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Four new species of the earthworm genus *Amynthas* Kinberg, 1867, with redescription of the type species (Clitellata: Megascolecidae)

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Abstract. The type species of the genus *Amynthas* Kinberg, 1867 was re-investigated using type specimens from Biozentrum Grindel und Zoologisches Museum, University of Hamburg and Swedish Museum of Natural History. Also we described four new species of the genus *Amynthas* from Thailand, two species of the *aelianus* species group, namely *A. arenulus* Bantaowong & Panha, new species, and *A. longicaeca* Bantaowong & Panha, new species, and two species of the *corticis* species group, *A. thakhantho* Bantaowong & Panha, new species, and *A. phucheefah* Bantaowong & Panha, new species, *Amynthas arenulus* and *A. thakhantho* occur in sandy habitats of dry dipterocarp and deciduous forest, respectively, and especially in the modified highland paddy fields, while the following two species, *A. longicaeca* and *A. phucheefah* occur in deciduous forest reserve areas in clay–rich topsoil.

Key words. *Amynthas*, Clitellata, systematics, biodiversity, Thailand

INTRODUCTION

The terrestrial earthworm genus *Amynthas* Kinberg, 1867, is the largest genus of the family Megascolecidae, containing 22 species groups with over 400 recognised species, but also large numbers of synonyms (Sims & Easton, 1972; Blakemore, 2004, 2007). After visiting Biozentrum Grindel und Zoologisches Museum, University of Hamburg, Germany, in September 2010 and September 2011, we had the chance to study most of the type specimens including the type species *Amynthas aeruginosus* Kinberg, 1867, and we also studied a type specimen of *A. aeruginosus* sent from Swedish Museum of Natural History on loan.

In Thailand, the current records of the genus *Amynthas* confirmed 19 described species occurring in many areas, whereas a total of 41 recognised species of terrestrial earthworms have been reported (Gates, 1939, 1972; Kosavititkul, 2005; Blakemore, 2006, 2011; Somniyam & Suwanwaree, 2009; Bantaowong et al., 2011). In this paper we describe four new *Amynthas* species collected recently from various parts of Thailand (Fig. 1), which were firstly classified in *aelianus* and *corticis* species groups, characterised by spermathecal pores in 6/7–8/9 and 5/6–8/9, respectively. The addition of these new species brings to 45 the total number of terrestrial earthworm species known so far from Thailand. The four new species are described by U. Bantaowong and S. Panha, who are the taxonomic authorities for *A. arenulus* Bantaowong & Panha, new species, *A. longicaeca* Bantaowong & Panha, new species, *A. thakhantho* Bantaowong & Panha, new species, and *A. phucheefah* Bantaowong & Panha, new species.

MATERIAL AND METHODS

The earthworms collected were anesthetised in 30% (v/v) ethanol, fixed in 10% (v/v) formalin, and preserved in 75% (v/v) ethanol. The descriptions are based on observations of dorsal dissections. Dimensions and segment counts are

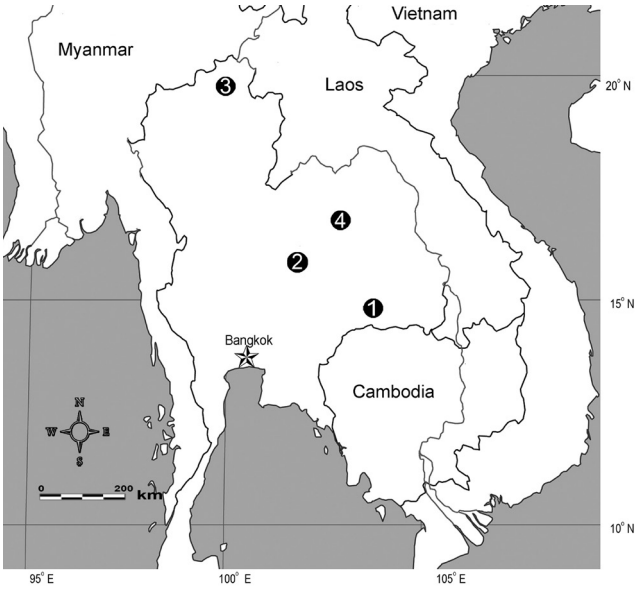

Fig. 1. Map of type localities of *Amynthas arenulus*, new species, from Ban Khok Pho, Surin (1), *Amynthas longicaeca*, new species, from Phu Lan Kha National Park, Chaiyaphum (2), *Amynthas phucheefah*, new species, from Phu Chee Fah, Chiang Rai (3), and *Amynthas thakhantho*, new species, from Tha Khantho, Kalasin (4).

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from clitellate adult specimens under the Olympus SZX7 stereoscopic light microscope. Illustrations were made of the body segments and the distinct external characters and internal organs.

The type specimens of the type species of *Amynthas* from Swedish Museum of Natural History (SMNH), Stockholm, Sweden, were critically examined. The specimens and type specimens of the *corticis* and *aelianus* species groups housed at the Biozentrum Grindel und Zoologisches Museum, University of Hamburg (ZMH) have been critically studied and also used to compare with the new species in this report. We have carefully studied in detail all morphological characters, made new illustrations and redescribed the type species of the genus *Amynthas* in this paper.

Holotype and paratype specimens of the new described species were deposited in the Chulalongkorn University, Museum of Zoology, Bangkok, Thailand (CUMZ). Additional paratypes will be deposited in the Natural History Museum (NHMUK), London, at the Biozentrum Grindel und Zoologisches Museum, University of Hamburg (ZMH), and the Zoological Reference Collection (ZRC) of the Lee Kong Chian Natural History Museum (ex Raffles Museum of Biodiversity Research Collection), Singapore.

Anatomical abbreviations: fp, female pore; gm, genital marking; gmg, genital marking gland; ic, intestinal caeca; mp, male pores; pg, prostate gland; sc, spermathecae; sp, spermathecal pores; sv, seminal vesicles.

SYSTEMATICS

Family Megascolecidae Rosa, 1891

Genus *Amynthas* Kinberg, 1867

Type species. *Amynthas aeruginosus* Kinberg, 1867, by monotypy.

Diagnosis. Perichaetine megascolecids with large number of setae distributed around segmental equators. Clitellum annular in XIV–XVI. Female pore single, medio–ventral in segment XIV. Spermathecal pores small or large, usually paired, intra- or inter-segmental within the range 4/5–8/9. Male pores paired in segment XVIII, superficial on porophore, copulatory pouches absent. Genital markings present or absent. Dorsal pores present. Ovaries paired in XIII. Spermathecae usually paired. Nephridia usually absent from the spermathecal ducts. One gizzard, behind septum 7/8. Intestine begins in or behind XV. Intestinal caeca present usually originating in XXVII. Single pair of racemose prostate glands with duct joining vas deferens within body cavity. Mostly holandric, rarely proandric or metandric. Seminal vesicles small to large in one or two of segments XI–XII, and sometimes XIII. Last pseudohearts in XIII. Genital marking glands stalked or sessile, present or absent, usually associated with genital markings.

Amynthas aeruginosus Kinberg, 1867
(Fig. 2)

Amyntas aeruginosus Kinberg, 1867: 101. Type locality: Guam, sub lapidibus prope rivulum. Michaelsen, 1899a: 434–437, fig. 2. Michaelsen, 1899b: 4.
Perichaeta aeriginosus: Beddard, 1891: 278.
Pheretima aeruginosa: Michaelsen, 1900: 253.
Amynthas aeruginosus: Sims & Easton, 1972: 211.

Material examined. A holotype was not designated, and the original description was based on more than one specimen (see Kinberg, 1867: 101; Michaelsen, 1899a). The syntype lot from the Swedish Museum of Natural History consists of 4 specimens in ethanol. The complete and sexually mature specimen, which is similar to the original description and a later description in Michaelsen (1899a: 434, fig. 2) is designated here as the lectotype SMNH 154.1 (Figs. 2A–C). The other three specimens, two complete and immature, and one fragmented and mature specimen from the same lot are recognised as the paralectotypes SMNH 154.2. In addition, we examined one specimen originally from the Kinberg type series, which was examined by Michaelsen (1899a: 434) and housed in Biozentrum Grindel und Zoologisches Museum, University of Hamburg. It is now recognised as paralectotype ZMH V5221 (Figs. 2D–F). This designation is to preserve the stability of the name and verify the unique characters of the type species, which were not mentioned in the original description.

Diagnosis. Quadrithecal with spermathecal pores in 7/8/9. Male pores paired, superficial in segment XVIII, each pore situated in the center of small round flat disc, genital markings lacking. Each spermatheca a large transversely oval sac and tubular diverticulum, its proximal end with a neck–like constriction. Intestinal caeca simple. Multilobed prostate gland with stout duct.

Description of lectotype. Dimension; 95 mm by 4.5 mm at segment X; body cylindrical with 99 segments. Setae regularly distributed around segment equators, numbering 49 at VIII, 57 at XX, 4 between male pores, setae formula AA:AB:ZZ:ZY=1.3:1:1:1 at XIII. Clitellum annular XIV–XVI, setae absent. Single female pore at XIV. Prostomium epilobic. Male pores are superficial in segment XVIII, 0.17 circumference apart ventrally; distance between male pores 2.5 mm, each pore situated in the center of small round flat disc. Genital markings absent. Spermathecal pores two pairs in 7/8–8/9, 0.16 circumference apart ventrally, distance between spermathecal pores 2.3 mm.

Septa 5/6–7/8 thick, 8/9–9/10 absent, 10/11–11/12 thin. Gizzard large behind 7/8, intestinal origin XV; the intestinal caeca originate in XXVII, simple and extend anteriorly to XXV. Typhlosole rudimentary. Lymph glands not observed. Oesophageal hearts four pairs in X–XIII. Holandric; testes and funnels in X and XI. Seminal vesicles paired in XI–XII. Prostate glands paired in XVIII, multi-lobed radiating fan-like from ental end of prostatic duct; ducts stout, thick muscular. Ovaries in XIII. Spermathecae two pairs in VIII and IX, ampulla large sac-shaped, diameter slightly greater than ampulla axis length, with a stout stalk, as long as ampulla. Diverticulum tubular, its proximal end with a neck-like constriction and iridescent.

Variation. The lectotype measures 95 mm body length, with 99 segments; the body lengths of four paralectotypes are 84, 85, 92, 100 mm, with 92, 94, 95, 96 segments.

Remarks. Michaelsen (1899a) records the history of *A. aeruginosus* type series, which comprises five spirit-preserved specimens. The adult and complete syntype specimen was examined and was used for the re-description of internal characters, but it was not designated as a lectotype (Michaelsen, 1899a; ICZN, 1999). We have examined all the type specimens and found that the pseudohearts and gizzard of Michaelsen's dissected specimen were missing. Therefore another complete adult specimen of Kinberg's collection is here designated as the lectotype.

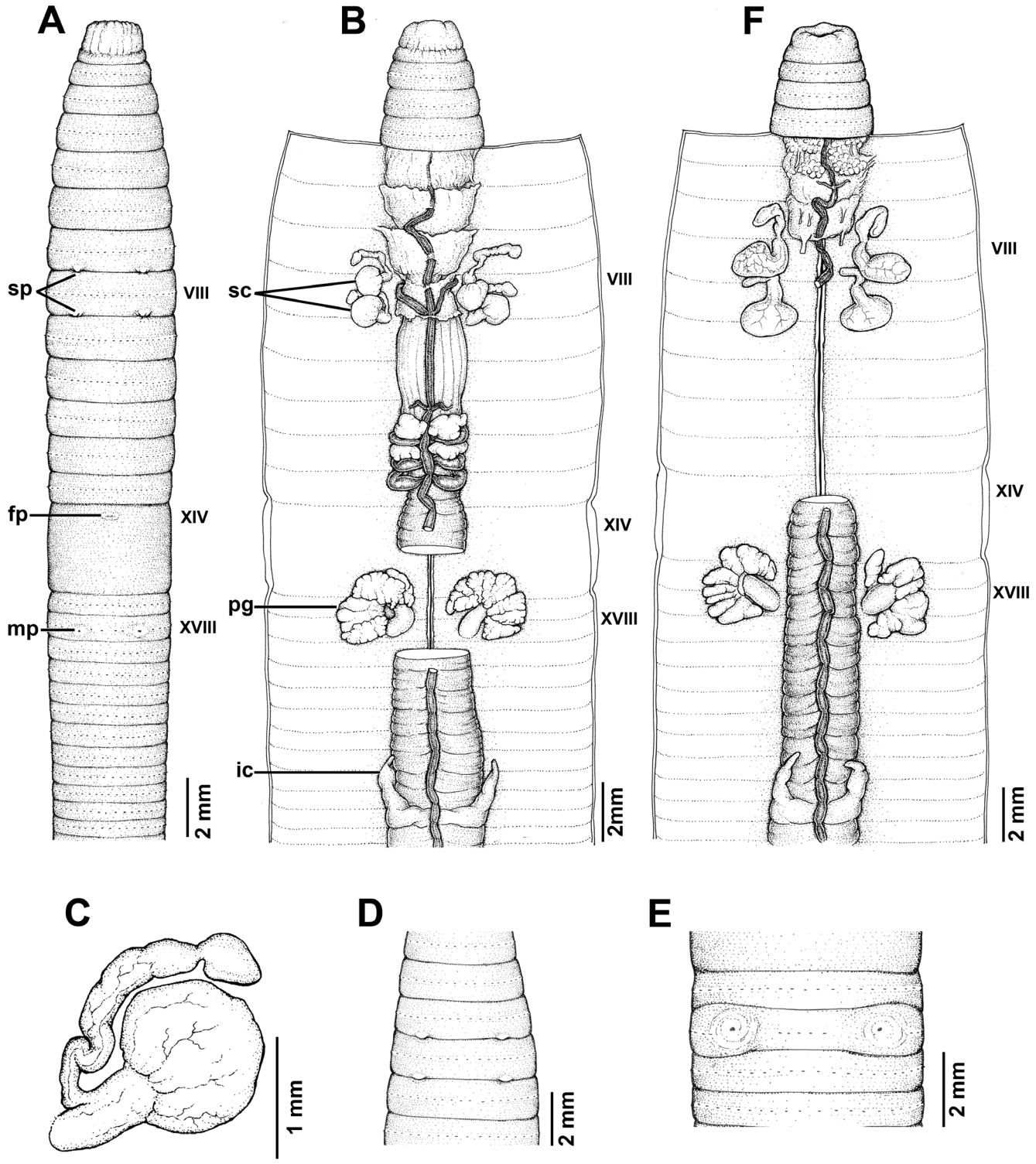

Fig. 2. External and internal morphology of *Amynthas aeruginosus*, the type species. A–C, lectotype (SMNH 154): A, external ventral view; B, internal dorsal view; C, spermathecae. D–F, paralectotype (ZMH V5221): D, spermathecal pores; E, male pores; F, incomplete internal dorsal view.

The description and measurements given herein are in agreement with those of Kinberg (1867) and Michaelsen (1899a). However, the species description published by Sims & Easton (1972) is slightly incongruent by having genital markings and 0.22 circumference apart ventrally of male pores. This difference is clear due to an expansion of the description to include another two nominal species, *A. upoluensis* (Beddard, 1887) and *A. rennellanus* (Gates, 1959), which were recognised as junior synonyms (see Sims & Easton, 1972; Lee, 1981). Currently, these two nominal species are widely accepted as separate species (Michaelsen, 1913; Gates, 1937, 1959; Blakemore, 1997). *Amynthas rennellanus* differs from *A. aeruginosus* by having single, presetal genital markings in some of IX–XI and XVII–XXI while, *A. upoluensis* from Western Samoa is distinct from *A. aeruginosus* in the presence of genital markings on VII–VIII and XVII–XIX.

Amynthas aeruginosus is still known only from the type specimens. Michaelsen (1899a) provided a brief illustration only of a spermatheca, but not other important features such as the male genital field, prostate glands and intestinal caeca. In this study, the completed description with schematic figures of the external ventral view and internal dorsal view are provided.

Amynthas arenulus Bantaowong & Panha, new species

(Figs. 3, 11A, B, 12; Table 1)

Material examined. Holotype: One semi-clitellate (CUMZ 3299) Ban Khok Pho, Prasat, Surin, Thailand, (14°33′5.33″N, 103°22′21.79″E), 172 m in elevation, coll. S. Panha, U. Bantaowong, C. Sutcharit, R. Chanabun & W. Siriwut, 15 October 2012. 16 paratypes: 10 adults (CUMZ 3300), 2 adults (ZMH), 2 adults (NHMUK), and 2 adults (ZRC), same collection data as for holotype.

Other material examined. 2 adults (CUMZ 3301), Khao Sala Temple, Buachet, Surin, Thailand, (14°25′9.7″N, 103°56′0.7″E), 340 m in elevation, 16 October 2012. 3 adults and 1 juvenile (CUMZ 3302), paddy field in Nam Yuen, Ubon Ratchathani (road no. 2248, about 18 km from Kantharalak, Sisaket), Thailand, (14°28′10.1″N, 104°52′33.2″E), 191 m in elevation, 17 October 2012. 5 adults (CUMZ 3303), Kaeng Lam Duan Waterfall, Nam Yuen, Ubon

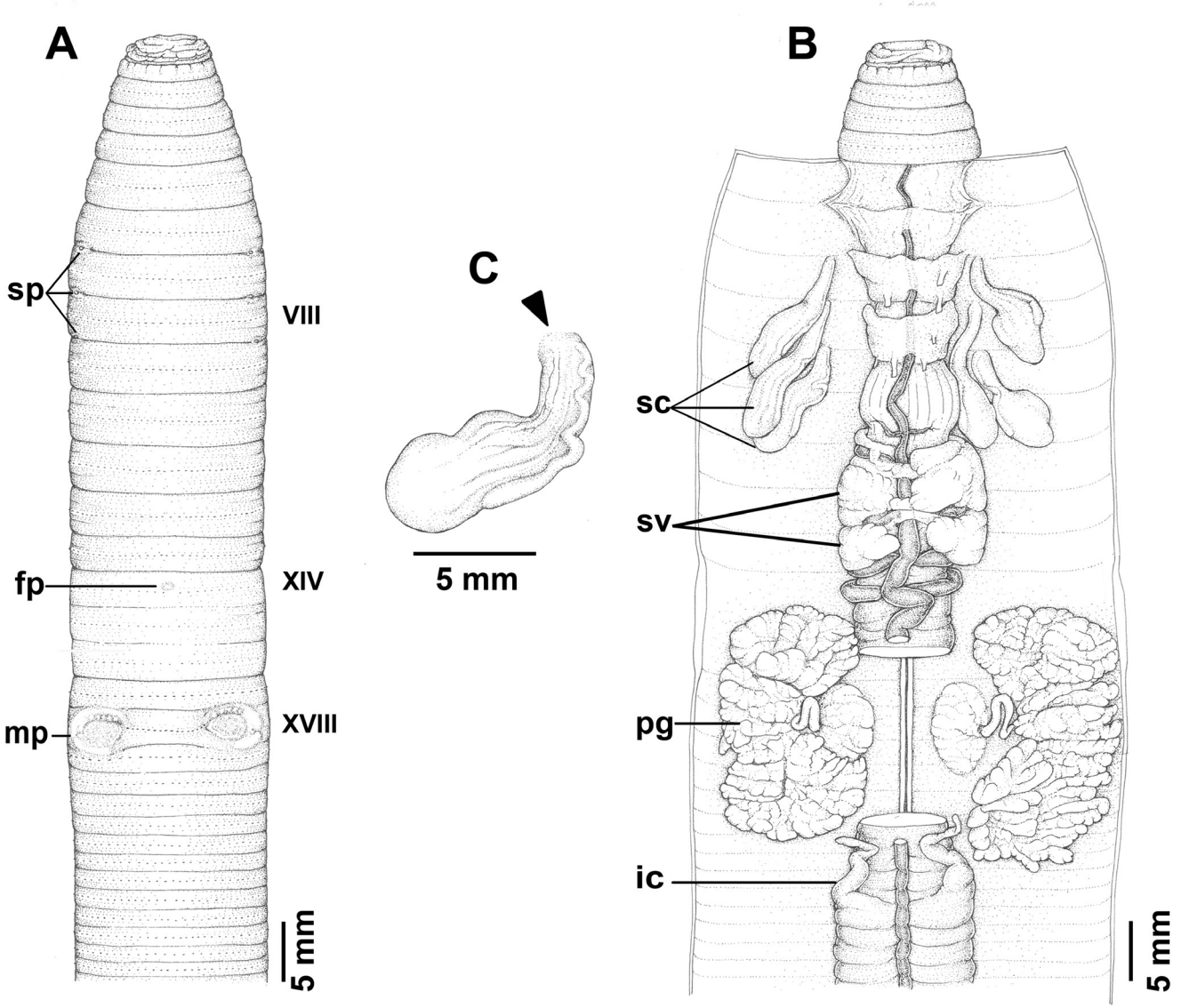

Fig. 3. External and internal morphology of holotype (CUMZ 3299) of *Amynthas arenulus*, new species: A, external ventral view; B, internal dorsal view; C, spermathecae. Dark arrow indicates the connection of the spermathecae and spermathecal pore.

Table 1. The comparison of characters among *A. arenulus,* new species, *A. longicaeca*, new species, and others *aelianus* species group in Thailand, Burma and Sumatra, *A. burchardi* Michaelsen, 1899, *A. osmastoni* (Michaelsen, 1907), *A. fucosus* (Gates, 1933) and *A. siam* Blakemore, 2011

Characters	***A. arenulus***	***A. longicaeca***	***A. burchardi***	***A. osmastoni***	***A. fucosus***	***A. siam***
Body length (mm)	465	278	270	250–320	120	73
Body width (mm)	13.3	10.1	9	10–11	6	3
Segment number	176	160	126	126–148	114	nd
Spermathecal pores	6/7/8/9	6/7/8/9	6/7/8/9	6/7/8/9	6/7/8/9	6/7/8/9
First dorsal pore	12/13	12/13	13/14	12/13	12/13	12/13
Setal number						
vii	68	53	40	nd	nd	nd
xx	101	81	49	65–84	nd	nd
Between male pores	26	25	13	10–20	29	nd
Genital markings						
Preclitellum	absent	absent	absent	median in VIII	absent	absent
Postclitellum	absent	crescent shape	group of small circular papillae on XVIII	absent	paired at 17/18, 18/19	paired at XVIII
Spermathecae	large sac	oval	oval	spherical	flatten	spherical
Diverticulum	slender	small ovate	long slender	tubular	tubular and coiled	convoluted
Prostate gland	XVII–XXII	XVI–XXI	XV–XX	XV–XXIV	XVII–XX	nd
Intestinal caeca	simple	simple	simple	simple	simple	simple
Type locality	Thailand	Thailand	Sumatra, Indonesia	South Andaman Islands	Burma	Thailand

nd=no data

Ratchathani, Thailand, (14°26′6.2″N, 105°06′17.0″E), 164 m in elevation, 17 October 2012.

Diagnosis. Large; length 267–465 mm. Male pores paired, superficial in segment XVIII, each on large transversely elliptical disc, male aperture inconspicuous, genital markings absent. Spermathecal pores paired in segments 6/7–8/9. Spermathecae large bulb-shaped ampulla, small tube-like diverticulum adherent to ampulla on its entire length. Holandric, intestinal caeca simple, first dorsal pore in 12/13. Prostate glands large, its duct flanked by large sessile glandular masses on body wall.

Description of holotype. Dimensions; 465 mm by 13.3 mm at segment VII, 15.7 mm at segment XX, 14.5 mm at clitellum; body cylindrical with 176 segments. Setae regularly distributed around segmental equators, numbering 68 at VII, 101 at XX, 26 between male pores, setae formula AA:AB:ZZ:ZY=1:1:2:1 at XIII. Single female pore at XIV. Prostomium epilobic. First dorsal pore at 12/13. Clitellum annular XIV–XVI with setae.

A pair of male pores located ventro-laterally in XVIII, 0.41 circumference apart ventrally, distance between male pores 18 mm, porophores large transversely elliptical discs, surrounded by elevated rim. The indistinct male apertures located at the outer edges of each porophore. No genital markings are observed. Three pairs spermathecal pores, transverse slits, in furrows 6/7–8/9, ventral, distance between each pair about 0.38 body circumference ventrally apart, distance between spermathecal pores 15 mm. No genital markings in the spermathecal pore area.

Septa 5/6–7/8 thick, 8/9–9/10 absent, 10/11–11/12 thin. Gizzard large behind 7/8, intestinal origin XV; the intestinal caeca originate in XXVII, are simple and bend to XXIII. Typhlosole simple fold one–fourth lumen diameter, begins in XXVII. Oesophageal hearts four pairs in X–XIII. Holandric; testes and funnels in X and XI. Seminal vesicles paired in XI–XII, are large. Prostate glands well developed, large, extending anteriorly to segment XVII, posteriorly to XXII. Prostate duct flanked by large sessile glandular masses on body wall.

Ovaries in XIII. Three pairs spermathecae in VII–IX. Ampulla large sac–shape, duct relatively stout, diverticulum adherent to duct and ampulla on its entire length, slender with a thin stalk, chamber a dilated, elongate bulb.

Variation. The holotype measures 465 mm body length with 176 segments; the 16 paratypes range in size from 267–340 mm (±26.62) body length with 133–169 segments.

Etymology. The specific epithet is from the Latin for a sandy place. This refers to the find-grained sandy area modified as a highland rice paddy system, which is the habitat of the new species.

Distribution. Surin, Sisaket and Ubon Ratchathani.

Habitat. The species lives in the sandy top soil at about 20–30 cm depth, in a highland paddy system modified from dipterocarp forest. Some forest patches are still present near the paddy fields.

Remarks. *Amynthas arenulus*, new species, is sexthecal with spermathecal pores in 6/7–8/9. The *Amynthas* species with these characters were formerly classified in the *sieboldi* species group (Sims & Easton, 1972); however, Easton (1981) transferred *A. sieboldi* (Horst, 1883) to the genus *Metaphire*, so the species group name is no longer appropriate. Thus James et al. (2005) have critically investigated and proposed the *aelianus* species group after *A. aelianus* (Rosa, 1892), to replace the *sieboldi* species group name. This is one of many modifications of the group names of Sims & Easton (1972); among those are the use of confirmed senior synonyms *corticis* species group (replacing *diffringens*) and *gracilis* species group (replacing *hawayanus*).

The *aelianus* species group consists of more than 50 species and also included nine recently described species from Taiwan and one species from Thailand (Sims & Easton, 1972; Tsai et al., 1999, 2010; Shen et al., 2003; James et al., 2005; Blakemore, 2011). In Thailand, only two species within this species group were reported from northeastern Thailand, *A. fucosus* (Gates, 1933) and *A. siam* Blakemore, 2011. However, *A. arenulus*, new species, is distinguished from the above related species in Thailand by the larger body with no genital markings while *A. fucosus* has two pairs of genital markings at 17/18, 18/19 and *A. siam* has single pair between the male pores.

Amynthas arenulus is also fairly similar to *A. osmastoni* (Michaelsen, 1907) from Burma, and *A. burchardi* Michaelsen, 1899, from Sumatra, in body size, but it is easily distinguished by having no genital markings, whereas the latter two species have genital markings. Moreover, the distance between the male pores as a fraction of the estimated circumference of segment XVIII is 0.25 and 0.28 in *A. osmastoni* and *A. burchardi*, respectively, while in *A. arenulus*, new species, this distance is 0.41 body circumference for the holotype. In addition, *A. arenulus*, new species, has unique spermathecae, the diverticulum being adherent to the duct-ampulla axis along its whole length, while in other *Amyntha*s species, the diverticulum is usually free of the duct and ampulla except at a single point of origin (Table 1).

Amynthas longicaeca Bantaowong & Panha, new species

(Figs. 4, 11C, D; Table 1)

Material examined. Holotype: One adult (CUMZ 3304) Phu Lan Kha National Park, Nong Bua Daeng, Chaiyaphum, Thailand, (16°00′01.70″N, 101°52′35.40″E), 660 m in elevation, coll. S. Panha, R. Chanabun, P. Tongkerd and W. Siriwut, 17 September 2011. One adult paratype (CUMZ 3305), same collection data as for holotype.

Diagnosis. Large; length 230–278 mm. Male pores paired, superficial in segment XVIII, somewhat convex, with a large crescent shape genital marking. Spermathecae three pairs,

in segments VII–IX, ampulla oval, with duct shorter than ampulla. Diverticulum very small with ovate knob, length less than half of ampulla. Intestinal caeca long, simple. First dorsal pore in 12/13. Prostate glands large, prostatic duct flanked by large sessile glandular masses on body wall.

Description of holotype. Dimensions; 278 mm by 10.1 mm at segment VII, 9.2 mm at segment XX, 8.2 mm at clitellum; body cylindrical with 160 segments. Setae regularly distributed around segmental equators, numbering 53 at VII, 81 at XX, 25 between male pores, setal formula AA:AB:ZZ:ZY=1:1:2:1 at XIII. Single female pore at XIV. Prostomium epilobic. First dorsal pore at 12/13. Clitellum annular XIV–XVI with no setae.

A pair of male pores located ventro-lateral in XVIII, 0.40 circumference apart ventrally, distance between male pores 9 mm. Male pores superficial, somewhat convex, located between small crescent genital markings. The paired median markings large crescent shape, 3–4 setal intervals distant from male aperture and separated from each other midventrally by a distance about equal to 8 intersetal intervals. Spermathecal pores three pairs, transverse slits, in furrows 6/7–8/9, ventral, paired pores about 0.45 body circumference ventrally apart, distance between spermathecal pores 10 mm. No genital markings in the spermathecal pores region.

Septa 5/6–7/8 thick, 8/9–9/10 absent, 10/11–12/13 thin. Gizzard large behind 7/8, intestinal origin in XV; the intestinal caeca simple and long located in XXVII to XXIV, when fully extended they reach as far forward as the prostate duct at XVIII. Typhlosole simple, one third intestinal diameter beginning at XXVII. No lymph glands observed. Oesophageal hearts four pairs in X–XIII. Holandric; testes and funnels in X and XI. Seminal vesicles paired in XI–XII, large. Prostate glands well developed, separated into two major lobes, extending XVI–XXI. Prostate duct long, slender and hairpin shape, flanked by large sessile glandular masses on body wall.

Ovaries in XIII. Spermathecae three pairs in VII–IX. The ampulla large oval, with duct shorter than ampulla, diverticulum small ovate knob, stalk very short, nephridia present on diverticulum and on segmental chambers in VII and VIII.

Variation. The holotype measures 278 mm body length with 160 segments; the paratype is 230 mm long with 115 segments.

Etymology. This species was named after the characteristic long intestinal caeca.

Distribution. The new species is known only from the type locality.

Habitat. Top soil at about 20 cm depth in the dipterocarp forest at elevation 660 meters of Phu Lan Kha National Park, Chaiyaphum, at pH 7, silt loam soil.

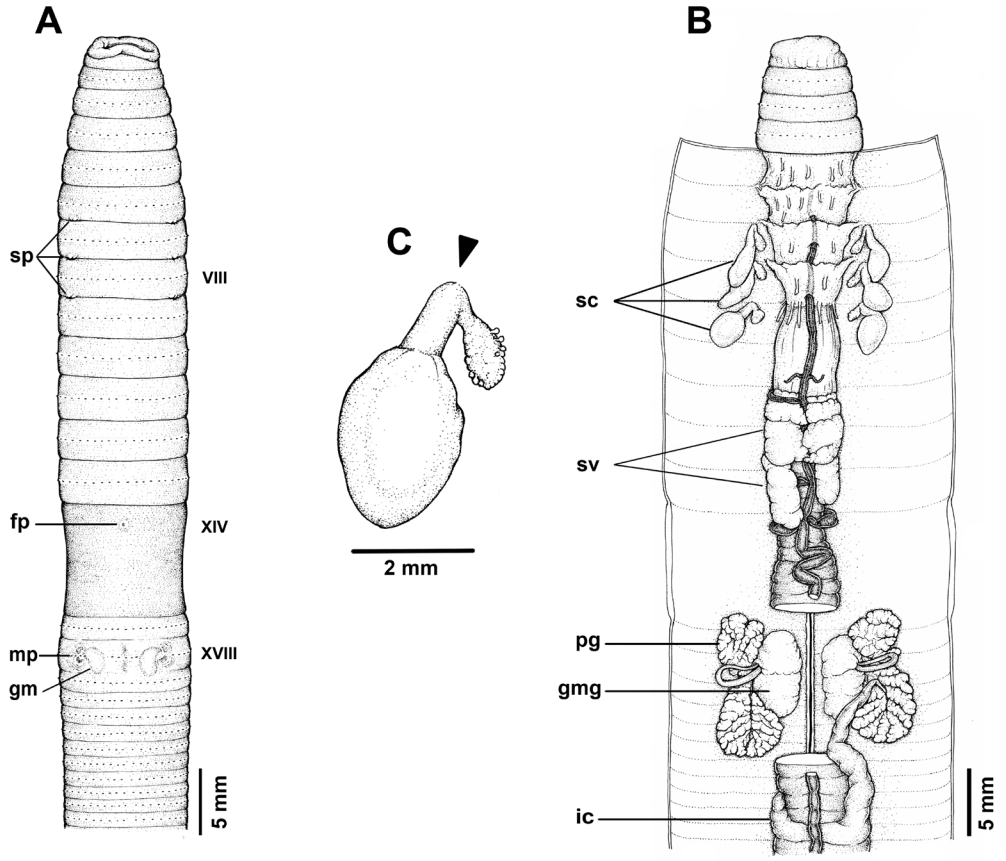

Fig. 4. External and internal morphology of holotype (CUMZ 3304) of *Amynthas longicaeca*, new species: A, external ventral view; B, internal dorsal view; C, spermathecae. Dark arrow indicates the connection of the spermathecae and spermathecal pore.

Remarks. *Amynthas longicaeca*, new species, is easily distinguished from the other two earthworms of the *aelianus* species group reported from Thailand, namely *A. fucosus* (Gates, 1933) and *A. siam* Blakemore, 2011, of 3–6 mm body width, while the current new species is about 10 mm in diameter. This new species is quite similar to *A. burchardi* from Sumatra and *A. osmastoni* from Andaman Island in body dimensions but differs in having crescent shaped genital markings in the male pore region while *A. burchardi* has a group of small circular papillae in mid-ventral XVIII and *A. osmastoni* has genital markings in the spermathecal pore region (Table 1).

Amynthas burchardi Michaelsen, 1899
(Fig. 5; Table 1)

Amyntas burchardi Michaelsen, 1899b: 88, fig. 14. Type locality: Bindjey Estate, Sumatra.
Amynthas burchardi: Sims & Easton, 1972: 237.

Material examined. Syntype from ZMH (V 3864. Fig. 5): One adult in ethanol, which was dissected by Michaelsen.

Remarks. *Amynthas burchardi* differs from *A. arenulus*, new species, and *A. longicaeca*, new species, by the having a mid-ventral group of 40 small circular papillae present in XVIII, which are related to the stalked genital marking glands. The spermathecal diverticulum is long and slender with an ovate sperm chamber (Table 1).

Amynthas osmastoni (Michaelsen, 1907)
(Fig. 6; Table 1)

Pheretima osmastoni Michaelsen, 1907: 163, fig. 11. Type locality: Port Blair, South Andaman. Gates, 1972: 204.
Amynthas osmastoni: Sims & Easton, 1972: 237.

Material examined. Syntype from ZMH (V 7171. Fig. 6): Four adults in ethanol (two specimens dissected by Michaelsen).

Remarks. *Amynthas osmastoni* differs from *A. arenulus*, new species, and *A. longicaeca*, new species, by the presence of a group of small round genital papillae in transverse rows, postsetal, median in VIII or XII or XIII. It also differs by having nephridia on spermathecae and on the segmental chambers in VI–XIV. The sessile genital marking glands are another difference from the new species mentioned above (Table 1).

Amynthas phucheefah Bantaowong & Panha, new species
(Fig. 7; Table 2)

Material examined. Holotype: One adult (CUMZ 3306), Phu Chee Fah, Thoeng, Chiang Rai, Thailand, (19°48′47.0″N, 100°26′20.4″E), 1205 m elevation, coll. S. Panha, U. Bantaowong, C. Sutcharit, P. Tongkerd, R. Chanabun, P. Pimvichai and P. Prasankok, 24 October 2008. Two paratypes (CUMZ 3307) same collection data as for holotype.

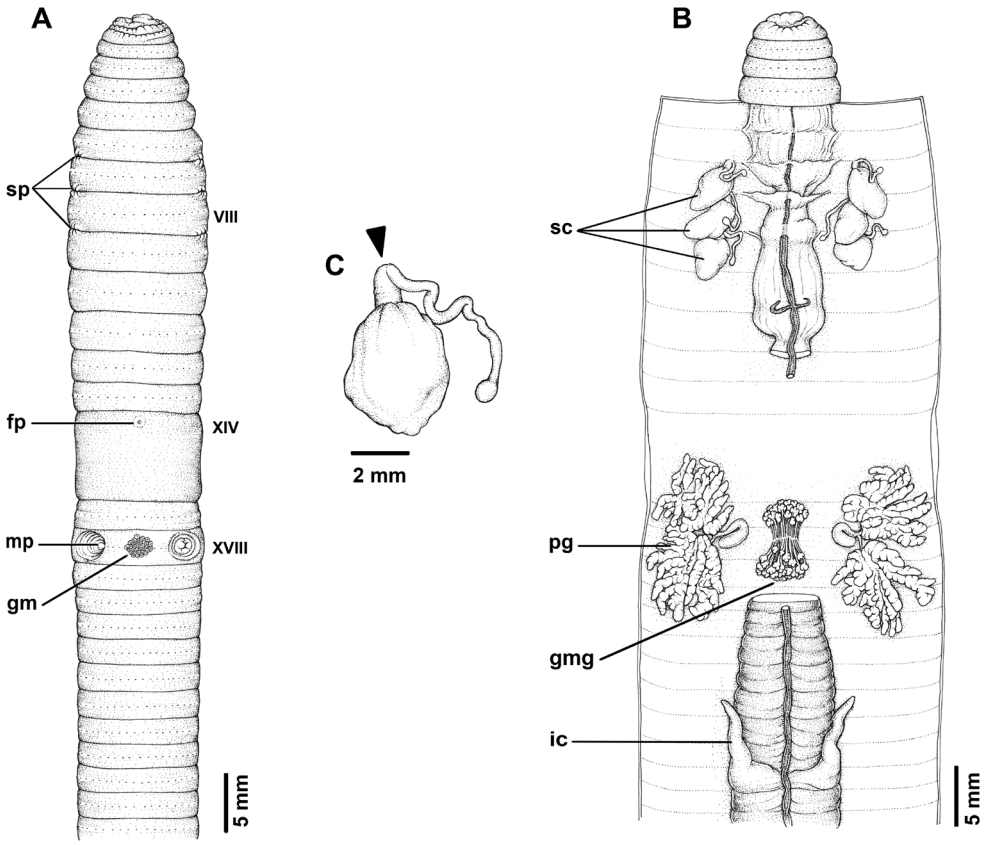

Fig. 5. External and internal morphology of syntype (ZMH V3864) of *Amynthas burchardi*: A, external ventral view; B, internal dorsal view; C, spermathecae. Dark arrow indicates the connection of the spermathecae and spermathecal pore.

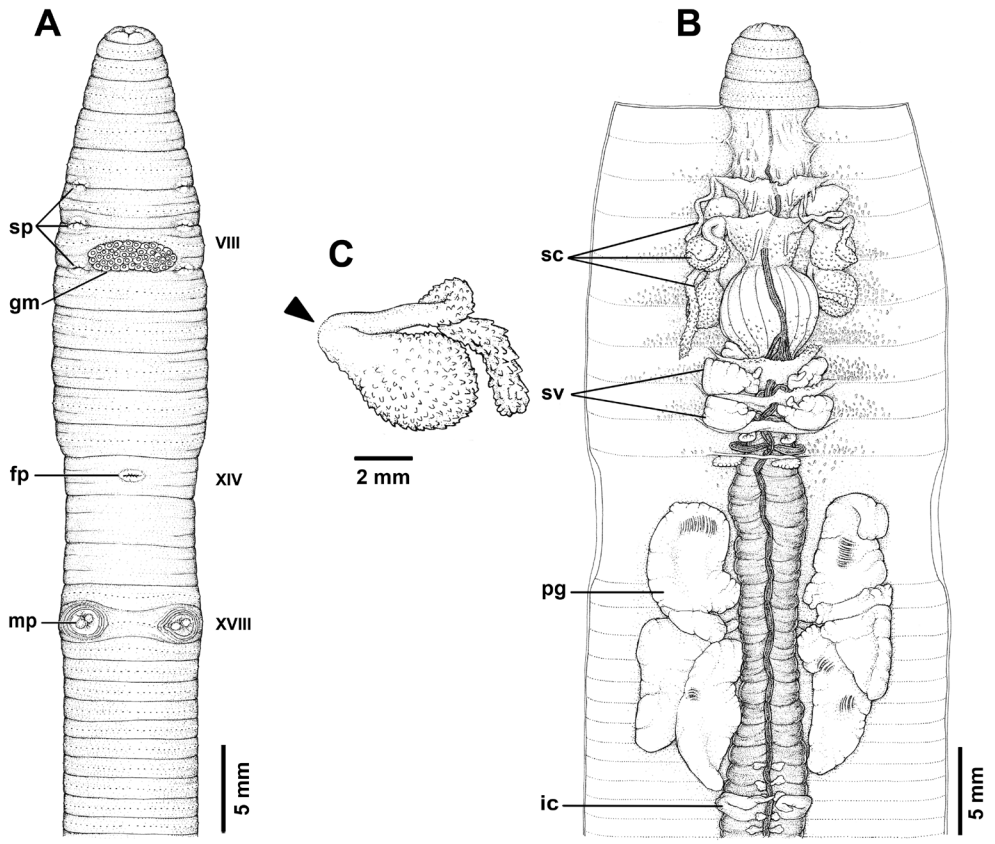

Fig. 6. External and internal morphology of syntype (ZMH V7171) of *Amynthas osmastoni*: A, external ventral view; B, internal dorsal view; C, spermathecae. Dark arrow indicates the connection of the spermathecae and spermathecal pore.

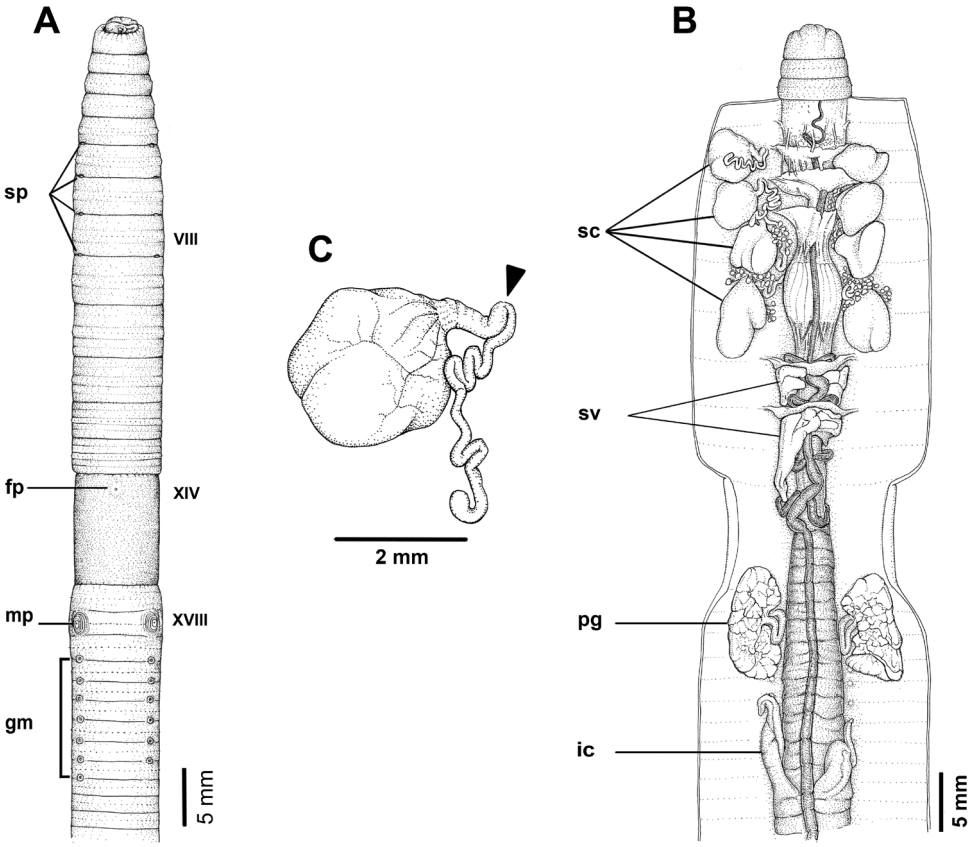

Fig. 7. External and internal morphology of holotype (CUMZ 3306) of *Amynthas phucheefah*, new species: A, external ventral view; B, internal dorsal view; C, spermathecae. Dark arrow indicates the connection of the spermathecae and spermathecal pore.

Table 2. The comparison of characters among *A. phucheefah*, new species, *A. thakhantho*, new species, and other *corticis* species group members in Thailand and nearby countries.

Characters	***A. phucheefah***	***A. thakhantho***	***A. alexandri***	***A. mekongianus***	***A. longicauliculatus***	***A. comptus***	***A. jacobsoni***	***A. suctoria***
Body length (mm)	314	332	145	1 metre	170	>86	137	75–135
Body width (mm)	8.7	11.1	4–9	8	7	6	7	4.5–7
Segment number	132	198	133	370	138	>120	90	103–123
Spermathecal pores	5/6/7/8/9	5/6/7/8/9	5/6/7/8/9	5/6/7/8/9	5/6/7/8/9	5/6/7/8/9	5/6/7/8/9	5/6/7/8/9
First dorsal pore	12/13	12/13	12/13	10/11	12/13	12/13	nd	12/13
Setal number								
vii	71	108	33–43	96–114	63–71	41	nd	60-70
xx	68	105	58–72	96–106	96	89–102	nd	75
Between male pores	19	23	13	10	29	31	3	2
Genital markings								
Preclitellum	absent	absent	absent	absent	absent	absent	absent	absent
Postclitellum	paired on 19/20–24/25	paired on XVII, XIX–XXI	absent	absent	paired on 18/19–20/21	three trios on 18/19–20/21	cluster on XVIII	absent
Spermathecae	large sac	large sac	oval	sacciform	spherical	nd	oval	pear-shaped
Diverticulum	loosely looped	zigzaged	moniliform	clavate	saccular	slender	intimately looped	bent
Prostate gland	XVII–XXI	XVI–XIX	XVII–XX	XVIII	XVIII	XVIII	XVII–XX	XVII–XIX
Intestinal caeca	simple	simple	simple	simple	simple	simple	simple	simple
Type locality	Thailand	Thailand	India	Mekong river, Vietnam	Burma	Burma	Indonesia	Andaman Islands

nd=no data

Diagnosis. Large; length 215–314 mm. Male pores paired, superficial in segment XVIII. Small circular genital markings widely paired on 19/20–24/25. Spermathecal pores paired in segments 5/6–8/9, spermathecae large sac–shaped ampulla with nephridia on the duct, diverticulum long, loosely coiled, intestinal origin at XV, intestinal caeca simple, first dorsal pore in 12/13. Holandric. Prostate glands large, small sessile genital marking glands corresponding to external genital markings.

Description of holotype. Dimensions; 314 mm by 8.7 mm at segment VII, 8.2 mm at segment XX, 8.0 mm at clitellum; body cylindrical with 132 segments. Setae regularly distributed around segmental equators, numbering 71 at VII, 68 at XX, 19 between male pores, setal formula AA:AB:ZZ:ZY=1:1:1:1 at XIII. Single female pore at XIV. Prostomium epilobic. First dorsal pore at 12/13. Clitellum annular XIV–XVI with no setae.

Male pores paired, located ventro-laterally in XVIII, 0.31 circumference apart ventrally, distance between male pores 6.5 mm. Male pores superficial on XVIII, each pore situated on a top of small and elongated oval papilla surrounded by 3–4 circular ridges. Genital markings widely paired on 19/20–24/25, in line with male pores, each one slightly elevated with a thick circular margin, and depressed in center. Single genital marking present on the left side of 25/26. Spermathecal pores four pairs, transverse slits, in furrows 5/6–8/9, ventral, distance between pairs about 0.3 body circumference ventrally apart, distance between spermathecal pores 10 mm. No genital markings on the spermathecal pores region.

Septa 5/6–7/8 thick, 8/9–9/10 absent, 10/11–11/12 thin. Gizzard large behind 7/8, intestine begins in XV. Typhlosole simple fold one-quarter lumen diameter from XXVII, the intestinal caeca originate in XXVII, simple and extend to XXIII. Oesophageal hearts four pairs in X–XIII. Holandric, testes in X and XI. Seminal vesicles small in XI and large asymmetrical in XII–XIV. Prostate glands extend from XVII to XXI. Prostate duct U shape. Genital marking glands small sessile, corresponding to each external genital marking.

Ovaries paired in XIII. Spermathecae four pairs in VI–IX. Ampulla large sac. Diverticulum long loosely looped, and tufted nephridia present on ducts of the spermathecae in VIII–IX.

Variation. The holotype is 314 mm long with 160 segments; the two paratypes are 215 and 227 mm long with 130 and 135 segments, respectively.

Etymology. This species was named after the type locality, Mt. Phu Chee Fah.

Distribution. The new species is known only from the type locality. Our collections in nearby areas have also found some earthworm species of the genus *Metaphire*.

Habitat. The new species exhibited swarming in October 2008 at 1,205 m asl, and most of them were juveniles. The reason is still unknown. We collected some specimens by chance. The worms emerged from the top soil of deciduous forest and tried to migrate across a road to another side of the mountain.

Remarks. *Amynthas phucheefah*, new species, would have been classified in the *diffringens* species group in Sims & Easton (1972), but the group has been renamed as the *corticis* species group, which is the most diverse group of the genus *Amynthas* with more than 90 species names (Sims & Easton, 1972). Some previously recorded species from Thailand exhibit 4 pairs of spermathecal pores in 5/6–8/9. These are *A. alexandri* Beddard, 1900, *A. mekongianus* (Cognetti, 1922), *A. exiguus* (Gates, 1930), *A. manicatus* (Gates, 1931), *A. corticis* (Kinberg, 1867), *A. comptus* (Gates, 1932), and *A. longicauliculatus* (Gates, 1931). Within the *corticis* species group in Thailand, the first two species lack genital markings, while the current newly described species shows six pairs of genital markings at the male pores lines. The three latter nominal species are smaller in body width (2.5–3 mm) compared with 8.7 mm of the new species and the last two species have genital markings in 18/19–20/21 and prostate glands small and confined to XVIII, and no nephridia on the spermathecal ducts while the new species has six pairs of genital markings in 19/20–24/25, prostate glands in XVII–XXI, and nephridia present on spermathecal ducts (Table 2).

Amynthas thakhantho Bantaowong & Panha, new species

(Figs. 8, 11E, F; Table 2)

Material examined. Holotype: One adult (CUMZ 3308), Wat Tham Phra, Tha Khantho, Kalasin, Thailand, (16°51′57.10″N, 103°15′17.60″E) 220 m in elevation, coll. P. Tongkerd, P. Pimvichai, B. Kongim and N. Nantarat, 15 October 2010. 10 paratypes: 7 adults (CUMZ 3309), 1 adult (ZMH), 1 adult (NHMUK), and 1 adult (ZRC), same collection data as for holoype.

Diagnosis. Large; length 320–402 mm. Male pores paired, superficial in segment XVIII, each on a transversely oval, slightly raised areas, four pairs of postsetal genital markings on segments XVII, XIX, XX and XXI. Spermathecal pores paired in segments 5/6–8/9. Spermathecae large sac-shaped ampulla, diverticulum long, coil or zigzag. Holandric, intestinal caeca simple, first dorsal pore in 12/13. Prostate glands large, its duct long slender, paired sessile genital marking glands on XVII, XIX, XX and XXI.

Description of holotype. Dimensions; 332 mm by 11.1 mm at segment VII, 10.7 mm at segment XX, 10.5 mm at clitellum; body cylindrical with 198 segments. Setae regularly distributed around segmental equators, numbering 108 at VII, 105 at XX, 23 between male pores, setal formula AA:AB:ZZ:ZY=1:1:2:1 at XIII. Single female pore at XIV. Prostomium epilobic. First dorsal pore at 12/13. Clitellum annular XIV–XVI with no setae.

Male pores paired located ventro-laterally in XVIII, 0.27 circumference apart ventrally, distance between male pores 8.5 mm. Male pores, superficial, small transversely oval, slightly raised. Four pairs of genital markings, postsetal on segments XVII, XIX, XX and XXI, in line with male pores.

Four pairs spermathecal pores in 5/6–8/9, ventro-lateral, depressed in furrows, almost invisible, distance between the pores about 0.27 body circumference ventrally apart, distance between spermathecal pores 8 mm. No genital markings in or near spermathecal segments.

Septa 5/6–7/8 thick, 8/9–9/10 absent, 10/11–11/12 thin. Gizzard large behind 7/8, intestine begins at XV; the intestinal caeca originate at XXVII, simple and extend to XXIII. Typhlosole rudimentary. Lymph glands begin on dorsal intestinal wall of XXVII. Oesophageal hearts four pairs in X–XIII. Holandric; testes and funnels in X and XI. Large seminal vesicles paired in XI–XII. Prostate glands divided into numerous main lobes, extending from the segment XVI to segment XIX. Prostate duct long, slender with hairpin bend. Sessile genital marking glands present corresponding to each external genital marking in XVII, XIX, XX and XXI.

Ovaries in XIII. Spermathecae four pairs in VI–IX. Large sac ampulla with a long slender duct, clearly marked off from ampulla. The diverticulum slender and long with elongated oval seminal chamber, the distal half of its stalk zigzag or coiled.

Variation. The holotype measures 332 mm body length with 198 segments; the nine paratypes range in size from 320–402 mm (±31.86) body length with segments varied from 196–207. The genital markings on segments XVII, XIX, XX are present in all individuals, with an additional pair in XXI (5), or unpaired in XVI (3), XXI (2), and XXII (1).

Etymology. This species was named after Tha Khantho, Kalasin, the type locality of the new species.

Distribution. The new species is known only from the type locality.

Habitat. Top soil at about 15 cm depth, at pH 7, loamy soil. Worms produce columnar or tower-like castings about 20 cm high and 4 cm diameter.

Remarks. *Amynthas thakhantho*, new species, is similar to *A. phucheefah*, new species, with regard to holandry, spermathecal pores in 5/6–8/9, and the body size, but differs in male pore structure, and number and arrangement of genital markings in the male field. *Amynthas thakhantho* has four pairs of postsetal genital markings on segments XVII, XIX, XX, XXI, whereas *A. phucheefah*, new species, has six intersegmental pairs on 19/20–24/25 (Table 2). Otherwise it also differs from other regional members of the *corticis* species group by a combination of body size and male field characters, as discussed for *A. phucheefah.*

Amynthas jacobsoni (Michaelsen, 1922)

(Fig. 9; Table 2)

Pheretima jacobsoni Michaelsen, 1922: 34, Type locality: Indonesia.
Amynthas jacobsoni: Sims & Easton, 1972: 235.

Material examined. Syntype from ZMH (V 9294. Fig. 9): One adult in 70% ethanol deposited at Biozentrum Grindel Zoologisches Museum, University of Hamburg, Germany.

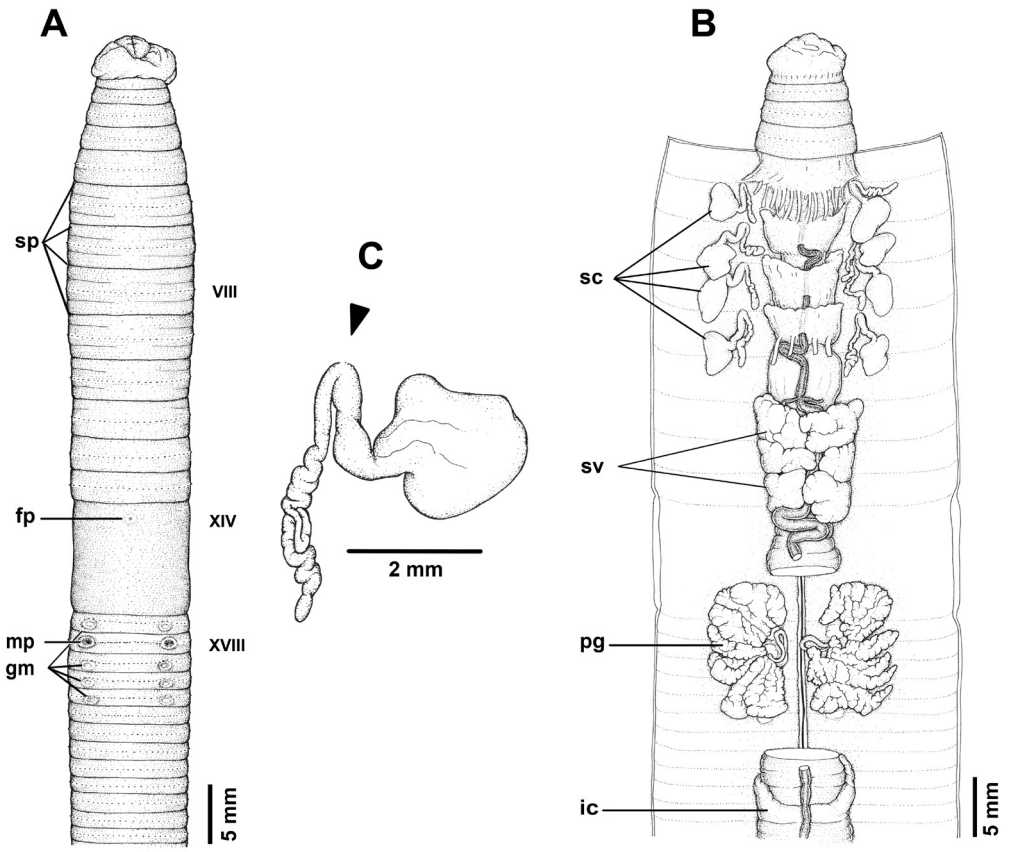

Fig. 8. External and internal morphology of holotype (CUMZ 3308) of *Amynthas thakhantho*, new species: A, external ventral view; B, internal dorsal view; C, spermathecae. Dark arrow indicates the connection of the spermathecae and spermathecal pore.

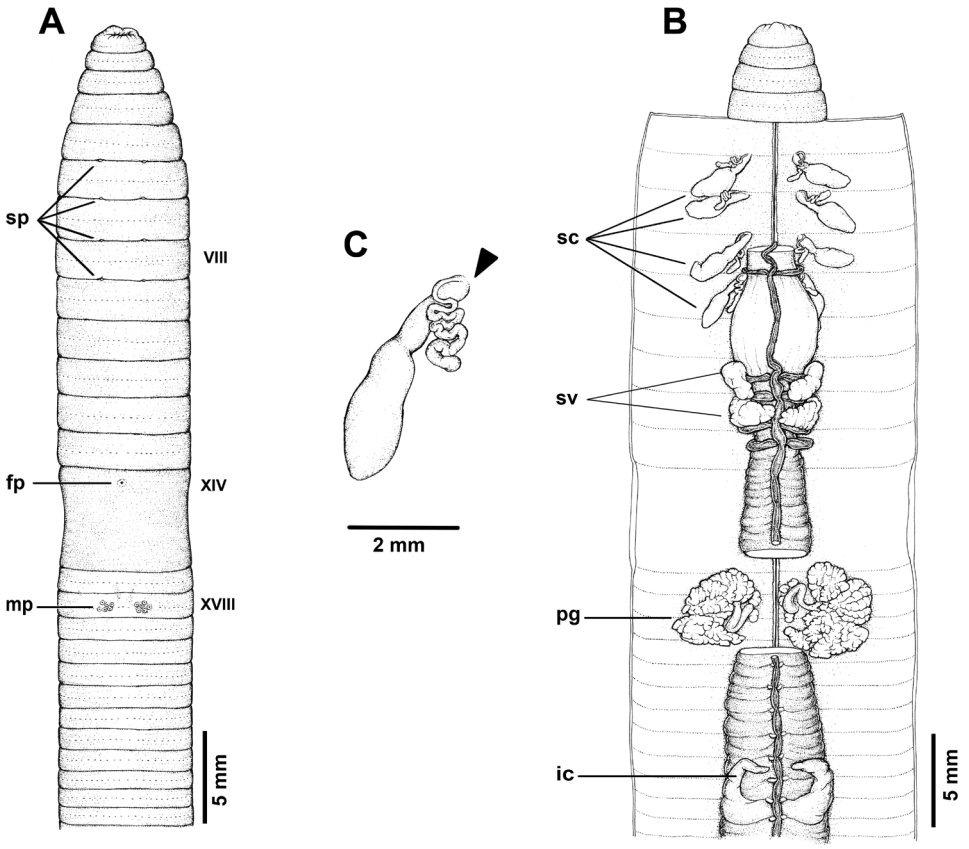

Fig. 9. External and internal morphology of the syntype (ZMH 9294) of *Amynthas jacobsoni*: A, external ventral view; B, internal dorsal view; C, spermathecae. Dark arrow indicates the connection of the spermathecae and spermathecal pore.

Remarks. *Amynthas jacobsoni* differs from *A. phucheefah*, new species, and *A. thakhantho*, new species, by having a group of 6 small circular papillae present on male pores area, which correspond to the sessile genital marking glands (Table 2).

Amynthas suctoria (Michaelsen, 1907)

(Fig. 10; Table 2)

Pheretima suctoria Michaelsen, 1907: 165, fig. 12. Type locality: Andaman Islands. Stephenson, 1922: 434, fig. 1; 1923: 311, fig. 123.

Amynthas suctoria: Sims & Easton, 1972: 235.

Material examined. Syntype from ZMH (V 7168. Fig. 10): Three adults and one sub-adult in 70% ethanol deposited at Biozentrum Grindel Zoologisches Museum, University of Hamburg, Germany.

Remarks. *Amynthas suctoria* differs from *A. phucheefah*, new species, and *A. thakhantho*, new species, by lacking genital markings at male pores area, but having a large pair of sessile genital marking glands (Table 2).

DISCUSSION

The descriptions of the new species of *Amynthas* are based on specimens collected on various occasions in various habitats. The four new species belong to two species groups and are relatively large compared to most Thai *Amynthas* species. Two species, *Amynthas longicaeca,* new species, and *A. phucheefah*, new species, were found in protected areas in which soils are still fertile containing clay–rich topsoil, but the other two species, *A. arenulus* new species and *A. thakhantho*, new species, were found in modified dipterocarp and deciduous forest areas used for rice and other economic plant cultivation. Soil textures are sandy in the cultivated areas with lower silt content, and farmers typically improve them by adding both organic and chemical fertilisers in each cropping season. Soil pH is close to 7 in both natural and modified areas. *Amynthas arenulus* has the largest body among the four new species, and as shown in Figure 11, it lives on the earthen barriers adjacent to paddy fields during cropping but moves to the paddy areas after harvesting. The area was formerly dipterocarp forest on sandy soil, but after modification the soil fertility is low. Individual casts deposits are usually separated by about 30–40 cm. The low mound-like casts exhibit the sandy soil texture of the sites and are the characteristic cast shape of this species (Fig. 11B). The worms live in shallow topsoil at about 20–30 cm where mostly juveniles were collected during cultivating in rainy season (June to October). Adults appear during the dry season before harvesting (end of October to January). Although juveniles are quite tolerant of chemical agriculture, the trend of organic farming probably poses fewer challenges to earthworm populations. Worms can consume organic matter such as crop residues or materials added by the farmers, enhancing its decomposition rate, and the transport and dispersion of the organic matter, and enrichment of the soil microorganisms through casting. In addition, while the

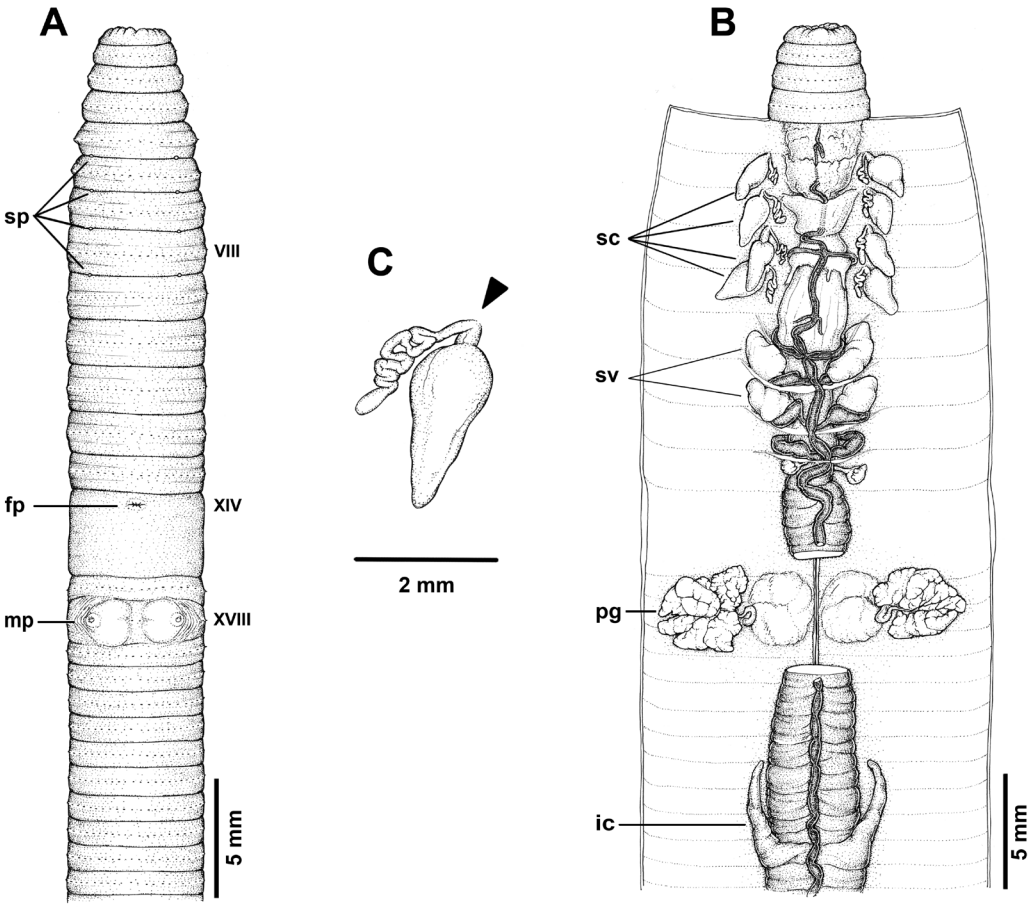

Fig. 10. External and internal morphology of the syntype (ZMH 7168) of *Amynthas suctoria*: A, external ventral view, B, internal dorsal view and C spermathecae, dark arrow indicates the connection of the spermathecae and spermathecal pore.

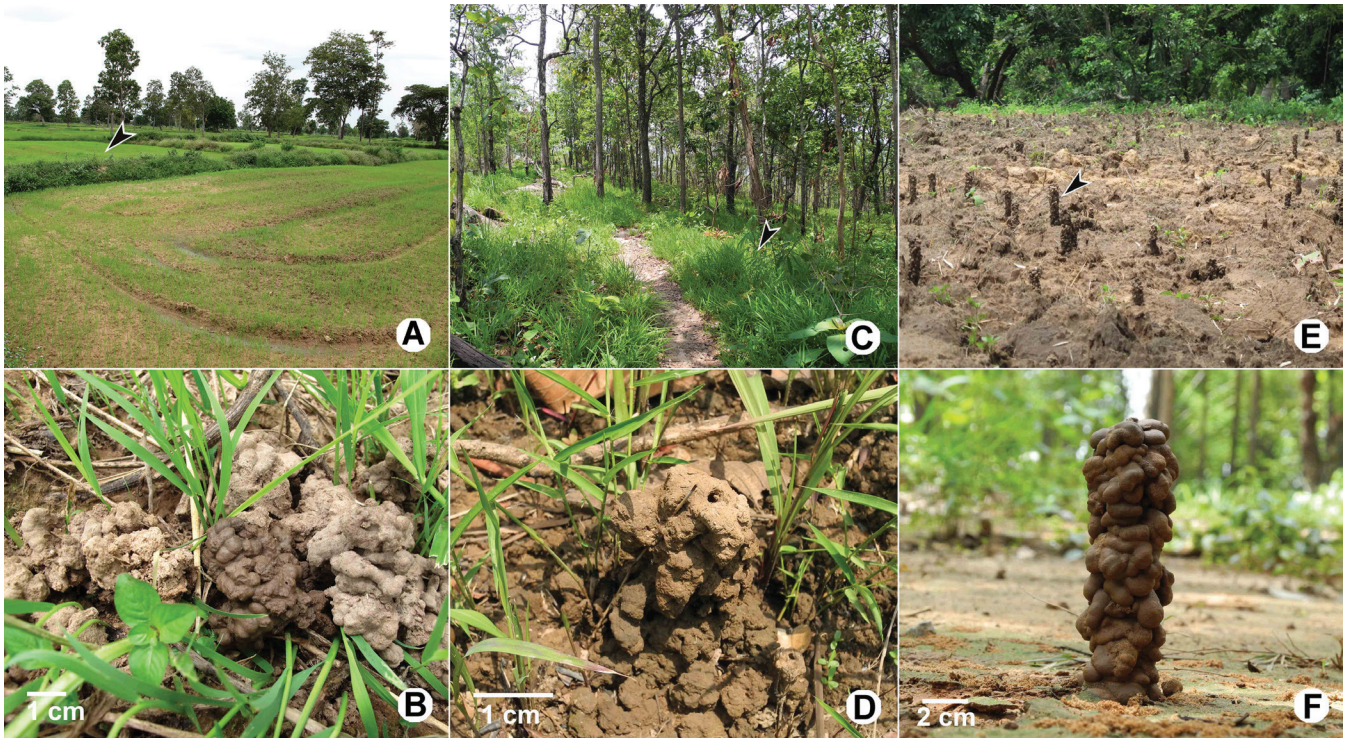

Fig. 11. Photographs showing typical habitat types of the new species: A, B, *Amynthas arenulus*, new species. A, earthen dyke around paddy field; B, casting. C, D, *Amynthas longicaeca*, new species. C, dipterocarp forest; D, casting. E, F, *Amynthas thakhantho*, new species. E, organic gardening; F, tower–like casting.

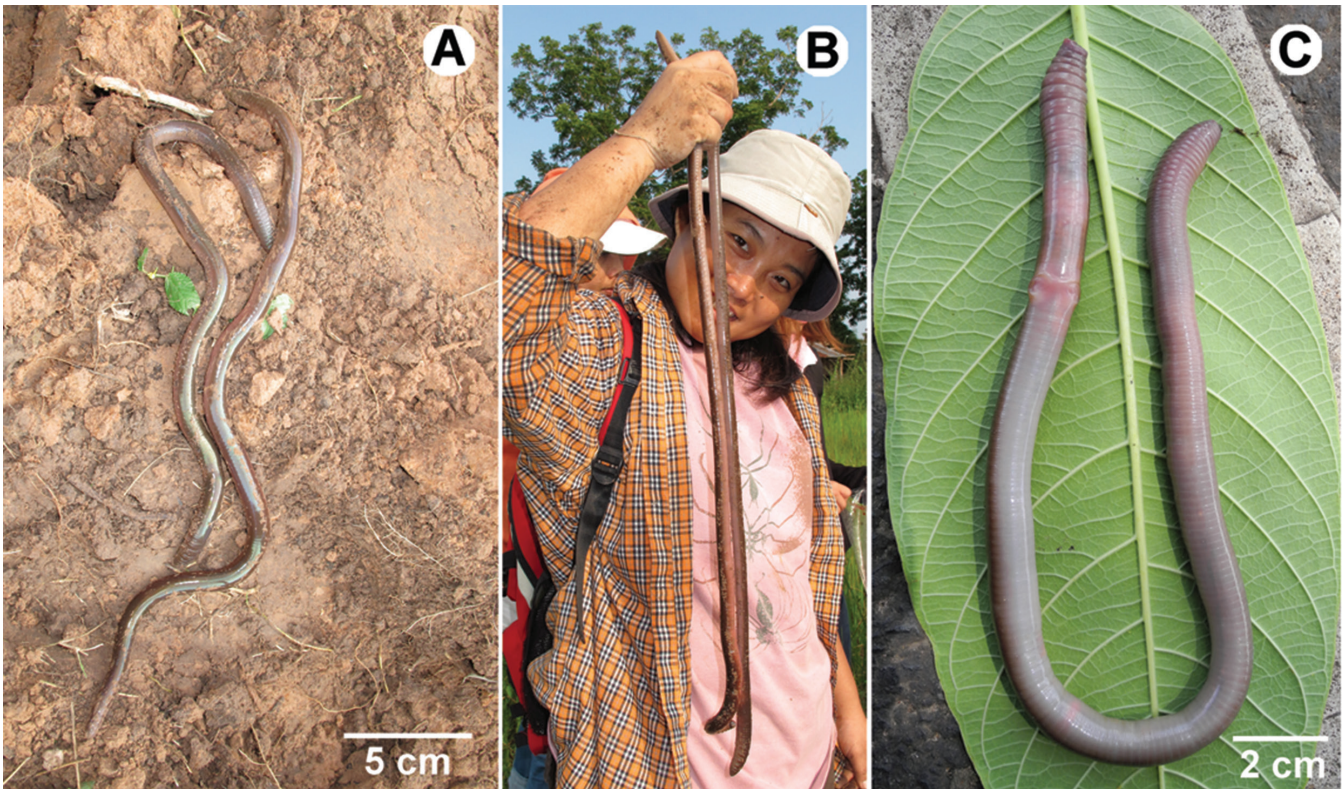

Fig. 12. Photographs of *Amynthas arenulus*, new species. A, B, living specimen from the type locality showing the coloration; C, specimen from Sisaket, just after anesthesis step in 30% (v/v) ethanol showing the coloration of the ventral side.

worms move throughout the soil they mechanically improve the soil aeration property, and so improve soil fertility for the next crop cycle.

Amynthas thakhantho also occurs in agricultural areas, formerly deciduous forest which produces a different leaf litter quality from dipterocarp forest. However, after conversion to agriculture the soil lost clay particles and became more sandy. This does not seem to deter the earthworms of these areas. The photos in Figure 11E and F show *A. thakhantho* is numerous in the farm lands cultivated according to organic farming protocols. The unique tower casts are spaced about 30 to 50 cm apart. The other two new species were found in nature reserve areas in which soil conditions are still unmodified from original, pH close to 7 and high in clay. *Amynthas longicaeca* lives in dry dipterocarp forest with abundant leaf litter. It also produces tower-like cast mounds and the casts are separated from each other by 30 to 70 cm (Figs. 11C, D) within a grass community. We have no precise habitat information of *A. phucheefah*, because this species was collected during its annual emergence in October 2008. Most emerged worms were juveniles. The location is in a nature reserve area under deciduous forest with fertile clay-rich soil. October is just at the end of the rainy season and becoming dry. We suggest that worms move to the more humid areas in order to better survive the dry 5–6 months before the next rainy season.

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