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Description of two new species of *Zinophora* Chamberlin, 1927 (Diplopoda: Spirostreptida: Harpagophoridae), with discussion of species groups in the genus

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ABSTRACT

The millipede genus *Zinophora* (Chamberlin, 1927) was previously revised based on the species present south of the Zambezi and Kunene Rivers. Since that revision, two additional new species have been discovered and are here described: *Zinophora lobata* (Mozambique) and *Z. taromberai* (Zimbabwe and Tanzania). This brings the total number of described species in the genus to 21. An updated key to species in the genus is presented. Detailed illustrations of the gonopods supplement the descriptions and a distribution map of *Z. taromberai* in Zimbabwe is provided. There appear to be up to three species groups in the genus and the character states defining these groups are discussed.

KEY WORDS: Harpagophoridae, *Zinophora*, millipedes, Mozambique, Tanzania, Zimbabwe, new species.

INTRODUCTION

The millipede family Harpagophoridae is not only found in Africa, but also occurs in Southeast Asia and the East Indies (Hoffman 1993), and is probably the most characteristic and conspicuous element of the millipede fauna of that region (Hoffman 1975). The family is represented in Africa by the following genera: *Poratophilus* Silvestri, 1897 (two species); *Harpagophora* Attems, 1909 (six species); *Zinophora* Chamberlin, 1927 (21 species); *Apoctenophora* Hoffman & Howell, 1982 (four species), and *Metaphora* Redman, 2003 (one species).

The most widely distributed and speciose genus of Harpagophoridae in Africa is *Zinophora*, which ranges from the Western Cape (South Africa) and Namibia in the southwest, to Mozambique, Zimbabwe, Zambia, Malawi and Tanzania in the east. It is largely restricted to the savannah biome, but some species are adapted to rainforest conditions (Hoffman 1993) and others to the grassland biome (Redman & Hamer 2003). The genus currently includes 19 named species (Redman *et al.* 2003), of which 16 are from Africa south of the Zambezi and Kunene rivers. Two species groups were identified by Redman *et al*. (2003), the *munda* group and the *gracilus* group. It is anticipated that more millipede species will be discovered as more sampling is conducted (Mwabvu *et al*. 2007).

Issues relating to poor collecting effort are particularly relevant in the millipedes, and this is attested to by the discovery of the new species described in this paper. There is a need for a much stronger drive to document the biodiversity of southern Africa. Invertebrates perform essential ecosystem functions, yet they are largely overlooked in mainstream conservation planning (Huntly *et al*. 2005), largely as a consequence of generally poor taxonomic data. More data will certainly contribute to the inclusion of invertebrates in biodiversity conservation planning (Slotow & Hamer 2000). The

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challenge is to cover as much of the poorly sampled areas in Africa as possible to overcome collecting bias and, more importantly, to achieve this in the face of the current accelerated rate of development in Africa (Hamer & Slotow 2002).

The aim of this paper is to assess the taxonomic status of new material of *Zinophora* collected outside South Africa, and to describe two new species represented by this material. In addition, a revised key including known species of the genus is presented and the possibility of three species groups in the genus is discussed.

MATERIAL AND METHODS

Material for this study was obtained from the Natal Museum (Pietermaritzburg, South Africa; NMSA) and the Virginia Museum of Natural History (Virginia, USA; VMNH).

Data for specimens examined are arranged in alphabetical order by country, followed by province, and then by date of collection, with the oldest specimen listed first. Information for each specimen lot (specimens from the same locality and with the same catalogue number) has been recorded as stated on the label.

The number of body rings (excluding the pre-anal ring) was counted, noting the position of the first ozopore. The anal valve was not counted as a segment. The following characters were examined: (1) the colour and texture of the head; (2) the colour and

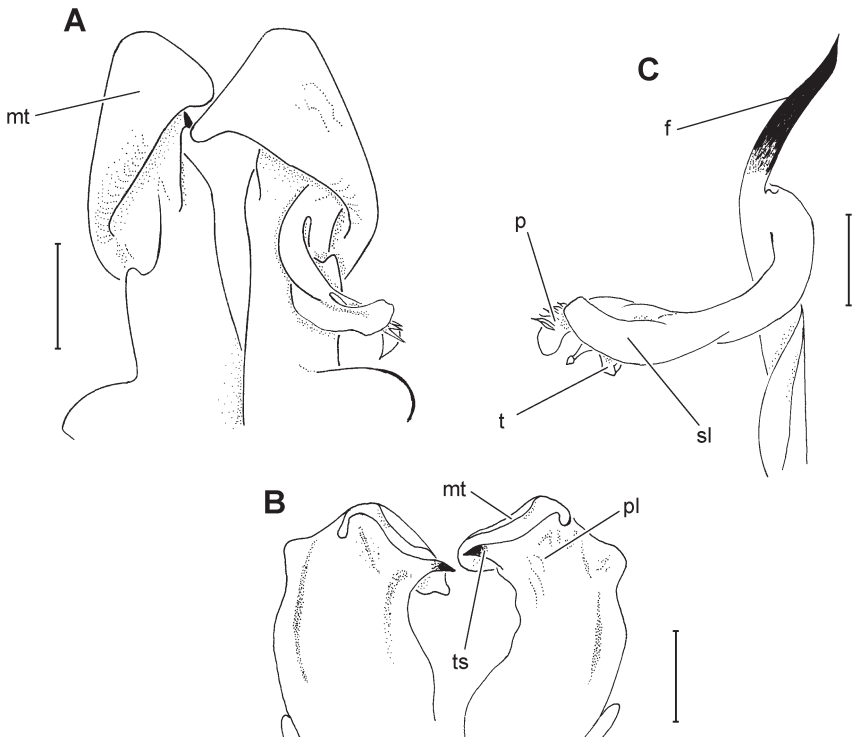


Fig. 1. Illustrations of gonopods labelled according to terminology employed: (A) *Zinophora lobata*, posterior view of gonopods; (B) *Z. taromberai*, gonopods with telocoxal spines, anterior view; (C) *Z. taromberai*, telopodite, posterior view. Abbreviations: f – femoral spine, mt – metaplica, p – palette, pl – proplica, sl – spatulate lobe, t – thumb, ts – telocoxal spine. Scale bars = 1 mm.

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texture of the clypeus, noting the number of supralabral pits present; (3) the number of ocelli and horizontal rows of ocelli; (4) the anterior and posterior angle, submarginal groove, and colour of the collum; (5) the gnathochilarium and prebasillar plate of the gnathochilarium; (6) the mandibles; (7) the colour, structure and length of the antennae and legs (the average from segments 5, 24 and the last segment); (8) the structure of the first pair of male legs; (9) the structure of the gonopods; (10) the colour and texture of the prozonites, mesozonites and metazonites; (11) the colour, structure and texture of the pre-anal ring, anal valve, and caudal spine; (12) the margin of the limbus; and (13) the shape of the hypoproct. Colour was described from specimens preserved in 70% ethanol since their collection.

All descriptions and measurements are based on males, unless otherwise stated. Measurements are provided in the following sequence: type specimen; minimum – maximum; [mean]. Means were only calculated when more than three specimens were measured. All measurements are in mm. Measurements of the legs, body and antenna were taken using Vernier callipers (range 0–200 mm). Body width measurements (horizontal diameter) were taken at the collum and at the widest trunk segment (between segments 20 and 31). For measurements of length, a specimen was straightened out and measured, and when this was not possible (as a result of specimens locked in a spiral position), a piece of soft wire was used to measure body length. In cases where the specimen was broken, the individual pieces were measured separately and these lengths were totalled.

The first pair of male legs and the gonopods were removed from the millipede and one of the telopodites was separated from the gonopod coxites. These structures were illustrated using a Wild Heerbrugg M5A stereo microscope and drawing tube, and photographed using auto montage software (Leica Microscope MZ12s with 3 CCD Toshiba Camera).

The lack of appropriate and consistently used descriptive terminology providing a suitable basis for comparison has hindered the comprehensive use of the diverse forms of the genitalia in spirostreptid taxonomy (Hoffman 2008). Currently the male genitalia provide the vast majority of informative taxonomic characters in the Harpagophoridae and in other millipede groups (Pimvichai *et al*. 2009). More recently a considerable amount of effort has been made to address these inconsistencies, which at times suggest unestablished homologies and development patterns, with suggestions for refinement of some existing terminology (Hoffman 2008; Pimvichai *et al*. 2009). For purposes of continuity, the terminology used for millipede anatomy and gonopod characters follows a combination of Attems (1928), Hoffman (1994), Hamer (1999), and Van den Spiegel & Hoffman (2001). It also factors in more descriptive terminology recently proposed by Hoffman (2008) and Pimvichai *et al*. (2009) (Fig. 1).

TAXONOMY

Key to the species of *Zinophora*

1 Metaplica lobed and with edge of lobe extending beyond medial margin of proplica, or even overlapping opposite metaplica medially (as in Figs 2, 7). Thumb of telopodite represented by one or two processes; if one it is narrow and elongate or broad based and elongate, otherwise reduced. Telopodite with one femoral spine (as in Fig. 4) 2

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– Metaplica short, not reaching medial margin of proplica, roughly triangular and never overlapping opposite metaplica medially. Thumb of telopodite a concave/saucer-shaped laminate plate, broadening apically, with dentate margin. Telopodite with one or two femoral spines 13

2 Thumb of telopodite formed into a single process (as in Figs 4, 5) 3
– Thumb of telopodite formed into two processes (as in Figs 9, 10) 6

3 Thumb of telopodite narrow at base 4
– Thumb of telopodite wide at base, tapering apically 5

4 Thumb reduced 7
– Thumb elongate 8

5 Metaplica with wide surface concealing telopodite and telocoxal spines, with margin formed into prominent lobes medially; apical margin of proplica sloping mesiad terminating in medially directed, downward curved telocoxal spines about (as in Fig. 2) ..... **lobata** Redman, sp. n.
– Metaplica with narrow surface exposing telopodite and telocoxal spines, with margin not formed into lobes; apical margin of proplica horizontal with telocoxal spines emerging from distal median margin with apices directed posteriorly ..... **annulosa** Kraus, 1958

6 Median margin of metaplica with posteriorly directed lobes (as in Fig. 7A); metaplica extended mesiad such that telocoxal spines are concealed (as in Fig. 7B); apical surface of metaplica with prominent ridge extending laterally (as in Fig. 7A) ..... **taromberai** Redman, sp. n.
– Median margin of metaplica not extending to median margin of proplica and without lobes; telocoxal spines exposed 12

7 Telocoxal spine directed distad (towards distal margin of opposite half of telocoxite). Viewed aborally, metaplica short with concave apical surface such that lateral margin is curled outwards ..... **brevilobata** (Attems, 1928)
– Telocoxal spine apex directed basad (towards proximal end of gonopod). Viewed aborally, lateral margin of metaplica is curled outwards, with horizontal, triangular lobe overlapping medially with opposite gonopod ..... **laminata** (Lawrence, 1965)

8 Femoral spine with slight curve, distally directed and concealed under metaplica 9
– Femoral spine falcate, medially directed and not concealed under metaplica 10

9 Proplica with one telocoxal spine 11
– Proplica with two telocoxal spines positioned one above the other ..... **diplodonta** (Attems, 1928)

10 Telocoxal spine short, with small but distinct hook at its apex ..... **sabulosa** (Attems, 1928)
– Telocoxal spine long, apically acute and not hooked ..... **munda** Chamberlin, 1927

11 Telocoxal spine short, broad at base, dentate along apical margin ..... **similis** (Carl, 1917)
– Telocoxal spine long, narrow at base with smooth apical margin ..... **junodi** (Carl, 1917)

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12 Telocoxal spines medially directed..... **knipperi** Kraus, 1958
– Telocoxal spines directed towards paracoxites..... **distincta** (Carl, 1917)

13 Ozopore series beginning on fifth segment 14
– Ozopore series beginning on sixth segment 15

14 Proplica with more than two telocoxal spines positioned apically on an angular medial process..... **slotowi** Redman, 2003
– Proplica with one telocoxal spine.....18

15 Telocoxal spine short, with narrow base, directed medially.....16
– Telocoxal spine long, with broad base, directed aborally..... .....**ochropygialis** (Schubart, 1966)

16 Telocoxal spine positioned near distal margin, distinct from medial margin, and hooked..... **brevispina** (Lawrence, 1965)
– Telocoxal spine continuous with medial margin of telocoxite, not obviously hooked.....17

17 Femoral spine short, directed distally. Anterior angle of collum about 90° ....**gracilis** (Brandt, 1841)
– Femoral spine elongate, falcate, medially directed. Anterior angle of collum acutely produced..... **punctata** (Attems, 1928)

18 Telopodite with one short, broad, flattened (i.e. not cylindrical) femoral spine..... ..... **mudenensis** Redman, 2003
– Telopodite with two cylindrical femoral spines.....19

19 Femoral spines of distinctly unequal length. Smaller femoral spine short, tooth-like and distally directed, emerging from oral surface of telopodite..... .....**pearlae** Redman, 2003
– Femoral spines subequal in length, both emerging from flexure of telopodite 20

20 Telocoxal spine broad at base, dentate on apical margin and directed medially. Two femoral spines angled at 90° .....**levis** (Attems, 1928)
– Telocoxal spine narrow at base, smooth on apical surface and directed aborally, with apex directed towards proximal part of telocoxite. Two femoral spines angled at about 45°, with one spine strongly curved medially ..... **thukela** Redman, 2003

Zinophora lobata Redman, sp. n.

Figs 1A, 2–6

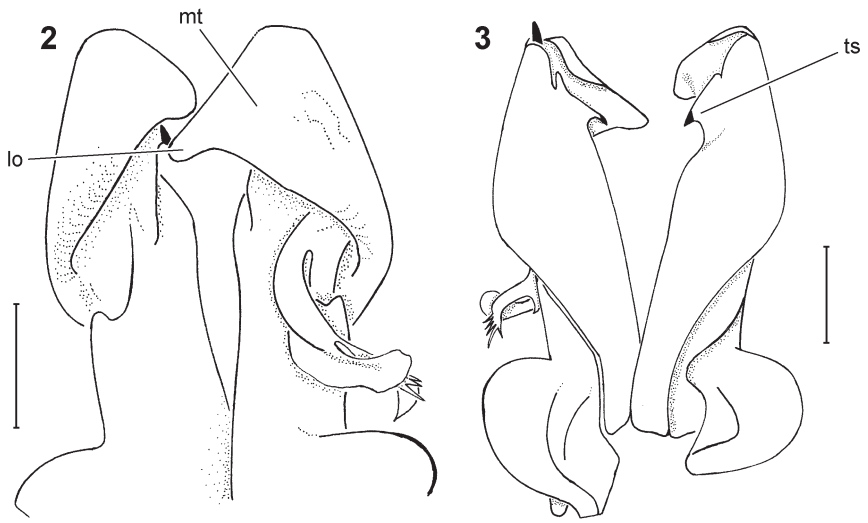
Etymology: From Latin *lobata* (lobed) adjective; refers to the elongated protuberance along the medial margin of the metaplica.

Diagnosis: Metaplica triangular, with medial margin formed into extended finger-like lobe or medial process directed posteriorly (Fig. 2). Telocoxal spines curved with apex-directed basad (Fig. 3). Telopodite with one long and narrow acutely produced femoral spine (Fig. 4). Thumb narrow, curved in direction of palette and apically acute (Fig. 5).

Description:

Dimensions (mm): Male, $n = 5$; Female, $n = 1$. Body width: male: 7, (6.5–8), [6.2]; female: 9.3; collum width: male: 7, (6–7), [6.8], female 8.4; body length: male: 75,

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Figs 2, 3. *Zinophora lobata* sp. n., telocoxites: (2) oral view, (3) aboral view. Abbreviations: lo – lobe, mt – metaplica, ts – telocoxal spine. Scale bars = 1 mm.

(50–82), [68], female: 79; leg length: male: 4, (3–4.8), female: 4; antenna length: male: 5, (4–5), [4.8], female: 5.

First ozopore: 6th segment.

Number of body rings: male: 43, (43–45), [44], female: 45.

Colour: Head brown; clypeus brown with reddish tinge. Collum dark brown. Prozonites light brown to orange, mesozonites brown, metazonites dark brown. Pre-anal ring brown. Legs and antennae brown.

Collum: Anterior corner rounded with one submarginal groove, surface with light markings and punctures, otherwise smooth.

Pre-anal ring: Caudal spine extending beyond margin of anal valve and upturned distally.

Anal valve: Surface bulbous and smooth. Margin smooth and raised, delimited by well-defined granular depression.

First pair of male legs: Prefemora in contact medially. Syncoxosternum with a slit medially between paracoxites (Fig. 6).

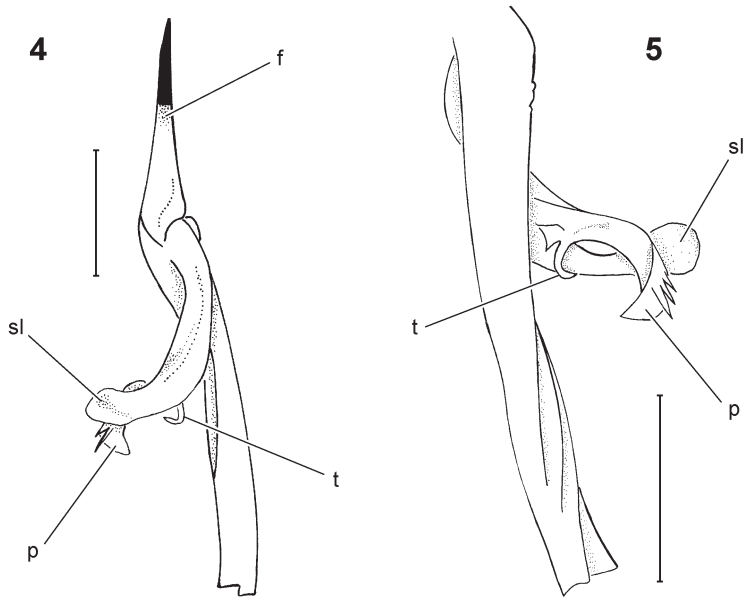
Gonopods: Lateral margin of metaplica distally rounded and sloping diagonally over proplica, concealing telocoxal and femoral spines (Fig. 2). Short, downcurved medial telocoxal spine (Figs 2, 3). Metaplica triangular, with medial margin formed into extended finger-like lobe (Fig. 2). Telopodite with one long, narrow and acutely produced femoral spine concealed by metaplica (Figs 3, 4). Thumb narrow, curved in direction of palette and acutely produced. Spatulate lobe a thin hyaline plate broadening apically, with tip curled away from other apical elements (Fig. 5).

Holotype: MOZAMBIQUE: *Inhambane*: 1♂ Pomene on road (23.01465°S:35.55040°E), 06.i.2003, D. Herbert (NMSA 22106).

Paratypes: 4♂ 1♀ same data as holotype (NMSA 22107).

Distribution: The only record for this species is from Pomene in the Inhambane province in southern Mozambique.

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Figs 4, 5. *Zinophora lobata* sp. n.: (4) telopodite with long and narrow acutely produced femoral spine, (5) telopodite showing apical elements. Abbreviations: f – femoral spine, p – palette, sl – spatulate lobe, t – thumb. Scale bars = 1 mm.

Remarks: The thumb on the apical elements of the telopodite is narrow, curved in the direction of the palette and acutely produced, making this species a member of the *Zinophora munda* group. The locality of the species is also consistent with the distribution of other species in the *Z. munda* group, which is generally in the northern half of South Africa, extending beyond the Limpopo River (Redman & Hamer 2003; Redman *et al*. 2003).

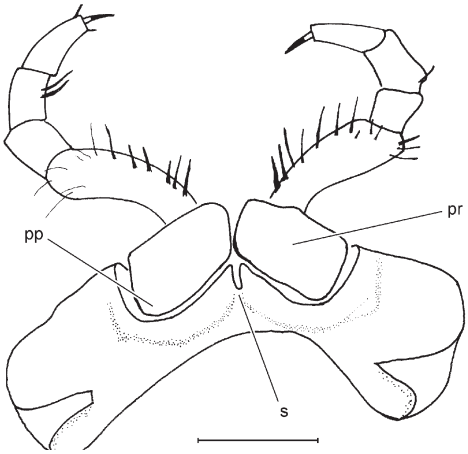


Fig. 6. *Zinophora lobata* sp. n., first pair of male legs. Abbreviations: pp – prefemoral process, pr – prefemora, s – syncoxosternum. Scale bar = 1 mm.

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Zinophora taromberai Redman, sp. n.

Figs 1B, 1C, 7–12

Etymology: The species epithet is a noun in apposition and honours Mr Tarombera Mwabvu who collected the type material of this species, and who has also made an enormous contribution to myriapod taxonomy in the region.

Diagnosis: Apical surface of metaplica with prominent ridge extending to lateral margin. Medial margin of metaplica formed into posteriorly directed lobes (Figs 7, 8). Telocoxal spines medially directed with broad base. Femoral spine long, reaching the distal margin of the metaplica, and curving slightly with the lateral margin of the metaplica (Fig. 9). Thumb on apical elements of telopodite formed into two processes, one narrow and falcate and directed towards palette, the other wide and concave (Figs 9, 10).

Description:

Dimensions (mm): Male, *n* = 9; Body width 7, (7–7.5), [7.25]; collum width 7.4; body length 85; leg length 4.7; antenna length 4.5.

First ozopore: 6th segment.

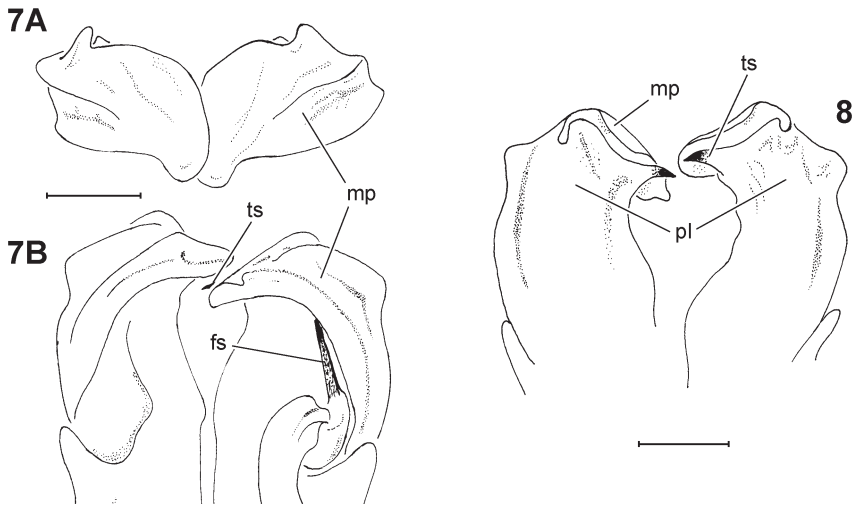
Number of body rings: 47, (47–51), [49].

Colour: Head and clypeus light brown. Collum brown. Prozonites light brown to orange, mesozonites brown, metazonite dark brown. Pre-anal ring brown. Legs and antenna brown.

Collum: Anterior corner acutely produced with one submarginal groove, surface with light markings and punctures, otherwise smooth.

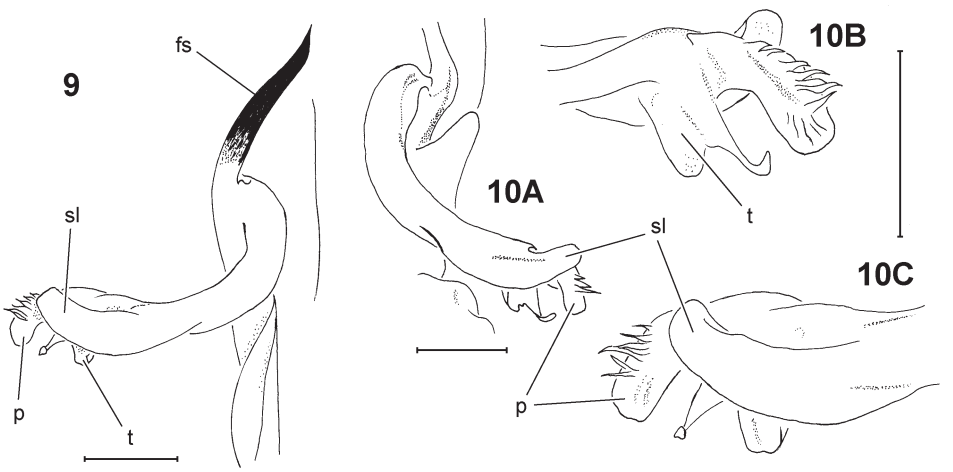
Pre-anal ring: Caudal spine extending well beyond margin of anal valve and upturned distally.

Anal valve: Surface bulbous and smooth. Margin smooth and raised, delimited by well-defined granular depression.



Figs 7, 8. *Zinophora taromberai* sp. n.: (7A) apical view of telocoxites, (7B) aboral view of telocoxite; (8) oral view of telocoxite. Abbreviations: mp – metaplica, fs – femoral spine, pl – proplica, ts – telocoxal spine. Scale bars = 1 mm.

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Figs 9, 10. *Zinophora taromberai* sp. n.: (9) telopodite; (10) apical elements of telopodites: (A) aboral view of right telopodite, (B) aboral view of left telopodite, (C) aboral view of left telopodite. Abbreviations: fs – femoral spine, p – palette, sl – spatulate lobe, t – thumb. Scale bars = 1 mm.

First pair of male legs: Prefemora in contact medially. Syncoxosternum with a slit medially between paracoxites. Prefemoral process produced into long finger-like protuberances supported by the coxal shelf.

Gonopods: Apical surface of metaplica with prominent ridge extending to lateral margin (Fig. 7A). Medial margin of metaplica formed into posteriorly-directed lobes (Fig. 7). Telocoxal spines medially directed, with broad base (Fig. 8). Telopodite with one long, narrow and acutely produced femoral spine partially concealed by metaplica with slight curvature (Fig. 9). Thumb on apical part of telopodite formed into two processes, one narrow and falcate and directed towards palette, the other wide and concave (Fig. 10). Spatulate lobe a thin hyaline plate broadening apically, with tip curled away from other apical elements (Fig. 10).

Holotype: ♂ ZIMBABWE: *Mashonaland West*: Ngezi Game Park nr Kadoma [*ca* 18.686673°S:30.412311°E], ix.2002, T. Mwabvu (NMSA 22099).

Paratype: 1♂ same data as holotype (NMSA 22096).

Other material Examined: TANZANIA: *Lindi Region*: 1♂ 1♀ Rondo Plateau, 800 m, iv.1986, Jan Kielland (VMNH); *Matemanga*: 1♂ nr Tunduru, on side of main road, 24.xii.1979, Stephanie Tyler; ZIMBABWE: *Mashonaland Central*: 2♂ Muzarabani, Zambezi Valley, ix.2002, T. Mwabvu (NMSA 22101); 1♂ Mount Darwin North/NE, ix.2002, T. Mwabvu (NMSA 220100); *Mashonaland West*: 1♂ Raffingora 20 km from Chinoyi, ix.2002, T. Mwabvu (NMSA 22097); 1♂ Chegutu, Chinoyi Road 15 km from Chegutu, Bachinia woodland, 19.xii.2008, T. Mwabvu (NMSA 21956); 11♂ Muterere Honde Valley, 25.xii.2008, T. Mwabvu, (NMSA 21948).

Distribution: Current records are from Zimbabwe (Raffingora, Chegutu, Ngezi Game Park, Muterere Honde Valley, Muzarabani in the Zambezi Valley and Mount Darwin) (Fig. 11) and Tanzania (Lindi region, Rondo Plateau; Matemanga near Tunduru).

Remarks: Hoffman first recognised this as a new species, but did not publish it. The specimen was collected from Kwe Kwe, Zimbabwe, but this material was not examined. Illustrations by Hoffman were made available for examination.

In one of the specimens (Fig. 12) the structure of the telocoxal spines on one of the gonopods was different from the general structure of gonopods observed in this

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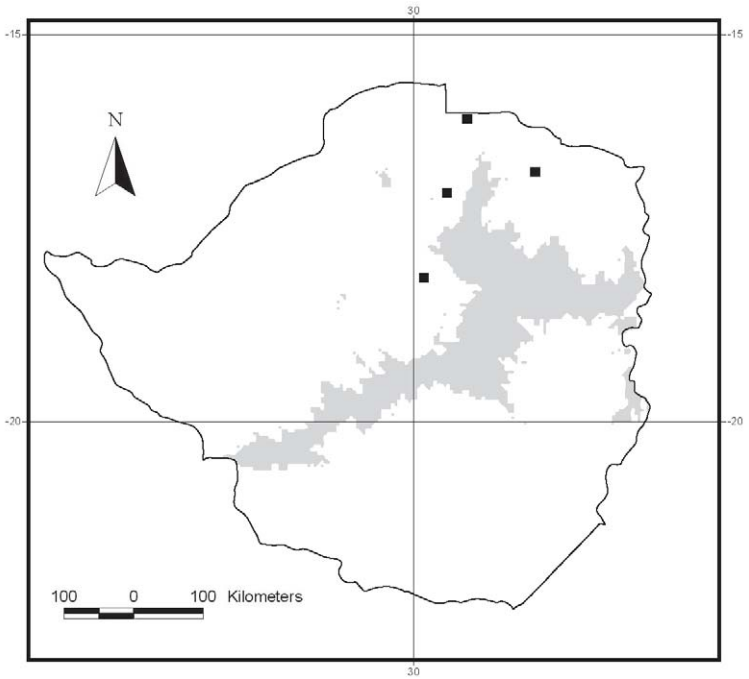


Fig. 11. Map of Zimbabwe illustrating distribution of currently known localities of *Z. taromberai*. Elevations higher than 1300 m along central plateau highlighted.

species, in that the apical surface of one of the telocoxal spines was dentate. A similar intraspecific deviation has been observed in other *Zinophora* species such as *Z. junodi*, *Z. thukela* and *Z. punctata*. However, in these species both the telocoxal spines were dentate, unlike in the *Z. taromberai* specimen, where only one of the telocoxal spines was dentate on the apical surface.

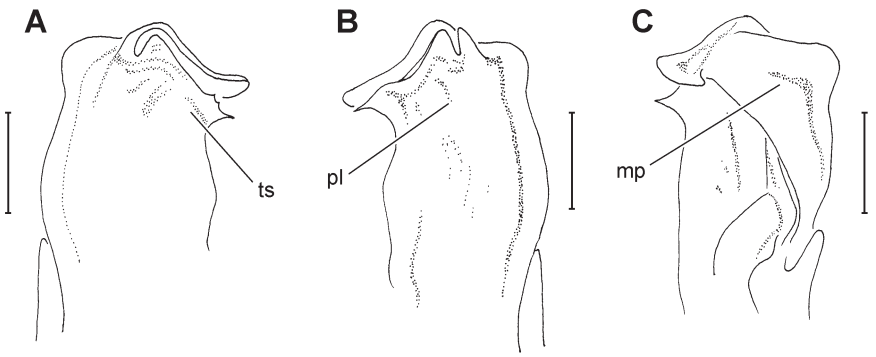


Fig. 12. *Zinophora taromberai* sp. n., variation in telocoxal spines: (A) oral view of right telocoxite, (B) oral view of left telocoxite, (C) aboral view of right telocoxite. Abbreviations: mp – metaplica, pl – proplica, ts – telocoxal spine. Scale bars = 1 mm.

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DISCUSSION

In all millipedes the male gonopods are known to offer useful taxonomic characters, and this is affirmed in *Zinophora* and in this study. In *Zinophora* the structure of the spatulate lobe, in combination with the general form of the distal margin of the telocoxites comprising a proplica and metaplica folded against each other, with the metaplica lobed mesiad and the proplica bearing a mesal projection or coxal spine, are the diagnostic characters of the genus. The structure of the spatulate lobe—one of the apical elements of the telopodite—is by far the most consistent character state distinguishing *Zinophora* from other genera of the Harpagophoridae and, together with several other character states, strongly defines the genus. The structure of the thumb, which is also located on the apical elements of the telopodite, is notable in distinguishing species groups.

In this study it became evident that some *Zinophora* species have a thumb on the apical region of the telopodite which is formed into a single finger-like projection (*Zinophora munda* group, 9 species), whereas some species have a single saucer-shaped laminate plate with a dentate margin (*Zinophora gracilis* group, 9 species), while in others it is represented by two processes which are a combination of the aforementioned character states. In *Z. lobata* the thumb is formed into a single finger-like projection, thereby making it a member of the *Z. munda* species group, however in species such as *Z. knipperi*, *Z. distincta* and *Z. taromberai*, a combination of the above mentioned character states (elongate finger-like process and saucer-shaped laminate plate) are observed. This suite of characters, together with the general shape of the telocoxite (i.e. comprising of a metaplica and proplica), suggests there may be three species groups in *Zinophora*.

The above distinctions have been based primarily on male genitalic morphological differences. We recommend that molecular investigations based on mitochondrial DNA be considered to provide further resolution by revealing the genetic diversity of the species groups. This could also clarify to what extent the apical elements of the telopodite in this genus provide accurate phylogenetic synapomorphies and what weight should be attached to the shape of spatulate lobe in distinguishing the genus, and the thumb in distinguishing the species groups. The morphological variation in the gonopod structure of the species groups could potentially be geographically associated but the phylogeographic basis for these species groups will be addressed in detail in a future paper.

Prior to this publication, only two species of Harpagophoridae were known from Mozambique (*Z. brevilobata* and *Z. junodi*), and a recent trip to the region resulted in the discovery of a new species (*Z. lobata*). A similar situation pertained in Zimbabwe, whence only one species was previously known (*Z. munda*) and a single field trip added another species with minimal collecting effort. This suggests that much more work in the region is needed to give a more accurate representation of regional millipede biodiversity, allowing more informed pronouncements on the conservation status of relevant taxa.

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