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New South African Acanthodrilinae earthworm species, with new data for some earlier known members of the genus *Parachilota* (Oligochaeta: Acanthodrilidae)

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ABSTRACT

Four acanthodriline species of the genus *Parachilota*, namely *abebaios* sp. n., *nkandu* sp. n., *uysae* sp. n., and *timothyi* sp. n., are described and illustrated. Additional information is given on the characters, geographical range and habitat of the earlier known six *Parachilota* species: *editha*, *hottentotianus*, *karkloofi*, *minimus*, *wahlbergi*, and *warreni*. The shape and number of spermathecal diverticula were considered as the diagnostic characters of studied species, and three species groups are recognized: unilobate, bilobate and multilobate. Species endemism is noted.

KEY WORDS: Oligochaeta, Clitellata, Acanthodrilidae, *Parachilota*, new species, taxonomy, anatomy, South Africa.

INTRODUCTION

This paper is a continuation of a survey of the acanthodriline species in South Africa, based on the collection in the Natal Museum, Pietermaritzburg, South Africa. During the present study it was observed that the structure of the spermathecae is a valuable specific character. Three species groups were recognized: (1) unilobate, with only one, externally not divided spermathecal diverticulum; (2) bilobate, with two variably shaped and located diverticula; and (3) multilobate, with spermathecae having more than two diverticula. For now, the recognition of these species groups is applied to the present material. A confident assignment of other *Parachilota* species to these, and probably other, species groups, requires a comprehensive revision of the entire genus, which is beyond the scope of the present paper.

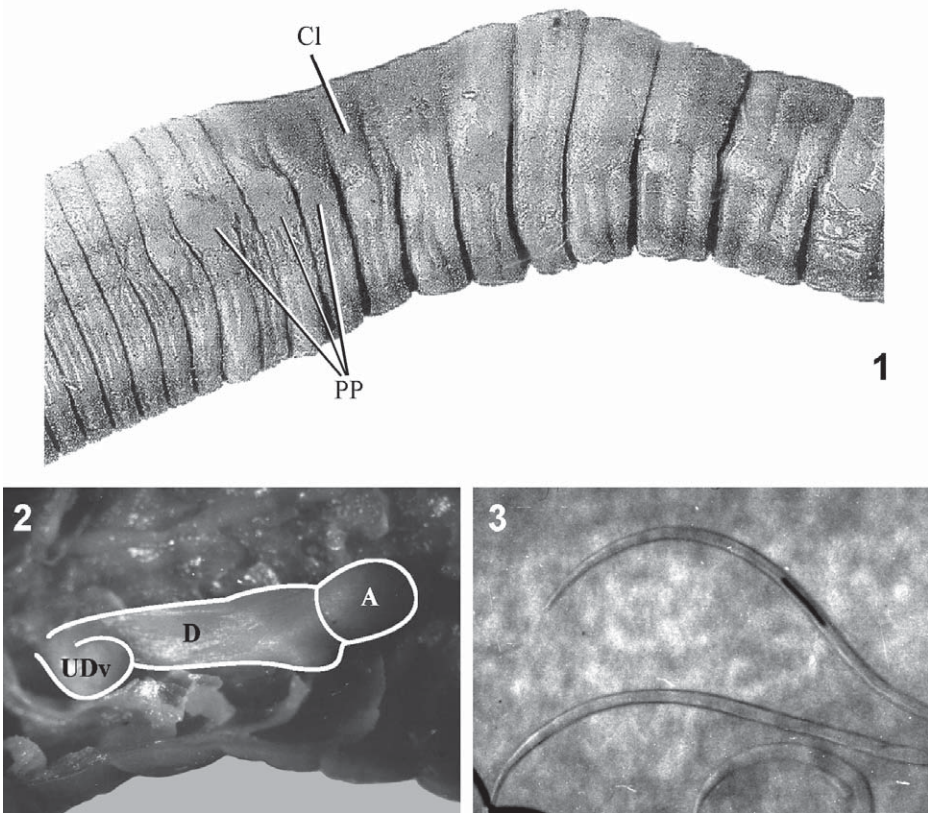
Three unilobate species, *abebaios* sp. n., *ncandu* sp. n. and *timothyi* sp. n., and the multilobate *uysae* sp. n., are described. Some taxonomical and distributional information is provided for the earlier known species: the unilobate *hottentotianus* Pickford, 1937, *wahlbergi* (Michaelsen, 1899); bilobate species *editha* (Pickford, 1927), *karkloofi* Zicsi, 1998, and *minimus* Zicsi & Pajor, 1992; and the multilobate *warreni* (Michaelsen, 1913). Generic characterisation is based on works by Pickford (1937), Zicsi (1998), and Plisko (2004, 2007).

MATERIAL AND METHODS

The study was based on the examination of earthworms collected by the author with assistance of Dr B.R. Stuckenberg and Mr T. Liversage, and on material donated by various collectors. Four new species and seven earlier known South African acanthodriline species kept at the Natal Museum were compared with the material described or revised by Pickford (1927, 1937) housed at the South African Museum in Cape Town and kindly loaned to the author. Although some studied specimens were preserved

differently, most were narcotised in 45 % alcohol, then fixed in 4 % formalin solution and thereafter transferred to 75 % alcohol. For the internal anatomy, dorsal longitudinal dissections were performed. Data were taken from the original labels. Coordinates are given in brackets for all place names as recorded on the original labels. Data not found on the original labels are given in square brackets. Measurements of the setal formulae are expressed in intersetal ratio. The photographs were taken with a Wild Heerbrugg M8 stereomicroscope. The methods and terminology used follow earlier publications (Plisko 2004, 2007). The shape and number of spermathecal diverticula considered as valuable specific characters are employed to separate species in the unilobate, bilobate and multilobate species groups. Types of the new species are deposited in the Natal Museum, Pietermaritzburg.

The following abbreviations and acronyms are used: BMNH – Natural History Museum, London, UK; NMSA – Natal Museum, Pietermaritzburg, South Africa; SAMC – South African Museum, Cape Town, South Africa, with A followed by a number of the SAMC Oligochaeta Collection; ZMUH – Zoological Museum and Institute, University of Hamburg, Germany; BRS – B.R. Stuckenberg; JDP – J.D. Plisko; KZN – KwaZulu-Natal province of South Africa; cl – clitellate; juv – juvenile.



Figs 1–3. *Parachilota abebaios* sp. n., holotype: (1) anterior part of body, laterally; (2) anterior left spermatheca, 180 \times ; (3) penial setae of 17. Abbreviations: A – ampulla, Cl – clitellum, D – spermathecal duct, PP – papillae of 8–10, UDv – unilobate diverticulum.

TAXONOMY

Subfamily Acanthodrilinae Claus, 1880

Genus *Parachilota* Pickford, 1937 emend.*Parachilota*: Pickford 1937: 180; Zicsi 1998: 63; Plisko 2004: 293.*Udeina* Michaelsen, 1910 [applied for *Parachilota* species]; Ljungström 1969: 370.*Udeina* [partim]: Ljungström 1972: 100.

Diagnosis:

Male reproductive organs acanthodriline. Testes and male funnels in proandric arrangement. Excretory system holoic, avesciculate. Seminal vesicles paired; in 9 and 11, or in 9, 11 and 12, variably developed, sometimes posterior pair much reduced. Two pairs of spermathecae, variably shaped, with unilobate, bilobate or multilobate diverticulum. Gizzard in 5 or 6, well developed, moderately developed, rudimentary or reduced. Last pair of lateral hearts in 12 or 13. Prostatic pores 2 pairs, not approximate towards the mid-ventral line, or situated close to the mid-ventral line, each pair on 17 and 19, or 18 and 20. Male pores 1 pair on 18 or 19. Spermathecal pores paired; in intersegmental furrows 7/8 and 8/9, or at the anterior borders of segments 8 and 9.

Species included: Sixty-seven species, endemic to South Africa.

UNILOBATE species-group

***Parachilota abebaios* sp. n.**

Figs 1–3

Etymology: From Greek *abebaios* (uncertain); refers to the unusual position of the seminal vesicles.

Diagnosis: Spermathecal pores in intersegmental furrows 7/8 and 8/9. Clitellum saddle-shaped, on 13–17. Prostatic pores not approximate towards the mid-ventral line, each pair in 17 and 19. Male pores in 18. Gizzard in 5, well developed. Commencement of intestine in 16. Last pair of lateral hearts in 13. Three pairs of seminal vesicles; in 9, 11, 12. Spermathecae with unilobate diverticulum attached to spermathecal duct at its basal part.

Description:

External features: Body cylindrical. *Colour*: In life violet dorsally, ventrally brownish grey; in alcohol-preserved specimens dorsal violet pigmentation fading, marking only thin strip on preclitellar segments. *Dimensions*: holotype 95×4 mm. *Segment number*: Holotype 155. *Prostomium*: Tanylobous with faint sutures. *Setae*: Distantly paired; on postclitellar segments $aa > ab$; $ab < cd$; $bc < cd$; distance between ab decreasing on 12–17, increasing on 19–26. *Dorsal pores*: Not observed. *Nephridial pores*: Not observed. *Spermathecal pores*: Paired; in intersegmental furrows 7/8 and 8/9, in front of b . *Female pores*: Paired, in 14 between aa . *Clitellum* (Fig. 1): Saddle-shaped, whitish grey, on 1/n13–17; clitellar anterior and posterior borders indistinct; ventrally extending slightly below c setal lines. *Prostatic pores*: Paired in 17 and 19, in swellings encircling b setae. *Male pores*: Paired, in 18, small vertical openings ventrally to b setae. *Seminal grooves*: Slightly curved. *Papillae*: Prominent oval swellings single or paired, at a setae, on 8–10.

Internal characters: *Salivary glands*: Do not extend backwards beyond septum 4/5. *Gizzard*: In 5, well developed, cylindrical, muscular. *Septa*: 5/6 thin but strong; 6/7–

11/12 increasing in thickness, with 10/11 and 11/12 most thickened; 12/13 and following thin. *Intestine*: Commences abruptly in 16, with oesophagus enlarged in 13, followed by longitudinal ridged valves in 14–15. *Lateral hearts*: In 9–13 with last pair in 13 much enlarged. *Nephridia*: Holoic, avesciculate. *Ovaries*: Not observed. *Testes* and *male funnels*: Ventrally in 10; funnels large, free, iridescent. *Vasa deferentia*: Thick single ducts run from 10 to 18. *Seminal vesicles*: 3 pairs; in 9, 11 and 12; anterior pair small, commencing at septum 9/10 ventrolaterally; second pair commencing at 10/11, in 11, moderate; posterior pair commencing dorsolaterally at 11/12 largest, lobulated, tufted. *Spermathecae* (Fig. 2): Paired; in 8 and 9; ampulla oval, small, 2.5 mm long; duct elongated, 4.5 mm long, 1.4 mm wide at its ental part; unilobate, small diverticulum 1.8 mm long, attaching to duct at its basal part, then narrows its width to nearly 0.7 mm. Iridescent sperm observed in diverticulum, and in spermathecal duct at its joint with ampulla. Ectal parts of spermathecal ducts enter body wall near septa 7/8 and 8/9. *Prostates*: Paired, tubular, multifolded, looped. Prostatic duct commences as muscular straight tube, extending into thin, tubular, looped and slightly coiled prostatic gland. Anterior pair confined to 17; posterior pair extends backwards, conically pushing septa 19/20–22/23 into space of three segments. Ectal parts of prostatic ducts enter body wall in 17 and 19 respectively. *Penial setae* (Fig. 3): *a* and *b* similar, not fully mature. *Penial setal retractor muscles*: Commence intersegmentally in 17/18 and 19/20.

Holotype: NMSA/Olig.01851, *Mpumalanga*: 17 km N of Amsterdam (26°37'S:30°40'E), on bank of small stream, in wet soil between roots of various plants, 5.xii.1992, JDP & BRS.

Distribution: *P. abebaios* is known only from the type locality in the north-eastern Drakensberg escarpment, Mpumalanga (the area earlier known as the Eastern Transvaal). The species occurs together with *P. timothyi* sp. n.

Biological notes: The large, mature, well-developed individual was collected in summer, during the rainy season. Iridescence observed in the male funnels and diverticula confirms sexual activity.

Discussion: *P. abebaios* is a distinct species with 3 well-developed pairs of seminal vesicles in 9, 11 and 12, the character first noted in this genus. It was observed (Pickford 1937) that in proandric *Parachilota* species, in which a reduction of posterior pair of testes took place, the seminal vesicles became reduced to two, having sometimes only a rudimentary posterior pair in 12 as was noted in *P. stephensonianus* Pickford, 1937. *P. abebaios* is also characterized by a distinctive shape of spermathecae with extended spermathecal duct and unilobate diverticulum.

Parachilota hottentotianus Pickford, 1937

Fig. 4

Parachilota hottentotianus: Pickford 1937: 410–412.

Material examined: *Western Cape*: NMSA/Olig.02002, Hottentots Holland Nat. Res., hiking trail opposite Landroskloof (34°02'S:18°59'E), eastern slope of mountain at ca 1350 m, on walking path on rainy day, 7.ix.1994, W.F. Sirgel; SAMC A21572 (holotype) and SAMC A21573 (paratype), Landrost Neck, at ca 1220 m, Hottentots Holland Mtns, Caledon side [34°16'S:19°25'E], i.1916, K.H. Barnard.

Distribution: The present record confirms the endemic occurrence of this species in the eastern part of the Hottentots Holland Mountains, extending the known range of the species slightly beyond the earlier noted site near Caledon.

Biological notes: New material was found in early spring, after a few rainy days, on the surface of a soaked pathway, together with the microchaetid *Kazimierzus sirgeli* (Plisko, 1996). The penial setae and spermathecae are in early development, and no sperm was observed in small diverticula, suggesting that the specimen was at the early sexual phase, although prostates were well developed, each confined to one segment (Fig. 4).

Comments: New material, although being not fully mature, with only slightly marked clitellum, matches the description of this species. The unilobate spermathecae and distal end of penial setae resemble these drawn by Pickford (1937), and match characters observed in the type material.

***Parachilota ncandu* sp. n.**

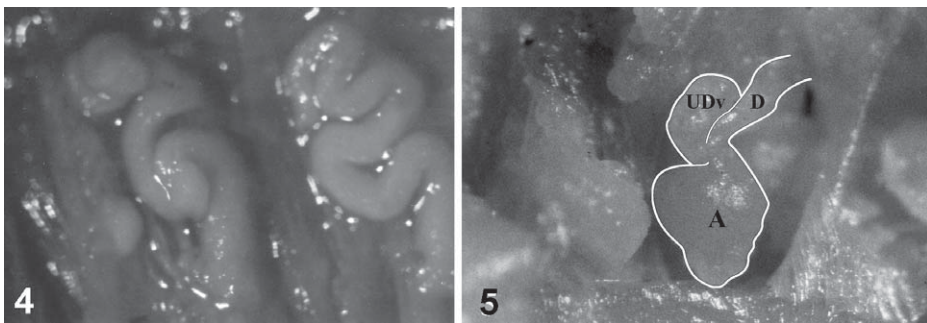
Fig. 5

Etymology: Named after the type locality Ncandu Nature Reserve.

Diagnosis: Spermathecal pores in intersegmental furrows 7/8 and 8/9. Clitellum saddle-shaped on 13, 1/n13–1/n17, 17. Prostatic pores not approximate towards the mid-ventral line, in 17 and 19. Male pores in 18. Gizzard in 5, developed moderately. Last pair of lateral hearts in 12. Commencement of intestine in 17. Spermathecae with duct curved at its middle part, and with unilobate diverticulum attached dorsally to spermathecal duct between its bowed part and link with ampulla.

Description:

External features: Body cylindrical; preserved material slightly softened and extended. *Colour*: Alcohol-preserved specimens yellowish brown or yellowish grey, with irregular, small patches of pigmentation. *Dimensions*: holotype 52×2 mm; paratypes 38–55×2–2.5 mm. *Segment number*: Holotype 112; paratypes 117–125. *Prostomium*: Epilobous; tongue open or with small transverse furrow in line with anterior edge of first segment. *Setae*: Distantly paired; on postclitellar segments $aa < bc$; $ab < cd$; $2ab$ nearly equal to aa . *Dorsal pores*: Not observed. *Nephridial pores*: Not observed. *Spermathecal pores*: Paired; in intersegmental furrows 7/8 and 8/9, in front of b , with small swellings around. *Female pores*: Externally not observed. *Clitellum*: Whitish yellow, or orange, on 13, 1/n13–1/n17, 17; saddle-shaped, broaden laterally to b or a setal lines; on some individuals clitellar tissues widen to nearly median line, although not encircling whole body; anterior



Figs 4, 5. (4) *Parachilota hottentotianus* Pickford, 1937, prostatic glands, 500×; (5) *P. ncandu* sp. n., holotype, spermatheca of segment 9, 400×. Abbreviations: A – ampulla, D – spermathecal duct, UDv – unilobate diverticulum.

and posterior clitellar borders obvious; ventral edges faint or evident, depending on individual state maturity. *Prostatic pores*: Paired, in 17 and 19, with small swellings encircling pores extending to *b* setae, occasionally widen to *a* setae. *Male pores*: Paired, in 18, small openings below *b* setae. *Seminal grooves*: Slightly curved. *Papillae*: Minute, single or paired, oval depressions on 16 and 17.

Internal characters: *Salivary glands*: Not extending backwards beyond septum 4/5. *Gizzard*: In 5, well developed; variations in gizzard muscular strength observed, what probably depends on individual maturity. *Septa*: All septa very delicate, thin; however in some mature individuals septa 6/7–10/11 slightly thicker than anterior; septum 16/17 extremely thin. *Intestine*: Commences in 17; preceded by oesophageal folds in segments 13–15; thin valve in 16 or only in part of 16. *Lateral hearts*: Last pair in 12. *Nephridia*: Holoic; thin, elongated coiled loops extending vertically; with no terminal vesicles. *Ovaries*: In 13, bushy, moderate, ventrally. *Testes* and *male funnels*: Ventrally in 10; male funnels large, iridescent; clotted sperm attached to lateral parts of funnels observed in few specimens. *Vasa deferentia*: Not observed due to thin body wall. *Seminal vesicles*: 2 pairs; in 9 and 11; anterior pair commencing at septum 9/10, oval sacs; posterior pair commencing at septum 10/11 and forming 3–5 folded sacs extends dorsolaterally in 11. *Spermathecae* (Fig. 5): Paired; in 8 and 9; ampulla globular, 1.3 mm long; duct 1 mm long, curved at its middle part; unilobate diverticulum attached dorsally to spermathecal duct between its bowed part and connection with ampulla; chambered. In some mature individuals sperm fill only basal region of diverticulum. In others, sperm was observed in diverticulum and in small parts of duct, but not in ampulla. Ectal parts of spermathecal ducts enter body wall at 7/8 and 8/9. *Prostates*: 2 pairs; in 17 and 19. Prostatic glands of anterior pair extend backwards by pushing conically septum 17/18 into segment 18; prostatic duct, slightly coiled, remains in ventral part of segment 17. Prostatic glands of posterior pair, extend through segments 19–20, 21, 22; prostatic ducts much thinner than prostatic glands, slightly coiled dorsolaterally, confined to only lateral part of segment 19. Ectal parts of prostatic ducts enter body wall in 17 and 19. Both prostatic glands may be observed externally through translucent body wall. *Penial setae*: *ab* of 17 and 19 transferred into penial setae; both similar, not ornamented, curved at their middle parts, with ectal end bent in opposite direction of seta curvature. *Penial setal retractor muscles*: Commence near septa 17/18 and 19/20.

Holotype: *KwaZulu-Natal*: NMSA/Olig.02364, Ncandu Nat. Res. (27°53'30"S:29°42'30"E), ca 1830 m, grassland plateau above Ulumbi R., under moist moss covering large rocks, 29.i.1996, JDP.

Paratypes: NMSA/Olig.03665, 13 in different states of maturity collected with holotype. NMSA/Olig.02345, 5 semi-mature, in wet, sandy soil, 30.i.1996. NMSA/Olig.02361, 16 in various states of maturity, collected between roots of diverse plants on bank of Ulumbi R., 31.i.1996 (associated with *Parachilota timothyi* sp. n.). All sites close to *locus typicus*, JDP.

Other material examined: NMSA/Olig.02342, 8 cl; NMSA/Olig.2358, 2 cl; NMSA/Olig.02359, 9 cl; NMSA/Olig.02360, 19 in different states of maturity. All found in area surrounding the type locality, in moist sandy soil, between or under various plant roots, in grassland, and on moist rocks with overspilling water, 29.i.1996. All material collected by JDP.

The species grouped by Pickford (1937) in the *P. erythrocephalus* species-group that was suspected to be similar to *P. ncandu* were also studied, but found to be different: *KwaZulu-Natal*: NMSA/Olig.00272 (paratype of *P. warreni* (Michaelsen, 1913)), SAMC A21620 (paratype of *P. nanus* Pickford, 1937). *Western Cape*: SAMC A21594 (paratype of *P. erythrocephalus* Pickford, 1937), SAMC A21584 (paratype of *P. bainellus* Pickford, 1937).

Distribution: Known from the type locality and its neighbourhood, in the Drakensberg Mountains in north-western KZN.

Biological notes: The Ncandu Nat. Res., earlier known as Incandu Forest Reserve and recently placed under the protection of Ezemvelo KZN Wildlife, is situated on the border of KZN and the Orange Free State. It extends to the Drakensberg northern escarpment, south-west of Newcastle (27°42'S:29°59'E). The area where the species was abundant extends over the indigenous grassland plateau along the Ulumbi R. at 1830 m above sea level. A large part of the plateau covered by indigenous grassland extends below the river with several small pockets of indigenous bushes, and continues on the other side of the river. *P. ncandu* was found in grassland moist soil, on the river bank, under stones, and under mosses covering large rocks with flowing surface water. A large species population at different states of development occurred in the grassland and forested areas. Iridescence observed in male funnels and in spermathecal diverticula suggests a summer phase of sexual activity. *P. ncandu* was collected together with *P. timothyi* sp. n. and the microchaetid *Proandricus bourquini* Plisko, 1996.

Discussion: The commencement of the intestine in segment 17 and the location of the lateral heart in 12, features observed in *P. ncandu* and *P. erythrocephalus* Pickford, 1937, might suggest species relationships. However, the shape of the spermathecal diverticulum and penial setae differ substantially in both species, and a relationship between these two species cannot be confirmed. Considering the geographical distance separating the species, it may rather be suspected that these characters have evolved independently, with parallel differentiation of the spermathecal diverticulum and penial setae. The species accredited by Pickford (1937) to the *P. erythrocephalus* species-group, *P. traegardhi* (Michaelsen, 1907), *P. warreni* (Michaelsen, 1913), and *P. nanus* Pickford, 1937, known from KZN differ from *P. ncandu* in the specificity of the spermathecal diverticulum and also in other features. *P. bainellus*, *P. ruficeps* and *P. adolphus*, described by Pickford (1937) and placed in the *erythrocephalus* species-group, are recorded from the Western Cape and differ in the complexity of their morphological characters.

***Parachilota timothyi* sp. n.**

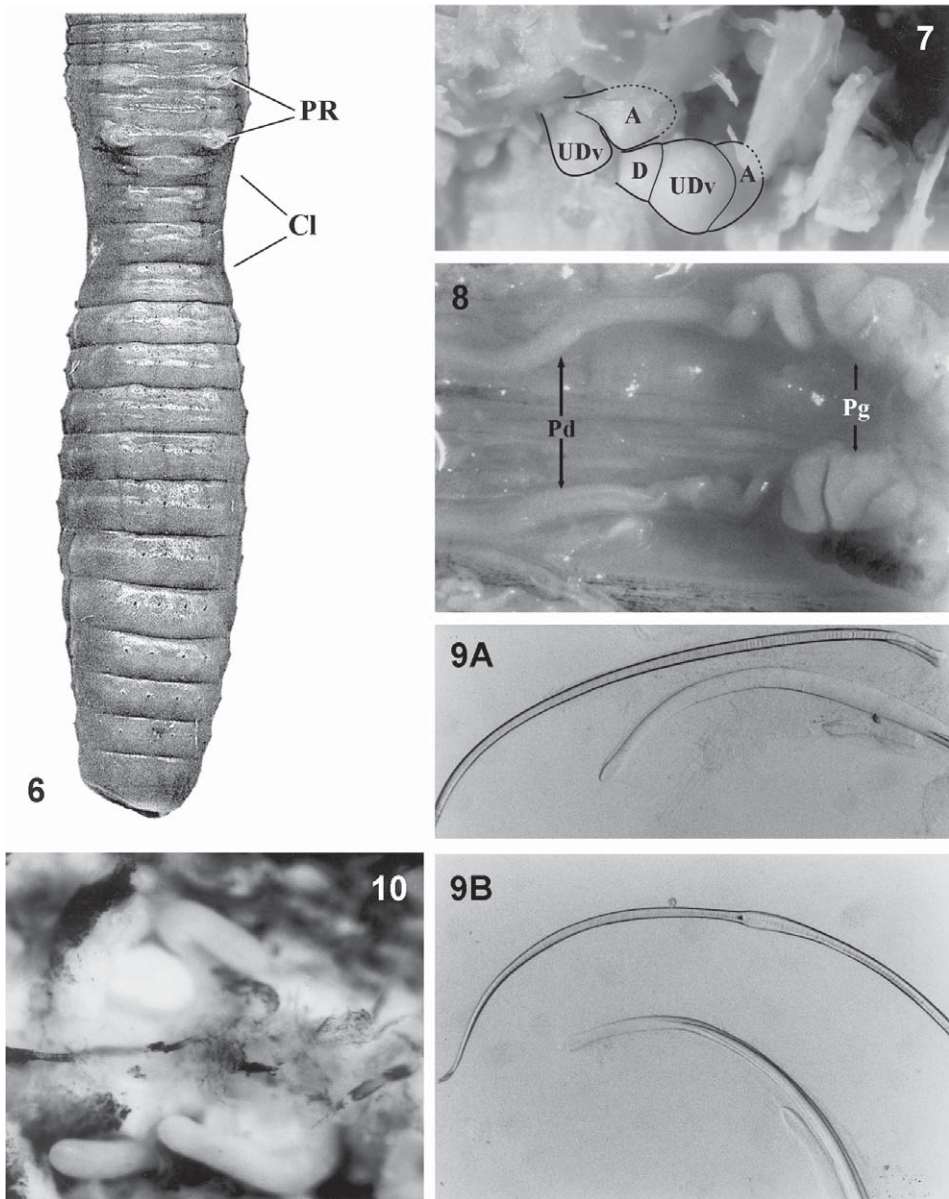
Figs 6–9

Etymology: Named after Mr Timothy Liversage, who assisted with collection of the type series.

Diagnosis: Spermathecal pores in intersegmental furrows 7/8 and 8/9. Clitellum saddle-shaped on 13, 14–1/n17, 17. Male pores in 18. Prostatic pores not approximate towards the mid-ventral line, in 17 and 19. Gizzard in 5, well developed. Commencement of intestine in 16. Last pair of lateral hearts in 13. Seminal vesicles paired, in 9 and 11. Spermatheca with unilobate diverticulum attached to basal part of spermathecal duct, extending to joint duct/ampulla and invagination of ampulla.

Description:

External features: Body cylindrical, firm. *Colour*: In life dorsally violet, ventrally brownish grey; alcohol-preserved dorsally violet, extending violet colouration laterally to *c* setal lines, with dark tint on preclitellar and few last posterior segments. Colour fading after extended preservation. *Dimensions*: Holotype 140×7 mm; clitellate paratypes 120–137×6–7 mm; juvenile 30–72 mm. *Segment number*: Holotype 153; clitellate paratypes 163–210; juvenile 109–220. *Prostomium*: Tanylobous with obvious sutures. *Setae*: Paired; on postclitellar segments *aa:ab:bc:cd* = 3.5:1.8:4:2; distance between *ab*



Figs 6–10. *Parachilota* species with unilobate diverticulum: (6–9) *P. timothyi* sp. n., holotype: (6) anterior part of body, ventrally, 40×; (7) spermathecae of segment 8 and 9, 400×; (8) prostates of 17 and 19, 370×; (9) genital setae of 17 (*a* seta, 9A) and 19 (*b* seta, 9B), 500×; (10) *P. wahlbergi* (Michaelson, 1899), spermathecae, 500×. Abbreviations: A – ampulla, Cl – clitellum, D – spermathecal duct, Pd – prostatic duct, Pg – prostatic gland, PR – prostatic pores of 17 and 19, Udv – unilobate diverticulum.

decreasing on 12–17, increasing on 19–27; this characters clearly observed also on juvenile specimens. *Dorsal pores*: Not observed. *Nephridial pores*: Not observed on holotype, although on some individuals noted occasionally in postclitellar intersegmental furrows, in *c* setal lines. *Spermathecal pores*: Paired; in 7/8 and 8/9, in front of *b*. *Female pores*: Paired, in 14 between *aa*. *Clitellum* (Fig. 6): Saddle-shaped, whitish yellow, on 13,14–1/n17,17; anterior borders obvious, posterior faint, ventrally extending to *b* setal lines. *Prostatic pores*: Paired in 17 and 19, on prominent swellings encircling *b* setae. *Male pores*: Paired, in 18, small vertical openings ventrally to *b* setae. *Seminal grooves*: Straight or slightly curved. *Papillae*: Prominent swellings, oval, single or paired, in *a* setae line, variably on some segments: 8, 10, 16–20, 21, 20–24.

Internal characters: *Salivary glands*: Do not extend backwards beyond septum 4/5. *Gizzard*: In 5, well developed, cylindrical, muscular. *Septa*: 5/6 and 6/7 little thickened; 7/8–10/11 increasing in thickness with 10/11 most thickened; 11/12–15/16 decreasing thickness, becoming less muscular, although strong; some variations in thickness intensity observed, but thickening always obvious in 7/8–15/16. *Intestine*: Commences abruptly in 16 or in the middle of 16; oesophageal longitudinal ridged valves in 14–15. *Lateral hearts*: In 9–13, first pair very thin vessel; last pair in 13 much enlarged. *Nephridia*: Holoic; thin, elongated coiled loops extend vertically, with no terminal vesicles. *Ovaries*: Not observed. *Testes* and *male funnels*: Ventrally in 10; funnels large, free, iridescent. *Vasa deferentia*: Not observed. *Seminal vesicles*: Paired, in 9 and 11; anterior pair small, commencing at septum 9/10 ventrolaterally, little lobulated; posterior pair commencing dorsolaterally at septum 10/11 large, brownish, much lobulated. *Spermathecae* (Fig. 7): Paired; in 8 and 9; ampulla smooth, 2 mm long and nearly 2 mm wide, with external indentation at link with spermathecal duct; duct 1 mm long; unilobate diverticulum commencing at basal part of spermathecal duct, extending to joint duct/ampulla locates its global ental part in ampulla's external dent. Iridescent sperm was observed in ental part of diverticulum. Ectal parts of spermathecal ducts enter body wall at 7/8 and 8/9. *Prostates* (Fig. 8): Paired, in 17 and 19. Prostatic duct commences as thin, soft tube, extending into thicker, muscular, folded, lobulate gland, confined to one segment; prostatic gland sometimes extends backwards, conically pushing septum into space of neighbouring segment. Ectal parts of prostatic ducts enter body wall in 17 and 19. *Penial setae* (Fig. 9): *a* and *b* transferred into penial setae; 5–6 mm long, slender; steam straight, curved at distal end. Variable in shape and size in individuals collected in the same locality. *Penial setal retractor muscles*: Commence intersegmentally in 17/18 and 19/20.

Holotype: *Mpumalanga*: NMSA/Olig.02204, 17 km N of Volksrust (27°22'S:29°53'E), right side at crossroad to Sandspruit, recently burnt grass, moist black soil, ca 25 cm deep between roots of various plants, 5.xii.1995, JDP & T. Liversage.

Paratypes: NMSA/Olig.03639, 10 cl, and NMSA/Olig.03640, 6 semi-mature, collected with holotype. *KwaZulu-Natal*: NMSA/Olig.02354, Ncandu Nat. Res. (27°53'30"S:29°42'30"E), ca 1830 m, grassland plateau along Ulumbi R., riverine bush mixed with exotic and indigenous trees, moist, rich soil, between roots of diverse plants, 31.i.1996, 2 cl & 20 in different states of maturity, JDP [specimens collected in close vicinity of *P. nkandu* sp. n.].

Other material examined: *Mpumalanga*: NMSA/Olig.01835, 3 juv, 32 km W of Volksrust, on bank of Skulspruit R., under willow tree (*Salix* sp.), marshy, wet soil, 3.xii.1992, JDP & BRS [indigenous microchaetid *Tritogenia palusicola* Plisko, 1997, exotic lumbricid *Aporrectodea rosea* (Savigny, 1826), *Aporrectodea trapezoides* (Dugès, 1828), and megascolecid *Amyntas* sp. collected in the same sample]. *KwaZulu-Natal*: Ncandu Nat. Res. grassland plateau around Ulumbi R., at ca 1830 m: NMSA/Olig.02353, 4 cl & 16 juv, below bank of Ulumbi R., in indigenous riverine bush, moist, rich soil, 30.i.1996; NMSA/Olig.02341, 14 cl, grassland plateau, on rocks covered by wet moss, under various plant roots, 29.i.1996; NMSA/Olig.02344,

15 cl & 11 juv, grassland, moist, sandy soil, 30.i.1996; NMSA/Olig.02346, 4 cl + 2 juv, and NMSA/Olig.02347, 3 juv, river bank, in wet sandy soil, 30.i.1996 [with exotic lumbricids *Octolasion lacteum* (Örley, 1881) and *Dendrodrilus rubidus* (Savigny, 1826)]; NMSA/Olig.02355 & NMSA/Olig.02356, 2 cl, wet sites, grassland near the river, 29.i.1996 [with endemic microchaetid *Proandricus bourquini* Plisko, 1996]. All material collected by JDP.

Comparative material of *Parachilota wittebergensis* Pickford, 1937 examined: *Eastern Cape*: SAMCA21616, Witteberg Mtns, Avoca farm, on bank of stream, damp soil, 1 cl, 3.v.1928, E.G. Pickford.

Distribution: Known from the outskirt of the Drakensberg Escarpment in the north-western part of KZN, and in Mpumalanga.

Biological notes: The species occurs in grassland and forest soil, on river banks, and near roads. Abundant in Ncandu Nat. Res. grassland plateau around the Ulumbi R., at ca 1830 m in moist soil, and between various plant roots on the river bank, in indigenous riverine bush, and on scattered grassland plateau rocks covered by moist moss watered by flowing water. The new species occurs together with the indigenous acanthodriline *Parachilota ncandu* sp. n., the microchaetids *Proandricus bourquini* Plisko, 1996 and *Tritogenia palusicola* Plisko, 1997, and with the exotic lumbricids *Aporrectodea rosea* (Savigny, 1826), *Aporrectodea trapezoides* (Dugès, 1828), *Octolasion lacteum* (Örley, 1881), *Dendrodrilus rubidus* (Savigny, 1826), and megascolecid *Amyntas* sp.

Discussion: *P. timothyi*, having the last pair of lateral hearts in 13 and the intestine commencing in 16, may be related to *P. wittebergensis* Pickford, 1937, known from Witteberg Mountains and Mont-aux-Sources, both sites located south of the occurrence of the new species, in the Drakensberg Mountains. The species differ in the shape of the spermathecae, which are bilobate in *wittebergensis*, attached to anterior face of spermathecal duct, while in *timothyi* the unilobate diverticulum is at the base of the duct, extending to the junction with the ampulla.

Parachilota wahlbergi (Michaelsen, 1899)

Fig. 10

Chilota wahlbergi: Michaelsen 1899: 441; 1900: 147; 1912: 146.

Chilota wahlbergi f. *typicus*: Michaelsen 1913a: 416.

Chilota wahlbergi n. f. *pulchior* Michaelsen, 1913a: 416; Pickford 1937: 461.

Parachilota wahlbergi (Michaelsen): Pickford 1937: 336.

Material examined: *KwaZulu-Natal*: NMSA/Olig.03650, 1 cl, farm Linwood [vicinity of Midmar Dam, 29°31'S:30°11'E], in temporary pool during dry phase, under moist rock, 27.ix.2002, R. Pott.

Biological notes and distribution: Pickford (1937), who summarized collection data published by Michaelsen (1899, 1900, 1913a) and the sites of the material studied by herself, accepted a broad occurrence of this species in north-eastern South Africa. It was known that the species was collected in moist or semi-moist localities, and in the neighbourhood of waterfalls, in KwaZulu-Natal, Gauteng, Mpumalanga and Limpopo. She also observed that some of the individuals from Krugersdorp area in Gauteng discharged a phosphorescent fluid. During my extended study on acanthodrilinae in South Africa, only one specimen of *wahlbergi*, the presently studied one, was collected in KZN in a small drying out artificial pool, in the neighbourhood of a man-made lake where environmental changes are taking place. It is possible that this species may be on the way to extinction as a result of anthropogenic environmental changes. The studied specimen was donated alive to the Natal Museum, and no phosphorescence was observed before and during preservation.

Comments: The new material matches descriptions of the type material (Michaelsen 1899, 1900) extended by additional data by Michaelsen (1913a) and Pickford (1937). Pickford (1937), concluding that in this species the degree of pigmentation is not a satisfactory taxonomic feature, noted body colouration fading after a few years of preservation and accounted Michaelsen's distinction of *wahlbergi* f. *pulchior* on the base of pigmentation not valid, and synonymised it with f. *typicus*. The currently examined specimen was violet pigmented dorsally in life, this colour extending to the middle of the body, and kept its tint for a short time in alcohol before the colour faded. The spermathecal ampulla is oval, slightly enlarged at its ental part. The diverticulum (Fig. 10) is unilobate, tubular, almost twice as long as ampulla. The anterior pair of the prostatic glands stretches through four segments, the posterior pair extending backwards through five segments. No penial setae were observed in the studied specimen.

BILOBATE species-group

Parachilota editha (Pickford, 1927)

Chilota editha: Pickford 1927: 452.

Parachilota editha (Pickford): Pickford 1937: 330; Zicsi 1998: 66.

Material studied: *KwaZulu-Natal*: NMSA/Olig.01874, 2 cl, Drakensberg, Giant Castle (29°20'S:29°27'E), *Protea* field, grassland, 9.iii.1993, JDP & BRS.

Biological notes and distribution: The species was described from a single specimen from the Eastern Cape, found in the graveyard area in the neighbourhood of Stutterheim [32°32'S:27°29'E], and Pickford suspected its accidental transportation from the Drakensberg foothills. Zicsi (1998) reported this species from the Karkloof Nat. Res. (29°18'S:30°13'E) in KZN. The present record from Giant's Castle supports Pickford's supposition that the species occurs in a broader area of the Drakensberg Mountains.

Comments: The new material matches the species description (Pickford 1927) and its re-description (Pickford 1937). However, on the drawing made by Pickford (1937: fig. 279) a diverticulum is presented as one lobe extended over the spermathecal duct, with no middle division. In currently studied material the spermathecal diverticulum is bilobate, with a groove in the middle of the diverticulum face, a character not previously noted. The ornamentation of the penial setae indicated in the re-description (Pickford 1937) was not observed in new material.

Parachilota karkloofi Zicsi, 1998

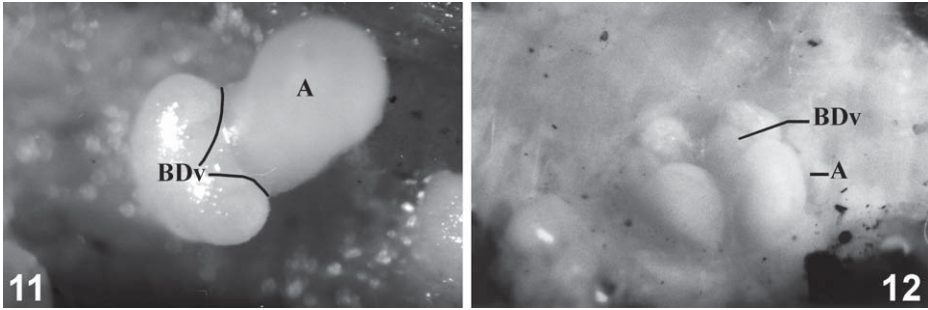
Fig. 11

Parachilota karkloofi: Zicsi 1998: 65.

Type material examined: *KwaZulu-Natal*: Holotype NMSA/Olig.00246, Karkloof Nat. Res. (29°18'S:30°13'E), at ca 1260 m, high part of mixed *Podocarpus* forest edge, in litter and first layer of soil, 22.ii.1989, JDP & BRS. Paratype NMSA/Olig.00246a, collected with holotype.

Distribution: This species is known only from the type locality in KZN. An assessment of its range must await the discovery of additional material.

Comments: The present study of the type material housed at the Natal Museum (Plisko 2006) allows this species to be assigned to the bilobate species-group. The spermathecal ampulla is ovoid, duct elongated with two separated, slightly chambered lobes (Fig. 11).



Figs 11, 12. Spermathecae of *Parachilota* species with bilobate diverticulum: (11) *P. karkloofi* Zicsi, 1998, holotype, 400 \times ; (12) *P. minimus* Zicsi & Pajor, 1992, 500 \times . Abbreviations: A – ampulla, BDv – bilobate diverticulum.

Parachilota minimus Zicsi & Pajor, 1992

Fig. 12

Parachilota minimus: Zicsi & Pajor 1992: 133.

Material studied: *KwaZulu-Natal*: NMSA/Olig.03817, 1 cl, Drakensberg, Cathedral Peak (28°45'S:29°05'E), at ca 1500 m, 13.xii.1991, A. Zicsi & I. Pajor; NMSA/Olig.02186, 1 cl, & NMSA/Olig.2191, 3 cl, Ngele Forest (30°35'S:29°41'E), moist litter & first 20 cm black, moist soil, 23–24.xi.1995, JDP & BRS.

Distribution: The species was reported by Zicsi and Pajor (1992) from the Cathedral Peak area, including the Ndumeni Forest, Doreen Falls, and the vicinity of the hotel buildings, all in the eastern Drakensberg Mountains. Present records extend the known range to Drakensberg foothills in southern KZN.

Comments: The studied material matches the description of the species (Zicsi & Pajor 1992). The species is characterized by a bilobate spermathecal diverticulum, clearly divided by a narrow furrow (Fig. 12). The ornamentation of the penial setae is similar to that shown in the type description, although it was observed only under 500 \times magnification.

MULTILOBATE species-group

***Parachilota uysae* sp. n.**

Fig. 13

Etymology: Named after Mrs C. Uys, who collected the type series.

Diagnosis: Spermathecal pores in intersegmental furrows 7/8 and 8/9. Clitellum ring-shaped on 13–17. Prostatic pores not approximate towards the mid-ventral line, in 17 and 19. Male pores in 18. Gizzard in 5, moderately developed. Commencement of intestine in 16. Last pair of lateral hearts in 12. Spermathecal multilobate diverticulum with three lobes attached to spermathecal duct at its basal part.

Description:

External features: Body cylindrical. Alcohol-preserved over three years: on preclitellar segments dorsally violet reddish, postclitellarly and ventrally yellowish grey. *Dimensions*: Holotype 45 \times 3 mm; paratypes 30 \times 2 mm. *Segment number*: Holotype 85, paratype 112. *Prostomium*: Tanylobous, tong wide with conspicuous sutures. *Setae*: Widely paired; postclitellarly $aa < bc$; $ab < cd$; $bc > cd$. *Dorsal pores*: Not observed.

Nephridial pores: Not observed. *Spermathecal pores*: Paired, in 7/8 and 8/9, in front of *b* setae. *Female pores*: In 14, between *aa* setae. *Clitellum*: On 13–17, ring-shaped; encircling segments equally. *Prostatic pores*: Paired, not approximated towards mid-ventral line, in 17 and 19, between *ab* setae; each pore with small encircling swelling. *Male pores*: In 18, small openings close to *b* setae. *Seminal grooves*: Curved. *Papillae*: Not observed.

Internal characters: *Salivary glands*: Do not extend beyond 4/5. *Gizzard*: In 5, moderate in size. *Septa*: Anterior thin, not muscular; 8/9–13/14 slightly thickened. *Intestine*: Preceded by thin folds in 15 commences abruptly in 16. *Lateral hearts*: Last pair in 12. *Nephridia*: Holoic; elongated coiled loops without terminal vesicles. *Ovaries*: Not observed. *Testes and male funnels*: Ventrally in 10; male funnels free, iridescent. *Vasa deferentia*: Not observed. *Seminal vesicles*: 2 pairs; in 9 and 11; anterior pair commencing at 9/10, smaller than posterior; posterior commencing ventrolaterally at 10/11 extends dorsolaterally; both irregularly shaped. *Spermathecae* (Fig. 13): Paired, in 8 and 9. Ampulla elongated-ovoid, smooth, empty; spermathecal duct, wide, extended. Diverticulum at basal part of duct with three chambered lobes: one middle lobe and two lateral lobes rounded, iridescent. Ectal parts of spermathecal ducts enter body wall near intersegmental furrows 7/8 and 8/9. *Prostates*: 2 pairs; in 17 and 19. Duct short, thin, confined to ventral part of one segment. Prostatic gland multi-looped extending dorso-laterally. *Penial setae*: Setae of 17 and 19 transferred into similar penial setae, although not fully mature. *Penial setal retractor muscles*: Commence at intersection of 17/18 and 18/19.

Comparison: The species has multilobate diverticula, similar to *P. warreni* (Michaelsen, 1913). The two species differ in the shape of the spermathecae and in the starting position of the intestine, which is in segment 16 in *P. uysae* and segment 17 in *P. warreni*.

Holotype: *KwaZulu-Natal*: NMSA/Olig.03916, uKahlamba-Drakensberg Park World Heritage, Injasuthi (29°06'35.4"S:29°26'20.7"E), van Hennings Pass Forest, at 1604 m, down steep slope, 20 m from path, near muddy, rocky patch in leaf litter, after rain, 21.iii.2004, C. Uys.

Paratypes: NMSA/Olig.03917, 1 juv collected with holotype; NMSA/Olig.03918, 1 semi-mature, uKahlamba-Drakensberg Park World Heritage, Injasuthi (29°07'10.2"S:29°26'10.9"E), yellow-wood *Podocarpus* forest, at 1466 m, in big old knarled yellow-wood log. All collected by C. Uys.

Biological notes and distribution: The presence of sperm in male funnels and spermathecal diverticula indicates sexual activity during the summer, extending to early autumn. This species was collected during a study of invertebrate diversity in Afrotropical forests of the Drakensberg Mountains undertaken by C. Uys. The study area falls under the protection of Ezemvelo KZN Wildlife, although beforehand it was variably exploited by people (Pooley & Player 1995). Human impact on the environment has had many serious implications for the survival of the endemic fauna. Uys (2006) evaluated patches of indigenous forests as refuges for many indigenous invertebrates. Although only three specimens of *P. uysae* were found in the investigated protected area, in the close neighbourhood the acanthodriline *Udeina adriani* Plisko, 2004, the microchaetid *Proandricus injasuti* Plisko, 2002 and other species: *Dichogaster* sp. of Benhamiinae, megascolecid *Amyntas* sp., and exotic lumbricids *Apporrectodea rosea* (Savigny, 1826), *Dendrodrilus rubidus* (Savigny, 1826) were also found, confirming the value of protected indigenous areas. *P. uysae* is known only from its type locality in the foothills of the Drakensberg Mountains in central KZN.

Parachilota warreni (Michaelsen, 1913)

Fig. 14

Chilota warreni: Michaelsen 1913a: 411–414; Plisko 1991: 287 [correction of erroneous data given in Reynolds & Cook 1976].

Chilota (Parachilota) warreni [partim]: Reynolds & Cook 1976: 189 [erroneous data]; Plisko 1991: 287 [correction of erroneous data].

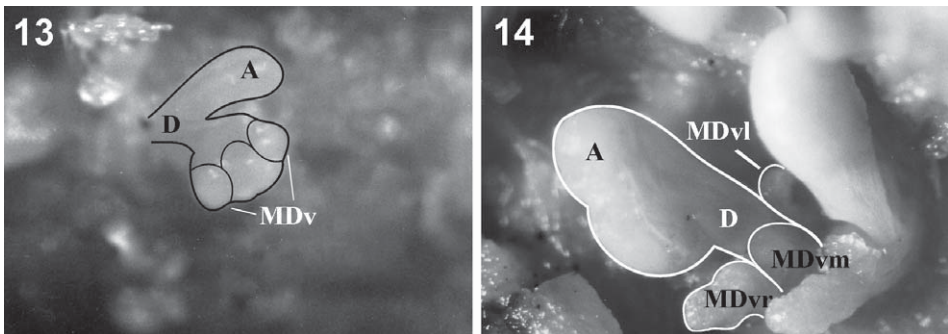
Parachilota warreni: Pickford 1937: 347–351; Zicsi 1998: 64 [partim].

Paratypes examined: *KwaZulu-Natal*: NMSA/Olig.00272 [old # MN 309], 1 cl, Drakensberg, Game Pass [29°22'S:29°37'E], vi.1912, H.C. Burnup; NMSA/Olig.00273 [old # MN 446], 1 cl, Howick [29°29'S:30°14'E], in detritus nr Umgeni Falls [= Howick Falls], 30.viii.1911, W. Michaelsen.

Other material examined: *KwaZulu-Natal*: SAMC A21627 (SAMC), 1 cl, Kranskop, K.C. Barnard, det. Pickford (1937); NMSA/Olig.03472, 1 cl & 2 juv, Karkloof Nat. Res. (29°17'58.419"S:30°12'32.347"E), A.J. Armstrong; NMSA/Olig.03955, 2 cl, Garden Castle (29°45'17.594"S:29°12'26.177"E), at 1960 m, N-slope in seepage area, grassland with *Themeda* grass, herbs & few shrubs, 1.iii.2005, A.J. Armstrong. *Eastern Cape*: NMSA/Olig.00582a, 3 cl, Hogsback (32°35'S:26°56'E), Auckland Forest, mixed riverine bush, from 1–15 cm saturated soil, 21.i.1990, JDP & BRS.

Comments: Michaelsen (1913a: 411) described this species as '*Chilota warreni* n. sp.' from numerous specimens collected in the neighbourhood of Pietermaritzburg and in the Drakensberg Mountains. A large part of the studied material was deposited in the ZMUH and some specimens in the BMNH. Two paratypes have been left in the NMSA, numbered MN 309 and MN 446, and are currently accessioned under the numbers NMSA/Olig.00272, and NMSA/Olig.00273 (Plisko 2006). In the same year Michaelsen (1913b: 547) described a microchaetid, giving the name '*Microchaetus warreni* n. sp.', depositing three type specimens in the ZMUH (#7765), and one paratype in the NMSA collection (present accession number NMSA/Olig.00271). For many years, the material of both species has not been examined, and this misled Reynolds and Cook (1976: 189) to state that *Microchaetus warreni* was a synonym of *Chilota (Parachilota) warreni*. Plisko (1991) has clarified the taxonomic status of both species.

P. warreni belongs to a group of species with spermathecal multilobate diverticula. The multilobes are attached to the front face of the spermathecal duct and are not fused posteriorly (Fig. 14). It is similar to *P. uysae*, but the species differ in the shape of the spermathecae and the commencement of the intestine.



Figs 13, 14. Spermathecae of *Parachilota* species with multilobate diverticulum, 500×: (13) *P. uysae* sp. n., holotype; (14) *P. warreni* (Michaelsen, 1913), spermathecae from ventral side of body. Abbreviations: A – ampulla, D – spermathecal duct, MDv – multilobate diverticulum, MDv1 – left part of multilobate diverticulum of anterior spermathecae, MDvm – medial part of multilobate diverticulum of posterior spermathecae, MDvr – right part of multilobate diverticulum of anterior spermathecae.

Biological notes and distribution: The species is known from distinct habitats, preferring moist or wet biotopes. It appears at distantly separated sites in the Drakensberg foothills in KZN, extending its range to the KZN midlands, and to Auckland Forest in the Eastern Cape. Although our knowledge of its distribution is still limited, it may be noted that its fragmented appearance is probably affected by anthropogenic changes to the environment.

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REFERENCES

- LJUNGSTRÖM, P.O. 1969. On the earthworm genus *Udeina* (Acanthodrilidae: Oligochaeta) in South Africa. *Zoologischer Anzeiger* **182**: 370–379.
- 1972. Taxonomic and ecological notes on the earthworm genus *Udeina* and a requiem for the South African acanthodrilines. *Pedobiologia* **12** (2) 100–110.
- MICHAELSEN, W. 1899. Revision der Kinberg'schen Oligochaeten-Typen. *Öfversigt af Kongliga Vetenskaps-Akademiens Förhandlingar* (Stockholm) **56** (5): 413–448.
- 1900. Oligochaeta. In: *Das Tierreich*. Lief. 10. Berlin: Verlag von Friedländer & Sohn, pp. 1–575.
- 1907. Oligochaeten von Natal und dem Zululand. *Arkiv für Zoologi* **4** (4) 1–12.
- 1910. Oligochäten von verschiedenen Gebieten. *Mitteilungen aus dem Naturhistorischen Museum in Hamburg* **27** (2): 1–169.
- 1912. Die terrestrischen Oligochaeten des tropischen Afrikas und ihre geographischen Beziehungen. *Wissenschaftliche Ergebnisse der Deutschen Zentral-Afrika Expedition 1907–1908*. Bd III, Zoologie 1. Leipzig: Klinkhart und Biermann, pp. 1–90.
- 1913a. The Oligochaeta of Natal and Zululand. *Annals of the Natal Museum* **2** (4): 394–457.
- 1913b. Oligochaeten des Kaplandes. *Zoologische Jahrbücher, Abteilung für Systematik* **34**: 473–556.
- PICKFORD, G.E. 1927. The Acanthodriline earthworms of South Africa east of the 25° meridian. *Records of the Albany Museum* **3** (5): 441–467.
- 1937. *A monograph of the Acanthodriline earthworms of South Africa*. Cambridge: W. Heffer & Sons Ltd.
- PLISKO, J.D. 1991. Redescription of some *Microchaetus* Rapp, 1849 species based on type material in the Natal Museum (Oligochaeta: Microchaetidae). *Annals of the Natal Museum* **32**: 279–292.
- 1996. Six new earthworm species of the southern African genus *Proandricus* Plisko, 1992 (Oligochaeta: Microchaetidae). *Annals of the Natal Museum* **37**: 295–307.
- 1997. New species of genus *Tritogenia* Kinberg, 1867 from southern Africa (Oligochaeta: Microchaetidae). *Annals of the Natal Museum* **38**: 241–281.
- 2004. Review of the balantine genus *Udeina* Michaelsen, 1910 with description of six new species in South Africa (Oligochaeta: Acanthodrilidae, Acanthodrilinae). *African Invertebrates* **45**: 287–313.
- 2006. The Oligochaeta type material housed at the Natal Museum, South Africa. *African Invertebrates* **47**: 57–61.

- 2007. New species of South African acanthodrilinae earthworms of the genera *Eodriloides* and *Chilota*, with a redescription of *Chilota quindecimus* (Oligochaeta: Acanthodrilidae). *African Invertebrates* **48** (2): 35–40.
- POOLEY, T. & PLAYER, I. 1995. *KwaZulu-Natal wildlife destinations*. Halfway House: Southern Book Publishers.
- REYNOLDS, J.W. & COOK, D.G. 1976. *Nomenclatura Oligochaetologica. A catalog of names, descriptions and type specimens of the Oligochaeta*. Ottawa: Runge Press.
- UYS, C.J. 2006. Invertebrate diversity in Afrotemperate forests: spatial and seasonal changes and implications for conservation. MSc Thesis. Pietermaritzburg: University of KwaZulu-Natal.
- ZICSI, A. 1998. Neue und seltene terrestrische Oligochaeten aus Südafrika. *Mitteilungen aus dem Naturhistorischen Museum in Hamburg* **95**: 59–77.
- ZICSI, A. & PAJOR, I. 1992. Über die Regenwürmer (Oligochaeta) in den Natal-Drakensbergen Südafrikas. *Opuscula Zoologica* **25**: 125–136.