

The intertidal polychaete (Annelida) fauna of the Sitakunda coast (Chittagong, Bangladesh), with notes on the Capitellidae, Glyceridae, Lumbrineridae, Nephtyidae, Nereididae and Phyllodocidae of the “Northern Bay of Bengal Ecoregion”

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Abstract

Of seven species of polychaetous annelids collected from the intertidal zone of Sitakunda coast, Chittagong, Bangladesh, five were new records for the country. The seven are listed, with brief notes on these, some previously recorded! species and others housed in the collections of the Natural History Museum, London. Keys are given to the recorded species of Phyllodocidae, Nereididae, Lumbrineridae, Nephtyidae and Capitellidae of the “Northern Bay of Bengal Ecoregion”, and to the recognised species of Glyceridae from the Bay of Bengal. The worms in this Ecoregion are subject to the outflows of the Irrawaddy, Ganges, Hooghly and Mahanadi Rivers, and many of them are known to be freshwater tolerant.

Keywords

Taxonomy, Polychaeta, new records, keys, Odisha, West Bengal, Myanmar

Introduction

There has long been an emphasis on taxonomy in marine studies, for example Hedgpeth (1957) recommends that the first procedure in any ecological works or applied research with organisms is the exercise of systematics. No ecological investigation can be successfully carried out without a comprehensive knowledge of the taxonomy of faunal resources.

Polychaete annelids are a major group within the soft bottom macro-invertebrates (Gray and Elliott 2009) and comprise a diverse, abundant and ecologically significant functional component of the coastal ecosystem (Misra 1999). These worms are pivotal parts of food webs and form the central link between the sediment systems and higher predators. They are often diverse and highly abundant, especially in areas of anthropogenic stress (Gray and Elliott 2009) and they have diverse feeding strategies (Fauchald and Jumars 1979).

The polychaete fauna of Bangladesh is little studied, despite the importance of marine resources to the country. The largest identification works for the littoral and shallow-water polychaetes of the Indian Ocean area are Fauvel (1953) for the Persian Gulf to Myanmar and Day (1967) for southern Africa. Hartman (1974a, 1974b) is more concerned with deep water polychaetes. There have been many smaller publications on the polychaetes of India, Thailand and Ceylon/Sri Lanka since Fauvel (1953), but only a few for Bangladesh (Mahmood et al. 1993, Belaluzzaman 1995, Alam et al. 1996, Das and Reynolds 2003, Pramanik et al. 2009) and even fewer for Myanmar (one new species each in Kirtley 1994 and Glasby 1999, one re-described species in Böttgeman 2002). The most relevant recent publications are probably Misra (1999) and Pramanik et al. (2009).

The present study therefore aims to provide further information on the taxonomy of polychaetes in Bangladesh waters at two sites on the Sitakunda Upazila coast, north of the city of Chittagong (see Table 1), one of which is affected by ship-breaking activity on the shore.

The “Northern Bay of Bengal Ecoregion” of the “Bay of Bengal Province” of the “Western Indo-Pacific Realm” was devised by Spalding et al., 2007, and it is shown in map form in Claus et al (2014). The ecoregion extends from between Ye and Dawei (14.61°N, 97.90°E) in Myanmar/Burma to near Konark (19.87°N 86.11°E) in Odisha/Orissa, India (Fig. 1), and reaches from the coastline to 370km offshore (or

Table 1. Details of the sampling sites.

Site	Name & location	Substratum	Remarks
1	Muradpur, 22°35'02"N; 91°34'09"E	Silty-muddy with fine grain of sand (towards sea side)	Relatively undisturbed site along with planted mangroves (relatively high Organic Carbon and Organic Matter compared to other site)
2	Madambabirhat, 22°30'56"N; 91°43'44"E	Sandy cum muddy	Highly polluted & disturbed area due to Ship Breaking Activities in intertidal zone of the coast (low OC & OM)

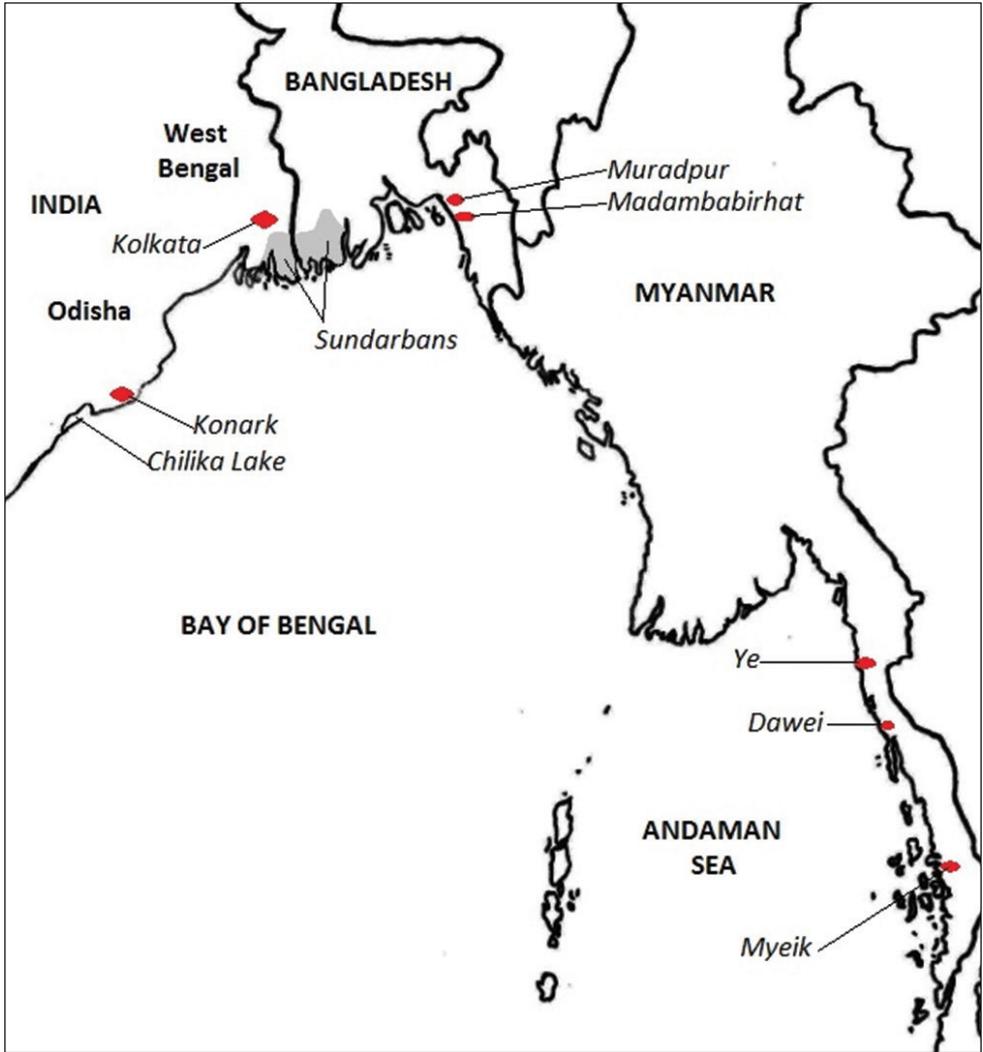


Figure 1. Map of localities mentioned in the text.

the 200m isobath if this is further offshore). It thus includes the Gulf of Martaban, the mouths of the Irrawaddy, Ganges and Hooghly Rivers, and most of the mouths of the Mahanadi River (one distributary leads to the Chilika Lake, usually referred to as Chilka Lake, which has its outlet to the sea in the neighbouring “Eastern India Ecoregion” of the “Bay of Bengal Province”). Southern Myanmar is in the “Andaman Sea Coral Coast Ecoregion” of the “Andaman Province”.

In this paper, the new specimens from Bangladesh are compared with the same families of polychaetes reported from the “Northern Bay of Bengal Ecoregion”, including the entire coast of Myanmar and the entire Odisha coast (to include the freshwater polychaetes of Chilka Lake). Important localities are shown in Figure 1.

Methods

Quantitative samples were collected between April 2007 and November 2008, but the present paper only deals with the taxonomic details of polychaetes collected at those sites. Samples were collected from the intertidal zone by using a hand-held corer with a depth penetration of 15 cm. The collected samples were washed through a 0.5 mm mesh hand sieve with filtered water at the collection point to separate animals from sediment. The materials retained on the sieve were placed in plastic vials to which 5% formalin was added for fixing the organisms, and labelled. The vital stain Rose Bengal was added to the vials to help in sorting the organisms from debris. In the laboratory the materials were poured into a round transparent Petri dish and separated from debris using needle, brush and magnifying glass. Then the organisms were preserved in 75% ethyl alcohol for identification. An Olympus compound microscope with video facility was used and relevant keys (Fauvel 1953, Day 1967) were followed for preliminary identification. Identification to species necessitated the use of many other papers, which are mentioned later in this publication.

Because there are so few records from Myanmar, some specimens deposited in the Natural History Museum, London, by Professors G.E. Gates (Judson College, Rangoon) and F.J. Meggitt (University College, Rangoon) between 1931 and 1938, and only partially published by C.C.A. Monro (1931, 1937), have been re-studied.

Identification keys are given in this paper, but any identifications made using them should be checked against good descriptions or reliably identified specimens, because not only may new records or even new species be found, but some of the older reports cited here may have been mis-identifications or represent cryptic species (it is interesting that the type locality of *Capitella capitata* is West Greenland (Blake 2009), and for *Glycera alba* is Norway (Böttgeman 2002)).

Taxonomy

Annelida

The taxonomy and systematics of the Annelida have been rapidly changing in recent years. It must be recognised that the classifications used in publications such as Fauvel (1953) and Day (1967) are now very dated. The fauna given in Fauvel (1953) shares many species with his earlier work on the fauna of France (Fauvel 1923, 1927), but it is not now considered likely that so many species from northern Europe would also be found in the Indian Ocean. A more modern classification (although still on classical lines) can be found in Chambers and Muir (1997). More strictly phylogenetic classifications are also available, such as Rouse (2000) and Appeltans et al. (2010). Keys to identify polychaetes to family level can be found in publications such as Fauchald (1977), Chambers and Muir (1997) and Glasby and Fauchald (2000).

Polychaetous annelids are often regarded as a marine group (albeit with some freshwater tolerant species), but it should be noted that non-marine species also exist (see Glasby et al. 2009), including some from Bangladesh (Das and Reynolds 2003 list two species of *Aeolosoma*).

Phyllodocidae

Eteone cf. *delta* Wu & Chen, 1963

One specimen was found: length 15 mm, width 0.75 mm for 92 segments, but anal cirri missing. Anteriorly the height of the segments is 1mm, but posteriorly the body becomes dorso-ventrally flattened. This specimen has two pairs of tentacular cirri on the first segment, the dorsal being shorter than the ventral ones (they are both, however, small and difficult to see). The first chaetae are on the second segment. The pharynx is everted, showing a smooth surface and a ring of 12 large subglobular papillae around the opening (Fig. 2). The dorsal cirri are small and rounded, compressed against the side of the body. The ventral cirri, distally rounded, are almost as long as the chaetal lobe anteriorly, but slightly longer posteriorly. The tip of the acicula is just emergent from the chaetal lobe in the anterior part of the body, but in the posterior part of the body is much more protuberant. The specimen is colourless in alcohol except for some brown markings dorsally by the pygidium.

This specimen, especially the structure of the pharynx, displays similarities to *Eteone delta* Wu & Chen, 1963, which is known from the Yangtze delta, the Pearl River and Zhangjiang estuary, China (Shen and Qi 1982, Chen et al. 2012). There are, however, differences such as the presence of emergent acicula. It is not considered advisable to describe this specimen as a species new to science, partly because there is only one specimen and partly because that specimen is incomplete (the shape of the anal cirri is important at the generic level for this group). It may be that this is a rare species which shows some morphological variation from one extreme of its geographic range to the other. Glasby et al. (2009) list *Eteone delta* as freshwater tolerant, found in the Palearctic and Oriental regions inhabiting lake/river freshwater and estuary and coastal lagoons (fresh-brackish) including supra-littoral areas. Shen and Qi (1982) say it is “favored in normal or rich trophic waters”, as opposed to over-trophic or polluted waters.

This is a new record for Bangladesh, no members of the family Phyllodocidae being recorded by Pramanik et al. (2009).

Discussion of Northern Bay of Bengal Phyllodocidae

Two specimens from Maungmagaun, Myanmar, in the Natural History Museum, London, (NHMUK ANEA 1935.1.31.34 and NHMUK ANEA 1937.1.4.4) have been identified as *Phyllodoce castanea* by C.C.A. Monro. On both of these specimens many of the

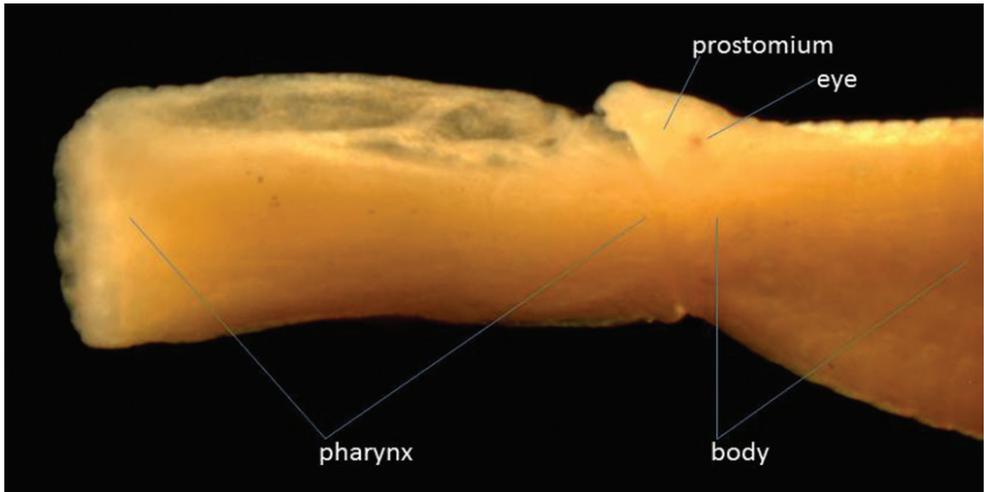


Figure 2. Lateral view of anterior end of *Eteone* cf. *delta* with pharynx extended.

head appendages are missing or regenerating, but the identifications are probably correct. The species is now known as *Nereiphylla castanea* (see synonymy in Alós et al. 2004). Fauvel (1932) records *Phyllodoce madeirensis* and *Eulalia (Pterocirrus) magalhaensis* from a depth of 2 fathoms (3.658 m) in the Mergui Archipelago.

Two species of *Eteone* are recorded from West Bengal (Misra 1999, Das et al. 2009, Mitra and Misra 2010). *Eteone barantollae* Fauvel, 1932, is now regarded as a member of the genus *Hypereteone* (see Wilson 1988). *Eteone ornata* Grube, 1878, has been referred to the genus *Mysta*, but may be a misidentification (Uschakov, in Wilson 1988).

In Odisha, *Anaitides madeirensis*, *Eteone (Mysta) ornata* and *Eteone barantollae* have been recorded from estuaries by Misra (1999) and Mitra et al. (2010). *Anaitides madeirensis* is now generally referred to as *Phyllodoce madeirensis*, and has a very wide distribution in temperate and tropical waters (Alós 2004).

These species from northern Bay of Bengal waters can be keyed out as follows, but any identifications must be checked against reliable descriptions as many other species are known from the Indo–Pacific area.

- | | | |
|---|---|--|
| 1 | Two pairs of tentacular cirri | 2 |
| – | Four pairs of tentacular cirri..... | 4 |
| 2 | Pharyngeal surface smooth, but terminates in a ring of 12 large subglobular papillae | <i>Eteone</i> cf. <i>delta</i> Wu & Chen, 1963 |
| – | Pharyngeal surface distally with rows of swollen papillae..... | 3 |
| 3 | Pharynx with five distal rows of swollen papillae..... | <i>Hypereteone barantollae</i> (Fauvel, 1932) |
| – | Pharynx with three to four rows of swollen papillae. Body with three rows of dark spots | <i>Mysta ornata</i> Grube, 1878 |
| 4 | Median antenna present on head | <i>Eulalia magalaensis</i> Kinberg, 1866 |

- Median antenna absent 5
- 5 Segments 1 and 2 fused, but not forming a collar; Pharynx with small, irregularly distributed, papillae..... *Nereiphylla castanea* (Marenzeller, 1879)
- Segment 1 covered dorsally by the posterior part of the prostomium, but not fused to segment 2; Pharynx with 12 longitudinal rows of papillae proximally and 6 rugose bands distally *Phyllodoce madeirensis* Langerhans, 1880

Nereididae

The pharynx is often not everted in preserved material, but the jaws and any paragnaths/papillae present may be seen by making a mid-ventral cut backwards from the mouth, cutting through the ventral surface of the pharynx as well as the body wall for several segments, and folding the resulting flaps to the side to reveal the complete jaw apparatus.

Neanthes chingrighattensis (Fauvel, 1932)

One specimen was found. This species could be regarded as a typical nereidid, having paragnaths on the pharynx and four pairs of tentacular cirri (Fig. 3). The arrangement of the paragnaths agrees with that depicted by Fauvel (1953). Falcigerous chaetae are entirely absent in this species. It is a new record for Bangladesh according to Pramanik et al. (2009). The type locality is Kolkata, West Bengal, and Misra (1999) states that the species is endemic in Indian waters.

Lycastonereis indica Rao, 1981

This species has no paragnaths on the pharynx and only three pairs of tentacular cirri (Fig. 4). It is, however, not a member of the genus *Namanereis* because it has parapodia with two distinct branches (notopodium and neuropodium) each with chaetae. Members of *Namanereis* only have one parapodial lobe with chaetae. This species is not mentioned in Pramanik et al. (2009) but is recorded by Alam et al. (1996) as common on the Haliashahar Coast and Misra (1999) states that the species is endemic in north-east coast of India. It is relatively common here, with nine specimens found.

Discussion of Northern Bay of Bengal Nereididae

Pramanik et al. (2009) record 12 species of nereidid from Bangladesh: *Dendronereides heteropoda*, *Dendronereis aestuarina*, *Dendronereis arborifera*, *Lycastis indica*, *Namanereis quadraticeps*, *Nereis caudata*, *Nereis falcaria*, *Nereis lamellosa*, *Nereis mossambica*, *Nereis operta*, *Tylonereis bogoyawlenskyi* (sic) and *Tylonereis fauveli*. Alam et al. (1996) add *Perinereis nuntia* as well as *Lycastonereis indica* to this list.



Figure 3. Dorsal view of anterior end of *Neanthes chingrighattensis*.

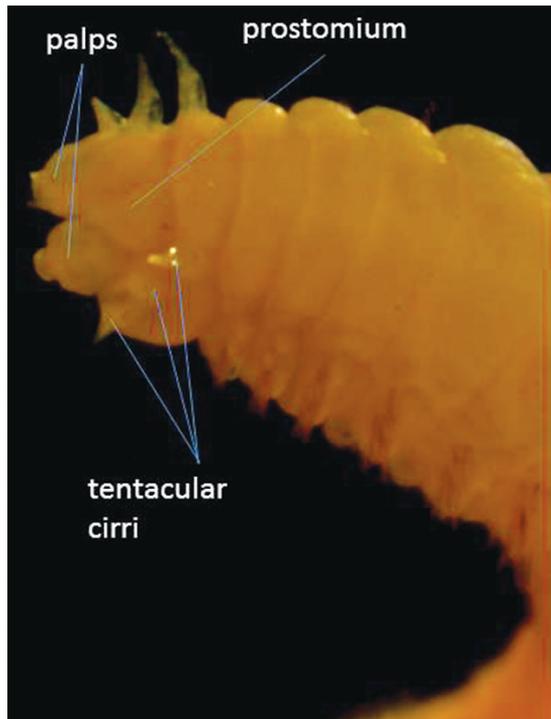


Figure 4. Dorsal view of anterior end of *Lycastonereis indica*.

The collections from Myanmar in the Natural History Museum, London, include: NHMUK ANEA 1933.3.18.43, NHMUK ANEA 1937.1.4.16-42 *Ceratonereis burmensis* Monro, 1937, Types; NHMUK ANEA 1931.6.22.70, NHMUK ANEA 2014.7 *Namalycastis abiuma* species group; NHMUK ANEA 1931.6.22.67-69 *Namalycastis multiseta* Glasby, 1999, Types; NHMUK ANEA 1931.6.22.71-73 *Neanthes meggitti* Monro, 1931, Types; NHMUK ANEA 1933.3.18.5-14, NHMUK ANEA 1935.1.31.6, NHMUK ANEA 1935.1.31.7-8 *Nereis falcaria*; NHMUK ANEA 1933.3.18.15-16 *Nereis* sp.; NHMUK ANEA 1933.3.18.1-4, NHMUK ANEA 1937.3.10.10-11 *Nereis zonata*; NHMUK ANEA 1937.3.10.12 *Perinereis cultrifera*?; NHMUK ANEA 1937.1.4.43-44 *Perinereis nuntia*; NHMUK ANEA 1932.11.25.5, NHMUK ANEA 1937.1.4.45-66 *Perinereis singaporiensis*; NHMUK ANEA 1932.11.25.2-3, NHMUK ANEA 1933.3.18.44-46, NHMUK ANEA 1935.1.31.16-18, NHMUK ANEA 1937.1.4.67-68 *Pseudonereis trimaculata*; NHMUK ANEA 1933.3.18.32-33 *Tylonereis bogoyawlenskyi*. Fauvel 1932 records *Leonnates jousseamei* (from the Mergui Archipelago, shore collecting), *Lycastis meraukensis* (from Mergui), *Nereis onychophora* (from the Jack and Una Islands, Mergui Archipelago, shore collecting), *Perinereis cultrifera* var. *helleri* (from Mergui), *Perinereis singaporiensis* (from the Jack and Una Islands, shore collecting) and *Tylonereis fauveli* (from Mergui harbour, 7 fathoms).

Chandra and Chakraborty (2008), Das et al. (2009), Khan (2003), Misra (1999), Mitra and Misra (2010), Neemann et al. (2007), Paul and Nandi (2003) and Sarkar et al. (2005) record 18 species (and one variety) of nereidid from coasts, estuaries, rivers and wetlands in West Bengal: *Ceratonereis burmensis*, *Dendronereides gangetica*, *Dendronereides heteropoda*, *Dendronereis aestuarina*, *Dendronereis dayi*, *Ganganereis sootai*, *Lycastonereis indica*, *Namalycastis fauveli*, *Namalycastis indica*, *Namalycastis meraukensis*, *Neanthes chilkaensis*, *Neanthes chingrighattensis*, *Neanthes glandicincta*, *Neanthes meggitti*, *Perinereis cavifrons*, *Perinereis cultrifera*, *Perinereis nigropunctata*, *Perinereis nuntia*, *Perinereis nuntia* var. *typica*.

Misra (1999), Mitra et al. (2010), Rao (1995) and Soota and Rao (1977) record 17 species of nereidid from coasts, estuaries, the Baitarani River and Chilka Lake in Odisha: *Ceratonereis burmensis*, *Dendronereides gangetica*, *Dendronereides heteropoda*, *Dendronereis aestuarina*, *Dendronereis dayi*, *Leonnates persica*, *Lycastonereis indica*, *Namalycastis fauveli*, *Namalycastis indica*, *Neanthes chingrighattensis*, *Nereis* (*Neanthes*) *chilkaensis*, *Nereis* (*Neanthes*) *glandicincta*, *Neanthes glandicincta*, *Nereis* (*Neanthes*) *reducta*, *Nereis* (*Neanthes*) *willeyi*, *Nereis* (*Nereis*) *persica*, *Perinereis cultrifera* and *Perinereis nigropunctata*.

Many of these species have had their names changed for taxonomic reasons, or are otherwise worthy of comment.

The genus *Ceratonereis* has been revised by Hartmann-Schröder (1985), who places the species *Ceratonereis burmensis* in the subgenus *Compositia*. *Compositia* has now been raised to generic level, but more work is needed on this grouping (Bakken and Wilson 2005).

Leonnates jousseamei has been synonymised with *L. indicus* by Qiu and Qian (2000), who also correct *L. persica* to *L. persicus*.

Glasby (1999) states that *Namanereis quadraticeps* is restricted to the Subantarctic and temperate shores of the Southern hemisphere, and Glasby et al. (2009) refer it to the *Namanereis quadraticeps* (Blanchard in Gay, 1849) species group.

Glasby (1999) accepts *Lycastis indica* as a member of the genus *Namalycastis*, and also places *Namalycastis meraukensis* in the *Namalycastis abiuma* (Grube, 1872) species group.

Nereis falcaria was reduced to a subspecies of *Nereis jacksoni* by Hartmann-Schröder (1974) but the two species were separated again by Wu et al. (1981, see Wu et al. 1985). Wilson (1984) accepts *Nereis caudata* as a member of the genus *Neanthes*. Most members of the genera *Neanthes* and *Nereis* need to have their type specimens compared with the descriptions in Bakken and Wilson (2005) before their generic placement can be confirmed.

Perinereis nuntia has been studied by Glasby and Hsieh (2006), Wilson and Glasby (1993) and Yousefi et al. (2011), and as Alam et al. (1996) did not give a full description of their specimens, it would be better to refer them to the *Perinereis nuntia* (Savigny, 1818) species group. The specimen 1937.1.4.43–44 from Maungmagaun, Myanmar, has been studied and identified as *P. nuntia* as defined by Glasby and Hsieh (2006). *Perinereis helleri* was kept separate from *Perinereis cultrifera* by Hutchings et al. (1991), but was synonymised with it by Khlebovich (1996). Problems with species of *Perinereis* were also discussed by Muir and Bamber (2008).

The very similar species *Pseudonereis trimaculata* and *Pseudonereis variegata* have been kept separate by Bakken (2007) and Villalobos-Guerrero and Tovar-Hernández (2013). Most characters seem to overlap completely, but in *P. trimaculata* the dorsal cirrus, rather being sub-terminal, is attached to the notopodium terminally from about chaetiger 40, and the ventral ligule of the neuropodium is 0.5–0.8 times as long as the acicular ligule in anterior chaetigers. In *P. variegata* only the last few dorsal cirri are attached terminally, and the ventral ligule of the neuropodium is as long as the acicular ligule in anterior chaetigers (it is as long as the acicular ligule in posterior chaetigers in both species). It is not surprising, therefore, that Monro labelled sample 1932.11.25.2–3 in the NHM as *Pseudonereis trimaculata* = *variegata*. The four samples from Myanmar have now been re-examined, and while some are definitely *P. trimaculata*, others have the longer ventral ligule of the neuropodium in anterior chaetigers of *P. variegata* while also having the dorsal cirrus attached to the notopodium terminally in the last quarter of the body. We are treating all the Myanmar specimens as *P. trimaculata*, but mentioning both species in the key.

The relevant species mentioned above can be keyed out as follows, but any identifications must be checked against reliable descriptions as many other species are known from the Bay of Bengal and other Indo–Pacific areas.

- 1 Three pairs of tentacular cirri. Paragnaths absent from pharynx *Lycastonereis indica* Rao, 1981
- Four pairs of tentacular cirri. Paragnaths present or absent 2
- 2 Paragnaths absent from pharynx 3

–	Paragnaths present on pharynx	16
3	Branchiae present dorsally on some notopodia.....	4
–	Branchiae absent from notopodia	8
4	Cluster of branchial filaments below dorsal cirrus on about segments 8 to 40 ...	5
–	Dorsal cirrus develops into bipinnate branchia on some middle segments...	6
5	Branchiae as row of simple filaments, later developing into two whorls of filaments, on segments 10–38.....	<i>Dendronereides gangetica</i> Misra, 1999
–	Cluster of branched branchiae below dorsal cirrus on segments 8 to 40	<i>Dendronereides heteropoda</i> Southern, 1921
6	Chaetae include homogomph and heterogomph spinigers. Papillae present on both rings of pharynx	<i>Dendronereis dayi</i> Misra, 1999
–	Chaetae all homogomph spinigers. Papillae absent or only on oral ring of pharynx	7
7	Pharyngeal papillae absent. All branchiae bipinnate. Anterior neuropodia with 5–6 lobes	<i>Dendronereis arborifera</i> Peters, 1854
–	Papillae present on oral ring of pharynx. First three pairs of branchiae pectinate, the rest bipinnate. Anterior neuropodia with 10–12 lobes and an inferior ligule (number decreasing posteriorly)	<i>Dendronereis aestuarina</i> Southern, 1921
8	Parapodia clearly biramous. All chaetae spinigers	10
–	Parapodia clearly biramous. Spinigers and homogomph falcigers present....	9
–	Parapodia with no deep separation between notopodium and neuropodium. Spinigers and heterogomph falcigers present.....	12
9	Falcigers present on all neuropodia	<i>Leonnates indicus</i> Kinberg, 1866
–	Falcigers not present on anterior neuropodia	<i>Leonnates persicus</i> Wesenberg-Lund, 1949
10	Neurochaetae include homo-, sesqui- and heterogomph spinigers	<i>Ganganereis sootai</i> Misra, 1999
–	All chaetae homogomph spinigers.....	11
11	Neuropodia trilobed anteriorly, bilobed posteriorly	<i>Tylonereis bogoyawlenskyi</i> Fauvel, 1911
–	All neuropodia bilobed	<i>Tylonereis fauveli</i> Southern, 1921
12	Body widest mid-anteriorly (chaetigers 9–20). Sub-neuroacicular chaetae heterogomph spinigers and falcigers.....	15
–	Body with uniform width anteriorly, tapering in far posterior region.....	13
13	Sub-neuroacicular chaetae heterogomph falcigers and heterogomph spinigers	14
–	Sub-neuroacicular chaetae heterogomph falcigers	<i>Namanereis quadraticeps</i> (Blanchard in Gay, 1849) species group
14	Prostomium 1.3–2.3× wider than long. Usually less than 10 sesquigomph spinigers in neuropodial supra-acicular fascicle in midbody	<i>Namalycastis abiuma</i> (Grube, 1872) species group

- Prostomium 2.4× wider than long or even wider. 10-30 sesquigomph spinigers in neuropodial supra-acicular fascicle in midbody.....
.....*Namalycastis multiseta* Glasby, 1999
- 15 Antennae minute, not reaching tip of palpophore. Heterogomph falcigers with boss extremely prolonged. Jaw with 2-3 subterminal teeth + 2-4 ensheathed proximally.....*Namalycastis fauveli* Rao, 1981
- Antennae more or less reaching tip of palpophore. Heterogomph falcigers with boss not prolonged. Jaw with 2-5 subterminal teeth + 3-5 ensheathed proximally*Namalycastis indica* (Southern, 1921)
- 16 Groups V, VI, VII and VIII with no paragnaths.....
.....*Composetia burmensis* (Monro, 1937)
- Groups V, VI, VII and VIII with paragnaths..... 17
- 17 Group VI = at least one transverse paragnath..... 18
- All paragnaths in the shape of cones or small dots..... 22
- 18 Group VI = one transverse bar 19
- Group VI = two transverse bars *Perinereis singaporiensis* Grube, 1878
- Groups V and VI have a continuous row of transverse bars.....
.....*Perinereis nuntia* (Savigny, 1818) species group
- 19 Group V absent *Perinereis cavifrons* Ehlers, 1920
- Group V = 1-3 paragnaths 20
- 20 Group I = 1-3 paragnaths 21
- Group I = 6-12 paragnaths in an irregular group
.....*Perinereis nigropunctata* (Horst, 1889)
- 21 Groups II-IV arranged in clusters*Perinereis cultrifera* (Grube, 1840)
- Groups II-IV arranged in regular comb-like rows 33
- 22 One simple falciger present in posterior notopodia
.....*Nereis onychophora* Horst, 1918
- Compound notopodial falcigers present posteriorly 23
- Notopodial falcigers absent posteriorly 26
- 23 Groups VII and VIII as a single row except in juveniles where it may be double
.....*Nereis falcaria* (Willey, 1905)
- Groups VII and VIII as an irregular band two to four deep 24
- 24 Apices of notopodial falcigers with 1-3 large teeth...*Nereis persica* Fauvel, 1911
- Apices of notopodial falcigers smooth or lightly serrate..... 25
- 25 Group I = 0, Group III = 5 in single transverse row, Groups VII and VIII = a broad band with an anterior row of large paragnaths and two to three posterior rows of smaller ones*Nereis jacksoni* Kinberg, 1866
- Group I = 1-3, Group III = 12-22 in a transverse group, Groups VII and VIII = 2 rows, the posterior with smaller, more numerous paragnaths
.....*Nereis zonata* Malmgren, 1867
- Group I = 1-3, Group III = about three rows totalling 20-30, Groups VII and VIII = three or four irregular rows*Nereis lamellosa* Ehlers, 1868
- 26 Falcigerous chaetae entirely absent...*Neanthes chingrihattensis* Fauvel, 1932

- Some falcigers present in neuropodia27
- 27 Paragnaths of basal ring forming a continuous band which is broad ventrally... 28
- Paragnaths of V and VI separate, Groups VII and VIII forming a band 2-4 deep *Neanthes willeyi* (Day, 1934)
- Paragnaths of V absent, Groups VII and VIII forming a band of one to three rows30
- 28 Group I = 1 paragnath*Neanthes operta* Stimpson, 1856
- Group I = 4-12 paragnaths, which may be small..... 29
- 29 Groups V, VI, VII and VIII form a complete broad band of several rows of paragnaths *Neanthes caudata* (Chiaje, 1841)
- Group V = 4-6 rather large paragnaths, Group VI = 5-6 paragnaths in a round cluster, Groups VII and VIII form 3-4 irregular rows of very large and small cones *Neanthes meggitti* Monro, 1931
- 30. Group VI = 1 paragnath 31
- Group VI = several paragnaths (may be minute) 32
- 31 Group VI = 1 paragnath; Group IV = 6-12 large paragnaths
.....*Neanthes glandicineta* (Southern, 1921)
- Group VI = 1 large, oval, paragnath; Group IV = a wedge of about 20 paragnaths..... *Neanthes mossambica* Day, 1957
- 32 Group I = 6-10 paragnaths, Group II = 18-20 paragnaths, Group III = a transverse band of 3-4 rows of paragnaths.....
..... *Neanthes chilkaensis* (Southern, 1921)
- Group I = 1 paragnath, Group II = 6 paragnaths, Group III = 11 paragnaths.....*Neanthes reducta* (Southern, 1921)
- 33 Group V = 1-3 paragnaths. Neuropodia of anterior chaetigers with ventral ligule shorter than the acicular ligule. Dorsal cirrus attached terminally in the last quarter of the body*Pseudonereis trimaculata* Horst, 1924
- Group V = 1 paragnath. Neuropodia of anterior chaetigers with ventral ligule as long as the acicular ligule. Dorsal cirrus terminal in the last few chaetigers only *Pseudonereis variegata* (Grube, 1857)

Lumbrineridae

The Lumbrineridae used to be regarded as part of the family Eunicidae (e.g. Fauvel (1953), Day (1967)), but is now regarded as a separate family alongside the Eunicidae and various others in the Order Eunicida (see George and Hartmann-Schröder (1985), Carrera-Parra (2006a)).

The pharynx is usually not everted in preserved material, but the maxillae may be seen by making a lateral cut (not a mid-ventral cut as used for nereidids) backwards from the side of the mouth, cutting through the side of the pharynx as well as the body wall for several segments, and folding the resulting flap to the side to reveal the complete jaw apparatus. If it is necessary to dissect the pharynx in this way, the anterior chaetae should be studied first.

Gesaneris malayensis (Rullier, 1969)

Six specimens of this species (Fig. 5) were found. The species, originally published as *Lumbriconereis malayensis*, was redescribed by Carrera-Parra (2006a) and transferred to a new genus. It is a new record for Bangladesh according to Pramanik et al. (2009). It is very similar to the description of *Eranno papillifera* (Fauvel, 1918) by Oug (2002). This latter species was also first published as a *Lumbriconereis* species. The most important difference is that in *Gesaneris* the maxillary apparatus has four pairs of maxillae, whereas in *Eranno* there are five pairs of maxillae.

Discussion of Northern Bay of Bengal Lumbrineridae

Previous records of lumbrinerids in Bangladesh are *Lumbrineris heteropoda heteropoda* (Marenzeller, 1879) and *Lumbrineris tetraura* (Schmarda, 1861), recorded by Alam et al. (1996) and Pramanik et al. (2009).

The collections of the Natural History Museum, London, contain a previously unpublished specimen (NHMUK ANEA 1937.3.10.15) collected by Prof. F.J. Meggitt at Maungmagaun, Myanmar, which can be identified using the key in Fauvel (1953) as *Lumbriconereis sphaerocephala*. This species has not been re-studied by recent taxonomists but it is similar to *Lumbrineris inflata* Moore, 1911 (see Carrera-Parra 2006b).

Das et al. (2009) record *Lumbrineris heteropoda*, *L. polydesma* and *L. notocirrata* from West Bengal.

In Odisha, the species *Lumbrineris heteropoda*, *Lumbrineris notocirrata* and *Lumbrineris polydesma* have been recorded from coasts and estuaries, while *Lumbrineris polydesma* and *L. simplex* were found in Chilka Lake (Misra 1999, Mitra et al. 2010, Rao 1995).

Lumbrineris heteropoda has been transferred to the genus *Kuwaita* by Carrera-Parra and Orensanz (2002) and to the genus *Scoletoma* by Budaeva (2005). The species appears to have a wide geographic range (Sea of Okhotsk to Red Sea) and may well be sub-divided

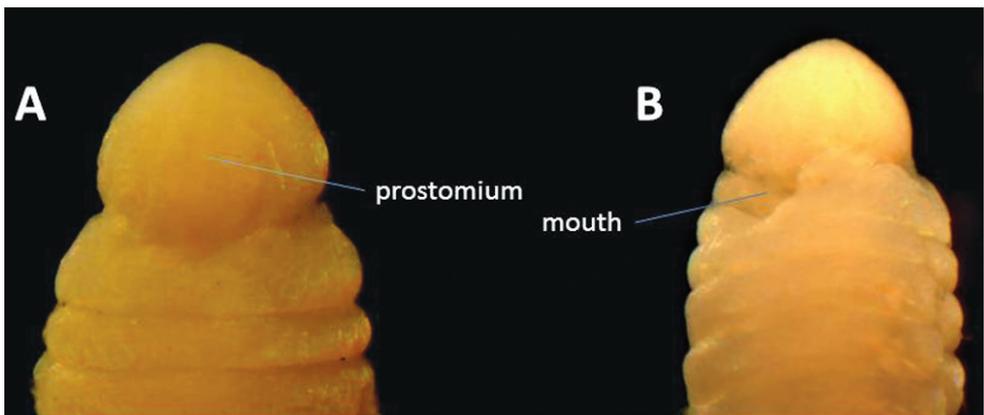


Figure 5. Anterior end of *Gesaneris malayensis*. **A** Dorsal view **B** Ventral view.

after further study, but for the moment we shall accept the name *Kuwaita heteropoda*, as Carrera-Parra and Orensanz (2002) studied a specimen from Japan, the type locality.

Lumbrineris tetraura is accepted as a member of the genus *Lumbrineris* by e.g. George and Hartmann-Schröder (1985) who say it is a cosmopolitan species, but Diaz-Castaneda and Rodriguez-Villanueva (1998), place it in the genus *Scoletoma*, the members of which only have simple hooded hooks, whereas *Lumbrineris* species possess both simple and composite hooded hooks. *Lumbrineris polydesma* may also be better placed in the genus *Scoletoma*, but it is not formally transferred here because the type specimens have not been studied.

Lumbrineris simplex, having no hooked chaetae and no antennae, is better placed in the genus *Arabellonereis*.

Lumbrineris notocirrata has been transferred to the genus *Ninoe* by Fauchald (1970), because of the presence of small branchiae.

The species *Lumbriconereis pseudobifilaris* Fauvel, 1932, has been recorded from 250 fathoms (about 450 m) depth off Akyab, Myanmar (Fauvel 1932), and from a sewage-fed fish culture pond near Calcutta, West Bengal, India (Mitra and Roy 2010). This species has no hooked chaetae but it does have two very long maxillary carriers. It is not included in the key because these characters make it a member of the family Oeononidae.

Lumbrinereis and *Lumbriconereis* are incorrect spellings of the generic name *Lumbrineris*. The northern Bay of Bengal ecoregion species of Lumbrineridae can be keyed out as follows, but any identifications must be checked against reliable descriptions as many other species are known from the Bay of Bengal and other Indo-Pacific areas.

- 1 Three antennae present *Kuwaita heteropoda* (Marenzeller, 1879)
- Antennae absent 2
- 2 Hooded hook chaetae absent *Arabellonereis simplex* (Southern, 1921)
- Hooded hook chaetae present 3
- 3 Simple hooded hooks only 4
- Compound hooded hooks present anteriorly, as well as simple hooded hooks along the body *Lumbrineris sphaerocephala* (Schmarda, 1861)
- 4 Lateral mouth pads present. Branchiae present in posterior part of body, as a small dorsal knob or transparent vesicle, a little above the base of the parapodium *Ninoe notocirrata* (Fauvel, 1932)
- Lateral mouth pads absent. Branchiae absent 5
- 5 Hooks start about chaetiger 29 or 30 ... *Lumbrineris polydesma* Southern, 1921
- Hooks start about chaetiger 1-4 6
- 6 Maxillary apparatus with five pairs of maxillae. Maxilla IV completely pigmented. Hooks with entire main tooth and crest of smaller teeth above it
..... *Scoletoma tetraura* (Schmarda, 1861)
- Maxillary apparatus with four pairs of maxillae. Maxilla IV with whitish central area. Hooks with furcate main tooth and crest of smaller teeth above it..
..... *Gesaneris malayensis* (Rullier, 1969)

Glyceridae

A posterior fragment of a glycerid was found in this collection, but it is unidentifiable to species. It is, however, a new record for Bangladesh because the fragment appears to bear branchiae on the parapodia, whereas *Glycera lancadivae* Schmarda, 1861, the only species in Pramanik et al. (2009), does not. Böggemann (2002) says that *Glycera lancadivae* is a *nomen dubium*, but similar to *Glycera brevicirris* (known from Sri Lanka and the Andaman Sea) and *Glycera tessellata* (nearest known localities Xisha Islands and Madagascar).

The collections of the Natural History Museum, London, contain a specimen of *Glycera cinnamomea* (NHMUK ANEA 1938.5.7.45) which was collected from Investigator station 549, at a depth of 24 fms (43.89 m), off Mergui Harbour (= Myeik, near the mouth of the Tanintharyi river, Myanmar), identified by Böggemann (2002). Fauvel (1932) records *Glycera cirrata* (from off Tenasserim, Burma, 50 fathoms (91.44 m)). Böggemann (2002) says this species is mixture of *Glycera brevicirris* (known from Sri Lanka and the Andaman Sea) and *Glycera americana* (nearest known localities on the coasts of South America).

Das et al. 2009 record *Glycera convoluta* and *G. rouxii* from West Bengal.

Glycera convoluta, *Glycera lancadivae*, *Glycera longipinnis*, *Glycera rouxii*, and *Glycera tessellata* have been reported by Misra (1999) and Mitra et al. (2010) from the coasts and estuaries of Odisha. According to the major revision by Böggemann (2002), *G. convoluta* is probably a junior synonym of *G. tridactyla*, *G. lancadivae* is a *nomen dubium*, *G. longipinnis* is a junior synonym of *G. sphyrabrancha*, *G. rouxii* is probably a junior synonym of *G. unicornis*, and *G. tessellata* is a good species. *Glycinde oligodon* Southern, 1921, has also been reported from the Chilka Lake, Odisha, as a glycerid by Rao (1995), but this species belongs to the family Goniadidae.

Böggemann (2002) accepts 14 species of glycerid from the Bay of Bengal area. The following key to these 14 species plus *G. tessellata* and *G. unicornis* (not previously recorded from the Bay of Bengal) is derived from Böggemann (2002), which contains full descriptions of these and many other species from the Indo–Pacific region.

- 1 All parapodia uniramous, notopodia absent. Ailerons rod-like *Hemipodia simplex* (Grube, 1857)
- Parapodia biramous after (usually) first two, notopodia with simple capillary chaetae. Ailerons with a more or less triangular or deeply incised base 2
- 2 Proboscideal papillae without terminal fingernail structure 3
- Proboscideal papillae with terminal fingernail structure 7
- 3 One postchaetal lobe in all parapodia 4
- Two postchaetal lobes at least on parapodia of mid-body 6
- 4 In mid-body, notopodial prechaetal lobes shorter than neuropodial lobes. Branchiae absent *Glycera lapidum* Quatrefages, 1866
- In mid-body, prechaetal lobes of about same length or notopodial lobes longer. Branchiae present or absent 5

- 5 Digitiform proboscideal papillae without ridges. Ailerons with deeply incised bases. Simple digitiform branchiae situated termino-dorsally on parapodia...
..... ***Glycera sphyrabrancha* Schmarda, 1861**
- Conical proboscideal papillae with about 5–20 transverse ridges. Ailerons with slightly arched bases. Branchiae absent ***Glycera oxycephala* Ehlers, 1887**
- 6 Ailerons with deeply incised bases. Postchaetal lobes short, rounded. Branchiae absent **7**
- Ailerons with interramal plate and triangular bases. Parapodia of mid-body with slender triangular notopodial and distinctly shorter rounded neuropodial postchaetal lobes. Retractable branchiae situated medially on anterior side of parapodia..... **8**
- 7 Digitiform proboscideal papillae with straight, median, longitudinal ridge ...
..... ***Glycera tessellata* Grube, 1863**
- Digitiform proboscideal papillae with about 6–20 transverse ridges.....
..... ***Glycera brevicirris* Grube, 1870**
- 8 Parapodia with slender triangular notopodial and distinctly shorter, rounded, neuropodial postchaetal lobes; simple digitiform retractile branchiae
..... ***Glycera nicobarica* Grube, 1868**
- Parapodia with two slender triangular postchaetal lobes of about same length or notopodial lobes only slightly longer than neuropodial lobes; digitiform retractile branchiae with 1–2 rami ***Glycera unicornis* Savigny, 1818**
- 9 Parapodia of mid-body with two slender triangular postchaetal lobes of about same length..... **10**
- Parapodia of mid-body with slender triangular notopodial and shorter, more or less rounded, neuropodial postchaetal lobes **11**
- 10 Parapodia without branchiae ***Glycera onomichiensis* Izuka, 1912**
- 1–5 digitiform branchial rami situated dorsally on parapodial bases.....
..... ***Glycera cinnamomea* Grube, 1874**
- 11 In mid-body and posterior parapodia neuropodial postchaetal lobes more or less rounded. Simple digitiform branchiae situated termino-dorsally on parapodia **12**
- In posterior parapodia neuropodial postchaetal lobes as long as notopodial lobes and equally slender triangular. Simple digitiform branchiae situated medio-dorsally on parapodia..... ***Glycera posterobranchia* Hoagland, 1920**
- 12 All biramous parapodia with two postchaetal lobes. Proboscideal papillae with long, medium or short stalk **13**
- In anterior parapodia only one, medially inserted slender triangular postchaetal lobe. Proboscideal papillae with short stalk
..... ***Glycera macrobranchia* Moore, 1911**
- 13 Proboscideal papillae with long stalk..... **14**
- Proboscideal papillae with medium-length or short stalk **15**
- 14 Stalk without ridges. Ailerons with pointed triangular bases
..... ***Glycera alba* (Müller, 1776)**

- Stalk with numerous ridges. Ailerons with triangular bases
..... *Glycera natalensis* Day, 1957
- 15 Proboscideal papillae with short stalk. Prostomium consisting of about 11–15
rings. Ailerons with triangular bases..... *Glycera tridactyla* Schmarda, 1861
- Proboscideal papillae with medium-length stalk. Prostomium consisting of
about 19–28 rings. Ailerons with pointed triangular bases
..... *Glycera africana* Arwidsson, 1899

Nephtyidae

Micronephthys oligobranchia (Southern, 1921)

The single 6.5 mm long worm found (Fig. 6) is probably this species, which has been well described by Imajima (1987) under the name *Nephtys oligobranchia*. The species has been transferred to the genus *Micronephthys* by Dnestrovskaya and Jirkov (2010), although they say the family needs to be fully reviewed. Glasby et al. (2009) list *N. oligobranchia* as a freshwater- and saltwater-tolerant species, found in the Palaearctic and Oriental regions inhabiting lake/river freshwater, estuary and coastal lagoons (fresh-brackish) including supra-littoral areas and inland lakes. Shen and Qi (1982) say it is “favored in normal or rich trophic waters”, as opposed to over-trophic or polluted waters.

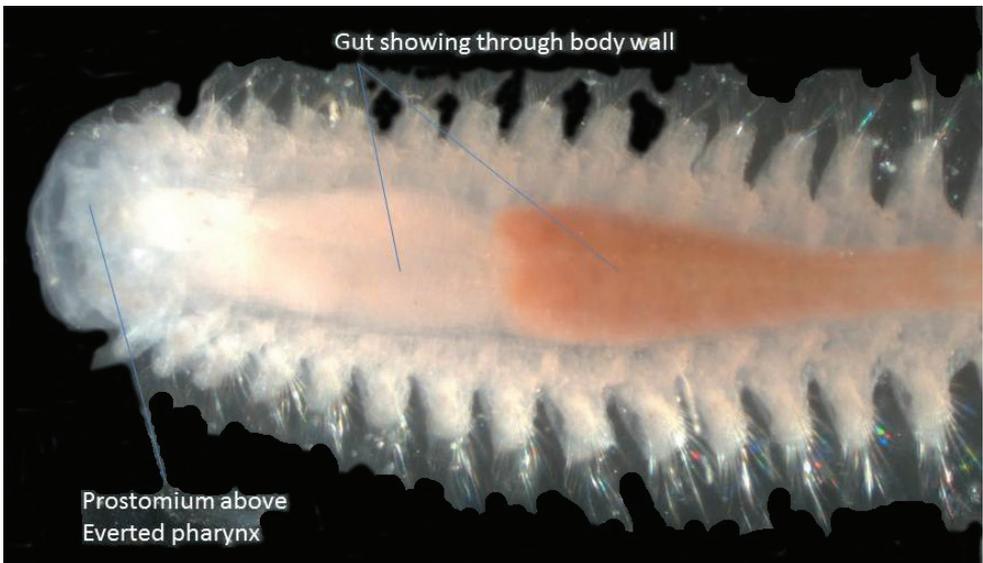


Figure 6. Dorsal view of semi-transparent specimen of *Micronephthys oligobranchia* with partially everted pharynx.

Discussion of Northern Bay of Bengal Nephtyidae

Nephtys oligobranchia is the only nephtyid recorded by Pramanik et al. (2009) from Bangladesh. It is also recorded by Fauvel (1932) from Mergui, Myanmar.

N. oligobranchia and *N. polybranchia* Southern, 1921, have both been recorded from West Bengal (Misra 1999) and the Ganges river system (Nesemann et al. 2007). Das et al. (2009) record *N. dibranchis* and *N. oligobranchia*. *Nephtys dibranchis* was placed in the genus *Aglaophamus* by Hartman (1950).

Nephtys oligobranchia is recorded from the Baitarani River, Odisha, by Misra (1999). *Nephtys oligobranchia* and *N. polybranchia* are both recorded from the Chilka Lake (Misra 1999, Mitra et al. 2010).

The northern Bay of Bengal ecoregion species of Nephtyidae can be keyed out as follows, but any identifications must be checked against reliable descriptions as many other species are known from the Bay of Bengal and other Indo-Pacific areas.

- 1 Interramal cirri (branchiae) large and curving in towards the body, especially anteriorly ***Aglaophamus dibranchis* (Grube, 1878)**
- Interramal cirri poorly developed **2**
- 2 Interramal cirri absent from posterior half of body
..... ***Micronephtys oligobranchia* (Southern, 1921)**
- Interramal cirri continuing more or less to end of body
..... ***Nephtys polybranchia* Southern, 1921**

Capitellidae

Specimens of Capitellidae, having no head appendages and usually no obvious parapodial lobes, can easily be mistaken for oligochaetes (e.g. Stephenson 1908, 1910). Without studying the reproductive system in detail, the most useful distinguishing character is the presence of hooked chaetae with a terminal hood covering the hook, which are found on the abdomen of capitellids (absent from oligochaetes).

Heteromastus filiformis sensu Day

Green (2002) gives a key to members of the genus *Heteromastus* found in the Indian Ocean. Unfortunately, there are variations in the descriptions of *Heteromastus filiformis* (Claparède, 1864) specimens described by different people. The three specimens found in this collection (Fig. 7), having expanded neuropodial lobes in the posterior abdomen and abdominal hooded hook chaetae with three teeth above the main fang, are more like those described by Day (1967) than those described by Hutchings and Rainer (1981), which had expanded notopodial lobes in the posterior abdomen

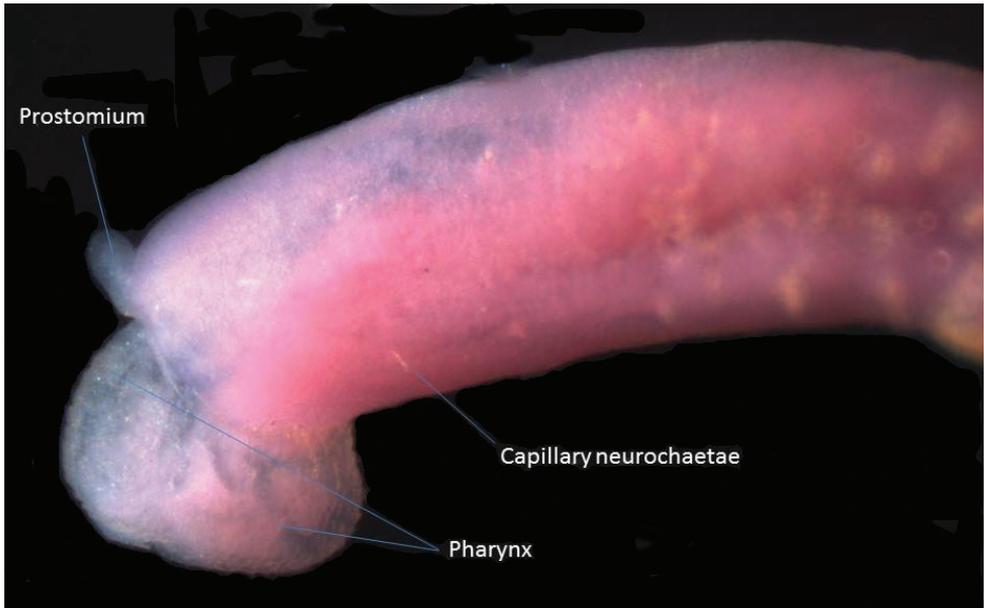


Figure 7. Lateral view of anterior end of *Heteromastus filiformis* with everted pharynx.

and abdominal hooded hook chaetae with 11–13 teeth above the main fang. The type locality of *H. filiformis* is in the Mediterranean (see Green 2002), so Day's specimens from South Africa could be a different species to Claparède's. Glasby et al. (2009) list *Heteromastus filiformis* as freshwater tolerant, but say that multiple species may have been reported under this name.

This is a new record according to Pramanik et al. (2009).

Discussion of Northern Bay of Bengal Capitellidae

Pramanik et al. (2009) give *Dasybranchus caducus* as the only capitellid species they know from Bangladesh.

The Natural History Museum, London, has a specimen of *Notomastus* near *latericeus* Sars, 1851 sensu Green 2002 (NHMUK ANEA 1933.3.18.71) and the type specimens of *Parheteromastus tenuis* Monro, 1937, from Maungmagaun, Myanmar (NHMUK ANEA 1937.1.4.151-163).

Matla bengalensis Stephenson, 1908, was described as a new genus and species of oligochaete from West Bengal, but is now (Stephenson 1910) recognised as a capitellid polychaete similar to *Capitella capitata*. Alam et al. (2010), Chandra and Chakraborty (2008), Das et al. (2009), Misra (1999), Mitra and Misra (2010) and Sarkar et al. (2005) report *Barantolla sculpta* Southern, 1921, *Capitella capitata* (Fabricius, 1780), *Mastobranchnus indicus* Southern, 1921, and *Parheteromastus tenuis* Monro, 1937, from coasts, mangroves, lakes and rivers of West Bengal.

In Odisha, five species of capitellid have been reported (Rao 1995), all of them from the Chilka Lake – *Barantolla sculpta*, *Capitella capitata*, *Heteromastus similis*, *Notomastus latericeus* and *Pulliella armata*. Magalhães and Bailey-Brock (2012) consider *Pulliella* to be a junior synonym of *Scyphoproctus*.

There follows a key to the reported species of capitellid from the Northern Bay of Bengal ecoregion, but any identifications must be checked against reliable descriptions as many other species are known from the Bay of Bengal and other Indo–Pacific areas. In particular, Green (2002) suggested earlier records of *Heteromastus similis* may be suspect. Also, as noted above, the type locality of *Capitella capitata* is West Greenland (Blake 2009). In both these cases further taxonomic work is needed, including the careful study of type specimens and probably comparisons of DNA, to see whether the Bay of Bengal specimens have been misidentified and actually represent new species (see, for example, Blake (2009), Blake et al. (2009), Wu et al. (1991)).

Most keys to capitellid genera start with the number of segments in the thorax. There may be a sudden change in size or shape of the segments at the start of the abdomen, but in many cases it is easier to make a temporary whole mount of the specimen and count the segments with capillary chaetae.

- | | |
|---|--|
| 1 | Posterior abdominal segments with stout acicular chaetae; pygidium with two stout, conical, diverging anal cirri ... <i>Scyphoproctus armatus</i> (Fauvel, 1929) |
| – | Posterior abdominal segments with hooded hook chaetae; anal cirri absent ... 2 |
| 2 | 4-7 anterior segments with capillary chaetae 3 |
| – | 11-13 anterior segments with capillary chaetae 6 |
| 3 | Thorax with 9 segments, all with chaetae... <i>Capitella capitata</i> (Fabricius, 1780) |
| – | Thorax with 12 segments, the first achaetous 4 |
| 4 | 4 anterior segments with capillary chaetae.....
..... <i>Parheteromastus tenuis</i> Monro, 1937 |
| – | 5 anterior segments with capillary chaetae..... 5 |
| – | 6 anterior segments with capillary chaetae ... <i>Barantolla sculpta</i> Southern, 1921 |
| 5 | Abdominal hooks with longer anterior shaft than posterior shaft (node posterior to middle of shaft), two rows of teeth above main fang; posterior abdomen with expanded notopodial lobes <i>Heteromastus similis</i> Southern, 1921 |
| – | Abdominal hooks with longer posterior shaft than anterior shaft (node anterior to middle of shaft), three teeth above main fang; posterior abdomen with expanded neuropodial lobes.....
..... <i>Heteromastus filiformis</i> (Claparède, 1864) sensu Day, 1967 |
| 6 | 11 anterior segments with capillary chaetae..... 7 |
| – | 13 anterior segments with capillary chaetae.....
..... <i>Dasybranchus caducus</i> (Grube, 1846) |
| 7 | Abdomen with anterior two or more segments with mixed fascicles of capillary chaetae and hooded hooks..... <i>Mastobranchnus indicus</i> Southern, 1921 |
| – | No segments with mixed chaetal fascicles.....
..... <i>Notomastus near latericeus</i> Sars, 1851 |

General discussion

Of the seven taxa identified above, five are new records for Bangladesh. This shows that the polychaete fauna of Bangladesh is still not well known.

Some earlier records of polychaetes will have to be re-studied before the fauna list of the Bangladesh area is complete, as names will change for taxonomic or nomenclatural reasons. An example of this is the genus *Talehsapia*, reported from the Hooghly estuary and South 24-Parganas, West Bengal by Misra (1999) and Mitra and Misra (2010). The genus was placed in the new family Talehsapiidae Misra, 1999, but it is now known to fit into the pilargid subfamily Synelminae (see Salazar-Vallejo et al. 2001). More recently, *Talehsapia* has been synonymised with the genus *Hermundura* (see Glasby and Hocknull 2010).

It is notable that some species reported from Bangladesh have very wide reported distributions – the same species being reported from both Bangladesh and northern Europe may be the result of misidentification or an unrecognised cryptic species. It is also notable that Ghosh (2014) reports that two polychaete species first found in this ecoregion – *Asychis gangeticus* Fauvel, 1932 (family Maldanidae; type locality the Gangetic delta) and *Pseudopolydora kempi* (Southern, 1921) (family Spionidae; type locality a canal at Chingrighatta near Kolkata) – were not found by the Zoological Survey of India between 1984 and 1989, possibly due to the river flow being reduced by dams.

While the surface salinity in the open part of the Bay of Bengal oscillates from 32–34.5‰, in the coastal region it varies from 10–25‰ and at the river mouths the surface salinity decreases to 5‰ or even less (Banglapedia 2010). It is no surprise, therefore, that some of the species in this paper are listed by Glasby et al. (2009) as being freshwater tolerant.

Further work on the occurrence and abundance of the macrobenthic fauna and ecology of the Sitakunda coast, Chittagong, will be published in the future (Hossain and M. Belal in prep.).

Acknowledgements

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Ecological Biogeography of the Terrestrial Nematodes of Victoria Land, Antarctica

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Abstract

The terrestrial ecosystems of Victoria Land, Antarctica are characteristically simple in terms of biological diversity and ecological functioning. Nematodes are the most commonly encountered and abundant metazoans of Victoria Land soils, yet little is known of their diversity and distribution. Herein we present a summary of the geographic distribution, habitats and ecology of the terrestrial nematodes of Victoria Land from published and unpublished sources. All Victoria Land nematodes are endemic to Antarctica, and many are common and widely distributed at landscape scales. However, at smaller spatial scales, populations can have patchy distributions, with the presence or absence of each species strongly influenced by specific habitat requirements. As the frequency of nematode introductions to Antarctica increases, and soil habitats are altered in response to climate change, our current understanding of the environmental parameters associated with the biogeography of Antarctic nematofauna will be crucial to monitoring and possibly mitigating changes to these unique soil ecosystems.

Keywords

Biodiversity, dispersal, climate change, *Eudorylaimus*, freeliving nematodes, *Geomonhystera*, habitat suitability, invasive species, *Panagrolaimus*, *Plectus*, *Scottinema*, soil

Introduction

Understanding the global distribution of biodiversity is critical for studying the evolution, ecology and dynamics of ecosystems and to address how global scale changes in climate, invasive species, and land use will affect ecosystems, ecosystem services, and subsequently, people. Antarctic terrestrial ecosystems might seem less sensitive to global change because this polar desert has low species diversity distributed across a limited area of biologically active ice-free land, comprising less than 0.32% of the continent's 14 million km² (Chown and Convey 2007). However, terrestrial ecosystems of Antarctica are not immune to global changes (Adams et al. 2009; Chown et al. 2012b). Small changes in polar climate are amplified through biophysical feedbacks leading to biologically significant alterations in soil habitats and their communities (Doran et al. 2002; Nielsen et al. 2011a). The low species diversity of Antarctic soils makes them uniquely suited for studying the relationships between soil biodiversity and ecosystem functioning, and identifying how global changes may affect species level changes in biodiversity, community composition and distribution (Barrett et al. 2008; Simmons et al. 2009). Measures to conserve, manage and sustain ecosystem functioning in Antarctic and Earth's other low diversity terrestrial environments will rely on knowledge of species diversity, distributions, and their role in ecosystem processes (Adams et al. 2006; Barrett et al. 2008; Wall 2004).

Aboveground, the diversity and biogeography of terrestrial flora (mosses, lichens and liverworts) has been recently assessed and used to further refine the geographic floral regions of Antarctica (Peat et al. 2007). It is well known that the warmer maritime and subantarctic ecosystems have higher precipitation, organic soils, a more diverse and abundant vegetation (Bölter et al. 2002; Maslen 1979; Nielsen et al. 2011b; Peat et al. 2007) and greater soil faunal diversity (including earthworms and beetles) than continental Antarctica (Block and Christensen 1985; Chown and Van Drimmelen 1992). For example, the northern maritime Antarctic has 100–115 moss and *c.* 350 lichen species compared to continental Antarctica's 20–30 moss and *c.* 90 lichen species (Peat et al. 2007). Throughout Victoria Land vascular plants are absent and fauna are reduced to only a few soil groups and are represented by a patchy spatial distribution of protozoans, nematodes, rotifers, tardigrades, springtails (Collembola), and mites (Acarina) (Adams et al. 2006; Bamforth et al. 2005; Frati et al. 1997; Moorhead et al. 1999; Stevens and Hogg 2002; Virginia and Wall 1999).

Nematoda are a major component of soil food webs in all terrestrial ecosystems including the exposed lands of Antarctica, though their spatial distribution and abundance are highly heterogeneous. In more productive ecosystems, they typically have much higher diversity (Wall Freckman and Virginia 1998) than the Antarctic (Boag and Yeates 1998; Bunt 1954; Maslen 1981). For example, 431 nematode species were recorded from a Cameroon tropical forest ecosystem, with a maximum of 89 species found in 200 individuals enumerated in a soil core (Bloemers et al. 1997). In contrast, the diversity of nematodes in all of Antarctica, including the continental, maritime, and Sub- Antarctic is 54 nematode species, of which only *c.* 22 species,

all endemic, occur on the ice-free terrestrial areas of the continent (Andrássy 1998; Andrássy 2008).

In Antarctica, soil nematodes have been studied primarily in localized and easily accessible areas largely centered around research bases and concentrated on the Antarctic peninsula and islands of the maritime Antarctic and further south in ice-free areas. As a consequence there is relatively little known of their regional biogeography or of the habitats that are suitable for functioning communities. Additionally, there are many remote inland ice-free areas which have yet to be sampled (Convey 1996; Wall 2005), adding to questions on how widespread species are, and whether species rich communities and habitats exist in the more extreme climate zones of the continent.

Regional to continental-scale descriptions of the Antarctic nematofauna have pointed to a paucity of distributional records for much of the continent (Andrássy 1998; Velasco-Castrillón and Stevens 2014). Amongst all regions of Antarctica, Victoria Land is arguably the most intensively studied (Adams et al. 2006). Victoria Land is “that part of Antarctica which fronts on the western side of the Ross Sea, extending southward from about 70°30'S to 78°00'S, and westward from the Ross Sea to the edge of the polar plateau” (USGS 2003). Here, we synthesize information on the nematode biodiversity, geographic distribution and soil and sediment habitats of the terrestrial nematodes in Victoria Land, Antarctica. Much of this information comes from a series of studies to assess nematode diversity and distribution begun in austral summer 1989–1990 by Wall (formerly Freckman) and Virginia and extending to the present as part of the McMurdo Dry Valley Long Term Ecological Research program funded by the US National Science Foundation (www.mcmlter.org). We report on findings of these studies through 2004 which captures most of the biodiversity information gathered by this research group, whereas more recent research has focused on nematode species response to climate change and soil resource manipulations (Ayes et al. 2010; Doran et al. 2002; Simmons et al. 2009). For purposes of our synthesis, we define two areas, Northern Victoria Land - the area from about 70°30'S to about 76°S, encompassing Terra Nova Bay, Edmonson Point and Cape Hallett (Figure 1); and Southern Victoria Land - the area from about 76°S to about 78°S including all of the McMurdo Dry Valleys and nearby coastal regions (Adams et al. 2006) (Figure 2).

The McMurdo Dry Valleys (76°5'S to 78°5'S, 160°0' to 164°0'E) are located along the TransAntarctic Mountains in Southern Victoria Land and comprise about 4,800 km² of ice-free land and have different geo/ecological legacies and climatic conditions (Lyons et al. 2000; Moorhead et al. 1999). They are the oldest, driest and coldest deserts on earth (Beyer et al. 1999; Campbell et al. 1998; Fountain et al. 1999). Annual precipitation is less than 10 cm water equivalent, most of which sublimates before it melts (Doran et al. 2002; Fountain et al. 1999). Mean annual air temperature is -20°C (Fountain et al. 1999) and surface soil temperature ranges from -59°C in winter to 26°C for short periods during summer (Doran et al. 2002). No vertebrate animals or vascular plants are present and mosses and lichens are rare and mostly confined to ephemeral meltponds, streams and lake moats (Cameron et al. 1970; Horowitz et al. 1972; Kappen 1993). Across the region soils are poorly developed, coarse textured (95 to 99% sand by

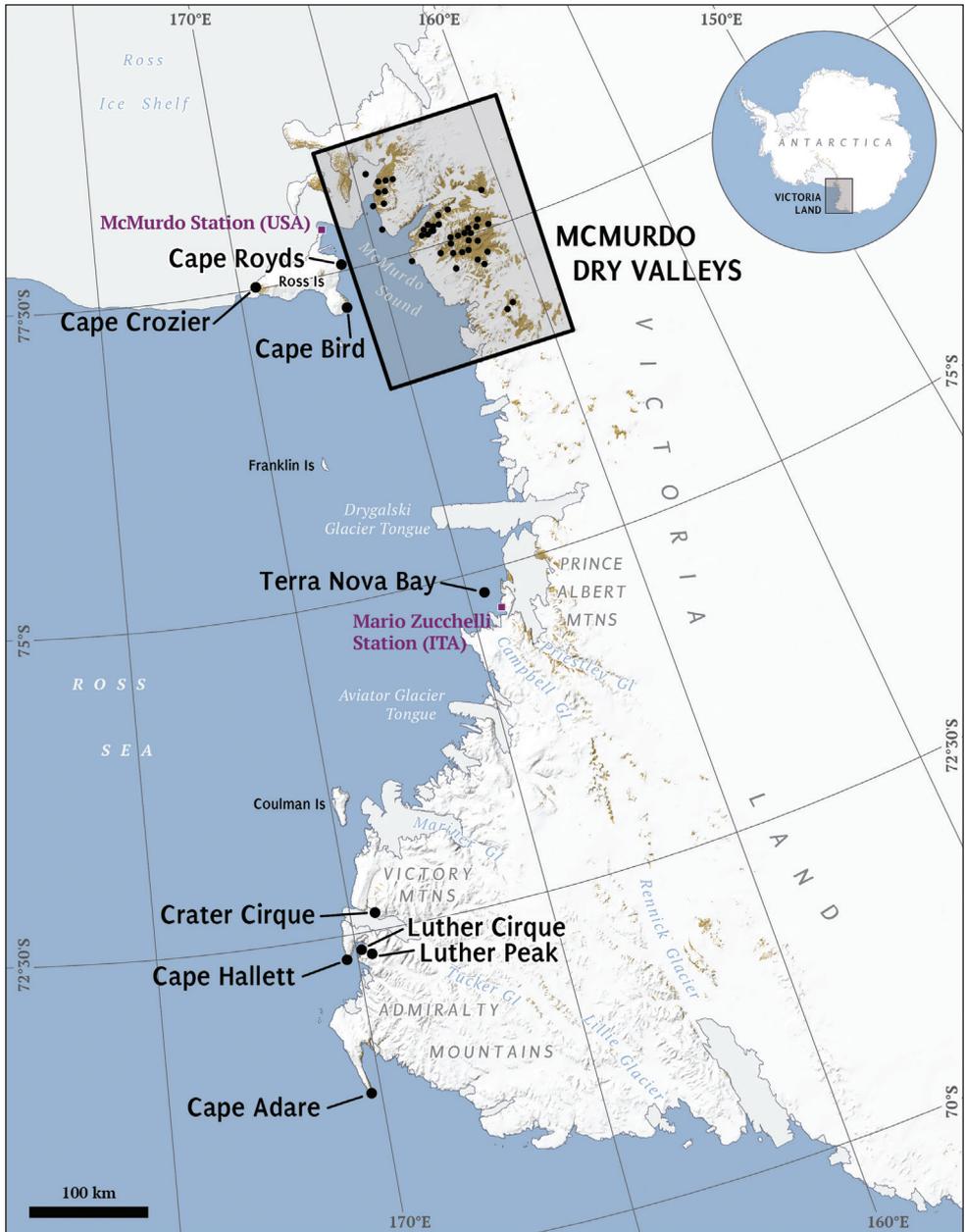


Figure 1. Victoria Land, Antarctica. Labeled areas represent study locations and major geographic features referenced in the tables and text. Box inset of the McMurdo Dry Valleys is rotated 180° and expanded in Figure 2.

weight) (Bockheim 1997), low in organic carbon (<1%) (Burkins et al. 2000), saline, and have low biological activity compared to warmer ecosystems (Ball et al. 2009; Barrett et al. 2006a; Parsons et al. 2004). Nematodes are the dominant soil invertebrate,



Figure 2. McMurdo Dry Valleys, Antarctica. Labeled areas represent study locations and major geographic features referenced in the tables and text.

but many soils (~35%) lack extractable soil invertebrates and approximately 50% of McMurdo Dry Valleys soils that contain invertebrates have only one invertebrate species (Freckman and Virginia 1997; Wall Freckman and Virginia 1998).

The distributions of the Dry Valley metazoan species are associated with specific sites and correlate to soil habitat differences in organic matter content, moisture and salinity, and microclimate differences encountered over environmental gradients of coastal to interior sites, latitude, and soil chronosequences and differences in glacial tills (Barrett et al. 2006a).

Coastal areas of Victoria Land are a moister environment than the Dry Valleys and are habitat for birds and marine mammals (e.g. skua gulls, penguins, and seals). Penguin rookeries are associated with ornithogenic soils with significant inputs of carbon and nitrogen transferred from the marine environment to the soil (Bargagli et al. 1997). Ornithogenic soils are the only soils south of the Antarctic Circle containing high concentrations (14–21%) of organic matter (Campbell and Claridge 1966; Heine and Speir 1989). However, even with high C and N availability these soils often have lower nematode diversity than soils of the Dry Valleys, probably owing to very high concentrations of salts and soil compaction and cementing (Porazinska et al. 2002a; Sinclair 2001).

Each of the unique soil ecosystems of Victoria Land imposes considerable physiological constraints on nematode life history traits, requiring adaptive responses to freeze/thaw cycling, osmotic and desiccation stress, and a short growing season (Convey 1996). Nematode responses include cryoprotective dehydration via anhydrobiosis (Adhikari et al. 2009; Adhikari and Adams 2011; Crowe et al. 1992), as well as tolerance to inter and intracellular freezing (Adhikari et al. 2010; Wharton 2003, 2010) and multiyear lifecycles (de Tomasel et al. 2013; Overhoff et al. 1993; Yeates et al. 2009). In addition to stress survival, anhydrobiosis also facilitates long-distance aeolian dispersal (Barrett et al. 2006a), an important mechanism implicated in explanations of their geographic distributions and population genetic structure (Adams et al. 2006; Courtright et al. 2000). All of the nematodes of Victoria Land are inferred to be microbivores with the exception of *Eudorylaimus*, which is omnivorous (Yeates et al. 1993) (but see Wall 2007).

Nematodes were first collected in Victoria Land by the British ‘Discovery’ expedition of 1901–1903, from Discovery Bay, South Victoria Land and described by Steiner (1916) as *Dorylaimus antarcticus* (syn. *Eudorylaimus antarcticus* (Yeates 1970)). The nematodes of Victoria Land then remained largely unstudied for over half a century, until the work of Yeates (1970) and Timm (1971). Between them, these two papers described or redescribed all Victoria Land genera of the time and laid the foundation for future taxonomic work. Yeates (1970) recorded *Plectus* from southern coastal Victoria Land and synonymized *Dorylaimus antarcticus* and *Antholaimus antarcticus* with *Eudorylaimus antarcticus*. However, subsequent studies have described further *Eudorylaimus* species from continental Antarctica: *E. glacialis* (Andrássy 1998), *E. nudicaudatus* (Heyns 1993) and *E. shirasei* (Kito et al. 1996), *E. quintus* (Andrássy 2008) and *E. sextus* (Andrássy 2008). Due to the taxonomic uncertainty of early accounts (Adams et al. 2006), we will henceforth use *Eudorylaimus* sp. in reference to all previous reports of distribution. Timm (1971)

synonymized *Plectus murrayi* with *P. antarcticus* (de Man 1904) and studied parts of southern and northern coastal Victoria Land and the McMurdo Dry Valleys. He also re-described three known species: *E. antarcticus* (Steiner 1916), *Monhystera villosa* (Bütschli 1873) and *Plectus frigophilus* (Kirjanova 1958), and described two new species, *Scottinema lindsayae* and *Panagrolaimus davidi*. *Monhystera villosa* was later synonymized with *Geomonhystera antarctica* (Andrássy 1998). These early studies focused exclusively on the identification and description of nematode species and not their ecologies.

In the McMurdo Dry Valley Region, most nematological studies have investigated the diversity, ecology and distribution patterns of up to three nematode genera; *Eudorylaimus*, *Plectus*, *Scottinema* (Adams et al. 2006), while the coastal areas of Victoria Land remain less well known (Adams et al. 2006; Bargagli et al. 1997; Barrett et al. 2006a; Porazinska et al. 2002a; Raymond et al. 2013a; Sinclair and Sjørnsen 2001; this paper; Timm 1971; Vinciguerra 1994). Our effort here is a synthesis of the biogeographic distribution of nematodes in Victoria Land and a consideration of the soil habitats that are associated with nematode distribution, diversity and abundance.

Materials and methods

Based on published and unpublished data, we summarized biogeographic information on the species represented within each nematode genus described in Victoria Land. In addition to published papers, we present information obtained from data on soil, and lake and stream sediment samples collected throughout Victoria Land, by the authors and team members during the austral summers between and including 1990 and 2004. Data referred to as “this study (year)” were derived from nematode soil extraction procedures optimized for Antarctic soils and all nematodes were identified to species (Freckman and Virginia 1993). Frozen soils from these samples are archived at the Wall lab in the Department of Biology at Colorado State University, Fort Collins, CO, USA. Formalin-preserved extracted specimens from these soils are archived in the meiofauna collection of the Monte L. Bean Life Science Museum at Brigham Young University, Provo, UT, USA. Non-occurrences are not reported but can be extrapolated from Tables 1–5. A brief summary of published information on the ecology of each genus is also provided (Table 6).

Results and discussion

Only five genera of terrestrial nematodes are recorded from Victoria Land Antarctica: *Scottinema*, *Plectus*, *Eudorylaimus*, *Panagrolaimus*, and *Geomonhystera*. For some genera species delimitation remains unresolved (Andrássy 1998; Velasco-Castrillón and Stevens 2014).

***Scottnema* (Rhabditida: Cephalobidae)**

Scottnema is an exclusively Antarctic genus comprised of only one species, *S. lindsayae* (Timm 1971). *Scottnema lindsayae* (synonymous with *S. lindsayi*) is thought to have evolved from a common ancestor of the genus *Acrobeles* (Shishida and Ohyama 1986), with a recent phylogenetic analysis placing the genus *Stegelletina* as its closest relative (Boström et al. 2011). *S. lindsayae* is the most southerly known occurring nematode in the world, found as far south as Mt Harcourt (83°08.99'S, 163°21.81'E) near the base of the Beardmore Glacier (Adams et al. 2007).

Biogeographic distribution. *Scottnema lindsayae* is the dominant nematode of Victoria Land (Table 1) based on abundance and widespread distribution in numerous samples from the McMurdo Dry Valleys (Courtright et al. 2001; Freckman and Virginia 1990; 1993, 1997; Moorhead et al. 1999; Porazinska et al. 2002b; Powers et al. 1995b; Powers et al. 1998; Treonis et al. 1999, 2000). *S. lindsayae* was first described in Victoria Land in samples from Wright Valley and the southern coastal region (Marble Point, Strand Moraines) (Timm 1971) and has since been recorded in the northern coastal region occurring as far north as Luther Cirque (72°22.20'S, 169°53.10'E) (Table 1).

S. lindsayae also occurs on two islands off the coast of Victoria Land: Ross Island (Porazinska et al. 2002a; Sinclair 2001; Timm 1971) and Kay Island (Vinciguerra 1994). On the opposite side of Antarctica, Shishida and Ohyama (1986) report *S. lindsayae* from Rundvågshetta, East Ongul Island (69°01'S, 39°58'E), and Mouratov et al. (2001) report *S. lindsayae* near Machu Picchu station (62°05.51'S, 58°28.21'W) on the coast of Admiralty Bay, although Andrassy (1998) questions this report.

Habitat. *S. lindsayae* survives in a wide range of terrestrial habitats (Table 1). In Victoria Land *S. lindsayae* occurs most commonly in dry, bare and sandy or rocky soils and has been found at 30–40 cm soil depth near south shore of Lake Hoare (Powers et al. 1995b). Less frequently, *S. lindsayae* occurs in the moister habitats such as: snow covered soil (subnivian); near streams and in lake sediments (this paper; Treonis et al. 1999; Vinciguerra 1994); and, under mosses (e.g. *Bryum antarcticum*) (Timm 1971; Vinciguerra 1994). *S. lindsayae* has also been found associated with an algal mat (Timm 1971) but whether the algal mat was from soil, a lake or a stream is unknown.

In comparison with other nematodes of Victoria Land, *S. lindsayae* occurs most frequently and at greater abundances in soil habitats with lower moisture, higher pH, higher EC, and higher inorganic C (Courtright et al. 2001; Freckman and Virginia 1997; Moorhead et al. 1999; Porazinska et al. 2002b; Powers et al. 1998; Treonis et al. 1999). In these habitat types, *S. lindsayae* may comprise >99% of invertebrates present (Treonis et al. 1999, 2002), and may be the only invertebrate present. Treonis et al. (2000) found that *S. lindsayae* becomes anhydrobiotic in coarse textured Dry Valley soils at a gravimetric soil moisture threshold of ~2%. In a study of 32 samples from one site on King George Island (62°05.51'S, 58°28.21'W), Mouratov et al. (2001) suggested soil moisture content may be one of the main factors determining the distribution of *S. lindsayae* and found that the species has a preference for soil moisture of 2–5%. Many studies in the McMurdo Dry Valleys (Barrett et al. 2006c; Courtright

Table 1. Biogeographic distribution of *Scottinema lindsayae* in Victoria Land, Antarctica. NP = not published. NA = specific coordinates not available within the named locale identified above. For references to “this paper”, the year collected refers to the year at the beginning of the austral summer in which samples were collected at 0-10 cm depth unless otherwise indicated. For abundance, ‘Present’ indicates no abundance information available, Low = >0 to 20 nematodes per kg dry soil, M-low = 21 to 200 nematodes per kg dry soil, Medium = 201 to 600 nematodes per kg dry soil, M-high = 601 to 1000 nematodes per kg dry soil, High = 1001 to 2000 nematodes per kg dry soil, V-high = >2000 nematodes per kg dry soil, *n* = number of samples and % = percentage of samples in which *S. lindsayae* occurred. ^aThere may have been a typographical error in the original publication reporting this latitude/longitude. *Geographic coordinates associated with the recognized Antarctic place name for a general feature as listed by the USGS Advisory Committee on Antarctic Names (<http://geonames.usgs.gov/antarctic/>) and updated by the Polar Geospatial Center (<http://www.pgc.umn.edu>).

Biogeographic location	Lat (S)	Long (E)	Habitat	Abundance	Reference
Victoria Land	*74°15.00'	163°00.00'			
-	NP	NP	“river”, wet mosses	Present	(Vincierra 1994)
McMurdo Dry Valleys	*77°30.00'	162°00.00'			
-	NP	NP	soil	Present	(Freckman and Virginia 1990)
-	NP	NP	soil	M-high	(Freckman and Virginia 1993)
-	NP	NP	soil	Present	(Freckman and Virginia 1997)
Alatina Valley	*76°52.82'	161°13.82'			
East, middle and south west end	NA	NA	soil	Medium (<i>n</i> =20, 40%)	This paper, collected in 1995
Battleship Promontory	*76°54.85'	160°59.34'			
-	NA	NA	soil	Medium (<i>n</i> =17, 88%)	This paper, collected in 1993
-	76°55.30'	161°04.79'	soil	M-high (<i>n</i> =9, 22%)	This paper, collected in 1994
-	NA	NA	soil	Medium (<i>n</i> =6, 83%)	This paper, collected in 1996
-	76°52.00'	161°05.00'	soil	Present	(Courtright et al. 2000)
Southwestern Bluff	76°55.00'	161°03.00'	soil	Medium (<i>n</i> =14, 57%)	This paper, collected in 2001
-	76°55.30'	161°04.22'	soil	Medium (<i>n</i> =6, 83%)	This paper, collected in 2003
Barwick Valley	*77°20.71'	161°06.09'	soil	Medium (<i>n</i> =10, 40%)	This paper, collected in 1994
Beacon Valley	*77°49.00'	160°39.00'	soil	Low (<i>n</i> =24, 4%)	This paper, collected in 1990
Garwood Valley	*78°02.00'	164°10.00'			
-	NA	NA	soil	High (<i>n</i> =6, 100%)	This paper, collected in 1993
-	78°02.00'	164°10.00'	soil	Medium	(Wall Freckman and Virginia 1998)
-	78°02.00'	164°10.00'	soil	Present	(Courtright et al. 2000)
-	NA	NA	soil	V-high (<i>n</i> =13, 100%)	This paper, collected in 2002

Biogeographic location	Lat (S)	Long (E)	Habitat	Abundance	Reference
<i>McKelvey Valley</i>	*77°26.00'	161°33.00'			
Upper	NA	NA	soil	High (n=18, 50%)	This paper, collected in 1990
Lower	NA	NA	soil	Low (n=14, 14%)	This paper, collected in 1990
<i>Miers Valley</i>	*78°06.00'	164°00.00'			
Miers Glacier	*78°05.00'	163°40.00'	moraine	Present	(Timm 1971)
-	NA	NA	soil	M-high (n=24, 88%)	This paper, collected in 1990
<i>Taylor Valley</i>	*77°38.82'	163°03.08'			
Canada Glacier	*77°37.00'	162°59.00'	soil	Present	(Timm 1971)
Lacroix Glacier	*77°40.00'	162°33.00'			
<i>Between Lake Bonney and Lacroix Glacier</i>	NP	NP	small runoff stream	Present	(Timm 1971)
<i>Southeast of Lacroix Glacier</i>	*77°40.00'	162°30.00'	sandy soil	Present	(Timm 1971)
Lake Bonney	*77°43.00'	162°25.00'			
<i>South side East Lobe</i>	77°42.92'	162°27.65'	soil	Low (n=9, 29%)	This paper, collected in 1993
-	NA	NA	soil polygons	Medium (n=99, 64%)	This paper, collected in 1994
-	NA	NA	soil	Medium (n=2, 50%)	This paper, collected in 1995
-	77°42.92'	162°27.65'	soil	Low	(Courtright et al. 1996)
-	NP	NP	soil polygons	Medium	(Moorhead et al. 1999)
<i>South side West Lobe</i>	77°42.5'	162°31.2'	soil	Medium (n=18, 94%)	This paper, collected in 1999, 2001 and 2002 (Simmons et al. 2009)
-	77°42.92'	162°27.65'	soil	Present	(Courtright et al. 2000)
-	NA	NA	soil and stream sediment	Medium (n=20, 45%)	This paper, collected in 2000
<i>South side West Lobe</i>	NA	NA	soil	M-low (n=96, 45%)	This paper, collected in 2000, 2002 and 2003
<i>South side East Lobe</i>	77°42.55'	162°27.39'	soil	Low	(Courtright et al. 2001)
Lake Chad	*77°38.55'	162°45.70'	soil	Medium (n=9, 22%)	This paper, collected in 1995
-	77°38.10'	162°48.15'	soil	Present	(Boström et al. 2011)
Lake Fryxell	*77°36.58'	163°09.10'			
-	NA	NA	soil	Medium (n=26, 23%)	This paper, collected in 1990
<i>South side</i>	77°35.94'	163°22.68'	soil	V-high (n=9, 100%)	This paper, collected in 1993
-	77°35.94'	163°22.68'	soil	High (n=10, 80%)	This paper, collected in 1993
-	NA	NA	soil	F-high (n=102, 87%)	This paper, collected in 1994

Biogeographic location	Lat (S)	Long (E)	Habitat	Abundance	Reference
-	NA	NA	soil	Medium (n=4, 75%)	This paper, collected in 1995
-	77°35.94'	163°22.68'	soil	V-high	(Courtright et al. 1996)
Von Guernard (F6) stream	77°36.49'	163°14.95'	soil	V-high (n=30, 100%)	This paper, collected in 1996, 1997, 1998, 2001 and 2003
-	NA	NA	soil	V-high (n=5, 100%)	This paper, collected in 1997
Von Guernard Stream/ Harnish Creek network	*77°37.00'	163°15.00'	soil and stream sediments	Medium	(Treonis et al. 1999)
-	NP	NP	soil polygons	High	(Moorhead et al. 1999)
Huey Creek stream	*77°36.00'	163°06.00'	soil	Medium (n=7, 29%)	This paper, collected in 1999
Von Guernard stream	*77°37.00'	163°15.00'	soil	High (n=8, 100%)	This paper, collected in 1999
South side F6 stream	77°36.49'	163°14.92'	soil	V-high (n=12, 100%)	This paper, collected in 1999 and 2001
-	*77°55.94'	163°22.68'	soil	Present	(Courtright et al. 2000)
Harnish Creek transect	*77°37.00'	163°13.00'	soil and stream sediment	M-high (n=20, 90%)	This paper, collected in 2000
South side by F6 (SF)	NA	NA	soil	V-high (n=96, 100%)	This paper, collected in 2000, 2002 and 2003
South-east shore	77°35.56'	163°22.41'	soil	V-high	(Courtright et al. 2001)
-	77°36.00'	^162°15.00'	soil	V-high	(Treonis et al. 2002)
South side near F6	77°36.40'	163°15.30'	soil and lake sediment	High (n=12, 67%)	This paper, collected in 2002
South side near Green Creek	77°37.36'	163°03.91'	soil	M-high (n=20, 85%)	This paper, collected in 2003
South side near F6	77°36.72'	163°15.18'	soil	High (n=20, 90%)	This paper, collected in 2003
Von Guernard stream	77°37.00'	163°15.00'	soil	High	(Barrett et al. 2006c)
Green Creek	77°37.36'	163°03.91'	soil	M-High	(Barrett et al. 2006c)
Lake Hoare	*77°38.00'	162°51.00'			
North side	77°37.49'	162°54.31'	soil	M-low (n=18, 100%)	This paper, collected in 1993
South side	77°38.03'	162°52.75'	soil	High (n=9, 100%)	This paper, collected in 1993
South side	77°37.59'	162°52.57'	soil	High (n=56, 100%)	This paper, collected in 1993, 1994, 1995, 1996, 1997 and 2001
North side	77°38.00'	162°53.00'	soil (0-2.5, 2.5-5, 5-10, 10-20 cm)	High	(Powers et al. 1994a; 1995a)
South shore	NP	NP	soil at varying elevation	Medium	(Powers et al. 1998)
-	NA	NA	soil polygons	High (n=104, 96%)	This paper, collected in 1994
South side	77°38.02'	162°52.23'	soil	High (n=40, 83%)	This paper, collected in 1994, 1995, 1996, 1997 and 2001
North side	77°38.00'	162°53.00'	soil	Medium	(Powers et al. 1995a)
South side	77°38.00'	162°53.00'	soil at varying elevation	M-high	(Powers et al. 1995a)

Biogeographic location	Lat (S)	Long (E)	Habitat	Abundance	Reference
South side	77°38.00'	162°53.00'	soil (0-2.5, 2.5-5, 5-10, 10-20 cm)	Medium	(Powers et al. 1995b)
South side	NA	NA	soil polygons	M-high (<i>n</i> =24, 100%)	This paper, collected in 1995
North side	77°37.49'	162°54.31'	soil	M-low	(Courtright et al. 1996)
South side	77°38.03'	162°52.75'	soil	M-high	(Courtright et al. 1996)
-	NP	NP	soil	Medium	(Freckman and Virginia 1997)
South side	NA	NA	soil	M-high (<i>n</i> =12, 100%)	This paper, collected in 1997
South side	77°38.00'	162°53.00'	soil	Medium	(Powers et al. 1998)
-	NP	NP	soil polygons	High	(Moorhead et al. 1999)
North side	NA	NA	soil	V-high (<i>n</i> =8, 100%)	This paper, collected in 1999
South side	NA	NA	soil	M-high (<i>n</i> =8, 100%)	This paper, collected in 1999
South side	77°38.07'	162°52.59'	soil	M-high (<i>n</i> =18, 100%)	This paper, collected in 1999, 2001 and 2002
North side	77°37.49'	162°54.31'	soil	Present	(Courtright et al. 2000)
South side	77°38.03'	162°52.75'	soil	Present	(Courtright et al. 2000)
South side	77°38.00'	162°53.00'	soil	M-high	(Treonis et al. 2000)
North side	77°37.29'	162°54.19'	soil	M-low	(Courtright et al. 2001)
South side	77°38.02'	162°52.45'	soil	M-high	(Courtright et al. 2001)
South side	77°38.00'	162°53.00'	soil	M-high	(Porazinska et al. 2002b)
-	77°38.00'	162°53.00'	soil	Medium	(Treonis et al. 2002)
-	77°37.90'	162°53.20'	soil and lake sediments	M-high (<i>n</i> =11, 73%)	This paper, collected in 2002
-	NP	NP	soil	Present	(Overhoff et al. 1993)
North side	NP	NP	lake bottom detritus	Present	(Vinciguerra 1994)
-	77°37.00'	160°50.00'	soil	Medium	(Wall Freckman and Virginia 1998)
South side	NA	NA	wetlands (upland ponds)	M-low (<i>n</i> =48, 19%)	This paper, collected in 2000
-	NP	NP	soil	F-high	(Treonis et al. 2000)
-	NP	NP	0-5 cm soil (exposed and subnivian)	F-high	(Gooseff et al. 2003)
South side	NP	NP	bare soil >80 m from wetlands (upland ponds)	Medium	(Moorhead et al. 2003)
Mummy Pond	77°40.06'	162°39.00'	soil	Low (<i>n</i> =5, 20%)	This paper, collected in 1997
Nussbaum Riegel	77°38.52'	162°46.89'	soil	V-High (<i>n</i> =5, 20%)	This paper, collected in 1997
Victoria Valley	*77°23.00'	162°00.00'			

Biogeographic location	Lat (S)	Long (E)	Habitat	Abundance	Reference
Lower Victoria Valley	77°21.81'	162°19.11'	soil	High (<i>n</i> =10, 60%)	This paper, collected in 1993
NP	77°21.81'	162°19.11'	soil	High (<i>n</i> =9, 100%)	This paper, collected in 1993
Lake Vida	*77°23.29'	161°56.05'			
-	NA	NA	soil	Medium (<i>n</i> =16, 19%)	This paper, collected in 1990
-	77°23.35'	162°02.60'	soil	Medium (<i>n</i> =10, 50%)	This paper, collected in 1993
-	NA	NA	soil	Medium (<i>n</i> =11, 27%)	This paper, collected in 1994
-	77°22.58'	161°13.56'	soil	NA (<i>n</i> =2, 100%)	This paper, collected in 2000
Vida Met Station	NA	NA	soil	Low (<i>n</i> =4, 50%)	This paper, collected in 2002
-	NA	NA	soil	M-high (<i>n</i> =10, 80%)	This paper, collected in 1997
-	77°23.00'	162°00.00'	soil	M-high	(Wall Freckman and Virginia 1998)
-	NA	NA	soil	NA (<i>n</i> =6, 83%)	This paper, collected in 2003
Victoria Lower Glacier	*77°18.00'	162°40.00'			
-	77°21.81'	162°19.11'	soil	High	(Courtright et al. 1996)
-	77°22.57'	162°13.56'	soil	NA (<i>n</i> =6, 83%)	This paper, collected in 2000
-	77°21.81'	162°19.11'	soil	Present	(Courtright et al. 2000)
South-west	77°21.49'	162°19.07'	soil	High	(Courtright et al. 2001)
Victoria Upper Glacier	*77°16.00'	161°25.00'			
-	77°17.35'	161°33.03'	soil	High (<i>n</i> =10, 60%)	This paper, collected in 1993
-	77°17.35'	161°33.03'	soil	Low (<i>n</i> =9, 11%)	This paper, collected in 1993
Victoria Upper Lake	*77°19.00'	161°35.00'	soil	M-high (<i>n</i> =20, 35%)	This paper, collected in 1990
Wright Valley	*77°31.39'	161°58.70'			
Dais	*77°33.00'	161°16.00'			
-	NP	NP	soil	Present	(Courtright et al. 2000)
-	NA	NA	soil	NA (<i>n</i> =3, 100%)	This paper, collected in 2000
East of Meserve Glacier	*77°31.00'	162°17.00'	algal mat	NP	(Timm 1971)
Labyrinth	*77°33.00'	160°50.00'			
West	77°33.04'	160°43.15'	soil	M-low (<i>n</i> =9, 100%)	This paper, collected in 1993
-	77°33.04'	160°43.15'	soil	M-low (<i>n</i> =9, 78%)	This paper, collected in 1993
-	77°33.04'	160°43.15'	soil	Low	(Courtright et al. 1996)
-	77°31.00'	161°50.00'	soil	M-low	(Wall Freckman and Virginia 1998)
West	77°33.02'	160°43.09'	soil	Low	(Courtright et al. 2001)

Biogeographic location	Lat (S)	Long (E)	Habitat	Abundance	Reference
-	NA	NA	soil	Low ($n=12$, 17%)	This paper, collected in 2003
Lake Brownworth	*77°26.00'	162°45.00'			
-	NP	NP	soil	Present	(Overhoff et al. 1993)
-	77°26.13'	162°42.61'	soil	M-low ($n=9$, 33%)	This paper, collected in 1993
-	77°26.13'	162°42.61'	soil	M-low	(Courtright et al. 1996)
-	77°26.13'	162°42.61'	soil	Present	(Courtright et al. 2000)
<i>South-west shore</i>	77°26.08'	162°42.37'	soil	M-low	(Courtright et al. 2001)
<i>Met Station</i>	NA	NA	soil	Medium ($n=4$, 75%)	This paper, collected in 2002
Bull Pass	*77°28.00'	161°46.00'	soil	Medium ($n=22$, 23%)	This paper, collected in 1990
<i>Lake Bull</i>	*77°31.51'	161°42.68'	soil	Low ($n=12$, 17%)	This paper, collected in 1990
-	77°28.00'	161°46.00'	soil	High ($n=24$, 33%)	(Poage et al. 2008)
Lake Vanda	*77°32.00'	161°33.00'			
<i>Near Lake Vanda</i>	77°32.00'	161°33.00'	soil	Present	(Timm 1971)
<i>Vanda Station</i>	77°31.00'	161°40.00'	soil	M-low ($n=2$, 100%)	This paper, collected in 2002
Unspecified Locations					
-	NA	NA	soil	M-low ($n=5$, 80%)	This paper, collected in 1997
-	NA	NA	soil	Present ($n=1$, 100%)	This paper, collected in 2000
-	NA	NA	soil	Present ($n=10$, 60%)	This paper, collected in 2003
Koetlitz Glacier and Southern Coastal Regions					
<i>Pévé Lake</i>	*78°15.00'	164°15.00'			
	*77°56.67'	164°16.87'	stony soil near the lake	Present	(Timm 1971)
<i>Strand Moraines</i>	*77°45.04'	164°29.90'	sandy soil	Present	(Timm 1971)
<i>Marble Point</i>	*77°26.00'	163°50.00'	mossy soil (<i>Bryum antarcticum</i>)	Present	(Timm 1971)
Northern Coastal Region					
<i>Cape Hallett</i>	72°19.29'	170°13.52'	soil	Low ($n=67$, 56%)	(Raymond et al. 2013a)
<i>Crater Cirque</i>	*72°37.49'	169°22.48'	lake bottom detritus and wet mosses	Present	(Vinciguerra 1994)
<i>Edmonson Point</i>	*74°20.00'	165°08.00'			
-	NA	NA	soil	Medium ($n=10$, 80%)	This paper, collected in 1996
-	NA	NA	soil	Present ($n=28$, 36%)	This paper, collected in 1996
-	NP	NP	soil	Present	(Bargagli et al. 1997)

Biogeographic location	Lat (S)	Long (E)	Habitat	Abundance	Reference
-	NA	NA	soil	Medium (n=8, 63%)	This paper, collected in 2001
<i>Gondwana Station</i>	74°37.57'	164°11.91'	soil	M-Low (n=371, 79%)	(Raymond et al. 2013a)
<i>Luther Peak</i>	*72°21.88'	169°50.91'			
Luther Cirque	72°22.20'	169°53.10'	soil	Medium (n=40, 85%)	This paper, collected in 2003
Luther Vale North	72°22.00'	169°53.00'	soil	Medium	(Barrett et al. 2006c)
Luther Vale South	72°22.00'	169°53.00'	soil	Medium	(Barrett et al. 2006c)
<i>Terra Nova Bay</i>	*74°54.51'	164°27.19'			
600 km north and south of the Italian station	NP	NP	mosses, lichens, fresh water sediments and penguin excrements (there are no details of whether <i>S. lindseyae</i> occurred in all habitats or only in some)	Present	(Vinciguerra et al. 1994)
-	74°20.00'	165°08.00'	soil	Present	(Courtright et al. 2000)

et al. 2001; Porazinska et al. 2002b; Powers et al. 1998) have identified a relationship between greater abundance of *S. lindsayae* and low soil moisture. *S. lindsayae* tolerates a wide range of soil moistures, but is typically absent from flowing meltstreams and saturated soils. Interactions between soil moisture and salinity are complex and create changing osmotic conditions in soils. In a comparative study of dry soil and moist soil under snowpacks no correlation was found between *S. lindsayae* and soil moisture (Gooseff et al. 2003), which could be attributed to changing osmotic potential and salinity. Soil salinity factors (EC and pH) have a significant influence on the distribution of *S. lindsayae* in the Dry Valleys (Freckman and Virginia 1997; Poage et al. 2008; Porazinska et al. 2002b). For example, *S. lindsayae* are found predominantly in soils with an $EC < 700 \text{ mS cm}^{-1}$ (Courtright et al. 2001; Nkem et al. 2006a; Poage et al. 2008), and appear unable to tolerate salinity over 4100 mS cm^{-1} (Nkem et al. 2006a).

S. lindsayae is recorded at a range of elevations, from the McMurdo Dry Valley floors to about 600 and 1300 m above sea level (at Mt. Suess and Battleship Promontory, respectively) in Victoria Land (Moorhead et al. 2003; Porazinska et al. 2002b; Powers et al. 1998; this paper) and 800 m above sea level outside of Victoria Land (Adams et al. 2006). On Ross Island, *S. lindsayae* occurs in soils located away from penguin rookeries and in soils with ornithogenic inputs (Sinclair and Sjurson 2001), but is absent within rookeries (Porazinska et al. 2002a; Sinclair 2001; Yeates et al. 2009). Similar observations are not recorded for Victoria Land. Other studies recording the presence of *S. lindsayae* outside of Victoria Land have found the nematode amongst mosses (e.g. *Saniona uncinata*) and at King George Island, associated with a perennial plant (*Deschampsia antarctica*) (Mouratov et al. 2001; Shishida and Ohyama 1986; Vinciguerra 1994; Wharton and Brown 1989).

***Plectus* (Plectida: Plectidae)**

Several *Plectus* species have been described from Antarctica: *P. antarcticus* (de Man 1904), *P. parietinus* (Bastian 1865), *P. parvus* (Bastian 1865), *P. cirratus* (Bastian 1865), *P. belgicae* (de Man 1904), *P. murrayi* (Yeates 1970), *P. acuminatus* (Bastian 1865) and *P. frigophilus* (Kirjanova, 1958). Many species are morphologically similar and several taxonomic statements remain unresolved (Andrássy 1998; Boström 2005; Velasco-Castrillón and Stevens 2014).

Biogeographic distribution. Four *Plectus* species have been recorded from Victoria Land: *P. antarcticus*, *P. frigophilus*, *P. murrayi* and *P. acuminatus*. Specimens of *P. antarcticus* previously described from Victoria Land have been reinterpreted as synonymous with *P. murrayi* (and *P. belgicae* and *P. parvus*) (Kito et al. 1991; Timm 1971; Yeates 1979) such that there are only three currently recognized *Plectus* species in Victoria Land. Most studies have described *Plectus* spp. (*murrayi* and *frigophilus*) from the McMurdo Dry Valleys (Gooseff et al. 2003; Porazinska et al. 2002b; Timm 1971; Wall Freckman and Virginia 1998) with only two studies reporting the occurrence of *Plectus* spp. in other areas of Victoria Land. Bargagli et al. (1997) reported *Plectus* spp.

Table 2. Biogeographic distribution of *Plecticus* species in Victoria Land, Antarctica. NP = not published, NA = not available, mur = *P. murrayi*, frig = *P. frigophilus*, where both exist = spp. For abundance, ^aabundance is per kg moss and adhering rock fragments not soil, Low = >0 to 20 nematodes per kg dry soil, M-low = 21 to 200 nematodes per kg dry soil, Medium = 201 to 600 nematodes per kg dry soil, M-high = 601 to 1000 nematodes per kg dry soil, High = 1001 to 2000 nematodes per kg dry soil, V-high = >2000 nematodes per kg dry soil, *n* = number of samples and % = percentage of samples in which *Plecticus* occurred. For references to “this paper”, the year collected refers to the year at the beginning of the austral summer in which samples were collected to 0-10 cm depth. ^bThis publication refers to a map for more details on sample location.

Biogeographic location	Lat (S)	Long (E)	Habitat	Species	Abundance	Reference
McMurdo Dry Valleys	*77°30.00'	162°00.00'				
-	NP	NP	soil	spp.	Present	(Freckman and Virginia 1990)
-	NP	NP	soil	spp.	Low	(Freckman and Virginia 1993)
-	NP	NP	soil	<i>mur</i>	Present	(Freckman and Virginia 1997)
-	NP	NP	streams	spp.	Present	(Moorhead et al. 1999)
<i>Alatina Valley</i>	*76°52.82'	161°13.82'				
Battleship Promontory	*76°54.85'	160°59.34'	soil	<i>mur</i>	Low (<i>n</i> =17, 6%)	This paper, collected in 1993
<i>East, middle and southwestern end</i>	NA	NA	soil	<i>mur</i>	Low (<i>n</i> =20, 10%)	This paper, collected in 1995
<i>Garwood Valley</i>	*78°02.00'	164°10.00'				
Garwood Lake	*78°02.00'	164°15.00'	NP	<i>frig</i>	Present	(Timm 1971)
-	NA	NA	soil	<i>mur</i>	M-low (<i>n</i> =6, 50%)	This paper, collected in 1993
-	78°02.00'	164°10.00'	soil	<i>mur</i>	M-low	(Wall Freckman and Virginia 1998)
-	NA	NA	soil	<i>mur</i>	Low (<i>n</i> =13, 8%)	This paper, collected in 2002
<i>Miers Valley</i>	*78°06.00'	164°00.00'				
Miers Glacier	*78°05.00'	163°40.00'	mossy soil from glacier foot, runoff stream	<i>frig</i>	Present	(Timm 1971)
-	NA	NA	soil	<i>mur</i>	M-low (<i>n</i> =24, 29%)	This paper, collected in 1990
<i>Taylor Valley</i>	*77°38.82'	163°03.08'				
Canada Glacier	*77°37.00'	162°59.00'				
<i>Near the glacier</i>	NP	NP	soil	<i>frig</i>	Present	(Timm 1971)
-	77°37.31'	162°58.26'	windblown sediment on top of glacier	<i>mur</i>	Present (<i>n</i> =2, 100%)	This paper, collected in 1997
<i>Waterfall (upper west)</i>	NA	NA	cryconite hole	<i>mur</i>	Present	This paper, collected in 2001
Lake Bonney	*77°43.00'	162°25.00'				

Biogeographic location	Lat (S)	Long (E)	Habitat	Species	Abundance	Reference
-	NP	NP	lake, soil nearby	<i>frig</i>	Present	(Timm 1971)
-	NA	NA	soil polygon cracks	<i>mur</i>	Low ($n=99$, 5%)	This paper, collected in 1994
-	NA	NA	soil	<i>mur</i>	Medium ($n=2$, 100%)	This paper, collected in 1995
-	NA	NA	algal mat	spp.	Present ($n=5$, 100%)	This paper, collected in 1995
West Lobe	77°43.50'	162°18.95'	soil	<i>mur</i>	Low ($n=18$, 33%)	This paper, collected in 1999, 2001 and 2002
-	NA	NA	soil and stream sediment	<i>mur</i>	M-low ($n=20$, 30%)	This paper, collected in 2000
West Lobe	NA	NA	soil	<i>mur</i>	Low ($n=72$, 7%)	This paper, collected in 2000 and 2003
-	77°43.40'	162°18.40'	soil and sediment	<i>mur</i>	Low ($n=12$, 25%)	This paper, collected in 2002
Lake Chad	*77°38.55'	162°45.70'				
-	NP	NP	NP	<i>frig</i>	Present	(Timm 1971)
-	NA	NA	algal mat	spp.	NA ($n=1$, 100%)	This paper, collected in 1995
-	NA	NA	soil	<i>mur</i>	M-low ($n=9$, 56%)	This paper, collected in 1995
Lake Fryxell	*77°36.58'	163°09.10'				
-	NP	NP	NP	<i>frig</i>	Present	(Timm 1971)
-	NP	NP	algae in a drift stream near the lake	spp.	Present	(Wharton and Brown 1989)
-	NA	NA	algal mat	<i>ant</i>	M-low ($n=10$, 100%)	This paper, collected in 1990
-	NA	NA	soil	<i>mur</i>	M-high ($n=26$, 77%)	This paper, collected in 1990
-	77°35.94'	163°22.68'	soil	<i>mur</i>	Low ($n=10$, 10%)	This paper, collected in 1993
-	NA	NA	algal mat	spp.	NA ($n=1$, 100%)	This paper, collected in 1995
-	NA	NA	soil	<i>mur</i>	Medium ($n=4$, 75%)	This paper, collected in 1995
Von Guerard stream/ Harnish Creek network	*77°37.00'	163°15.00'	stream sediments and surrounding soils	spp.	M-low	(Treonis et al. 1999)
Huey Creek	*77°36.00'	163°06.00'	soil	<i>mur</i>	M-low ($n=7$, 57%)	This paper, collected in 1999
Harnish Creek	*77°37.00'	163°13.00'	soil and sediment	<i>mur</i>	M-low ($n=20$, 60%)	This paper, collected in 2000
South side	NA	NA	soil	<i>mur</i>	Low ($n=72$, 4%)	This paper, collected in 2000 and 2002
South side	77°36.40'	163°15.30'	soil and sediment	<i>mur</i>	V-High ($n=12$, 75%)	This paper, collected in 2002
South side	77°36.49'	163°14.95'	soil	<i>mur</i>	Low ($n=6$, 17%)	This paper, collected in 2003
South side	77°36.49'	163°14.92'	soil	<i>mur</i>	Low ($n=6$, 17%)	This paper, collected in 2003
South side near Green Creek	77°37.36'	163°03.91'	soil	<i>mur</i>	Medium ($n=20$, 60%)	This paper, collected in 2003

Biogeographic location	Lat (S)	Long (E)	Habitat	Species	Abundance	Reference
Green Creek	77°37.36'	163°03.91'	soil	<i>mur</i>	Medium	(Barrett et al. 2006c)
Lake Hoare	*77°38.00'	162°51.00'				
North side	77°37.49'	162°54.31'	soil	<i>mur</i>	Low (n=18, 6%)	This paper, collected in 1993
South side	NP	NP	soil at varying elevation	spp.	Low	(Powers et al. 1994b; 1998)
South side	77°38.00'	162°53.00'	soil (0-2.5, 2.5-5, 5-10, 10-20 cm)	<i>mur</i>	Low	(Powers et al. 1995a)
South side	77°37.93'	162°53.19'	soil at varying elevation	<i>mur</i>	Low (n=150, 6%)	This paper, collected in 1995, 1998 and 2002
North side	77°37.49'	162°54.31'	soil	<i>mur</i>	Low	(Courtright et al. 1996)
South side	77°38.00'	162°53.00'	soil	<i>mur</i>	Low	(Powers et al. 1998)
North side	NA	NA	soil	<i>mur</i>	M-low (n=8, 50%)	This paper, collected in 1999
North side	77°37.29'	162°54.19'	soil	<i>mur</i>	Low	(Courtright et al. 2001)
South side	77°38.02'	162°52.23'	soil	<i>mur</i>	Low (n=8, 13%)	This paper, collected in 2001
South side	77°38.00'	162°53.00'	soil	<i>mur</i>	Low	(Porazinska et al. 2002b)
-	77°37.90'	162°53.20'	soil and lake sediment	<i>mur</i>	V-High (n=11, 82%)	This paper, collected in 2002
South side	77°38.02'	162°53.05'	soil	<i>mur</i>	Low (n=6, 17%)	This paper, collected in 2003
-	77°37.00'	162°50.00'	soil	<i>mur</i>	M-low	(Wall Freckman and Virginia 1998)
South side	NP	NP	soil	<i>mur</i>	M-low	(Treonis et al. 2000)
South side	NA	NA	high elevation upland pond areas	spp.	Low (n=48, 19%)	This paper, collected in 2000
South side	NP	NP	0-5 cm soil (subnivian)	<i>mur</i>	M-low	(Gooseff et al. 2003)
South side	NP	NP	high elevation upland pond areas	spp.	M-low	(Moorhead et al. 2003)
Taylor Glacier	*77°44.00'	162°10.00'	windblown sediment on top of glacier	<i>mur</i>	Present (n=1, 100%)	This paper, collected in 1998
Suess Glacier	*77°38.00'	162°40.00'	soil nearby	<i>frig</i>	Present	(Timm 1971)
Suess Lake	NP	NP	NP	<i>frig</i>	Present	(Timm 1971)
Victoria Valley	*77°23.00'	162°00.00'	soil	<i>mur</i>	Present (n=6, 17%)	This paper, collected in 2003
Wright Valley	*77°31.39'	161°58.70'				
Along Onyx River	*77°31.31'	161°49.39'	pond	spp.	Present	(Timm 1971)
East of Meserve Glacier	*77°31.00'	162°17.00'	algal mat	spp.	Present	(Timm 1971)
Canopus Pond	NP	NP	NP	<i>frig</i>	Present	(Timm 1971)
Lake Vanda	*77°32.00'	161°33.00'	lake, soil nearby	<i>frig</i>	Present	(Timm 1971)
Lower Wright Lake (=Lake Brownworth)	*77°26.00'	162°45.00'	NP	<i>frig</i>	Present	(Timm 1971)

Biogeographic location	Lat (S)	Long (E)	Habitat	Species	Abundance	Reference
Edge of Lake Canopus	*77°33.00'	161°31.00'	algal growth at the edge of the lake	spp.	Present	(Wharton and Brown 1989)
Between Lake Vanda and Lake Bull	NP	NP	dry algae around the edge of small ponds	spp.	Present	(Wharton and Brown 1989)
Between Lake Vanda and Lake Bull	NP	NP	wet algae in meltwater and around the edge of small ponds	spp.	Present	(Wharton and Brown 1989)
Bull Pass	*77°28.00'	161°46.00'	soil	<i>mur</i>	M-low (<i>n</i> =22, 18%)	This paper, collected in 1990
Lake Bull	*77°31.51'	161°42.68'	soil	<i>mur</i>	Low (<i>n</i> =12, 8%)	This paper, collected in 1990
-	77°31.00'	161°50.00'	soil	<i>mur</i>	M-low	(Wall Freckman and Virginia 1998)
Koertitz Glacier and Southern Coastal Regions						
Cape Chocolate (just north of)	*77°56.05'	164°34.70'	moraine	<i>frig</i>	Present	(Timm 1971)
Marble Point	*77°26.00'	163°50.00'				
-	NP	NP	moss (<i>Bryum antarcticum</i>)	<i>mur</i>	V-high ^A	(Yeates 1970)
-	NP	NP	mossy soil and melt pools with abundant algae (<i>Nostoc commune</i>)	<i>mur</i>	Present	(Timm 1971)
-	NP	NP	melt pools w/ abundant algae (<i>Nostoc commune</i>), mossy soil	<i>frig</i>	Present	(Timm 1971)
Peve Lake	NP	NP	NP	<i>frig</i>	Present	(Timm 1971)
Strand Moraines	*77°45.04'	164°29.90'				
-	NP	NP	mossy soil and melt pools with abundant algae (<i>Nostoc commune</i>)	spp.	Present	(Timm 1971)
-	NP	NP	sandy soil, mossy soil, stream with abundant algae	<i>frig</i>	Present	(Timm 1971)
Northern Coastal Region						
Cape Hallett	*72°19.00'	170°16.00'				
-	NP	NP	NP	spp.	Present	(Timm 1971)
Willett Cove	72°19.00'	170°14.00'	soil	<i>mur</i>	Medium	(Barrett et al. 2006c)
-	NA	NA	soil amongst penguin rookery	<i>mur</i>	M-low (<i>n</i> =20, 30%)	This paper, collected in 2003
-	72°19.29'	170°13.52'	soil		Low (<i>n</i> =67, 56%)	(Raymond et al. 2013a)
Edmonson Point	*74°20.00'	165°08.00'				
- _B	NP	NP	wet moss near a brook	<i>mur</i>	Present	(Vinciguerra 1994)
-	NP	NP	soil	spp.	Present	(Bargagli et al. 1997)
-	NA	NA	soil	<i>mur</i>	M-high (<i>n</i> =10, 70%)	This paper, collected in 1996

Biogeographic location	Lat (S)	Long (E)	Habitat	Species	Abundance	Reference
-	NA	NA	soil	<i>mur</i>	NA (n=28, 50%)	This paper, collected in 1996
-	NA	NA	soil	<i>mur</i>	M-low (n=8, 63%)	This paper, collected in 2001
Gondwana Station	74°37.57'	164°11.91'	soil		Low (n=371, 84%)	(Raymond et al. 2013a)
Luther Peak	72°22.20'	169°53.10'	soil	<i>mur</i>	Low (n=40, 8%)	This paper, collected in 2003
Luther Vale South	72°22.00'	169°53.00'	soil	<i>mur</i>	Low	(Barrett et al. 2006c)
Terra Nova Bay	*74°54.51'	164°27.19'				
600 km north and south of the Italian station	NP	NP	mosses, lichens, fresh-water sediments and penguin excrements (no details of whether <i>Plectus</i> occurred in all habitats or only in some)	spp.	Present	(Vinciguerra et al. 1994)
Barclay Glacier						
-	NP	NP	algae growing in meltwater	<i>mur</i>	Present	(Wharton and Brown 1989)

from Edmonson Point and Vinciguerra et al. (1994) found *P. antarcticus*, *P. frigophilus* and *P. acuminatus* at Terra Nova Bay.

In the McMurdo Dry Valleys, only *P. murrayi* and *P. frigophilus* occur, with *P. murrayi* the most abundant and widespread (Table 2). *P. murrayi* and *P. frigophilus* (Kito et al. 1991; Shishida and Ohyama 1986) are endemic to the Antarctic, but not solely to Victoria Land. Close to Victoria Land, *P. murrayi* and *P. frigophilus* have been recorded frequently from Ross Island (e.g. Cape Royds, Cape Evans, Cape Crozier, McMurdo Station and Rocky Point) (Dougherty et al. 1960; Murray 1910; Porazinska et al. 2002a; Sinclair 2001; Wharton and Brown 1989) and *P. frigophilus* has been recorded on Dunlop Island (Timm 1971; USGS 2003). *P. antarcticus* occurs primarily in the maritime, and thus most of the recordings of *P. antarcticus* on the continent are assumed to be *P. murrayi* (Andrássy 1998).

Habitat. All *Plectus* spp. of Victoria Land occupy similar habitats. They are present in soils and sediments (Ayres et al. 2007) and are frequently associated with moist environments and areas supporting algae (e.g. *Nostoc commune*) and moss (e.g. *Bryum antarcticum*) (Table 2). This is consistent with the habitats in which *Plectus* spp. are found in other regions of Antarctica (Andrássy 1998; Andrássy and Gibson 2007; Timm 1971; Wharton and Brown 1989; Yeates 1970).

Soil moisture is a critical factor determining the suitability of habitats for *Plectus* spp. Mouratov et al. (2001) studying *Plectus* spp. in the maritime Antarctic found that they had a preference for soil water content of 7–10%. In the McMurdo Dry Valleys, Courtright et al. (2001) similarly observed *P. murrayi* was more likely to occur in habitats with higher moisture contents. This moisture requirement may explain other distributional trends in the occurrence of *Plectus*. In the maritime Antarctic, Mouratov et al. (2001) found *Plectus* spp. abundance to be highest in the deepest soil layer they studied and under the moss, *Saniona uncinata*. In these environments soil moisture is likely to be higher at depth in the soil profile and also under mosses than in bare surface soil habitats. Courtright et al. (2001) also noted that *P. murrayi* were more frequently found in soils with higher $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, organic C, and organic C/organic N ratios than other nematode genera (e.g. *Scottinema*). *Plectus* spp. seem to be sensitive to variation in soil salinity and only occur in soils with low EC ($<100 \text{ mS cm}^{-1}$), which typically are moist environments where salts have been leached from the soil or sediment. Shishida and Ohyama (1986) noted that *P. frigophilus* seems to prefer habitats of fresh water algae to those of mosses.

***Eudorylaimus* (Dorylaimida: Dorylaimidae)**

There are six recognized *Eudorylaimus* species endemic to continental Antarctica: *E. antarcticus* (Yeates, 1970), *E. nudicaudatus* (Heyns, 1993), *E. shirasei* (Kito, Shishida & Ohyama, 1996), *E. glacialis* (Andrássy, 1998), *E. quintus* (Andrássy 2008) and *E. sextus* (Andrássy 2008). *E. antarcticus* is nearly universally reported as the sole species recovered from Victoria Land, but it has been suggested that this species is widely

Table 3. Biogeographic distribution of *Eudorylaimus* species in Victoria Land, Antarctica. NP = not published. NA = not available. *ant* = *E. antarcticus*, *gla* = *E. glacialis*. For abundance, Low = >0 to 20 nematodes per kg dry soil, M-low = 21 to 200 nematodes per kg dry soil, M-medium = 201 to 600 nematodes per kg dry soil, M-high = 601 to 1000 nematodes per kg dry soil, High = 1001 to 2000 nematodes per kg dry soil, V-high = >2000 nematodes per kg dry soil, *n* = number of samples and % = percentage of samples in which *Eudorylaimus* occurred. ^AThere may have been a typographical error in the original publication reporting this longitude. ^BASPA = Antarctic Specially Protected Area (previously Site of Special Scientific Interest). For references to “this paper”, the year collected refers to the year at the beginning of the austral summer in which samples were collected at 0–10 cm depth.

Biogeographic location	Lat (S)	Long (E)	Habitat	Species	Abundance	Reference
McMurdo Dry Valleys	*77°30.00'	162°00.00'				
-	NP	NP	soil	<i>ant</i>	Present	(Freckman and Virginia 1990)
-	NP	NP	soil	<i>ant, gla</i>	M-low	(Freckman and Virginia 1993)
-	NP	NP	soil	<i>ant</i>	Present	(Freckman and Virginia 1997)
-	NP	NP	soil, sediment	<i>ant</i>	Present	(Moorhead et al. 1999)
<i>Alatina Valley</i>	*76°52.82'	161°13.82'				
Bartleship Promontory	*76°54.85'	160°59.34'				
-	NA	NA	soil	<i>ant</i>	M-low (<i>n</i> =17, 65%)	This paper, collected in 1993
-	76°55.30'	161°04.79'	moist soil, green with algae and between dolomite rocks	<i>ant</i>	Low (<i>n</i> =9, 22%)	This paper, collected in 1994
-	NA	NA	soil	<i>ant</i>	M-low (<i>n</i> =6, 17%)	This paper, collected in 1996
<i>Southwestern Bluff</i>	76°55.00'	161°03.00'	soil	<i>ant</i>	Low (<i>n</i> =14, 7%)	This paper, collected in 2001
-	NA	NA	soil	<i>ant</i>	Low (<i>n</i> =6, 50%)	This paper, collected in 2003
<i>Garwood Valley</i>	*78°02.00'	164°10.00'				
Garwood Lake	*78°01.58'	164°15.42'	NP	<i>ant</i>	Present	(Timm 1971)
-	NA	NA	soil	<i>ant</i>	M-low (<i>n</i> =6, 100%)	This paper, collected in 1993
-	78°02.00'	164°10.00'	soil	<i>ant</i>	M-low	(Wall Freckman and Virginia 1998)
-	NA	NA	soil	<i>ant</i>	M-low (<i>n</i> =13, 2.3%)	This paper, collected in 2002
<i>McKelvey Valley</i>	*77°26.00'	161°33.00'				
Upper	NA	NA	soil	<i>ant</i>	M-low (<i>n</i> =18, 33%)	This paper, collected in 1990
<i>Miers Valley</i>	*78°06.00'	164°00.00'				
Miers Glacier (the foot of)	*78°05.00'	163°40.00'	moss	<i>ant</i>	Present	(Timm 1971)
<i>Runoff stream from the Miers Glacier</i>	*78°05.00'	163°40.00'	NP	<i>ant</i>	Present	(Timm 1971)
Miers Lake	*78°06.00'	163°51.00'	NP	<i>ant</i>	Present	(Timm 1971)

Biogeographic location	Lat (S)	Long (E)	Habitat	Species	Abundance	Reference
-	NA	NA	soil	<i>ant</i>	M-low ($n=24$, 50%)	This paper, collected in 1990
<i>Taylor Valley</i>	*77°38.82'	163°03.08'				
Lake Bonney	*77°43.00'	162°25.00'				
-	NP	NP	NP	<i>ant</i>	Present	(Timm 1971)
-	NA	NA	soil	<i>ant</i>	Low ($n=99$, 52%)	This paper, collected in 1994
-	NA	NA	soil	<i>ant</i>	M-low ($n=2$, 100%)	This paper, collected in 1995
-	NA	NA	algal mat	<i>ant</i>	NA ($n=5$, 60%)	This paper, collected in 1995
-	NP	NP	soil, sediment	<i>ant</i>	Low	(Moorhead et al. 1999)
<i>West Lobe</i>	77°43.50'	162°18.95'	soil	<i>ant</i>	Low ($n=18$, 61%)	This paper, collected in 1999, 2001 and 2002
-	NA	NA	soil, sediment	<i>ant</i>	M-low ($n=20$, 35%)	This paper, collected in 2000
<i>West Lobe</i>	NA	NA	soil	<i>ant</i>	Low ($n=48$, 2%)	This paper, collected in 2000
Lake Chad	*77°38.55'	162°45.70'				
-	NP	NP	NP	<i>ant</i>	Present	(Timm 1971)
-	NA	NA	soil	<i>ant</i>	M-low ($n=9$, 56%)	This paper, collected in 1995
-	NA	NA	algal mat	<i>ant</i>	NA ($n=1$, 100%)	This paper, collected in 1995
Lake Fryxell	*77°36.58'	163°09.10'				
-	NP	NP	NP	<i>ant</i>	Present	(Timm 1971)
-	NP	NP	algae in a drift stream near the lake	<i>ant</i>	Present	(Wharton and Brown 1989)
-	NA	NA	plant material	<i>ant</i>	Present ($n=10$, 100%)	This paper, collected in 1990
-	NA	NA	soil	<i>ant</i>	Medium ($n=26$, 77%)	This paper, collected in 1990
<i>South side</i>	77°35.94'	163°22.68'	soil	<i>ant</i>	Low ($n=9$, 11%)	This paper, collected in 1993
-	NA	NA	soil	<i>ant</i>	Low ($n=102$, 41%)	This paper, collected in 1994
<i>South side</i>	77°36.49'	163°18.95'	soil	<i>ant</i>	Low ($n=18$, 33%)	This paper, collected in 1996, 1998 and 2001
-	NA	NA	soil	<i>ant</i>	Low ($n=5$, 20%)	This paper, collected in 1997
-	NA	NA	algal mat	<i>ant</i>	Present ($n=1$, 100%)	This paper, collected in 1998
-	NA	NA	soil	<i>ant</i>	Medium ($n=4$, 75%)	This paper, collected in 1998
<i>Von Guenard stream/ Harnish Creek</i>	*77°37.00'	163°15.00'	stream sediments and surrounding soils	<i>ant, gla</i>	Medium	(Iretonis et al. 1999)
-	NP	NP	soil, sediment	<i>ant</i>	Low	(Moorhead et al. 1999)
<i>Von Guenard stream</i>	*77°37.00'	163°15.00'	soil	<i>ant</i>	M-low ($n=8$, 63%)	This paper, collected in 1999
<i>Huey Creek stream</i>	*77°36.00'	163°06.00'	soil	<i>ant</i>	M-low ($n=7$, 29%)	This paper, collected in 1999
<i>South side</i>	77°36.49'	163°14.92'	soil	<i>ant</i>	M-low ($n=12$, 83%)	This paper, collected in 1999 and 2001

Biogeographic location	Lat (S)	Long (E)	Habitat	Species	Abundance	Reference
Harnish Creek	*77°37.00'	163°13.00'	soil and stream sediment	<i>ant</i>	Medium (<i>n</i> =20, 70%)	This paper, collected in 2000
South side	NA	NA	soil	<i>ant</i>	M-low (<i>n</i> =96, 97%)	This paper, collected in 2000, 2002 and 2003
-	77°36.00'	^162°15.00'	soil	<i>ant</i>	Low	(Ireonis et al. 2002)
South side near F6 stream	77°36.40'	163°15.30'	soil and lake sediment	<i>ant</i>	M-low (<i>n</i> =12, 33%)	This paper, collected in 2002
South side near Green Creek	77°37.36'	163°03.91'	soil	<i>ant</i>	Medium (<i>n</i> =20, 45%)	This paper, collected in 2003
South Side near F6 stream	77°36.72'	163°15.18'	soil	<i>ant</i>	M-low (<i>n</i> =20, 35%)	This paper, collected in 2003
Green Creek	77°37.36'	163°03.91'	soil	?	Medium	(Barrett et al. 2006c)
Von Guenard stream	*77°37.00'	163°15.00'	soil	?	M-Low	(Barrett et al. 2006c)
Lake Hoare	*77°38.00'	162°51.00'				
North side	77°37.49'	162°54.31'	soil	<i>ant</i>	Low (<i>n</i> =18, 78%)	This paper, collected in 1993
South side	77°38.03'	162°52.75'	soil	<i>ant</i>	Low (<i>n</i> =9, 33%)	This paper, collected in 1993
South side	NA	NA	soil	<i>ant</i>	Low (<i>n</i> =12, 25%)	This paper, collected in 1993
South side	77°37.59'	162°52.57'	soil	<i>ant</i>	M-low (<i>n</i> =56, 77%)	This paper, collected in 1993, 1994, 1995, 1996, 1997 and 2001
North side	77°38.00'	162°53.00'	soil (0-2.5, 2.5-5, 5-10, 10-20 cm)	<i>ant</i>	M-low	(Powers et al. 1994a)
South side	NP	NP	soil at varying elevations	<i>ant, gla</i>	M-low	(Powers et al. 1994b)
-	NA	NA	soil polygons	<i>ant</i>	Low (<i>n</i> =104, 17%)	This paper, collected in 1994
North side	77°38.00'	162°53.00'	soil (0-2.5, 2.5-5, 5-10, 10-20 cm)	<i>ant</i>	M-low	(Powers et al. 1995b)
South side	77°38.00'	162°53.00'	soil at varying elevations	<i>ant</i>	Low	(Powers et al. 1995a)
South side	NA	NA	soil polygons	<i>ant</i>	Low (<i>n</i> =24, 54%)	This paper, collected in 1995
South side	77°37.93'	162°53.19'	soil	<i>ant</i>	M-low (<i>n</i> =150, 51%)	This paper, collected in 1995, 1998 and 2002
North side	77°37.49'	162°54.31'	soil	<i>ant</i>	Low	(Courtright et al. 1996)
-	NP	NP	soil	<i>ant</i>	M-low	(Freckman and Virginia 1997)
South side	77°38.00'	162°53.00'	soil	<i>ant, gla</i>	Medium	(Powers et al. 1998)
-	NP	NP	soil, sediment	<i>ant</i>	Low	(Moorhead et al. 1999)
North side	NA	NA	soil	<i>ant</i>	Low (<i>n</i> =8, 38%)	This paper, collected in 1999
South side	NA	NA	soil	<i>ant</i>	M-low (<i>n</i> =8, 75%)	This paper, collected in 1999
South side	77°38.00'	162°53.00'	soil	<i>ant</i>	M-low	(Ireonis et al. 2000; 2002)
North side	77°37.29'	162°54.19'	soil	<i>ant</i>	Low	(Courtright et al. 2001)
South side	77°38.07'	162°52.59'	soil	<i>ant</i>	Low (<i>n</i> =12, 58%)	This paper, collected in 2001, 2002
South side	77°38.00'	162°53.00'	soil	<i>ant</i>	M-low	(Porazinska et al. 2002b)
-	77°37.90'	162°53.20'	soil and lake sediment	<i>ant</i>	M-low (<i>n</i> =11, 64%)	This paper, collected in 2002

Biogeographic location	Lat (S)	Long (E)	Habitat	Species	Abundance	Reference
-	77°37.00'	160°50.00'	soil	<i>ant</i>	M-low	(Wall Freckman and Virginia 1998)
-	NP	NP	soil	<i>ant</i>	M-low	(Iretonis et al. 2000)
-	NP	NP	0-5 cm soil (subnivian)	<i>ant</i>	M-low	(Gooseff et al. 2003)
Nussbaum Riegel	77°38.52'	162°46.89'	soil	<i>ant</i>	Low (<i>n</i> =5, 60%)	This paper, collected in 1997
Suess Glacier, 50 m away	*77°38.00'	162°40.00'	soil	<i>ant</i>	Present	(Timm 1971)
Suess Pond	NP	NP	NP	<i>ant</i>	Present	(Timm 1971)
Victoria Valley	*77°23.00'	162°00.00'				
Lake Vida	*77°23.29'	161°56.05'	NP	<i>ant</i>	Present	(Timm 1971)
Upper	NA	NA	soil	<i>ant</i>	Low (<i>n</i> =20, 5%)	This paper, collected in 1990
Victoria Upper Glacier	77°17.35'	161°33.03'	soil	<i>ant</i>	Low (<i>n</i> =10, 43%)	This paper, collected in 1993
-	77°23.00'	162°00.00'	soil	<i>ant</i>	Low	(Wall Freckman and Virginia 1998)
-	NA	NA	soil	<i>ant</i>	Present (<i>n</i> =6, 50%)	This paper, collected in 2003
Wright Valley	*77°31.39'	161°58.70'				
Between Lake Vanda and Lake Bull	NP	NP	dry algae around the edge of small ponds	<i>ant</i>	Present	(Wharton and Brown 1989)
Dais	*77°33.00'	161°16.00'	soil	<i>ant</i>	Low (<i>n</i> =3, 67%)	This paper, collected in 2000
East of Meserve Glacier	*77°31.00'	162°17.00'	algal mat	<i>ant</i>	Present	(Timm 1971)
Labyrinth	*77°33.00'	160°50.00'				
West	77°33.04'	160°43.15'	soil	<i>ant</i>	Low (<i>n</i> =9, 89%)	This paper, collected in 1993
-	77°33.04'	160°43.15'	soil	<i>ant</i>	Low (<i>n</i> =9, 11%)	This paper, collected in 1993
-	77°33.04'	160°43.15'	soil	<i>ant</i>	Low	(Courtright et al. 1996)
West	77°33.02'	160°43.09'	soil	<i>ant</i>	Low	(Courtright et al. 2001)
-	NA	NA	soil	<i>ant</i>	Low (<i>n</i> =12, 8%)	This paper, collected in 2003
Bull Pass	*77°28.00'	161°46.00'	soil	<i>ant</i>	Low (<i>n</i> =12, 33%)	This paper, collected in 1990
Bull Lake	*77°31.51'	161°42.68'	soil	<i>ant</i>	Low (<i>n</i> =22, 5%)	This paper, collected in 1990
-	*77°28.00'	161°46.00'	soil	<i>ant</i>	M-Low (<i>n</i> =24, 12.5%)	(Poage et al. 2008)
Lake Vanda	*77°32.00'	161°33.00'				
-	NP	NP	NP	<i>ant</i>	Present	(Timm 1971)
<i>Near Lake Vanda and Pévé Lake</i>	*77°32.00'	161°33.00'	stony soil	<i>ant</i>	Present	(Timm 1971)
<i>Mer Station</i>	NA	NA	soil	<i>ant</i>	M-low (<i>n</i> =2, 100%)	This paper, collected in 2002

Biogeographic location	Lat (S)	Long (E)	Habitat	Species	Abundance	Reference
Lake Brownworth	*77°26.00'	162°45.00'	NP	<i>ant</i>	Present	(Timm 1971)
-	NA	NA	soil	<i>ant</i>	Low (<i>n</i> =5, 60%)	This paper, collected in 1997
-	77°31.00'	161°50.00'	soil	<i>ant</i>	M-low	(Wall Freckman and Virginia 1998)
-	NA	NA	soil	<i>ant</i>	Present (<i>n</i> =10, 50%)	This paper, collected in 2003
Onyx River pond	*77°32.00'	161°45.00'	NP	<i>ant</i>	Present	(Timm 1971)
Linnaeus Terrace ASPA ^B	77°35.83'	161°05.00'	soil	<i>ant</i>	Low (<i>n</i> =16, 6%)	This paper, collected in 1990
Koetitz Glacier and Southern Coastal Regions	*78°15.00'	164°15.00'				
<i>Cape Chocolate</i> (north)	*76°56.00'	164°35.00'	moraine	<i>ant</i>	Present	(Timm 1971)
<i>Strand Moraines</i>	*77°45.04'	164°29.90'	algal mat (in stream bed), sandy soil	<i>ant</i>	Present	(Timm 1971)
<i>Marble Point</i>	*77°26.00'	163°50.00'	NP	<i>ant</i>	Present	(Timm 1971)
Northern Coastal Regions						
<i>Cape Adare</i>	*71°17.00'	170°14.00'	NP	<i>ant</i>	Present	(Timm 1971)
<i>Cape Hallett</i>	*72°19.00'	170°16.00'				
Hallett Station	*72°19.00'	170°16.00'	NP	<i>ant</i>	Present	(Timm 1971)
-	NA	NA	soil	<i>ant</i>	Low (<i>n</i> =20, 20%)	This paper, collected in 2003
Cape Hallett	72°19.29'	170°13.52'	soil		Low (<i>n</i> =67, 67%)	(Raymond et al. 2013a)
<i>Edmonson Point</i>	*74°20.00'	165°08.00'				
-	NA	NA	soil	<i>ant</i>	Low (<i>n</i> =10, 30%)	This paper, collected in 1996
-	NA	NA	soil	<i>ant</i>	Present (<i>n</i> =28, 7%)	This paper, collected in 1996
-	NP	NP	NP	<i>ant, gla</i>	Present	(Bargagli et al. 1997)
-	NA	NA	soil	<i>ant</i>	Low (<i>n</i> =8, 25%)	This paper, collected in 2001
<i>Gondwana Station</i>	74°37.57'	164°11.91'	soil	<i>ant</i>	Low (<i>n</i> =371, 37%)	(Raymond et al. 2013a)
<i>Luther Peak</i>	*72°21.88'	169°50.91'	soil	<i>ant</i>	M-low (<i>n</i> =40, 85%)	This paper, collected in 2003
Luther Vale North	72°22.00'	169°53.00'	soil	?	M-Low	(Barrett et al. 2006c)
Luther Vale South	72°22.00'	169°53.00'	soil	?	M-Low	(Barrett et al. 2006c)
<i>Terra Nova Bay</i>	*74°54.51'	164°27.19'				
600 km north and south of the Italian station	NP	NP	mosses, lichens, fresh-water sediments and penguin excrement (there are no details of whether <i>Eudorylaimus</i> occurred in all habitats or only in some)	<i>ant</i>	Present	(Vinciguerra et al. 1994)
<i>Bardley Glacier</i>	NP	NP	algae in meltwater	<i>ant</i>	Present	(Wharton and Brown 1989)

codistributed with *E. glacialis* (Andrássy 2008). We report both where two distinct morphotypes were observed.

Biogeographic distribution. *E. antarcticus* is widely distributed within Victoria Land (Table 3). Steiner (1916) described the original specimens, which were collected by the Discovery Expedition from Discovery Bay (no notes were made on habitat). Later studies list *E. antarcticus* from locations throughout the McMurdo Dry Valleys, (reported most frequently from Taylor Valley) and in northern Victoria Land at Edmonson Point and Terra Nova Bay (Table 3).

Outside of the Victoria Land region, *E. antarcticus* has been reported from several of the maritime islands (Signy, Alexander, King George, Anvers) (e.g. Maslen 1982; Mouratov et al. 2001; Shishida and Ohyama 1989; Spaul 1973a, b; Wharton and Block 1993). Andrásy (1998, 2008), in contrast, argues for a more restricted distribution within Victoria Land (Andrásy 2008).

Habitat. *E. antarcticus* in Victoria Land occurs at varying elevation and most commonly in soils and in lake sediments. The genus has also frequently been associated with algal mats, both dry and moist found in meltwater, streambeds and lakes. *E. antarcticus* has been reported less frequently in areas of moss and from soils. In contrast, outside Victoria Land (e.g. Ross Island) the occurrence of *E. antarcticus* in a moss habitat (e.g. *Bryum argenteum*) is common, but it does not occur in penguin rookeries (on Ross Island or in Victoria Land). In soils of the McMurdo Dry Valleys *E. antarcticus* tends to be found in soils with higher moisture, $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, organic C, and organic C/organic N ratios, and only occurs in soils with low salinity ($\text{EC} < 100 \text{ mS cm}^{-1}$) (Courtright et al. 2001).

***Panagrolaimus* (Panagrolaimida: Panagrolaimidae)**

Biogeographic distribution. The Antarctic *Panagrolaimus* consists of two species, *P. magnivulvatus* and *P. davidi* (but see Raymond et al. 2013b). Both are endemic (Andrásy 1998). *P. davidi* is the only species recorded from Victoria Land and its occurrence is rare (see Table 4). Until the present study, the only record of *P. davidi* in Victoria Land was from Marble Point (Timm 1971). The current study shows that *P. davidi* is also present in the northern coastal region of Victoria Land, at Edmonson Point and Cape Hallett and in Miers Valley, one of the McMurdo Dry Valleys. Thus, *P. davidi* occurs most frequently in coastal regions but is not necessarily restricted to them.

P. davidi has been recorded from Ross Island (e.g. Freckman and Virginia 1993; Porazinska et al. 2002a; Sinclair 2001; Sinclair and Sjørnsen 2001; Timm 1971; Wharton and Brown 1989). *Panagrolaimus* spp. have also been reported from several of the maritime islands (summarized in Andrásy 1998 and references therein, see also Raymond et al. 2013b).

Habitat. Penguin rookeries and moss-covered soils appear to be the most favorable habitats for *P. davidi* in Victoria Land and are consistent with the habitats where *P. davidi* has been found in other Antarctic ice-free areas (Porazinska et al. 2002a; Sin-

Table 4. Biogeographic distribution of *Panagrolaimus davidi* in Victoria Land, Antarctica. NP = not published. NA = not available. For references to “this paper”, the year collected refers to the year at the beginning of the austral summer in which samples were collected. For abundance, M-low = 21 to 200 nematodes per kg dry soil, Medium = 201 to 600 nematodes per kg dry soil, *n* = number of samples and % = percentage of samples in which *Panagrolaimus* occurred.

Biogeographic location	Lat (S)	Long (E)	Habitat	Abundance	Reference
McMurdo Dry Valleys	*77°30.00'	162°00.00'			
Miers Valley	*78°06.00'	164°00.00'	soil	M-low (<i>n</i> =24, 29%)	This paper, collected in 1990
Southern Coastal Region					
Marble Point	*77°26.00'	163°50.00'	mossy soil (<i>Bryum antarcticum</i>)	Present	(Timm 1971)
Northern Coastal Region					
Cape Bird	77°13.00'	166°26.00'	soil in penguin rookery	Medium (<i>n</i> =29, 52%)	(Porazinska et al. 2002a)
Cape Crozier	77°27.00'	169°11.00'	soil in penguin rookery	M-low (<i>n</i> =27, 48%)	(Porazinska et al. 2002a)
Cape Hallett	*72°19.00'	170°16.00'			
-	NA	NA	soil in penguin rookery	Low (<i>n</i> =2, 50%)	This paper, collected in 2002
Willet Cove	72°19.00'	170°14.00'	soil	M-High	(Barrett et al. 2006c)
Seabee Spit	72°18.83'	170°13.00'	soil	Low	(Barrett et al. 2006c)
Cape Hallett	72°19.29'	170°13.52'	soil	M-Low (<i>n</i> =56, 56%)	(Raymond et al. 2013a)
Cape Royds	77°33.00'	166°10.00'	soil amongst penguin rookery	M-low (<i>n</i> =66, 20%)	(Porazinska et al. 2002a)
-	NA	NA	soil pits amongst penguin rookery	Med (<i>n</i> =20, 70%)	This paper, collected in 2003
Edmonson Point	*74°20.00'	165°08.00'	soil	Present (<i>n</i> =28, 4%)	This paper, collected in 1996
Gondwana Station	74°37.57'	164°11.91'	soil	M-Low (<i>n</i> =371, 34%)	(Raymond et al. 2013a)

clair 2001; this paper; Timm 1971; Wharton and Brown 1989). Evidence indicates *P. davidi* occurs in habitats of high primary productivity and soil organic matter (as does *P. magnivulvatus*) regardless of its source of origin (e.g. mosses or penguin guano) though it is primarily associated with penguin rookeries (Porazinska et al. 2002a; Sinclair and Sjørnsen 2001). The presence of *P. davidi* is strongly correlated with organic carbon, organic nitrogen, chlorophyll *a* (a measure of primary productivity) and ammonium (Porazinska et al. 2002a; Sinclair and Sjørnsen 2001). The species is also more abundant in the highly productive areas of moss and algae along snow melt streams than in adjacent soils (Sinclair and Sjørnsen 2001).

***Geomonhystera* (Monhysterida: Monhysteridae)**

Several nematode species originally described as *Monhystera* were redescribed by Andr ssy in 1981 as *Geomonhystera*. Among these was *Monhystera villosa* from the Antarctic (Timm 1971), which Andr ssy subsequently redescribed as a new species, *Geomonhystera antarctica* (Andr ssy 1998). It is the only known species of *Geomonhystera* on the continent, thus, we report all published observations of the genus from Victoria Land as *G. antarctica*.

Biogeographic distribution. *G. antarctica* are generally rare, and along with *P. davidi* are the least abundant and most patchily distributed of all nematodes in Victoria Land. Other species of *Geomonhystera* occur in the islands of the maritime Antarctic (Signy, Coronation, Elephant, Intercurrence and Galindez) where *G. antarctica* is one of the most common nematode species (Maslen 1981; Newsham et al. 2004; Spaul 1973a, b, c). They were originally recorded as Monhysterid genus A. and renamed as *Monhystera villosa* by Maslen (1979). Newsham et al. (2004) identified specimens from Signy Island as *G. villosa*.

Sohlenius et al. recorded *Monhystera* from the Nunataks of Dronning Maud Land, East Antarctica (Sohlenius et al. 1995, 1996), and they have also been recovered from Macquarie Island of the Sub-Antarctic (Bunt 1954) and Signy Island of the maritime Antarctic (Caldwell 1981; Maslen 1981; Spaul 1973a, b, c; Wharton and Block 1993) but only identified as *Monhystera* spp., so it is unknown whether these nematodes could also be *Geomonhystera*. Some previously recorded *Monhystera* of the subantarctic (*M. vulgaris*, and *M. filiformis*) (Bunt 1954) are not *Geomonhystera* but more likely *Eumonhystera* (Andr ssy 1981) or *Halomonhystera* (Andr ssy 2006).

Habitat. The habitat of *Geomonhystera* in Victoria Land differs from that of *Geomonhystera* as described by Andr ssy (1981), and for *Geomonhystera* of the maritime Antarctic, and *Monhystera* spp. of the maritime Antarctic and Dronning Maud Land. In Victoria Land, *Geomonhystera* are similarly found in soil, but have also been associated with algal mats (e.g. Timm 1971; Wharton and Brown 1989) and moss carpets (Andr ssy 1998, this paper). *Monhystera* spp. described from the Nunataks of Dronning Maud Land (Sohlenius et al. 1995; 1996) have only been found under lichens but there is no apparent link between *Geomonhystera* of Victoria Land and lichens.

Table 5. Biogeographic distribution of *Geomonhystera antarctica* in Victoria Land, Antarctica. NP = not published. NA = not available. For references to “this paper”, the year collected refers to the year at the beginning of the austral summer in which samples were collected. For abundance, Low = >0 to 20 nematodes per kg dry soil, M-low = 21 to 200 nematodes per kg dry soil, n = number of samples and % = percentage of samples in which *Geomonhystera* occurred.

Biogeographic location	Lat (S)	Long (E)	Habitat	Abundance	Reference
McMurdo Dry Valleys	*77°30.00'	162°00.00'			
<i>Alarna Valley</i>	*76°52.82'	161°13.82'			
Battleship Promontory	*76°54.85'	160°59.34'			
-	NA	NA	soil	Low (n=17, 47%)	This paper, collected in 1993
<i>Southwestern Bluff</i>	76°55'.00	161°03'.00	soil	Low (n=14, 14%)	This paper, collected in 2001
-	NA	NA	soil	Low (n=6, 50%)	This paper, collected in 2003
<i>Taylor Valley</i>	*77°38.82'	163°03.08'			
Lake Bonney	*77°43.00'	162°25.00'	soil	M-low (n=2, 50%)	This paper, collected in 1998
<i>Wright Valley</i>	*77°31.39'	161°58.70'			
183 m east of Messerve Glacier	*77°31.00'	162°17.00'	algal mat on soil	Present	(Timm 1971)
Between Lake Vanda and Lake Bull	NP	NP	dry algae from the edge of a small pond	Present	(Wharton and Brown 1989)
-			soil	Low (n=10, 20%)	This paper, collected in 2003
Northern Coastal Region					
<i>Edmonson Point</i>	*74°20.00'	165°08.00'	soil	Present	(Bargagli et al. 1997)

Table 6. Ecology of Nematode Genera in Victoria Land.

Genus	Co-occurs with	Nematode community complexity	Feeding	Reproduction
<i>Scottinema</i>	<i>Eudorylaimus</i> , <i>Plectus</i> , <i>Geomonhystera</i> , <i>Panagrolaimus</i> (rare, only in Dry Valleys; Bargagli et al. 1997; Courtright et al. 2001; this paper),	1 species- most common 2 species- often (usually <i>E. antarcticus</i>), 3 or 4 species- rare 5 species- not recorded (Courtright et al. 2001; Freckman and Virginia 1997; this paper)	bacteria, yeast (Overhoff et al. 1993)	amphimictic (Overhoff et al. 1993)
<i>Plectus</i>	<i>Scottinema</i> , <i>Eudorylaimus</i> , <i>Geomonhystera</i> , <i>Panagrolaimus</i>	1 species- rare 2 species- most common (usually with <i>Eudorylaimus</i>), 3- often 4 species- rare 5 species- not recorded	bacteria (Wharrron and Brown 1989)	usually unisexual (parthenogenic), males do exist but are very rare (Andrássy 2008; Kito et al. 1991; Vinciguerra 1994)
<i>Eudorylaimus</i>	<i>Scottinema</i> , <i>Plectus</i> , <i>Geomonhystera</i> , <i>Panagrolaimus</i>	1 species- not recorded 2 species- most common (usually with <i>Scottinema</i> or <i>Plectus</i>), 3- often 4 species- rare 5 species- not recorded	<i>Eudorylaimus</i> are thought to feed on fungi, unicellular algae and soil invertebrates (Raymond et al. 2013a; Yeates et al. 1993); presence of chloroplasts in esophagus (Wall 2007)	amphimictic (<i>E. antarcticus</i>) (Yeates 1970)
<i>Panagrolaimus</i>	<i>Scottinema</i> (rare, only in Dry Valleys), <i>Eudorylaimus</i> , <i>Plectus</i>	1 species- common (most common outside of Victoria Land) 2 species- rare 3- common (with <i>Eudorylaimus</i> and <i>Plectus</i>), 4 species- rare, only in Dry Valleys 5 species- not recorded (Porazinska et al. 2002a; this paper)	bacteria (Wharrron 1994; Wharrron and Barclay 1993)	amphimictic (Timm 1971)
<i>Geomonhystera</i>	<i>Scottinema</i> , <i>Eudorylaimus</i> , <i>Plectus</i>	1 species- not recorded 2 species- often (with <i>E. antarcticus</i>) 3- most common (with <i>S. lindsayae</i> and <i>E. antarcticus</i>) 4 species- often 5 species- not recorded (this paper)	algae, fungi, actinobacteria (Newsham et al. 2004)	amphimictic (Andrássy 1981; Timm 1971)

Discussion

Nematode diversity in Victoria Land is low compared to the Antarctic Peninsula, but the presence of a few cryptic species is likely (Barrett et al. 2006c; Raymond et al. 2013b). Extensive sampling across broader geographic scales, combined with molecular techniques will likely recover additional species from both locations. With the exception of *Panagrolaimus davidii* and *Geomonhystera* spp., all species are widely distributed throughout Victoria Land, from the south coast and the most southern McMurdo Dry Valleys to the northern coastal region. This distribution suggests that their dispersal is ubiquitous and primarily by wind while in anhydrobiois (Nkem et al. 2006b), and it is the suitability of the soil habitat that determines the likelihood of population and community establishment and functioning (Virginia and Wall 1999).

Our knowledge of nematode biodiversity, distribution, and function in Victoria Land is based on clusters of studies from a few distinct regions, such as the McMurdo Dry Valleys, and far northern coastal Victoria Land, which are accessible from established research stations. The rest of Victoria Land (including other inland ice-free areas) has been largely inaccessible. Studies throughout the McMurdo Dry Valleys are also patchy with some valleys being studied heavily (e.g. Taylor Valley) whilst others (e.g. Barwick Valley) have barely been investigated. More undescribed nematodes may occur in these less studied regions.

Conclusions

Habitat suitability for each nematode species is determined primarily by variations in soil factors such as quantities and types of organic material, moisture and salinity (Nkem et al. 2006a; Virginia and Wall 1999). *Scottinema lindsayae* is the most abundant and widespread nematode and has a unique tolerance for a wide range of extreme soil habitats, and it is also the most tolerant to low soil moisture and high salinity of all the nematode species studied. These conditions define the most common soil habitats throughout the cold desert ecosystems of Victoria Land and explain the high abundance and broad distribution of *S. lindsayae* throughout the region. There are less extensive suitable habitats available in Victoria Land for *Plectus* spp. and *Eudorylaimus antarcticus* as their distributions are limited to habitats with higher moisture, greater organic material and lower salinity. *P. davidii* has a very limited biogeographic distribution, almost entirely restricted to coastal Victoria Land. This species is found in habitats with high primary productivity, of which there are few. Factors defining suitable habitats and the biogeographic distribution of *Geomonhystera* spp. in Victoria Land are the least understood, largely due to very low abundance and limited occurrence, although they have been recovered from sites across Victoria Land. There appears to be an association with algae but little else is known of their habitat requirements.

We have made considerable progress in understanding the basic relationships between soil properties and the distribution of the key nematode taxa throughout

Victoria Land. Suitable habitats can be defined by moisture, salinity, organic matter and nutrient content, and the interactions between these factors. Manipulations of soil moisture and field observations of environmental change during pulse warming events show that nematode community composition can respond on time scales of seasons to decades (Ayres et al. 2010; Doran et al. 2002). The climate of Victoria Land is expected to change with warmer conditions (Adams et al. 2009; Jones et al. 1998; Salby et al. 2011; Solomon et al. 2007; Steig et al. 2009; Thompson and Solomon 2002) leading to increasing soil moisture, redistribution of salts, and potentially higher productivity (Gooseff et al. 2011; Nielsen et al. 2012). These changes may alter the spatial distributions of suitable habitats for individual nematode species and/or alter population size and community diversity (Nielsen et al. 2011b). Studies have shown the important role of nematodes in carbon cycling, suggesting that changes in nematode biogeography will be linked with changes in ecosystem functioning in Antarctic soils (Barrett et al. 2008).

The nematofauna of Victoria Land are capable of long distance dispersal by wind (Nkem et al. 2006b) but the Antarctic continent is effectively isolated from source populations elsewhere in the southern hemisphere (Convey et al. 2008; Convey and Stevens 2007). This leaves anthropogenic dispersal by way of tourists and scientists as the primary mechanism for the movement of alien species to Antarctica (Chown et al. 2012a). From a field sample collected in Wright Valley in the 2011–2012 field season, we recovered an individual living female *Cuticularia fermata*, a nematode heretofore known only from South Orkney Island (subantarctic island). Whether this specimen was transported to the site on clothing or equipment used by scientists or if there are established, low-density, isolated populations in the area is unknown. It is highly likely that the frequency of nematode introductions to Victoria Land will increase as tourism and scientific research increases (Chown et al. 2012a). There is a growing international consensus that action is needed to reduce the potential introductions of invasive soil species to continental Antarctica and the Peninsula and maritime regions (Chown et al. 2012b). A greater knowledge of nematode biogeography will be essential in understanding how to protect special soil habitats to preserve existing biodiversity and to prevent the introduction of non-native species and the potential harm they cause to the unique soil ecosystems of Antarctica.

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Genetics and shell morphometrics of assimineids (Mollusca, Caenogastropoda, Truncatelloidea) in the St Lucia Estuary, South Africa

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Abstract

The Assimineidae are a family of amphibious microgastropods that can be mostly found in estuaries and mangroves in South Africa. These snails often occur in great numbers and are ecologically important to the St Lucia Estuary, which forms a crucial part of the iSimangaliso Wetland Park, a UNESCO World Heritage Site. Genetic and shell morphometric analyses were conducted on individuals collected from nine localities distributed from the northern lake regions to the southern lake and the mouth of the St Lucia estuarine lake. Mitochondrial (COI) and nuclear (28S) DNA was used to construct Bayesian Inference, Neighbour-joining, Maximum Parsimony and Maximum Likelihood trees. Principal Component Analysis and Cluster Analysis were performed on standard shell parameter data. Results indicate that two different taxa are present in St Lucia. The taxon comprising individuals from the South Lake and St Lucia Estuary Mouth is identified as *Assiminea* cf. *capensis* Bartsch, in accordance with the latest taxonomic consensus. The taxon comprising assimineid individuals from False Bay, North Lake and South Lake, is here tentatively named “A.” aff. *capensis* (Sowerby). These two taxa exhibit patterns of spatial overlap that appear to vary depending on environmental parameters, particularly salinity. The need to resolve the complex taxonomy of assimineids is highlighted.

Keywords

Microgastropods, *Assiminea*, taxonomy, St Lucia Estuary, iSimangaliso Wetland Park

Introduction

Assimineidae is a poorly understood family of small amphibious gastropods, belonging to the superfamily Truncatelloidea (previously Rissooidea) (Criscione and Ponder 2013) and are found in estuaries, mangroves, freshwater springs, rivers, streams and terrestrial habitats such as forests, limestone areas and mountain sides (Abbott 1958; Millard and Broekhuysen 1970; Appleton 2002; Fukuda and Ponder 2003; Strong et al. 2008). Some assimineids are recorded inhabiting environments with salinities ranging from freshwater to seawater (Appleton 2002), with a species identified as *Assimineea bifasciata* having been recorded in salinities ranging from 8.3 to 37.6 (Millard and Broekhuysen 1970). Assimineids can be traced to the mid-Tertiary of the Caenozoic Era (65–5 mya, Blair et al. 2001) but probably have a much longer fossil record. They are widely distributed throughout tropical and temperate regions of the world (Abbott 1958). Sometimes referred to as “sentinel snails”, they tend to have brown shells with well-defined spires and are less than 10 mm in height (Appleton 2002). Most assimineids are gonochoristic and it is difficult to distinguish between different species (Appleton 2002). The taxonomy of assimineids is in a constant state of flux at both the specific and generic level. For example, the generic name *Assimineea* is used both broadly and in a more restricted sense (e.g. Fukuda and Ponder 2005, 2006; Hershler et al. 2007). While efforts have been made to genetically and morphologically describe assimineids occurring in some areas of the world (e.g. Abbott 1958; Fukuda and Ponder 2003, 2005), species occurring in South Africa require clarification although partial revisions have been attempted by Connolly (1939), Barnard (1963) and Brown (1994).

The St Lucia Estuary is the largest estuarine system in Africa, a Ramsar site of International Importance and forms part of South Africa’s first UNESCO World Heritage Site, the iSimangaliso Wetland Park (Fielding et al. 1991; Cyrus and Vivier 2006). Lake St Lucia is a rich and diverse biological ecosystem (Pillay and Perissinotto 2008) with a number of endemic species (e.g. Carrasco and Perissinotto 2012; Daly et al. 2012). Assimineids are vitally important to the ecology of the St Lucia Estuary. They are historically a dominant component of the benthic invertebrate assemblages within the system and contribute towards the diet of various higher trophic organisms. Day et al. (1954) lists *Assimineea* sp. as common throughout the estuarine system. Millard and Broekhuysen (1970) reported *A. bifasciata* as common to all areas of the lake, dominating on mud banks, mangroves and aquatic vegetation. This occurred during a period of low salinity. In a survey of the benthic fauna of the St Lucia system following a high salinity period, Boltz (1975) stated that *A. bifasciata* was by far the most dominant species present (in terms of biomass and numbers) and also served as an important dietary component for the macrobenthic community. In a review of benthic surveys in St Lucia, Owen et al. (2010) list *Assimineea* sp. as having been present in all sampling endeavours since 1948. Gut content analyses of iliophagus fish in the St Lucia Estuary revealed that *A. bifasciata* was a significant component of the diet of several species, including *Chanos chanos*, *Mugil cephalus*, *Liza macrolepis* and *Liza dumerilii* (Whitfield and Blaber 1978). *Assimineea* is also one of the main sources of food for the newly

described species of sea anemone, *Edwardsia isimangaliso*, which is regarded as micro-endemic to the system (Daly et al. 2012).

While the ecological importance of *Assimineea* is widely recognised, there are inconsistencies in the literature in terms of what species are present in the St Lucia Estuary. Much of the earlier literature refers to *A. bifasciata* as the only species of *Assimineea* present in the system (Day et al. 1954; Millard and Broekhuysen 1970; Bolt 1975; Whitfield and Blaber 1978). *A. sinesis* was also recorded from KwaZulu-Natal in early surveys (Abbott 1958), however subsequent literature makes little reference to this species. More contemporary literature makes mention of *A. ovata* (Miranda et al. 2011; Carrasco et al. 2012; Daly et al. 2012). This is due to a change in the taxonomic status of *A. bifasciata* to *A. ovata*, as reported in Appleton (2002). However, *A. globifera* (Taylor et al. 2006) and *A. durbanensis* (Weerts 1993) have also been reported from St Lucia. One of the latest surveys lists three species of *assimineids* in St Lucia (MacKay et al. 2010). Other recent studies make reference to *Assimineea* sp. (Pillay and Perissinotto 2008; Owen et al. 2010), supposedly due to the difficulties encountered with identifying the species.

The present study is the first to address the genetics and shell morphometrics of *assimineids* in the St Lucia Estuary. The aim is to determine the number of distinct taxonomic groups that are present and resolve taxonomic inconsistencies in the literature. This is done by comparing the nuclear and mitochondrial DNA, as well as shell dimensions of individuals of nine different microgastropod populations present inside the system. The specific techniques chosen for this investigation have been used successfully to resolve similar inconsistencies involving *assimineids* in the Rio Grande region of Mexico (Hershler et al. 2007). It is hypothesised that the *assimineids* of St Lucia comprise several distinct phylogenetic groups.

Methods

Study Site. The St Lucia Estuary (28°23'S, 32°24'E) covers an area of approximately 350 km² (Taylor et al. 2006) and is Africa's largest estuarine lake (Cyrus 1988). The system is comprised of three large shallow (average 0.9 m depth) lakes, namely False Bay, North Lake and South Lake (Fig. 1). Salinities can range from oligohaline (salinity 0-5) to hypersaline levels (salinity >100) over the course of a number of years (Day et al. 1954; Cyrus 1988, 2010). During periods of low freshwater input and high evaporative water loss, the system exhibits a reverse salinity gradient: a lower salinity can be recorded in the southern regions closer to the mouth, whereas the northern regions of the system tend to become hypersaline. Droughts occur on an almost decadal basis (Taylor et al. 2006). At the time of the present study, St Lucia was emerging from the most severe drought event on record. This dry period ended with freshwater input from Cyclone Irina in March 2012, which led to a system-wide drop in salinity resulting in near marine levels in the northern regions and fresh and brackish conditions prevailing in the southern regions of the system.

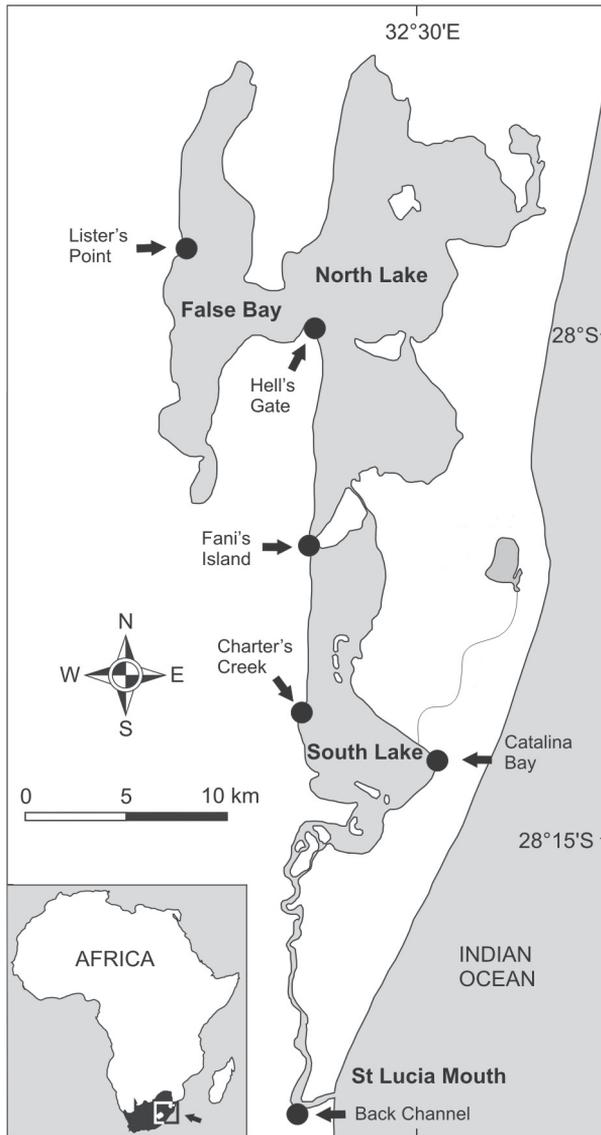


Figure 1. Map of St Lucia Estuary. Sample localities are indicated by arrows and dots (Modified from Miranda et al. 2010).

Sampling. Specimens from 8 populations were collected by net and by hand at 6 localities in the St Lucia Estuary in July and October 2012 (Fig. 1). Snails were collected from two sites at Lister's Point, False Bay, (Site A: $27^{\circ}58'10.66''S$, $32^{\circ}23'5.57''E$ and Site B: $27^{\circ}58'22.30''S$, $32^{\circ}22'28.24''E$). Hell's Gate ($28^{\circ}0'51''S$, $32^{\circ}26'48''E$) and Fani's Island populations ($28^{\circ}6'34''S$, $32^{\circ}26'03''E$) represent the North Lake samples. The False Bay and North Lake region is characterised by highly fluctuating salinities and periodic hypersaline conditions (see Table 1). Charter's Creek ($28^{\circ}11'52''S$,

Table 1. Ranges of physico-chemical parameters in the St Lucia Estuary, measured during 2012.

	False Bay and North Lake region	South Lake Western Shores	South Lake Eastern Shores	St Lucia Mouth region
Temperature (°C)	19.79–37.49	21.26–34.98	17.56–32.41	15.44–27.29
Salinity	39.62–92.20	4.74–12.46	3.07–9.66	8.87–14.42
pH	8.27–8.76	8.53–9.14	8.23–9.27	8.30–9.20
Dissolved oxygen (mg/L)	5.27–7.96	7.33–9.05	6.18–9.32	6.63–9.23
Turbidity (NTU)	144.60–270.45	129.65–308.60	0.70–124.35	16.45–111.83

32°25'05"E) and Catalina Bay (28°13'29"S, 32°29'12"E) samples comprised populations of both larger *Asimineia* cf. *capensis* Bartsch and a smaller species similar to a species originally named *Rissoa capensis* Sowerby and here tentatively named "A." aff. *capensis* (Sowerby) that could thus be separated based on shell height (SH) (see also Table 3). These make up the samples from South Lake, a more stable environment with lower salinities (Table 1) due to higher freshwater input. At the St Lucia mouth, snails were collected from the Back Channel (28°23'45"S, 32°25'09"E) only in October 2012. All specimens were preserved in absolute ethanol prior to analyses.

Molecular analysis. Between 4 and 11 individuals from each population were sampled for nuclear and mitochondrial DNA analysis. Genomic DNA was isolated using a Zymogen© extraction kit using the solid tissue protocol and extracted from the remainder of the samples using the entire specimen and following a phenol extraction protocol. Universal primers COIL1490 and COIH2198 were used to amplify and sequence 506 base pair regions of mitochondrial cytochrome c oxidase subunit I (COI) (Folmer et al. 1994). COI amplification followed the protocol: 95 °C for three minutes, followed by 36 cycles (30 seconds at 94°C, 30 seconds at 40°C and one minute at 72°C), followed by a final extension step at 72°C for 10 minutes. A 728 base pair region of 28S rRNA was amplified and sequenced using D6R and D23F primers (Park and Ó Foighil 2000). The 28S rRNA amplification followed the following protocol: initial denaturing at 95°C for three minutes, followed by 36 cycles (30 seconds at 94°C, 30 seconds at 60°C and one minute at 72°C) and additional extension at 72°C for 10 minutes. PCR reactions consisted of 12.5 µl EconoTaq®, 9.82 µl PCR water, 2 µl Buffer, 1.8 µl MgCL, 1 µl BSA, 0.84 µl of each primer (relevant to the DNA being amplified), 0.2 µl SuperTherm Taq® and 1 µl DNA extract. Some samples required reamplification and 28S rRNA samples required gel extraction.

Sequencing was done at Inqaba Biotech Industries (Pretoria, South Africa) with an ABI 3730 Capillary Sequencer using Big Dye technology. Sequences were edited using BioEdit (v7.0.9.0) (Hall 1999) and haplotypes generated, and molecular diversity indices calculated, with DnaSP (v4.90.1) (Rozas et al. 2003). An AMOVA was performed with GenAlEx (v6.4) in order to determine molecular variance between samples (Peakall and Smouse 2005). Maximum parsimony (MP), neighbour-joining (NJ), maximum likelihood (ML) and Bayesian Inference methods were used to infer phylogenetic relationships. PAUP (v4.0b10) was used to perform the MP, NJ and ML analyses (Swofford 1998) while the Bayesian analyses were done using MrBayes

(v3.1.2) (Huelsenbeck and Ronquist 2001). Modeltest (v3.7), under the Akaike Information Criterion (Posada and Crandall 2005), selected a HKY model for construction of the NJ and ML trees (A = 0.275; C = 0.178; G = 0.161; T = 0.387; Ti/tv ratio = 12.438 and rates = equal) for COI and K80 for 28S (A = 0.202; C = 0.257; G = 0.261; T = 0.280; Ti/tv ratio = 2.283 and rates = equal). 1000 bootstrap replicates were used to evaluate node support for trees. The tree bisection-reconnection algorithm was used to generate ML and MP trees. COI trees were rooted with the out-group *Pseudomphala latericea*. 28S trees were rooted with *P. miyazakii*, with *Paludinellassiminea japonica* as an additional out-group. Bayesian analyses comprised of two independent runs of four simultaneous Markov Chain Monte Carlo chains. Bayesian analyses were run for 20 000 000 generations and a sample frequency of 1000 generations with a *burn-in* of 25%. The “sump” command was used in MrBayes and Tracer v1.6 (Rambaut and Drummond: <http://evolve.zoo.ox.ac.uk/software.html?id=tracer>) were used to evaluate the convergence and *burn-in* for likelihood values for post-analysis trees and parameters. The “sumt” command in MrBayes was used to calculate posterior probabilities for trees remaining after *burn-in*.

Morphometric analysis. Standard shell parameters were measured and compared between individuals from different localities. Adult individuals were selected from amongst the largest specimen in each sample. Sexual dimorphism was not addressed. 25 individuals from each population were used for morphometrical analysis. Micrographs were taken using a Nikon AZ100 stereo microscope. Snail shells were mounted and orientated with the spiral facing upwards and the aperture facing the optical lens. NIS-Elements (v3.2.00) digital measuring software was used to take measurements. The height and width of the shell (SH, SW), body whorl height (BWH) and aperture height and width (AH, AW) were measured. The number of shell whorls (Whorl) was counted. In addition the ratios of SW/SH, BWH/SH and AH/SH were calculated (Hershler et al. 2007). Primer 6© (v6.1.6) was used to conduct a Principal Component Analysis (PCA) on the normalised data. A SIMPROF cluster analysis using Euclidian distances was carried out in order to group similar samples (Clarke and Gorley 2001).

Results

Molecular analysis. The results of the AMOVA and molecular diversity data are summarised in Table 2. This revealed that for both COI and 28S, the vast majority of the molecular variation (78%) occurred between the populations, with just over 20% occurring within. A high diversity was also found amongst haplotypes but with little variation within. This can be seen by the high haplotype diversity and relatively low variance for both genes (Table 2).

The COI data set yielded 11 haplotypes (Table 2) with 98 variable sites, 87 of which were parsimony informative. The average G+C content was 37%. Haplotype 1 was the most common and was represented by individuals from both Lister’s Point sites. All other haplotypes were represented by 1-3 individuals from single populations.

Table 2. Molecular diversity and AMOVA data for 28S and COI (*denotes statistical significance).

	28S	COI
Molecular Diversity Data		
Haplotypes Generated	18	11
G+C Content	0.633	0.370
Variable Sites	30	16
Parsimony Informative Sites	18	14
Haplotype Diversity	0.769	0.882
Haplotype Variance	0.00305	0.00414
Nucleotide Diversity	0.00788	0.09162
Nucleotide Variance	1.2×10^{-6}	6.92×10^{-5}
Tajima's D	-0.83178	2.497
AMOVA		
Variance among populations	78%*	96%
Variance within populations	22%*	4%

All phylogenetic analyses strongly supported the separation of the False Bay (Lister's Point, i.e. "*A.*" aff. *capensis* (Sowerby)) and South Lake (Charter's Creek and Catalina Bay, i.e. *A. cf. capensis* Bartsch) samples into distinct clades, with supporting bootstrap values of 100% NJ and MP, 98% for ML and 1.0 for Bayesian inference (Fig. 2). All trees showed weak to moderate support for sub clades including Haplotype 2 and 3. All trees showed weak to moderate support for a Haplotype 6, 8 and 9 sub clade and Bayesian inference and MP trees for a Haplotype III and VI sub clade. The average variance between the two regions was 86.23 base pairs, which equates to a 17.04% genetic variance (Table 2).

The 28S data set yielded 18 haplotypes (Table 2) with 30 variable sites, 18 of which were parsimony informative. The average G+C content was 63.3%. Haplotype 7 was the most common (27 individuals) and was represented by all individuals from all populations, except the large Charter's Creek, large Catalina Bay and Back Channel individuals. Phylogenetic analyses showed varying support for the separation of two clades (Fig. 3). The first clade was made up entirely of all the individuals from the large Charter's Creek, large Catalina Bay and Back Channel individuals (i.e. *A. cf. capensis* Bartsch). This clade was strongly supported by all phylogenetic analyses with the exception of ML. The MP and NJ trees showed strong support for the separation of a second clade. This clade was made up entirely of all samples from the other four populations (i.e. "*A.*" aff. *capensis* (Sowerby)). All trees differed only slightly in the position of the branches within the clades.

Morphometric analysis. Generally larger shell sizes (SH, SW, BWH, AH and AW) were recorded for *A. cf. capensis* Bartsch in comparison to "*A.*" aff. *capensis* (Sowerby) (Table 3). Adult *A. cf. capensis* also tended to have a greater number of whorls (Whorl) (Table 3). However, the *A. cf. capensis* populations from Back Channel, Charter's Creek and Catalina Bay were grouped separately from the "*A.*" aff. *capensis* populations at Lister's Point, Hell's Gate, Fani's Island, Charter's Creek and Catalina

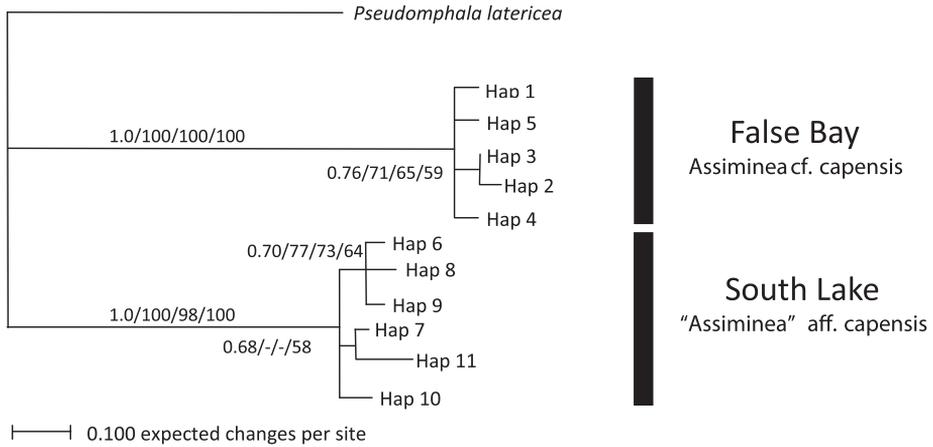


Figure 2. Bayesian Inference tree for COI data. Support values are as follows: Bayesian Inference/NJ/ML/MP.

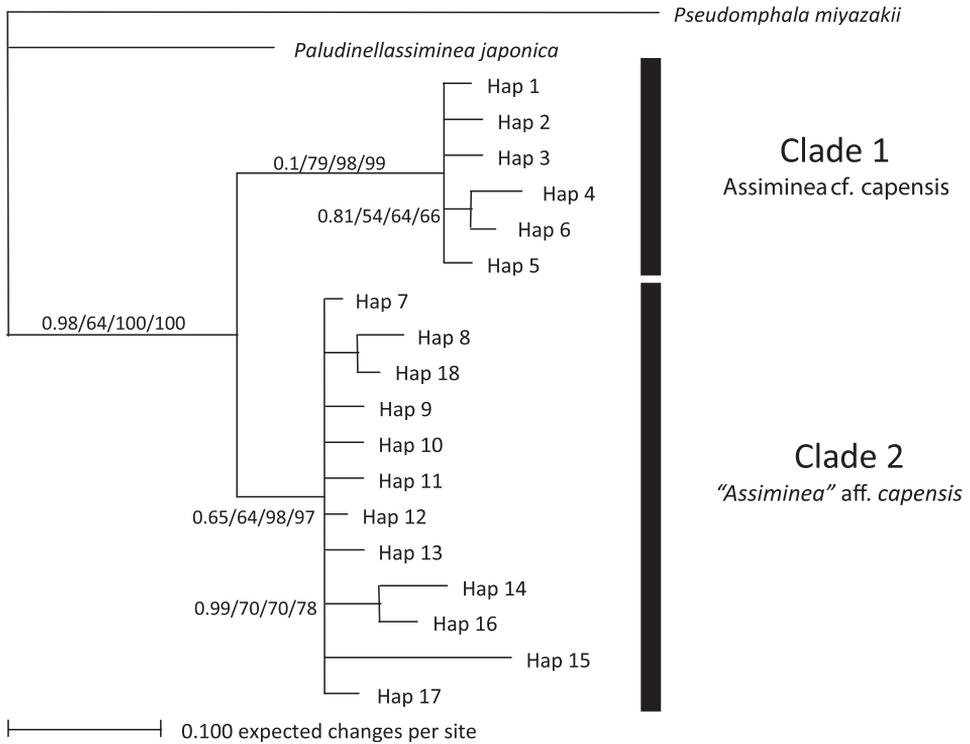


Figure 3. Bayesian Inference tree for 28S data. Support values are as follows: Bayesian Inference/ML/MP/NJ.

Bay, on the basis of shell morphometry in the cluster analysis (Fig. 4). The first two principal components (PCs) accounted for 89.1% of the total variation in shell morphometry (Table 4). All the shell dimensions recorded loaded high in PC1 and the ratios loaded high in PC2. This would suggest that samples are separated primarily on the basis of size (PC1) and shape (PC2).

Table 3. Shell parameters (mean \pm standard deviation) of populations of *Assiminea* cf. *capensis* and “*Assimineea*” aff. *capensis* occurring in the St Lucia Estuary during 2012.

Parameter	<i>Assiminea</i> cf. <i>capensis</i>			“ <i>Assimineea</i> ” aff. <i>capensis</i>				
	Charter’s Creek	Catalina Bay	Back Channel	Lister’s Point	Hell’s Gate	Fani’s Island	Charter’s Creek	Catalina Bay
SH	3.82 \pm 0.25	3.99 \pm 0.32	3.86 \pm 0.66	2.22 \pm 0.18	1.22 \pm 0.19	1.70 \pm 0.20	1.26 \pm 0.12	1.07 \pm 0.06
SW	2.52 \pm 0.16	2.73 \pm 0.19	2.42 \pm 0.35	1.30 \pm 0.89	0.81 \pm 0.10	1.04 \pm 0.11	0.79 \pm 0.06	0.67 \pm 0.03
BWH	2.67 \pm 0.16	2.90 \pm 0.24	2.70 \pm 0.43	1.52 \pm 0.12	0.92 \pm 0.13	1.22 \pm 0.13	0.93 \pm 0.07	0.83 \pm 0.05
AH	1.81 \pm 0.15	1.97 \pm 0.17	1.85 \pm 0.26	0.98 \pm 0.08	0.61 \pm 0.08	0.75 \pm 0.08	0.58 \pm 0.06	0.49 \pm 0.03
AW	1.59 \pm 0.14	1.73 \pm 0.15	1.47 \pm 0.21	0.81 \pm 0.06	0.49 \pm 0.07	0.63 \pm 0.06	0.48 \pm 0.05	0.41 \pm 0.02
Whorl	6.00 \pm 0.01	4.80 \pm 0.41	6.04 \pm 0.20	4.94 \pm 0.33	4.00 \pm 0.01	4.80 \pm 0.41	4.20 \pm 0.41	3.92 \pm 0.28
SW/SH	0.66 \pm 0.03	0.68 \pm 0.03	0.63 \pm 0.03	0.59 \pm 0.03	0.67 \pm 0.04	0.62 \pm 0.04	0.63 \pm 0.02	0.63 \pm 0.03
BWH/SH	0.70 \pm 0.02	0.73 \pm 0.03	0.70 \pm 0.02	0.69 \pm 0.03	0.76 \pm 0.04	0.72 \pm 0.04	0.75 \pm 0.03	0.77 \pm 0.03
AH/SH	0.42 \pm 0.02	0.433 \pm 0.02	0.38 \pm 0.02	0.37 \pm 0.02	0.40 \pm 0.03	0.37 \pm 0.03	0.38 \pm 0.03	0.39 \pm 0.02

Measuring units are in mm. Sample size is 25 for each population and locality.

Table 4. Factor loadings from principal component analysis for normalised data.

Variable	PC1	PC2	PC3	PC4	PC5
SH	-0.407	0.048	-0.147	0.106	-0.057
SW	-0.408	-0.038	-0.097	0.082	-0.134
BWH	-0.406	-0.001	-0.231	0.091	-0.044
AH	-0.407	-0.021	-0.16	0.074	-0.056
AW	-0.408	-0.049	-0.077	0.167	0.028
Whorl	-0.326	0.251	0.184	-0.823	0.345
SW/SH	-0.102	-0.602	0.328	-0.334	-0.63
BWH/SH	0.179	-0.495	-0.761	-0.305	0.205
AH/SH	-0.148	-0.568	0.405	0.242	0.644
Eigenvalues	5.91	2.11	0.441	0.289	0.239
% Cum Var	65.7	89.1	94	97.2	99.9

Discussion

Molecular (COI and 28S) as well as shell morphometric analyses support a clear distinction of two clades within the *assimineids* occurring in the St Lucia estuarine lake during the study period (Figures 2-4). There is a large divergence in mitochondrial DNA (17.04%) and the variance in the slower evolving nuclear rDNA between the two clades. The divergence in the COI gene is greater than that previously shown for other congeneric truncatelloidean gastropods, which ranged from 1.1 to 14.8% (e.g. Hershler et al. 1999; Liu and Hershler 2005; Hershler et al. 2006, 2007). At least two distinct species exist in the St Lucia Estuary. These two separate species have tentatively been identified as *Assimineea* cf. *capensis* Bartsch (the larger-sized Charter’s Creek, Catalina Bay and Back Channel populations) and “A.” aff. *capensis* (Sowerby) (the

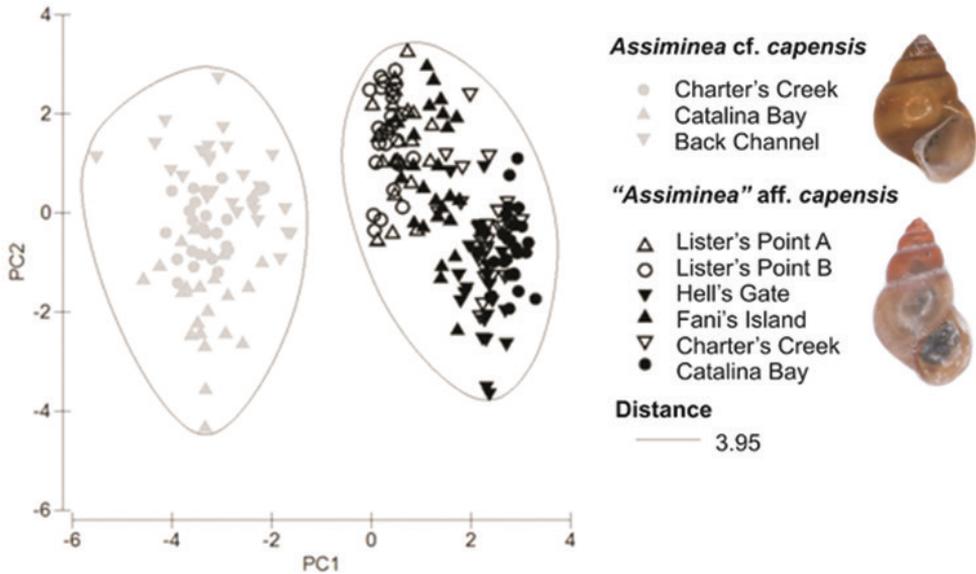


Figure 4. Plot of first two principal components of PCA for morphometric data. The cluster analysis ellipses are associated with $P = 0.001$.

smaller-sized Lister's Point, Hell's Gate, Fani's Island, Charter's Creek and Catalina Bay populations) (W P pers. obs.). Although on average *A. cf. capensis* is larger than "*A.*" aff. *capensis*, both species have variable shell morphology and multivariate analyses are required to make clear distinctions based on morphometry alone (Fig. 4, Table 3). Shell size ratios (SW/SH, BWH/SH and AH/SH) are not useful to differentiate between the species (Table 3). *Assiminea cf. capensis* may be the taxon previously recognised as *A. ovata* and *A. bifasciata* from the St Lucia Estuary and possibly generally in South Africa (e.g. Kilburn and Rippey 1982).

Environmental conditions, salinity in particular, strongly influence the spatial and temporal distribution and overlap patterns of *A. cf. capensis* and "*A.*" aff. *capensis* in the St Lucia Estuary. In an earlier benthic survey of St Lucia conducted by Bolt (1975), an initial sampling effort was conducted under high salinity conditions and *A. bifasciata* (= *A. cf. capensis* Bartsch) was not found in False Bay. Following an extended period of freshwater input, salinity dropped from levels as high as 80 to below that of sea water. Subsequent sampling efforts demonstrated the rapid recolonisation of False Bay and North Lake by *A. bifasciata* (Bolt 1975). According to the present study, *A. cf. capensis* was not found in the highly saline False Bay area between November 2011 and February 2012 (salinity 56–92). In March 2012, high freshwater input associated with Cyclone Irina, caused salinity in False Bay to drop (to about 30) and a rapid population boom of "*A.*" aff. *capensis* was recorded at the same time. Furthermore, in July 2013, both *A. cf. capensis* and "*A.*" aff. *capensis* were found at Lister's Point. Taylor et al. (2006) suggested that *A. cf. capensis* take refuge in freshwater seepage areas in the South Lake under drought conditions. By acting as a constant source of

freshwater, ground water plays a role in stabilising salinity and water level conditions in the South Lake (Vrdoljak and Hart 2007). It is there that both “*A.*” aff. *capensis* and *A. cf. capensis* co-exist in Charter’s Creek and at Catalina Bay. Both species can avoid desiccation and hypersaline conditions by inhabiting freshwater refugia and recolonize the system when optimal environmental conditions are re-established (as reported by Millard and Broekhuysen 1970). However, it is hypothesised that “*A.*” aff. *capensis* has wider environmental tolerance limits (particularly upper salinity limits, allowing it to also persist in False Bay), compared to *A. cf. capensis*.

Given the morphological and ecological similarities, as well as spatial overlap displayed by *A. cf. capensis* and “*A.*” aff. *capensis*, it is not surprising that both species have been misidentified in the past. Millard and Broekhuysen (1970) reported the presence of *A. bifasciata* in soft mudbanks and mangrove forests at salinities ranging from 8.3 to 37.6. These authors also reported an expansion of its range from South Lake in July 1964 to False Bay by January 1965, coinciding with an overall significant rise in salinity. Interestingly, they also reported the occurrence of another microgastropod, *Syncera* sp., in South Lake and False Bay at salinities ranging from 36.0 to 52.6 (“on *Zostera* and on banks”). *Syncera* Gray, 1821 is *nomen nudum* and treated as a synonym of *Assimineea* (Fukuda and Ponder 2003). Due to coincidences in terms of the general shape of the shell, the locations where specimens were found and their reported salinity range which extends to hypersaline conditions, it is likely that the species that Millard and Broekhuysen (1970) referred to as *Syncera* sp. was actually “*A.*” aff. *capensis*. “*Assimineea*” aff. *capensis* has been referred to as *Coriandria durbanensis* and *A. durbanensis* in previous studies (Weerts 1993; Raw et al. 2013). However, “*A.*” aff. *capensis* is of unknown relationship since the 1980s and *C. durbanensis* was even mistakenly suggested to be a member of the Hydrobiidae (Ponder and Yoo 1980). The specimens tentatively named “*A.*” aff. *capensis* in the current study are *assimineids* but in an as yet unnamed genus. There is clearly a great need for taxonomic revision based on comparative anatomy and molecular analysis.

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Typhlonesticus gocmeni sp. n., a new cave-dwelling blind spider species from the Aegean region of Turkey (Araneae, Nesticidae)

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Abstract

A new species of the troglobitic spider genus *Typhlonesticus* is described from specimens found in Keloğlan Cave (Denizli Province, Dodurgalar Town), Turkey. *Typhlonesticus gocmeni* sp. n. is described on the basis of both sexes; and its phylogenetic relationships with closely related European genera and species are discussed based on morphological and molecular data (the *cox1*, *rrnL* and *H3* genes). Three new combinations are proposed: *Typhlonesticus idriacus* (Roewer, 1931), **comb. n.**, *Typhlonesticus morisii* (Brignoli, 1975) **comb. n.** and *Typhlonesticus obcaecatus* (Simon, 1907), **comb. n.** all ex *Nesticus*.

Keywords

Arachnida, taxonomy, description, caves, Anatolia, troglobiont

Introduction

Nesticids are medium-sized spiders common in underground ecosystems in the northern Mediterranean basin and many of them exhibit all the typical troglobite characters: depigmentation, anophthalmia and appendage lengthening. The following four genera have been recorded from this region: *Aituaria* Esyunin & Efimik, 1998; *Carpathonesticus* Lehtinen & Saaristo, 1980; *Nesticus* Thorell, 1869 and *Typhlonesticus* Kulczyński, 1914, representing a total of 49 species. Two more genera occur in bordering regions: *Canarionesticus* Wunderlich, 1992, endemic to the Canarian archipelago and *Nesticella* Lehtinen & Saaristo, 1980, broadly spread throughout the Asian continent. *Nesticella mogera* (Yaginuma, 1972) was recorded from the southeast of Caucasus (Marusik and Guseinov 2003), and in Europe has been cited in Berlin and Poland (Bielak-Bielecki and Rozwałka 2011) as an introduced species.

Most described species are well defined and illustrated, but the taxonomy of the group is not well established at the genus level, mainly in *Carpathonesticus* and *Nesticus* which show conspicuous morphological variability in their genital organs, suggesting the existence of independent evolutionary lineages. This morphological variability was already pointed out by Lehtinen and Saaristo (1980) and López-Pancorbo and Ribera (2011).

The genus *Typhlonesticus* was described in 1914 and included two species, but a type species was not selected. Kratochvíl (1933) designated the type species, but incorrectly. His designation was corrected by Lehtinen and Saaristo (1980). Currently the genus comprises the single species *T. absoloni* (Kratochvíl, 1933), a species known from several caves in Montenegro (Platnick 2014). The phylogenetic affinities of this genus are unknown and it has been regarded by some authors as an aberrant species, “the most aberrant of Nesticini in regard to both female and male genital organs is *Typhlonesticus*, and its relationships to other genera remain obscure” (Lehtinen and Saaristo 1980) or “an old relict, ... with a solitary position within the genus” (Deeleman-Reinhold 1974). However, Fage (1931) reported some morphological relationships with regard to *N. obcaecatus* (*la forme de l'épigyne rappelle un peu celle du N. obcaecatus de l'Espagne*) and López-Pancorbo and Ribera (2011) pointed out the morphological affinities of the male and female copulatory organs between *T. absoloni* and *N. obcaecatus*, *N. idriacus* and *N. morisii*.

An extensive survey of caves in Anatolia during the last 10 years has provided a high number of morphospecies, one of which, from Keloğlan Cave in the Denizli Province, shows a clear morphological similarity with *T. absoloni*. The discovery of this new species of *Typhlonesticus* has also led us to review some of the described Mediterranean species that show morphological similarity with *T. absoloni*, such as *N. obcaecatus* from the Spanish Pyrenees, *N. morisii* from Italy and *N. idriacus* from Austria and Italy. In order to check the phylogenetic relationships among these species a molecular phylogenetic analysis based on nuclear and mitochondrial gene sequences was performed.

The aim of this paper is to describe a new species belonging to the genus *Typhlonesticus* and to propose three new combinations of the above mentioned species.

Material and methods

Molecular data

Taxonomic sampling. Representatives of Mediterranean *Nesticus*, *Carpathonesticus* and *Typhlonesticus* were included in the analysis. We could not include representatives of the genus *Aituaria*, the easternmost Mediterranean nesticid genus whose range extends from southern Urals to the northwest of Caucasus, due to lack of suitable material for molecular analysis. Sequences from *Canarionesticus quadridentatus* Wunderlich, 1992 from Canary Islands were used to root the tree. We have also included sequences of *Typhlonesticus absoloni*, *Nesticus idriacus*, *N. morisii* and *N. obcaecatus* Simon, to check the phylogenetic relationships of these species (see Appendix 1 for localities and GenBank accession numbers).

Sample storage and DNA extraction. For DNA studies, live specimens were collected in the field, fixed in 96% or absolute ethanol and stored at 4°C. Total genomic DNA was extracted from legs or from the prosoma of a single specimen using the QIamp® DNA Mini Kit (QIAGEN) following the manufacturer's protocols. The approximate concentration and purity of the DNA obtained were verified using 1% agarose/TBE gel electrophoresis.

PCR amplification and sequencing. Partial fragments of two mitochondrial (cytochrome oxidase I: *cox1* and 16S rRNA: *rnl*) and one nuclear (Histone 3: *H3*) genes were selectively amplified and sequenced using the primers and conditions shown in Appendix 2. The PCR reaction mixture contained a final concentration of 0.2 µM of each primer, 0.2 mM of each dNTPs, 0.5 U Taq polymerase (Promega), with the supplied buffer, and 1.5–2.5 mM Mg Cl₂ in a final volume of 25 µL. The PCR products were cycle-sequenced in both directions using the same PCR primers and the BigDye Terminator version 3.1 Cycle Sequencing Kit (Applied Biosystems) and analyzed using an ABI 3700 automated sequencer at the Serveis Científic-Tècnics of the Universitat de Barcelona.

Alignment, genetic distances and phylogenetic analyses. Raw sequences were edited and assembled with GENEIOUS v. 4.6.5 (Drummond et al. 2009). The new sequences used in this study have been deposited in GenBank under the accession numbers shown in Appendix 1. Alignment of the *cox1* and *H3* gene fragments was trivial due to the absence of length polymorphism. However, there were some length differences among the *rnl* fragments, suggesting the occurrence of insertion/deletion events during the evolution of these sequences. Automatic alignment algorithms have been considered as superior to manual protocols due to their objectivity and repeatability (Giribet et al. 2002). The *rnl* sequences were aligned using the online version of MAFFT, applying the Q-INS-i algorithm (Katoh and Toh 2008). The uncorrected genetic distances between the taxa were assessed using MEGA v.5.0 (Tamura et al. 2011).

Maximum Likelihood (ML) analyses of the combined data matrix corresponding to the three sequenced genes were conducted using the online version of RAxML

(Stamatakis et al. 2008), independently applying the parameters of the Gamma model of rate heterogeneity for each partition. The online version obtains the bootstrap support values by means of 100 pseudoreplicates.

Taxonomy

The following abbreviations are used in the text and figures: **E** = embolus, **T** = tegulum, **ST** = subtegulum, **MA** = median apophysis, **TTA** = theridioid tegular apophysis, **p1** = process 1 of TTA, **p2** = process 2 of TTA, **P** = paracymbium, **vp** = ventral process of paracymbium, **dp** = dorsal process of paracymbium, **co** = copulatory orifice, **id** = insemination duct, **fd** = fertilization duct, **S** = spermatheca, **AUZM** Anadolu University Zoological Museum (Eskişehir, Turkey), **CRBA** Centre de Recursos de Biodiversitat Animal de la Universitat de Barcelona (Spain). All measurements are in millimetres.

Specimens of *Typhlonesticus gocmeni* sp. n. were collected using hand aspirators and placed directly into 96% ethanol in the field. Body colour descriptions are based on digital images taken in the cave environment. Photography was performed using a Nikon D100 camera equipped with a Nikon 105mm f/2.8G ED-IF AF-S VR Micro-Nikkor lens and a Sigma EM-140 DG macro ring flash for Nikon SLR cameras.

The female vulva was removed and treated with 30% KOH prior to examination. After observation and drawings, the vulva was washed in distilled water and stored in 70% ethanol. The left male palp was drawn in all cases. We follow Coyle and McGarity (1992) for describing the paracymbium and Huber (1993) and Agnarsson et al. (2007) for other parts of the male and female copulatory organs.

Digital images of the palps and vulvae were taken with a Leica DFC295 digital camera attached to a Leica S8AP0 stereomicroscope, with 5–15 photographs taken in different focal planes and combined using image stacking software. Photographic images were edited using PHOTOSHOP CS2 and COREL-DRAW X3 was used to create the plates. For SEM micrographs, the male palps were dried at -30 °C and coated with a thin layer of gold using an Electron Microscopy sciences EMS 550X sputter coater. The materials were examined at an acceleration voltage of 12 kV using a ZEISS ULTRA PLUS Scanning Electron Microscope (University of Anadolu, Eskişehir, Turkey).

In addition of the new species we also examined the following material: *N. morisii* (♀) from Sotterranei del Forte di Vernante, Vernante, Cuneo, Italy, 19.09.2007, leg. A. López-Pancorbo & M. Isaia; *N. idriacus* (♂♀) from Grotte Pre Oreak, Nimis, Friuli, Italy, 15.09.2007, leg. A. López-Pancorbo; *N. obcaecatus* (♂♀) from Cueva Del Molino de Aso, Boltaña, Prov. Huesca, Spain, 27.05.2004, leg. S. Carranza; and *T. absoloni* (♀) from Baba Tusha Cave, Trnovo, Virpazar Distr., Montenegro, 24.03.2006, leg. B. Petrov & S. Lazarov. Baba Tusha Cave is located about 10 km in a straight line from Grbočica pećina, in Krivošije (locus typicus of *T. absoloni*) and about 20 km away from Cetinsjska pećina, from which Deeleman-Reinhold (1974) illustrated both sexes of this species. For morphology of the male palps of *T. absoloni* and *N. morisii* we rely on Kratochvíl (1939) and Deeleman-Reinhold (1974).

Results

Taxonomy

Family Nesticidae Simon, 1894

Genus *Typhlonesticus* Kulczyński, 1914

Type species. *Nesticus absoloni* Kratochvíl, 1933; see Lehtinen and Saaristo (1980).

Typhlonesticus gocmeni sp. n.

<http://zoobank.org/E3A3721A-0E71-479B-9EA9-A31A47D6E8C6>

Figs 2–21

Material examined. *Holotype* ♂ (AUZM) Denizli Province, Acıpayam District, Dodurgalar Town, Keloğlan Cave (37°23'14.74"N; 29°34'18.29"E), 10.07.2011, leg. M. Elverici. *Paratypes* 1 ♂ 1 ♀ 9 juveniles (AUZM), 1 ♂ 1 ♀ (CRBA) same data as holotype.

Derivatio nominis. The specific name is given in honour of the prominent Turkish biologist, Prof. Dr. Bayram Göçmen (University of Ege, İzmir, Turkey). Noun in apposition.

Diagnosis. Males of the new species differ from *T. absoloni* by the shape and length of the tegulum, the shape of p1 and p2 processes, the arrangement of the embolus and the shape and arrangement of the paracymbial apophyses, mainly the ventral one, which is erected as a thin spine in *T. gocmeni* sp. n., whereas in *T. absoloni* it consists of a curved lamella. Females differ from *T. absoloni* by the shape of the epigyne and the position of the spermathecae. The dimension and orientation of the insemination and fertilization ducts are also diagnostic. In *T. gocmeni* sp. n. the epigyne is scarcely sclerotized and the spermathecae and insemination ducts are visible through the tegument, moreover the spermathecae are nearly spherical and separated by a distance approximately equal to their diameter. In *T. absoloni* the epigyne is strongly sclerotized and the spermathecae are separated by almost twice their diameter. In *T. absoloni* the insemination and fertilization ducts are thicker and almost fill the entire genital area.

Male. Coloration. Carapace whitish, slightly yellowish. Appendages and sternum slightly testaceous. Opisthosoma brownish, with many dark patches (Fig. 20). The specimens preserved in alcohol have a whitish opisthosoma, slightly greyer than the prosoma.

Prosoma. Carapace approximately circular in dorsal view. Cephalic region not differentiated from the rest of the carapace. Eyeless (Figs 18, 19).

Opisthosoma. Sub-elliptical in dorsal view.

Appendages. prolateral margin of the chelicerae with 3 teeth, the central slightly longer. **Male palp** (Figs 2–13). Paracymbium short, dorsal and ventral processes scarcely developed. The ventral process consists of a short and flattened lamella, curved towards the apex and prolonged into a thin spine. The ventral one consisting of a

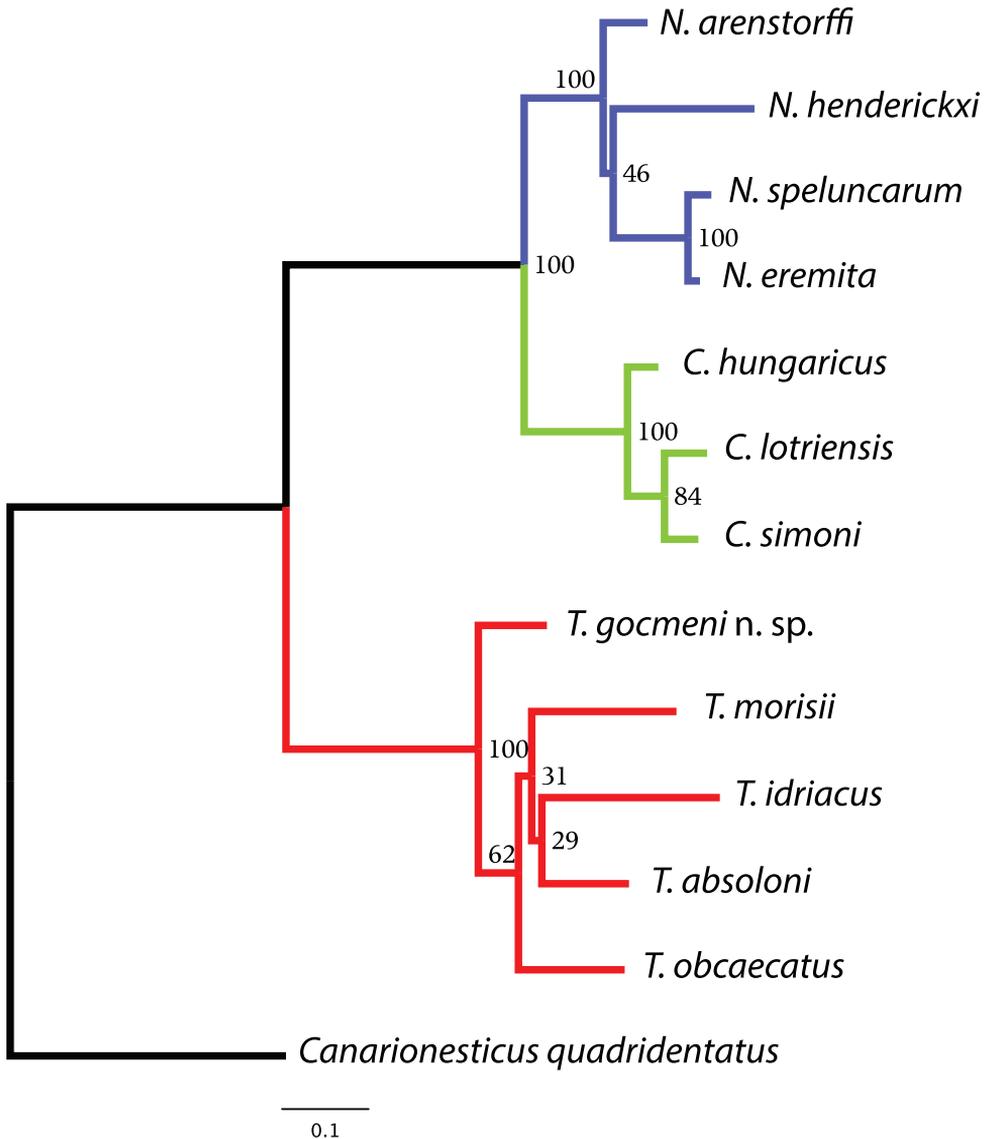
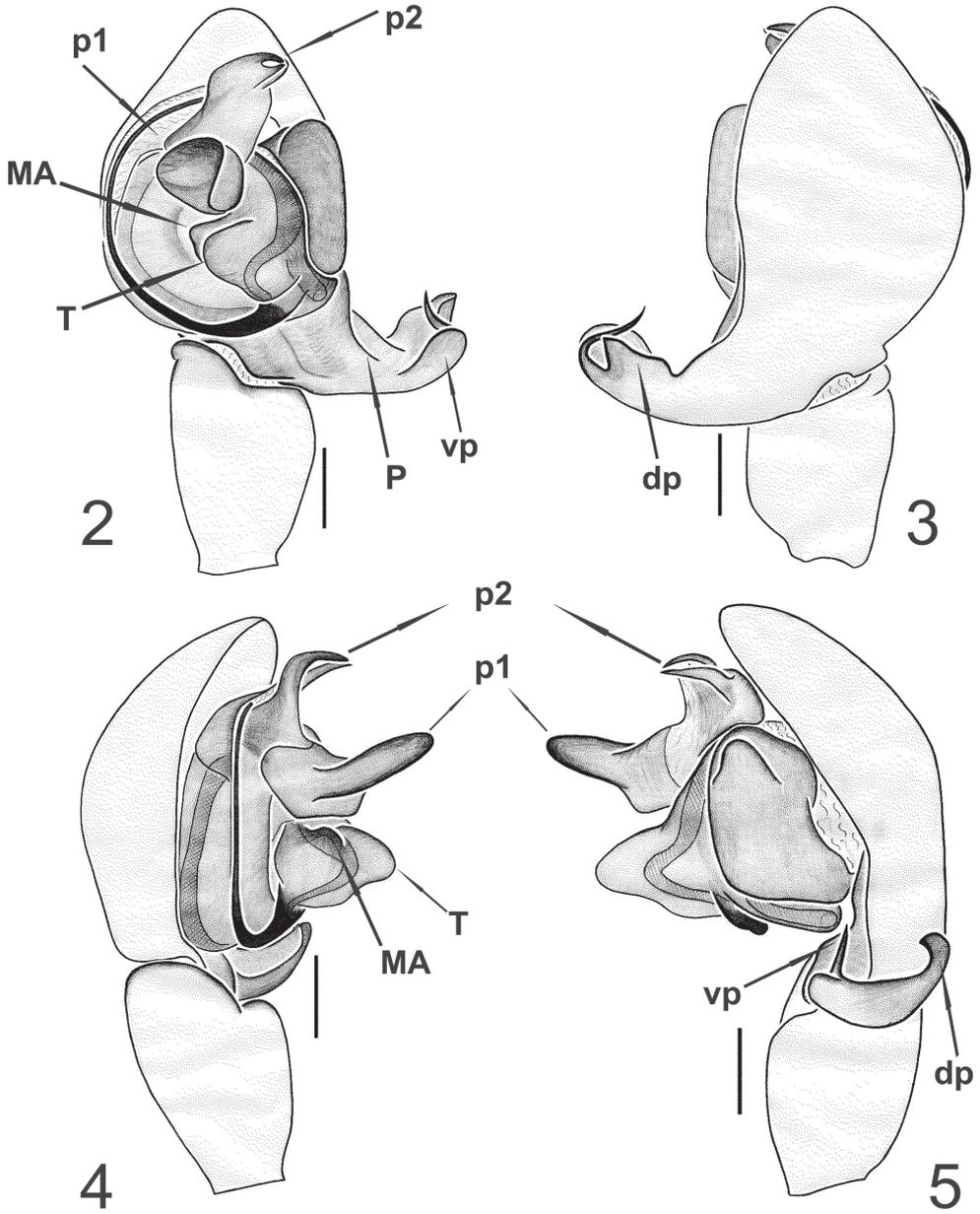


Figure 1. ML tree inferred using the concatenated dataset of *cox1*, *rrnL* mtDNA and *H3* nuDNA gene fragments. Numbers next to nodes correspond to bootstrap support values. The tree was rooted using *Canarionesticus quadridentatus* from the Canary Islands.

short laminar apophysis, apically curved toward to the ventral side. Distal, paradistal and dorsomedian paracymbial apophyses absent (Figs 2–3 and 5–7). Tegulum very prominent, consisting of a ventrally directed triangular apophysis. Small inconspicuous median apophysis located behind the tegulum (Figs 2, 4, 6, 8, 12). TTA with two well developed processes (p1 and p2): p1 is saddle-shaped, longer than wide, slightly curved in the middle and directed ventrally; p2 is in an apical position and ends with



Figures 2–5. *Typhlonesticus gocmeni* sp. n. male palp. **2** ventral view **3** dorsal view **4** prolateral view **5** retrolateral view. Abbreviations: **T** = tegulum, **MA** = median apophysis, **p1** = process 1 of TTA, **p2** = process 2 of TTA, **P** = paracymbium, **vp** = ventral process of paracymbium, **dp** = dorsal process of paracymbium. Scale bars 0.1 mm.

two convergent apical hooks running as a conductor for the embolus (Figs 2, 4–6, 8, 11, 13). Embolus filamentous following a semicircular course towards the apex and bordering the tegulum.

Measurements (holotype ♂): carapace length 1.15, width 0.88, opisthosoma length 1.60, width 0.84. Total length = 2.75.

Leg	coxa	troc.	femur	patella	tibia	meta.	tarsus	total
I	0.40	0.20	3.28	0.52	3.48	3.12	1.13	12.13
II	0.28	0.20	2.20	0.45	2.20	2.00	0.88	8.21
III	0.25	0.18	1.75	0.43	1.45	1.55	0.68	6.29
IV	0.30	0.20	2.42	0.40	2.15	1.95	0.89	8.31

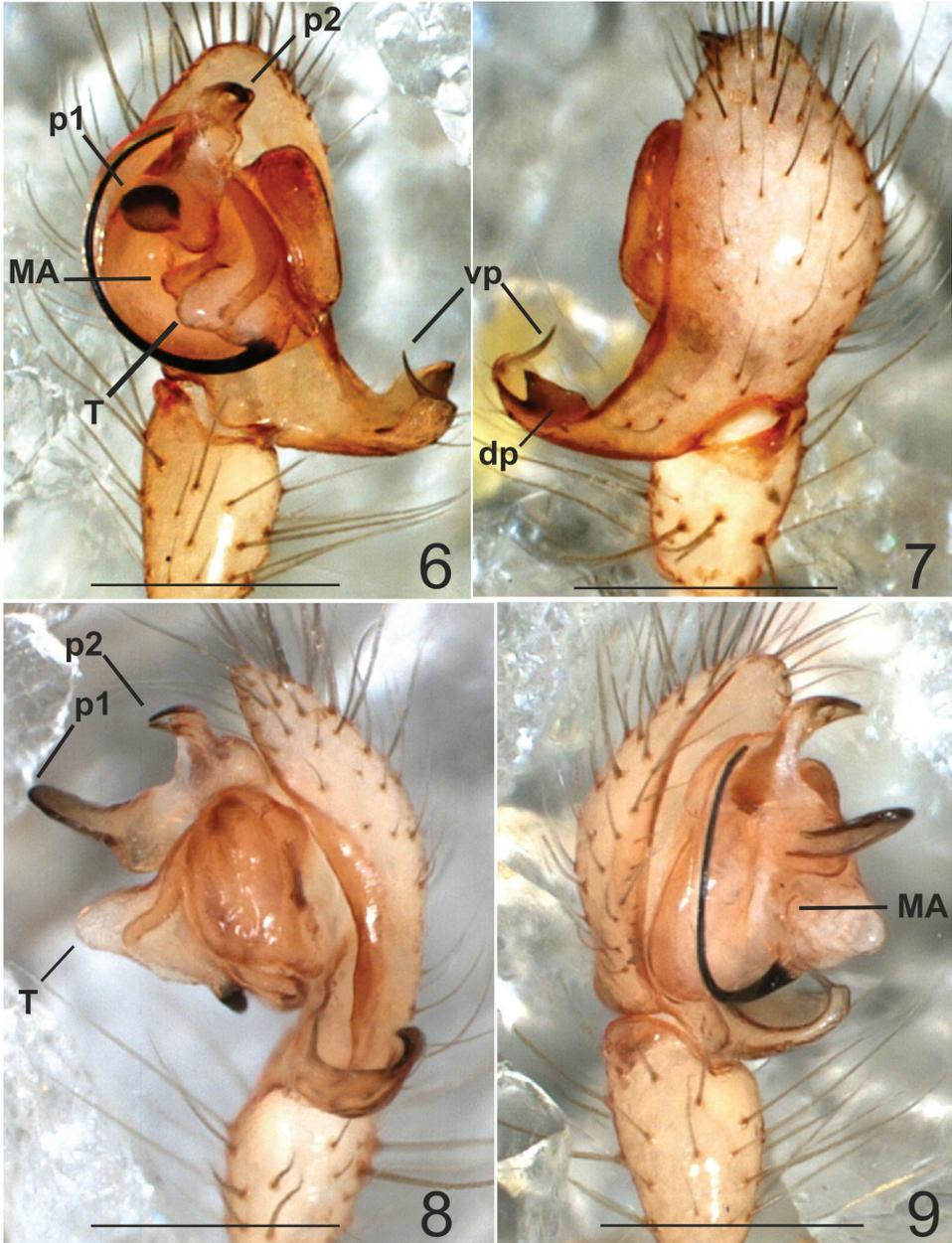
Female. All somatic characters as in male but slightly larger in size. **Epigyne** convex and prominent, without sclerotized plates (Fig. 14). The posterior edge is slightly sclerotized. Spermathecae and insemination ducts can be observed through the tegument. **Vulva** quite simple (Figs 15–17), consisting of two almost spherical spermathecae, insemination and fertilization ducts. Insemination duct coiled, forming two laps around the fertilization duct before reaching the spermatheca. Vulval pockets absent.

Measurements (paratype ♀): carapace length 1.20, width 1.00, opisthosoma length 2.04, width 1.28. Total length = 3.24.

Leg	coxa	troc.	femur	patella	tibia	meta.	tarsus	total
I	0.38	0.15	2.64	0.45	3.40	2.80	1.11	10.93
II	0.32	0.13	2.48	0.45	2.25	1.95	0.93	8.51
III	0.20	0.13	1.75	0.34	1.40	1.20	0.61	5.63
IV	0.37	0.14	2.52	0.42	2.36	1.88	0.97	8.66

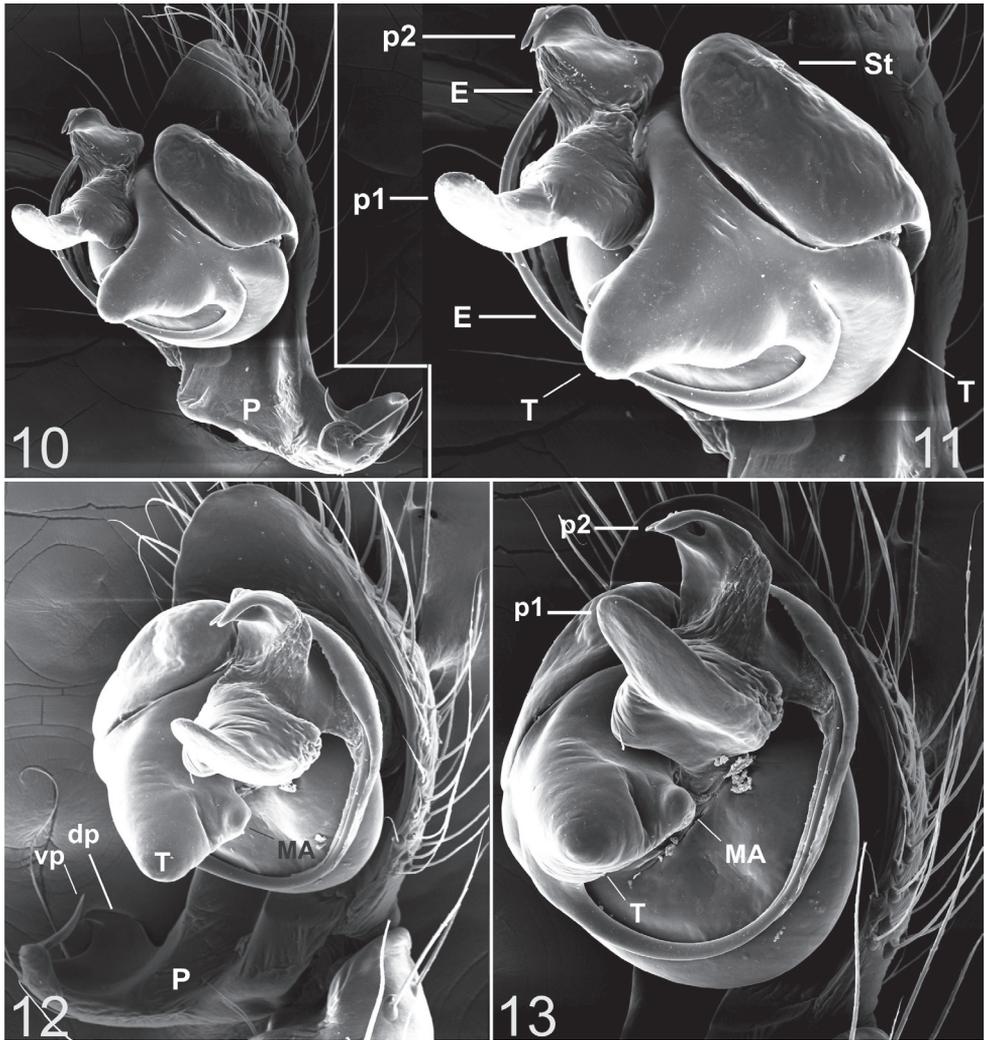
Distribution. *Typhlonesticus gocmeni* sp. n. is only known from the type locality. This new species was previously identified as *N. morisii* by Aydın Topçu and collaborators (2013). The cave is located at the northern part of the West Taurus karst region; on the east side of the Acıpayam polje, at the south eastern slope of the Karadağ hill, about 200 m above the polje level (MTA 1998). It is a fossil cave, almost horizontal and 145 m long with a roof height varying between 1–9 m with many calcite speleothem formations. It is one of the tourist caves in Turkey, open to public access since 2003, with formed tracks and fixed lighting that extend almost the full length of the cave. Specimens were collected or observed during 3 visits on 20.03.2011, 10.07.2011 and 16.10.2011. Adult specimens from both sexes were only collected in July, but also observed in October; while only subadults could be found in March. Specimens were abundant in the dark zone all along the cave, located on their webs build on the speleothem formations.

Molecular data. Specimens, locality and sequences with corresponding GenBank accession numbers analyzed in the present study are listed in Appendix 1. The final concatenated dataset of the three partial genes sequences includes 13 terminals and 1807 aligned characters (*cox1* = 1049, *rrnL* = 420 and H3 = 338). Primer fidelity across taxa was not always consistent in *cox1*, consequently some specimens have slightly



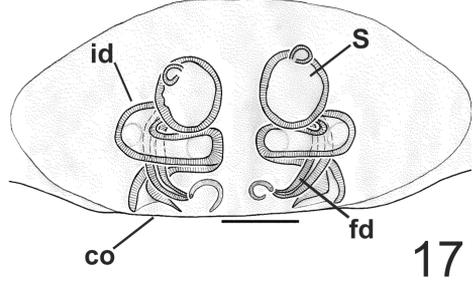
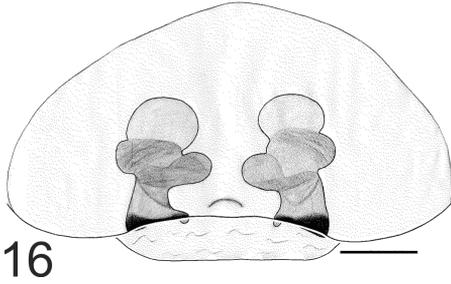
Figures 6–9. *Typhlonesticus gocmeni* sp. n. male palp. **6** ventral view **7** dorsal view **8** retrolateral view **9** prolateral view. Abbreviations: **T** = tegulum, **MA** = median apophysis, **p1** = process 1 of TTA, **p2** = process 2 of TTA, **vp** = ventral process of paracymbium, **dp** = dorsal process of paracymbium. Scale bars 0.5 mm.

truncated sequence lengths. Uncorrected *cox1* genetic divergences among terminal taxa, and uncorrected genetic *cox1* divergences within and between the analyzed genera are summarized in Appendices 3 and 4.



Figures 10–13. *Typhlonesticus gocmeni* sp. n. male palp. **10** nearly retrolateral view **11** ditto **12** nearly ventral view **13** ventral view. Abbreviations: **E** = embolus, **T** = tegulum, **St** = subtegulum, **MA** = median apophysis, **p1** = process 1 of TTA, **p2** = process 2 of TTA, **P** = paracymbium, **vp** = ventral process of paracymbium, **dp** = dorsal process of paracymbium.

Figure 1 shows the ML tree inferred using the combined data matrix. The new species groups with *Typhlonesticus absoloni*, *Nesticus morisii*, *N. obcaecatus* and *N. idriacus*. These five species constitute a highly supported evolutionary lineage (bootstrap support =100). The remaining species included in the analysis belong to the genera *Nesticus* and *Carpathonesticus*, which constitute independent and highly supported evolutionary lineages as well. *Typhlonesticus gocmeni* sp. n. occupies a basal position in the *Typhlonesticus* clade, and is the sister species of the European representatives. Within this lineage the evolutionary relationships of the species are poorly supported (low bootstrap supports).



Figures 14–17. *Typhlonesticus gocmeni* sp. n. epigyne and vulva. **14** epigyne ventral view **15** vulva ventral view, **16** ditto **17** vulva dorsal view. Abbreviations: **co** = copulatory orifice, **id** = insemination duct, **fd** = fertilization duct, **S** = spermatheca. Scale bars **14–15** 0.25 mm **16–17** 0.1 mm.



Figures 18–21. *Typhlonesticus gocmeni* sp. n. **18–19** male, prosoma **18** dorsal view **19** frontal view **20** male in the web **21** female.

The mean uncorrected p-distances of *cox1* between and within taxa analyzed (Appendices 3–4) show high values. The mean p-distance between genera ranges from 11.29% (*Nesticus* versus *Carpathonesticus*) to 17.19% (*Typhlonesticus* versus *Carpathonesticus*). Also, the average evolutionary divergence within the representatives of the three Mediterranean genera analyzed ranges from 6.43% (*Carpathonesticus*) to 11.11% (*Typhlonesticus*).

Discussion

This paper describes a new species belonging to the genus *Typhlonesticus*. The molecular phylogenetic analysis including representatives of *Nesticus*, *Carpathonesticus* and *Typhlonesticus*, all of them from the Mediterranean basin indicates that the new species lies with *Typhlonesticus absoloni* along with *Nesticus morisii*, *N. obcaecatus* and *N. idriacus*. These five species form a highly supported clade (bootstrap value =100) suggesting that all of them constitute a well-defined evolutionary lineage. Accordingly, we propose the following new combinations:

Typhlonesticus idriacus (Roewer, 1931), comb. n., ex *Nesticus*
Typhlonesticus morisii (Brignoli, 1975), comb. n., ex *Nesticus*
Typhlonesticus obcaecatus (Simon, 1907), comb. n., ex *Nesticus*.

These new data increase significantly the distribution of the genus, which is spread throughout the northern Mediterranean, from the Iberian Peninsula to Turkey.

To date, the *Typhlonesticus* generic diagnosis has been based on a single species (Kratochvíl 1933; Deeleman-Reinhold 1974; Lehtinen and Saaristo 1980). Certainly, the five species that currently constitute this genus will allow a more comprehensive diagnosis. Unfortunately we have no males of *T. absoloni* nor of *T. morisii* (see material examined). Moreover, a molecular systematic study of all Mediterranean Nesticidae is currently being performed to test the validity of the current generic status. Therefore, we believe it appropriate to postpone an extensive generic redescription until a robust phylogenetic framework for Mediterranean nesticids has been established and until we can examine males of *T. absoloni* and *T. morisii*.

A very special trait of these species is that all of them have highly troglomorphic characters, such as the absence of eyes or reduced eye size and number (only six eyes in *T. obcaecatus*) and lack of body pigment. In addition, most of these species are known from a single or a small number of caves, and all of them have very narrow ranges. On other hand, the uncorrected genetic distances of *cox1* between *T. gocmeni* n. sp., *T. absoloni*, *T. morisii*, *T. obcaecatus* and *T. idriacus* range between 10.03 to 12.19%. Assuming an average substitution rate for arthropod mitochondrial genes of between 2% (DeSalle et al. 1987) and 2.3% (Brower 1994) we can conclude that the origin of these species preceded the Pleistocene glacial cycles. These data alongside its phylogenetic uniqueness (basal position and a deep genetic distance from the other Mediterranean genera) suggest that these species constitute an indigenous, proper fauna of Southern

Europe and the Middle East and should be considered as primitive wildlife relicts, representative of a tropical or subtropical climate fauna, that should be serious candidates for protection through conservation.

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Appendix 1

Species included in the phylogenetic analysis and GenBank accession numbers for the *cox1*, *rrnL* and *H3* partial sequences.

Species	Locality	cox1	rrnL	H3
<i>Typhlonesticus gocmeni</i> sp. n.	Kelođlan Cave. Dodurgalar Town, Acıpayam District. Denizli Province. Turkey, (37°23'14.74"N; 29°34'18.29"E)	KF939310	KF939307	KF939313
<i>T. absoloni</i> (Kratohvil, 1933)	Baba Tušha Cv. Trnovo, Virpazar Distr., Montenegro, (N42°17'25,1" / E019°02'10,8" / 350m)	KF417410	KF417397	KF417416
<i>T. idriacus</i> (Roewer, 1931)	Grotte Pre Oreak, Nimis, Friuli. Italy	KF939312		
<i>T. morisii</i> (Brignoli, 1975)	Sotterranei del Forte di Vernante, Vernante, Cuneo, Italy	KF939311	KF939308	
<i>T. obcaecatus</i> (Simon, 1907)	Cueva del Molino de Aso, Boltaña, Prov. Huesca, Spain.	KF939309	EU746437	
<i>Nesticus eremita</i> Simon, 1879	Pishurka Cave. (=Paganetijeva Pécina), Korchula, Korchulalsl., Croatia. (N 42°57,568; E 17°07,751 / 58m)	KF417414	KF417400	
<i>N. speluncarum</i> Pavesi, 1873	Shpella e Dragoit, Gjirokaštër, Albania	KF417405		KF417421
<i>N. arenstorffi</i> Kulczyński, 1914	Chora Pecina Cave. Crni nugli, Dragalsko polje, Gorno krivoshije, Shelakov dol, Risan Distr. Montenegro. (N42°35'36,5" / E018°41'41,6" / 750m)	KF417407	KF417403	KF417422
<i>N. henderickxi</i> Bosselaers, 1998	Kournas Cave. Kournas. Crete	KF417409	KF417404	
<i>Carpathonesticus hungaricus</i> (Chyzer, 1894)	Pestera Cave. Liliecilor, Cheile Ampoitei Gorges, Romania. (N46°08'21.7748" / E23°23'39.8507")	KF417412	KF417402	KF417419
<i>C. lotriensis</i> Weiss, 1983	Unnamed Cave in Lotrioara Valley, Lotrului Mountains, Sibiu, Romania. (45°34'45.8319" / 24°11'16.7493")	KF417413	KF417399	KF417418
<i>C. simoni</i> (Fage, 1931)	Unnamed Cave in Bisbrita Gorges, Stogu-Vinturarita Mts., Romania. (N45°11'42.2789" / E024°02'03.2702" / 491m)	KF417408	KF417398	KF417417
<i>Canarionesticus quadridentatus</i> Wunderlich, 1992	Cv. Felipe Reventón, Icod de los Vinos, Tenerife, Canary Islands. (N28°21'00.7727" / W016°42'17.1028" / 595m)	KF417411		KF417415

Appendix 2

Primers and conditions used in the present study.

Gene fragment	Primer	Or.	Sequence (5'-3')	PCR Conditions	Reference
<i>cox1</i>	C1-J-1718	F	GGAGGATTTGGAAATTGATTAGTTCC	94°(1'); 94°(30"), 45°(30"), 72°(80") × 35; 72°(4')	Simon et al. 1994
	C1-N-2191	R	CCCGGTAATAATATAAACTTC		Simon et al. 1994
	C1-J-2183	F	CAACATTTATTTTGATTTTTGG	94°(1'); 94°(30"), 45°(30"), 72°(80") × 35; 72°(4')	Simon et al. 1994
	C1-N-2776	R	GGATAATCAGAATATCGTCGAGG		Hedin and Maddison 2001
<i>rrnL</i>	LR-N-13398	F	CGCCTGTTTATCAAAAACAT	94°(1'); 94°(30"), 48°(35"), 72°(80") × 35; 72°(4')	Simon et al. 1994
	LR-J-12864	R	CTCCGGTTTGAACCTCAGATCA		Arnedo et al. 2001
<i>H3</i>	H3a	F	ATGGCTCGTACCAAGCAGACVGC	94°(1'); 94°(30"), 48°(30"), 72°(80") × 35; 72°(4')	Colgan et al. 1998
	H3a	R	ATATCCTTRGGCATRATRGTGAC		Colgan et al. 1998

Appendix 3

Uncorrected genetic distances of *cox 1* gene between terminal taxa.

<i>C. quadridentatus</i>																			
<i>T. gocmeni</i> sp. n	0.1874																		
<i>T. obcaecatus</i>	0.2002	0.1003																	
<i>T. obsoloni</i>	0.1941	0.1090	0.0947																
<i>T. morisii</i>	0.1953	0.1178	0.1078	0.1078															
<i>T. idriacus</i>	0.2021	0.1219	0.1144	0.1194	0.1205														
<i>C. simoni</i>	0.1798	0.1785	0.1639	0.1706	0.1898	0.1860													
<i>C. lotriensis</i>	0.1791	0.1687	0.1604	0.1715	0.1847	0.1845	0.0471												
<i>C. hungaricus</i>	0.1763	0.1530	0.1531	0.1608	0.1705	0.1822	0.0697	0.0775											
<i>N. arenstorffi</i>	0.1880	0.1476	0.1458	0.1601	0.1774	0.1791	0.1096	0.1093	0.1007										
<i>N. henderickxi</i>	0.1788	0.1504	0.1515	0.1548	0.1572	0.1798	0.1265	0.1202	0.1143	0.0905									
<i>N. speluncarum</i>	0.1657	0.1485	0.1540	0.1582	0.1595	0.1694	0.1176	0.1075	0.1143	0.0791	0.0992								
<i>N. eremita</i>	0.1723	0.1507	0.1508	0.1609	0.1700	0.1660	0.1140	0.1102	0.1105	0.0760	0.0925	0.0190							

Appendix 4

Average evolutionary divergence between groups (below diagonal), standard error (above diagonal), and average evolutionary divergence within groups (d) and standard error (SE) of *cox 1* over sequence pairs.

<i>Canarionesticus</i>		0.0107	0.0106	0.0104	d	SE
<i>Typhlonesticus</i>	0.1958		0.0104	0.0086	0.1111	0.0065
<i>Carpathonesticus</i>	0.1784	0.1719		0.0091	0.0643	0.0083
<i>Nesticus</i>	0.1762	0.1596	0.1129		0.0768	0.0059

Two new species of the genus *Abrus* Dai & Zhang, 2002 (Hemiptera, Cicadellidae, Deltocephalinae) from China

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Abstract

Two new species of leafhoppers: *Abrus damingshanensis* sp. n. (from Guangxi) and *A. expansivus* sp. n. (from Guizhou) are described and illustrated from China. A map showing the geographic distribution of the two new species is given. Taxonomic notes on species of the genus *Abrus* is also provided.

Keywords

Homoptera, leafhopper, morphology, taxonomy, distribution

Introduction

The genus *Abrus* belonging to the tribe Athysanini of subfamily Deltocephalinae, was established by Dai and Zhang (2002) with six species: *A. hengshanensis*, *A. brevis*, *A. huangi*, *A. wuyiensis*, *A. bifurcatus* and *A. coneus* from China and with *A. hengshanensis* as its type species. It belongs to the tribe Athysanini of subfamily Deltocephalinae (Hemiptera: Cicadellidae). Later, Li and Wang (2006) described two new species: *A. concavelus* and *A. leigongshanensis*. Dai and Zhang (2008) reviewed this genus

and added a new species *A. breviolus*. Recently, Li (in Li et al. 2011) described two new species: *A. biprocessus* and *A. graciaedeagus*, and recorded *A. brevis*, *A. coneus* and *A. leigongshanensis* feeding on bamboo. Chen, Yang and Li (2012) described four new species, namely, *A. anlongensis*, *A. bambusanus*, *A. daozenensis* and *A. yunshanensis*. Yang and Chen (2013) described two new species: *A. xishuiensis* and *A. langshanensis*, and provided a key to 13 known species. Moreover, *A. brevis*, *A. coneus*, *A. leigongshanensis*, *A. anlongensis*, *A. bambusanus*, *A. daozenensis*, *A. yunshanensis*, *A. xishuiensis* and *A. langshanensis* were recorded that they feed on bamboo (Li et al. 2011; Chen et al. 2012; Yang and Chen 2013). So far, 17 species of this genus were known from China, of them, all species are distributed in the Oriental Region (China: Guizhou, Sichuan, Hunan, Hubei, Guangxi, Guangdong, Fujian and Zhejiang), and only *A. coneus* is also distributed in the Palaearctic Region (China: Gansu).

This genus is distinguished by its crown with two pairs of similar black spots on anterior margin, clypellus expanded apically, male pygophore with a long membranous process from its inner apex, and aedeagus with a well-developed basal projection dorsally (except *A. breviolus* and *A. langshanensis*).

In the present paper, two new species: *A. damingshanensis* sp. n. and *A. expansivus* sp. n. are described and illustrated from China (Oriental Region, Fig. 23). The type specimens of the new species are deposited in the Institute of Entomology, Guizhou University, Guiyang, China (GUGC).

Material and methods

Terminology of morphological and genital characters follow Dai and Zhang (2008). Male specimens were used for the description and illustration. External morphology was observed under a stereoscopic microscope and characters were measured with an ocular micrometer. Color pictures for adult habitus were obtained by KEYENCE VHX-1000 system. The genital segments of the examined specimens were macerated in 10% NaOH and drawn from preparations in glycerin jelly using a Leica MZ 12.5 stereomicroscope. Illustrations were scanned with Canon CanoScan LiDE 200 and imported into Adobe Photoshop CS8 for labeling and plate composition.

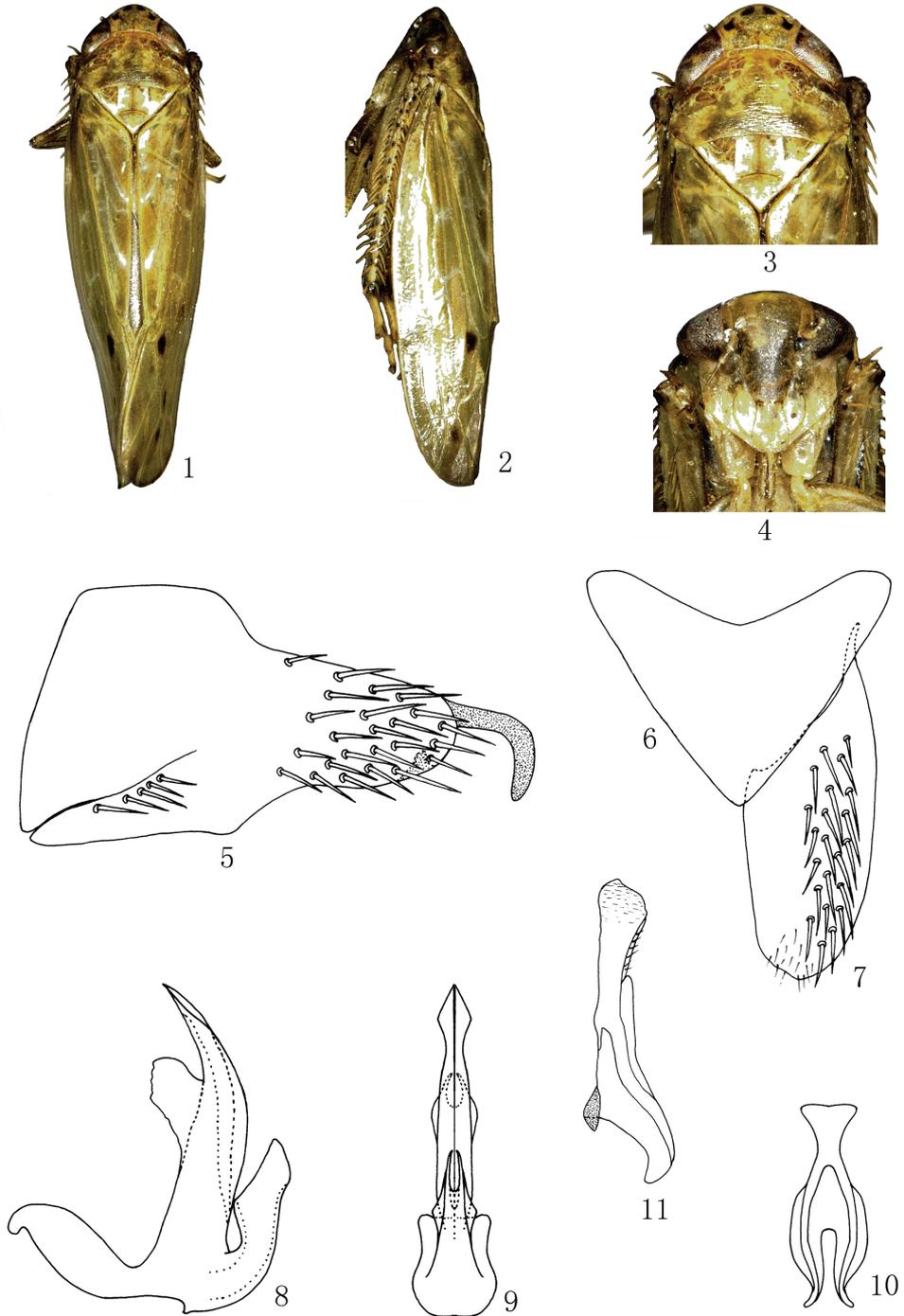
Descriptions of species

Abrus damingshanensis Xing & Li, sp. n.

<http://zoobank.org/211F15BE-9FD5-4A84-9D74-E3A16BA498DD>

Figs 1–11

Description. Yellowish brown species. Crown with two pairs of similar blackish brown spots on anterior margin. Eyes brown. Ocelli pale yellow. Pronotum with yellowish-brown stripe on anterior part. Inner and central antepical cells at apex, third and



Figures 1–11. *Abrus damingshanensis* sp. n., 1 ♂, dorsal view 2 ♂, lateral view 3 ♂, head and thorax, dorsal view 4 ♂, face 5 Male pygofer side, lateral view 6 Valve, ventral view 7 Subgenital plate, ventral view 8 Aedeagus, lateral view 9 Aedeagus, caudal view 10 Connective, ventral view 11 Style, dorsal view.

fourth apical cells at base each with a dark brown spot. Face brown, frontoclypeus yellowish brown. Forewings yellowish. Legs marked with brown.

Body elongate, robust. Head including eyes narrower than greatest width of pronotum. Vertex with fore margin produced roundly, median length shorter than width between eyes. Eyes fairly large. Ocelli on anterior margin, separated from corresponding eye by approximately their own diameter. Frontoclypeus distinctly longer than wide, anteclypeus expanded apically. Antennae arising near lower corner of eye. Pronotum with anterior margin strongly and roundly produced, posterior margin slightly concave. Scutellum triangular, slightly shorter than pronotum, with transverse suture curved and depressed. Forewing with 3 subapical and 4 apical cells, 4 times as long as wide, appendix wide. Hind wings with three apical cells and two anteapical cells. Profemur with 2 dorsoapical setae. Hind femur apical setal formula 2+2+1. Hind tibia flattened and nearly straight, with PD setae very long. Metabasitarsomere with three platellae and two setae on apical transverse row.

Male genitalia. Male pygofer side longer than high, with many macrosetae posteriorly and some at midventral margin; posterior margin lobe elongate and with a long membranous process at inner apex (Fig. 5). Valve subtriangular with anterior margin concaved and posterior margin strongly produced medially (Fig. 6). Subgenital plate narrowing to rounded apex, outer margin rounded, with uniseriate row of macrosetae along lateral margin (Fig. 7). Aedeagus with well-developed basal projection on dorsal margin, tapered to acute apex, with pair of dorsal quadrilateral flange at midlength on dorsal margin; aedeagal shaft about half length of basal projection, expanded medially, apically branched in the caudal view, gonopore apical (Figs 8, 9). Connective Y-shaped, stem robust, arms well developed, articulated with the aedeagus (Fig. 10). Style long, broad at base, narrow at middle, apical margin expanded (Fig. 11).

Measurement. Length (including tegmen): ♂, 9.1–9.2 mm.

Type material. Holotype ♂, **China: Guangxi** Autonomous Region, Nanning City, Mt. Damingshan, 13 August 2011, coll. Zaihua Yang (GUGC); paratypes 2♂♂, same data as holotype (GUGC).

Diagnosis. The new species is similar to *A. leigongshanensis* Li & Wang, 2006, but can be distinguished from the latter by the aedeagal shaft broad and short (about half length of basal projection); the basal projection tapered to acute apex, with pair of quadrilateral flange at midlength; and the apical process of style expanded.

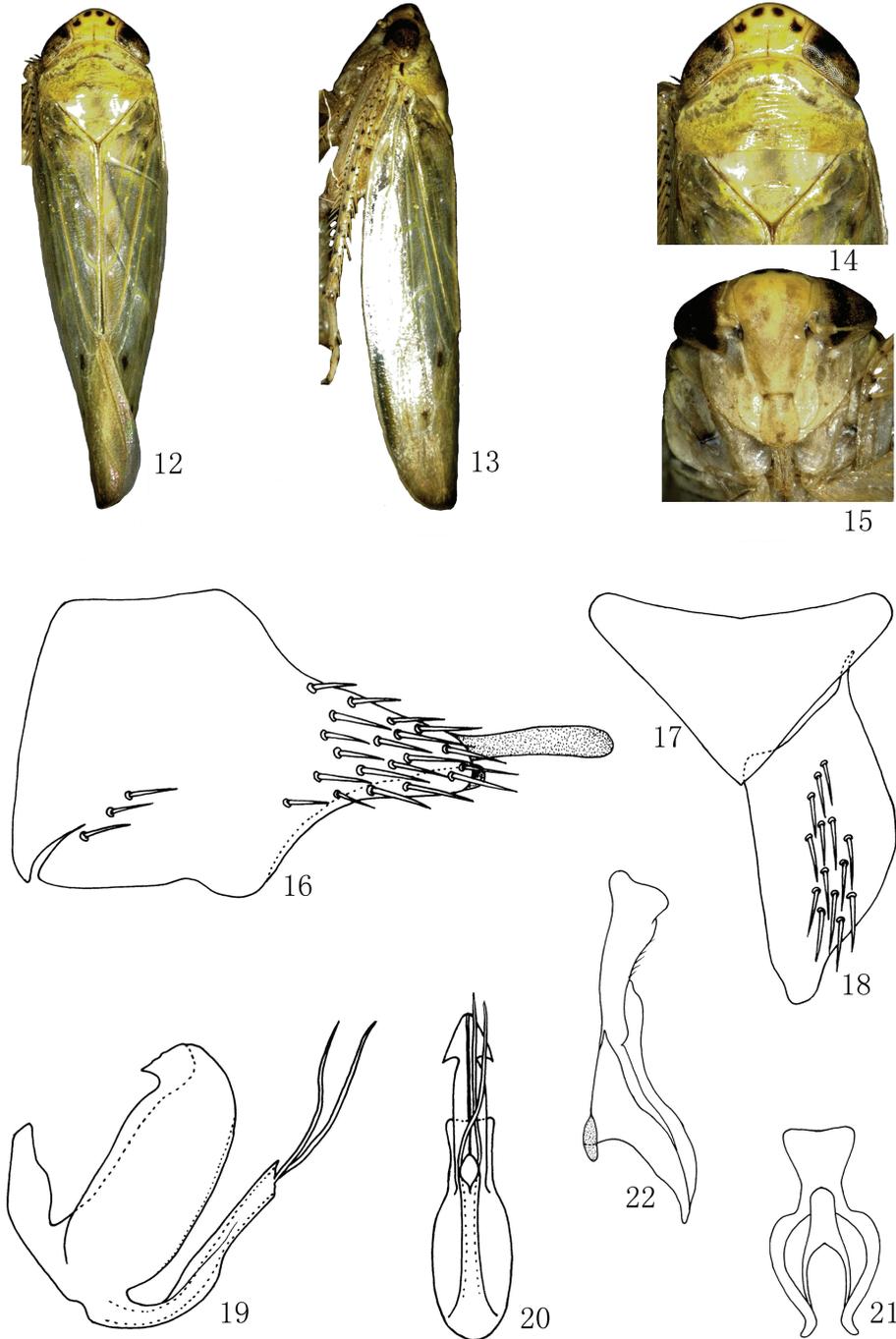
Etymology. This new species is named after the type locality, Damingshan, Guangxi Autonomous Region in China.

***Abrus expansivus* Xing & Li, sp. n.**

<http://zoobank.org/9C25F88C-D706-481F-B6B1-089C0EE2D4D8>

Figs 12–22

Description. External features resemble as *Abrus damingshanensis* sp. n., but color light yellow and body slightly small.



Figures 12–22. *Abrus expansivus* sp. n., 12 ♂, dorsal view 13 ♂, lateral view 14 ♂, head and thorax, dorsal view 15 ♂, face 16 Male pygofer side, lateral view 17 Valve, ventral view 18 Subgenital plate, ventral view 19 Aedeagus, lateral view 20 Aedeagus, caudal view 21 Connective, ventral view 22 Style, dorsal view.

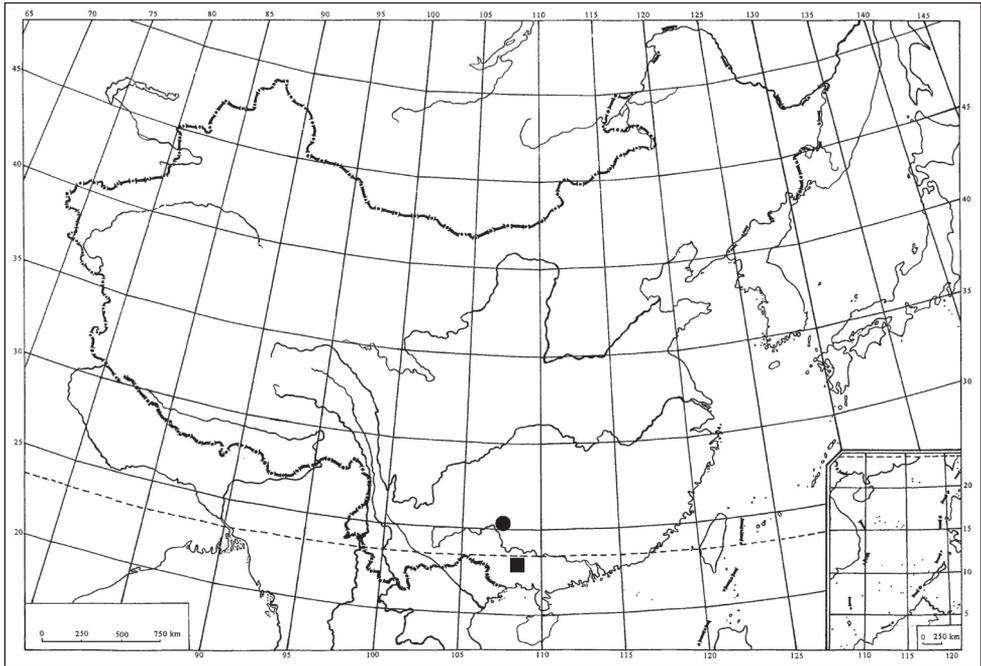


Figure 23. Geographic distribution of two new *Abrus* species in China: *A. damingshanensis* sp. n. (■); *A. expansivus* sp. n. (●).

Male genitalia. Male pygofer side elongate with many macrosetae posteriorly and a few at midventral margin; posterior margin lobe elongate and with a long membranous process at inner apex (Fig. 16). Valve subtriangular with anterior margin concave and posterior margin strongly produced medially (Fig. 17). Subgenital plate broad and short, outer margin rounded, with many macrosetae on lateral margin (Fig. 18). Aedeagus with broad and flat basal projection from dorsal margin, deeply concave at dorsal margin, the basal projection without processes; aedeagal shaft slightly shorter than basal projection, with a pair of slender apical processes and its length equal to aedeagal shaft, gonopore apical (Figs 19, 20). Connective Y-shaped, stem robust, arms well developed, articulated with the aedeagus (Fig. 21). Style long, broad at base, narrow at middle, apex slightly widening (Fig. 22).

Measurement. Length (including tegmen): ♂, 8.1 mm.

Type material. Holotype ♂, **China: Guizhou** Province, Dushan County, 16 July 2012, coll. Qiongzhang Song (GUGC).

Diagnosis. This new species is very similar to *A. brevis* Dai & Zhang, 2002 in aedeagal shaft with a pair of long apical appendages, but can be distinguished from the latter by the aedeagal shaft longer than half length of basal projection; aedeagal shaft with apical processes located medially in lateral view and its length equal to aedeagal shaft; the apical process of style wide and flat; and the subgenital plate narrow apically.

Etymology. The new species name is derived from the Latin word “*expansivus*”, referring to the apical process of style wide and expand.

Taxonomic notes on *Abrus* species

Species of *Abrus* are all very similar in coloration and difficult to distinguish externally, but the structure of aedeagus are markedly different. This genus now contains 19 species, they can be divided into 3 types based on the structure of aedeagus: 1) basal projection of aedeagus very small or absent (*A. breviolus* and *A. langshanensis*); 2) aedeagal shaft obviously shorter than basal projection (*A. brevis*, *A. leigongshanensis*, *A. damingshanensis* sp. n. and *A. expansivus* sp. n.); 3) aedeagal shaft as long as or longer than basal projection (other 13 species).

Above mentioned the second type structure of aedeagus, of them, two species (*A. brevis* and *A. damingshanensis* sp. n.) with aedeagal shaft about half length of basal projection, two species (*A. brevis* and *A. expansivus* sp. n.) with aedeagal shaft apically have a pair of slender processes, and two species (*A. damingshanensis* sp. n. and *A. expansivus* sp. n.) with the apical process of style expand.

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***Onthophagus cervicornis* Kirby, 1825, new synonym under *Onthophagus dama* (Fabricius, 1798) (Coleoptera, Scarabaeidae, Scarabaeinae)**

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Abstract

After examining syntypes of *Onthophagus cervicornis* Kirby, 1825, previously considered to be a synonym of the North American *Onthophagus striatulus* (Palisot de Beauvois, 1809), we confirm the true identity and new synonymy under South Asian *Onthophagus dama* (Fabricius, 1798).

Keywords

Dung beetles, North America, India

Introduction

Kirby (1825: 565) described *Onthophagus cervicornis* in a paper of new species and genera that were soon to be published in the “introduction to entomology” (Kirby 1826). The specimens of *Onthophagus cervicornis* were cited by Kirby (1825: 565) as originat-

ing from “Ex. Mus. D. Francillon”. The collection of John Francillon (1744–1818) was sold at auction by King in 1816 (duplicate insects, 253 lots) and 1818 (Foreign Insects, 1328 lots) (Chalmers-Hunt 1976: 76–77) and it must have been at this second sale, after the death of Francillon that Kirby, who was known to frequent these auctions, purchased the specimen(s). Kirby (1826: 310) stated “I have a beautiful little specimen in my cabinet, (I believe collected by Mr. Abbott of Georgia,) in which the horns have a lateral tooth, or short branch, like those of a stag; and which I have therefore named *O. cervicornis*.” The discrepancy between Kirby (1825: 565) and Kirby (1826: 311) as to the origin of the specimen can be explained by the fact that John Francillon and John Abbot (1752–1840) ‘of Georgia’ were known to each other, and Francillon acted as Abbot’s natural history agent. It is possible that Francillon mislabelled the specimen(s) or Kirby himself made the assumption as to the origin “Georgia, Amer.?” (which we now know to be incorrect), possibly under the impression that Abbot had sent *Onthophagus* material to Francillon. Unfortunately, locality labels on specimens were infrequent during this early period in collections. The presumed male specimen mentioned in Kirby (1826: 311) has no labelling other than “cervicornis” in Kirby’s own distinctive hand (DJM confirmed by comparison with known Kirby handwritten labels).

The collection of William Kirby (1759–1850) was presented to the Entomological Society of London during 1835, but was later (1858, 1863) sold at Stevens auction in lots (Chalmers-Hunt 1976: 102, Neave 1933: 71). Kirby specimens are now dispersed amongst a number of Museum Collections, with the bulk being housed in the Natural History Museum, London, and to a lesser extent the Oxford University Museum of Natural History. It is unclear how the Kirby material arrived at Manchester Museum. The female syntype of *Onthophagus cervicornis* is labelled with a modern type faced label “ex. coll. Hinks and Dibb” (Fig. 4), as is one other specimen. However, the majority of the *Onthophagus* specimens recognisable as Kirby’s (9 in total) do not possess similar labelling, suggesting that the later addition of these ‘accession’ labels may be mistaken. The female syntype of *Onthophagus cervicornis* (Fig. 2) was recognised as such by curators at the Manchester Museum and labelled as a syntype (Fig. 4). However, the male syntype (Fig. 1) remained unrecognised until now.

Harold (1869: 1030) appears to be the first author to consider *Onthophagus cervicornis* to be included under *Onthophagus janus* (Panzer, 1794), as he lists the first as a variety of the later. It was later followed by Horn (1875: 139) and others (e.g. Boucomont and Gillet 1927: 206, Howden and Cartwright 1963, Smith 2003: 30, Krajčik 2006: 134, Pulido-Herrera and Zunino 2007: 116), who considered both *Onthophagus cervicornis* and *Onthophagus janus* as synonyms under *Onthophagus striatulus* (Palisot de Beauvois, 1809). In their revision of the North American *Onthophagus*, the original description provided by Kirby led Howden and Cartwright (1963: 41) to consider that *Onthophagus cervicornis* was possibly African in origin, due to the branched horns of the male; nonetheless the authors retained the synonymy of *Onthophagus cervicornis*, as well as *Onthophagus janus* under *Onthophagus striatulus striatulus* (Palisot de Beauvois, 1809). In the most recent catalogue of new world *Onthophagus*, Pulido-Herrera and Zunino (2007: 116) maintain the synonymic placement of Howden and Cartwright (1963: 41).

Material and methods

The morphological study was carried out using syntypes of *Onthophagus cervicornis* housed in the entomological collection of the Manchester Museum (MMUE, Dmitri Logunov) and currently on loan to one of us (DJM), as well as syntypes of *Onthophagus dama* (Fabricius coll.), formally ownership of the Zoological Museum of the University of Kiel, Germany, and permanently on loan to the Natural History Museum of Denmark (ZMUC, Alexey Y. Solodovnikov). Specimens were analysed and photographed with a stereomicroscope Leica M165 and a Leica DFC 490 digital camera attached. Pictures were firstly mounted with Helicon Focus 5.1 (Helicon Soft Ltd.) and then enhanced with GIMP 2.8 (www.gimp.org).

Results and discussions

On examining syntypes of *Onthophagus cervicornis* the authors recognised that they correspond to a species widely known in collection as *Onthophagus dama* (Fabricius, 1798), a widespread and abundant species distributed across the Indian subcontinent.

Onthophagus dama (Fabricius, 1798)

Fig 1–4

Copris dama Fabricius 1798: 32

Scarabaeus aeneus Olivier 1789: 131

Onthophagus dama (Fabricius 1798) Arrow 1931: 280

Onthophagus zubaci Balthasar 1932: 151

Onthophagus (*Onthophagus*) *dama* (Fabricius 1798) Balthasar 1963: 325

Onthophagus cervicornis Kirby 1825: 565, **syn. n.**

Remarks. As no major nomenclatural concern can affect the current taxonomic status of *Onthophagus cervicornis*, we decided to maintain the syntypic status (Art. 73.2.1) for the examined specimens (ICZN 1999: 74.7.3). Instead, in order to maintain the nomenclature stability for *Onthophagus dama*, as well as the correct identification of further specimens, a male lectotype is here designated by choosing a name-bearing type specimen.

Geographical distribution. Nepal, Bhutan, Sri Lanka and India: Chhattisgarh, Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Tamil Nadu, Uttar Pradesh, Uttarakhand (Chandra and Gupta 2013: 4665), and Sikkim (Balthasar 1963: 326).

Type material examined. Syntypes (1♂ + 1♀): 1♂, dry pinned. Original label: “cervicornis” [cream label, W. Kirby black handwritten]; “♂ syntype Onthophagus cervicornis Kirby 1825: 565 = Onthophagus dama (F.) Rossini & Mann, 2014” [printed] (MM). 1♀, dry pinned. Original labels: “♀” [cream label, black hand-



Figures 1–4. Syntypes of *Onthophagus cervicornis* Kirby, 1825. **1** Dorsal habitus of the male **2** Dorsal habitus of the female **3** Labels of the male (Kirby handwriting) **4** Labels of the female.

written)/ *cervicornis* coll. Kirby [cream label with black border, black handwritten] / “Ex. Coll. Hincks & Dibb” [white label, black written printed] / “Manchester Museum, SYNTYPE” [blue label, black written printed] “♀ syntype *Onthophagus cervicornis* Kirby 1825: 565 = *Onthophagus dama* (F.) Rossini & Mann, 2014” [printed] (MM).

Ecology. coprophagus, mostly attracted by cattle and human excrements, tunneler, active in any seasons and diurnal (Venugopal et al. 2012). Very widespread and abundant in tropical dry forest and agricultural habitats.

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New data on the *Paederus biacutus* species group from mainland China (Coleoptera, Staphylinidae, Paederinae)

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Abstract

Paederus jianyueae Peng & Li, **sp. n.** (Zhejiang: Qingliangfeng) is described and illustrated. Additional records of *P. biacutus* Li, Zhou & Solodovnikov, 2014 and *P. parvidenticulatus* Li, Zhou & Solodovnikov, 2014 are reported.

Keywords

Coleoptera, Staphylinidae, *Paederus*, new species, new records, mainland China

Introduction

The *Paederus* fauna of China previously comprised 36 species, some of which were assigned to subgenera and some are listed as *incertae sedis* (Smetana 2004; Li et al. 2013, 2014). Five species, all of them brachypterous and more or less locally endemic, were placed in the *Paederus biacutus* species group: *P. biacutus* Li & al., 2014 (Fujian),

P. parvidenticulatus Li & al., 2014 (Guizhou), *P. sinisterobliquus* Li & al., 2014 (Hubei), *P. symmetricus* Li & al., 2014 (Guizhou, Guangxi), and *P. volutobliquus* Li & al., 2014 (Guangdong). This group can be easily distinguished from other groups or subgenera of *Paederus* Fabricius, 1775 by the special color pattern (black head, elytra and abdomen; brownish red pronotum; elytra with weakly or distinctly metallic hue), four regularly arranged protrusions on the anterior margin of the labrum, the trapeziform elytra with weakly pronounced humeral angles, the notched posterior margin of the male sternite IX, the strongly sclerotized and more or less symmetrical aedeagus with a hooked or straight apex of the dorsal plate, and a pair of distinct round or triangular posterior excisions of the female sternite VIII.

A study of *Paederus* material from mainland China yielded some new records and a new species of the *P. biacutus* group.

Material and methods

The morphological studies were conducted using an Olympus CX31 microscope. The images were prepared using a Canon EOS 70D (with an MP-E 65 macrolens) and Canon G12 camera. The line drawings were created using Adobe Illustrator CS3 software.

The following abbreviations are used in the text, with all measurements in millimeters:

Body length (**BL**): length of body from the anterior margin of the labrum to the apex of the abdomen.

Forebody length (**FL**): length of forebody from the anterior margin of the labrum to the posterior margin of elytra at suture.

Head length (**HL**): length of head from the anterior clypeal margin to the occipital constriction.

Head width (**HW**): maximum width of head (including eyes).

Antenna length (**AnL**): length of antennae from base of antennomere I to apex of antennomere XI.

Pronotum length (**PL**): length of pronotum along midline.

Pronotum width (**PW**): maximum width of pronotum.

Elytral length (**EL**): at the suture from the apex of the scutellum to the posterior margin of the elytra (at the sutural angle).

Elytral width (**EW**): maximum width of elytra.

Abdominal width (**AW**): maximum width of abdomen.

Aedeagus length (**AL**): length of the aedeagus from the apices of the parameres to the base of the aedeagal capsule.

The labels are cited in the original spelling. The type material is deposited in the Insect Collection of Shanghai Normal University, Shanghai, China (**SNUC**).

Taxonomy

Paederus biacutus Li, Zhou & Solodovnikov, 2013

Figs 1–2

Paederus biacutus Li, Zhou & Solodovnikov, 2013: 565.

Material studied (8 ♂♂, 2 ♀♀). 1 ♂, 1 ♀, “China: Fujian Prov., Wuyishan, Guadun, 27°44'N, 117°38'E, 02.vi.2012 1,300 m, Peng & Dai leg.” (SNUC); 1 ♂, “China: Fujian Prov., Wuyishan, Guadun, Xianfengling, 27°42'N, 117°39'E, 08.iv.2013 1,200 m, Wen-Xuan Bi leg.” (SNUC); 1 ♂, “China: Fujian Prov., Wuyishan, Sangang, 27°44'59"N, 117°40'47"E, 02.vii.? 750 m, Da-Kang Zhou leg.” (SNUC); 2 ♂♂,

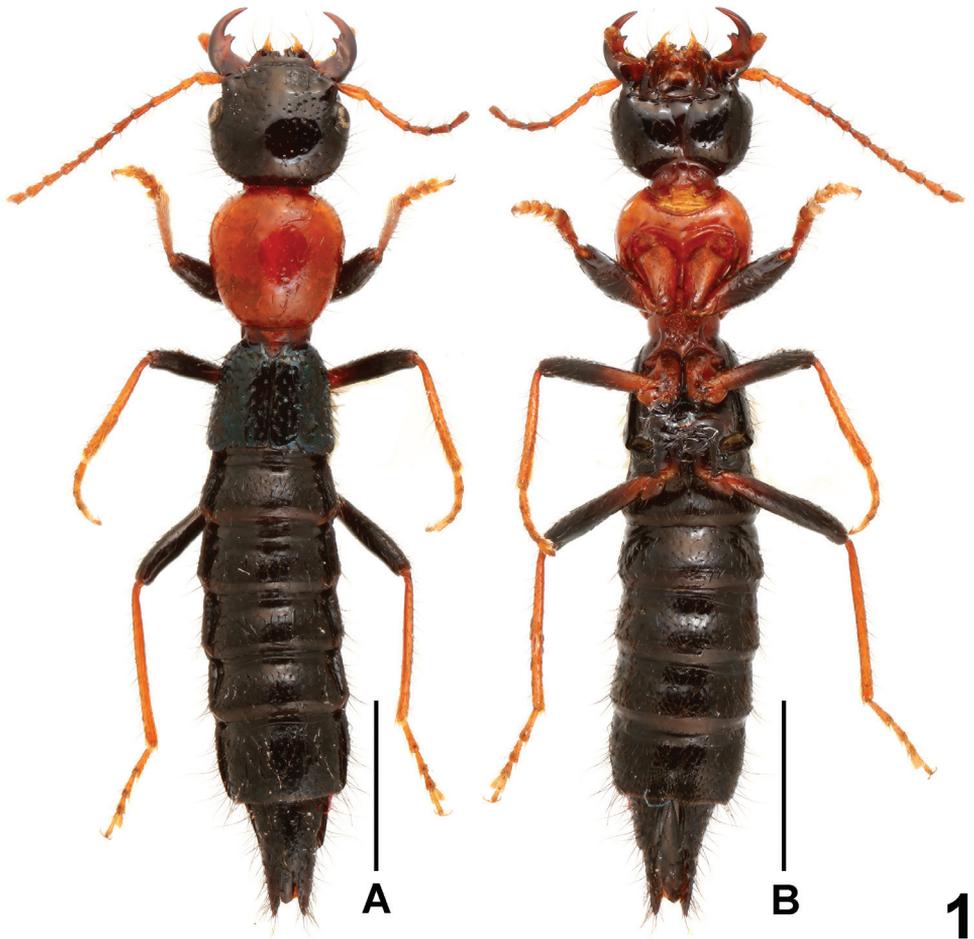


Figure 1. Habitus of *Paederus biacutus*. **A** lateral view **B** ventral view. Scales: 2.0 mm.

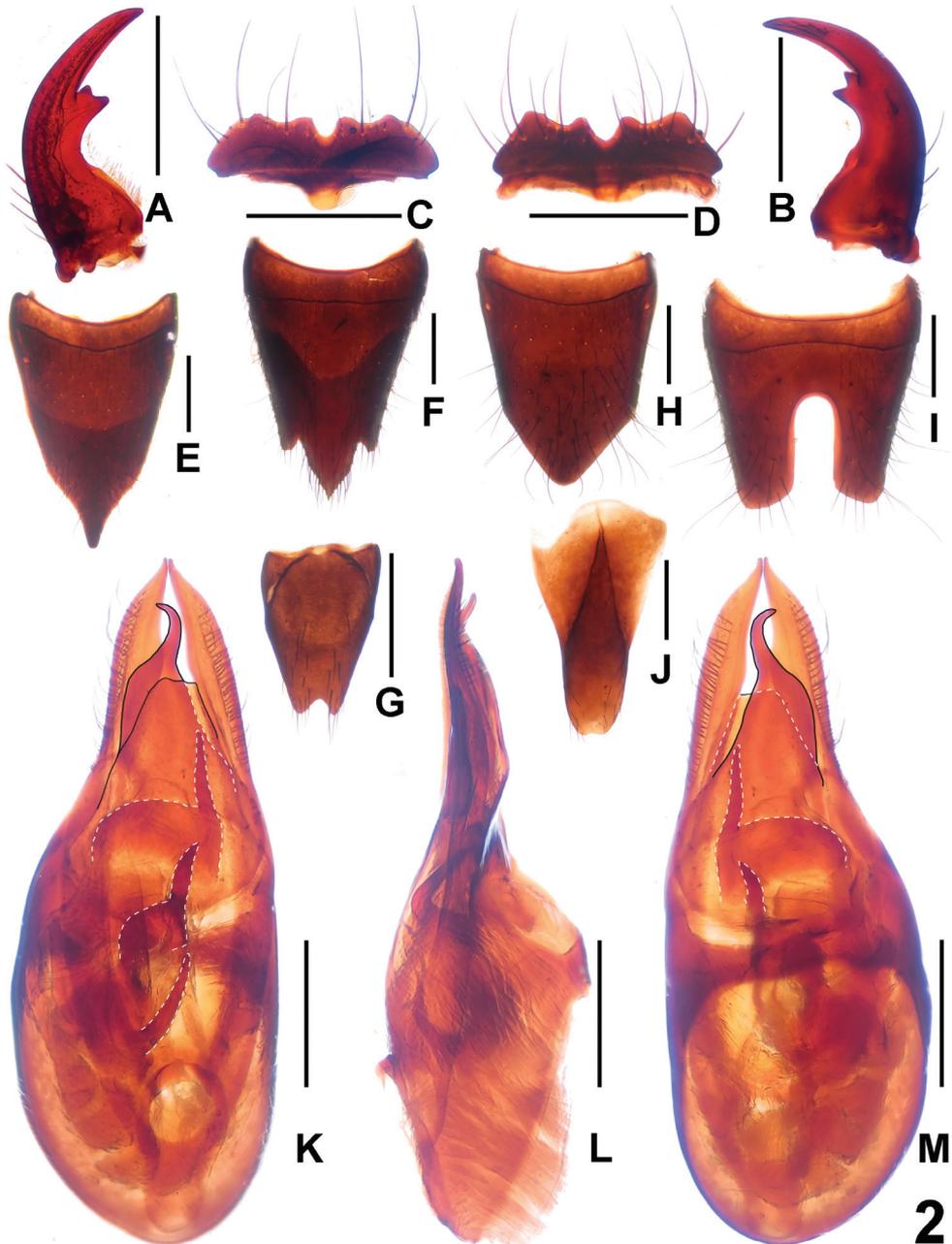


Figure 2. *Paederus biacutus*. **A** male left mandible **B** male right mandible **C** male labrum **D** female labrum **E** female tergite VIII **F** female sternite VIII **G** female sternite IX **H** male tergite VIII **I** male sternite VIII **J** male tergite IX **K** aedeagus in ventral view **L** aedeagus in lateral view **M** aedeagus in dorsal view. Scales: 0.5 mm.

“China: Fujian Prov., Wuyishan, Guadun, 27°44'02"N, 117°38'26"E, 30.viii.2009 1,200 m, Hao Huang leg.” (SNUC); 3 ♂♂, 1 ♀, “China: Jiangxi Prov., Yanshan County, Wuyi Shan, 27°55'45"N, 117°40'43"E, 10.v.2005 alt. 950 m, Hu & Tang leg.” (SNUC).

Comment. A comparison of the original description of *P. biacutus* and the additional material from the type locality and its vicinity revealed some differences in the sexual characters. According to the original description and illustration, the female sternite VIII is transverse (oblong in the additional material, Fig. 2F) and the internal sac of the aedeagus has two sclerotized spines (three spines in the additional material, Fig. 2K). The previously known distribution of *P. biacutus* included the Chinese province of Fujian (Li et al. 2013). The above record from Jiangxi represents a new province records.

Paederus parvidenticulatus Li, Zhou & Solodovnikov, 2013

Figs 3–6

Paederus parvidenticulatus Li, Zhou & Solodovnikov, 2013: 567.

Material studied (16 ♂♂, 21 ♀♀). 1 ♂, “China: Guangxi Prov., Xing’an, Maoer Shan, 25°52'23"N, 110°25'06"E, 23.vii.2012 1950–2000 m, Hu & Song leg.” (SNUC); 1 ♂, 4 ♀♀, “China: Guangxi Prov., Xing’an, Maoer Shan, 25°54'23"N, 110°27'41"E, 24.vii.2012 1550–1750 m, Hu & Song leg.” (SNUC); 4 ♂♂, 14 ♀♀, “China: Guangxi Prov., Xing’an, Maoer Shan, 25°52'18"N, 110°25'01"E, 10.vii.2011 1900–2100 m, He, Tang & Peng leg.” (SNUC); 7 ♂♂, 1 ♀, “China: Guangxi Prov., Xing’an, Maoer Shan, 25°54'17"N, 110°28'04"E, 02.vi.2012 1100–1700 m, Liu & Living leg.” (SNUC); 1 ♂, 1 ♀, “China: Guizhou Prov., Leishan County, Leigong Shan, 26°22'38"N, 108°11'47"E, 06.vi.2012 1500–1600 m, Liu & Living.” (SNUC); 2 ♂♂, 1 ♀, “China: Guizhou Prov., Leigong Shan, Lianhuaping, 15.ix.2005 1450–1500 m, Li-Long Zhu leg.” (SNUC).

Comment. An examination of the above material from the type localities of *P. symmetricus* and *P. parvidenticulatus* revealed that they are conspecific. A paper formally proposing the respective synonymy is being prepared by Xiao-Yan Li (pers. comm.).

Paederus jianyueae Peng & Li, sp. n.

<http://zoobank.org/49639086-9045-438B-8153-21D951D84CAC>

Figs 7–8

Type material. (14 ♂♂, 28 ♀♀). HOLOTYPE: ♂, labelled ‘China: Zhejiang Prov., Lin’an, Qingliangfeng, 30°05'48"N, 118°51'36"E, alt. 1500–1700 m 22.v.2012, Yi & Zhang leg.’ (SNUC). PARATYPES: 12 ♂♂, 28 ♀♀, same label data as holotype

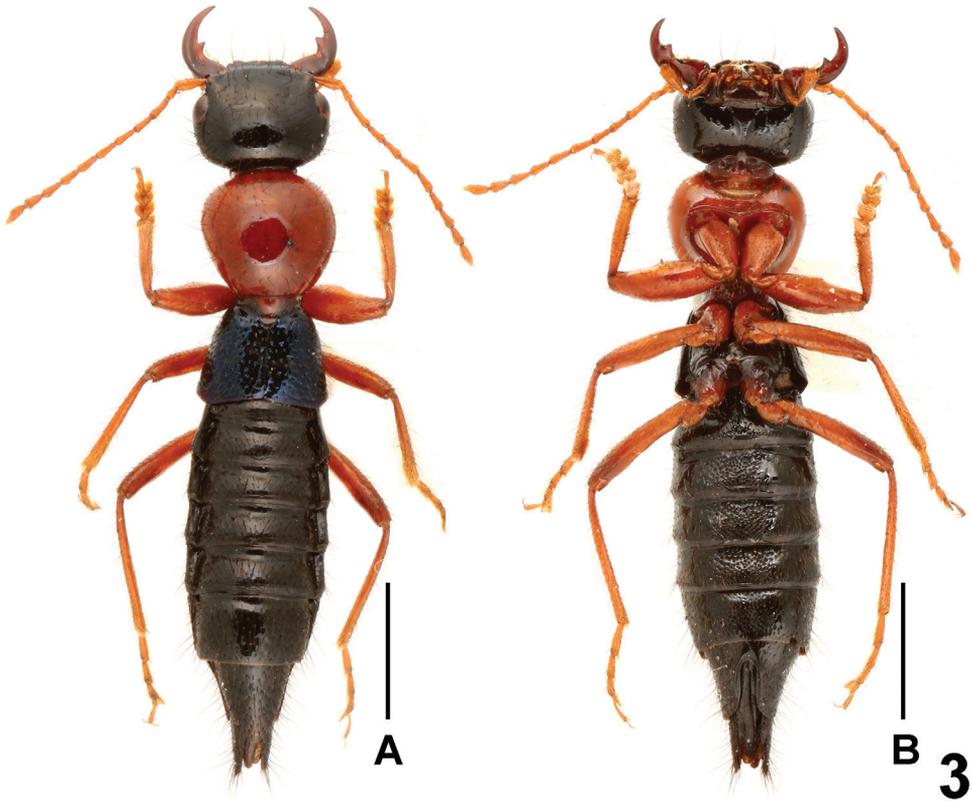


Figure 3. Habitus of *Paederus parvidenticulatus* (Leigong Shan). **A** lateral view **B** ventral view. Scales: 2.0 mm.

(SNUC); 1 ♂, same data, but ‘Anhui Prov. Huang Shan, 30°07'51"N, 118°09'51"E, 18.v.2005 alt. 1700 m, Wen-Xuan Bi leg.’ (SNUC).

Description. Measurements (in mm) and ratios: BL 9.23–10.34, FL 4.56–4.78, HL 1.30–1.41, HW 1.52–1.61, AnL 2.78–2.95, PL 1.59–1.67, PW 1.54–1.66, EL 1.02–1.13, EW 1.52–1.61, AW 1.70–1.85, AL 1.04–1.09, HL/HW 0.85–0.89, HW/PW 0.95–0.98, HL/PL 0.81–0.85, PL/PW 0.98–1.03, EL/PL 0.64–0.68, diameter of eye: 0.37–0.44.

Habitus as in Fig. 7. Coloration: head, pronotum and abdomen black; elytra black with faint blueish hue; legs and antennae dark-yellowish, apices of femora and tibiae not infuscate.

Head transverse; shape without apparent sexual dimorphism; widest across eyes; punctuation moderately coarse and very sparse; interstices glossy. Eyes distinctly convex, 0.6–0.8 times as long as postocular region in dorsal view. All antennomeres oblong.

Pronotum nearly globulous, strongly convex in cross-section; punctuation similar to that of head, very sparse.

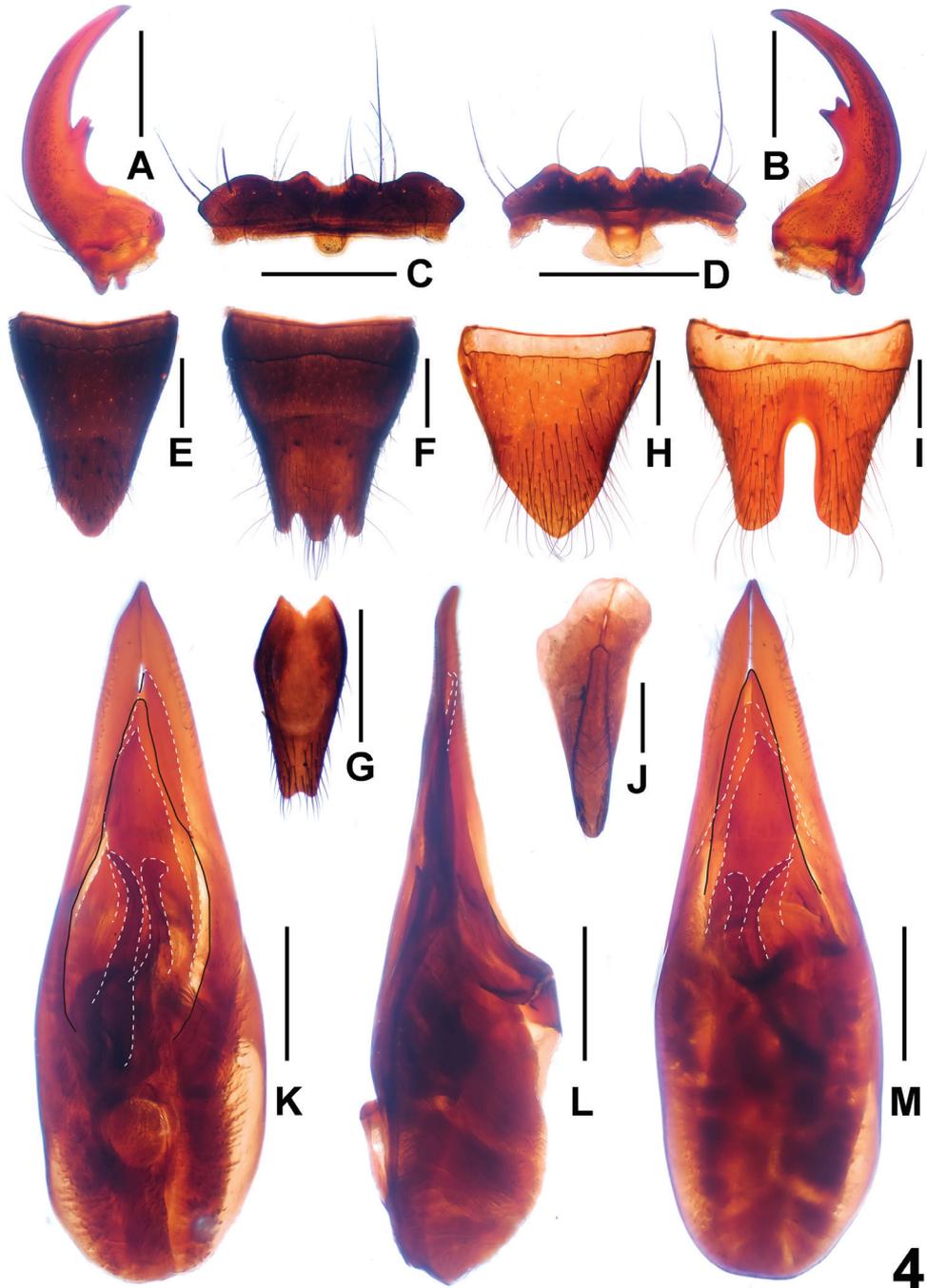


Figure 4. *Paederus parvidenticulatus* (Leigong Shan). **A** male left mandible **B** male right mandible **C** male labrum **D** female labrum **E** female tergite VIII **F** female sternite VIII **G** female sternite IX **H** male tergite VIII **I** male sternite VIII **J** male tergite IX **K** aedeagus in ventral view **L** aedeagus in lateral view **M** aedeagus in dorsal view. Scales: 0.5 mm.

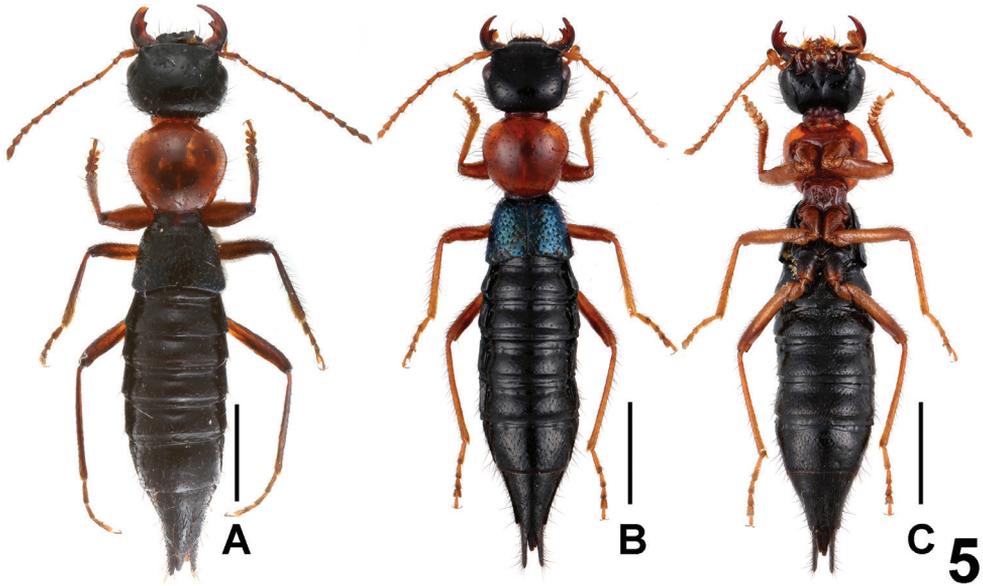


Figure 5. Habitus of *Paederus parvidenticulatus* (Maoer Shan). **A–B** lateral view **C** ventral view. Scales: 2.0 mm.

Elytra trapeziform; punctuation coarse, moderately defined, and dense. Hind wings completely reduced. Metatarsomere I as long as combined length of metatarsomeres II and III.

Abdomen distinctly broader than elytra; punctuation sparse; interstices with shallow microsculpture; posterior margin of tergite VII without palisade fringe; posterior margin of tergite VIII (Fig. 8E, H) strongly convex.

Male. Labrum (Fig. 8C) distinctly sinuate, anterior margin with two pairs of obtuse teeth; mandibles (Fig. 8A–B) long and robust, inner margin with one bicuspidate tooth. Sternite VII unmodified; sternite VIII (Fig. 8I) weakly transverse and with deep and narrow posterior incision, this incision approximately 0.4 times as long as sternite VIII; sternite IX (Fig. 8J) asymmetric; aedeagus as in Fig. 8K–M; dorsal plate of median lobe asymmetric, curved in lateral view and not reaching apices of parameres, its base broad and narrowed posteriad; parameres symmetric and slender; internal sac with three distinctive sclerotized spines.

Female. Labrum as in Fig. 8D. Posterior margin of sternite VIII symmetric and trifurcate as in Fig. 8F; sternite IX (Fig. 8G) symmetrical and stout.

Distribution and natural history. The species was found in two geographically close localities: Qingliangfeng, western Zhejiang and the Huang Shan, southeastern Anhui. The specimens were sifted from leaf litter and moss in coniferous forests at altitudes of 1500–1700 m.

Etymology. The species is named after Jian-Yue Qiu, who lent extensive support to our research.

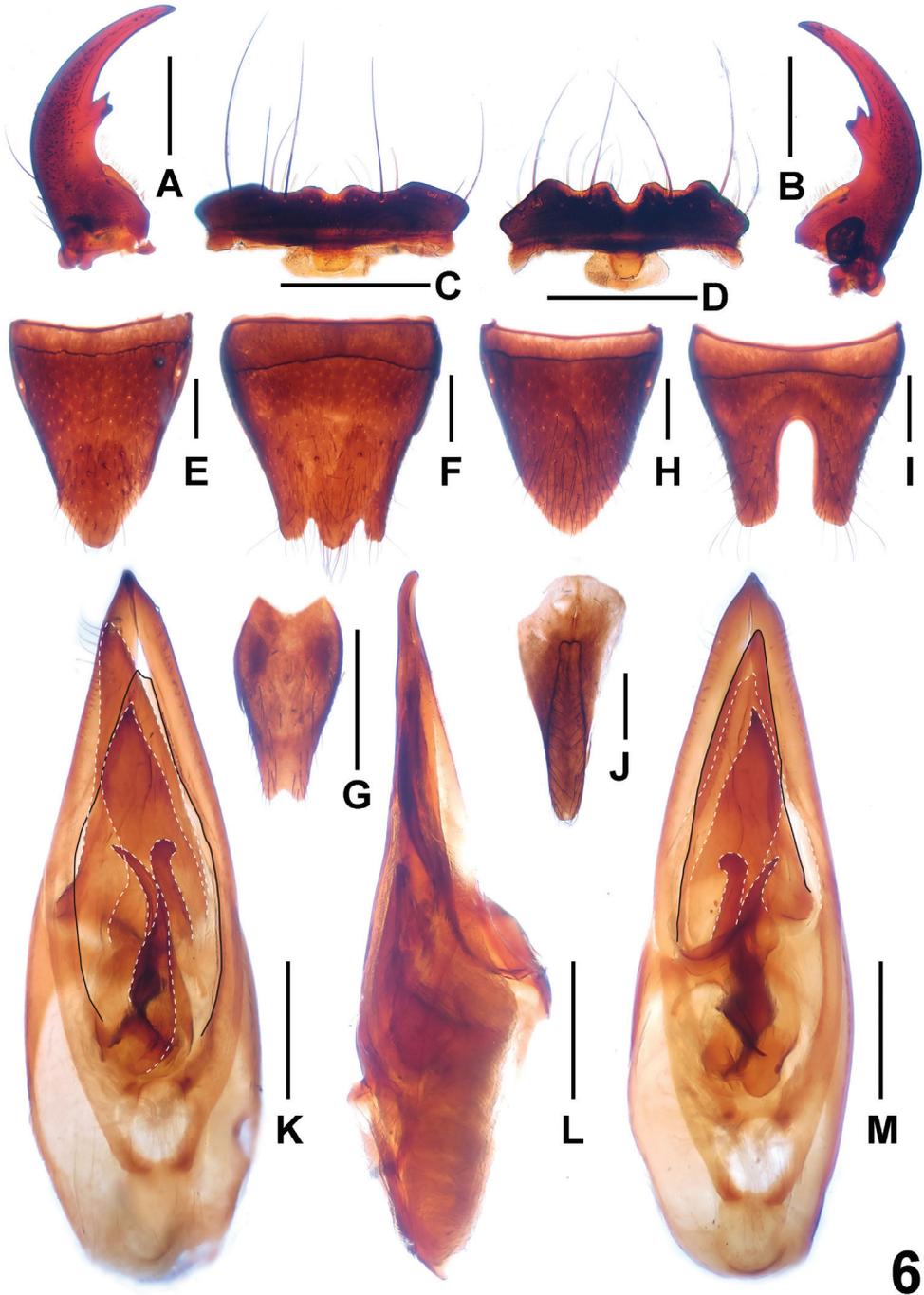


Figure 6. *Paederus parvidenticulatus* (Maoer Shan). **A** male left mandible **B** male right mandible **C** male labrum **D** female labrum **E** female tergite VIII **F** female sternite VIII **G** female sternite IX **H** male tergite VIII **I** male sternite VIII **J** male tergite IX **K** aedeagus in ventral view **L** aedeagus in lateral view **M** aedeagus in dorsal view. Scales: 0.5 mm.

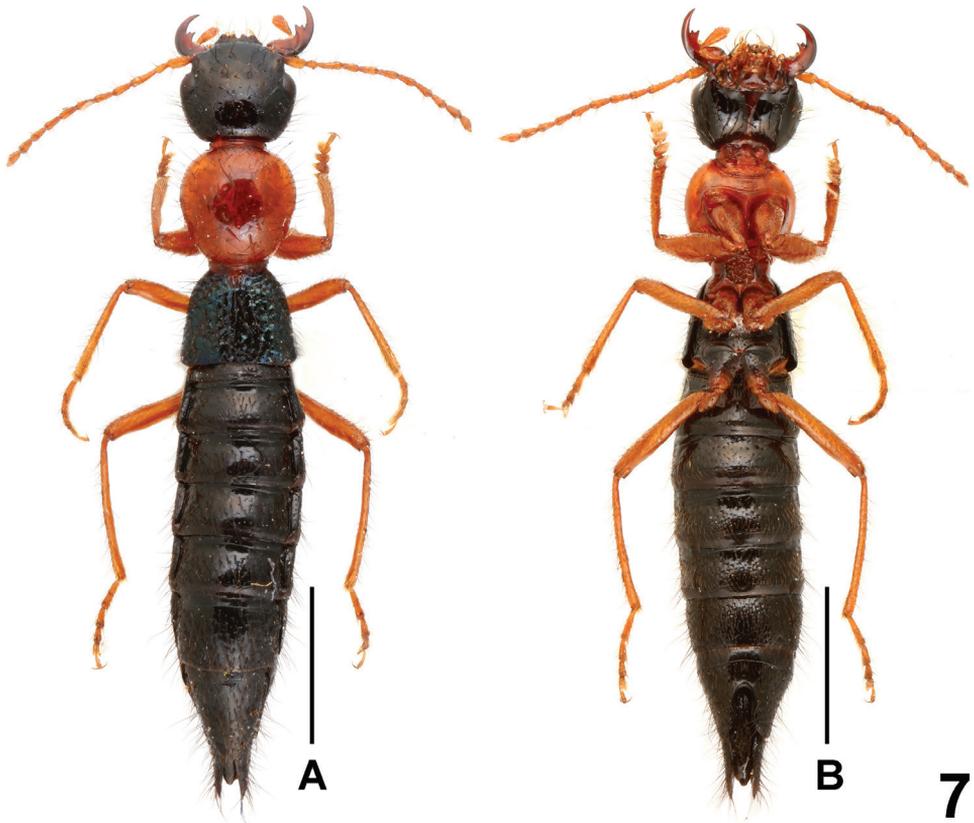


Figure 7. Habitus of *Paederus jianyueae*. **A** lateral view **B** ventral view. Scales: 2.0 mm.

Comparative notes. *Paederus jianyueae* belongs to the *P. biacutus* group, as can be inferred both from the sexual characters and from the external morphology (special color pattern, four protrusions on anterior margin of labrum, morphology of the aedeagus, shape of the male sternite IX and the female sternite VIII). This new species is distinguished from other species of this group by the shape of female sternite VIII and the morphology of the aedeagus (more slender dorsal plate of the median lobe; slender parameres; three distinctive sclerotized spines in the internal sac). Based on the similar morphology of the aedeagus, *P. jianyueae* may be most closely related to *P. biacutus* Li, Zhou & Solodovnikov, 2013.

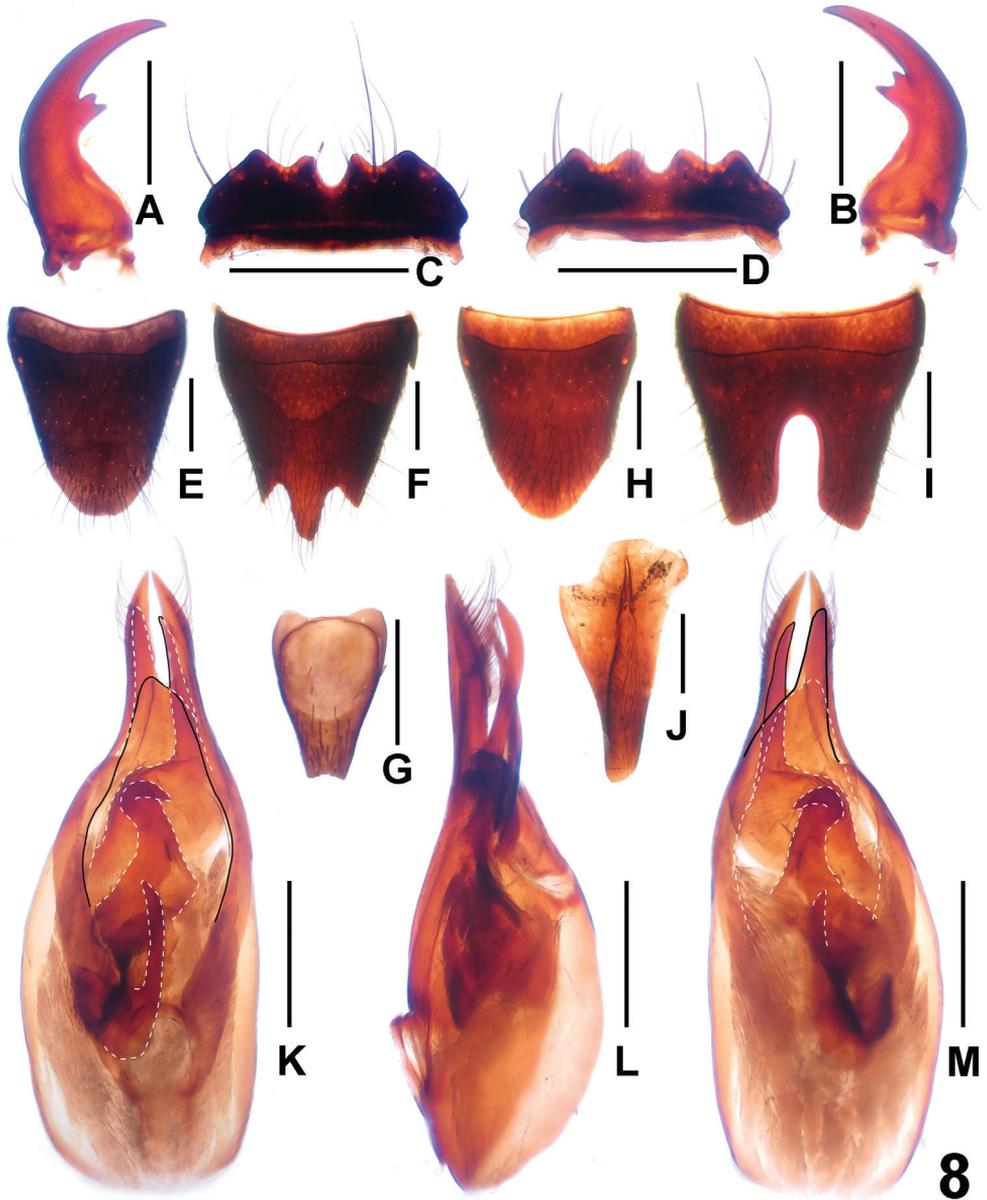


Figure 8. *Paederus jianyueae*. **A** male left mandible **B** male right mandible **C** male labrum **D** female labrum **E** female tergite VIII **F** female sternite VIII **G** female sternite IX **H** male tergite VIII **I** male sternite VIII **J** male tergites IX **K** aedeagus in ventral view **L** aedeagus in lateral view **M** aedeagus in dorsal view. Scales: 0.5 mm.

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A new species of *Diartiger* Sharp (Staphylinidae, Pselaphinae, Clavigeritae) from the Fengyangshan – Baishanzu Nature Reserve, East China

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Abstract

A new clavigerine pselaphine, *Diartiger zhejiangensis* Yin & Li, **sp. n.**, from the Fengyangshan – Baishanzu Nature Reserve, southern Zhejiang, is described, illustrated, and compared with congeners. The species is hosted by ants in the genus *Lasius*. The key to *Diartiger* species from China is modified to accommodate the new species.

Keywords

Taxonomy, Clavigeritae, *Diartiger*, new species, myrmecophily, *Lasius*, Asia

Introduction

In a recent publication (Yin and Li 2013), the relationship between *Diartiger* Sharp and *Microdiartiger* Sawada was discussed, the synonymy of the two genera defended, and two new species were described from Anhui, East China. As a result of that work, the Chinese *Diartiger* includes four species, with *D. dentatus* Yin & Li, *D. kunmingensis* Nomura, and *D. yaoluopingensis* Yin & Li placed in the *D. fossulatus* group, and *D. songxiaobini* (Yin & Li) in the *D. japonicus* group.

During a survey (26.iv–03.v.2014) of the staphylinid beetles at the Fengyangshan – Baishanzu Nature Reserve, Zhejiang, three adults of an undetermined *Diartiger* were discovered, two in *Lasius* colonies, and one from a sifted litter sample. This species can

be separated from all known congeners by a unique combination of external characters, and is formally described herein. The key to *Diartiger* species occurring in China is modified to accommodate the new species.

Materials and methods

All material treated in the present study is housed in the Insect Collection of Shanghai Normal University, Shanghai, China (SNUC).

This study is based on three adults collected during a recent survey of the staphylinid beetles at the Fengyangshan – Baishanzu Nature Reserve by our lab students Zhong Peng and Xiao-Bin Song. The two *Diartiger* adults and host ants from Baishanzu Nature Reserve were transported to our lab alive for behavioral observations and photos.

Observations and dissections were carried out using an Olympus SZ61 Stereo microscope. Dissected parts were preserved in Euparal mounting medium (BioQuip Products, Inc., CA, U.S.A.) on plastic slides that were placed on the same pin with the specimen. Digital habitus images of dead and live adults were created using a Canon 7D digital camera in conjunction with a Canon MP-E 65mm f/2.8 1-5X Macro Lens, a Canon MT-24EX Macro Twin Lite Flash, and a flash light diffuser made by parchment paper. Images of the dissected parts were made using a Canon G9 camera mounted by hand on a Olympus CX31 microscope. Zerene Stacker version 1.04 was used for image stacking, and all images were edited and grouped in Adobe Photoshop CS5 Extended (version 12.0).

The following abbreviations are applied: **AL**—length of the abdomen along the midline; **AW**—maximum width of the abdomen; **EL**—length of the elytra along the sutural line; **EW**—maximum width of the elytra; **HL**—length of the head from the anterior clypeal margin to the occipital constriction; **HW**—width of the head across eyes; **PL**—length of the pronotum along the midline; **PW**—maximum width of the pronotum. Length of the body is a combination of HL + PL + EL + AL.

Taxonomy

Diartiger zhejiangensis Yin & Li, sp. n.

<http://zoobank.org/20113B64-96ED-4879-AB1D-D23243DBEF12>

Figs 1–3

Type material (2 ♂♂, 1 ♀). **Holotype**: CHINA: ♂, labeled 'China: S. Zhejiang, Qingyuan, Baishanzu N.R., 27°45'14"N, 119°11'55"E, Fagaceae forest, ant nest in rotten wood, 1650 m, 01.v.2014, X.-B. Song leg. / HOLOTYPE [red], *Diartiger zhejiangensis* sp. n., det. Yin & Li, 2014, SNUC'. **Paratypes**: CHINA: 1 ♀, same area and date, except '27°45'27"N, 119°12'05"E, mixed leaf litter, sifted, 1700 m, Z. Peng leg.'; 1 ♂ [disarticulated specimen preserved in Euparal on plastic slides], labeled 'China: S. Zhejiang, Longquan, Fengyang Shan, creek valley nr. hotel, 27°54'42"N, 119°11'52"E, *Rhododen-*

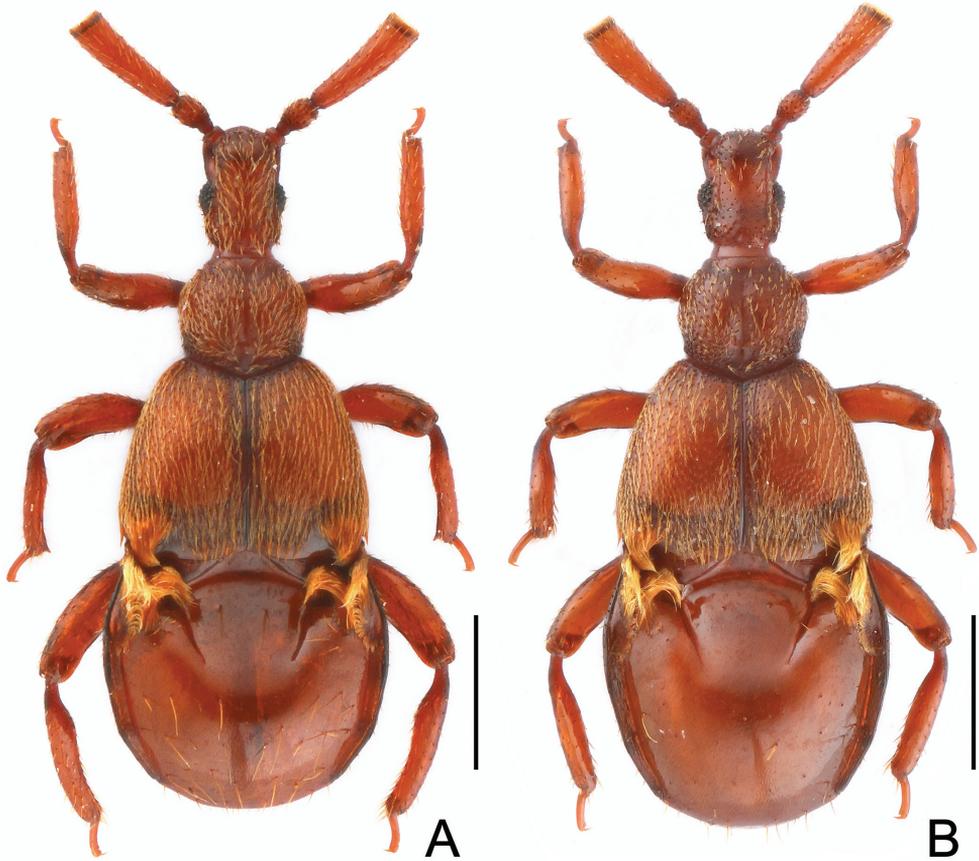


Figure 1. Habitus of *Diartiger zhejiangensis*. **A** Male **B** Female. Scales: 0.5 mm.

dron and fir forest, ant nest in erect rotten fir trunk, 1250 m, 28.iv.2014, Peng leg.'. Each paratype bears a type label similar to that of the holotype except 'PARATYPE [yellow]'.

Description. Male. Body (Fig. 1A) length 2.14–2.15 mm; reddish brown. Head longer than wide, HL 0.39–0.40 mm, HW 0.27–0.28 mm; clypeus with slightly angularly rounded anterior margin; eyes each composed of about 20 facets; antennomeres IV (Fig. 2A) more than twice length of III, with truncate apex. Pronotum about as long as wide, PL 0.37–0.38 mm, PW 0.39–0.41 mm. Elytra (Fig. 2E) wider than long, EL 0.53–0.56 mm, EW 0.80–0.82 mm; lacking microsculpture; with small tuft of setae at posterolateral margins, and bigger triangular, posteriorly-narrowed trichomes at posterior margins. Metathoracic wings fully-developed. Mesoventrite (Fig. 2F) lacking median carina, metaventrite (Fig. 2F) slightly convex, both meso- and metaventrites with row of setae along midline. Profemora (Fig. 2B) with long ventral setae at base, protibiae narrowed at base and thickened from basal third toward apex; mesotrochanters (Fig. 2C) with large, bluntly triangular ventral spine, mesofemora lacking spine; mesotibiae with small apical spur; metatibiae (Fig. 2D) lacking spine or modification.

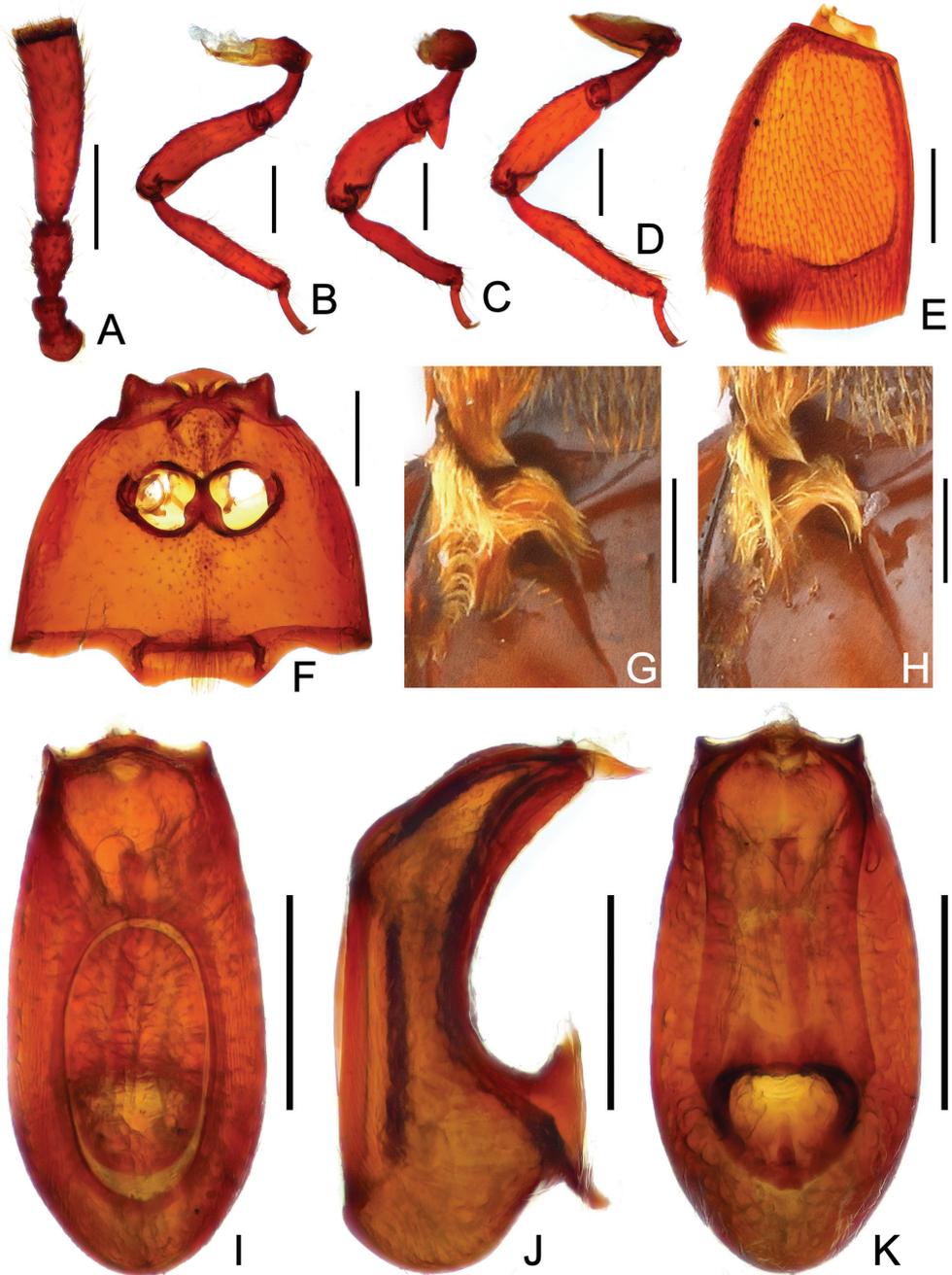


Figure 2. Diagnostic features of *Diartiger zhejiangensis* (A–G, I–K male H female). A Antenna B Fore leg C Mid leg D Hind leg E Left elytron F Meso- and metaventrites G–H Trichomes of elytra and composite tergite I Aedeagus, in dorsal view J Same, in lateral view K Same, in ventral view. Scales: 0.2 mm.



Figure 3. Habitat and host of *Diartiger zhejiangensis*. **A** General habitat of the *Rhododendron* and fir forest at Fengyang Shan Nature Reserve **B** Rotten trunk where the female paratype was collected **C** General habitat of the Fagaceae forest at Baishanzu Nature Reserve **D** Rotten wood where the holotype was collected **E–F** Living male adult of *D. zhejiangensis* with host ants.

Abdomen slightly wider than long, AL 0.82–0.84 mm, AW 0.88–0.92 mm; composite tergite with transverse basolateral trichomes curved mesally, first pair of paratergites with linear trichomes (Fig. 2G). Aedeagal length 0.50–0.52 mm; median lobe (Fig. 2I–K) with sinuate apical margin in dorso-ventral view.

Female. General form (Fig. 1B) and trichomes on elytra and composite tergite (Fig. 2H) similar to those of male; fourth antennomeres slightly shorter, mesotrochanters and mesotibiae lacking spine; abdomen relatively larger. Each eye composed of about 20 facets. Measurements: BL 2.23 mm, HL 0.41 mm, HW 0.28 mm, PL 0.39 mm, PW 0.43 mm, EL 0.55 mm, EW 0.83 mm, AL 0.88 mm, AW 0.92 mm.

Comparative notes. This species is placed as a member of the *D. fossulatus* group. Males are most similar to those of *D. dentatus* in possessing relatively short antennomeres III, and in similarities of trichomes on the posterior margins of the elytra and the base of the composite tergite, and in the aedeagal form. The two species can be readily separated by the lack of spines on the mesofemora and middle of the mesotibiae, and lack of a small tubercle on the ventral margin of the metacoxa in *D. zhejiangensis*, while *D. dentatus* possesses a sharp basal spine on the ventral margin of the mesofemur, the mesotibia possesses a triangular spine at the middle, and the metacoxa possesses a small tubercle on the ventral margin.

Distribution. East China: Zhejiang.

Bionomics. The male holotype was collected from a colony of *Lasius* cf. *koreanus* (det. Maruyama, pers. comm. 2014) nesting in rotten wood in a predominantly Fagaceae forest (Fig. 3C, D). The female paratype from Baishanzu was collected from a sifted litter sample. The other female paratype collected from Fengyang Shan was found in a small colony of the same *Lasius* species nesting under bark of a standing rotten fir trunk in a *Rhododendron* and fir forest (Fig. 3A, B). During a two-day observation period, the adults of *D. zhejiangensis* (Fig. 3E, F) were totally ignored by the ant workers, and vice versa. This may have been a consequence of the disturbance of being transported and housed in the artificial environment.

Etymology. The specific epithet refers to the province where the type locality of the new species lies.

Modified couplets of the key (Yin and Li 2013) to *Diartiger* males from China

- 2 Fourth antennomeres (Fig. 2A; Yin and Li 2013: 372, Fig. 2A) more than twice length of third antennomeres..... **2a**
 – Fourth antennomeres (Yin and Li 2013: 372, Fig. 3A; Nomura 1997: 99, Fig. 4 ‘km.’) less than twice as long as third antennomeres..... **3**
 2a Mesofemora with a sharp ventral spine at base; mesotibiae with a triangular spine at middle (Yin and Li 2013: 372, Fig. 2C), metacoxae (Yin and Li 2013: 372, Fig. 2D) with a small tubercle at ventral margin. (East China: Anhui) ..
 ***D. dentatus* Yin & Li, 2013**
 – Mesofemora and middle area of mesotibiae (Fig. 2C) lacking spine, metacoxae (Fig. 2D) lacking tubercle. (East China: Zhejiang)..... ***D. zhejiangensis* sp. n.**

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