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New and little known giant earthworms from Madagascar (Oligochaeta: Kynotidae)

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ABSTRACT

During a survey of the soil macrofauna of Madagascar three giant earthworm species were collected in the eastern part of the island. One of them, *Kynotus friderici* Michaelsen, 1931, is a known species described as *K. longus* var. *friderici* Michaelsen, 1931 and elevated to species rank herein. The other two species, *K. giganteus* sp. n. and *K. proboscideus* sp. n., proved to be new to science. *K. giganteus* measures alive 1350–1400 mm in length, 20–25 mm in diameter; *K. proboscideus* alive is ca 500–600 mm long and 15–20 mm in diameter. All worms belong to the Malagasy endemic family Kynotidae.

KEY WORDS: Oligochaeta, Kynotidae, earthworms, Afrotropical, Madagascar, new species, endemics.

INTRODUCTION

Earthworms constitute a major part of the soil macrofauna and play a paramount role in the soil processes; therefore they are regarded as soil ecosystem engineers (Jones *et al.* 1994, Decaëns *et al.* 2001). In spite of their importance, taxonomic research on earthworms, especially in Africa, is quite limited. Apart from some sporadic papers (e.g. Csuzdi 2005, 2010a, b; Zicsi 1996, 1997), organised earthworm research is progressing only in South Africa (e.g. Plisko 2006, 2008, 2009, 2010, and papers cited therein). It is especially remarkable that no research has been carried out in Madagascar, although the island is listed among the five most important biodiversity hotspots of the world (Myres *et al.* 2000).

Previous data on the earthworms of Madagascar are quite scarce and usually have resulted from occasional collecting by different naturalists travelling on the island. The first species *Geophagus darwinii* was described by the German traveller Conrad Keller in 1887. In a summary of the earthworm fauna of the Malagasy Region, Michaelsen (1897) enumerated 18 species, including eight belonging to the native genus *Kynotus*. The last taxonomic paper on the Malagasy earthworms was published 80 years ago (Michaelsen 1931). Up to that time 32 species were recorded, in seven families, the Megascolecidae, Kynotidae (endemic family with a single genus), Acanthodrilidae, Eudrilidae, Ocneodrilidae, Octochaetidae and Glossoscolecidae. Among the species reported 19 (59%) are autochthones and 13 (41%) are introduced.

After 1931, no taxonomic study was carried out until April 2008, when a project entitled Fauna-M was launched. The main goals of this project were to explore the soil macrofauna of Madagascar in order to create a database and set up a museum collection for earthworms and other soil invertebrates (termites, coleopteran larvae). As the first scientific output of this project, Razafindrakoto *et al.* (2010) summarized the introduced earthworms of Madagascar, recording three new occurrences for the island. In this paper, we report on three giant earthworm species found during expeditions to different parts of Madagascar.

MATERIAL AND METHODS

All sampling was carried out on the eastern part of Madagascar. According to its vegetation, Madagascar is divided into two parts: the eastern part is generally covered by tropical forest and the western part by dry forest. The northern region around Antsiranana (Diego Suarez) is characterized by a tropical climate with two distinct seasons. The mean annual temperature is around 27 °C with two maxima (March 30.75 °C, December 28.1 °C). The yearly precipitation is 900–1250 mm, with a seven-month dry season and five-month rainy season. The vegetation belongs to the western-type dry forests. More to the south, along the eastern coast, is the region of Ambatondrazaka (the Mangoro-Alaotra hollow). In this region the climate is cooler, the yearly temperature is around 20–22 °C and the precipitation is around 1100 mm. The original vegetation was medium-altitude dense forest, but these forests have largely disappeared and now only exist in isolated patches. In the south-eastern coastal part of Madagascar (the Atsimo-Atsinanana region) the annual mean temperature is *ca* 24 °C and the precipitation is around 2000 mm. The original vegetation was characterized by rain forest but most of it has been destroyed by the traditional slash-and-burn agriculture (“tavy”), and the vegetation is now represented by secondary forests mixed with savannah (Donque 1972; Koechlin 1972).

During fieldwork we searched for casts of the worms. When casts were found, digging and hand sorting were used to collect earthworms. We also applied the diluted formaldehyde method (Raw 1959) to extract earthworms when we found fresh casts; however, in the case of *Kynotus giganteus* the villagers did not permit us to use this method. Earthworms collected were killed in 50 % ethanol and preserved either in 96 % ethanol or in 4 % formaldehyde solution. Samples were identified in the laboratory of the Mixed Unit of Research in functional ecology and biogeochemistry of soils (UMR Eco&Sols), Montpellier, France and in the Hungarian Natural History Museum.

Specimens were deposited in the Hungarian Natural History Museum (HNHM) and in the Zoological Museum of the University of Antananarivo (ZMUA).

TAXONOMY

Family Kynotidae Jamieson, 1971

Diagnosis: Body cylindrical, dorsal pores absent. Clitellum annular or saddle-shaped (juvenile?), tubercula pubertatis absent. Male pores paired on 16, rarely on 15 (erroneous?) within copulatory pouches which when everted form clasper-like “appendages”. Spermathecal pores multiple, praeclitellar frequently inconspicuous. Oesophageal gizzard 5, intestinal gizzard and calciferous glands absent. Supra-oesophageal vessel present. Tubular, prostate-like setal glands associated with copulatory pouches and the genital setae present. Excretory system holoic.

Genus *Kynotus* Michaelsen, 1891*Kynotus friderici* Michaelsen, 1931, **stat. n.**

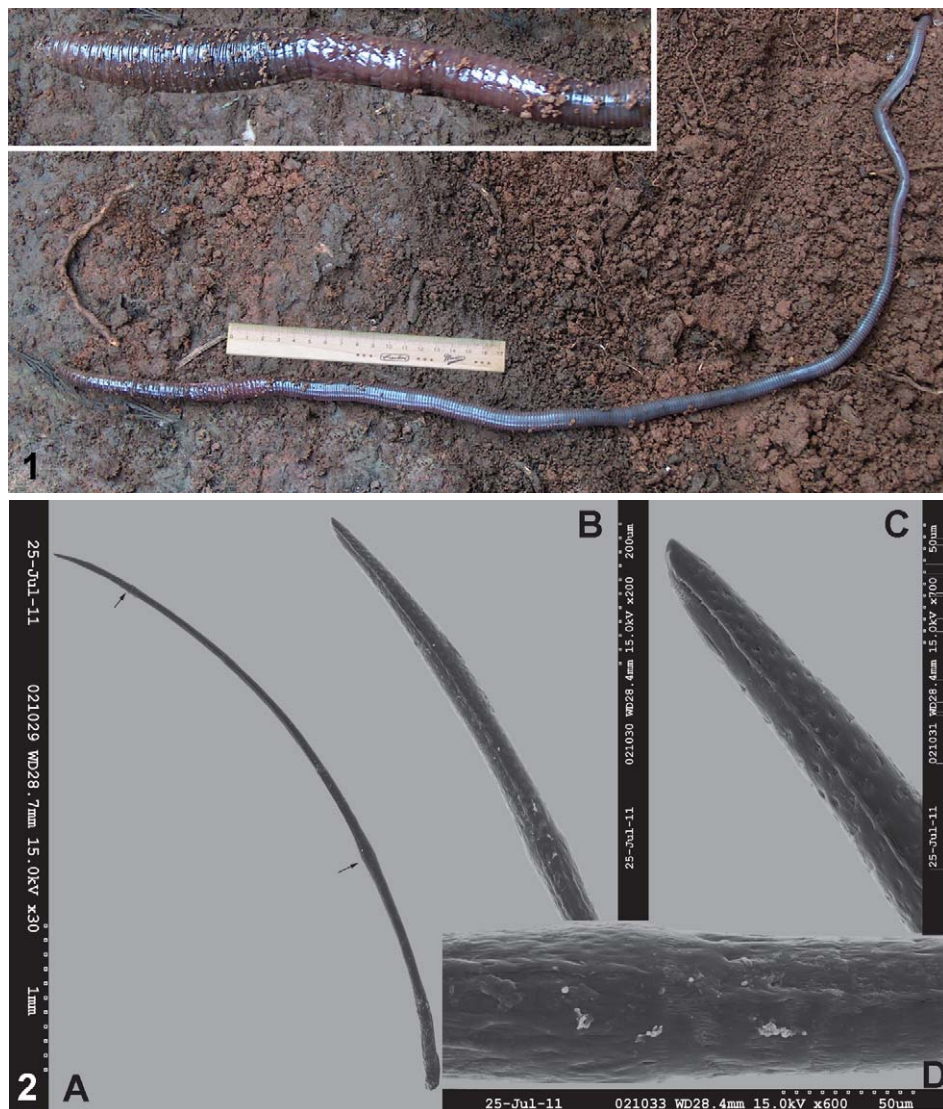
Figs 1, 2

Kynotus longus var. *friderici* Michaelsen, 1931: 532.

Diagnosis: Length alive *ca* 1000 mm, diameter 10–15 mm, preserved length 550 mm diameter 15 mm (Fig. 1). Colour dark nut-brown on dorsum, paler on ventrum. Seg-

ments 1–3 simple, 4–13 double ringed. Setae *ab* and *cd* appear from segment 17. Male pore on 16. Clitellum well developed, circular on $\frac{1}{2}21$ – $\frac{1}{2}40$. Setae closely paired, both *ab* and *cd* lateral. Spermathecae intramuscular, around *ab*, 4–8 on each side in 14/15, 15/16. Genital setal glands in 13, 14, 15. Genital setae 4.5 mm long, diameter 0.075 mm, tip claw-shaped with a subterminal nodulus. Ornamentation small serrations on the tip, transversally arranged long hairs around the nodulus (Fig. 2).

Material examined: MADAGASCAR: near of the Amber Hill national park, along the road near Joffreville in Antsiranana (12°28'46.5"S:49°12'47.8"E), 8.ii.2011, M. Razafindrakoto & E. Blanchart (HNHM AF/5538 1 ex., ZMUA-069 1 ex.).



Figs 1, 2. *K. friderici* Michaelsen: (1) body view, with enlarged anterior end on inset; (2) penial seta: (A) whole seta, (B) tip of the seta, (C) ornamentation of the tip, (D) ornamentation around the nodulus.

Habitat: The vegetation in the locality is formed by mango plants and *Tithonia diversifolia*, the soil is covered by *Thelepogon elegans* mixed with *Sida rhombifolia* and *Corchorus olitorius*. The dead mango leaves are humified on the soil and the rain brings some sandy soil and other organic materials.

Remarks: *Kynotus longus* var. *friderici* Michaelsen, 1931 was described possibly on a regenerated specimen (Michaelsen 1931: 533); this might be the reason for the much smaller length (330 mm) given. Michaelsen argued that *friderici* is very close to the typical form and there are differences only in the spermathecal system, which is entirely intraparietal in *friderici* but large and intracoelomic in *longus*. This is a difference with taxonomic significance therefore *K. longus* var. *friderici* is hereby elevated to species rank.

***Kynotus giganteus* sp. n.**

Figs 3–5

Etymology: From Latin *giganteus* (giant), in reference to the size of the captured worms.

Diagnosis: Length alive 1350–1400 mm, diameter 20–25 mm; preserved length 1080–1840 mm diameter 15–20 mm. Colour slightly reddish at the head, pale after the clitellum. Segments 1–2 simple, 3–16 double ringed. Setae *ab* and *cd* appear from segment 17. Male pore on 16, on the second ringlet. Clitellum indistinct on 22–47, 48. Setae closely paired, both *ab* and *cd* lateral. Spermathecal pores from above *ab* to Md, 9–14 on each side in 13/14, 14/15, 15/16. Spermathecae intramuscular. Genital setal glands in 14, 15, 16. Genital setae spoon-shaped, slightly tetrahedral. Length *ca* 6 mm, diameter 0.04 mm, ornamentation dense serrations.

Description:

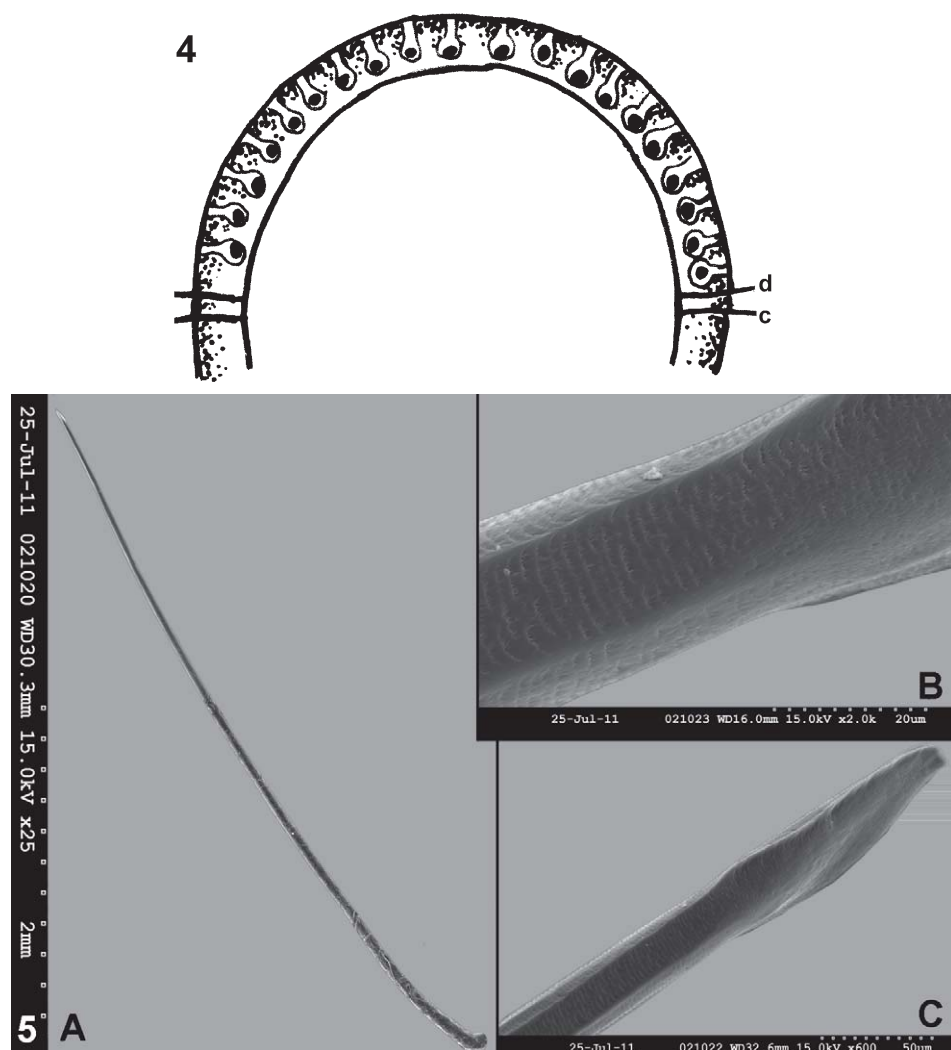
Holotype: Preserved length 1450 mm, diameter after clitellum 15 mm (Fig. 3). *Segment number*: 1330. *Paratypes*: 1080–1840 mm in length 15–20 mm in diameter. *Segment number*: 1300–1350. Weight of preserved worms ranges between 184–195 g. *Colour*: Alive slightly reddish at head, whitish after clitellum; preserved greyish. *Head*:



Fig. 3. *K. giganteus* sp. n., body view and enlarged anterior end.

Prolobous. *Segments*: 1–2 simple, 3–16 clearly double ringed. *Dorsal pores*: Lacking. *Setae*: Small, both *ab* and *bc* became observable on segment 17. All setae lateral, setal ratio $aa:ab:bc:cd:dd = 100:1:10:1:90$. *Nephridial pores*: Begin on segment 2, somewhat dorsal to setal line *ab*.

Clitellum: Only indistinctly developed on segments 22–47, 48. *Male pore*: Ventral on 16, large oval slit on second ringlet. *Female pores*: Small slits on 14, in line of male pores. *Spermathecal pores*: In intersegmental furrows 13/14, 14/15, 15/16, numerous, 9–14 on each side, begin around the line of nephridial pores and scattered until mid-dorsal line. Spermathecal lines sometimes interrupted and continue not in intersegmental furrow but in furrows of two ringlets. *Genital setal pores*: Segmental, irregularly occur on lateral sides of segments 14, 15 and 16.



Figs 4, 5. *K. giganteus* sp. n.: (4) spermathecae; (5) penial seta: (A) whole seta, (B) ornamentation under the tip, (C) tip of the seta.

Internal characters: *Muscular gizzard*: In 5, well-developed, cylindrical. *Septa*: 5/6, 12/13, 13/14 thickened, 6/7–11/12 highly strengthened. *Calciferous glands*: Lacking, even lamellar thickening of oesophagus missing. *Dorsal blood vessel*: Simple. *Hearts*: In 6–11, large moniliform, especially last two pairs. *Testes* and *sperm funnels*: In 10, 11 enclosed in peritoneal sack. *Seminal vesicles*: Lacking. *Ovaries*: In 13. *Copulatory chamber*: Large, oval, occupies the ventral place of segments 15–17. Each copulatory chamber bears irregular prostate-like gland (pseudoprostate) bulging up to segment 13; gland's position highly variable, sometimes dorsal but sometimes running towards tail. *Spermathecae*: Small, numerous, completely embedded in body wall, only shining sperm can be seen from inside. Cutting body wall at intersegmental furrow 13/14, several small oval spermathecae can be seen that open to surface with small duct (Fig. 4). *Genital setal organ*: Three pairs in segments 14, 15, 16. They consist of large, slightly spiral gland similar in shape to pseudoprostates and genital setal sac containing several genital setae. *Genital setae*: Spoon-shaped, slightly tetrahedral, *ca* 6 mm long, 0.04 mm in diameter and provided with characteristic serrated ornamentation (Fig. 5).

Holotype: MADAGASCAR: Atsimo-Atsinanana region, Farafangana district, Fianarantsoa town, near village of Ankazomafaitsy (22°38'27.8"S:47°49'40.8"E), 45 m, 23.i.2010, M. Razafindrakoto (HNHM AF/5513).

Paratypes: Same data as holotype (HNHM AF/5514 1 ex., ZMUA-030 3 ex.).

Habitat: The vegetation in the locality is formed by savannah and secondary forest with *Ravenala madagascariensis* very dominant.

Remarks: The new species exceeds in size all known *Kynotus* species. It is similar to *K. darwini* Keller, 1887 (= *K. madagascariensis* Michaelsen, 1891) but differs from the latter in its larger size, the position of the genital setae (13–15 in *darwini*, 14–16 in *giganteus*) and in the spermathecae (which are intracoelomic and sac-shaped in *K. darwini*, intramuscular and egg-shaped in *K. giganteus* sp. n.). Regarding its spermathecal apparatus the new species is similar to *K. friderici* Michaelsen, 1931; however, this species possesses only two spermathecal lines (14/15, 15/16) with 2–2 spermathecae on each side. A further difference can be found in the genital setae, which are claw-shaped in *K. friderici* and spoon-shaped in *K. giganteus* sp. n.

It is remarkable that this giant worm possesses very small spermathecae completely embedded in the body wall, similar to several giant Ecuadorian earthworms such as *Martiodrilus ischuros* Zicsi, 1990, *Martiodrilus crassus* (Rosa, 1895) and *Martiodrilus olivaceous* James, 1990 (each *ca* 1000 mm long).

***Kynotus proboscideus* sp. n.**

Figs 6–9

Etymology: From Latin *proboscis*, referring to the presence of two protrusions on the prostomium.

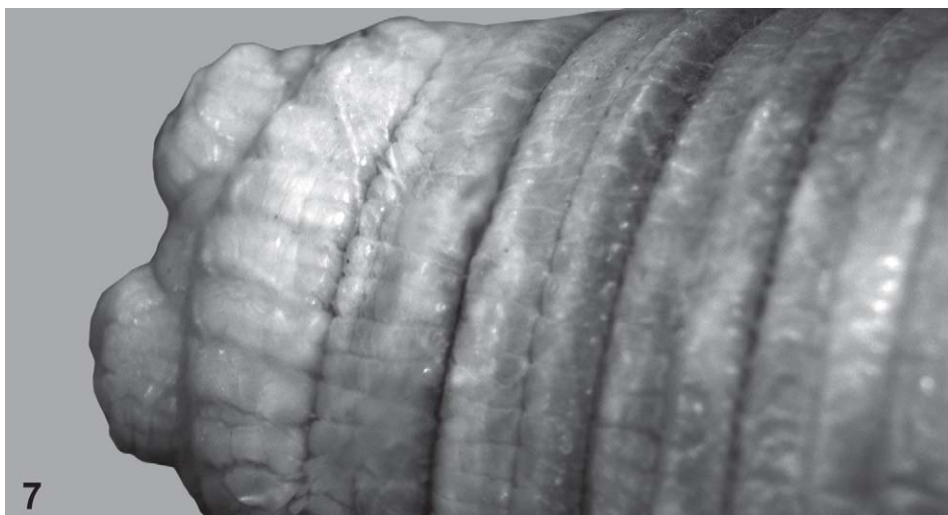
Diagnosis: Length alive *ca* 500–600 mm, diameter 15–20 mm; preserved length 280–320 mm diameter 18–20 mm. Colour dark red on dorsum, pale on ventrum. Head with two protrusions. Segments 1–3 simple, 3–13 double ringed. Setae *ab* and *cd* appear from segment 17. Male pore on 16. Clitellum circular on 22–47, 48. Setae closely paired, both *ab* and *cd* lateral. Spermathecal pores lateral, 6–9 on each side



6A



6B



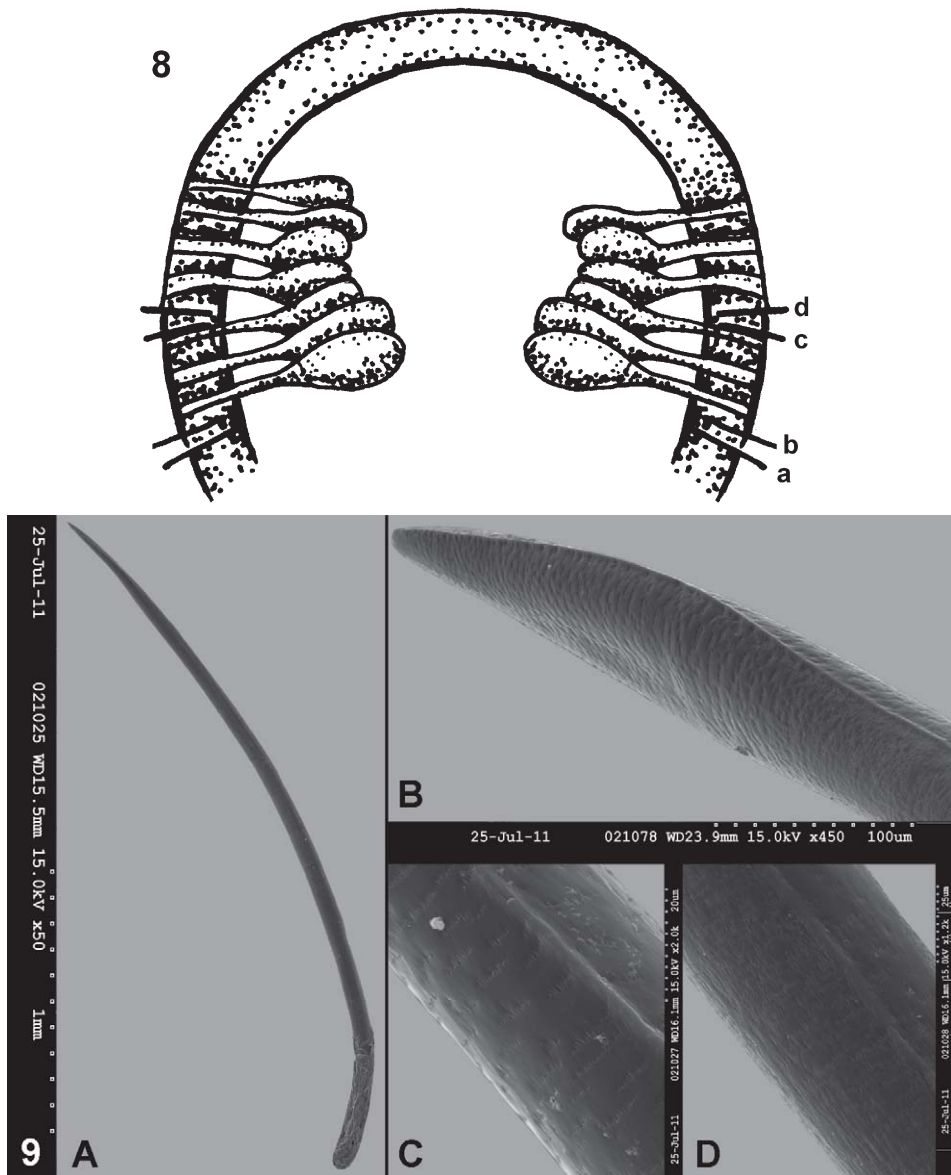
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Figs 6, 7. *K. proboscideus* sp. n.: (6) general view (A) and enlarged anterior part of the body (B); (7) prostomium.

in 13/14, 14/15, 15/16. Spermathecae large, irregular sac-shaped, duct short. Genital setal glands in 13, 14, 15. Genital setae lanceolate, length 3.2 mm, diameter 0.06 mm, ornamentation dense serrations.

Description:

Holotype: Contracted length 320 mm, diameter after clitellum 20 mm. *Segment number*: 734 (Fig. 6). *Paratypes*: Contracted length 280–320 mm, 13–20 mm in diameter. *Segment number*: 532–601. The weight of the preserved worms ranges between 44–58 g. *Colour*: Alive dark red on dorsum becoming pale abruptly ventrally from *cd*, preserved dark brown on dorsum and lighter on ventrum. *Head*: Prolobous with two



Figs 8, 9. *K. proboscideus* sp. n.: (8) spermathecae; (9) penial seta: (A) whole seta, (B) tip of the seta, (C) ornamentation around the tip, (D) ornamentation under the tip.

prominent protrusions (Fig. 7). *Segments*: 1–3 simple, 4–13 clearly double ringed. *Dorsal pores*: Lacking. *Setae*: Small, both *ab* and *bc* became observable on segment 17. All setae lateral, setal ratio $aa:ab:bc:cd:dd = 40:1.25:7.5:1:37.5$. *Nephridial pores*: Begin on segment 2, somewhat dorsal to setal line *ab*.

Clitellum: Circular on segments 22–47, 48. *Male pores*: Ventral on 16. *Female pores*: Not observable. *Spermathecal pores*: Lateral, 6–9 on each side in intersegmental furrows 13/14, 14/15, 15/16. *Genital setal pores*: Segmental, irregularly occur on lateral sides of segments 13, 14 and 15.

Internal characters: *Muscular gizzard*: In 5, well developed, cylindrical. *Septa*: 5/6–12/13 strongly thickened. *Calciferous glands*: Lacking, even lamellar thickening of oesophagus missing. *Dorsal blood vessel*: Simple. *Hearts*: In 6–11, large moniliform, especially those in 10, 11. *Testes and sperm funnels*: In 10, 11 enclosed in peritoneal sack. *Seminal vesicles*: Lacking. *Ovaries*: In 13. *Copulatory chamber*: Large, oval, occupies ventral part of segments 15–20. Each copulatory chamber bears irregular prostate-like gland (pseudoprostate) bulging up to segment 25. *Spermathecae*: In 13/14, 14/15, 15/16, 6–9 per side, irregular sac-shaped, their size increases toward ventral pairs (Fig. 8). *Genital setal organ*: Three pairs in segments 13, 14, 15, consisting of slightly spiral gland similar in shape to pseudoprostates and genital setal sac containing several genital setae. *Genital setae*: Lanceolate, tip slightly depressed, 3.2 mm in length, 0.06 mm in diameter, with unequal serrated ornamentation. Serrations on dorsal side small and scattered, on ventral side dense and long (Fig. 9).

Holotype: MADAGASCAR: Ambatondrazaka district, Toamasina town, Mangalaza (17°18'32.3"S: 48°46'40.6"E), 800 m, 17.iii.2010, M. Razafindrakoto (HNHM AF/5511).

Paratypes: Same data as holotype (HNHM AF/5512 1 ex, ZMUA-027: 2+2 ex.); Ambatondrazaka district, Toamasina town, Tsarahonenana (17°18'40.1"S:48°36'58.4"E), 935 m, 25.iii.2010, M. Razafindrakoto (ZMUA-029 1 ex.); Ambatondrazaka district, Toamasina town, Vohitsoa (17°26'57.3"S:48°33'52.3"E), 765 m, 25.iii.2010, M. Razafindrakoto (ZMUA-028 1 ex.).

Habitat: At all places the vegetation is formed by bush composed of invasive species (*Phytolacca acinosa*, *Salvia coccinea*, *Ageratum conyzoides*, *Lantana camara*, *Ricinus communis*, *Sida rhombifolia*), with many dead leaves on the soil and some other plant material that starts to be humified.

Remarks: The new species is similar to *K. kelleri* Michaelsen, 1892 in its size and colour, but clearly differs from it by the higher number of spermathecae (1–3 per side in *kelleri*, 6–9 in *proboscideus*) and the presence of two prominent probosces on the prostomium. There is only one other species with similar head structure, *K. schistocephalus* Michaelsen, 1897, but the new species is easy to distinguish because of its longer clitellum (21–40 in *schistocephalus*, 22–27, 48 in *proboscideus*) and the higher number of spermathecae (1–3 in *schistocephalus*, 6–9 in *proboscideus*).

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