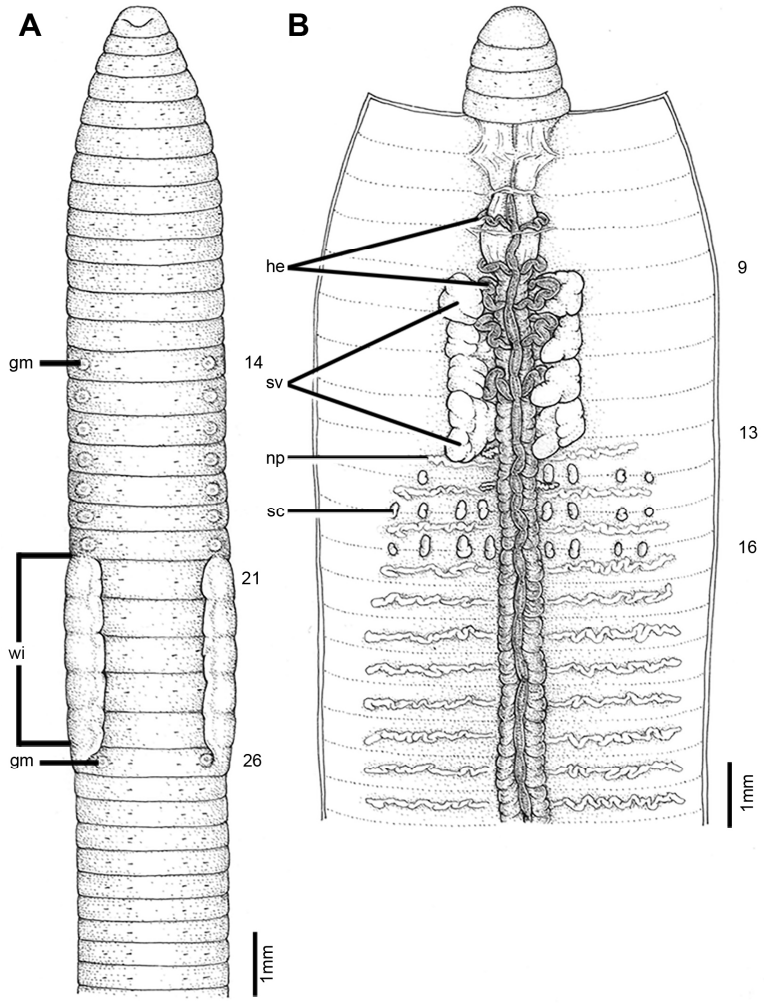

FIGURE 3. Morphology of holotype (CUMZ 3801) of *Glyphidrilus tonywhitteni*, new species. **(A)** External ventral view, annular clitellum in 14–30 and **(B)** internal dorsal view

Distribution. – The new species is known from the type locality at a bank of the Paalaung River, Mandalay. This city is the second largest city and the last royal capital of Myanmar, located in the north of Yangon on the east bank of the Irrawaddy River. In addition, this new species was also collected from Bahin Village, Pakkoku, Magway.

Habitat. – Found on the shore of the River Paalaung near the Apache Cement Factory Pyinyaung, Mandalay, and waterway in Bahin Village, Pakkoku, Magway, Myanmar. The river bank soil surface was covered with worm casts.

Remarks. – *Glyphidrilus tonywhitteni*, new species, from Mandalay, Myanmar has clitellum at 14, 15–30, 31, wings at 21–25, ½26 and spermathecae at 13/14–15/16. *Glyphidrilus papillatus* (Rosa, 1890) from Burma (type specimen) and from Kandawgyi

Lake, Yangon (present specimens) differs by the longer clitellum at 14, 15–35, 36, 37, 38, 39, 40, longer wings at 18, 19–23, 24, 25, 26, and spermathecae at 14–17 or 13/14–16/17. The following characters of *G. birmanicus* Gates, 1958 differ from the new species: the longer clitellum at 12, 13–43, 44 and longer wings at 21–29. The new species differs from *G. horsti* Stephenson, 1930 from Pulau Berhala, Straits of Malacca (type specimen), Turut Track, Kranji Wireless Station, Singapore (Shen and Yeo, 2005), Ban Namyen, Phayarhtan Cave and Bok Myiek, Myanmar (current specimens) by the positions of clitellum in 16, 17, 18, ½18, 19–29, 30, ½31, 31, wings in 21, 22, 23, ½23, –½28, 28, 29 and spermathecae in 14–17 or 13/14(14/15)–16/17(17/18) of the latter. This species also differs from *G. wararamensis* Chanabun and Panha, 2013 from Wat Tham Wararam, Phanom, Suratthani in that *G. wararamensis* has a longer clitellum in 11, 12, 13–34, 35, widely genital markings on 11–13, 14, 15, 17, 18, 19, 20, 28, 29, 30, and spermathecae in 13/14–17/18. In addition, *Glyphidrilus tonywhitteni*, new species, was previously recognized as an undescribed species (sp. 14) and its status was supported by an integrative taxonomic analysis, in which the juveniles from Bahin Village, Pakkoku, Magway, Myanmar was identified based on molecular data (Jirapatrasilp et al., 2019).

Glyphidrilus papillatus (Rosa, 1890)

(Figs. 1, 4, 5)

Bilimba papillata Rosa, 1890a: 386, fig. 1. Type locality: Myanmar. Beddard, 1895: 687.

Glyphidrilus papillatus—Michaelsen, 1896: 196, 1910: 104. Stephenson, 1923: 493. Gates, 1933: 603, 1958: 60. Chen, 1938: 426. Jamieson, 1968: 393. Brinkhurst and Jamieson, 1971: 763. Chanabun et al., 2012a: 268. Chanabun et al., 2013: 17.

Material examined. – Additional records: 10 juveniles (CUMZ 3724), pathway to PK-3, 2, Bahin Village, Magway, Myanmar, 21° 45' 10.4" N, 94° 39' 50.8" E (11 February 2014); 15 adults and 43 juveniles (CUMZ 3723), Kandawgyi Lake, Yangon, Myanmar, 16° 47' 58.2" N, 96° 9' 46.5" E (11 June 2015).

Description. – Dimensions: 41–78 mm body length by 2.5–3.0 mm in the anterior body region, body cylindrical in the anterior part but quadrangular in transverse section after clitellum, with 129–267 segments. Body colour pale brown. Dorsal surface considerably broader than ventral at the posterior end. Clitellar wings on ventro-lateral part of the clitellum at 18, 19–25, 26, are 3.5–4.0 mm long, and 0.5–1.0 mm wide on both sides. Prostomium zygolobous. Dorsal pores absent. Clitellum annular shape from 14, 15–35, 36, 37, 38, 39. Four pairs of setae per segment from segment 2. Female, male and spermathecal pores not visible. Genital markings: lateral series paired or asymmetrical, between bc in 16, 17, 18; unpaired median series between aa in 12, 13, 18.

Septa 4/5–8/9 thick, 9/10–14/15 moderately thick and extremely thin from 15/16 to the end. Gizzard globular in 7–8. Intestine enlarged from 15. Dorsal blood vessel anterior to 7. Hearts from 7–11. No nephridia distinguishable in the first twelve segments. Four pairs of seminal vesicles in 9–12. Ovaries in 13–14. Prostate and accessory glands absent. Spermathecae sessile, globular, 0.2–0.3 mm in diameter, on segments 13/14–16/17, numerous on each side per segment.

Habitat. – Found at Kandawgyi Lake, Yangon, Myanmar, on the lake shore the

FIGURE 4. Photographs showing the **(A, B)** locality of *Glyphidrilus papillatus* (Rosa, 1890) in Kandawgyi Lake, Yangon, Myanmar; and **(C)** coloration of the newly collected specimens (CUMZ 3723) after the first preservation step in 30% (v/v) ethanol

sandy mud topsoil and also under water at a depth of about 5–10 cm, where the bank soil surface was covered with worm casts. This species was previously known from Burma (Myanmar) as in the original description and in the recent collections there are records from Kandawgyi Lake, Yangon, Myanmar. In addition, this species was also collected along the pathway to PK-3, 2, Bahin Village, Magway, Myanmar.

Remarks. – *Glyphidrilus papillatus* from Myanmar reported by Rosa (1890a) has

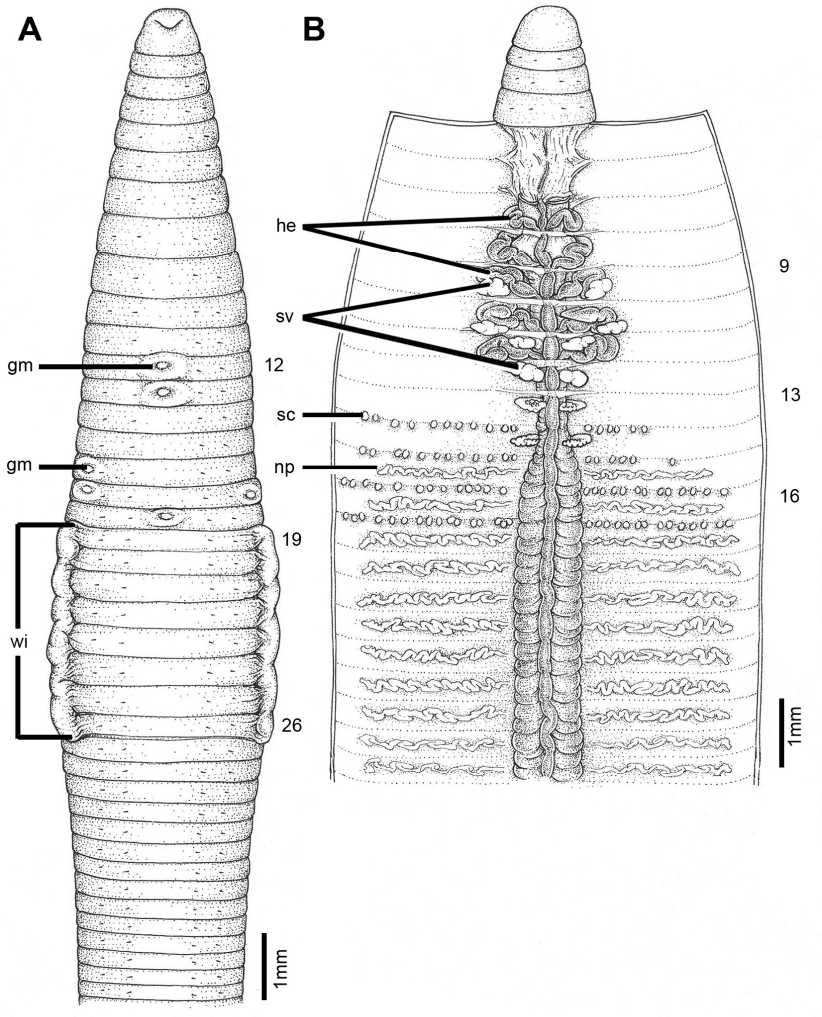

FIGURE 5. Morphology of *Glyphidrilus papillatus* (Rosa, 1890) (CUMZ 3723). **(A)** External ventral view and **(B)** internal dorsal view

clitellum in 14–40, wings in 18–23, 24, 25, 26 and spermathecae in 14–17. The specimens collected from Kandawgyi Lake, Yangon, Myanmar in this study are slightly different from the type specimen by a smaller size than the type specimen. Positions of the clitellum and spermathecae also are slightly different from those of the type specimen by one segment in 14, 15–35, 36, 37, 38 and 39 for the clitellum, and at intersegment in 13/14–16/17 for the spermathecae. The lateral series of paired and unpaired median series of genital markings of the type specimens are more widespread than those of the specimens found in this study. Most of the morphological characteristics are quite similar to the type specimen. Photographs

and drawings of the specimens collected from Kandawgyi Lake, Yangon, Myanmar are shown in Figures 4 and 5. In addition, the status of this species was also supported by an integrative taxonomic analysis, in which the juveniles from the pathway to PK-3, 2, Bahin Village, Magway, Myanmar were identified based on molecular data (Jirapatrasilp et al., 2019).

Glyphidrilus horsti Stephenson, 1930
(Figs. 1, 6, 7)

Glyphidrilus horsti Stephenson, 1930: 4. Type locality: Pulau Berhala, Straits of Malacca. Jamieson, 1968: 392. Brinkhurst and Jamieson, 1971: 759. Shen and Yeo, 2005: 18, fig. 2. Chanabun et al., 2013: 30, fig. 15.

Material examined. – Additional records: 3 adults (CUMZ 3695), Ban Namyen, Lenya National Park, Tanintharyi, Myanmar, 11° 15' 56.53" N, 99° 13' 0.55" E, 79 meters above mean sea level (amsl) (31 May 2015); 82 adults and 16 juveniles (CUMZ 3811), Phayarhtan Cave (Buddha Cave), Lenya National Park, Tanintharyi, Myanmar, 11° 13' 49.61" N, 99° 10' 34.51" E, 200 meters amsl (3 June 2015). 9 adults and 8 juveniles (CUMZ 3696) (Fig. 7), Bok Myiek, Myanmar, 12° 40' 54.0" N, 98° 44' 56.0" E (5 April 2016).

Description. – Dimensions: 47–112 mm body length by 1.4–2.0 mm in the anterior body region, body cylindrical in the anterior part but quadrangular in transverse section after clitellum, with 148–277 segments. Body colour pale brown. Dorsal surface considerably broader than ventral at the posterior end. Clitellar wings on ventro-lateral part of the clitellum in 21, 22, 23–26, 27, 28, 29 are 2.8–4.5 mm long, and 0.5–1.3 mm wide on both sides. Prostomium zygolobous. Dorsal pores absent. Clitellum annular shape from 16, 18–29, 30, 31. Four pairs of setae per segment from segment 2. Female, male and spermathecal pores not visible. Genital markings: lateral series paired or asymmetrical, between line bc in 13–15, 17, 18, 21, 22; unpaired median series between aa in 18, 19, 29–31.

Septa 4/5–8/9 thick, 9/10–14/15 moderately thick and extremely thin from 15/16 to the end. Gizzard globular in 7–8 or 8. Intestine enlarged from 15 or 16. Hearts from 9–11. No nephridia distinguishable in the first twelve segments. Four pairs of seminal vesicles in 9–12. Ovaries in 13–14. Prostate and accessory glands absent. Spermathecae sessile, globular, 0.2–0.3 mm diameter, on segments 13/14 or 14/15–16/17 or 17/18, two on each side per segment.

Habitat. – The specimens in this study were found on the shore of the river, in sandy mud topsoil, at a depth of about 5–10 cm. The river bank soil surface was covered with worm casts at Ban Namyen, Phayarhtan Cave (Buddha Cave), Lenya City, Tanintharyi, Myanmar and Bok Myiek, Myanmar.

Remarks. – *Glyphidrilus horsti* from Pulau Berhala, Straits of Malacca (Stephenson, 1930) and Turut Track, Kranji Wireless Station, Singapore (Shen and Yeo, 2005) have clitellum in 17, 18, ½18, 19–28, 29, 30, ½31, wings in 23, ½23–27, 28, and spermathecae in 14–17 or 14/15–17/18. The specimens in this study are slightly different from the type specimen. The positions of the clitellum and wings of the additional specimens are different from the type specimen by one or two segments for wings in 21, 22, 23–26, 27, 28, 29, and clitellum in 16, 18–29, 30, 31 and spermathecae in 13/14(14/15)–16/17(17/18). Photographs and drawings of the additional specimens are shown in Figures 6 and 7. In addition, the status of this species was also supported by an integrative taxonomic analysis, in which

FIGURE 6. Photographs showing the A and B, localities of *Glyphidrilus horsti* Stephenson, 1930 at **(A)** Ban Namyen, Lenya National Park, Tanintharyi, Myanmar and **(B)** Phayarhtan Cave (Buddha Cave), Lenya National Park, Tanintharyi, Myanmar. **(C)** Coloration of newly collected specimens (CUMZ 3696) after the first preservation step in 30% (v/v) ethanol and **(D)** *G. horsti* casts

the specimens from Myanmar belong to the same clade as specimens from Southern Thailand and Peninsular Malaysia (Jirapatrasilp et al., 2019).

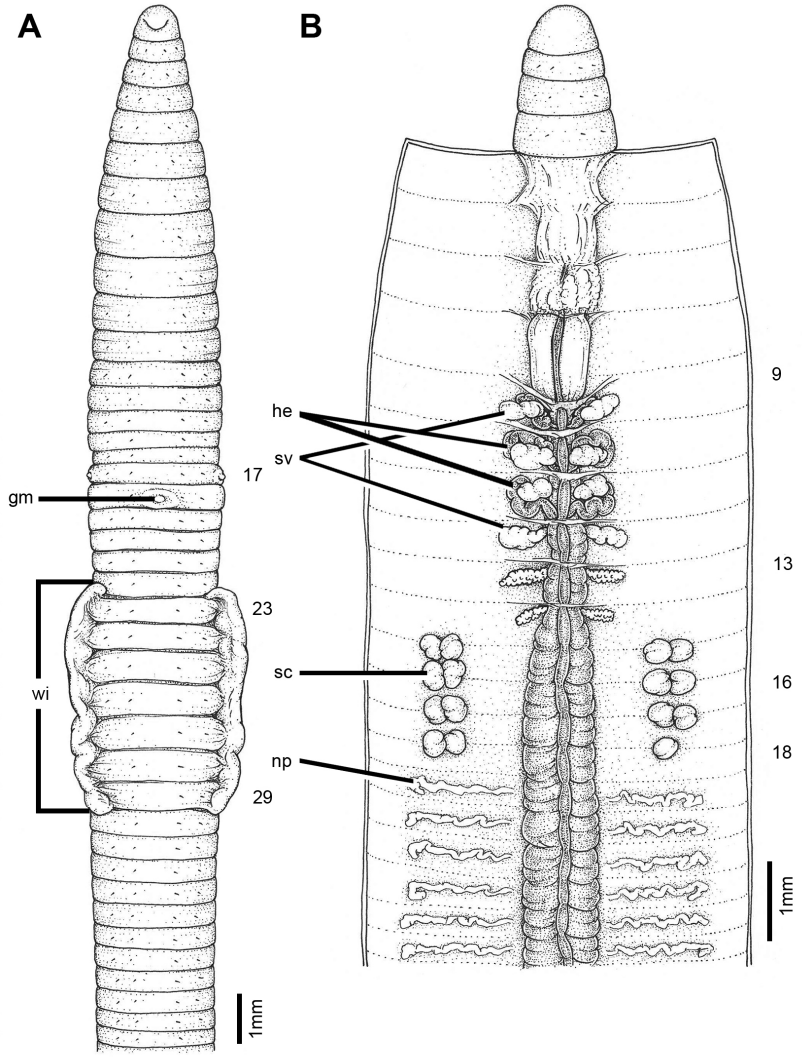

FIGURE 7. External and internal morphology of *Glyphidrilus horsti* Stephenson, 1930 (CUMZ 3696). **(A)** External ventral view and **(B)** internal dorsal view

Glyphidrilus birmanicus Gates, 1958

Glyphidrilus birmanicus Gates, 1958: 61. Type locality: Myanmar. Gates, 1972: 236. Jamieson, 1968: 392. Brinkhurst and Jamieson, 1971: 756. Chanabun et al., 2013: 31.

Remarks. – *Glyphidrilus birmanicus* Gates, 1958 from Myanmar differs from *G. tonywhitteni*, new species by having longer wings in 21–29, a longer clitellum in 12, 13–43, 44, no median series of genital markings, and spermathecae in 14–18.

This species is known only from Myanmar as in the original description. No specimen was found in the recent collections.

DISCUSSION

The semi-aquatic freshwater earthworm fauna of Myanmar has received very little attention in the past, where only two species had been reported. *Glyphidrilus papillatus* was the first species described by Rosa (1890a). Later, Gates (1958) studied the earthworms from the collection of the Indian Museum and described *G. birmanicus* being the second species reported from Myanmar (Burma). After that, there has been no report on semi-aquatic freshwater earthworms in Myanmar until now. This study reports one new species, *Glyphidrilus tonywhitteni*, and one new record, *Glyphidrilus horsti* Stephenson, 1930. *Glyphidrilus tonywhitteni*, new species, occurred at the banks of the Paalaung River, Mandalay and waterway in Bahin Village, Pakkoku, Magway, both of which are tributaries of the Irrawaddy River (Ayeyarwady River). In addition, *Glyphidrilus horsti* Stephenson, 1930 is reported herein as the first record for this country. This earthworm species was firstly described from Pulau Berhala, Straits of Malacca, and subsequently from Singapore at Turut Track, Kranji Wireless Station (Shen and Yeo, 2005). Here we report *G. horsti* from Ban Namyen, Phayarhtan Cave (Buddha Cave) and Bok, Myiek in Myanmar.

Both external (e.g. wings and genital markings) and internal (e.g. hearts and spermathecae locations) morphological characters have been used for identification of earthworms in the genus *Glyphidrilus* (Gates, 1958, 1972; Chanabun et al., 2013). However, Michaelsen (1910) and Gates (1958) often used only the external morphology such as locations of the wings and clitellum, position and arrangement of genital papillae, but later Gates (1972) adopted both external and internal characters for identification. Therefore, both external and internal characters are valuable for species identification especially in *Glyphidrilus*.

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