

Tasmanian Trechinae and Psydrinae (Coleoptera, Carabidae): a taxonomic and biogeographic synthesis, with description of new species and evaluation of the impact of Quaternary climate changes on evolution of the subterranean fauna⁽³⁾

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ABSTRACT

This paper provides taxonomic, distributional and ecological data for 59 species in 17 genera of Trechinae and Psydrinae from Tasmania, and describes 18 new species in six existing genera (*Pterocyrtus*, *Tasmanorites*, *Sloanella*, *Trechistus*, *Goedtrechus*, *Tasmanotrechus*) collected from caves, forest and montane habitats: *Pterocyrtus grayi* sp. nov., *P. meridionalis* sp. nov., *Tasmanorites beatricis* sp. nov., *T. daccordii* sp. nov., *T. lynceorum* sp. nov., *T. microphthalmus* sp. nov., *Sloanella gordonii* sp. nov., *Trechistus gordonii* sp. nov., *Goedtrechus minutus* sp. nov., *G. rolani* sp. nov., *G. florentinus* sp. nov., *G. damperi* sp. nov., *Tasmanotrechus gordonii* sp. nov., *T. alticola* sp. nov., *T. montisfieldi* sp. nov., *T. osbornianus* sp. nov., *T. moorei* sp. nov., *T. rolani* sp. nov. Forty-one (41) previously described species have been re-examined and illustrated with supplementary descriptions. New collection records combined with the published literature revealed 196 records of 83 species in 21 genera, collected from 41 localities (including 11 karst areas). Regional-scale survey coverage has been patchy and three biogeographic regions stand out as poorly surveyed: Flinders, South East, and Northern Midlands. Local-scale survey efforts have been intensive at just a few localities, the richest being 18 species recorded at Cradle Mountain. Seventeen (17) described species of Zolini and Trechini are troglobites with distribution ranges restricted to individual karst areas. Some karst areas and caves harbour multiple congeneric species which differ in their degree of troglomorphic specialization suggesting heterochronic colonisations, possibly linked to multiple Quaternary glacial / inter-glacial cycles. Palaeo-climatic and palaeo-vegetation evidence is examined to test the ‘Climatic Relict Hypothesis’ as a mechanism driving evolution of the subterranean fauna. It is proposed that present-day troglobitic Trechinae in Tasmania are derived from troglophilic progenitors that colonised subterranean habitats from adjacent forest ground litter habitats during Pleistocene inter-glacial periods, while retreat of forests during glacial periods isolated subterranean populations from surface populations facilitating troglogenesis. It is predicted that future collecting efforts will reveal many additional new subterranean species, including in non-karstic Shallow Subterranean Habitats (SSH).

Key words: Tasmania, Trechinae, Psydrinae, cave, beetles

INTRODUCTION

Tasmania is well known to be remarkably rich in endemic ground beetles, especially the Trechinae (Donabauer 2001). After the monographic work by Sloane (1920) on Carabidae of Tasmania, Jeannel (1927) was the first to deal in an organic way with the systematics of the Trechini of Tasmania. After these fundamental contributions, fifty years elapsed before two contributions by Moore (1963, 1972) addressed in a systematic manner the Carabidae, Trechodina, Trechina and Psydrini of this island. Later, a tentative key to the genera of Australian and Tasmanian Trechini known at the time was given by Casale & Laneyrie (1982). Subsequently, Moore,

in a series of specific works (1978, 1983, 1984 and 1994), described several cave dwelling genera and species. Donabauer (2001) described a new species of *Tasmanorites* and provided drawings of the male genitalia of several other species in this genus. Most recently, Baehr (2005) provided an excellent review of Australian species of Amblytelini. This contribution stems initially from specimens collected from caves in the 1980’s by one of the authors (S.E.) and sent to the late Lucien Genest of Grenoble (France). Lucien Genest, before his passing, sent these materials to the second author (P.M.G.) thereby stimulating his interest in the carabid beetle fauna of Tasmania. This original collection has been added to with material obtained from other en-

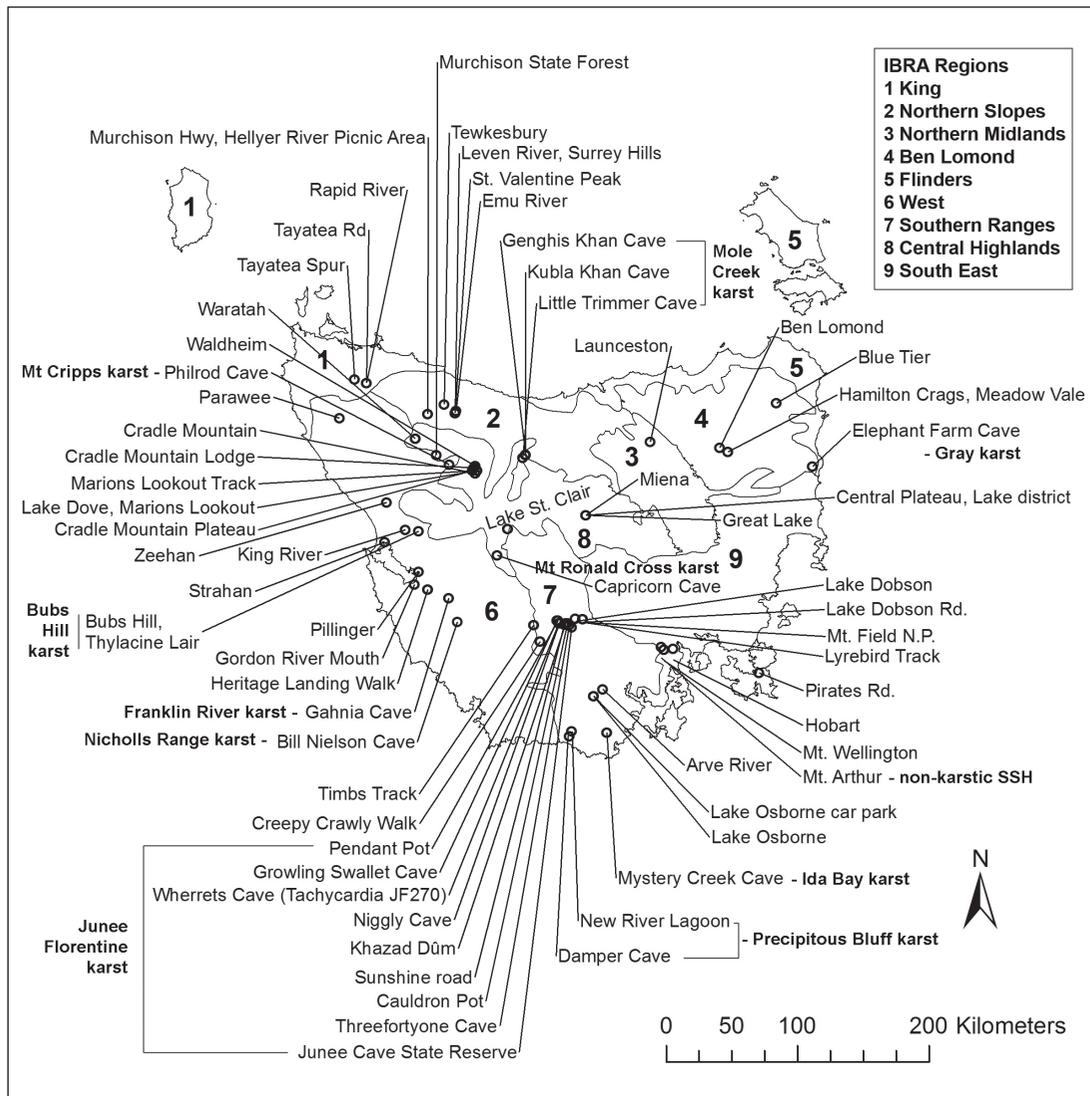
tomologists and further collections made by P.M.G in 1998, 1999 and 2002 during research expeditions sponsored by the Accademia Nazionale dei Lincei in Rome (Map 1). These expeditions focused on finding species already identified as new to science but known only from single individuals (Giachino 2005). Attempts to collect additional specimens of some species were not always successful, however, they resulted in the finding of additional new species described herein. Besides our field collections, forty-one (41) previously described species were re-examined as part of this study, and given the scarcity of illustrations in the literature (Jeannel 1927; Donabauer 2001; Moore 1963, 1972, 1978, 1983, 1984, 1994) we saw the need to provide drawings of male genitalia and the habitus (often of the type material), in addition to a brief description where possible. We have also mapped the collection sites for

all species mentioned in this paper, which will help to consolidate the systematics and biogeography of Tasmanian Carabidae and assist in future identification, description and focusing of survey and conservation efforts.

MATERIAL AND METHODS

The examined materials are preserved in the following collections:

- BMNH** The Natural History Museum, London, England
QVML Queen Victoria Museum, Launceston, Tasmania, Australia
MVM Museum of Victoria, Melbourne, Victoria, Australia



Map 1 - Localities for carabid material collected during this study shown in relation to Tasmania's Biogeographic Regions (IBRA version 6.1 Commonwealth of Australia 2004).

MCSNG	Museo Civico di Storia Naturale “G. Doria”, Genova, Italia
MRSN	Museo Regionale di Scienze Naturali, Torino, Italia
SAM	South Australian Museum, Adelaide, South Australia
TMH	Tasmanian Museum and Art Gallery, Hobart, Tasmania, Australia
CGi	Giachino Collection, Torino, Italia

The following acronyms for type material have been used:

HT	Holotype
PT, PTT	Paratype(s)
CT	Cotype
LT	Lectotype
PLT, PLTT	Paralectotype(s)

The drawings of the habitus were made using a camera lucida attached to a Leica MZ 12.5 microscope. The drawings of male genitalia, after inclusion in Canada balsam, were made using a camera lucida attached to a Leica DM 2500 microscope with interference contrast.

Total length of specimens was measured from apical margin of labrum to tip of elytra. The acronym PW/PL represents instead the width/length ratio of the pronotum.

Given the scarcity of iconography available in the literature (Jeannel 1927; Donabauer 2001; Moore 1963, 1972, 1978, 1983, 1984, 1994) drawings of male genitalia and the habitus of previously described species (often of the type material), in addition to a brief description, were made whenever possible.

The suprageneric systematics used is that proposed by Lorenz (2005).

TAXONOMY

Trechinae Bonelli, 1810

Zolini Sharp, 1886

Genus *Percodermus* Sloane, 1920

Type species: *Percodermus niger* Sloane, 1920

Percodermus Sloane, 1920: 140.

Percodermus Sloane: Moore et al, 1987: 123.

Percodermus Sloane: Lorenz, 2005: 201.

Percodermus niger Sloane, 1920

(Figs 1-2)

Loc. Typ.: Great Lake, Tasmania.

Percodermus niger Sloane, 1920: 140.

Percodermus niger Sloane: Moore et al, 1987: 123.

Percodermus niger Sloane: Lorenz, 2005: 201.

Type material

LT ♂, Great Lake 3/91 (white, handwritten and printed), Type (white, printed), *Percodermus niger* Sl. Id. by

T.G. Sloane (white, handwritten and printed), *Percodermus niger* Sl. Tasmania Type (white with black and red handwriting), Lectoholo- *P. niger* Sl. PID (red, handwritten) (SAM).

Examined material

2 ♂♂ 1 ♀, Australia, Tas., Lake St. Clair N.P. m 740, rainforest sieved litter, 23.I.2002, P.M. Giachino leg. (CGi); 1 ♂, Australia, Tas., Cradle Mts N.P., Cradle Mts Lodge m 800, 30.I.2002, P.M. Giachino leg. (CGi).

Diagnosis and redescription

Length mm 5.67-6.06. Body elliptical-oval, subdepressed, black and shiny; legs and antennae piceous or piceous red with femora darker than tibiae and base of antennae reddish. Head short, with eyes large, round and prominent. Antennae slender, hardly exceeding the base of the pronotum when stretched backwards. Pronotum subquadrate, widest in the middle or just before the middle; sides arcuate anteriorly, straight or subsinuate to base. Base straight, widest than anterior side, with angles obtuse, blunted, not prominent. Basal setae absent, anterior marginal setae inserted in the middle. Elytra elliptical, with disc lightly striate; juxtascutellar stria present (between scutellum to 1st stria), short; apical recurrent stria short, subrectilinear, ending at the level of 6th stria. Chaetotaxis: juxtascutellar pore present; third interval 4-(or 5-) with setiferous pores. Aedeagus (Fig. 2) small (length 1.24 mm), with basal bulb small; median lobe, in lateral view, abruptly curved at the basal 6th, rectilinear in the apical 5/6. Apex short, stumpy and slightly bent upwards in a beak shape. Inner sac medially provided with a copulatory piece shaped like a large spoon. Parameres broad and not very long, reaching the apical third, each provided with 5 apical setae.

Distribution and ecology

Sloane (1920) and Moore et al (1987) mention this species only in the zone of Great Lake (Central Tasmania) and there are not at present, as far as we know, any other data in the literature. The new sites of Lake St. Clair and Cradle Mts. increase considerably towards W and NW the known area of this species (Map 2). Even in the two new localities, as shown by Moore et al (1987), *P. niger* was found by sieving litter in a tall *Nothofagus* forest.

Genus *Sloaneana* Csiki, 1933

Type species: *Brachydema tasmaniae* Sloane, 1915.

Brachydema Sloane, 1915: 452 (nec *Brachydema* Fairmaire, 1881).

Brachydema Sloane: Sloane, 1920: 139.

Sloaneana Csiki, 1928: 224 (nom. nov. for *Brachydema* Sloane, 1915; nec *Sloaneana* Jeannel, 1927).

Sloaneana Csiki, 1933: 1651 (nom. nov. for *Sloaneana* Csiki, 1928).

Sloaneana Csiki: Moore et al, 1987: 123.

Sloaneana Csiki: Lorenz, 2005: 201.

Sloaneana tasmaniae (Sloane, 1915)
(Figs 3-4)

Loc. Typ.: Mt. Wellington, Tasmania.

Brachydema tasmaniae Sloane, 1915: 452.

Brachydema victoriae Sloane, 1915: 452.

Brachydema tasmaniae Sloane: Sloane, 1920: 139.

Sloaneella tasmaniae Sloane: Csiki, 1928: 224.

Sloaneana tasmaniae Sloane: Csiki, 1933: 1651.

Sloaneana tasmaniae (Sloane): Moore et al, 1987: 123.

Sloaneana tasmaniae (Sloane): Lorenz, 2005: 201.

Examined material

9 ♂♂ 9 ♀♀, Australia, Tas., Mt. Field N.P., Lake Dobson Rd., m 690, 16.I.2002, P.M. Giachino leg. (CGi); 3 ♂♂ 5 ♀♀, Australia, Tas., Hartz Mts. N.P., Lake Osborne car park, m 900, 20.I.2002, rainforest, P.M. Giachino leg. (CGi); 11 ♂♂ 6 ♀♀, Australia, Tas., Lake St. Clair N.P. m 740, rainforest sieved litter, 23.I.2002, P.M. Giachino leg. (CGi); 1 ♂ 1 ♀, Australia, Tas., Murchison Hwy., Hellyer Gorge St. Res., Hellyer River Picnic Area, 30.I.2002, P. M. Giachino leg. (CGi); 1 ♂ 2 ♀♀, Australia, Tas., South Arthur Forest, Tayatea Rd., Tayatea Spur 7, 29.I.2002, P. M. Giachino leg. (CGi); 2 ♂♂, Australia, Tas., Gordon River Rd., Florentine Valley, Timbs Track, m 460, 17.I.2002, P.M. Giachino leg. (CGi); 1 ♂ Australia, Tas. Hampshire, Companion Reserve, m 600, S. Valentine Peak (rainforest), 29.XI.1998, P.M. Giachino leg. (CGi); 1 ♂, Australia, Tas., Mt. Field N.P., m 750, under bark, 5.XII.1998, P.M. Giachino leg. (CGi); 1 ♂, Australia, Tas., Maydena, Southwest N.P., Florentine Valley, Timbs Track, m 500, 5.XII.1998, P.M. Giachino leg. (CGi); 1 ♀, Australia, Tas., Mt. Field N.P., Lyrebird Track, m 700, 7.XII.1998, P.M. Giachino leg. (CGi); 1 ♀, Australia, Tas., Strahan, Macquarie Harbour, Gordon River Mouth, 26.I.2002, P.M. Giachino leg. (CGi); 1 ♀, Tas. Mt. Wellington, Lea (SAM).

Diagnosis and redescription

Length mm 4.52-5.26. Body oval (Oodes-like), convex, black and shiny; legs and antennae piceous or piceous red. Head short, with eyes large, round and prominent. Antennae slender, hardly exceeding the base of the pronotum when stretched backwards. Pronotum transverse, widest at the basal 4th; sides regularly arcuate. Base straight, widest than anterior side, with angles obtuse, lightly blunted, not prominent. Basal setae present, anterior marginal setae inserted at the anterior 3rd. Elytra oval, with disc lightly striate; juxtascutellar stria absent; apical recurrent striole short, subrectilinear, ending at the level of 6th stria. Chaetotaxis: juxtascutellar pore present; third interval with two setiferous pores. Aedeagus (Fig. 4) small (length 0.84 mm), with basal bulb small; median lobe, in lateral view, abruptly curved at the basal 3rd, subrectilinear in apical 2/3. Apex short, pointed and straight. Inner sac medially provided with two copulatory pieces: one like a wide spoon of and one

stick-shaped. Parameres large, weak and long, reaching the apical 5th, each provided with 4 apical setae.

Distribution and ecology

S. tasmaniae appears widely distributed throughout Tasmania where it is found by sieving litter in primary forests, at elevations between a few m a.s.l. (Hobart) and 900 m (Hartz Mts, Lake Osborne) (Map 2). This species is also known from Victoria (Warburton), where it was originally described as *Brachydema victoriae* (Sloane 1915) and then placed in synonymy with *Brachydema tasmaniae* (Sloane 1915) by Sloane himself (1920). The comparative study of aedeagi has helped to confirm the synonymy proposed by Sloane (1920).

Genus *Idacarabus* Lea, 1910

Type species: *Idacarabus troglodytes* Lea, 1910

Idacarabus Lea, 1910: 54.

Idacarabus Lea: Sloane, 1920: 139.

Idacarabus Lea: Moore et al, 1987: 123.

Idacarabus Lea: Lorenz, 2005: 201.

Idacarabus cordicollis Moore, 1967

Loc. Typ.: Newdegate Cave, Hasting, Tasmania.

Idacarabus cordicollis Moore, 1967: 179.

Idacarabus cordicollis Moore: Moore et al, 1987: 123.

Idacarabus cordicollis Moore: Lorenz, 2005: 201.

Examined material

1 ♂ 1 ♀, Tasmania, Hastings, King George V Cave, 16.XII.1984, S. Eberhard leg. QVM 12: 43761 (QVML, CGi).

Distribution and ecology

At present, this troglomorphic species is known only from caves in the Hastings karst area, southern Tasmania: Newdegate Cave and King George V Cave (Map 3).

Idacarabus troglodytes Lea, 1910

Loc. Typ.: Ida Bay Caves, Tasmania.

Idacarabus troglodytes Lea, 1910: 55.

Idacarabus troglodytes Lea: Moore et al, 1987: 123.

Idacarabus troglodytes Lea: Moore, 1994: 80.

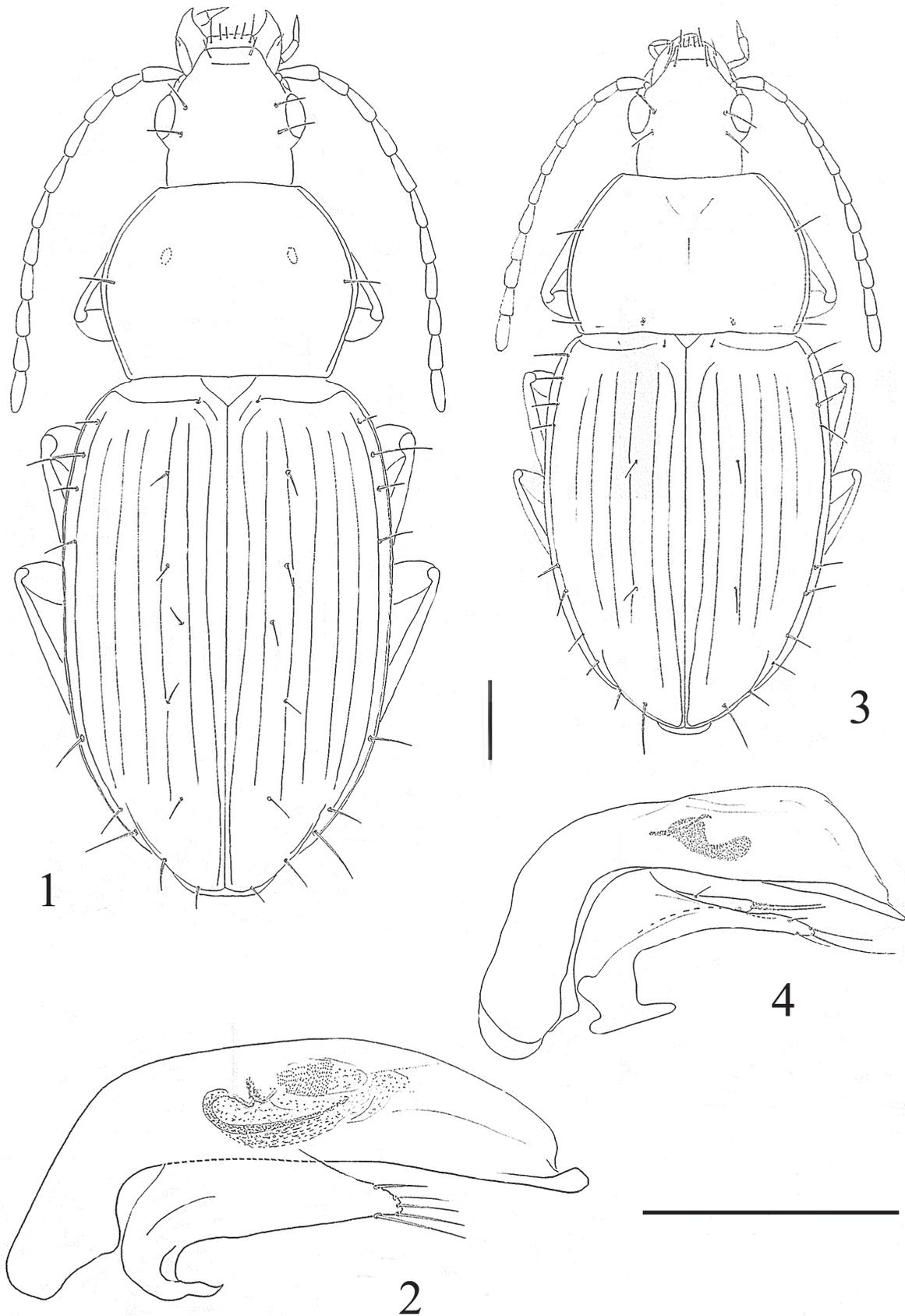
Idacarabus troglodytes Lea: Lorenz, 2005: 201.

Examined material

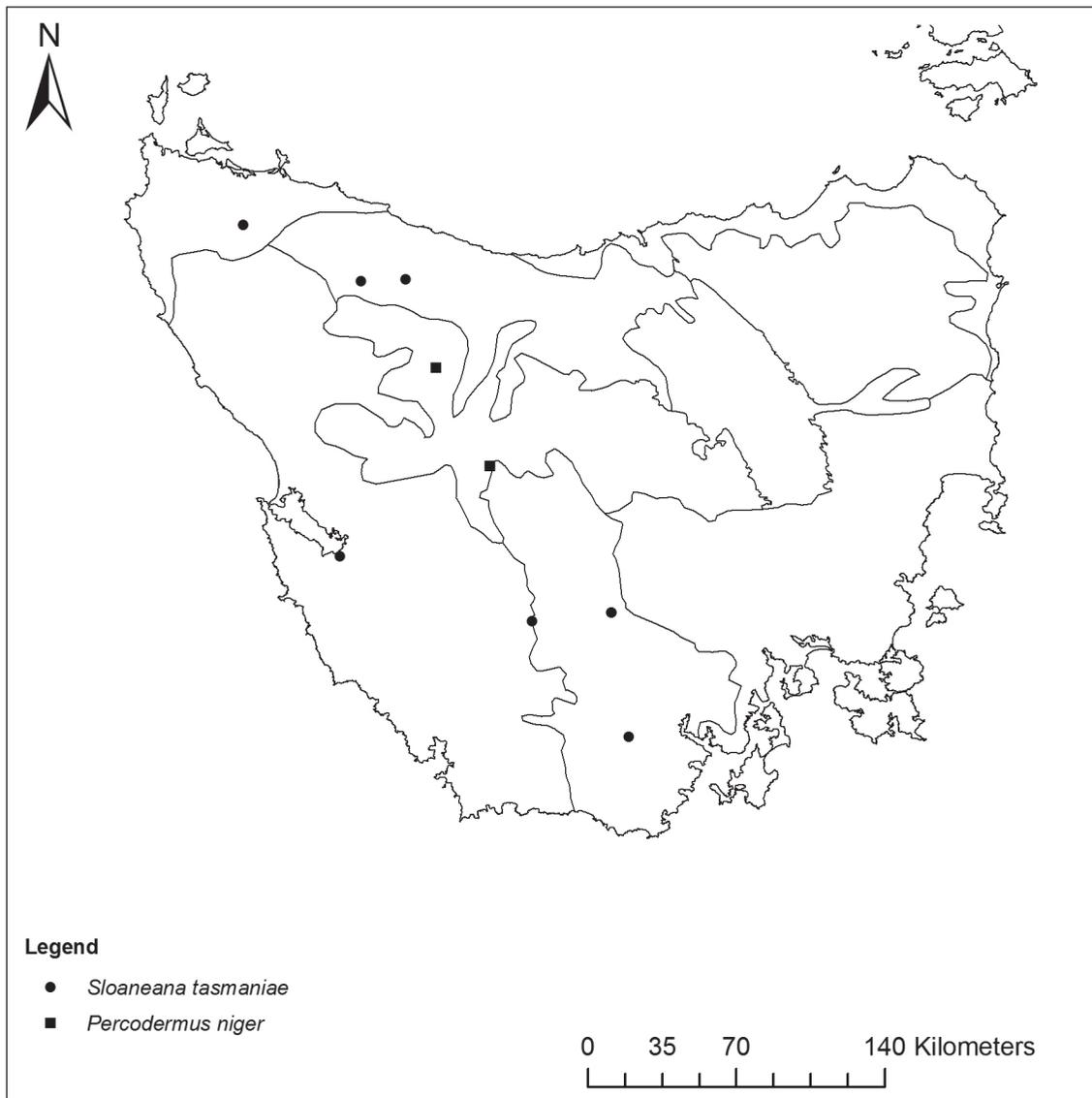
1 ♀, Tasmania, Ida Bay, Exit Cave, 18.VII.1985, S. Eberhard leg., QVM 12: 43759 (QVML); 1 ♀, (remains), Tasmania, Ida Bay, MysteryMystery Creek Cave, 1 Jan. 2009, S. Eberhard leg. (TMH); 2 ♀♀, Hastings, MysteryMystery Creek Cave, 21.I.2002, P.M. Giachino leg. (CGi).

Distribution and ecology

At present, this troglomorphic species is known only from caves in the Ida Bay karst area, southern Tasmania: Exit Cave, Mystery Cave, Revelation Cave, and



Figs 1-4. *Percodermus niger* Sloane: 1) habitus of ♂ from Lake St. Clair; 2) aedeagus in lateral view of LT from Great Lake. *Sloaneana tasmaniae* (Sloane): 3) habitus of ♂ from Lake St. Clair; 4) aedeagus in lateral view of ♂ from Lake Osborne. Scale: 0.5 mm.



Map 2 - Collection sites for *Percodermus niger* and *Sloaneana tasmaniae*.

numerous other caves (Map 3). The species is common in many caves within this karst area, and its distribution extends from the transition zone to the deep cave zone.

Idacarabus longicollis Moore, 1978

Loc. Typ.: Damper Cave, Precipitous Bluff.

Idacarabus longicollis Moore, 1978: 23.

Idacarabus longicollis Moore: Moore et al, 1987: 123.

Idacarabus longicollis Moore: Lorenz, 2005: 201.

Examined material

1 ♂ 1 ♀, Tasmania, Precipitous Bluff, PB4-10, Cueva Blanca, 21.III.1986, Eberhard leg., QVM 12:43760 (QVML, CGi).

Distribution and ecology

At present, this troglomorphic species is known only from caves in the Precipitous Bluff karst area, southern Tasmania: Damper Cave and Cueva Blanca (Map 3).

Genus *Pterocyrtus* Sloane, 1920

Type species: *Pterocyrtus globosus* Sloane, 1920.

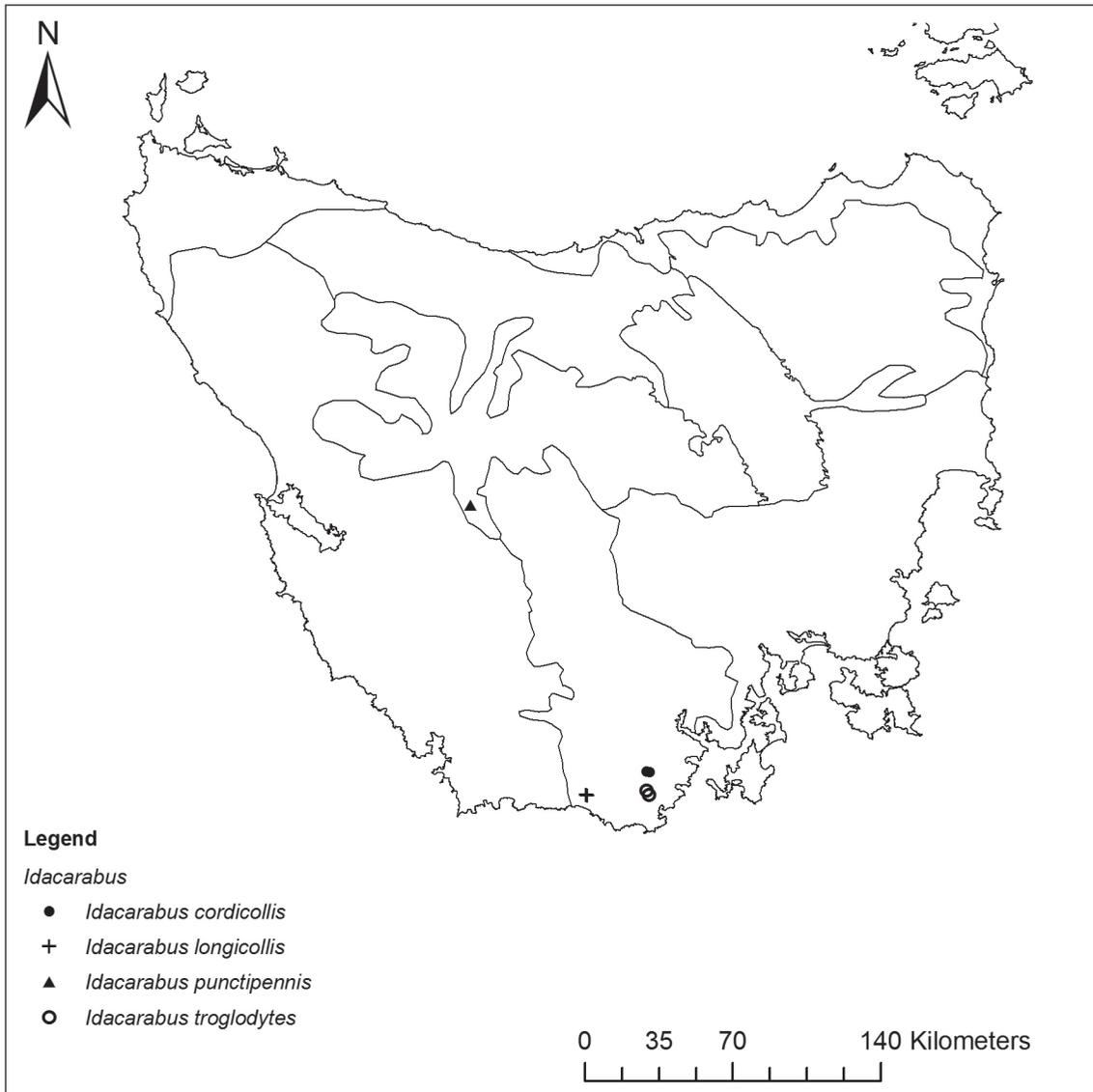
Pterocyrtus Sloane, 1920: 140.

Pterocyrtus Sloane: Moore et al, 1987: 123.

Pterocyrtus Sloane: Lorenz, 2005: 201.

KEY TO TASMANIAN SPECIES

- 1 Eyes large and convex, prominent 2
- Eyes large or reduced, but flat and not prominent.... 6
- 2 Pronotum transverse 3
- Pronotum cordiform *P. tasmanicus*
- 3 Pronotum very transverse about 1.5 times wider than long. Elytra with striae obsolete 4
- Pronotum less transverse about 1.2–1.3 times wider than long. Elytra decidedly striate on disc 5
- 4 Bigger (5.5 mm). Sides of pronotum clearly sinuate before basal angles. Basal angles prominent.....
- *P. globosus*



Map 3 - Collection sites for *Idacarabus* spp.

- Less big (4.75 mm). Sides of pronotum not sinuate before basal angles. Basal angles obtuse, not prominent.....*P. meridionalis* sp. nov.
- 5. Pronotum less transverse about 1.2 times wider than long. Sides of pronotum before basal angles from straight to subsinuate. Elytra short and ovoidal
.....*P. striatulus*
- Pronotum more transverse about 1.3 times wider than long. Sides of pronotum before basal angles clearly sinuate. Elytra longer and elliptic.....*P. cavicola*
- 6. Very large (6.48 mm). Pronotum cordiform; sides of pronotum before basal angles straight not sinuate
.....*P. grayi* sp. nov.
- Small (3.95-4.0 mm). Pronotum transverse; sides of pronotum before basal angles clearly sinuate
.....*P. rubescens*

Pterocyrtus grayi sp. nov.
(Fig. 5)

Loc. Typ.: Tasmania, Gray, Elephant Farm Cave, 41°37'S 148°12'E.

Type series

HT ♀, Tas, 41°37'S 148°12'E, G-X2-11, Gray, Elephant Farm Cave, dark zone, 11.VIII.1988, S. Eberhard leg., QVM 12: 43762 (QVML).

Diagnosis

A black-brown, shiny, large-sized (6.48 mm) *Pterocyrtus*, characterized by eyes not reduced, but flat and poorly protruding, pronotum cordiform with the sides posteriorly subrectilinear and the basal angles sharp and slightly protruding; elitrae ovoidal and globose. From *P.*

tasmanicus, similar for the shape of pronotum and elytra, it differs markedly for the neatly bigger size; from *P. striatulus*, *P. globosus*, *P. meridionalis* sp. nov. and *P. rubescens* it differs, besides the larger size, also for the pronotum cordiform and not transverse. Only from *P. striatulus* it differs also for the elytra with less evident striae. From *P. cavicola*, a species of similar size, it differs finally for the pronotum with sides posteriorly rectilinea, not sinuate, and for the elytra less globose.

Description of HT ♀

Length mm 6.48. Body obovate (Fig. 5), with a very small fore-body in comparison with the elytra, which are short, big, ample and very convex. Dorsal surface glabrous, with microsculpture vanishing, so the surface is shiny. Metathoracic wings absent. Colour blackish brown, with lateral margins of elytra, elytral suture, epipleura, legs, antennae, and palpi reddish brown. Head normal. Clypeus distinctly convex at the base, with one apical seta on each side. Eyes flat and not prominent. Neck constriction evident, well marked also in the dorsal part. Labrum transverse, with a slightly emarginated apex; mandibles slender. Antennae slender, as long as half of the body. Second antennal segment slightly longer than the first one. Pronotum cordiform (PW/PL: 1.18), widest at about 2/3 from base. Base usually slightly wider than the anterior margin. Sides subrectilinear before the base, which is nearly straight, only slightly oblique near the hind angles, which are rectangular and a little projected outwards. Front angles rounded and not advanced. Lateral margins narrow, not widening posteriorly; anterior seta inserted near the middle; basal seta present. Basal foveae smooth, slightly impressed, subcircular. Median line distinct. Discal surface gently convex. Elytra broad, oval, widest in the middle, very convex. Shoulders rounded but visible, with humeral border continuing inwards almost at the base of 4th stria. Lateral border of elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. From second to seventh stria vestigial, more visible in the basal third of the elytra and reduced to a series of obsolete points progressively. First stria shallow but evident on the whole length; juxtascutellar stria absent; apical recurrent striole short, gently curved, ending at the level of the 6th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; three setiferous pores on the third stria, respectively, at the basal fourth, in the middle and at the apical fourth. Two preapical pores placed backwards and closer to the recurrent striole. Male unknown.

Etymology

From the name of the type locality, located near the village of Gray (NE Tasmania).

Distribution and ecology

P. grayi sp. nov. is currently known only from the type locality, the Elephant Farm Cave, located near the

village of Gray (NE Tasmania), where it was collected in winter (August) in the dark zone of the cave (Map 4). *P. grayi* sp. nov., while not presenting any of the typical characters adaptive to the subterranean environment (depigmentation of the body, pronounced eye reduction, significant elongation of appendages), can be seen, within the genus *Pterocyrtus*, as the most specialized species known today. It presents a pronotum no longer transverse but cordiform, a first hint of eye reduction and, most importantly, a significant elongation of the antennae. The rarity of the finds in the cave (and the complete absence of finds in the epigeal environment) may indicate a preference toward fissure environments, due to situations of MSS or Superficial Subterranean Habitat sensu Howarth (1983) and Giachino and Vailati (2010).

Pterocyrtus globosus Sloane, 1920 (Figs 6, 11)

Loc. Typ.: Cradle Mts.

Pterocyrtus globosus Sloane, 1920: 142

Pterocyrtus globosus Sloane: Moore et al, 1987: 123.

Pterocyrtus globosus Sloane: Lorenz, 2005: 201.

Type material

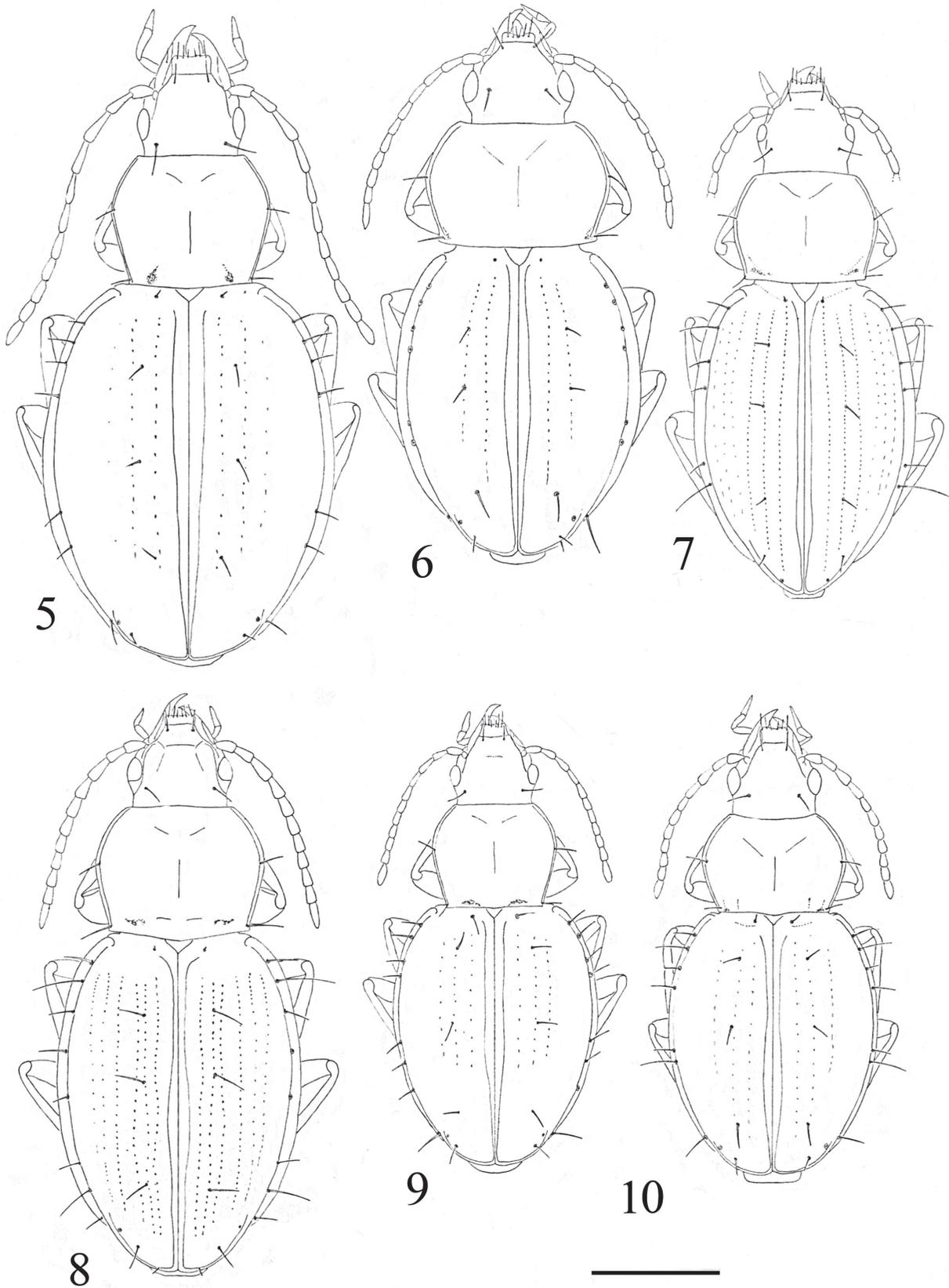
LT ♂ and PLT ♀ (on the same label LT pointed out as 1, PLT pointed out as 2), Cradle Mtn. Tasmania, Carter & Lea (white, printed); Type (white, printed); *Oopterus globosus* Sl. Id. by T.G. Sloane (white, handwritten and printed); I. 7305 *Pterocyrtus globosus* Sl., Tasmania, Type (white, handwritten with black and red writing); Lectoholo-*P. globosus* Sl. P.J.D. (red, handwritten); Lectotypus ♂ (1) *Pterocyrtus globosus* Sloane P.M. Giachino des. 2009 (red, handwritten and printed); Paralectotypus ♀ (2) *Pterocyrtus globosus* Sloane P.M. Giachino des. 2009 (red, handwritten and printed) (SAM).

Examined material

2 ♀♀, Tas, 42°40'S 146°27'E, Junee-Florentine Windy Rift, Growling Swallet Cave, 26.III.1989, S. Eberhard leg., QVM 12: 43764 (QVML, CGi).

Diagnosis and redescription

A brown black, shiny, small-sized (4.3-5.0 mm) *Pterocyrtus*, characterized by big, convex, and prominent eyes, pronotum very transverse with the sides sinuate posteriorly, and basal angles right and protruding. Elytra broad, oval, widest in the middle, very convex. Second stria vestigial and reduced to a series of points; 3rd to 7th stria obsolete; first stria shallow but evident on the whole length; juxtascutellar stria absent; apical recurrent striole short, gently curved, ending at the level of the 6th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; three setiferous pores on the third stria, respectively, at the basal 4th, a little behind the middle and at the apical 5th. Two preapical pores placed backwards and closer to the recurrent striole. Aedeagus (Fig. 11) large (length 0.85 mm), long, stout, very compressed



Figs 5-10. Habitus of *Pterocyrtus* spp.: 5) *P. grayi* sp. nov., HT ♀ from Elephant Farm Cave; 6) *P. globosus* Sloane, LT ♂ from Cradle Mtn.; 7) *P. rubescens* Sloane, HT ♂ from Waratah; 8) *P. striatulus* Sloane, LT ♂ from Cradle Mtn.; 9) *P. tasmanicus* (Castelnau), ♂ from Tasmania; 10) *P. meridionalis* sp. nov., HT ♂ from Lake Osborne. Scale: 1 mm.

laterally, with basal bulb broadly opened; median lobe, in lateral view, very long, curved in the basal 3rd, subrectilinear in the distal 3rd; apex short, with the apical blade bold and rounded. Inner sac without the copulatory piece. Parameres long and narrow, reaching the apical 3rd of the median lobe, each provided with 5 setae.

Distribution and ecology

P. globosus is known, as a typical element of forest litter, from Cradle Mts. (type locality) and Waratah (Sloane, 1920; Moore et al, 1987). The collection of this non-trogomorphic species deep inside Growling Swallet Cave is most likely a result of the specimens being washed underground during regular flooding, however this record expands the known distribution for this species considerably southwards (Map 4).

Pterocyrtus rubescens Sloane, 1920
(Figs 7, 12)

Loc. Typ.: Waratah

Pterocyrtus rubescens Sloane, 1920: 142

Pterocyrtus rubescens Sloane: Moore et al, 1987: 124.

Pterocyrtus rubescens Sloane: Lorenz, 2005: 201.

Type material

HT ♂, Waratah T. H.S.O. 1.18 (white, handwritten); *Oopterus rubescens* Sl. Id. by T.G. Sloane (white, handwritten and printed); Type (white, printed); *Pterocyrtus rubescens* Sl. Tasmania, I. 10805, Type (white, handwritten with black and red writing); Lectoholo- *P. rubescens* Sl. P.J.D. (red, handwritten) (SAM).

Examined material

4 ♂♂ 1 ♀, Waratah, Tas. Lea (SAM, CGi).

Diagnosis and redescription

A reddish brown, shiny, small-sized (3.95-4.0 mm) *Pterocyrtus*, characterized by small, flat, poorly prominent eyes, pronotum transverse with sides sinuate posteriorly, and basal angles right and not protruding. Elytra broad, elliptical, widest in the middle, very convex. All striae evident and pointed; juxtascutellar stria absent; apical recurrent striole short, gently curved, ending at the level of the 6th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; three setiferous pores on the third stria, respectively, at the basal 5th, a little behind the middle and at the apical 4th. Two preapical pores placed backwards and closer to the recurrent striole. Aedeagus (Fig. 12) large (length 0.94 mm), long, stout, very compressed laterally, with the basal bulb broadly opened; median lobe, in lateral view, very long, abruptly curved in the basal 6th, subrectilinear in the distal 5/6; apex short, with the apical blade attenuate and broadly rounded. Inner sac with two small, copulatory pieces. Parameres long and narrow, reaching the apical 3rd of the median lobe, each one provided with 5 setae.

Distribution and ecology

P. rubescens is known only from the type locality of Waratah in NW Tasmania (Map 4). Moore et al (1987) mention it as an element of the forest litter.

Pterocyrtus striatulus (Sloane, 1920)
(Figs 8, 13)

Loc. Typ.: Cradle Mts.

Pterocyrtus striatulus Sloane, 1920: 141.

Pterocyrtus striatulus Sloane: Moore et al, 1987: 124.

Pterocyrtus striatulus Sloane: Lorenz, 2005: 201.

Type material

LT ♂ and PLT ♀ (on the same label LT pointed out as 1, PLT pointed out as 2), Cradle Mtn. Tasmania, Carter & Lea (white, printed); Type (white, printed); *Oopterus striatulus* Sl. Id. by T.G. Sloane (white, handwritten and printed); I. 10804 *Pterocyrtus striatulus* Sl., Tasmania, Type (white, handwritten with black and red writing); Lectoholo- *P. striatulus* Sl. P.J.D. (red, handwritten); Lectotypus ♂ (1) *Pterocyrtus striatulus* Sl. P.M. Giachino des. 2009 (red, handwritten and printed); Paralectotypus ♀ (2) *Pterocyrtus striatulus* Sl. P.M. Giachino des. 2009 (red, handwritten and printed) (SAM).

Examined material

1 ♂, NW Tas., Parawee, Jan. 1997 (CGi); 1 ♂, Parawee NW Tas., Dec. 1936 (CGi); 1 ♀ immature (without certain determination), Tas., 42°52'S 147°15'E, WE-X1-4, Mount Wellington, Mount Arthur Cave 1, in litter, 7.II.1989, S. Eberhard leg., QVM 12: 43765 (QVML); 1 ♀, Tasmania, Zeehan (SAM).

Diagnosis and redescription

A brown black, shiny, big-sized (5.0-5.5 mm) *Pterocyrtus*, characterized by big and prominent eyes, pronotum slightly transverse with sides subrectilinear posteriorly, and basal angles right and slightly protruding. Elytra broad, elliptical, widest in the middle, very convex. All striae evident and pointed; juxtascutellar stria absent; apical recurrent striole short, gently curved, ending at the level of the 6th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; three setiferous pores on the third stria, respectively, at the basal 4th, a little behind the middle and at the apical 4th. Two preapical pores placed backwards and closer to the recurrent striole. Aedeagus (Fig. 13) small (length 0.59 mm), stout, very compressed laterally, with the basal bulb broadly opened; median lobe, in lateral view, short, slightly curved in the basal 3rd, gently curved in the distal 2/3; apex short, with the apical blade attenuate and broadly rounded. Inner sac with a small, bifid, copulatory piece. Parameres short and stout, reaching the apical 3rd of the median lobe, each one provided with 5 setae.

Distribution and ecology

The type locality of *P. striatulus* is Cradle Mts. (Sloane, 1920), the indication by Moore et al (1987) from Bottomless Pit in the Gray karst in NE Tasmania needs confirmation (Map 4). In fact, in the same area there is *P. grayi* sp. nov. Conversely the specimens studied from Parawee and Zeehan (not very far from the type locality) are fully compliant with the type. Also the record of the site of Mt Wellington needs to be confirmed (very distant from the known range of this species) and identified on a single extremely immature female.

Pterocyrtus cavicola Moore, 1994

Loc. Typ.: Nicholls Range, Bill Nielson Cave.

Pterocyrtus cavicola Moore, 1994: 77.

Pterocyrtus cavicola Moore: Lorenz, 2005: 201.

Examined material

1 ♀, Tasmania, Franklin River, Gahnia Cave, 20.III.1989, S. Eberhard leg. QVM 12: 43763 (QVML); 2 ♀♀, Tasmania, Gordon River, Bill Nielson Cave, 4032300E 5271300N, 18.4.2009, R. Eberhard leg. (TMH).

Notes

The description, but above all the drawings of the habitus and of the aedeagus, given by Moore (1994) in his description, are sufficiently accurate; therefore no further additions are necessary.

Distribution and ecology

This weakly troglomorphic but probably obligate subterranean species is known from two caves located in the Gordon-Franklin Rivers karsts of SW Tasmania: Bill Nielson Cave located in Nicholls Range karst (type locality of this species) and Gahnia Cave in the Franklin River karst (Map 4).

Pterocyrtus tasmanicus (Castelnau, 1867)
(Figs 9, 14)

Loc. Typ.: Tasmania

Drimostoma tasmanica Castelnau, 1867: 113.

Pterocyrtus (Drimostoma) tasmanicus Castelnau:
Sloane, 1920: 142.

Pterocyrtus tasmanicus (Castelnau): Moore et al,
1987: 124.

Pterocyrtus tasmanicus (Castelnau): Lorenz, 2005: 201.

Examined material

1 ♂ 1 ♀, Tasm^a, Simson, Fry Coll. 1900.100 (sub *Oopterus tasmanicus* Cast.) (BMNH); 2 ♀♀ Launceston Tasmania 91-83 (sub *Drimostoma tasmanicum* Cast., id by T. G. Sloane) (BMNH); 1 ♀, Blue Tier (SAM).

Diagnosis and redescription

A black, shiny, small-sized (3.2-4.2 mm) *Pterocyrtus*, characterized by big and prominent eyes, pronotum

cordiform with sides subrectilinear posteriorly, and basal angles obtuse and not protruding. Elytra broad, oval, widest at the anterior 3rd, very convex. Second stria vestigial and reduced to a series of points; 3rd to 7th stria obsolete; first stria shallow but evident on the whole length; juxtascutellar stria absent; apical recurrent striole short, gently curved, ending at the level of the 6th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; three setiferous pores on the third stria, respectively, at the basal 6th, a little behind the middle, and at the apical 5th. Two preapical pores placed backwards and closer to the recurrent striole. Aedeagus (Fig. 14) small (length 0.68 mm), delicate, very compressed laterally, with the basal bulb broadly opened; median lobe, in lateral view, slightly curved in the basal 4th, gently curved in the distal 2/3; apex short, with the apical blade attenuate. Inner sac without the copulatory piece. Parameres long and narrow, reaching the half of the median lobe, each one provided with 5 setae.

Distribution and ecology

Sloane (1920) and Moore et al (1987) mention it from Blue Tier, as a typical litter element (Map 4).

Pterocyrtus meridionalis sp. nov.

(Figs 10, 15)

Loc. Typ.: Tasmania, Hartz Mts. National Park, Lake Osborne.

Type series

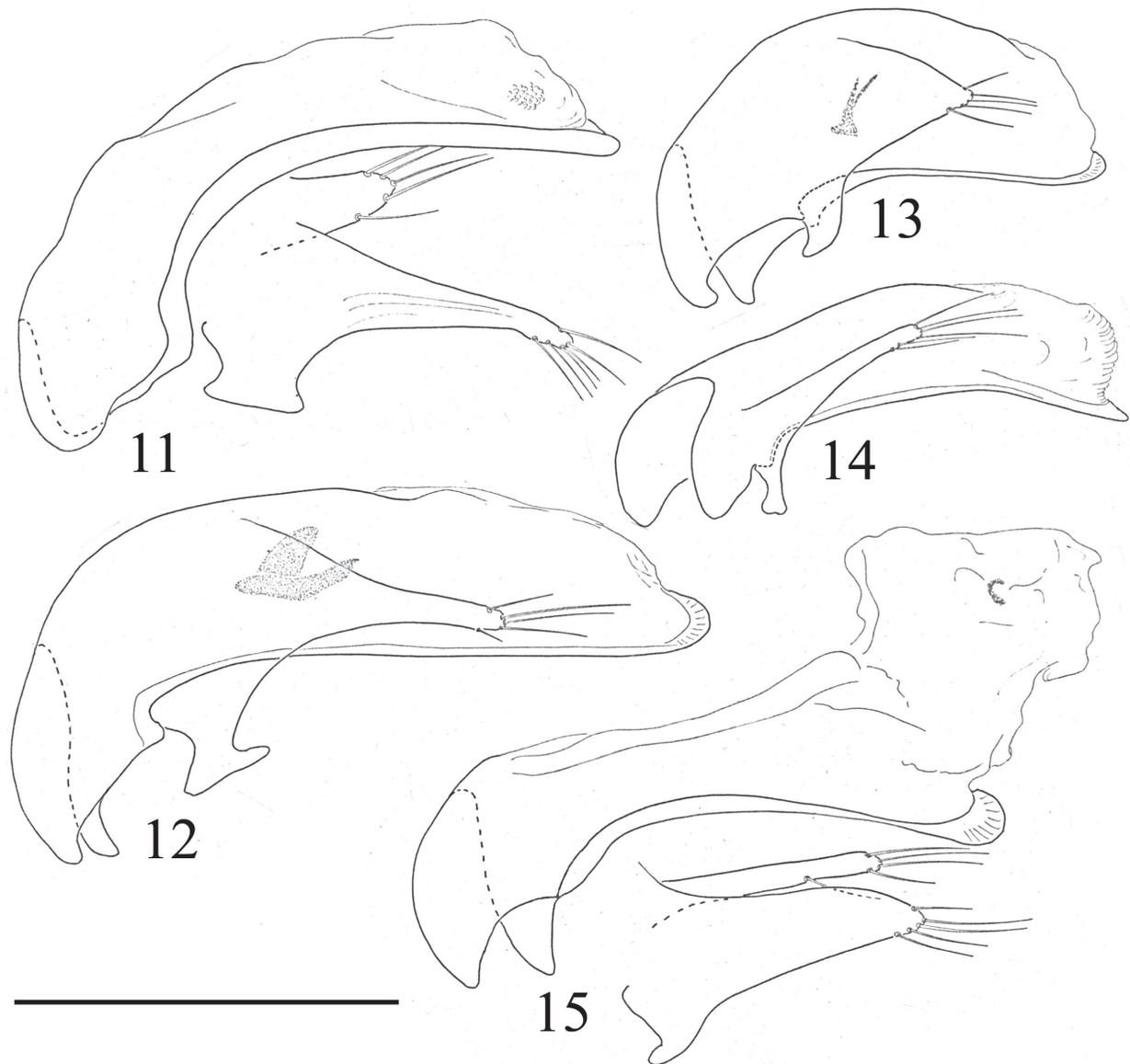
HT ♂, Australia, Tas., Hartz Mts. N.P., Lake Osborne Jan. 1997 (CGi);

Diagnosis

A black brown, shiny, small (4.75 mm) *Pterocyrtus*, characterized by big and prominent eyes, pronotum transverse with the sides subrectilinear posteriorly, and basal angles obtuse and not protruding; elytra oval and globose. It differs from *P. tasmanicus*, similar in size, in the transverse pronotum; from *P. rubescens* it differs by the larger size, the more transverse pronotum, and by the elytra more oval, less elongated; it differs from *P. striatulus*, *P. globosus*, *P. grayi* sp. nov., and *P. cavicola* in the smaller size. Finally, it differs only from *P. grayi* sp. nov. for the significantly transverse pronotum.

Description of HT ♂

Length mm 4.75. Body obovate (Fig. 10), with a small fore-body in comparison with the elytra, which are short, ovate and very convex. Dorsal surface glabrous, with the microsculpture vanishing, so the surface is shiny. Metathoracic wings absent. Colour blackish brown, with lateral margins of the elytra, elytral suture, epipleura, legs, antennae, and palpi reddish brown. Head normal. Clypeus distinctly convex at the base, with one apical setae on each side. Eyes convex and prominent. Neck constriction less evident, but marked also in the dorsal part.



Figs 11-15. Aedeagus in lateral view of *Pterocyrtus* spp.: 11) *P. globosus* Sloane, LT ♂ from Cradle Mtn.; 12) *P. rubescens* Sloane, HT ♂ from Waratah; 13) *P. striatulus* Sloane, LT ♂ from Cradle Mtn.; 14) *P. tasmanicus* (Castelnau), ♂ from Tasmania; 15) *P. meridionalis* sp. nov., HT ♂ from Lake Osborne. Scale: 0.5 mm.

Labrum transverse, with a slightly emarginated apex; mandibles slender. Antennae short and slender, less long than a half of the body. Second antennal segment as long as the first one. Pronotum transverse (PW/PL: 1.53), widest at about 2/3 from base. Base usually wider than the anterior margin. Sides not sinuate before the base, which is nearly bisinuate, subrectilinear near the hind angles, which are obtuse and not projected outwards. Front angles rounded and not advanced. Lateral margins narrow, not widening posteriorly; anterior seta inserted near the middle; basal seta present. Basal foveae smooth, very impressed, subcircular. Median line distinct. Discal surface gently convex. Male with two dilated protarsomeres. Elytra broad, oval, widest in the middle, very convex.

Shoulders rounded but well visible, with the humeral border continuing inwards almost to the base of the 4th stria. Lateral border of elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Second stria vestigial and reduced to a series of points; from 3rd to 7th stria obsolete; first stria shallow but evident on the whole length; juxtascutellar stria absent; apical recurrent striole short, gently curved, ending at the level of the 6th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; three setiferous pores on the third stria, respectively at the basal 5th, a little behind the middle, and at the apical 5th. Two preapical pores placed backwards and closer to the recurrent striole. Aedeagus (Fig. 15) small (length

0.79 mm), delicate, very compressed laterally, with the basal bulb broadly opened; median lobe, in lateral view, slightly curved in the basal third, from gently curved to subrectilinear in the distal 2/3; apex short, stout, with the apical blade attenuate, broadly rounded. Inner sac apically provided with a small C-shaped copulatory piece. Parameres long, reaching the apical third of the median lobe: the left one broad, the right one narrow; each one provided with 5 setae.

Etymology

The specific name wants to underline that this species has a more southern distribution.

Distribution and ecology

P. meridionalis sp. nov. is currently known only from the type locality, Lake Osborne in the Hartz Mts. National Park (S Tasmania), where it was collected in summer (January) (Map 4). There are no other known data on the way of collecting. Investigations, sometimes in search of other specimens and conducted personally by one of the authors (PMG) at Lake Osborne at a height of 900 m a.s.l. in January 2002, were fruitless. For the general morphology of the body (small, stocky, pigmented, with short legs and antennae, and big eyes) *P. meridionalis* sp. nov. could be a typical element of the forest litter.

Trechini Bonelli, 1810

Trechodina Jeannel, 1926

Genus *Trechobembix* Jeannel, 1926

Type species: *Trechus baldiensis* (Blackburn 1894)

Trechobembix Jeannel, 1926: 506.

Trechobembix Jeannel: Moore, 1972: 6.

Trechobembix Jeannel: Casale & Laneyrie, 1982: 37.

Trechobembix Jeannel: Moore et al, 1987: 125.

Trechobembix Jeannel: Lorenz, 2005: 166.

Trechobembix baldiensis baldiensis (Blackburn 1894)

Loc. Typ.: Mt. Baldi, Victoria.

Trechus baldiensis Blackburn, 1894: 88.

Trechobembix baldiensis Blackburn: Jeannel, 1926: 508.

Trechobembix baldiensis (Blackburn): Moore, 1972: 6.

Trechobembix baldiensis (Blackburn): Casale & Laneyrie, 1982: 37.

Trechobembix baldiensis (Blackburn): Moore et al, 1987: 125.

Trechobembix baldiensis (Blackburn): Lorenz, 2005: 166.

Examined material

1 ♂, Australia, Tas., Lake St. Clair N.P., L. St. Clair, m 740, 22.I.2002, P.M. Giachino leg. (CGi); 1 ♀, Australia, Tas., South Arthur Forest, Tayatea Rd., river, 29.I.2002, P. M. Giachino leg. (CGi); 2 ♂♂ 2 ♀♀, Australia, Tas., Lake St. Clair N.P., L. St. Clair, m 700, 29.XI.1998, P.M. Giachino leg. (CGi).

Notes

The drawings provided by Jeannel (1926) and Moore (1972) are sufficiently comprehensive and it is not necessary to make them again.

Distribution and ecology

T. baldiensis, a widespread species in Australia (Moore et al 1987), is known from different additional habitats in Tasmania (Map 5). Based on personal observations by one of the authors (PMG) *T. baldiensis* populates the banks of lakes and wetlands, which are characterized by a sandy-pebble substrate.

Genus *Cyphotrechodes* Jeannel, 1926

Type species: *Trechodes gibbipennis* Blackburn, 1901

Cyphotrechodes Jeannel, 1926: 480.

Cyphotrechodes Jeannel: Moore, 1972: 11.

Cyphotrechodes Jeannel: Casale & Laneyrie, 1982: 37.

Cyphotrechodes Jeannel: Moore et al, 1987: 125.

Cyphotrechodes Jeannel: Lorenz, 2005: 166.

Cyphotrechodes gibbipennis (Blackburn 1901)

Loc. Typ.: Lake district, Tasmania.

Trechodes gibbipennis Blackburn, 1901: 119.

Cyphotrechodes gibbipennis Blackburn: Jeannel, 1926: 482.

Cyphotrechodes gibbipennis (Blackburn): Moore, 1972: 11.

Cyphotrechodes gibbipennis (Blackburn): Casale & Laneyrie, 1982: 37.

Cyphotrechodes gibbipennis (Blackburn): Moore et al, 1987: 125.

Cyphotrechodes gibbipennis (Blackburn): Lorenz, 2005: 166.

Examined material

2 ♂♂ 1 ♀, Australia, Tas., Lake St. Clair N.P., L. St. Clair, m 740, 22.I.2002, P.M. Giachino leg. (CGi).

Notes

The drawings supplied by Jeannel (1926) are sufficiently detailed and it is not necessary to make them again.

Distribution and ecology

This species is known in Tasmania from different localities: Lake district, Hartz Mountains. Lake St. Clair, N of Zeehan (Moore 1972) (Map 5). Based on personal observations by one of the authors (P.M.G.) *C. gibbipennis* populates the banks of lakes and swampy areas, but on a sandy-pebble substrate.

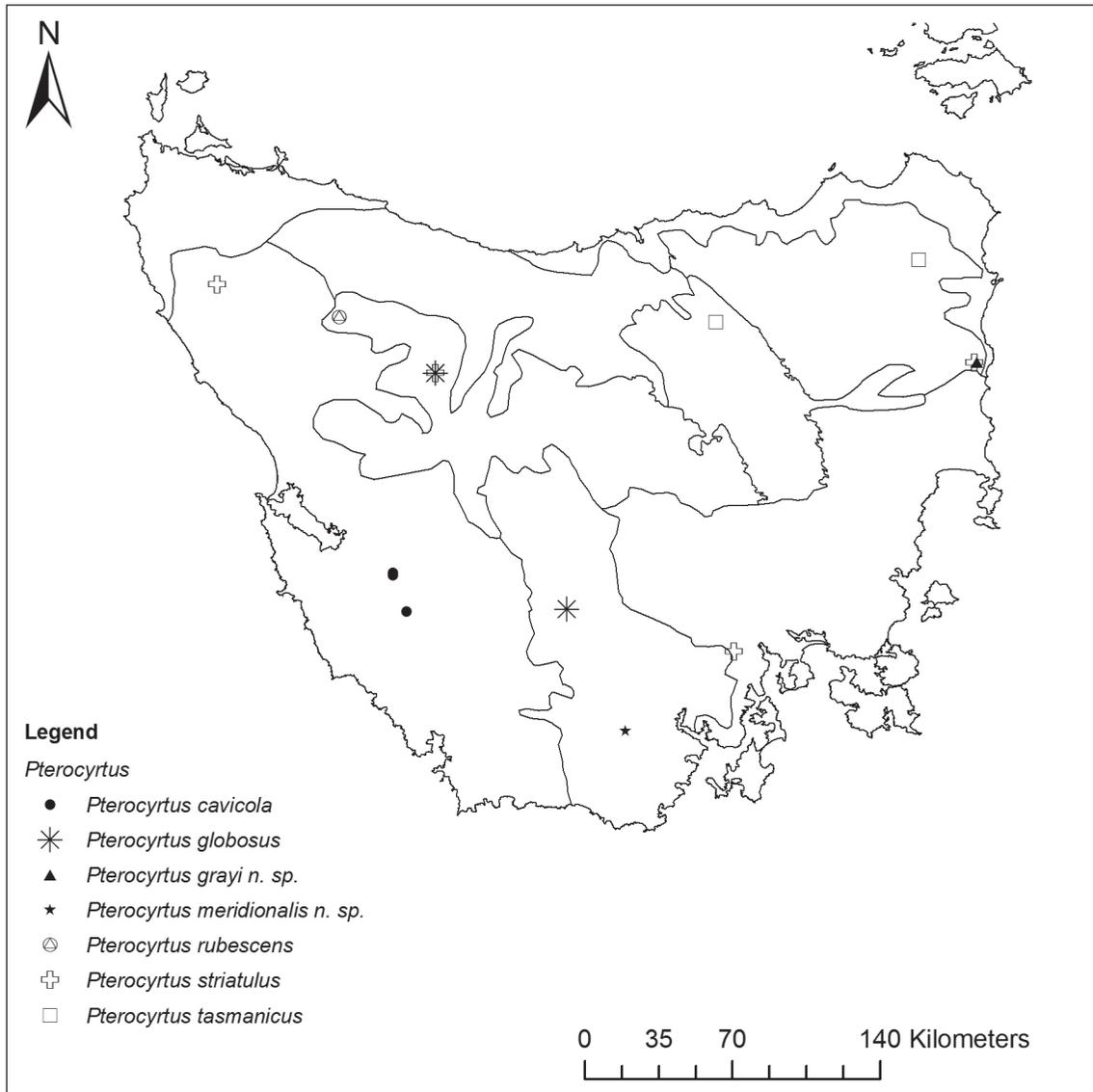
Trechina Bonelli, 1810

Genus *Tasmanorites* Jeannel, 1927

Type species: *Trechus nitens* Putzeys, 1974

Tasmanorites Jeannel, 1927: 71.

Tasmanorites Jeannel: Moore, 1972: 15.



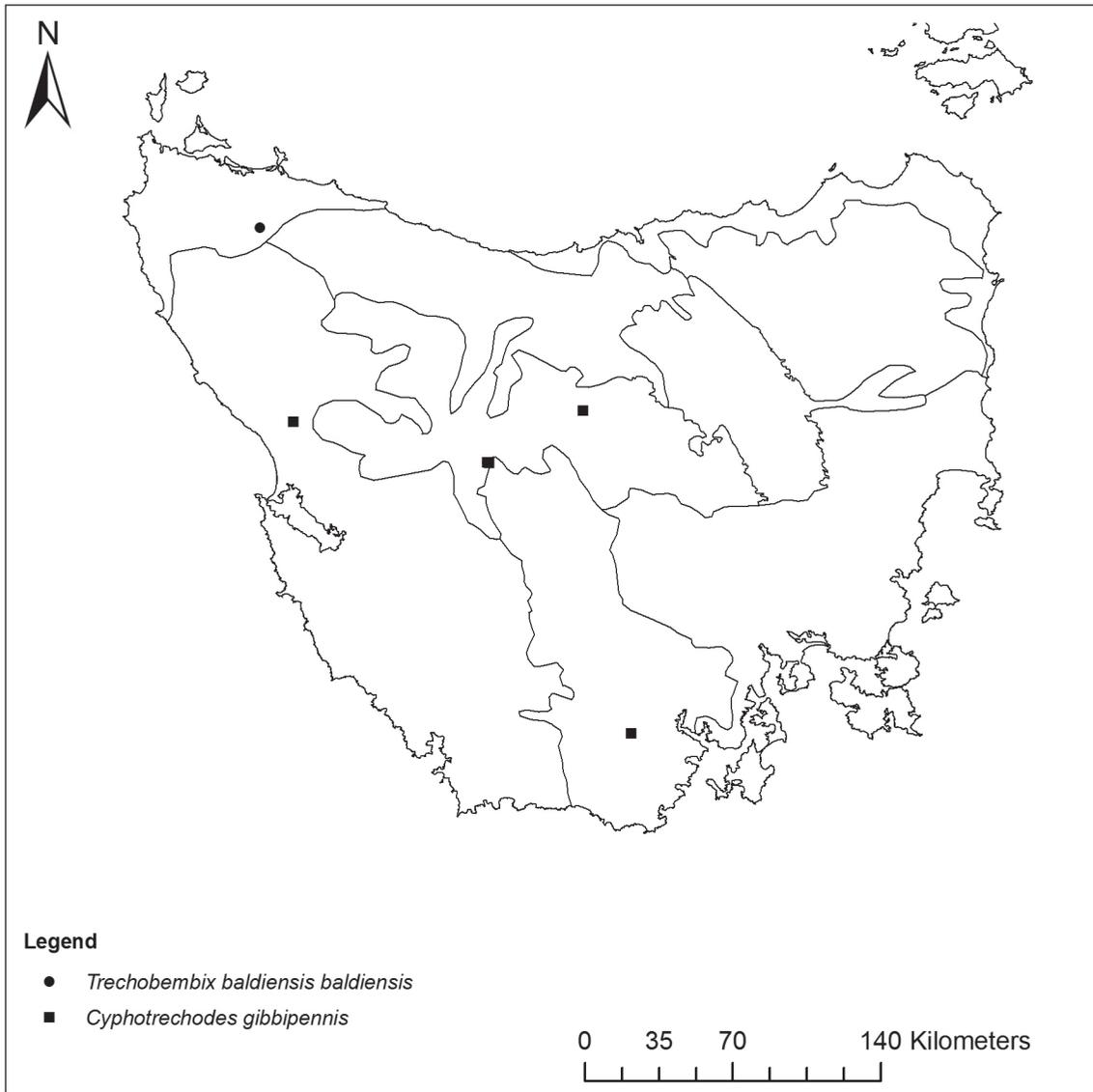
Map 4 - Collection sites for *Pterocyrtus* spp.

Tasmanorites Jeannel: Casale & Laneyrie, 1982: 59.
Tasmanorites Jeannel: Moore, 1983: 1.
Tasmanorites Jeannel: Moore et al, 1987: 126.
Tasmanorites Jeannel: Donabauer, 2001: 101.
Tasmanorites Jeannel: Lorenz, 2005: 168.

KEY TO SPECIES (AFTER MOORE, 1972 AND DONABAUER, 2001 MODIFIED)

- 1 Third interval with only 2 setiferous pores 2
- Third interval with 3 or more such pores 4
- 2 Eyes very reduced *T. microphthalmus* sp. nov.
- Eyes of normal size 3
- 3 Pronotal hind angle more marked and notably reflexed, asetose; size bigger (length 5-6 mm).....
 *T. grossus*

- Pronotal hind angle rounded, slightly reflexed, basal seta present; size smaller (length about 4.5 mm)
T. madidus
- 4 Elytra maculate..... 5
- Elytra immaculate 9
- 5 Head and pronotum mostly pale; base of pronotum bisinuate *T. riparius*
- Head and pronotum dark; base of pronotum subrectilinear..... 6
- 6 Side of pronotum sinuate, hind angles sharp..... 8
- Side of pronotum not sinuate, hind angles rounded ..7
- 7 Size smaller (length 3.18-3.35 mm); elytra short with bigger maculae; 3rd elytral pore placed more backward.....
T. beatricis sp. nov.
- Size bigger (length 3.7-4.0 mm); elytra long with smaller maculae; 3rd elytral pore placed less backward.....
T. brevinotatus



Map 5 - Collection sites for *Trechobembix baldiensis baldiensis* and *Cyphotrechodes gibbipennis*.

- | | |
|---|---|
| <p>8 Size bigger (length about 5.5 mm); elytra pyriform...
.....
..... <i>T. elegans</i></p> <p>- Size smaller (length about 5.5 mm); elytra subrectangular..... <i>T. longinotatus</i></p> <p>9 Base of pronotum wider than the anterior margin.....
..... <i>T. laticollis</i></p> <p>- Base of pronotum as wide as, or less wide than the anterior margin 10</p> <p>10 Pronotal hind angles well marked, moderately prominent..... 11</p> <p>- Pronotal hind angles rounded, not marked..... 17</p> <p>11 7th interval with setiferous pores..... <i>T. aberrans</i></p> <p>- 7th interval without setiferous pores 12</p> <p>12. Elytra ovoid, broad at the base, humeri marked ... 13</p> <p>- Elytra pyriform, narrow at the base, humeri obsolete..
..... 16</p> | <p>13 Pronotal hind angles acute and turned out 14</p> <p>- Pronotal hind angles obtuse, scarcely projecting
..... <i>T. austrinus</i></p> <p>14 Size bigger (length about 5 mm)..... <i>T. magnus</i></p> <p>- Size smaller (length about 3.19-3.5 mm)..... 15</p> <p>15 Pronotum more transverse, antennae short, eyes bigger.....
..... <i>T. lynceorum</i> sp. nov.</p> <p>- Pronotum less transverse, antennae long, eyes smaller.....
..... <i>T. nitens</i></p> <p>16 Posterior pronotal marginal seta present; 4 inner striae strong
..... <i>T. flavipes</i></p> <p>- Posterior pronotal marginal seta missing; only 2 inner striae strong
..... <i>T. cordicollis</i></p> <p>17 Size bigger (length about 3.5-4.1 mm)..... 18</p> <p>- Size smaller (length about 3.0-3.3 mm)..... 20</p> <p>18 Antennae longer, reaching the anterior 4th of the elytra;
hind angle of pronotum less marked..... 19</p> |
|---|---|

- Antennae shorter, not reaching the anterior 4th of the elytra; hind angle of pronotum more marked.....
..... *T. glaebarum*
- 19 Median lobe of the aedeagus, in lateral view, more curved also in the apical half..... *T. blackburni*
- Median lobe of the aedeagus, in lateral view, less curved, subrectilinear in the apical half... *T. intermedius*
- 20 Elytra with 3 inner striae lightly impressed 22
- Elytra with 3-4 inner striae strongly impressed 21
- 21 Base of the pronotum wider; elytra longer; apex of the median lobe of the aedeagus, in lateral view, pointed.
..... *T. tasmaniae*
- Base of the pronotum less wide; elytra shorter; apex of the median lobe of the aedeagus, in lateral view, rounded..... *T. daccordii* sp. nov.
- 22 Aedeagus relatively shorter, apex only very slightly upturned..... *T. pullus*
- Aedeagus very elongated, apex clearly upturned.....
..... *T. perkinsi*

Tasmanorites grossus Moore, 1972
(Figs 16, 19)

Loc. Typ.: Hartz Mountain, SE Tasmania

Tasmanorites grossus Moore, 1972: 16.

Tasmanorites grossus Moore: Casale & Laneyrie, 1982: 59.

Tasmanorites grossus Moore: Moore et al, 1987: 127.

Tasmanorites grossus Moore: Lorenz, 2005: 168.

Examined material

1 ♀, Australia, Tas., Hastings, Mystery Creek Cave, 2.I.2002, P.M. Giachino leg. (CGi); 1 ♂, Australia, Tas., Hartz Mts. N.P., Lake Osborne car park, m 900, 20.I.2002, rainforest, P.M. Giachino leg. (CGi); 2 ♂♂, Nat. Park, Tas., Jan. 1933, F.E. Wilson, 3500' altitude (MVM, CGi).

Notes

The original description by Moore (1972) is sufficiently accurate and does not need any additions, but here we contribute a drawing of the habitus (Fig. 16) and aedeagus (Fig. 19).

Distribution and ecology

Moore (1972) mentions *T. grossus* of Hartz Mountain and Mt Field and Lune River (south of Hastings), recent data in our possession confirm this distribution (Map 6). At Lake Osborne *T. grossus* was collected by sieving litter in a small humid forest near the car park, while the discovery of a specimen in the Mystery Creek Cave is considered incidental.

Tasmanorites madidus Moore, 1972
(Fig. 17)

Loc. Typ.: Mt. Field, SE Tasmania

Tasmanorites madidus Moore, 1972: 17.

Tasmanorites madidus Moore: Casale & Laneyrie, 1982: 59.

Tasmanorites madidus Moore: Moore et al, 1987: 127.

Tasmanorites madidus Moore: Lorenz, 2005: 168.

Examined material

2 ♂♂ 1 ♀, Australia, Tas., Cradle Mts. N. P., Marion Lookout Track, m 1100, 25.XI.1999, P.M. Giachino leg. (CGi). 2 ♀♀, Australia, Tas., Gordon River Rd., Creepy Crawly Walk, m 565, 17.I.2002, P.M. Giachino leg. (CGi).

Notes

The original description by Moore (1972) is sufficiently accurate and does not need any additions, while we believe it is useful to supply a drawing of the habitus (Fig. 17).

Distribution and ecology

Moore (1972) mentions *T. madidus* of Mt. Field, Waldheim, and Lake St. Clair.; the new locality of Creepy Crawly Walk, situated along the Gordon River Rd., expands the known range slightly southwestwards (Map 6). In this new site *T. madidus* was collected by sieving rainforest litter.

Tasmanorites riparius Moore, 1972
(Figs 18, 20, 21)

Loc. Typ.: Waldheim, Tas.

Tasmanorites riparius Moore, 1972: 17.

Tasmanorites riparius Moore: Casale & Laneyrie, 1982: 59.

Tasmanorites riparius Moore: Moore et al, 1987: 128.

Tasmanorites riparius Moore: Lorenz, 2005: 168.

Examined material

2 ♂♂ 1 ♀, Australia, Tas., Murchison St. For., 30.I.2002, P. M. Giachino leg. (CGi).

Notes

The original description is sufficiently accurate and requires no additions, while we believe it is useful to provide a drawing of the habitus (Fig. 18) and of the aedeagus (Figs 20, 21), the latter was not given by Moore (1972).

Distribution and ecology

Moore (1972) mentions *T. riparius* of Waldheim, Waratah, Corinna, and N of Zeehan; the new findings of Murchison State Forest, confirm the range of this species (Map 6). In this station *T. riparius* was collected sieving rain forest litter beside a small stream.

Tasmanorites brevinotatus (Sloane, 1920)
(Figs 22, 24)

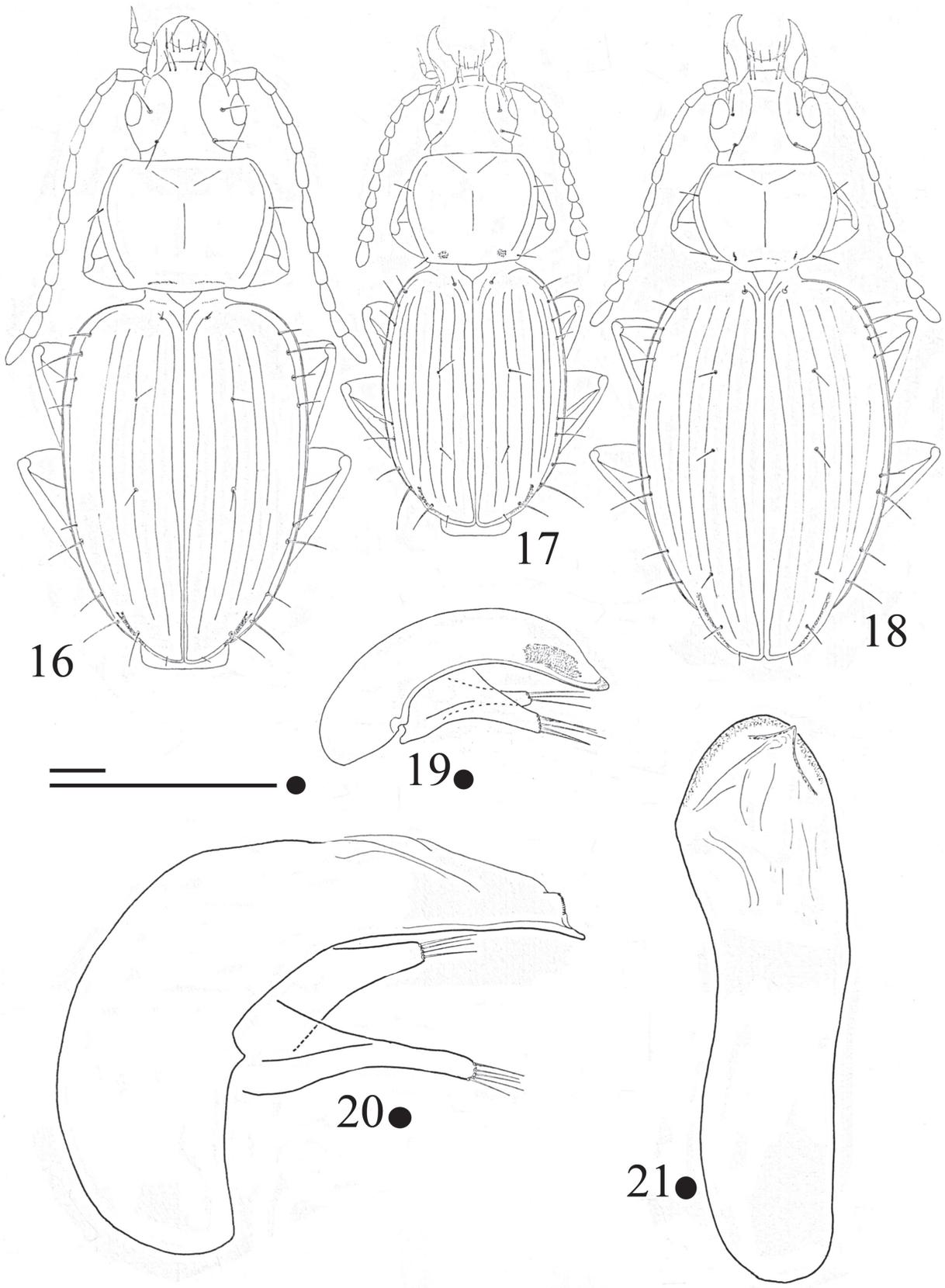
Loc. Typ.: Great Lake

Trechus brevinotatus Sloane, 1920: 149.

Tasmanorites brevinotatus Sloane: Jeannel, 1927: 79.

Tasmanorites brevinotatus (Sloane): Moore, 1972: 17.

Tasmanorites brevinotatus (Sloane): Casale & Laneyrie, 1982: 59.



Figs 16-21. Habitus (16, 17, 18), aedeagus in lateral view (19, 20) and aedeagus in dorsal view (21) of *Tasmanorites* spp.: 16, 19) *T. grossus* Moore, ♂ from Lake Osborne; 17) *T. madidus* Moore, ♀ from Creepy Crawly Walk; 18, 20, 21) *T. riparius* Moore, ♂ from Murchison State Forest. Scale: 0.5 mm.

Tasmanorites brevinotatus (Sloane): Moore et al, 1987: 126.

Tasmanorites brevinotatus (Sloane): Donabauer, 2001: 103.

Tasmanorites brevinotatus (Sloane): Lorenz, 2005: 168.

Type material

HT ♂, Great Lake 3/91 (white, handwritten and printed), Type (white, printed), *Trechus brevinotatus* Sl. Id. by T.S. Sloane (white, handwritten and printed), *Trechus brevinotatus* Tasmania S.10815, Type (white, handwritten with black and red writing), Holotype *T. brevinotatus* Sl. (red, handwritten) (SAM).

Notes

The original description by Sloane (1920) and subsequent additions by Jeannel (1927) and Moore (1972) are sufficiently accurate and do not require any additions, while we believe it is useful to provide the drawing of the habitus (Fig. 22) and of the aedeagus (Fig. 24), the latter had never been made before.

Distribution and ecology

T. brevinotatus is known from the type locality of Great Lake (Map 7). Moore (1972) also mentions Lake St. Clair on specimens collected from litter by the Darlings. This deserves further confirmation.

Tasmanorites beatricis sp. nov.
(Figs 23, 25)

Loc. Typ.: Tasmania, Cradle Mts National Park, Cradle Mts Lodge m 800.

Type series

HT ♂, Australia, Tas., Cradle Mts N.P., Cradle Mts Lodge m 800, 30.I.2002, P.M. Giachino leg. (QVML). PTT: 11 ♂♂ 8 ♀♀, Australia, Tas., Cradle Mts N.P., Cradle Mts Lodge m 800, 30.I.2002, P.M. Giachino leg. (CGi)

Diagnosis

A small-sized (mm 3.18-3.35) *Tasmanorites*, similar to *T. brevinotatus* for the shape of the body and of the aedeagus. It is well distinct for the size slightly smaller (3.70 mm in *T. brevinotatus*), for the less elongated elytra, for bigger elytral maculae (humeral and apical), and for the more rearward position of the third discal seta. From *T. brevinotatus* it also differs in the shape of the median lobe of the aedeagus, less elongated and less sharply bent at the level of the basal bulb, as well as in the apical blade that is not folded hookwise upwards.

Description

Length mm 3.18-3.20 ♂♂, 3.25-3.35 ♀♀. Body obovate (Fig. 23), with a small fore-body in comparison with the elytra, which are short and ovate. Dorsal surface glabrous and shiny, with an isodiametric microsculpture. Metathoracic wings absent. Colour blackish brown, with

lateral margins of elytra and pronotum, elytral suture, epipleura, legs, first antennomere, and palpi testaceous-yellow; elytra with two testaceous-yellow humeral maculae extended to the first discal seta and two apical testaceous-yellow maculae laterally extended to the apical 4th. Head large. Clypeus convex at the base, with two apical setae on each side. Eyes big, convex but not prominent. Neck constriction evident. Labrum transverse, with a slightly emarginated apex; mandibles slender. Antennae short and slender, as long as the half of the body. Second antennal segment less long than the first one. Pronotum transverse (PW/PL: 1.37), widest at about 2/3 from the base. Base narrower than the anterior margin. Sides not sinuate and subrectilinear before the base, which is subrectilinear; hind angles obtuse, rounded and not projected outwards. Front angles rounded and not advanced. Lateral margins narrow, widening posteriorly; anterior seta inserted near 2/3 from the base; basal seta present, inserted before the angles. Basal foveae smooth, lightly impressed, stretched. Median line distinct. Discal surface gently convex. Male with two dilated protarsomeres. Elytra broad, oval, largest in the middle, slightly convex. Shoulders rounded, with the humeral border continuing inwards almost to the base of 3rd stria. Lateral border of the elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with all the striae visible; juxtascutellar stria present; apical recurrent striole long, gently curved, ending at the level of the 6th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; three setiferous pores on the third stria, respectively, at the basal 5th, in the middle, and at the apical 5th. One preapical pore placed backwards and closer to the recurrent striole. Aedeagus (Fig. 25) small (length 0.65 mm), stout, with the basal bulb large; median lobe, in lateral view, curved in the basal third, from gently curved to subrectilinear in the distal 2/3; apex long, with the apical blade stout, subtruncate, and not bent upwards. Inner sac apically provided with a patch of sclerotized scales. Parameres long and stout, reaching the apical third of the median lobe, each one provided with 4 setae.

Etymology

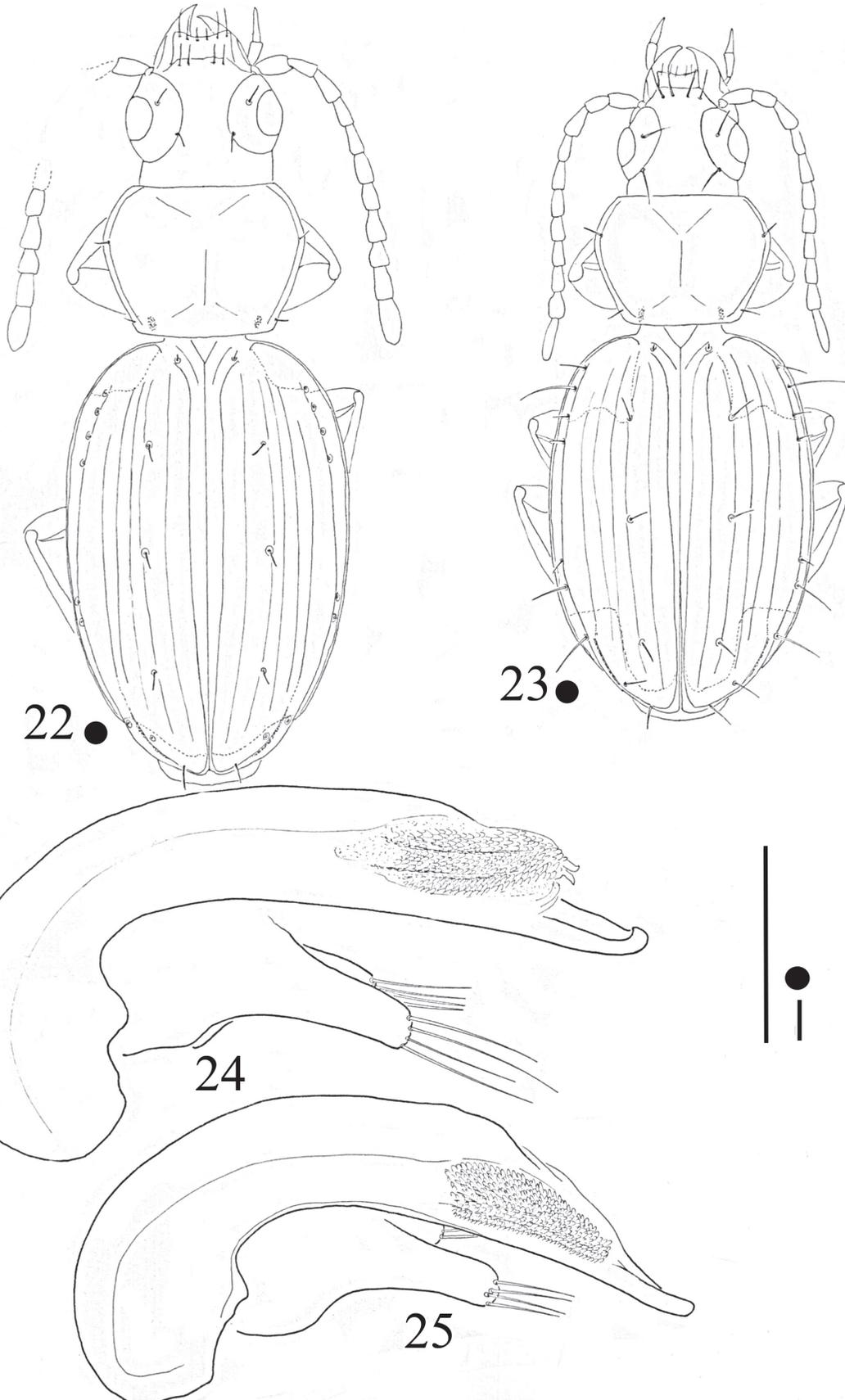
I dedicate this new species with pleasure and affection to Beatrice Sambugar, a research companion during the first trip to Tasmania of one of us (P.M.G.)

Distribution and ecology

T. beatricis sp. nov. is currently known only from the type locality of Cradle Mts Lodge in Cradle Mts National Park, where it was collected by sieving *Nothofagus* litter at a height of 800 m a.s.l. (Map 7).

Tasmanorites elegans Moore, 1972
(Fig. 26)

Loc. Typ.: St. Marys, in "Bottomless Pit", Gray Mountain, NE Tasmania.



Figs 22-25. Habitus (22, 23) and aedeagus in lateral view (24, 25) of *Tasmanorites* spp.: 22, 24) *T. brevinotatus* (Sloane), HT ♂ from Great Lake; 23, 25) *T. beatricis* sp. nov., HT ♂ from Cradle Mts. Scale: 0.2 mm.

Tasmanorites elegans Moore, 1972: 18.

Tasmanorites elegans Moore: Casale & Laneyrie, 1982: 59.

Tasmanorites elegans Moore: Moore et al, 1987: 126.

Tasmanorites elegans Moore: Lorenz, 2005: 168.

Examined material

2 ♀♀ and 1 spec. (remains: elytra and abdomen without genitalia), Tas., 41°37'S 148°12'E, G-X2 – 10 Gray, Elephant Fram Cave, dark zone, 11.VIII.1988, S. Eberhard leg., QVM 12: 43785 (QVML, CGi);

Notes

The original description is sufficiently accurate and requires no additions, while we believe it is useful to provide a drawing of the habitus (Fig. 26), that was not given by Moore (1972).

Distribution and ecology

T. elegans is currently known from two sites, both caves, near Gray (NE Tasmania): Bottomless Pit and Elephant Fram Cave (Map 7). The species is not obviously troglomorphic and is considered a troglophile.

Tasmanorites longinotatus (Sloane 1920)

Loc. Typ.: Mt. Ben Lomond

Trechus longinotatus Sloane, 1920: 148

Tasmanorites longinotatus Sloane: Jeannel, 1927: 78.

Tasmanorites longinotatus Sloane: Moore, 1972: 18.

Tasmanorites longinotatus Sloane: Casale & Laneyrie, 1982: 59.

Tasmanorites longinotatus Sloane: Moore et al, 1987: 126.

Tasmanorites longinotatus Sloane: Lorenz, 2005: 168.

Examined material

1 ♂ 3 ♀♀, Australia, Tas., Ben Lomond N. P., Hamilton Crags, Meadow Vale, m 1400, 30.XI.1999, P.M. Giachino (CGi).

Distribution and ecology

T. longinotatus is currently known from three localities in the mountains of Ben Lomond and Mt Barrow in NE Tasmania (Moore, 1972) (Map 7).

Tasmanorites aberrans Moore, 1972
(Figs 27, 30)

Loc. Typ.: King River (between Lake St. Clair and Queenstown), central Tasmania.

Tasmanorites aberrans Moore, 1972: 21.

Tasmanorites aberrans Moore: Casale & Laneyrie, 1982: 59.

Tasmanorites aberrans Moore: Moore et al, 1987: 126.

Tasmanorites aberrans Moore: Lorenz, 2005: 168.

Examined material

9 ♂♂ 1 ♀, Australia, Tas., Strahan, Kelly Cove, Pillinger, 26.I.2002, P. M. Giachino leg. (CGi); 1 ♀, Australia, Tas., Strahan, Franklin-Gordon Wild River N.P., Gordon River, Heritage Landing Walk, 25.I.2002, P. M. Giachino leg. (CGi); 3 ♂♂ 3 ♀♀, Lake St. Clair, Tas., Jan 1941, C. Oke (MVM, CGi); 2 ♂♂, Mt. Wellington? (MVM);

Notes

The original description is sufficiently accurate and requires no additions, while we believe it is useful to provide a drawing of the habitus (Fig. 27) and of the aedeagus (Fig. 30), that had not been made by Moore (1972).

Distribution and ecology

Moore (1972) described *T. aberrans* from King River, south of Queenstown, which has remained until now the only known locality of the species. Recent data from Pillinger (Kelly Cove, near Strahan) and Heritage Landing Walk (Gordon River, near Strahan) are relatively close to the type locality, while the collection site of Lake St. Clair, on old specimens collected by C. Oke in 1941, significantly extends the range of this species to the east (Map 6). Doubtful, and very far geographically, is the collection site of Mt Wellington, lacking among other details the collector's name. In the original description, Moore (1972) mentions the species collected in "long grass beside a shallow pool"; the specimens collected by one of us (PMG) near Strahan were collected by sieving rain forest litter along bank of the Gordon River.

Tasmanorites austrinus (Sloane 1920)
(Figs 28, 31)

Loc. Typ.: Great Lake

Trechus austrinus Sloane, 1920: 147.

Sloanella austrina Sloane: Jeannel, 1927: 88.

Tasmanorites austrinus (Sloane): Moore, 1972: 21.

Tasmanorites austrinus (Sloane): Casale & Laneyrie, 1982: 59.

Tasmanorites austrinus (Sloane): Moore et al, 1987: 126.

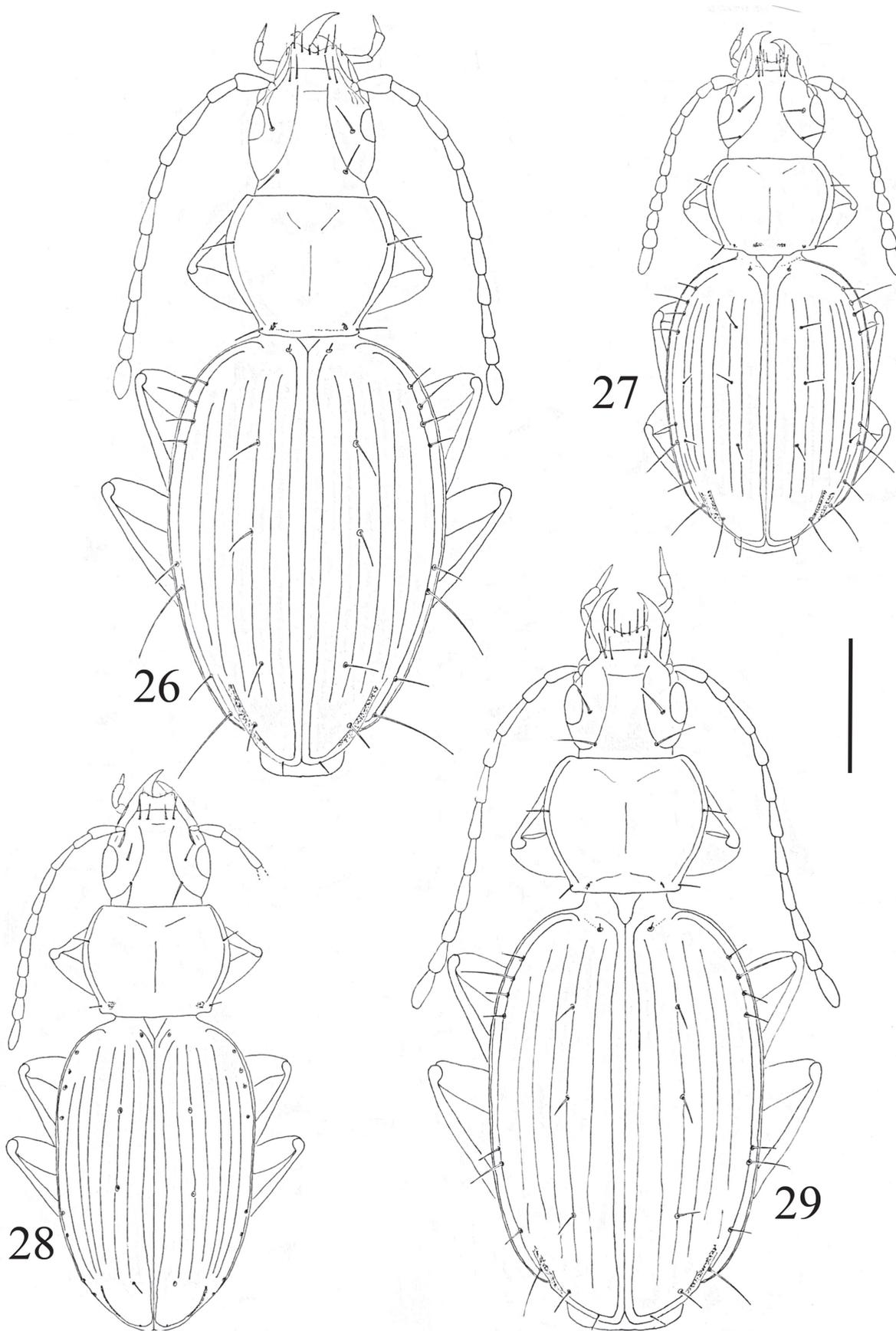
Tasmanorites austrinus (Sloane): Lorenz, 2005: 168.

Type material

HT ♂, Great Lake 3/91, (white, printed), *Trechus austrinus* Sl. Id. by T.S. Sloane (white, handwritten and printed), Type (white, printed), *Trechus austrinus* Sl. Tasmania S. 10813 Type (white, handwritten with black and red writing), Holotype *T. austrinus* Sl. PID (red, handwritten) SAM.

Examined material

1 ♀, Australia, Tas., Lake St. Clair N.P. m 740, rain-forest sieved litter, 23.I.2002, P.M. Giachino leg. (CGi).



Figs 26-29. Habitus of *Tasmanorites* spp.: 26) *T. elegans* Moore, ♀ from Elephant Fram Cave; 27) *T. aberrans* Moore, ♂ from Pillinger, Kelly Cove; 28) *T. austrinus* (Sloane), HT ♂ from Great Lake; 29) *T. magnus* Moore, ♂ from Ben Lomond. Scale: 1 mm.

Notes

The original description by Sloane (1920) and subsequent additions by Jeannel (1927) and Moore (1972) are sufficiently accurate and need no further additions, but we believe it is useful to provide a drawing of the habitus (Fig. 28) and of the aedeagus (Fig. 31) of the holotypus.

Distribution and ecology

Sloane (1920) describes *T. austrinus* from Great Lake, while Moore (1972) mentions it also from Lake St. Clair on collections of Darlington. The specimen collected by one of us (PMG) near Lake St. Clair (by sieving rainforest litter), compared with holotypus deposited in the SAM, confirmed the accuracy of Moore's additions (1972) (Map 6).

Tasmanorites magnus Moore, 1972
(Figs 29, 32)

Loc. Typ.: Mt. Ben Lomond (3000-4000 ft), NE Tasmania.

Tasmanorites magnus Moore, 1972: 22.

Tasmanorites magnus Moore: Casale & Laneyrie, 1982: 59.

Tasmanorites magnus Moore: Moore et al, 1987: 127.

Tasmanorites magnus Moore: Lorenz, 2005: 168.

Examined material

16 ♂♂ 12 ♀♀, Australia, Tas., Ben Lomond N. P., Hamilton Crags, Meadow Vale, m 1400, 30.XI.1999, P.M. Giachino (MRSN, CGi); 6 ♂♂ 3 ♀♀, Australia, Tas., Ben Lomond N. P., Legger Tor m 1530, 14.I.2002, P.M. Giachino leg. (CGi); 23 ♂♂ 15 ♀♀, Australia, Tas., Ben Lomond N. P., Hamilton Crags, Meadow Vale m 1450, 13-14.I.2002, P.M. Giachino leg. (CGi)

Notes

The original description is sufficiently accurate and requires no additions, while we believe it is useful to provide a drawing of the habitus, that had not been given by Moore (1972) (Fig. 29) and of the aedeagus (Fig. 32).

Distribution and ecology

T. magnus is currently known from the type locality of Ben Lomond and Mt Barrow nearby (Map 7). At Ben Lomond it was collected by one of the authors (PMG) under stones along the streams of the plateau near the Ski Resort.

Tasmanorites nitens (Putzeys, 1874)
(Figs 33, 35)

Loc. Typ.: Tasmania.

Trechus nitens Putzeys, 1874: 50.

Tasmanorites nitens Putzeys: Jeannel, 1927: 75.

Tasmanorites nitens (Putzeys): Moore, 1972: 22.

Tasmanorites nitens (Putzeys): Casale & Laneyrie, 1982: 59.

Tasmanorites nitens (Putzeys): Moore et al, 1987: 127.

Tasmanorites nitens (Putzeys): Donabauer, 2001: 103.

Tasmanorites nitens (Putzeys): Lorenz, 2005: 168.

Type material

LT ♂, Tasmania, Coll. Castelnau (white, handwritten); Mus. de Genes (white, handwritten); *Trechus nitens* Putz., R. Jeannel det. (white, handwritten and printed); Syntypus, *Trechus nitens* Putzeys, 1874 (red, handwritten and printed); Lectotypus ♂, *Trechus nitens* Putzeys, P.M. Giachino det. 2009 (MCSNG). PLT ♀, Tasmania, Coll. Castelnau (white, handwritten and printed); Tasmania (white, handwritten); Syntypus, *Trechus nitens* Putzeys, 1874 (red, handwritten and printed); *Trechus nitens* Putz. t. Putz. (white, handwritten); *Trechus nitens* Putz., R. Jeannel det. (white, handwritten and printed); Paralectotypus ♀, *Trechus nitens* Putzeys, P.M. Giachino det. 2009 (MCSNG). PLTT 2 ♀♀, Tasmania (white, handwritten); Tasmania, Coll. Castelnau (white, handwritten and printed); Syntypus, *Trechus nitens* Putzeys, 1874 (red, handwritten and printed); *Trechus nitens* Putz., R. Jeannel det. (white, handwritten and printed); Paralectotypus ♀, *Trechus nitens* Putzeys, P.M. Giachino det. 2009 (MCSNG).

Examined material

1 ♂, Tas. Summit of Mt. Wellington, Lea (SAM).

Notes

In order to ascertain the validity of *T. lynceorum* sp. nov., described below, it was necessary to examine the type series of *T. nitens* deposited in the MCSNG, and to designate the Lectotype. The description by Jeannel (1927), who had the chance to examine the type material is sufficiently accurate and requires no further additions, but again we believe it is useful to provide a drawing of the habitus (Fig. 33) and of the aedeagus (Fig. 35) of the holotype.

Distribution and ecology

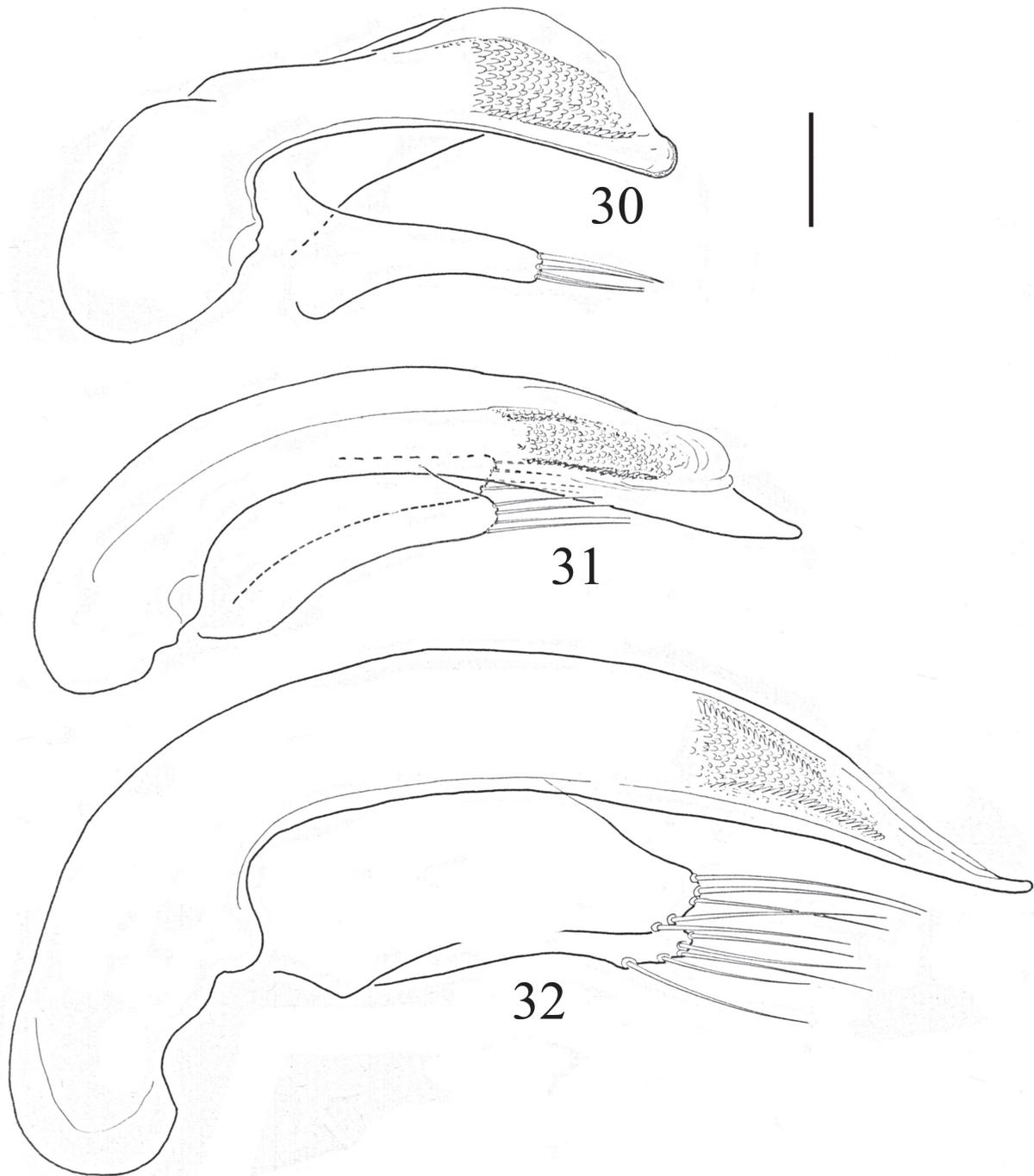
T. nitens is currently known only from the type locality of Mt Wellington where it is present, among the roots of grasses, above the tree line (Moore 1972) (Map 7). But in this environment, one of the authors (PMG) has found, in January, the closely related *T. lynceorum* sp. nov., described below.

Tasmanorites lynceorum sp. nov.
(Figs 34, 36)

Loc. Typ.: Tasmania, Hobart, Mt. Wellington, m 1200

Type series

HT ♂, Australia, Tas., Hobart, Mt. Wellington, m 1200, 19.I.2002, P.M. Giachino leg. (QVML). PTT: 6 ♀♀, Australia, Tas., Hobart, Mt. Wellington, m 1200, 19.I.2002, P.M. Giachino leg. (CGi); 6 ♂♂ 7 ♀♀, Australia, Tas., Hobart, Mt. Wellington, m 1270 27.XI.1999, P.M. Giachino leg. (MRSN, MVM, CGi).



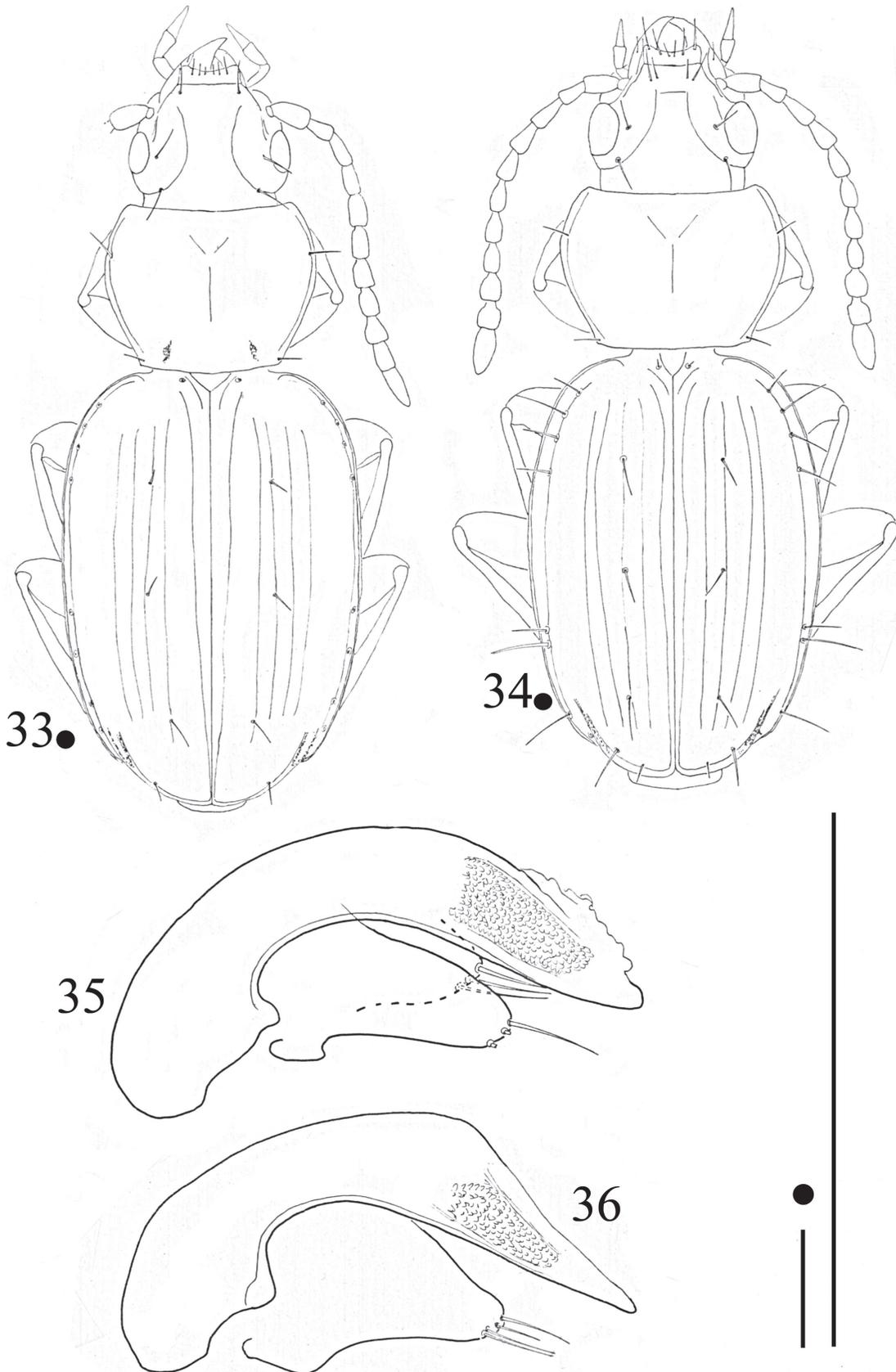
Figs 30-32. Aedeagus in lateral view of *Tasmanorites* spp.: 30) *T. aberrans* Moore, ♂ from Pillinger, Kelly Cove; 31) *T. austrinus* (Sloane), HT ♂ from Great Lake; 32) *T. magnus* Moore, ♂ from Ben Lomond. Scale: 0.1 mm.

Diagnosis

A small-sized (mm 3.16-3.30) *Tasmanorites*, similar to *T. nitens* for the general shape of the body and of the aedeagus. Well separated from it for the pronotum more transverse, the antennae shorter, the eyes bigger and the shape of the median lobe of the aedeagus, in lateral view, with an acute apex (Figs 35, 36).

Description

Length mm 3.16-♂, 3.21-3.30 ♀♀. Body obovate (Fig. 34), with a relatively large fore-body in comparison with the elytra, which are short and ovate. Dorsal surface glabrous and shiny, with the microsculpture isodiametric on the pronotum, as transverse meshes on the elytra. Metathoracic wings absent. Colour blackish brown, with legs,



Figs 33-36. Habitus (33, 34) and aedeagus in lateral view (35, 36) of *Tasmanorites* spp.: 33, 35) *T. nitens* (Putzeys), LT ♂ from Tasmania; 34, 36) *T. lynceorum* sp. nov., HT ♂ from Mt. Wellington. Scale: 0.5 mm.

antennomeres, and palpi testaceous. Head large. Clypeus convex at the base, with two apical setae on each side. Eyes large, convex but not prominent. Neck constriction evident. Labrum transverse, with an emarginated apex; mandibles stout. Antennae short and slender, as long as the half of the body. Second antennal segment less long than the first one. Pronotum transverse (PW/PL: 1.44), widest at about 2/3 from the base. Base narrower than the anterior margin. Sides slightly sinuate before the base, which is subrectilinear; hind angles obtuse, edged and slightly turned out. Front angles rounded and slightly advanced. Lateral margins narrow, widening posteriorly; anterior seta inserted near 2/3 from the base; basal seta present, inserted at the angles. Basal foveae smooth, slightly impressed, stretched. Median line distinct. Discal surface gently convex. Male with two dilated protarsomeres. Elytra broad, oval, largest in the middle, slightly convex. Shoulders rounded, with the humeral border continuing inwards almost to the base of 3rd stria. Lateral border of elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with 1st – 5th striae visible, the others obsolete; juxtascutellar stria present; apical recurrent striole long, gently curved, ending at the level of the 7th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; three setiferous pores on the third stria, respectively, at the basal 4th, in the middle, and at the apical 5th. One preapical pore placed backwards and closer to the recurrent striole. Aedeagus (Fig. 36) small (length 0.47 mm), slender, with the basal bulb large; median lobe, in lateral view, curved in the basal third, subrectilinear in the distal half; apex long, with the apical blade triangular and not bent upwards. Inner sac apically provided with a patch of sclerotized scales. Parameres long and very stout, reaching the apical fourth of the median lobe, each one provided with 4 setae.

Etymology

The name of this new species comes from the Accademia Nazionale dei Lincei in Rome, Italy, to which it is dedicated respectfully as a token of acknowledgement for the interest and the support that studies of one of the authors on the Australian fauna were gratified with.

Distribution and ecology

T. lynceorum sp. nov. is currently known only from the type locality of Mt. Wellington, near Hobart, where it was collected by sieving litter beneath bushes close to the top, above the tree line, at an elevation of 1200 m a.s.l. (Map 7).

Tasmanorites flavipes (Lea 1910)
(Figs 37, 38)

Loc. Typ.: Ida Bay Caves, Tas.

Idacarus flavipes Lea, 1910: 56.

Tasmanorites flavipes (Lea): Moore, 1972: 22.

Tasmanorites flavipes (Lea): Casale & Laneyrie, 1982: 59.

Tasmanorites flavipes (Lea): Moore et al, 1987: 126

Tasmanorites flavipes (Lea): Lorenz, 2005: 168.

Type material

HT (very largely destroyed), *flavipes* Lea Type, Ida Bay Caves (white, handwritten and printed); Type (red printed); *Idacarus flavipes* Lea, Type, Ida Bay Caves, 14123 (white, handwritten with black and red writing) (SAM).

Examined material

1 ♂, Tas., 42°42'S 146°35'E, JF4-26, Junee-Florentine, Khazad Dûm, near entrance in streamway, 27.VI.1989, Jean Jackson leg., QVM 12: 43788 (QVML); 1 ♀, Tas., 42°42'S 146°35'E, JF4-26, Junee-Florentine, Khazad Dûm, near entrance in streamway, 27.VI.1989, Jean Jackson leg. (CGi); 1 ♀, Tas., 42°40'S 146°27'E, Junee-Florentine Windy Rift, Growling Swallet Cave, Glow worm chamber, JF36-7, 26.III.1989, S. Eberhard leg., QVM 12: 43787 (QVML); 1 ♀, Tas., 42°40'S 146°27'E, Junee-Florentine Windy Rift, Growling Swallet Cave, Glow worm chamber, JF36-16, 6.II.1985, S. Eberhard leg. (CGi).

Notes

As pointed out by Moore (1972) the type of *T. flavipes* deposited at SAM is largely destroyed by dermestids and we believe it is useful to provide a drawing of the habitus (Fig. 37) and of the aedeagus (Fig. 38) of the ♂ specimen examined by us.

Distribution and ecology

According with Moore (1972) and Moore et al (1987) *T. flavipes* is a hygrophilous species currently known from Ida Bay Caves, Arve River and Florentine Valley (Map 6).

Tasmanorites tasmaniae (Blackburn 1901)
(Figs 39, 44-46)

Loc. Typ.: Lake district, Tas.

Trechus tasmaniae Blackburn, 1901: 118.

Trechus tasmaniae Blackburn: Sloane, 1920: 150.

Tasmanorites tasmaniae Blackburn: Jeannel, 1927: 76.

Tasmanorites tasmaniae (Blackburn): Moore, 1972: 22.

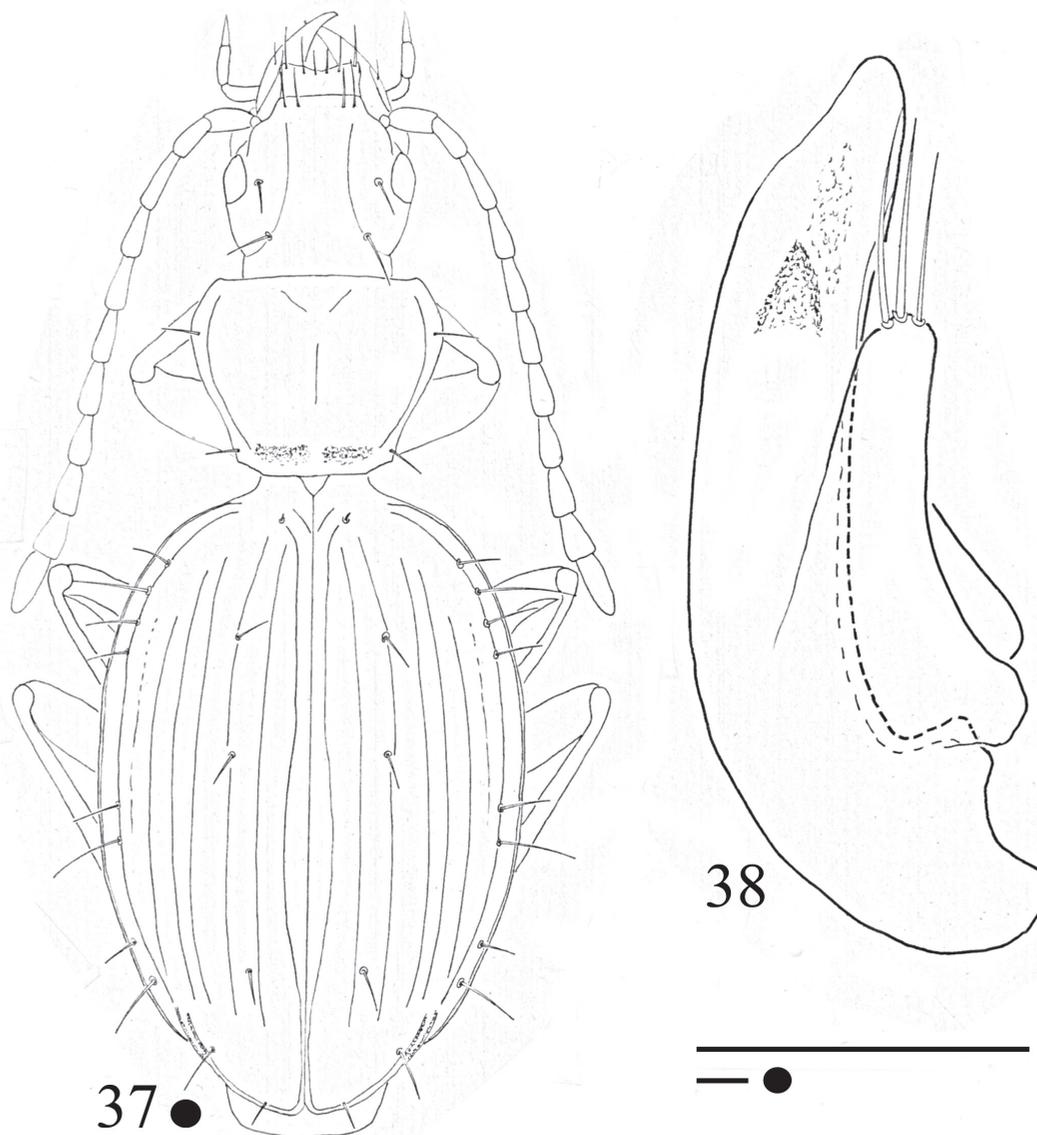
Tasmanorites tasmaniae (Blackburn): Casale & Laneyrie, 1982: 59.

Tasmanorites tasmaniae (Blackburn): Moore et al, 1987: 127.

Tasmanorites tasmaniae (Blackburn): Lorenz, 2005: 168.

Type material

T ♂, 6956 T T.J.S. 4 a Yes (near indecipherable) (red and black handwriting on the card holding the insect), Type (circular, printed with a red margin), Blackburn coll. 1910-236 (white, printed), *Trechus tasmaniae* Blackb. (BMNH). CT ♂, *Trechus tasmaniae* Bl., Tasma-



Figs 37-38. Habitus (37) and aedeagus in lateral view (38) of *Tasmanorites flavipes* (Lea), ♂ from Khazad Dûm cave, Junee-Florentine. Scale: 0.2 mm.

nia, g-7729 Cotype (white, handwritten with black and red writing), *Trechus Tasmaniae* Blackb., Co-type (white, handwritten) (SAM).

Notes

Moore (1972) mentions *T. tasmaniae* from central Tasmania: Lake District (type locality) and Mt Field, but he provides - probably misled by the illustrations given by Jeannel (1927: 76) and illustrating habitus and aedeagus of a specimen coming from Cradle Mts. (and therefore actually a specimen of *T. daccordii* sp. nov., described below) - a drawing of aedeagus and pronotum that do not correspond to the drawings derived from the specimens of the type series deposited in the BMNH and SAM (Figs 44-46). Conversely they seem to adapt well to the drawings (very schematic) proposed by Moore (1972) for *T. pullus* Moore, 1972. However the

drawings of the aedeagi of the two subspecies of *T. pullus* provided by Donabauer (2001) allow the exclusion of the synonymy between *T. tasmaniae* and *T. pullus* s.l. We consider it useful to provide a brief diagnosis and drawings of habitus (Fig. 39) and aedeagus (Figs 44-46) of *T. tasmaniae*.

Diagnosis

A small-sized (mm 3.15-3.20) *Tasmanorites*, with the body oval elongated of a blackish colour, with palpi and tibia blackish brown, antennae blackish. Similar, in the shape of the body, and particularly of pronotum and elytra, to *T. daccordii* sp. nov., but well separated from this species by the pronotum narrower at the base, the elytra more elongated (Figs 39, 40), and the shape of the median lobe of the aedeagus more elongated and with the apex acute in lateral view and truncate in dorsal view (Figs 44-48).

Distribution and ecology

Contrary to the assertion by Sloane (1920), Jeannel (1927), Moore (1972), Moore et al (1987), and Donabauer (2001) mentioning *T. tasmaniae* also from Cradle Mts. and/or Mt Field, the only certain locality of this species is the typical one of the Lake district, unfortunately not better specified in the original description by Blackburn (1901) (Map 7)

Tasmanorites daccordii sp. nov.
(Figs 40, 47, 48)

Loc. Typ.: Tasmania, Cradle Mts National Park,
Cradle Plateau m 1250.

Type series

HT ♂, Australia, Tas., Cradle Mts. N.P., Cradle Plateau m 1250, 31.I.2002, P. M. Giachino leg. (QVML). PTT: 5 ♂♂ 3 ♀♀, Australia, Tas., Cradle Mts. N.P., Cradle Plateau m 1250, 31.I.2002, P. M. Giachino leg. (CGi).

Diagnosis

A small-sized (mm 3.20-3.32) *Tasmanorites*, with an oval elongated body of a dark testaceous color. Similar in the shape of the body, particularly of pronotum and elytra, to *T. tasmaniae*. Well separated from this by the pronotum being less restricted at the base, the elytra less elongated (Figs 39, 40), and the shape of the median lobe of the aedeagus being less elongated and with the apex rounded in lateral view and not truncated in dorsal view (Figs 44-48).

Description

Length mm 3.20-3.25 ♂♂, 3.23-3.32 ♀♀. Body obovate (Fig. 40), with a relatively large fore-body in comparison with the elytra, which are short and ovate. Dorsal surface glabrous and shiny, with the microsculpture isodiametric on the pronotum, as transverse meshes on the elytra. Metathoracic wings absent. Colour blackish testaceous, with legs, antennomeres, and palpi testaceous. Head large. Clypeus convex at the base, with two apical setae on each side. Eyes large, convex but not prominent. Neck constriction evident. Labrum transverse, with a slightly emarginated apex; mandibles slender. Antennae short and slender, as long as a half of the body. Second antennal segment shorter than the first one. Pronotum transverse (PW/PL: 1.21), widest almost in the middle. Base narrower than the anterior margin. Sides slightly curved before the base, which is subrectilinear; hind angles obtuse, broadly rounded and not turned out. Front angles rounded and not advanced. Lateral margins narrow, widening posteriorly; anterior seta inserted near 3/5 from the base; basal seta present, inserted before the angles. Basal foveae smooth, slightly impressed, rounded. Median line distinct. Discal surface gently convex. Male with two dilated protarsomeres. Elytra broad, oval, largest in the middle, slightly convex. Shoulders rounded,

with the humeral border continuing inwards almost to the base of the 2nd-3rd stria. Lateral border of the elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with 1st – 5rd striae visible, the others obsolete; juxtascutellar stria present; apical recurrent striole long, gently curved, ending at the level of the 6th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; three setiferous pores on the third stria, respectively, at the basal 4th, in the middle, and at the apical 4th. One preapical pore placed backwards and closer to the recurrent striole. Aedeagus (Figs 47, 48) small (length 0.51 mm), slender, with the basal bulb large; median lobe, in lateral view, curved in the basal 4th, from gently curved to subrectilinear in the distal half; apex short, stout, rounded with the apical blade very reduced and, in dorsal view, subtriangular. Inner sac apically provided with a patch of sclerotized scales. Parameres long and moderately stout, reaching the apical 3rd of the median lobe, each one provided with 4 setae.

Etymology

We dedicate this new species with pleasure to Dr. Mauro Daccordi, a research companion of one of us (PMG) in Tasmania.

Distribution and ecology

T. daccordii sp. nov. is currently known only from the type locality of Cradle Plateau in Cradle Mts., where it was collected by sieving litter beneath *Nothofagus* bushes above the tree line, at an altitude of 1,250 m a.s.l. (Map 7). In this locality *T. daccordii* sp. nov. was collected in syntopy with *Tasmanotrechus alticola* sp. nov.

Tasmanorites blackburni (Sloane 1920)
(Figs 41, 49, 50)

Loc. Typ.: Cradle Mountain.

Trechus blackburni Sloane, 1920: 149.

Tasmanorites blackburni Sloane: Jeannel, 1927: 77.

Tasmanorites blackburni (Sloane): Moore, 1972: 24.

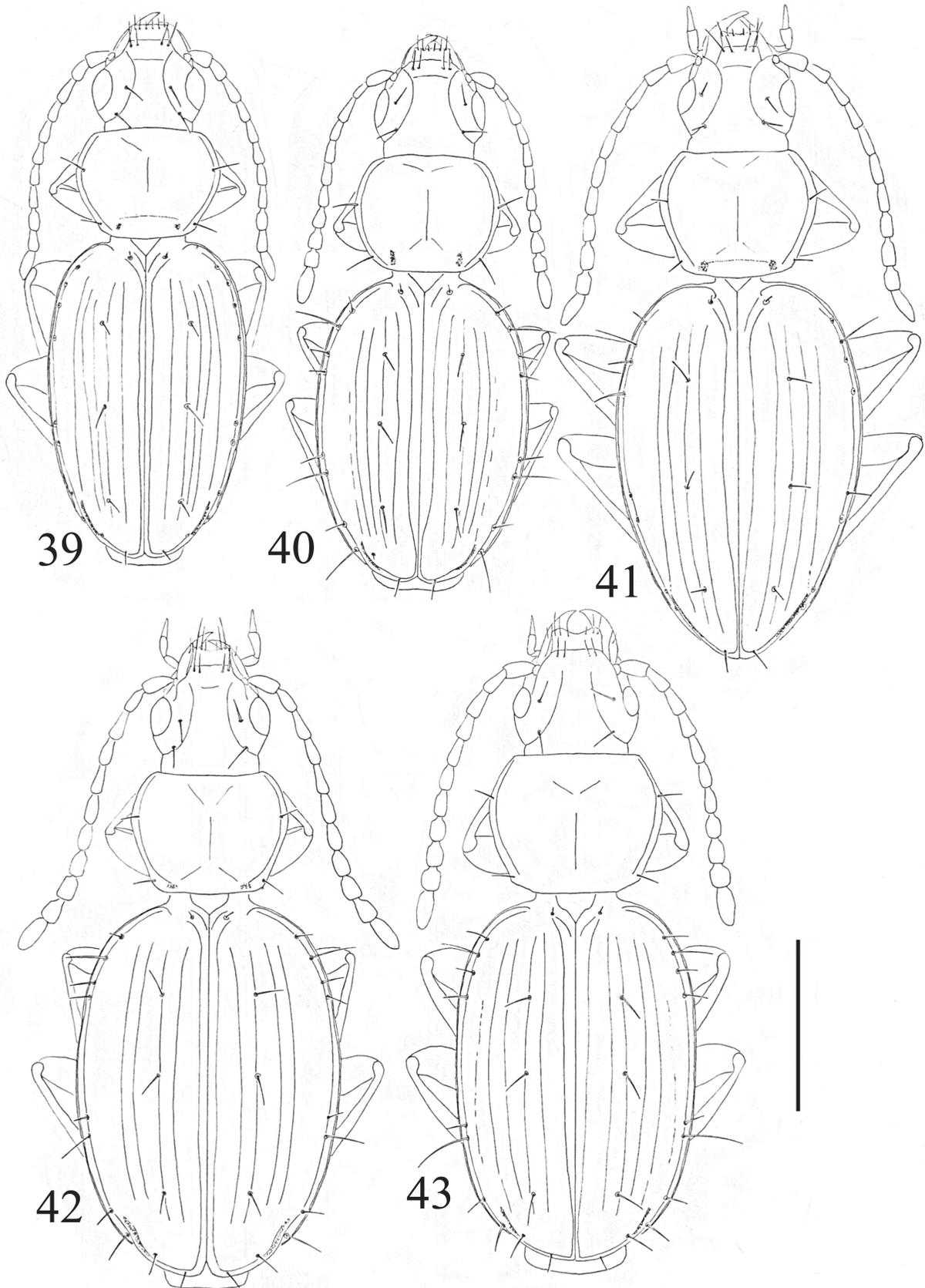
Tasmanorites blackburni (Sloane): Casale & Laneyrie, 1982: 59.

Tasmanorites blackburni (Sloane): Moore et al, 1987: 126.

Tasmanorites blackburni (Sloane): Lorenz, 2005: 168.

Type material

LT ♂, Cradle Mtn. Tasmania, Carter & Lea (white, printed), In Moss and Lichens (white, printed), Type (white, printed), *Trechus blackburni* Sl. Id. by T.S. Sloane (white, handwritten and printed), *Trechus blackburni* Sl. Tasmania S. 10816 Type (white, handwritten with black and red writing), Lectoholo- *T. blackburni* Sl. PID (red, handwritten), Lectotypus ♂ *Trechus blackburni* Sloane P.M. Giachino det. 2009 (red, handwritten and printed) (SAM). PLTT: 1 ♂ 1 ♀ (on the same card), Cradle Mtn. Tasmania, Carter & Lea (white, printed), co-type (white,



Figs 39-43. Habitus of *Tasmanorites* spp.: 39) *T. tasmaniae* (Blackburn) CT ♂, from Tasmania; 40) *T. daccordii* sp. nov., HT ♂ from Cradle Plateau; 41) *T. blackburni* (Sloane), LT ♂ from Cradle Mtn. (specimen with apex of the elytra deformed and laterally compressed); 42) *T. glaebarum* Moore, ♂ from Mt. Field; 43) *T. intermedius* Moore, ♂ from Mt. Field. Scale: 0.1 mm.

printed), *Trechus blackburni* Sl. Id. by T.S. Sloane (white, handwritten and printed), *Trechus blackburni* Sl. Tasmania S. 19680 Cotype (white, handwritten with black and red writing), Paralectotypus ♂ ♀ *Trechus blackburni* Sloane P.M. Giachino det. 2009 (red, handwritten and printed) (SAM).

Notes

In order to ascertain the validity of *T. daccordii* sp. nov., described above, it was necessary to examine the types of other species from Cradle Mts. including the type series of *T. blackburni* deposited in the SAM, designating the Lectotype. The description by Sloane (1920) and Jeannel (1927) are sufficiently accurate and need no further additions. Moore (1972) provides only very schematic drawings of pronotum and aedeagus; therefore we believe it is useful to supply again the drawing of the habitus (Fig. 41) and the aedeagus (Figs 49, 50) of the Lectotypes.

Distribution and ecology

T. blackburni is known with certainty only from the type locality of Cradle Mts. (Map 7); in our opinion, Moore's indication (1972) of Lake St. Clair deserves further confirmation.

Tasmanorites glaebarum Moore, 1972

(Figs 42, 51)

Loc. Typ.: Mt. Field, Lake Dobson

Tasmanorites glaebarum Moore, 1972: 24.

Tasmanorites glaebarum Moore: Casale & Laneyrie, 1982: 59.

Tasmanorites glaebarum Moore: Moore et al, 1987: 127.

Tasmanorites glaebarum Moore: Donabauer, 2001: 103.

Tasmanorites glaebarum Moore: Lorenz, 2005: 168.

Examined material

1 ♂ 1 ♀, Australia, Tas., Mt. Field N.P., Lake Dobson Rd., m 690, 16.I.2002, P.M. Giachino leg. (CGi).

Notes

The description by Moore (1972) is sufficiently accurate and requires no further additions. Moore, however, provides only the very schematic drawings of pronotum and aedeagus; therefore we believe it is useful to supply again the drawing of habitus (Fig. 42) and aedeagus (Fig. 51).

Distribution and ecology

T. glaebarum is currently known only from the type locality of Mt Field (Moore 1972) (Map 7). The new datum increases significantly the altitudinal range of this species, found at 690 m a.s.l., whereas before it was known only from Lake Dobson at 4000 ft a.s.l. The specimens collected by one of the authors (PMG) were found by sieving litter in a mixed forest.

Tasmanorites intermedius Moore, 1972

(Figs 43, 52)

Loc. Typ.: Mt. Field (3000-4000 ft), Tas.

Tasmanorites intermedius Moore, 1972: 25.

Tasmanorites intermedius Moore: Casale & Laneyrie, 1982: 59.

Tasmanorites intermedius Moore: Moore et al, 1987: 127.

Tasmanorites intermedius Moore: Donabauer, 2001: 103.

Tasmanorites intermedius Moore: Lorenz, 2005: 168.

Examined material

4 ♂♂ 1 ♀, Australia, Tas., Mt. Field N.P., m 650, Lyrebird Track, 7.XII.1998 (moss, sieve), P.M. Giachino leg. (CGi).

Notes

The description by Moore (1972) is sufficiently accurate and requires no further additions. Moore, however, provides only the very schematic drawings of pronotum and aedeagus; therefore we believe it is useful to supply again the drawing of habitus (Fig. 43) and aedeagus (Fig. 52).

Distribution and ecology

T. intermedius is currently known only from the type locality of Mt Field (Moore 1972) (Map 7). The new datum increases significantly the altitudinal range of this species, found at 650 m a.s.l., whereas before it was known at elevations between 3,000 and 4,000 ft a.s.l. The specimens collected by one of the authors (PMG) were found by sieving moss in a mixed forest.

Tasmanorites pullus minor Moore, 1972

Loc. Typ.: Cradle Mountain.

Tasmanorites pullus minor Moore, 1972: 25.

Tasmanorites pullus minor Moore: Casale & Laneyrie, 1982: 59.

Tasmanorites pullus minor Moore: Moore et al, 1987: 128.

Tasmanorites pullus minor Moore: Donabauer, 2001: 102.

Tasmanorites pullus minor Moore: Lorenz, 2005: 168.

Examined material

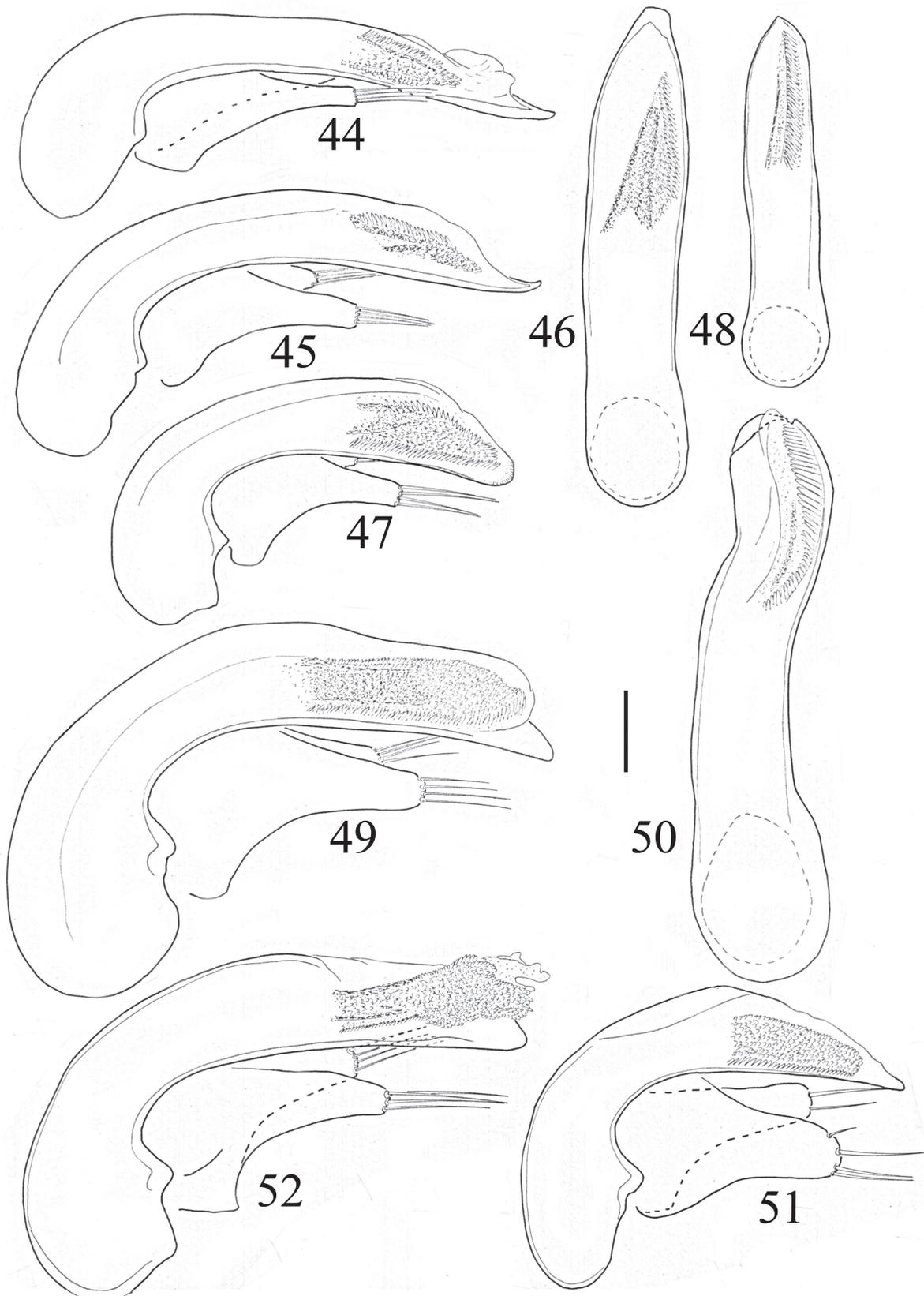
1 ♂, Australia, Tas., Cradle Mts. N.P., Cradle Plateau, m 1200, 25.XI.1999, M. Daccordi leg. (CGi).

Notes

The description by Moore (1972) is sufficiently accurate and requires no further additions. Donabauer (2001) provides a good drawing of the aedeagus.

Distribution and ecology

T. pullus minor is currently known only from the type locality of Cradle Mts. (Moore 1972) (Map 7).



Figs 44-52. Aedeagus in lateral (44, 45, 47, 49, 52) and dorsal (46, 48, 50) view of *Tasmanorites* spp.: 44) *T. tasmaniae* (Blackburn) HT ♂, from Tasmania; 45, 46) *T. tasmaniae* (Blackburn) CT ♂, from Tasmania; 47, 48) *T. daccordii* sp. nov., HT ♂ from Cradle Plateau; 49, 50) *T. blackburni* (Sloane), LT ♂ from Cradle Mtn.; 51) *T. glaebarum* Moore, ♂ from Mt. Field; 52) *T. intermedius* Moore, ♂ from Mt. Field. Scale: 0.1 mm.

Tasmanorites microphthalmus sp. nov.

(Fig. 53)

Loc. Typ.: Tasmania, Mount Cripps, Philrod Cave,
41°35'S 145°46E.

Type series

HT ♀, Tas., 41°35'S 145°46E, CR3 – 4, Mount Cripps, Philrod Cave, 26.VII.1990, S. Eberhard leg., QVM 12: 437775 (QVML) PT: 1 spec. (remains: elytra and pronotum), Tas., 41°35'S 145°46E, CR3 – 7, Mount Cripps, Philrod Cave, 26.VII.1990, S. Eberhard leg. (CGi).

Diagnosis

A big-sized (mm 4.39) *Tasmanorites*, with a specialized facies, elongated, depigmented, microphthalmous, with long antennae, and cordiform pronotum. Apparently, on the basis of the habitus, it is not similar to any of the known species. It is necessary to know the male before making unnecessary speculations.

Description of HT ♀

Length mm 4.39. Body elongate (Fig. 53), with a relatively small fore-body in comparison with the elytra, which are relatively long and ovate. Dorsal surface glabrous and shiny, with the microsculpture as transverse meshes on pronotum and elytra. Metathoracic wings absent. Colour testaceous, with legs, antennomeres, and palpi light testaceous. Head narrow. Clypeus convex at the base, with two apical setae on each side. Eyes small, flat and not prominent. Neck constriction evident. Labrum transverse, with a slightly emarginated apex; mandibles long and slender. Antennae long and slender, longer than the half of the body. Second antennal segment as long as the first one. Pronotum cordiform (PW/PL: 1.11), widest at about 2/3 from the base. Base as narrow as the anterior margin. Sides sinuate before the base, which is evidently bisinuate; hind angles from right to slightly obtuse, and slightly turned out. Front angles not advanced. Lateral margins narrow, widening posteriorly; anterior seta inserted near 3/4 from the base; basal seta present, inserted at the angles. Basal foveae smooth, slightly impressed, rounded. Median line distinct. Discal surface gently convex. Elytra broad, oval, and elongate, largest in the middle, slightly convex. Shoulders rounded, with the humeral border continuing inwards almost to the base of the 4th stria. Lateral border of the elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with all striae visible; juxtascutellar stria present; apical recurrent striole long, gently curved, ending at the level of the 6th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; two setiferous pores on the third stria, respectively, a little before the middle and at the apical 5th. One preapical pore placed backwards and closer to the recurrent striole. Male unknown.

Etymology

Its name recalls the strong eye reduction that this species shows.

Distribution and ecology

T. microphthalmus sp. nov. is a troglobite and currently known only from the type locality, Philrod Cave situated in Mount Cripps (NW Tasmania) (Map 7).

Genus *Sloanella* Jeannel, 1927

Type species: *Trechus simsoni* Blackburn, 1894

Sloanella Jeannel, 1927: 84.

Sloanella Jeannel: Moore, 1972: 26.

Sloanella Jeannel: Casale & Laneyrie, 1982: 59.

Sloanella Jeannel: Moore, 1983: 3.

Sloanella Jeannel: Moore et al, 1987: 127.

Sloanella Jeannel: Lorenz, 2005: 168.

KEY TO SPECIES (AFTER MOORE, 1983 MODIFIED)

- 1 Species predominantly dark; elytra 7th interval with a single pore *S. obscura*
- Species predominantly pale; elytra 7th interval without a pore 2
- 2 Size bigger (length 5 mm or more) *S. suavis*
- Size smaller (length under 4 mm) 3
- 3 Pronotal hind angles tuberculate; posterior marginal seta present *S. pallida*
- Pronotal hind angles not tuberculate; posterior marginal seta missing 4
- 4 Pronotal lateral side, before hind angles, strongly sinuate *S. simsoni*
- Pronotal lateral side, before hind angles, not sinuate ..
..... *S. gordonii* sp. nov.

Sloanella gordonii sp. nov.

(Figs 54, 55)

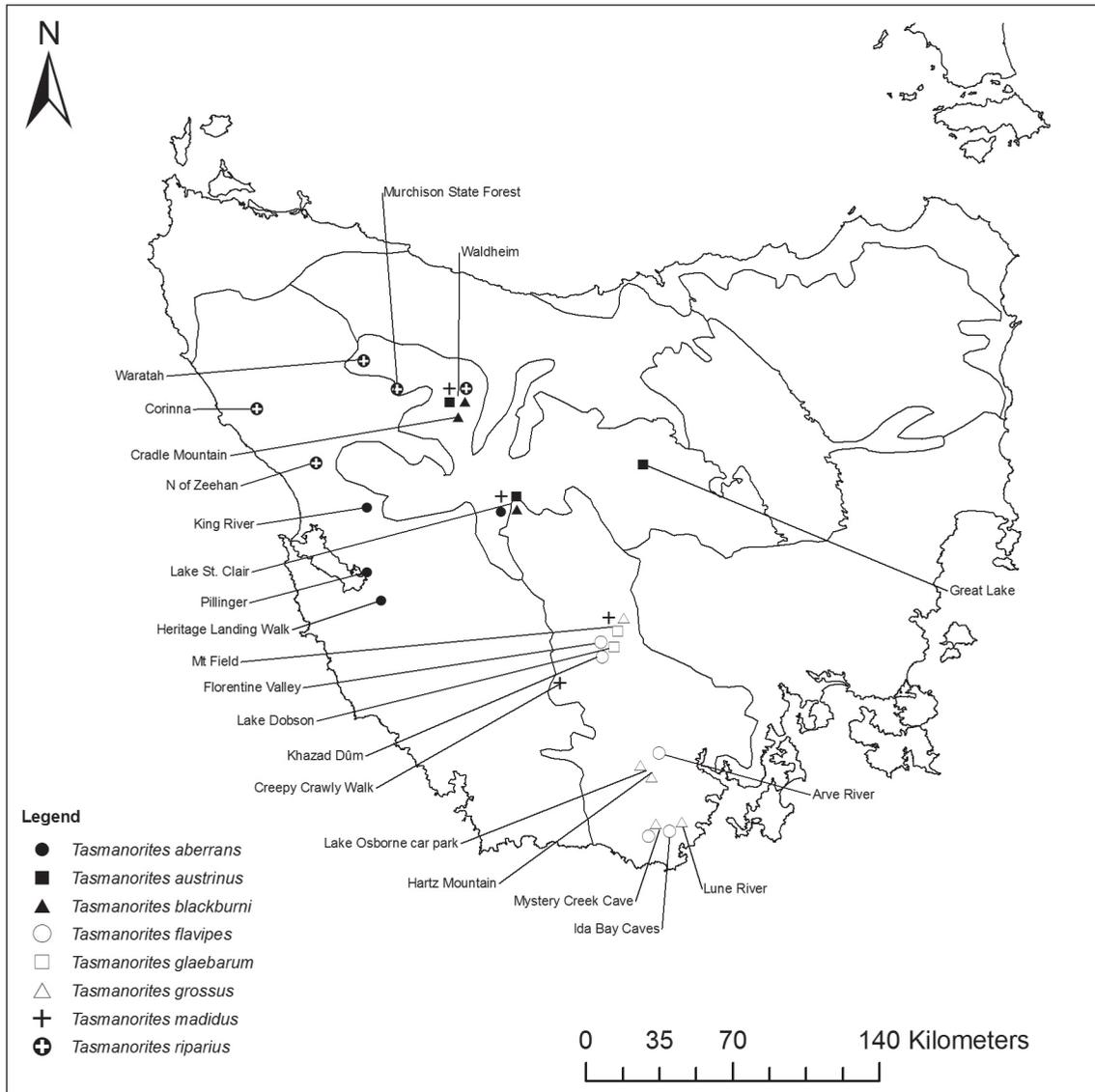
Loc. Typ.: Tasmania, Strahan, Franklin-Gordon Wild River National Park, Gordon River, Heritage Landing Walk.

Type series

HT ♂, Australia, Tas., Strahan, Franklin-Gordon Wild River N.P., Gordon River, Heritage Landing Walk, 25.I.2002, P. M. Giachino leg. (QVML). PT: 1 ♂, Australia, Tas., Strahan, Franklin-Gordon Wild River N.P., Gordon River, Heritage Landing Walk, 25.I.2002, P. M. Giachino leg. (CGi).

Diagnosis

A small-sized (length mm 3.79-3.81) *Sloanella*, with predominantly pale colours. Similar to *S. simsoni* for the missing basal seta of the pronotum and for the general shape of the median lobe of the aedeagus; it differs from this species especially for the sides of the pronotum curved and not sinuate before the basal angles.

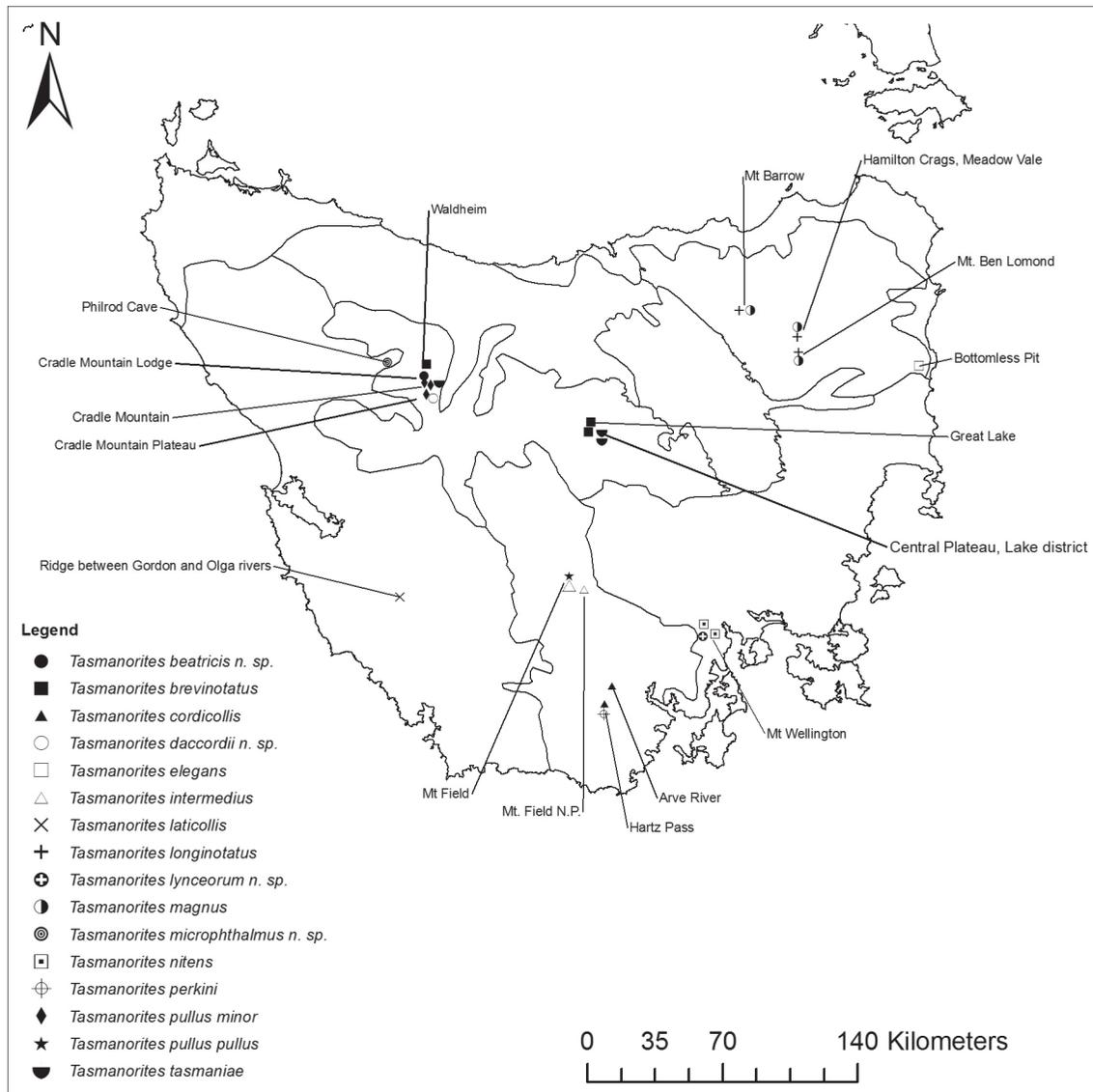


Map 6 - Collection sites for *Tasmanorites* spp. known from four or more localities.

Description

Length mm 3.79-3.81 ♂♂. Body stout, obovate (Fig. 54), with a relatively large fore-body in comparison with the elytra, which are short, stout, and ovate. Dorsal surface glabrous and shiny, with the microsculpture isodiametric on the pronotum, as transverse meshes and very lightly impressed on the elytra. Metathoracic wings absent. Colour mostly pale, testaceous, with blackish brown maculae on pronotum and elytra; head pale. Lateral margins and fore-lateral part of the pronotum pale; elytra pale with only a V-shaped dark macula on the posterior half. Legs, antennomeres, and palpi testaceous. Head large. Clypeus convex at the base, with two apical setae on each side. Eyes large, convex, slightly prominent. Neck constriction evident. Labrum transverse, with a deeply emarginated apex; mandibles stout. Antennae short and slender, as long as the half of the body. Second antennal segment as long as the first one.

Pronotum transverse (PW/PL: 1.36), widest at about 2/3 from the base. Base narrower than the anterior margin. Sides slightly curved before the base, which is subrectilinear; hind angles obtuse, rounded, and turned out. Front angles not advanced. Lateral margins broad, widening posteriorly; anterior seta inserted just before the middle; basal seta absent. Basal foveae smooth, slightly impressed, rounded. Median line distinct. Discal surface gently convex. Male with two dilated protarsomeres. Elytra short, broad, ovoid, largest in the middle, slightly convex. Shoulders rounded, with the humeral border not continuing inwards. Lateral border of elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with all striae visible and anastomosed near the tip; juxtascutellar stria present; apical recurrent stria long, gently curved, ending at the level of the 6th stria and with a short apical carina. Chaetotaxis: juxtascutellar



Map 7 - Collection sites for *Tasmanorites* spp. known from one, two, or three localities.

cutellar pore present; three setiferous pores on the third stria, respectively, at the basal 4th, in the middle, and at the apical 4th. One preapical pore placed backwards and closer to the recurrent stria. Aedeagus (Fig. 55) small (length 0.53 mm), slender; basal bulb small with a large sagittal carina. Median lobe, in lateral view, gently curved, with the apex long, stout, and rounded. Inner sac apically provided with a very small patch of sclerotized scales. Parameres long and moderately stout, reaching the apical 3rd of the median lobe, each one provided with 4 setae. Female unknown.

Etymology

After the banks of the Gordon River along which is the type locality.

Distribution and ecology

S. gordonii sp. nov. is currently known only from the type locality, the Heritage Landing Walk (Gordon River,

near Strahan), where it was collected by sieving rainforest litter. In this locality *S. gordonii* sp. nov. coexists with *Tasmanorites aberrans* and *Tasmanotrechus gordonii* sp. nov. Published collection records for five described species in the genus *Sloanella* are shown in Map 8.

Genus *Tasmanotrechus* Moore, 1972

Type species: *Trechus leai* Sloane, 1920.

Tasmanotrechus Moore, 1972: 33.

Tasmanotrechus Moore: Casale & Laneyrie, 1982: 61.

Tasmanotrechus Moore: Moore, 1983: 5.

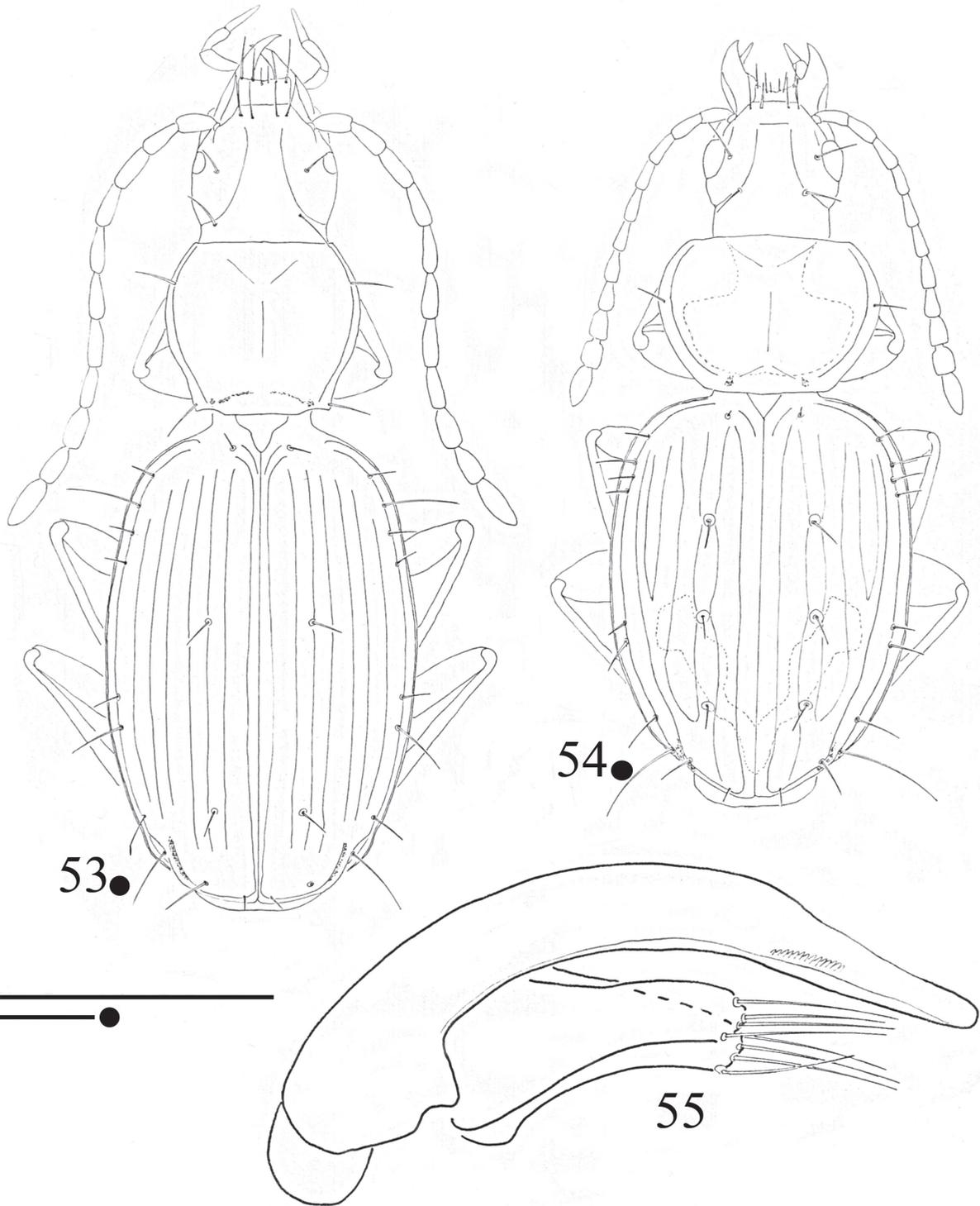
Tasmanotrechus Moore: Moore et al, 1987: 127.

Tasmanotrechus Moore: Moore, 1994: 75.

Tasmanotrechus Moore: Lorenz, 2005: 169.

KEY TO THE SPECIES GROUP

- 1 Lateral side of pronotum, before hind angles, rounded..... <<leai group>>



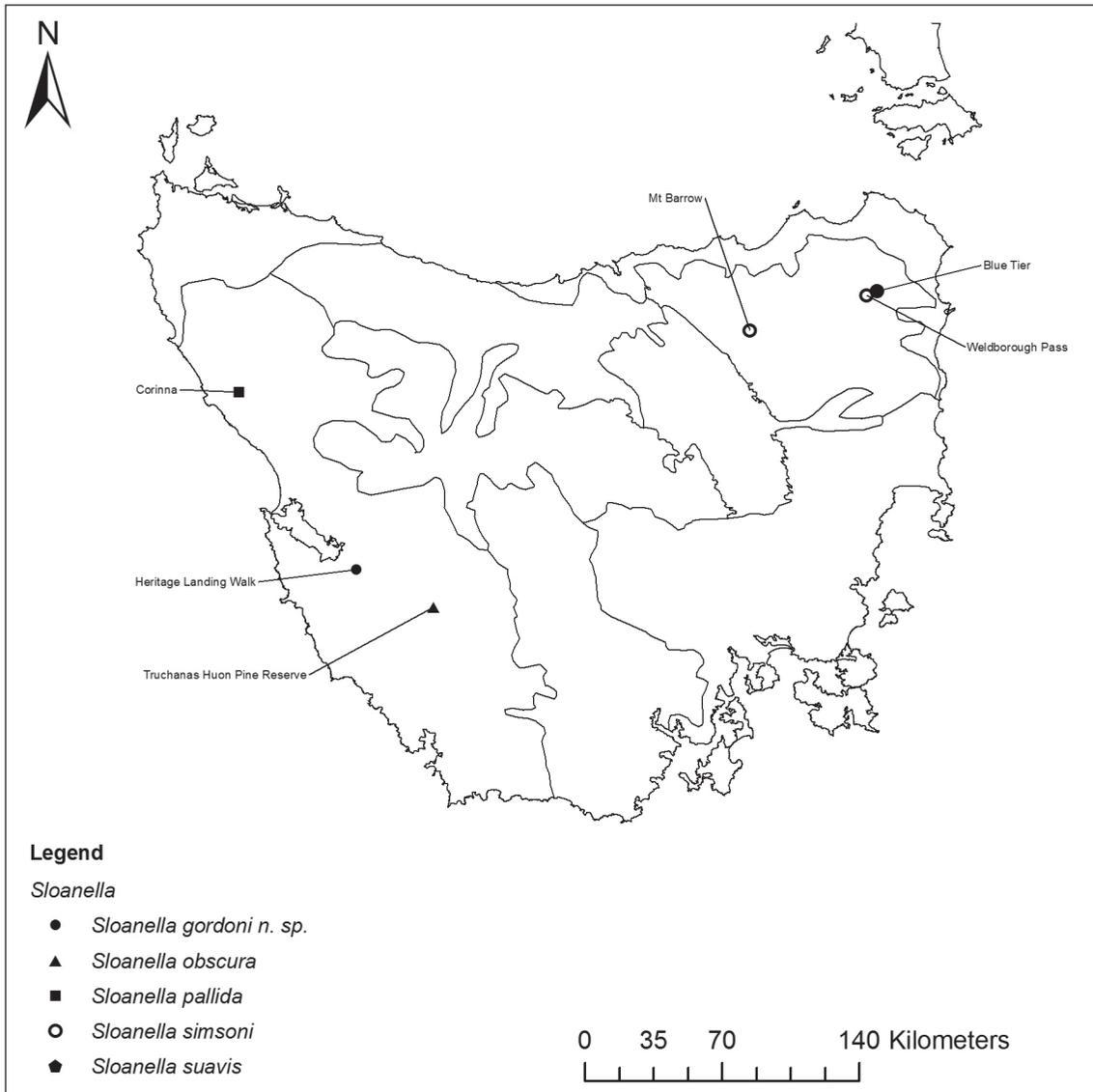
Figs 53-55. Habitus (53, 54) and aedeagus in lateral view (55) of: 53) *Tasmanorites microphthalmus* sp. nov., HT ♀ from Philrod Cave; 54, 55) *Sloanella gordonii* sp. nov., HT ♂ from Heritage Landing Walk. Scale: 0.2 mm.

- Lateral side of pronotum, before hind angles, sinuate.. 2
- 2 Pronotum always transverse, not cordiform; aedeagus long and slender <<cockerilli group>>
- Pronotum cordiform; aedeagus short and stout <<elongatus group>>

<<*T. leai* group>>

Diagnosis

A group of less specialized forest litter-dwelling species, with less ocular reduction, rounded lateral side of pronotum.



Map 8 - Collection sites for *Sloanella* spp.

As far as we presently know, the following species belong to this species group:

- T. leai* (Sloane 1920)
- T. concolor* Moore 1972
- T. gordonii* sp. nov.
- T. alticola* sp. nov.
- T. montisfieldi* sp. nov.
- T. compactus* Moore, 1983
- T. osbornianus* sp. nov.

KEY TO THE SPECIES (FROM MOORE, 1983 MODIFIED)

- 1 Base of pronotum, wider than the anterior margin... 2
- Base of pronotum, as wide as the anterior margin *T. montisfieldi* sp. nov.
- 2 Pronotum more transverse (width/length c. 1.25).... 3

- Pronotum less transverse (width/length c. 1.13-1.20).. 5
- 3 Elytral outer striae weak or obsolescent..... 4
- Elytral outer striae strong *T. osbornianus* sp. nov.
- 4 Pronotal side margins subrectilinear before the hind angles; elytra broadly ovate..... *T. concolor*
- Pronotal side margins rounded before hind the angles; elytra less rounded at sides *T. compactus*
- 5. Elytra broadly ovate, strongly wider than pronotum *T. leai*
- Elytra less broad, less rounded at sides and not so wider than pronotum 6
- 6 Pronotum more transverse (width/length c. 1.20)..... *T. gordonii* sp. nov.
- Pronotum less transverse (width/length c. 1.13) *T. alticola* sp. nov.

Tasmanotrechus leai (Sloane 1920)

(Figs 56, 63)

Loc. Typ.: Cradle Mts., Tas.

Trechus leai Sloane, 1920: 145.*Trechiella leai* Sloane: Jeannel, 1927: 94.*Tasmanotrechus leai* (Sloane): Moore, 1972: 34.*Tasmanotrechus leai* (Sloane): Casale & Laneyrie, 1982: 61.*Tasmanotrechus leai* (Sloane): Moore, 1983: 5.*Tasmanotrechus leai* (Sloane): Moore et al, 1987: 130.*Tasmanotrechus leai* (Sloane): Lorenz, 2005: 169.*Type material*

HT ♀, Cradle Mt, L., H.J.C. 1.18 (white, handwritten); Type (white, printed); *Trechus leai* S. (1918) Id. by T.G. Sloane (white, handwritten and printed); Holotype *T. leai* Sl. P.J.D. (red, handwritten); I. 10808, *Trechus leai* Sln. Tasmania, Type (white with black and red handwriting) (SAM).

Examined material

1 ♂, Tas., 42° 05'S 145° 45'E, BH203- 7 Bubs Hill, Thylacine Lair, 11.VI.1988, S. Eberhard leg. QVM 12: 43781 (QVML).

Notes

The descriptions by Sloane (1920) and Jeannel (1927) are sufficiently accurate and need no further additions. Moore (1972) only provides the drawing, very schematically, of the pronotum, so we believe it is useful to supply the drawing of the habitus (Fig. 56) of the Holotype and of the aedeagus (Fig. 63) of the specimen from Thylacine Lair.

Distribution and ecology

Moore (1972) mistakenly mentions Great Lake as the type locality of this species and adds Waratah as another locality. Subsequently, Moore et al (1987) corrected the mistake regarding the type locality, but maintained the location of Great Lake without confirming it. Our datum of Thylacine Lair (Bubs Hill, NW Tasmania) seems to confirm, for *T. leai*, a relatively large area of distribution, between Waratah to the NW, Bubs Hill to the W, Cradle Mts. to the N, and possibly, Great Lake to the E (Map 10).

Tasmanotrechus gordonii sp. nov.

(Figs 57, 64)

Loc. Typ.: Tasmania, Strahan, Gordon River, Heritage Landing Walk.

Type series

HT ♂, Australia, Tas., Strahan, Gordon River, Heritage Landing Walk, Jan. 1997 (CGi).

Diagnosis

A small-sized (length 4.60 mm) *Tasmanotrechus*, similar in the shape of the body and of the median lobe

of the aedeagus to *T. leai*. Well separate from this for the smaller size, for the elytra narrower and parallel, for the pronotum less transverse, and the median lobe of aedeagus more elongated and more abruptly bent at the base.

Description of the HT ♂

Length mm 4.60. Body elongate (Fig. 57), with a relatively large fore-body in comparison with the elytra, which are short and ovate. Dorsal surface glabrous and shiny, with the microsculpture isodiametric on the pronotum, as transverse meshes on the elytra. Metathoracic wings absent. Colour rufus-testaceous, with antennomeres and palpi testaceous. Head narrow. Clypeus convex at the base, with two apical setae on each side. Eyes large, but flat and not prominent. Neck constriction evident. Labrum transverse, with an emarginated apex; mandibles slender. Antennae short and slender, as long as the half of the body. Second antennal segment as long as the first one.

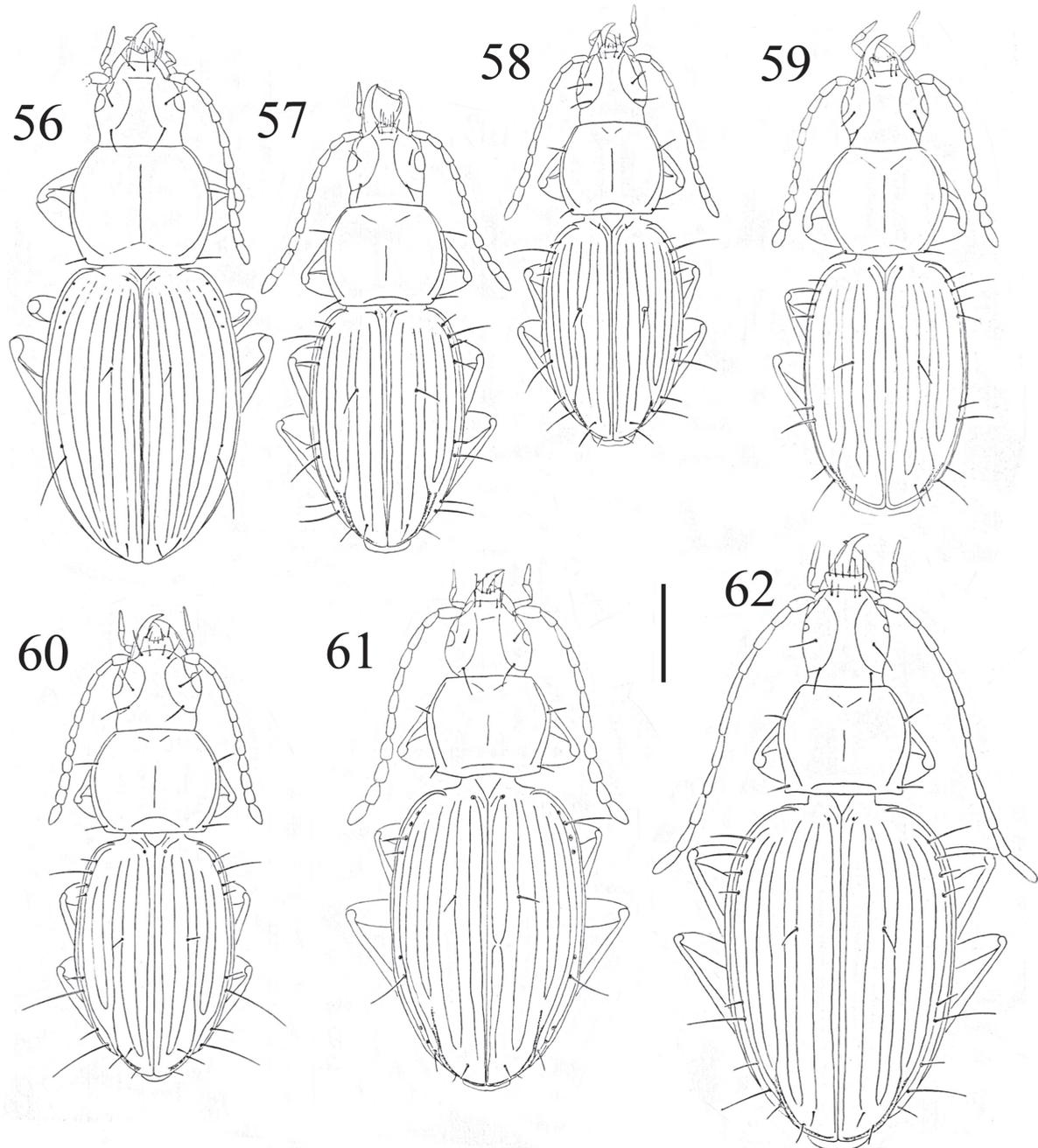
Pronotum transverse (PW/PL: 1.20), widest almost in the middle. Base wider than the anterior margin. Sides slightly curved before the base, which is subrectilinear; hind angles obtuse, but evident. Front angles rounded and not advanced. Lateral margins narrow, widening posteriorly; anterior seta inserted near 2/3 from the base; basal seta present, inserted just before the angles. Basal foveae smooth, slightly impressed, rounded. Median line distinct. Discal surface gently convex. Male with undilated protarsomeres. Elytra narrow, oval, widest in the middle, slightly convex. Shoulders rounded but evident, with the humeral border continuing inwards almost to the base of the 4th stria. Lateral border of the elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with all striae visible; juxtascutellar stria short and rudimentary; apical recurrent striole long, gently curved, ending at the level of the 7th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; one setiferous dorsal pore on the third stria almost at the basal 3rd. One preapical pore placed backwards and closer to the 3rd stria. Aedeagus (Fig. 64) small (length 0.9 mm), slender; basal bulb small with a large sagittal carina; median lobe, in lateral view, curved in the basal 5th, from gently curved to subrectilinear in the distal part; apex long, slender, with the apical blade acute. Inner sac centrally provided with a small patch of sclerotized scales. Parameres long and moderately slender, reaching the apical half of the median lobe, each one provided with 4 setae. Female unknown.

Etymology

After the Gordon River along the banks of which is the type locality.

Distribution and ecology

T. gordonii sp. nov. is currently known only from the type locality, the Heritage Landing Walk (Gordon River,



Figs 56-62. Habitus of *Tasmanotrechus* spp.: 56) *T. leai* (Sloane), HT ♀ from Cradle Mt.; 57) *T. gordonii* sp. nov., HT ♂ from Heritage Landing Walk; 58) *T. alticola* sp. nov., HT ♂ from Cradle Plateau; 59) *T. montisfieldi* sp. nov., HT ♀ from Mt. Field; 60) *T. osbornianus* sp. nov., HT ♂ from Lake Osborne; 61) *T. moorei* sp. nov., HT ♂ from Kubla Khan Cave; 62) *T. rolani* sp. nov., HT ♂ from Little Trimmer Cave. Scale: 1 mm.

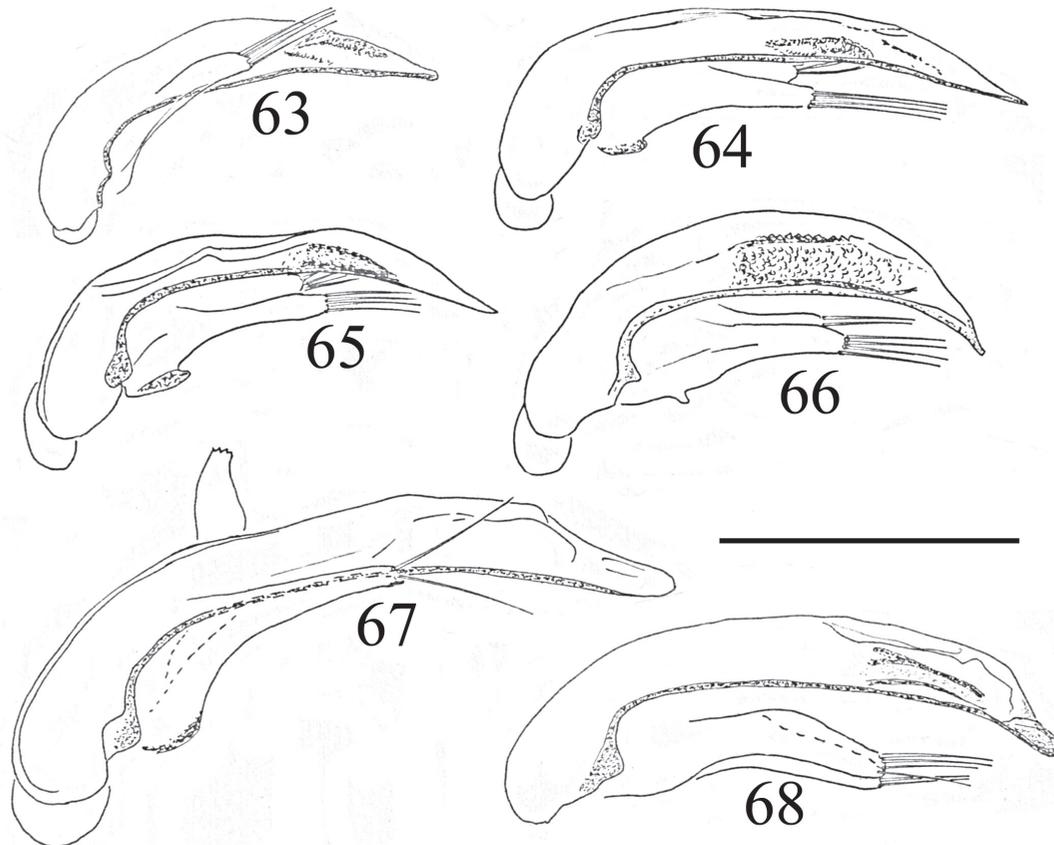
near Strahan) (Map 10). The only known specimen is devoid of additional collecting information. Investigations aimed at finding other specimens of this species, conducted by one of the authors (PMG) have given negative results, permitting instead to collect, in syntopy, two different species of Trechini, *Tasmanorites aberrans* and *Sloanella gordonii* sp. nov.

Tasmanotrechus alticola sp. nov.
(Figs 58, 65)

Loc. Typ.: Tasmania, Cradle Mts. National Park, Cradle Plateau m 1250.

Type series

HT ♂, Australia, Tas., Cradle Mts. N.P., Cradle Plateau m 1250, 31.I.2002, P. M. Giachino leg. (QVML).



Figs 63-68. Aedeagus in lateral view of *Tasmanotrechus* spp.: 63) *T. leai* (Sloane), ♂ from Thylacine Lair; 64) *T. gordonii* sp. nov., HT ♂ from Heritage Landing Walk; 65) *T. alticola* sp. nov., HT ♂ from Cradle Plateau; 66) *T. osbornianus* sp. nov., HT ♂ from Lake Osborne; 67) *T. moorei* sp. nov., HT ♂ from Kubla Khan Cave; 68) *T. rolani* sp. nov., HT ♂ from Little Trimmer Cave. Scale: 0.5 mm.

PT: 1 ♀, Australia, Tas., Cradle Mts. N.P., Cradle Plateau m 1250, 31.I.2002, P. M. Giachino leg. (CGi).

Diagnosis

A small-sized (length mm 4.28-4.32) *Tasmanotrechus*, similar in the shape of the body - particularly its elytra - and of the median lobe of the aedeagus to *T. gordonii*. It is well separate from this by the smaller size, the elytra even narrower and more parallel, the pronotum less transverse, and the median lobe of the aedeagus shorter and more bent in the apical half.

Description

Length mm 4.28 ♂ 4.32 ♀. Body elongate (Fig. 58), with a large fore-body in comparison with the elytra, which are short and ovoidal. Dorsal surface glabrous and shiny, with the microsculpture as transverse meshes. Metathoracic wings absent. Colour blackish testaceous, with sutural stria, legs, antennomeres, and palpi testaceous. Head narrow. Clypeus convex at the base, with two apical setae on each side. Eyes large, but flat and not prominent. Neck constriction evident. Labrum transverse, with an emarginated apex; mandibles slender. Antennae short and slender, as long as the half of the

body. Second antennal segment as long as the first one. Pronotum transverse (PW/PL: 1.13), widest at about 1/3 from the base. Base larger than the anterior margin. Sides slightly curved before the base, which is subrectilinear; hind angles obtuse, but evident. Front angles rounded and not advanced. Lateral margins narrow, widening posteriorly; anterior seta inserted near 2/3 from the base; basal seta present, inserted just before the angles. Basal foveae smooth, slightly impressed, rounded. Median line distinct. Discal surface gently convex. Male with undilated protarsomeres. Elytra narrow, ovoidal, largest in the middle, slightly convex. Shoulders rounded but evident, with the humeral border continuing inwards almost to the base of the 4th stria. Lateral border of the elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with all striae visible; juxtascutellar stria short and well marked; apical recurrent striole long, gently curved, ending at the level of the 7th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; one setiferous dorsal pore on the third stria just before the middle. One preapical pore placed backwards and closer to the 3rd stria. Aedeagus (Fig. 65) small (length 0.9 mm), slender, basal bulb small with a large sagittal carina; median lobe,

in lateral view, curved in the basal 5th, gently curved in the distal part; apex long, slender, with the apical blade acute. Inner sac apically provided with a small patch of sclerotized scales. Parameres long and moderately slender, reaching the apical 3rd of the median lobe, each one provided with 4 setae.

Etymology

The name wants to remember the relatively high elevation of the type locality.

Distribution and ecology

T. alticola sp. nov. is currently known only from the type locality of the Cradle Plateau in the Cradle Mts. N.P. (Tasmania) where it was collected by sieving litter under bushes of *Nothofagus* at 1,250 m a.s.l. (Map 10). In this locality *T. alticola* sp. nov. was collected in syntopy with *Tasmanorites daccordii* sp. nov.

Tasmanotrechus montisfieldi sp. nov.

(Fig. 59)

Loc. Typ.: Tasmania, Mt. Field National Park, road for Lake Dobson, m 700.

Type series

HT ♀, Australia, Tas., Mt. Field N.P., road for Lake Dobson, m 700, Jan. 1997 (CGi).

Diagnosis

A small-sized (length 4.9 mm) *Tasmanotrechus*, similar in the shape of the body, and in particular of the elytra, to *T. alticola* and *T. gordonii*. Well separate from them for the bigger size, the pronotum with a narrow base, and the presence of a long and well marked juxtascutellar stria.

Description of the HT ♀

Length mm 4.9. Body elongate (Fig. 59), with a large fore-body in comparison with the elytra, which are short and ovoidal. Dorsal surface glabrous and shiny, with the microsculpture isodiametric on the pronotum, as transverse meshes on elytra. Metathoracic wings absent. Colour blackish testaceous, with sutural stria, legs, antennomeres, and palpi testaceous. Head narrow. Clypeus convex at the base, with two apical setae on each side. Eyes less reduced, flat and not prominent. Neck constriction evident. Labrum transverse, with an emarginated apex; mandibles slender. Antennae short and slender, as long as the half of the body. Second antennal segment as long as the first one. Pronotum transverse (PW/PL: 1.13), widest at about 2/3 from the base. Base as wide as the anterior margin. Sides slightly curved to subrectilinear before the base, which is subrectilinear; hind angles obtuse, but pointed and evident. Front angles rounded and not advanced. Lateral margins narrow, widening posteriorly; anterior seta inserted near 2/3 from the base; basal seta present, inserted just before the angles. Basal foveae smooth, slightly impressed, rounded. Median line dis-

tinct. Disal surface gently convex. Elytra narrow, ovoidal, largest in the middle, slightly convex. Shoulders rounded but evident, with the humeral border continuing inwards almost to the base of the 4th stria. Lateral border of the elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with all striae visible; juxtascutellar stria long and well marked; apical recurrent striole long, gently curved, ending at the level of the 7th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; one setiferous dorsal pore on the third stria just before the middle. One preapical pore placed backwards and closer to the 3rd stria. Male unknown.

Etymology

After the type locality of Mt. Field.

Distribution and ecology

T. montisfieldi sp. nov. is currently known only from the type locality of Mt Field, where it was collected at 700 m a.s.l. along the road to Lake Dobson (Map 10). The only known specimen does not bear any other collection data. Investigations conducted by one of the authors (PMG), aimed at finding other specimens, gave negative results, but enabling the finding, in this area, of other species of Trechinae, such as *Sloaneana tasmaniae*, *Tasmanorites glaebarum*, and *Mecyclothorax punctipennis*.

Tasmanotrechus osbornianus sp. nov.

(Figs 60, 66)

Loc. Typ.: Tasmania, Hartz Mts., Lake Osborne.

Type series

HT ♂, Australia, Tas., Hartz Mts., Lake Osborne, Jan. 1997 (CGi).

Diagnosis

A small-sized (length 4.73 mm) *Tasmanotrechus*, similar in the shape of the body, and in particular of pronotum and elytra, to *T. gordonii*. Well separate from this by the larger head, and the median lobe of the aedeagus, shorter, stocky, and more bent in the apical half. The male of *T. osbornianus* sp. nov. has also, unlike *T. leai*, *T. gordonii* sp. nov., and *T. alticola* sp. nov., the first two protarsomeres distinctly dilated.

Description of the HT ♂

Length mm 4.73. Body elongate (Fig. 60), with a large fore-body in comparison with the elytra, which are short and ovoidal. Dorsal surface glabrous and shiny, with the microsculpture as transverse meshes. Metathoracic wings absent. Colour blackish testaceous, with sutural stria, legs, antennomeres, and palpi testaceous. Head wide. Clypeus convex at the base, with two apical setae on each side. Eyes large, but flat and not prominent. Neck constriction evident. Labrum transverse, with an emarginated apex; mandibles slen-

der. Antennae very short and slender, shorter than the half of the body. Second antennal segment as long as the first one. Pronotum transverse (PW/PL: 1.25), widest almost in the middle. Base wider than the anterior margin. Sides slightly curved before the base, which is subrectilinear; hind angles obtuse, but evident. Front angles rounded and not advanced. Lateral margins narrow, widening posteriorly; anterior seta inserted near 2/3 from the base; basal seta present, inserted just before the angles. Basal foveae smooth, slightly impressed, rounded. Median line distinct. Discal surface gently convex. Male with two dilated protarsomeres. Elytra narrow, ovoidal, widest in the middle, slightly convex. Shoulders rounded but evident, with the humeral border continuing inwards almost to the base of the 4th stria. Lateral border of the elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with all striae visible; juxtascutellar stria short and rudimentary; apical recurrent striole long, gently curved, ending at the level of the 7th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; one setiferous dorsal pore on the third stria just before the middle. One preapical pore placed backwards and closer to the 3rd stria. Aedeagus (Fig. 66) small (length 0.8 mm), relatively stout, basal bulb small with a large sagittal carina; median lobe, in lateral view, curved in the basal 5th, gently and regularly curved in the distal part; apex long, slender, with the apical blade acute. Inner sac centrally provided with a small patch of sclerotized scales. Parameres long and moderately slender, reaching the apical 3rd of the median lobe, each one provided with 4 setae. Female unknown.

Etymology

After the type locality of Lake Osborne.

Distribution and ecology

T. osbornianus sp. nov. is currently known only from the type locality, Lake Osborne in the Hartz Mts. National Park (S Tasmania) (Map 9), where it was collected in summer (January). There are no other collecting data. Investigations made in search of other specimens and conducted personally by one of the authors (PMG) at Lake Osborne at a height of 900 m a.s.l. in January 2002 were fruitless.

<<*T. elongatus* group>>

Diagnosis

Specialized cave-dwelling form characterized by ocular reduction, cordiform pronotum with sinuate lateral sides, aedeagus short and stout. To date, only one species displaying these characters has been described, *T. elongatus* Moore, 1994, a troglobite recorded from caves in the Bubs Hill karst in western Tasmania (Moore 1994) (Map 9).

<<*T. cockerilli* group>>

Diagnosis

A group of specialized cave-dwelling species, with ocular reduction, pronotum transverse with sinuate lateral sides, aedeagus long and slender.

As far as we presently know, the following species belong to this species group:

T. cockerilli Moore, 1972

T. moorei sp. nov.

T. rolani sp. nov.

KEY TO THE SPECIES

- 1 Size smaller (length 5.34 mm); eyes less reduced
..... *T. moorei* sp. nov.
- Size bigger (length 6.0-6.5 mm); eyes more reduced..
..... 2
- 2 Pronotum less transverse (width/length c. 1.10)
..... *T. cockerilli*
- Pronotum more transverse (width/length c. 1.20)
..... *T. rolani* n. sp.

Tasmanotrechus cockerilli Moore, 1972

Loc. Typ.: George's Hall Cave, Mole Creek, Tas.

Tasmanotrechus cockerilli Moore, 1972: 36.

Tasmanotrechus cockerilli Moore: Casale & Laneyrie, 1982: 61.

Tasmanotrechus cockerilli Moore: Moore, 1983: 5

Tasmanotrechus cockerilli Moore: Moore, 1994: 76.

Tasmanotrechus cockerilli Moore: Moore et al, 1987: 130.

Tasmanotrechus cockerilli Moore: Lorenz, 2005: 169.

Examined material

1 ♀, Tasmania, Mole Creek Scott's Cave, 23.XII.1974, S. Uéno leg. (CGi).

Notes

The description by Moore (1972) is sufficiently accurate and needs no other additions.

Distribution and ecology

Moore (1972) mentions *T. cockerilli* from several caves in the Mole Creek karst: Georgie's Hall Cave, Scott's Cave, Herbert's Pot, and Baldock's Cave. The species is troglobitic.

Tasmanotrechus moorei sp. nov.

(Figs 61, 67)

Loc. Typ.: Tasmania, Mole Creek, Kubla Khan Cave, 41°30'S 146°20'E.

Type series

HT ♂, Tas. 41°30'S 146°20'E, MC1-59, Mole Creek, Kubla Khan Cave, under stone, near litter, riparian silt-

bank, Caim Hall, deep zone, 31.X.1990, S. Eberhard leg. QVM 12: 780 (QVML).

Diagnosis

A relatively small-sized (mm 5.34) *Tasmanotrechus* of the “*cockerilli* group”, clearly distinguishable from the other two known species of the group for the eyes less reduced and the antennae shorter.

Description of the HT ♂

Length mm 5.34. Body stout (Fig. 61), with a relatively large fore-body in comparison with the elytra, which are long, wide, and ovoidal. Dorsal surface glabrous and shiny, with the microsculpture as transverse meshes. Metathoracic wings absent. Colour entirely testaceous. Head wide. Clypeus convex at the base, with two apical setae on each side. Eyes reduced, flat and not prominent. Neck constriction evident. Labrum transverse, with an emarginated apex; mandibles slender. Antennae relatively short and slender, as long as the half of the body. Pronotum transverse (PW/PL: 1.25), widest at about the 2/3 from the base. Base wider than the anterior margin. Sides sinuate before the base, which is bisinuate; hind angles straight, evident and upturned. Front angles rounded and not advanced. Lateral margins narrow, widening posteriorly; anterior seta inserted near 2/3 from the base; basal seta present, inserted just before the angles. Basal foveae smooth, slightly impressed, rounded. Median line distinct. Discal surface gently convex. Male with two dilated protarsomeres. Elytra broad, ovoidal, widest in the middle, slightly convex. Shoulders rounded but evident, with the humeral border continuing inwards almost to the base of the 4th stria. Lateral border of the elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with all striae visible; juxtascutellar stria short and well marked; apical recurrent striole long, gently curved, ending at the level of the 7th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; one setiferous dorsal pore on the third stria before the middle. One preapical pore placed backwards and near to the 3rd stria. Aedeagus (Fig. 67) large (length 1.16 mm), long, and narrow; basal bulb small with a large sagittal carina; median lobe, in lateral view, curved in the basal 6th, gently and regularly curved in the distal part; apex long, slender, with the apical blade rounded. Inner sac unarmed. Parameres long and moderately slender, not reaching the apical 3rd of the median lobe, each one provided with 4 setae. Female unknown.

Etymology

We are glad to dedicate this species to Barry P. Moore as a sign of appreciation for the important role played in the knowledge of the Australian carabid fauna.

Distribution and ecology

T. moorei sp. nov. is currently known only from the type locality: Kubla Khan Cave, near Mole Creek, Tasmania (Map 9), where it lives in sympatry with another species of troglobitic *Tasmanotrechus* of the same group of species, but more specialized to subterranean life, *T. rolani* sp. nov.

Tasmanotrechus rolani sp. nov.

(Figs 62, 68)

Loc. Typ.: Tasmania, Mole Creek, Little Trimmer Cave, 41°30'S 146°20'E.

Type series

HT ♂, Tas. 41°30'S 146°20'E, MC39-1, Mole Creek, Little Trimmer Cave, Siltbank in end chamber, deep zone, 23.V.1990, Rolan Eberhard leg., QVM 12: 43777 (QVML). PTT: 2 spec. (remains: elytra), Tas. 41°30'S 146°20'E, MC39-1, Mole Creek, Little Trimmer Cave, Siltbank in end chamber, deep zone, 23.V.1990, Rolan Eberhard leg., QVM 12: 43777 (QVML, CGi); 1 ♀, Tas. 41°30'S 146°20'E, MC1-85, Mole Creek, Kubla Khan Cave, under stone, near litter, riparian siltbank, Caim Hall, deep zone, 31.X.1990, S. Eberhard leg. (CGi); 1 spec. (remains), Tas. 41°30'S 146°20'E, MC1-29, Mole Creek, Kubla Khan Cave, on siltbank, Caim Hall, deep zone, 23.X.1990, S. Eberhard leg. (QVML); 2 spec. (remains), Tas. 41°30'S 146°20'E, MC1-23, Mole Creek, Kubla Khan Cave, on siltbank, Caim Hall, deep zone, 20-26.X.1990, S. Eberhard leg. (QVML); 3 spec. (remains), Tas. 41°30'S 146°20'E, MC1-23, Mole Creek, Kubla Khan Cave, on flowstone in Dulcimer chamber at top of cracked slab., deep zone, 20-26.X.1990, S. Eberhard leg., QVM 12: 43778 (QVML); 3 spec. (remains: elytra), Tas. 41°30'S 146°20'E, MC38-19, Mole Creek, Genghis Khan Cave, top of Aragonite chamber near tree roots, deep zone, 19.X.1990, S. Eberhard leg., QVM 12: 43: 779 (QVML).

Diagnosis

A large-sized (mm 6.13-6.17) *Tasmanotrechus* of the “*cockerilli* group”, clearly distinguishable from *T. moorei* sp. nov. by the eyes smaller and the antennae longer. It is well distinguishable from *T. leai* by the head narrower and more elongated, and by the pronotum more transverse.

Description

Length mm 6.13 ♂ 6.17 ♀. Body stout (Fig. 62), with a relatively small fore-body in comparison with the elytra, which are long, wide, and ovoidal. Dorsal surface glabrous and shiny, with the microsculpture as transverse meshes. Metathoracic wings absent. Colour entirely testaceous. Head narrow. Clypeus convex at the base, with two apical setae on each side. Eyes very reduced. Neck constriction evident. Labrum transverse, with a

slightly emarginated apex; mandibles slender. Antennae long and slender, longer than the half of the body. Pronotum transverse (PW/PL: 1.20), widest almost in the middle. Base wider than the anterior margin. Sides sinuate before the base, which is slightly bisinuate; hind angles straight, evident, and upturned. Front angles rounded and not advanced. Lateral margins narrow, widening posteriorly; anterior seta inserted near 2/3 from the base; basal seta present, inserted just before the angles. Basal foveae smooth, slightly impressed, rounded. Median line distinct. Discal surface gently convex. Male with two dilated protarsomeres. Elytra very broad, ovoidal, widest at the anterior 3rd, slightly convex. Shoulders rounded but evident, with the humeral border continuing inwards almost to the base of the 4th stria. Lateral border of the elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with all striae visible, but gently impressed; juxtascutellar stria short and rudimentary; apical recurrent striole long, gently curved, ending at the level of the 7th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; one setiferous dorsal pore on the third stria before the middle. One preapical pore placed backwards and near to the 2nd stria. Aedeagus (Fig. 68) small (length 0.93 mm), long, and narrow; basal bulb small with a large sagittal carina; median lobe, in lateral view, curved in the basal 6th, gently and regularly curved in the distal part; apex short, slender, with the apical blade rounded. Inner sac apically provided with a large patch of sclerotized scales. Parameres long and moderately slender, reaching the apical 3rd of the median lobe, each one provided with 4 setae.

Etymology

We are glad to dedicate this new species to Rolan Eberhard who collected the first specimens.

Distribution and ecology

T. rolani sp. nov. is currently known from three caves in the Mole Creek karst area: Little Trimmer Cave, Kubla Khan Cave, and Genghis Khan Cave (Map 9). In Kubla Khan Cave *T. rolani* sp. nov. lives in sympatry with another troglobitic species of *Tasmanotrechus* of the same group of species, but less specialized, *T. moorei* sp. nov.

Taxonomic comments

Within the genus *Tasmanotrechus* three distinct groups can be recognized based on morphology. The “*T. leai* group” includes seven species typically occurring in forest litter. They are, pigmented, pronotum with rounded sides, not sinuate posteriorly, characterized by a mild ocular reduction but not highly specialized for life in deep subterranean environments. All species are morphologically well differentiated and geographically vicariant. Within this group *T. leai*, *T. concolor*, *T. gor-*

doni sp. nov., *T. alticola* sp. nov., and *T. montisfieldi* sp. nov. appear morphologically similar to each other, while *T. compactus* and *T. osbornianus* sp. nov. are most similar to each other. Species in the “*T. leai* group” have been collected from three IBRA regions in central, western and southern Tasmania (Map 9).

The other two “groups”, referred to as the “*T. elongatus* group” and “*T. cockerilli* group”, include species that are morphologically more adapted to the subterranean environment in terms of depigmentation, and characterized by a more or less enhanced ocular reduction and pronotum with sides sinuate posteriorly. These two “groups” of troglobites are geographically vicariant; the *T. elongatus* form occurs in caves of the Bubs Hill karst in western Tasmania, while the “*T. cockerilli* group” comprises at least three species recorded from caves in the Mole Creek karst in northern Tasmania. While the *T. elongatus* “group” is monospecific, within the group of *T. cockerilli* all three species are morphologically well differentiated, two of which *T. cockerilli* and *T. rolani* sp. nov. are more specialized and one, *T. moorei* sp. nov., is less specialized. The interesting zoogeographic datum is that two of these species, with a different degree of specialization, are sympatric in Kubla Khan Cave, which suggests heterochronic colonisations of the hypogean environment.

Genus *Goedetrechus* Moore, 1972

Type species: *Goedetrechus talpinus* Moore, 1972.

Goedetrechus Moore, 1972: 36.

Goedetrechus Moore: Casale & Laneyrie, 1982: 63.

Goedetrechus Moore: Moore et al, 1987: 130.

Goedetrechus Moore: Lorenz, 2005: 169.

KEY TO THE SPECIES GROUP

- 1 Eyes traceable, though very reduced..... 2
- Eyes absent..... <<*mendumae* group>>
- 2 Base of the pronotum markedly lobate. Eyes reduced..
- <<*talpinus* group>>
- Base of the pronotum truncate. Eyes traceable
- <<*parallelus* group>>

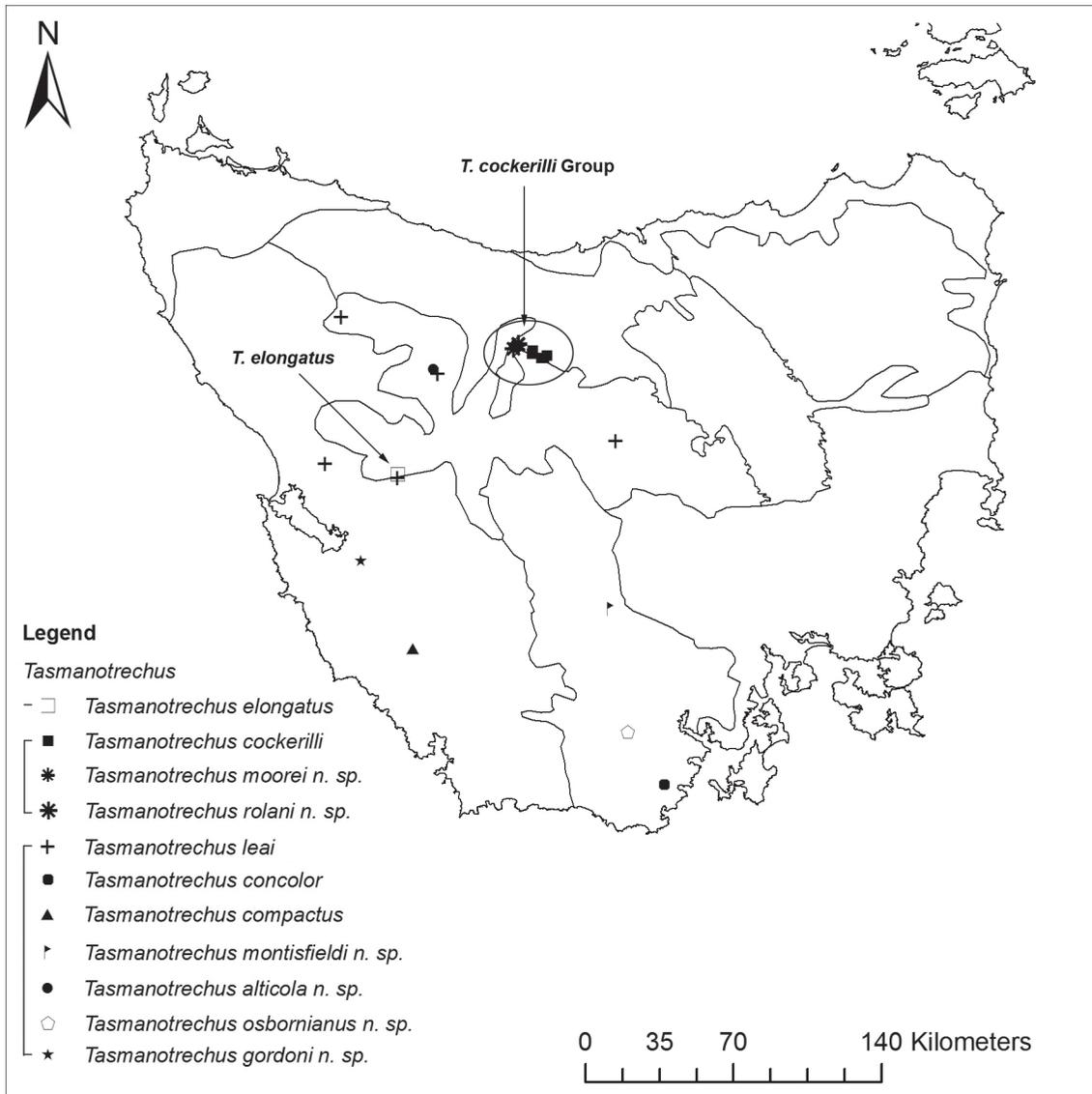
<<*G. talpinus* group>>

Diagnosis

A form less specialized to subterranean life – likely “endogeous” after Moore (1972) but probably a forest litter-dwelling species - with less ocular reduction and pronotum less cordiform.

Distribution and ecology

G. talpinus Moore, 1972, is the only representative of this “group” currently described. It is geographically isolated, and recorded only from a montane habitat (Blue Tier) in northeast Tasmania.



Map 9 - Collection sites for *Tasmanotrechus* spp.

<<*G. parallelus* group>>

Diagnosis

A group of specialized cave-dwelling species, with eyes reduced or vestigial.

The following described species belong to this group:

- G. parallelus* Moore, 1972
- G. rolani* sp. nov.
- G. florentinus* sp. nov.
- G. minutus* sp. nov.

KEY TO THE SPECIES

- 1. Size bigger (c. mm 4.9-5.1). Pronotum more elongate.2
- Size smaller (c. mm 4.13). Pronotum less elongate ...
..... *G. minutus* sp. nov.

- 2. Head globose, lateral side of the pronotum posteriorly slightly sinuate ... *G. rolani* sp. nov.
- Head elongate, lateral side of the pronotum posteriorly very sinuate ... *G. florentinus* sp. nov.

Goedetrechus minutus sp. nov.
(Fig. 69)

Loc. Typ.: Tasmania, Junee-Florentine, Niggly Cave, 42°40'S 146°30'E

Type series

HT ♀, Tas., 42°40'S 146°30'E, Junee-Florentine, JF237-1, Niggly Cave, deep zone, 28.IV.1990, S. Eberhard leg., QVM 12: 43773 (QVML).

Diagnosis

A *Goedetrechus* of the *parallelus* group, characterized by the small size (4.13 mm) and the relatively poorly elongated pronotum, similar in this to *G. parallelus*. It is

well separate from this by the elytra narrower and more elongated.

Description of the HT ♀

Length mm 4.13. Body elongate (Fig. 69), with a small fore-body in comparison with the elytra, which are elongated and subparallel. Dorsal surface glabrous and shiny, with the microsculpture as transverse meshes. Metathoracic wings absent. Colour entirely testaceous. Head narrow. Clypeus convex at the base, with two apical setae on each side. Eyes reduced to a very small macula. Neck constriction evident. Labrum transverse, with an emarginated apex; mandibles long and slender. Antennae very long and slender, longer than the half of the body. Pronotum cordiform (PW/PL: 0.97), widest at about the basal 3rd. Base narrower than the anterior margin. Sides sinuate before the base, which is bisinuate; side only very slightly curved anteriorly; hind angles straight, evident and upturned. Front angles rounded and not advanced. Lateral margins narrow, widening posteriorly; anterior seta inserted near 3/4 from the base; basal seta present, inserted at the angles. Basal foveae smooth, slightly impressed, rounded. Median line distinct. Discal surface gently convex. Elytra elongated and subparallel, widest in the middle, slightly convex. Shoulders rounded, slightly evident, with the humeral border not continuing inwards. Lateral border of the elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with all striae visible, but gently impressed; juxtascutellar stria present but short and very slightly impressed; apical recurrent striole long, gently curved, ending at the level of the 7th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; two setiferous pores on the third stria, the first one at the basal 4th, the second one in the middle. One preapical pore placed backwards and near to the 2nd stria. Male unknown.

Etymology

The name wants to remember the small size of the species.

Distribution and ecology

G. minutus sp. nov. is currently known only from the type locality of Niggly Cave, located in the Junee-Florentine karst in southern Tasmania (Map 9). The only known specimen of this species was collected from riparian mudbanks at approximately 350 metres depth in the cave.

Goedetrechus rolani sp. nov.

(Figs 70, 73)

Loc. Typ.: Tasmania, Junee-Florentine, Pendant Pot, 42°40'S 146°35'E.

Type series

HT ♂, Tas., 42°40'S 146°35'E, JF37-8, Junee-Florentine, Pendant Pot, April 1984, Rolan Eberhard leg., QVM 12: 43769 (QVML). PTT: 1 ♀, Tas., 42°40'S 146°27'E,

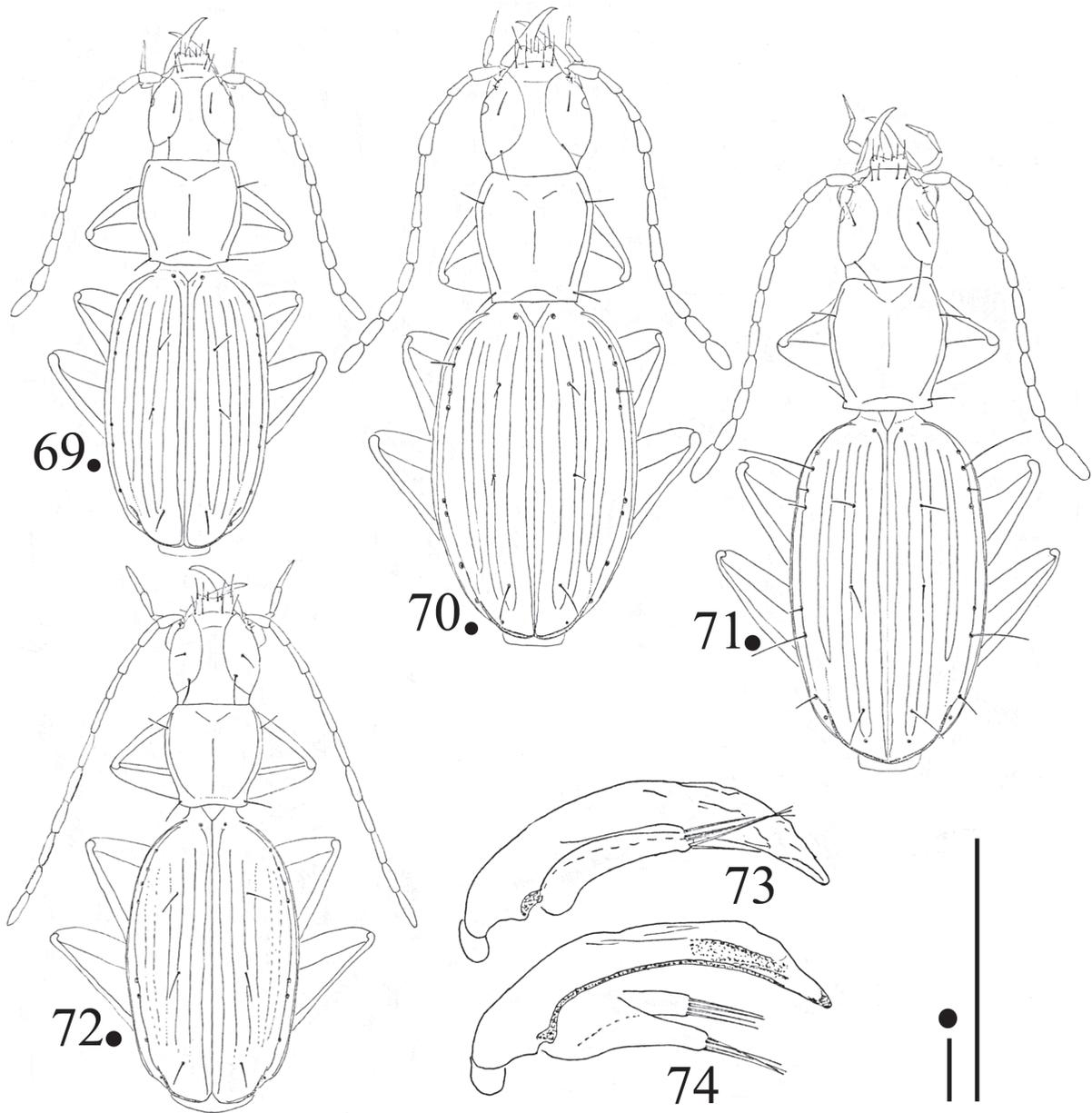
Junee-Florentine Windy Rift, Growling Swallet Cave, wood & litter on bank, deep zone, JF36-6, 26.III.1989, S. Eberhard leg. (CGi); 1 ♀, (immature), Tas., 42°40'S 146°27'E, Junee-Florentine, Junee-Florentine Windy Rift, Growling Swallet Cave, 13.V.1990, S. Eberhard leg.. QVM 12: 768 (QVML); 1 ♀, Tas., 42°40'S 146°30'E, Junee-Florentine, Wherrets Cave, JF-X6-5, 26.XII.1989, S. Eberhard leg., QVM 12: 43770 (QVML); 1 spec. (remains), Tas., 42°42'S 146°35'E, JF341-5, Junee-Florentine, Threefortyone Cave, deep zone July 1988, S. Eberhard leg. QVM 12: 43771 (QVML).

Diagnosis

A large-sized (4.93-5.05 mm) *Goedetrechus* of the *parallelus* group, with an elongated pronotum, similar in this to *G. florentinus* sp. nov.; it is well-differentiated from the latter by the macrocephaly, the shape of the pronotum, and the elytra with less parallel sides. It differs from *G. florentinus* also for the median lobe of the aedeagus, in lateral view, with a much greater diameter.

Description

Length mm 4.93 ♂ 5.0-5.05 ♀♀. Body elongate (Fig. 70), with a small fore-body in comparison with the elytra, which are elongated and subparallel. Dorsal surface glabrous and shiny, with the microsculpture as transverse meshes. Metathoracic wings absent. Colour entirely testaceous. Head large and globose. Clypeus convex at the base, with two apical setae on each side. Eyes reduced to a very small macula. Neck constriction evident. Labrum transverse, with a deeply emarginated apex; mandibles long and slender. Antennae very long and slender, longer than the half of the body. Pronotum cordiform (PW/PL: 0.91), widest at about the apical 5th. Base narrower than the anterior margin. Sides slightly sinuate before the base, which is rectilinear; sides very slightly curved to subrectilinear anteriorly; hind angles straight, evident, and upturned. Front angles rounded and not advanced. Lateral margins narrow, widening posteriorly; anterior seta inserted near 4/5 from the base; basal seta present, inserted before the angles. Basal foveae smooth, slightly impressed, rounded. Median line distinct. Discal surface gently convex. Male with two dilated protarsomeres. Elytra elongate and ovate, largest in the middle, slightly convex. Shoulders rounded, slightly evident, with the humeral border not continuing inwards. Lateral border of the elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with all striae visible; juxtascutellar stria present but short and very slightly impressed; apical recurrent striole long, gently curved, ending at the level of the 7th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; two setiferous pores on the third stria, the first one at the basal 4th, the second one in the middle. One preapical pore placed backwards and near to the 2nd stria. Aedeagus (Fig. 73) small (length 0.71 mm), long and stout, basal bulb small with a large sagit-



Figs 69-74. Habitus (69-72) and aedeagus in lateral view (73, 74) of *Goedetrechus* spp.: 69) *G. minutus* n. sp., HT ♀ from Niggly Cave; 70, 73) *G. rolani* n. sp., HT ♂ from Pendant Pot; 71, 74) *G. florentinus* n. sp., HT ♂ from Cauldron Pot; 72) *G. damperi* n. sp., HT ♀ from Damper Cave. Scale: 0.5 mm.

tal carina; median lobe, in lateral view, regularly curved from base to apex; apex short, stout, with the apical blade rounded. Inner sac unarmed. Parameres long and moderately slender, not reaching the apical 3rd of the median lobe, each one provided with 4 setae.

Etymology

We are glad to dedicate this new species to Rolan Eberhard who collected the first specimens.

Distribution and ecology

G. rolani sp. nov. is known from caves forming parts of the Growling Swallet- Junee Cavedrainage system in the Junee-Florentine karst: Growling Swallet Cave, Pendant Pot and Wherrets Cave in the northwestern portion of the system, and also from Threefortyone Cave (JF341) in the eastern end of the karst drainage system (Map 9). All known specimens of this species were collected in the deep areas of the caves.

Goedetrechus florentinus sp. nov.

(Figs 71, 74)

Loc. Typ.: Tasmania, Junee-Florentine, Cauldron Pot,
42°42'S 146°35'E.

Type series

HT ♂, Tas., 42°42'S 146°35'E, JF2-3, Junee-Florentine, Cauldron Pot, deep zone, 15.VII.1989, S. Eberhard leg. QVM 12: 43772 (QVML);

Diagnosis

A large-sized (5.06 mm) *Goedetrechus* of the *parallelus* group with an elongated pronotum, similar in this to *G. rolani* sp. nov.; it is well-differentiated from the latter by the head not macrocephalic, the shape of the pronotum, and the elytra with more parallel sides. It differs from *G. rolani* also for the median lobe of the aedeagus, in lateral view, with a decidedly smaller diameter.

Description of the HT ♂

Length mm 5.06. Body elongate (Fig. 71), with a small fore-body in comparison with the elytra, which are elongate and subparallel. Dorsal surface glabrous and shiny, with the microsculpture as transverse meshes. Metathoracic wings absent. Colour entirely testaceous. Head narrow. Clypeus convex at the base, with two apical setae on each side. Eyes reduced to a very small macula. Neck constriction evident. Labrum transverse, with a deeply emarginated apex; mandibles long and slender. Antennae very long and slender, longer than the half of the body. Pronotum cordiform (PW/PL: 0.90), widest at about the apical 4th. Base as wide as the anterior margin. Sides sinuate before the base, which is gently curved; sides very slightly curved to subrectilinear and angular anteriorly; hind angles straight, evident and upturned. Front angles rounded and not advanced. Lateral margins narrow, widening posteriorly; anterior seta inserted near the anterior 4th; basal seta present, inserted before the angles. Basal foveae smooth, slightly impressed, rounded. Median line distinct. Discal surface gently convex. Male with two dilated protarsomeres. Elytra elongate and subparallel, largest in the middle, slightly convex. Shoulders rounded slightly evident, with the humeral border not continuing inwards. Lateral border of the elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with all striae visible; juxtascutellar stria present but short and very slightly impressed; apical recurrent striole long, gently curved, ending at the level of the 7th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; two setiferous pores on the third stria, the first one at the basal 4th, the second one in the middle. One preapical pore placed backwards and near to the 2nd stria. Aedeagus (Fig. 74) small (length 0.69 mm), long

and slender, basal bulb small with a large sagittal carina; median lobe, in lateral view, regularly curved from base to apex; apex short, stout, with the apical blade rounded. Inner sac apically provided with a large patch of sclerotized scales. Parameres long and moderately slender, not reaching the apical 3rd of the median lobe, each one provided with 4 setae.

Etymology

After the Florentine Valley near where the type locality is situated.

Distribution and ecology

G. florentinus sp. nov. is known only from the type locality, Cauldron Pot cave which forms part of the Growling Swallet- Junee Cavedrainage system in the Junee-Florentine karst in southern Tasmania (Map 9). The only known specimen of this species was collected in the deep area of the cave.

<<*G. mendumae* group>>*Diagnosis*

A group of highly modified cave-dwelling species, eyeless, with very long antennae, and elytra with very obsolete humeri.

The following described species belong to this group:

G. mendumae Moore, 1972*G. damperi* sp. nov.*KEY TO THE SPECIES*

- 1 Size bigger (mm 5.0-5.4); pronotum less cordiform; elytral humeri less rounded *G. mendumae*
- Size smaller (mm 4.23); pronotum more cordiform; elytral humeri more rounded *G. damperi* sp. nov.

Goedetrechus damperi sp. nov.

(Fig. 72)

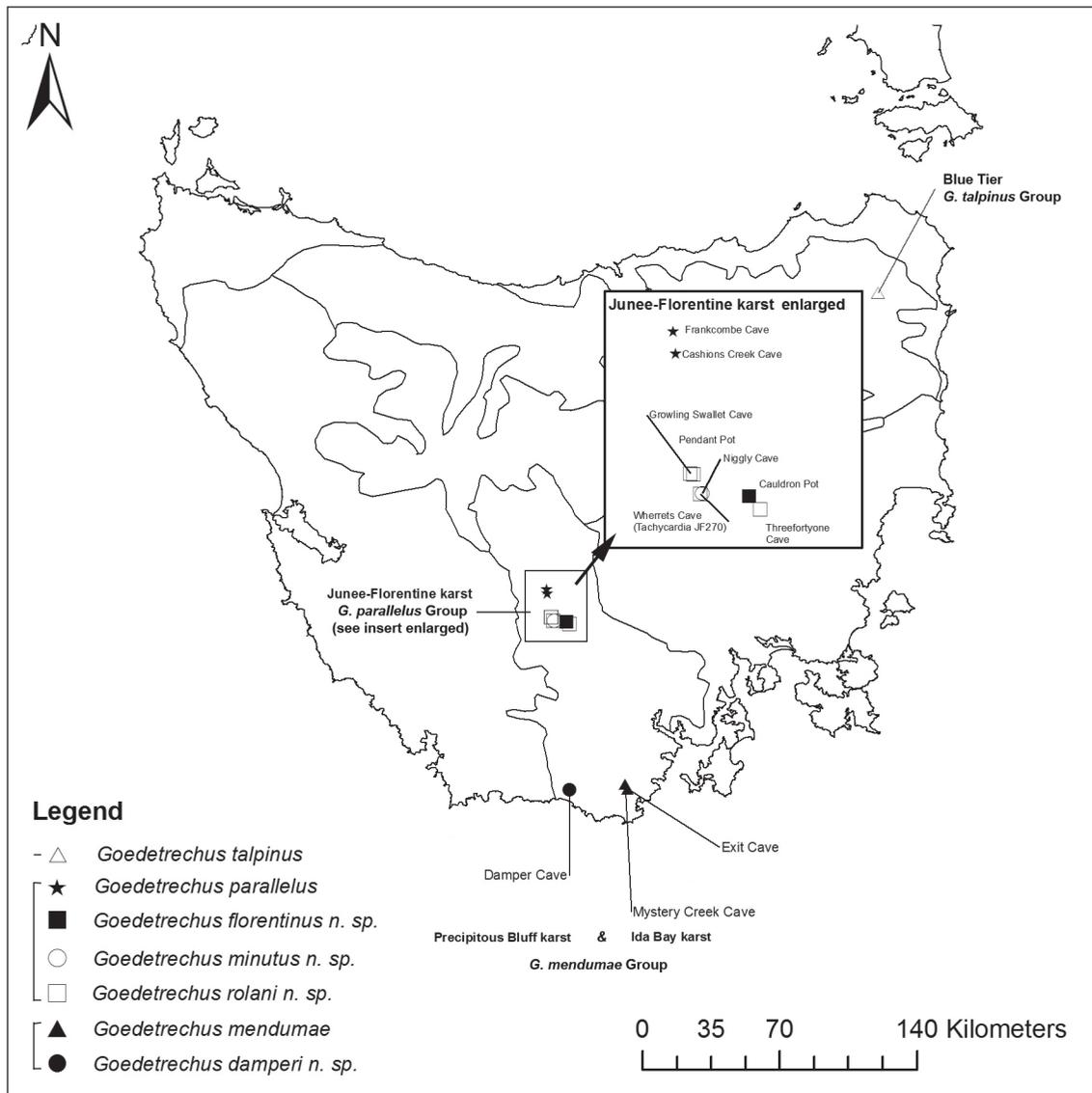
Loc. Typ.: Tasmania, Precipitous Bluff, Damper Cave,
43°27'51"S 146°36'51"E.

Type series

HT ♀, Tas., 43°27'51"S 146°36'51"E, PB1-1, Precipitous Bluff, Damper Cave, deep zone, streamway, 27.XII.1988, S. Eberhard leg. QVM 12: 43774 (QVML).

Diagnosis

A small-sized (4.23 mm) *Goedetrechus* of the *mendumae* group, with the pronotum elongated, more cordiform than in *G. mendumae*; it is well-differentiated from the latter, besides for the shape of the pronotum, for the elytra pyriform, with less obvious humeri.



Map 10 - Collection sites for *Goedtrechus* spp.

Description of the HT ♀

Length mm 4.23. Body elongate (Fig. 72), with a small fore-body in comparison with the elytra, which are elongate and pyriform. Dorsal surface glabrous and shiny, with the microsculpture as transverse meshes. Metathoracic wings absent. Colour entirely light testaceous. Head large. Moderately macrocephalous. Clypeus convex at the base, with two apical setae on each side. Eyes absent. Neck constriction evident. Labrum transverse, with a deeply emarginated apex; mandibles long and slender. Antennae very long and slender, as long as 3/4 of the body. Pronotum cordiform (PW/PL: 0.94), widest at about the apical 4th. Base narrower than the anterior margin. Sides strongly sinuate before the base, which is gently bisinuate; sides very slightly curved anteriorly; hind angles obtuse, evident and up-turned. Front angles rounded and not advanced. Lateral margins narrow, widening posteriorly; anterior seta inserted near the anterior 5th; basal seta present, inserted

just before the angles. Basal foveae smooth, slightly impressed, rounded. Median line distinct. Discal surface gently convex. Elytra elongate and pyriform, largest in the middle, slightly convex. Shoulders obsolete, with the humeral border not continuing inwards. Lateral border of the elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with all striae visible, but gently impressed; juxtascutellar stria present but short and very slightly impressed; apical recurrent striole long, gently curved, ending at the level of the 7th stria and with an apical carina. Chaetotaxis: juxtascutellar pore present; two setiferous pores on the third stria, the first one at the basal 4th, the second one just after the middle. One preapical pore placed backwards and near to the 2nd stria. Male unknown.

Etymology

After the type locality in Damper Cave.

Distribution and ecology

G. damperi sp. nov. is known only from the type locality, the Damper Cave, in the Precipitous Bluff karst in the far south of Tasmania (Map 9). The only known specimen of this species was collected in the deep zone of the cave, on the cobble bed of a small stream.

Taxonomic comments

Within the genus *Goedetrechus* it is quite easy to identify, on a morphological basis, three distinct groups of species. The monospecific group of *T. talpinus* includes the typical species of forest litter, poorly depigmented, less specialized to life in the subterranean environment, characterized by a lesser ocular reduction and the pronotum less cordiform. This group includes a species morphologically well differentiated and geographically isolated in the NE of Tasmania (Blue Tier). The other two groups, respectively, of *G. parallelus* and *G. mendumae*, comprise species that are morphologically modified for subterranean life; depigmented, characterized by a more or less accentuated ocular reduction and the pronotum definitely cordiform. The two groups are geographically vicariant, the former is located in the Junee-Florentine area (central Tasmania), while the latter is located in the far south of the island. The group of *G. parallelus* includes *G. parallelus*, *G. rolani* sp. nov., *G. florentinus* sp. nov., and *G. minutus* sp. nov. These are all species morphologically less specialized and poorly differentiated from each other, indicating the phenomenon of a probably recent differentiation, but all four species are recorded from different caves within the Junee-Florentine karst, although some species are recorded from multiple caves, for example the range of *G. rolani* sp. nov. extends from caves in the Growling Swallet portion of this karst to caves in the Junee Ridge portion, but all these caves are hydrologically connected parts of the Growling Swallet-Junee Cave karst drainage system. *G. parallelus* is recorded from two caves (Frankcombes Cave and Cashions Creek Cave) (Moore 1972) in a more northern portion of the Junee-Florentine karst, which is not hydrologically connected to the former system. The group of *G. mendumae* includes *G. mendumae* and *G. damperi* sp. nov. These species are geographically vicariant, occurring in separate karst areas but both in far southern Tasmania. These species are morphologically more specialized but well differentiated from each other, indicating the phenomenon of a probably more ancient colonisation of subterranean environments. The interesting zoogeographic possibility is that these three species groups, including species with a different degree of specialization, are the current outcome of heterochronic colonisation of the hypogean environment.

Genus *Trechistus* Moore, 1972

Type species: *Trechistus humicola* Moore, 1972

Trechistus Moore, 1972: 41.

Trechistus Moore: Casale & Laneyrie, 1982: 63.

Trechistus Moore: Moore et al, 1987: 130.

Trechistus Moore: Lorenz, 2005: 169.

KEY TO THE SPECIES (FROM MOORE, 1972 MODIFIED)

- 1 Elytra with pale maculae 2
- Elytra entirely dark *T. inconspicuus*
- 2 Pronotum cordate, the sides distinctly sinuate before the posterior angles *T. stenoderus*
- Pronotum suborbicular, sides without sinuation 3
- 3 Pronotum largely pale, dark only on the disk *T. sylvaticus*
- Pronotum largely dark, only the border pale 4
- 4 Smaller (length 3.5-4.0 mm); scutellar striae missing; median lobe more arcuate *T. terricola*
- Bigger (length 4.4-5.1 mm); scutellar striae present or missing; median lobe more arcuate 5
- 5 Scutellar striae present *T. humicola*
- Scutellar striae missing *T. gordonii* sp. nov.

Trechistus terricola Moore, 1972

(Figs 75, 79)

Loc. Typ.: Hartz Mts. 3000 ft, Tas.

Trechistus terricola Moore, 1972: 42.

Trechistus terricola Moore: Casale & Laneyrie, 1982: 63.

Trechistus terricola Moore: Moore et al, 1987: 131.

Trechistus terricola Moore: Lorenz, 2005: 169.

Examined material

11 ♂♂ 10 ♀♀, Australia, Tas., Hartz Mts. N.P., Lake Osborne car park, m 900, 20.I.2002, rainforest, P.M. Giachino leg. (CGi); 1 ♀, Australia, Tas., Hartz Mts. N.P., Lake Osborne, m 900, 26.XI.1999, P.M. Giachino leg. (CGi);

Notes

The original description by Moore (1972) is sufficiently accurate and requires no additions, while we believe it is useful to provide drawings of habitus (Fig. 75) and aedeagus (Fig. 79).

Distribution and ecology

Until now known from the Hartz Mts. at a height of 3,000 ft and without further details of locality; it was collected by one of us (PMG) near Lake Osborne by sieving in a pocket of moist forest (Map 11).

Trechistus humicola Moore, 1972

(Figs 76, 80)

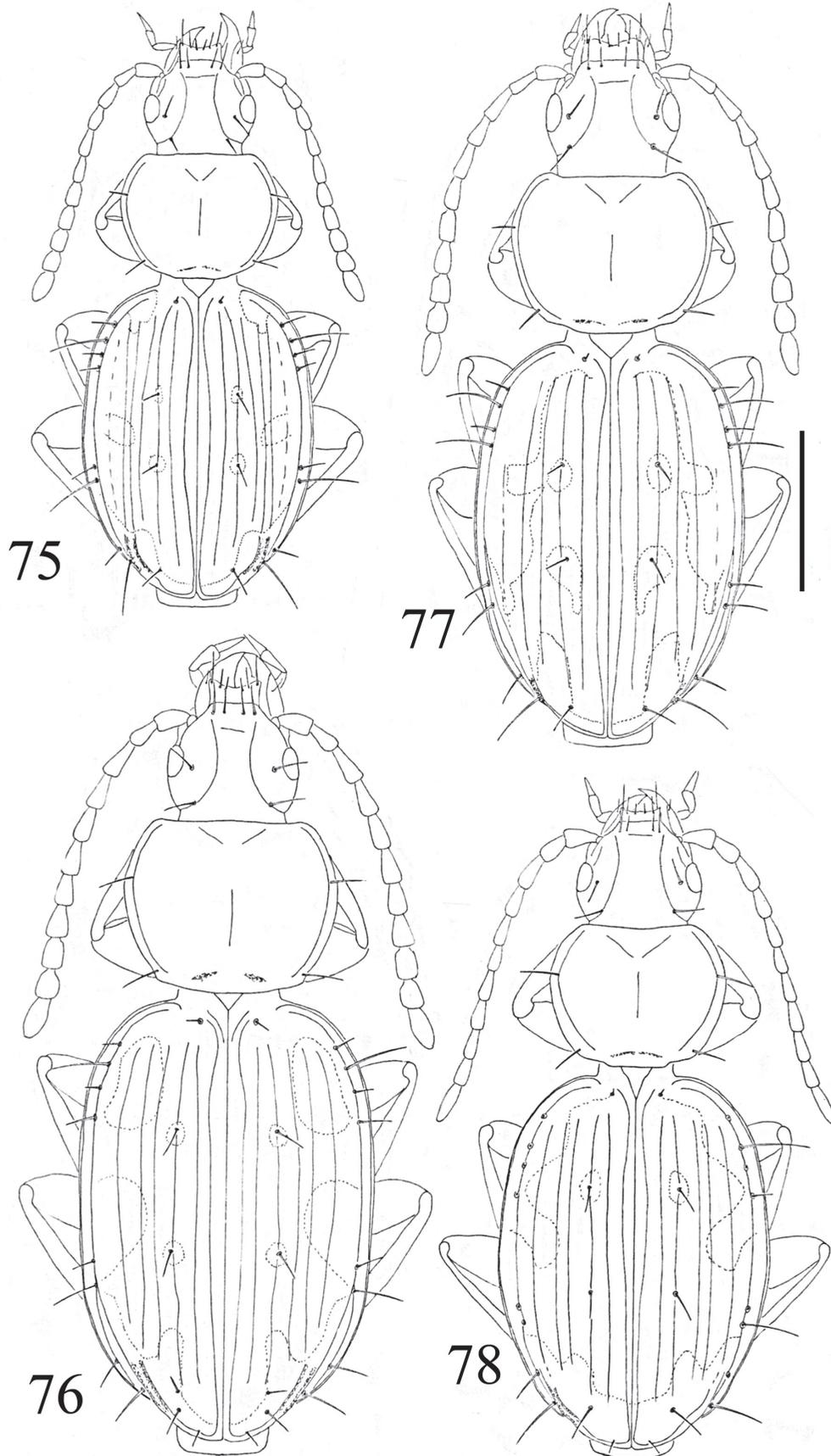
Loc. Typ.: Arve River, Hartz Mts. Natl. Park, Tas.

Trechistus humicola Moore, 1972: 41.

Trechistus humicola Moore: Casale & Laneyrie, 1982: 63.

Trechistus humicola Moore: Moore et al, 1987: 130.

Trechistus humicola Moore: Lorenz, 2005: 169.



Figs 75-78. Habitus of *Trechistus* spp.: 75) *T. terricola* Moore, ♂ from Lake Osborne; 76) *T. humicola* Moore, ♂ from Mt. Wellington; 77) *T. gordonii* n. sp., HT ♂ from Creepy Crawly Walk; 78) *T. sylvaticus* Moore, ♂ from Capricorn Cave. Scale: 1 mm.

Examined material

1 ♀, Tas., 42°52'S 147°15'E, WE-X1-18, Mount Wellington, Mount Arthur Cave 1, leaf litter, 7.II.1989, Mark Nelson leg., QVM 12: 43784 (QVML); 1 ♀, Mt. Wellington, Tas., 7.12.53, C. Oke (MVM); 1 ♂, Mt. Wellington, Tas., 6.12.53, C. Oke (MVM); 1 ♂, Mt. Wellington, Tas., 4.10.54, C. Oke (CGi);

Notes

The original description by Moore (1972) is sufficiently accurate and requires no additions, while we believe it is useful to provide drawings of habitus (Fig. 76) and aedeagus (Fig. 80).

Distribution and ecology

Previously known from the Hartz Mts.; it was collected by one of us (SE) in a dolerite talus cave on Mt Arthur, a part of the Wellington Range near Hobart. At the same time we were able to examine two specimens collected on Mt. Wellington in the 1850s. These records extend significantly the known range of *T. humicola* (Map 11).

Trechistus gordonii sp. nov.

(Figs 77, 81)

Loc. Typ.: Tasmania, Gordon River Rd., Creepy Crawly Walk, m 565.

Type series

HT ♂, Australia, Tas., Gordon River Rd., Creepy Crawly Walk, m 565, 17.I.2002, P.M. Giachino leg. (QVML). PTT: 2 ♂♂ 5 ♀♀, Australia, Tas., Gordon River Rd., Creepy Crawly Walk, m 565, 17.I.2002, P.M. Giachino leg. (CGi); 2 ♀♀, Tas., 42°40'S 146°27'E, Junee-Florentine Windy Rift, Growling Swallet Cave, Glow worm chamber, JF36-8, 26.III.1989, S. Eberhard leg., QVM 12: 43783 (QVML).

Diagnosis

A large-sized (mm 4.55-4.80) *Trechistus*, similar in size, colour, shape of the pronotum and of the median lobe of the aedeagus to *T. humicola*. It is well-differentiated from the latter by the pronotum with completely curved sides before the basal angles, the different arrangement of elytral maculae, and the lack of juxtascutellar stria.

Description

Length mm 4.55- 4.60 ♂♂ 4.62-4.80 ♀♀. Body obovate (Fig. 77), with a relatively large fore-body in comparison with the elytra, which are short and ovate. Dorsal surface glabrous and shiny, with the microsculpture as transverse meshes and very slightly impressed on the elytra. Metathoracic wings absent. Colour largely dark reddish-brown, with pale maculae on elytra; head light reddish-brown. Lateral margins of the pronotum pale; elytra dark, with two pale humeral maculae extended postero-laterally to 2/3 of the elytral length; one pale, large and U shaped macula on the apical 4th, and 4 small

maculae corresponding to the discal pores. Legs, antennomeres, and palpi testaceous. Head large. Clypeus convex at the base, with two apical setae on each side. Eyes large, convex, slightly prominent. Neck constriction evident. Labrum transverse, with a deeply emarginated apex; mandibles stout. Antennae short and slender, as long as the half of the body. Second antennal segment as long as the first one. Pronotum transverse (PW/PL: 1.25), widest at about 2/3 from the base. Base narrower than the anterior margin. Sides slightly curved before the base, which is bisinuate; hind angles obtuse and rounded. Front angles advanced. Lateral margins broad, widening posteriorly; anterior seta inserted at about the anterior 3rd; basal seta present, inserted before the angles. Basal foveae smooth, slightly impressed, rounded. Median line distinct. Discal surface gently convex. Male with two dilated protarsomeres. Elytra short, ovoid, widest in the middle, slightly convex. Shoulders rounded, with the humeral border continuing inwards to the level of the 3rd stria. Lateral border of the elytra wide and sharply narrowed backwards, ending in the slight preapical emargination. Elytral tip broad and rounded. Elytral disc with all striae visible; juxtascutellar stria absent; apical recurrent striole long, gently curved, ending at the level of the 6th stria and with a short apical carina. Chaetotaxis: juxtascutellar pore present; two setiferous pores on the third stria, respectively, at the basal 3rd, and just after the middle. One preapical pore placed backwards and closer to the 3rd stria. Aedeagus (Fig. 81) small (length 0.45 mm), stout; basal bulb small without a sagittal carina. Median lobe, in lateral view, gently curved and progressively reduced in diameter, with the apex short, stout and rounded. Inner sac apically provided with a small patch of sclerotized scales. Parameres long and moderately slender, reaching the apical 3rd of the median lobe, each one provided with 4 setae.

Etymology

After the Gordon Lake near which there is the type locality.

Distribution and ecology

T. gordonii sp. nov. is currently known from two localities not much far from each other and both situated on the eastern edge of the Franklin-Gordon River National Park. In the first locality of Creepy Crawly Walk, located along the Gordon River Rd, this new species was collected by sieving rainforest litter at an altitude of 565 m a.s.l., and the second locality is Growling Swallet Cave of the Junee Florentine karst area, where its occurrence underground is likely to be incidental (Map 11).

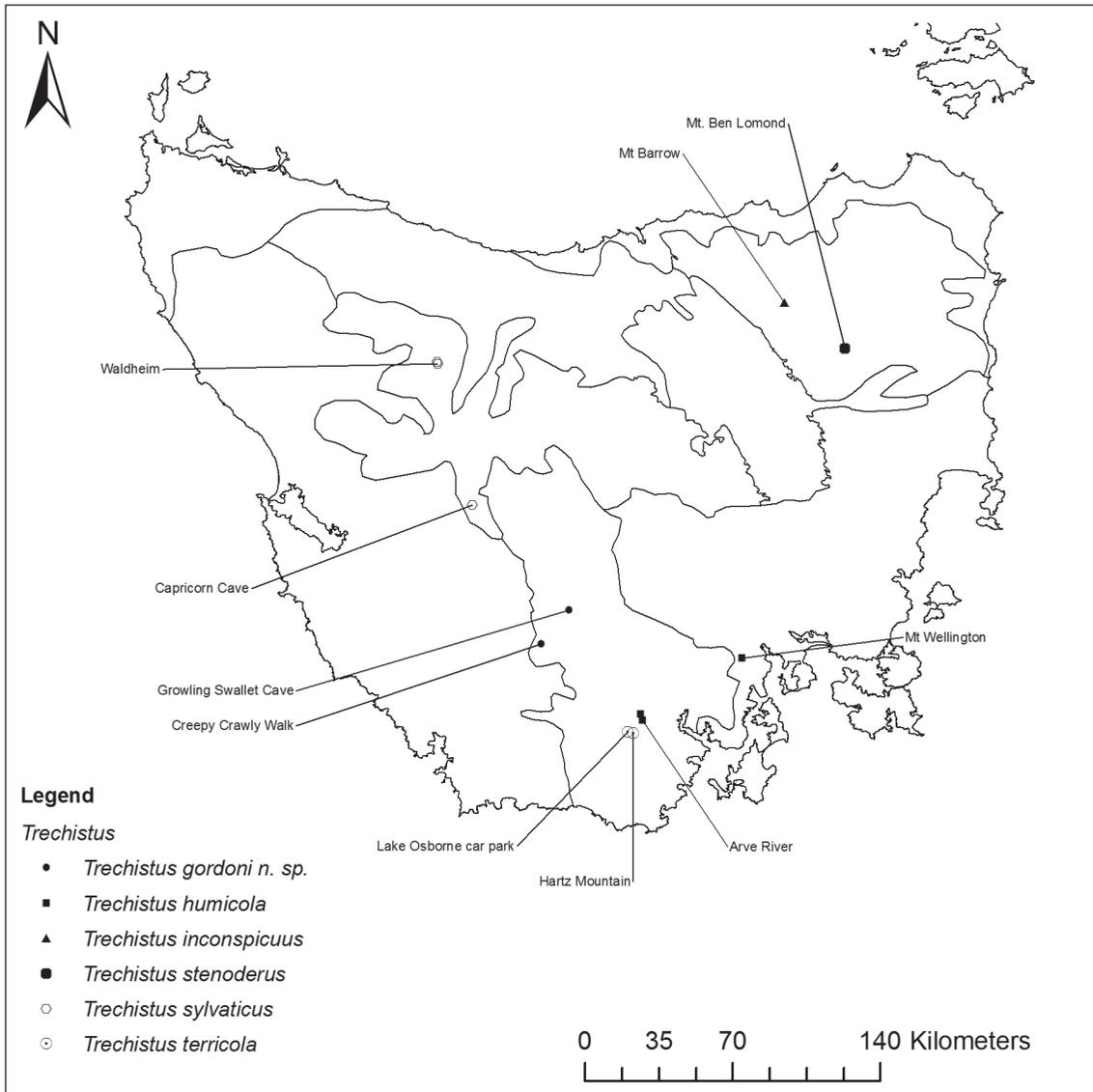
Trechistus sylvaticus Moore, 1972

(Figs 78, 82)

Loc. Typ.: Waldheim, 4000 ft, Tas.

Trechistus sylvaticus Moore, 1972: 42.

Trechistus sylvaticus Moore: Casale & Laneyrie, 1982: 63.



Map 11 - Collection sites for *Trechistus* spp.

Trechistus sylvaticus Moore: Moore et al, 1987: 131.

Trechistus sylvaticus Moore: Lorenz, 2005: 169.

Examined material

1 ♂ 1 ♀, Tas., 42°10'S 146°05'E, MR204-4 Mount Ronald Cross, Capricorn Cave, flood litter dark zone, 30.I.1989, S. Eberhard leg., QVM 12: 43782 (QVML, CGi);

Notes

The original description by Moore (1972) is sufficiently accurate and requires no additions, while we believe it is useful to provide drawings of habitus (Fig. 78) and aedeagus (Fig. 82).

Distribution and ecology

Previously known only from the type locality, the two non-trogomorphic specimens collected as incidental cav-

ericoles at Mount Ronald Cross, extend considerably southwards the known range of this species (Map 11).

Genus *Trechimorphus* Jeannel, 1927

Type species: *Trechus diemenensis* Bates, 1878.

Trechimorphus Jeannel, 1927: 79.

Trechimorphus Jeannel: Moore, 1972: 51.

Trechimorphus Jeannel: Casale & Laneyrie, 1982: 65.

Trechimorphus Jeannel: Moore et al, 1987: 133.

Trechimorphus Jeannel: Lorenz, 2005: 169

Trechimorphus diemenensis (Bates 1878)

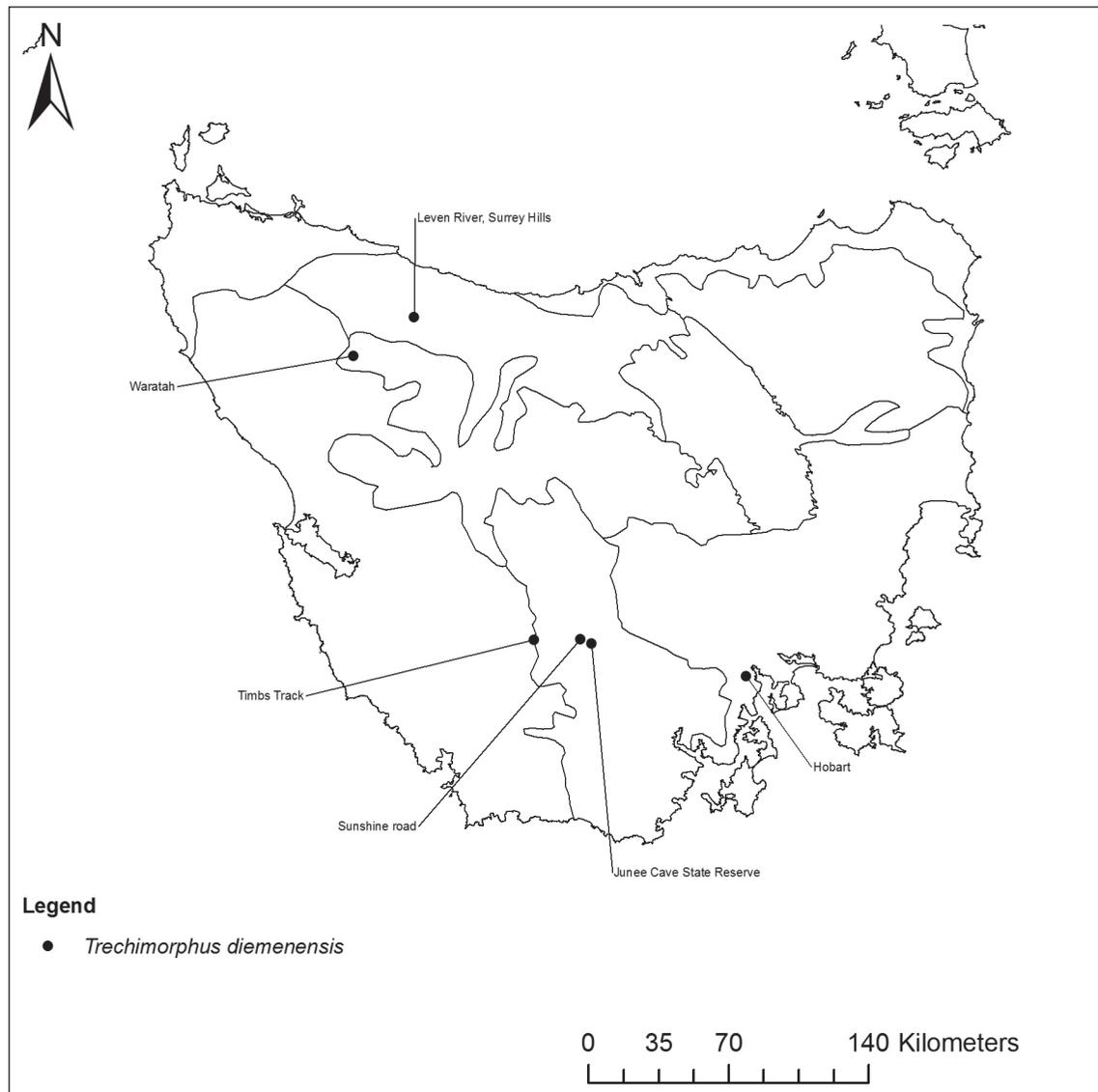
Loc. Typ.: South or Central Tasmania.

Trechus diemenensis Bates, 1878: 322.

Trechimorphus diemenensis Bates: Jeannel: 1927: 81.

Trechimorphus diemenensis (Bates): Moore, 1972: 51.

Trechimorphus diemenensis (Bates): Casale & Laneyrie, 1982: 65.



Map 12 - Collection sites for *Trechimorphus diemenensis*.

Trechimorphus diemenensis (Bates): Moore et al, 1987: 133.

Trechimorphus diemenensis (Bates): Lorenz, 2005: 169.

Examined material

1 ♂, Tas., 42°43'S 146°33'E, JFs 19, Junee-Florentine, Sunshine Road in rotting regrowth forest surface, 21.I.1990, S. Eberhard leg., QVM 12: 43786 (QVML); 2 ♂♂, Waratah, 13.3.40, E. Smith (MVM, CGi); 1 ♂, Hobart, 11.3.40, E. Smith (MVM); 1 ♀, Brighth, H.W. Davey (MVM); 3 ♂♂ 1 ♀, Australia, Tas., Maydena, Southwest N.P., Florentine Valley, Timbs Track, under bark, 5.XII.1998, P.M. Giachino leg. (CGi); 1 ♀ Australia, Tas. Hampshire, Companion Reserve, m 650, Leven River, Surrey Hills, 29.XI.1998, P.M. Giachino leg. (CGi); 1 ♂, Australia, Tas. Maydena, Junee Cave St. Res. m 300, 5.XII.1998, P.M. Giachino leg. (CGi).

Distribution and ecology

This species is widely spread across Tasmania (Moore et al 1987) (Map 12).

Psydrinae LeConte, 1853

Psydrini LeConte, 1853

Genus *Mecyclothorax* Sharp, 1903

Type species: *Cyclothorax punctipennis* Macleay, 1871

Cyclothorax Macleay, 1871: 104.

Mecyclothorax Sharp, 1903: 243.

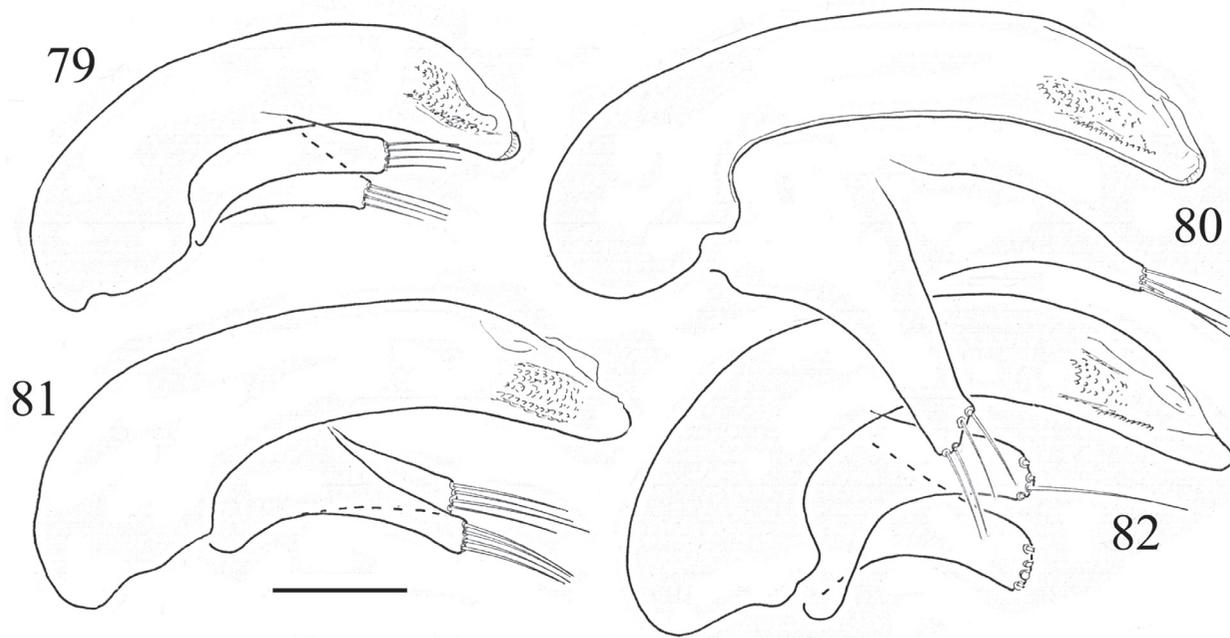
Mecyclothorax Sharp: Sloane, 1920: 153

Mecyclothorax Sharp: Moore, 1963: 286.

Mecyclothorax Sharp: Moore, 1984: 161.

Mecyclothorax Sharp: Moore et al, 1987: 147.

Mecyclothorax Sharp: Lorenz, 2005: 243.



Figs 79-82. Aedeagus in lateral view of *Trechistus* spp.: 79) *T. terricola* Moore, ♂ from Lake Osborne; 80) *T. humicola* Moore, ♂ from Mt. Wellington; 81) *T. gordonii* n. sp., HT ♂ from Creepy Crawly Walk; 82) *T. sylvaticus* Moore, ♂ from Capricorn Cave. Scale: 0.1 mm.

Mecyclothorax ambiguus (Erichson 1842)

Loc. Typ.: Tasmania.

Anchomenus ambiguus Erichson, 1842: 130

Mecyclothorax ambiguus Erichson: Sloane, 1920: 153

Mecyclothorax ambiguus (Erichson): Moore, 1984: 161.

Mecyclothorax ambiguus (Erichson): Moore et al, 1987: 147.

Mecyclothorax ambiguus (Erichson): Lorenz, 2005: 243.

Examined material

1 ♀, Tas., 43°27'S 146°36'E, PBs-3, Precipitous Bluff, New River Lagoon, surface litter in mixed forest, 1.I.1990, S. Eberhard leg., QVM 12: 43767 (QVML); 1 ♂ 1 ♀, Australia, Tas., Lake St. Clair N.P. m 740, 22.I.2002, P.M. Giachino leg. (CGi); 1 ♀, Australia, Tas., Lake St. Clair N.P. m 740, 29.XI.1998, P.M. Giachino leg. (CGi); 2 ♀♀, Australia, Tas., Great Lake, Miena, m 930, 8.XII.1998, P.M. Giachino leg. (CGi).

Distribution and ecology

According to Moore (1984) and Moore et al (1987) this species is present across Tasmania (Map 13).

Mecyclothorax punctipennis (Macleay 1971)

Loc. Typ.: Gayndah. Qld.

Cyclothorax punctipennis Macleay, 1871: 105.

Cyclothorax obsoletus Blackburn, 1889: 1389.

Mecyclothorax punctipennis (Macleay): Moore, 1984: 162.

Mecyclothorax punctipennis (Macleay): Moore et al, 1987: 149.

Mecyclothorax punctipennis (Macleay): Lorenz, 2005: 244.

Examined material

1 ♂ 1 ♀, Australia, Tas., Mt. Field N.P., Lake Dobson Rd., m 690, 16.I.2002, P.M. Giachino leg. (CGi).

Distribution and ecology

It was recorded by Moore (1984) and Moore et al (1987) in W.A., S.A., Vic., N.S.W., and Qld. This is the first record for Tasmania (Map 13).

Genus *Theprisa* Moore, 1963

Type species: *Phersita convexa* Sloane, 1920.

Theprisa Moore, 1963: 285.

Theprisa Moore: Moore et al, 1987: 150.

Theprisa Moore: Lorenz, 2005: 245.

Theprisa convexa (Sloane 1920)

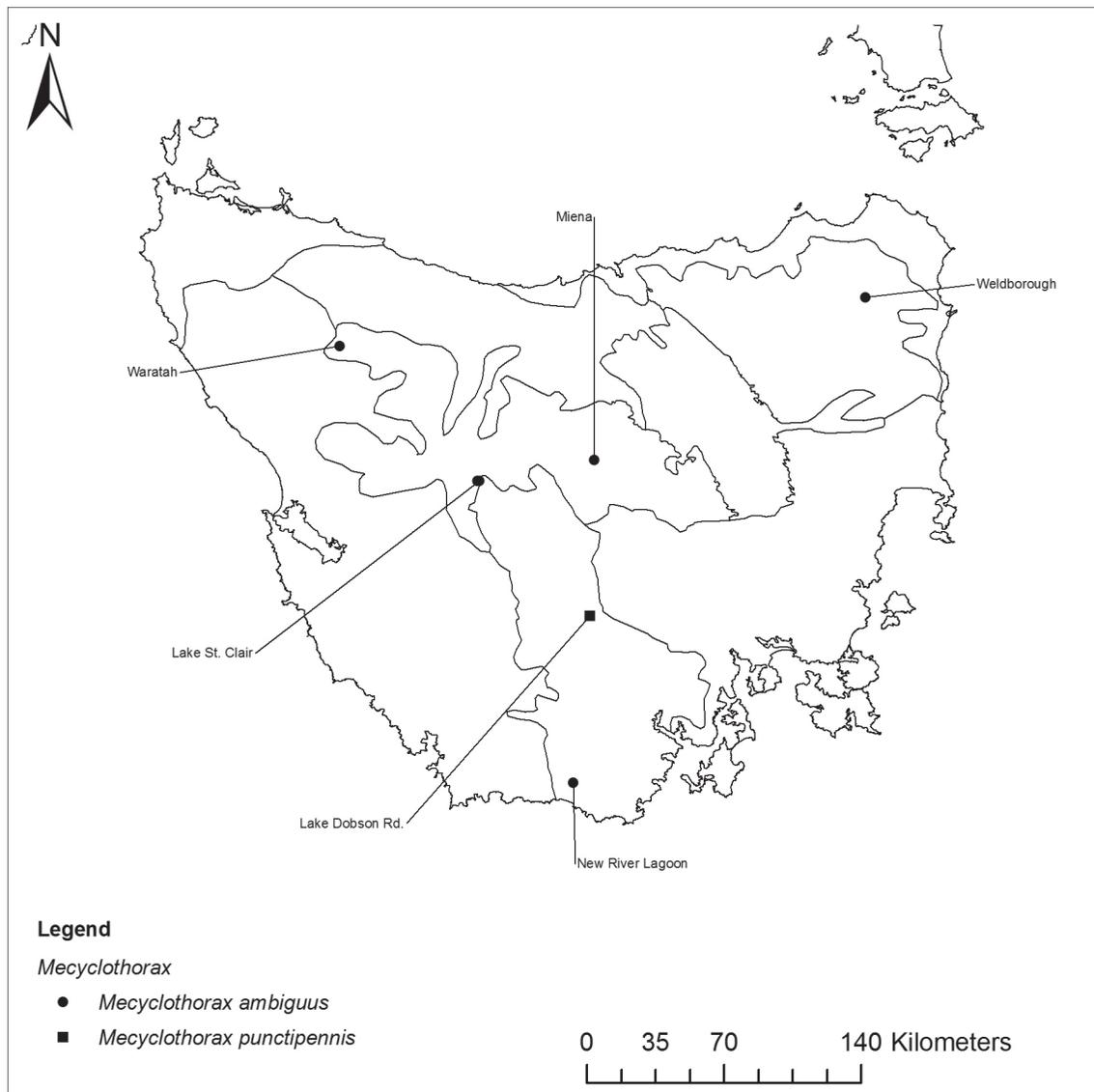
Loc. Typ.: Zeehan, Strahan and Waratah, Tas.

Phersita convexa Sloane, 1920: 158.

Theprisa convexa (Sloane): Moore, 1963: 285.

Theprisa convexa (Sloane): Moore et al, 1987: 150.

Theprisa convexa (Sloane): Lorenz, 2005: 245.



Map 13 - Collection sites for *Mecyclothorax* spp.

Examined material

1 ♂, Tas., 42°40'S 146°27'E, Junee-Florentine Windy Rift, Growling Swallet Cave, 26.III.1989, S. Eberhard leg., QVM 12: 43766 (QVML); 1 ♀, Tasmania, Waratah (CGi); 2 ♂♂ 1 ♀ Australia, Tas. Hampshire, Companion Reserve, m 550, Emu River (rainforest), 29.XI.1998, P.M. Giachino leg. (CGi); 1 ♂ Australia, Tas. Hampshire, Companion Reserve, m 600, S. Valentine Peak (rainforest), 29.XI.1998, P.M. Giachino leg. (CGi); 1 ♂ Australia, Tas. Tewkesbury m 600, 1.XII.1998, P.M. Giachino leg. (CGi); 1 ♂, Australia, Tas., Maydena, Southwest N.P., Florentine Valley, Timbs Track, m 500, 5.XII.1998, P.M. Giachino leg. (CGi); 1 ♀, Australia, Tas., Murchison Hwy., Hellyer Gorge St. Res., Hellyer River Picnic Area, 30.I.2002, P. M. Giachino leg. (CGi).

Distribution and ecology

The new localities expand slightly east and southwards the range of this species (Map 14). The single record of this species in a cave must be considered incidental.

Genus *Pterogmus* Sloane, 1920

Type species: *Pterogmus rufipes* Sloane, 1920.

Pterogmus Sloane, 1920: 155.

Pterogmus Sloane: Moore, 1963: 282.

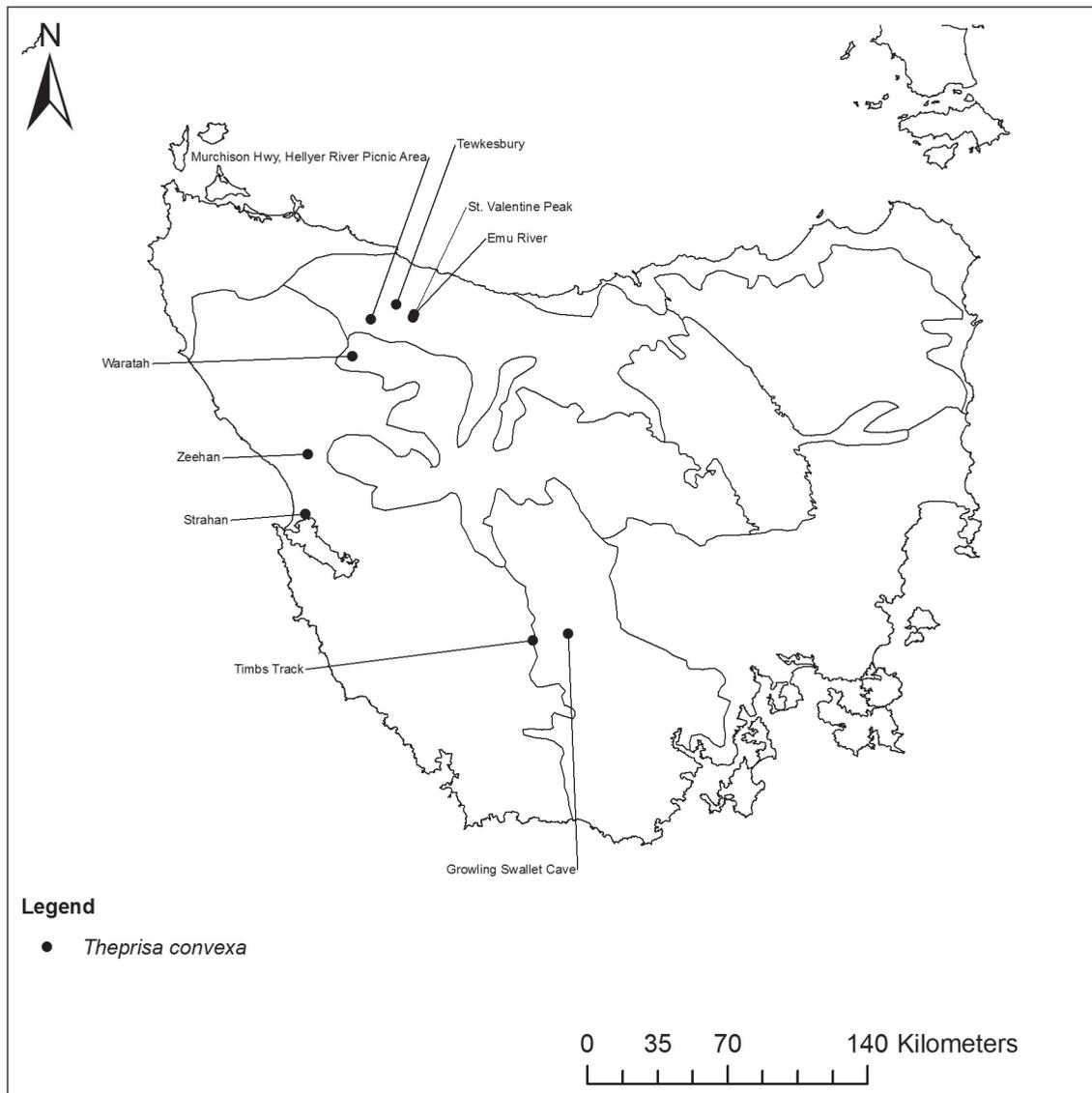
Pterogmus Sloane: Moore et al, 1987: 151.

Pterogmus Sloane: Lorenz, 2005: 245.

Pterogmus rufipes Sloane, 1920

Loc. Typ.: Ben Lomond and Waratah.

Pterogmus rufipes Sloane, 1920: 156.



Map 14 - Collection sites for *Theprisa convexa*.

Pterogmus rufipes Sloane: Moore, 1963: 282.

Pterogmus rufipes Sloane: Moore et al, 1987: 151.

Pterogmus rufipes Sloane: Lorenz, 2005: 245.

Examined material

3 ♀♀, Australia, Tas., Gordon River Rd., Florentine Valley, Timbs Track, m 460, 17.I.2002, P.M. Giachino leg. (CGi).

Distribution and ecology

The new locality expands southwards the range of this species (Map 15). The specimens examined were collected by sieving litter in rainforest.

Genus *Amblytelus* Erichson, 1842

Type species: *Carabus curtus* Fabricius, 1801.

Amblytelus Erichson, 1842: 129.

Amblytelus Erichson: Sloane, 1920: 153.

Amblytelus Erichson: Moore, 1963: 279.

Amblytelus Erichson: Moore et al, 1987: 154.

Amblytelus Erichson: Baehr, 2005: 27.

Amblytelus Erichson: Lorenz, 2005: 245.

Amblytelus niger Sloane, 1920

Loc. Typ.: Mt. Wellington, Tas.

Amblytelus niger Sloane, 1920: 154.

Amblytelus niger Sloane: Csiki, 1929: 492.

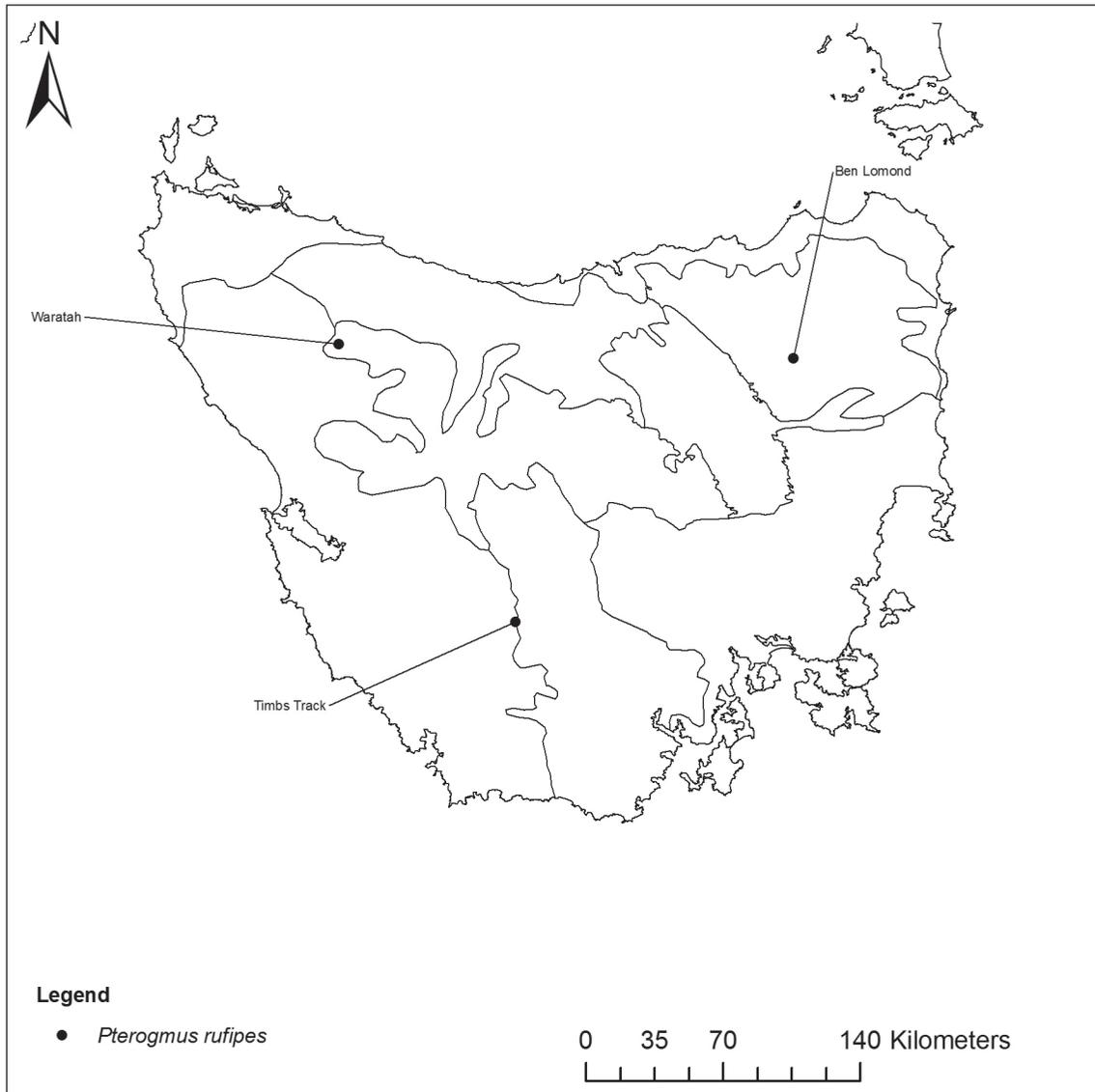
Amblytelus niger Sloane: Moore et al, 1987: 155.

Amblytelus niger Sloane: Baehr, 2005: 54.

Amblytelus niger Sloane: Lorenz, 2005: 246.

Examined material

1 ♂, Australia, Tas., Hobart, Mt. Wellington, m 1200, 19.I.2002, P.M. Giachino leg. (CGi).



Map 15 - Collection sites for *Pterogmus rufipes*.

Distribution and ecology

The specimen examined was collected by sieving litter beneath bushes on the top plateau of Mt. Wellington (Map 16).

Amblytelus montiscampi Baehr, 2005

Amblytelus montiscampi Baehr: Lorenz, 2005:246.

Examined material

1 ♂, Australia, Tas., Cradle Mt. N.P., Lake Dove, Marions Lookout, m 1100, 30.XI.1998, P.M. Giachino leg. (CGi).

Distribution and ecology

The specimen examined was collected by sieving litter beneath bushes at 1100 m a.s.l.

Genus *Dystrichothorax* Blackburn, 1892

Type species: *Amblytelus amplipennis* Macleay, 1871.

Dystrichothorax Blackburn, 1892: 88.

Dystrichothorax Blackburn: Sloane, 1920: 153.

Dystrichothorax Blackburn: Moore, 1963: 279.

Dystrichothorax Blackburn: Moore et al, 1987: 156.

Dystrichothorax Blackburn: Baehr, 2005: 128

Dystrichothorax Blackburn: Lorenz, 2005: 246.

Dystrichothorax tasmaniensis Baehr, 2005

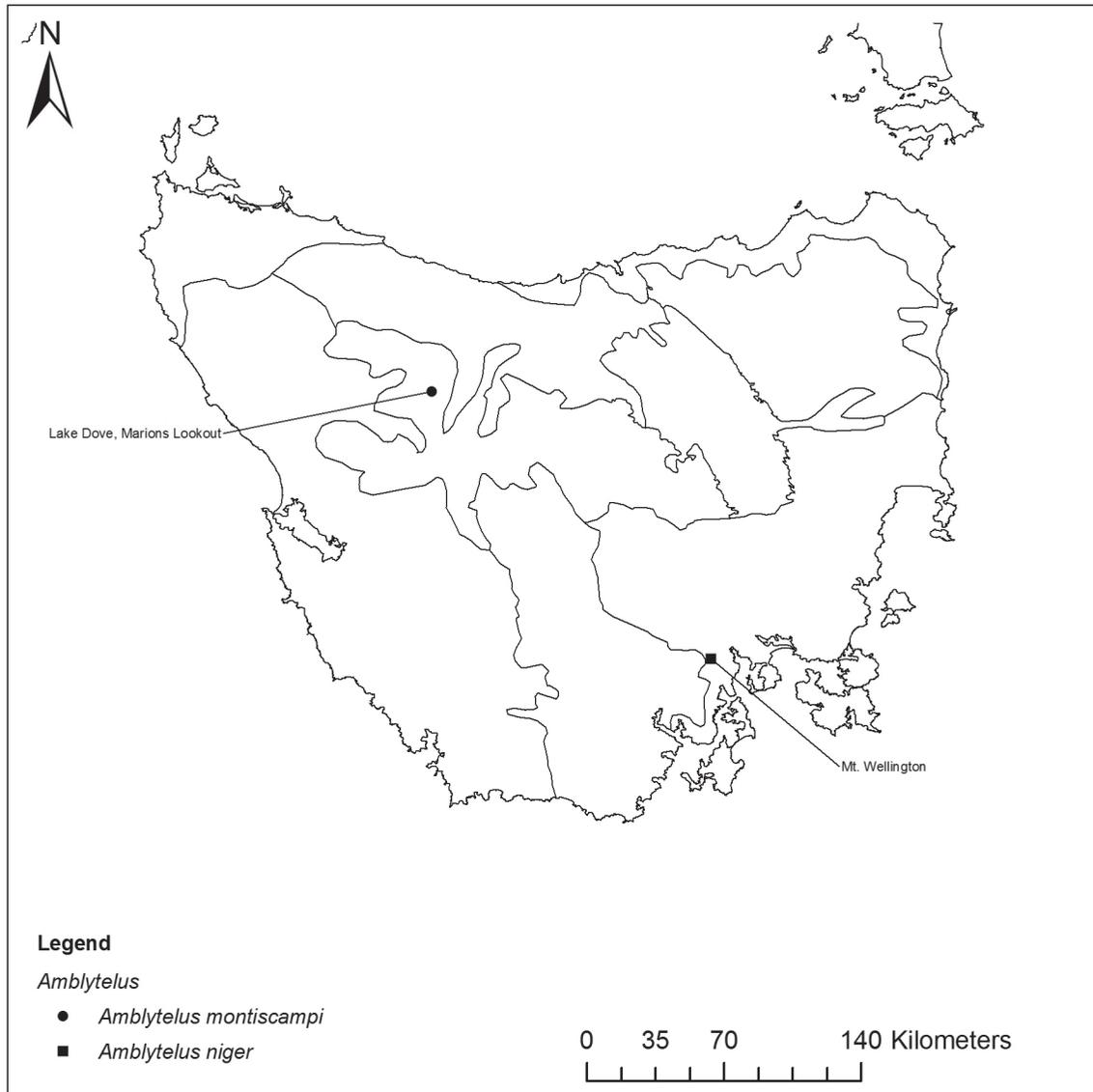
Loc. Typ.: Tas., Pirates Rd. Tasman Peninsula

Dystrichothorax tasmaniensis Baehr, 2005: 200.

Dystrichothorax tasmaniensis Baehr: Lorenz, 2005: 246.

Examined material

1 ♂, Australia, Tas., South Arthur Forest, Rapid Rd., Rapid River, 29.I.2002, P. M. Giachino leg. (CGi); 1 ♀,



Map 16 - Collection sites for *Amblytelus* spp.

Australia, Tas., Hartz Mts. N.P., Lake Osborne, m 1000, 20.I.2002, M. Daccordi leg. (CGi).

Distribution and ecology

According to Baehr (2005) this species is widely distributed in Tasmania (Map 17).

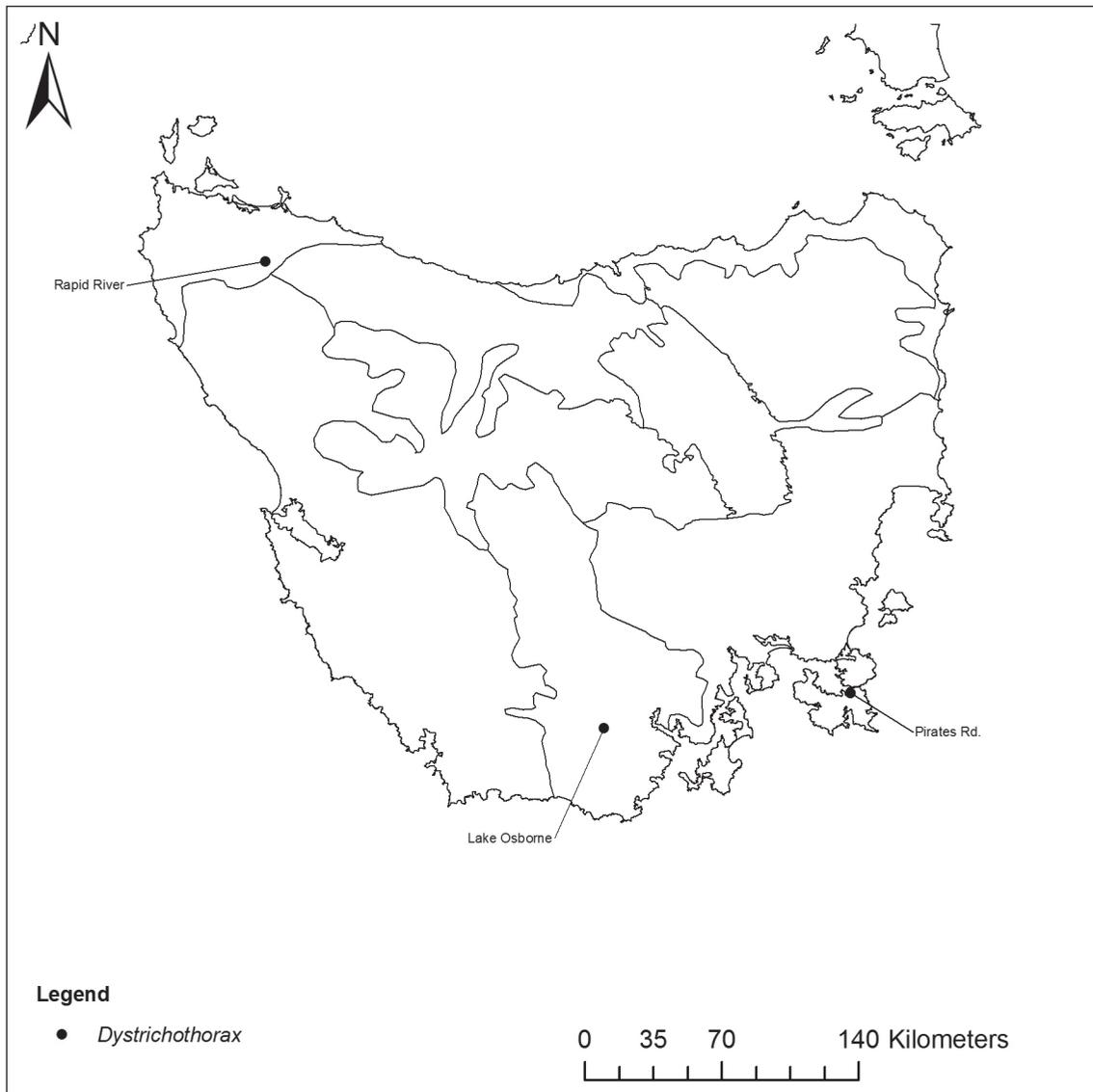
DISCUSSION

SURVEY COVERAGE

To evaluate the current state of knowledge of Tasmanian Carabidae from a biogeographic perspective, we combined our collection records with the published literature records (110 records, 60 species) of Jeannel (1927), Donabauer (2001), Moore (1963, 1972, 1978, 1983, 1984, 1994), and a few additional records in Eberhard et al (1991) and Eberhard (1999, 2000, 2001a, 2001b), and mapped these in relation to the Interim Biogeographic

Regionalization for Australia (IBRA) version 6.1 (2004) (Map 18). IBRA regions represent a landscape based approach to classifying the land surface, including attributes of climate, geomorphology, landform, lithology, and characteristic flora and fauna. While it is inevitable that much collected carabid material exists in non-museum collections and/or unpublished reports not readily available for incorporation herein, Map 18 suffices to give an indication of existing survey coverage and major knowledge gaps. Not unexpectedly, geographic survey coverage is quite patchy and large areas have no published records, although this paper makes substantial new contributions to filling geographic and taxonomic knowledge gaps in the West, Central Highlands, Ben Lomond, Northern Slopes and Southern Ranges IBRA regions, including karst areas.

The entire survey effort (published literature and this manuscript) and diversity recorded across IBRA regions is summarised in Table 1. Overall, 196 published records of 83 species in 21 genera were recorded from 41 locali-



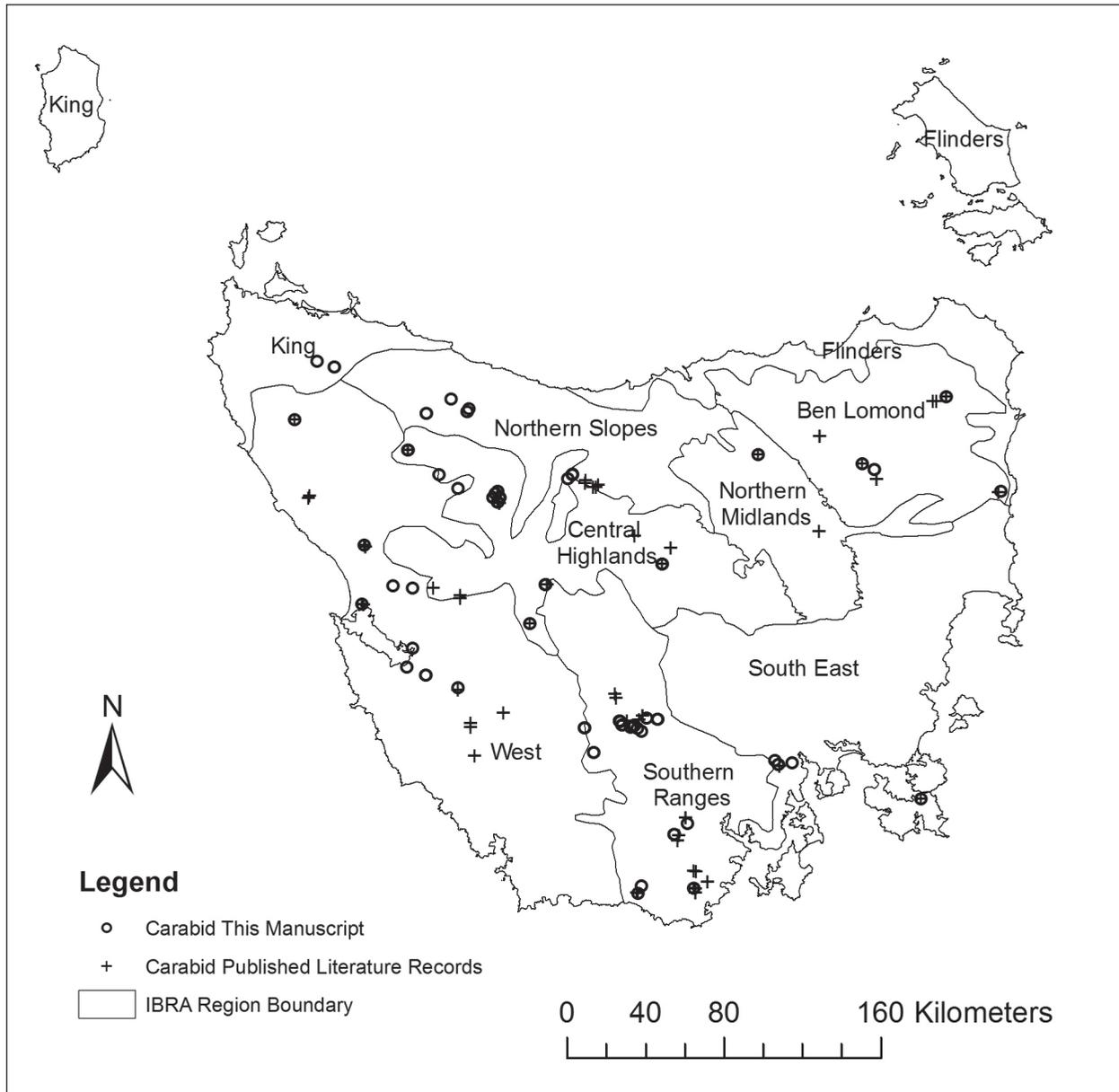
Map 17 - Collection sites for *Dystrichothorax tasmaniensis*.

ties (including 11 karst areas). In all IBRA regions, survey efforts have generally been focused at just a few localities subjected to repeated visits by different collectors over the years, and no IBRA region has more than ten sampled localities (Table 1, Map 18). Not surprisingly, there is a relationship between collection records and recorded diversity, the Central Highlands (31 species) and Southern Ranges (32) have received the most attention and have the highest recorded diversity. The next richest regions are West (18 species) and Ben Lomond (14).

Three IBRA regions clearly stand out as either, unsurveyed (Flinders), or poorly surveyed (South East and Northern Midlands). These three regions are characterised, physiographically, by lower average altitude and effective precipitation, and as a consequence more generally support dry (versus wet) forest types. From an anthropogenic perspective, these regions have also been more impacted by land-clearing and ruralisation. With

due consideration to physiographic and anthropogenic factors we consider that the observed patterns also reflect an historical artefact of surveyor preferences towards renowned and publically more accessible locations such as roadsides and National Parks.

Tasmania is well endowed with karst and caves, which are developed predominantly in Ordovician limestones and Precambrian dolomites (Map 19). Some 300 discrete karst areas and more than 1,000 caves ranging up to about 15 kilometres in length and 375 metres in depth are recorded (Kiernan 1995). A diverse terrestrial cave fauna has been documented (Eberhard 2001a) although only a small proportion of the known caves (estimated less than 20%) and karst areas (about 10%) have been biologically investigated with only a handful of these subject to repeated sampling, most notably at Mole Creek, Bubs Hill, Ida Bay, Hastings, Precipitous Bluff and Junee-Florentine (Eberhard et al 1991). Major areas



Map 18 - Tasmania's Biogeographic Regions (IBRA) and Carabidae distribution records distinguishing collection records first appearing in this paper ("O") and previous published literature records ("+"). IBRA version 6.1 (2004) Commonwealth of Australia.

of Tasmanian karst have never been surveyed, or only cursorily surveyed, notably in NW Tasmania, King Island, Flinders Island, West and Southern Ranges.

For subterranean carabids, the observed distribution patterns are predominantly controlled by the distribution of cavernous karstic rocks, these being poorly represented in the South East, Northern Midlands and Flinders IBRA regions (Map 19). Nonetheless, the occurrence of troglomorphic species in the geo-physiographically distinct and isolated Gray karst area in eastern Tasmania indicates that surveys for carabids in moist refugial habitats of drier eastern and northern Tasmania may be fruitful.

There has been little searching for subterranean beetles in non-karstic rocks or meso-cavernous habitats, but

in other parts of the world diverse troglobitic faunas have been recorded from Superficial (or Shallow) Subterranean Habitat (SSH) (*sensu* Howarth 1983; Giachino and Vailati 2010; Culver and Pipan 2009) or Milieu Superficial Souterrain (MSS, *sensu* Juberthie 1984). This SSH / MSS fauna was originally described from North Temperate montane (peri-) glaciated regions of continental Europe (Giachino & Vailati 2010), and subsequently in North Tropical arid oceanic island environments (Ormi and Martin 1992). In Tasmania, a cave invertebrate community comprising troglophiles (including *P. striatulus*) and troglobitic arachnids (Opiliones), is recorded from caves formed in dolerite talus at 1100 m altitude on Mount Wellington (Eberhard 2001a; Eberhard et al

Table 1 - Survey effort and recorded diversity by IBRA region arranged in order of increased survey effort. Survey effort measured by number of sampled localities and collection records; diversity represented by number of described genera and species. Karst localities and cave records / troglobitic taxa shown in brackets “()”.

IBRA Region	Survey Effort		Recorded Diversity	
	Sampled Localities (karst)	Collection Records (cave)	No. Genera (troglobites)	No. Species (troglobites)
Flinders	0			
Northern Midlands	2	2	2	2
King	2	3	3	3
South East	3	7	6	7
Northern Slopes	4 (1)	16 (9)	4 (1)	6 (3)
Ben Lomond	5 (1)	21 (3)	8 (1)	14 (1)
West	10 (3)	26 (5)	9 (2)	18 (2)
Central Highlands	6 (2)	57 (2)	16 (2)	31 (2)
Southern Ranges	10 (4)	64 (25)	13 (2)	32 (8)
Total	41 (11)	196 (44)	21 (5)	83 (17)

1991). Dolerite boulder fields and talus slopes of glacial - periglacial origins, and deeply fissured cliffs, are common and well-developed in mountainous areas of Tasmania, and we predict that these SSH / MSS habitats will be prospective for diverse troglobitic faunas, including Carabidae.

DIVERSITY

This study has made a significant contribution towards further recording and describing the remarkably rich ground beetle fauna of Tasmania. The fauna includes a significant proportion (about 50 %) of species endemic to Tasmania, and, an interesting suite of specialized subterranean forms exhibiting various degrees of troglomorphy, and which display highly localised distribution patterns. A systematic checklist of all described Tasmanian Trechinae (excluding Bembidiini) and treated Psydrinae is presented in Table 2.

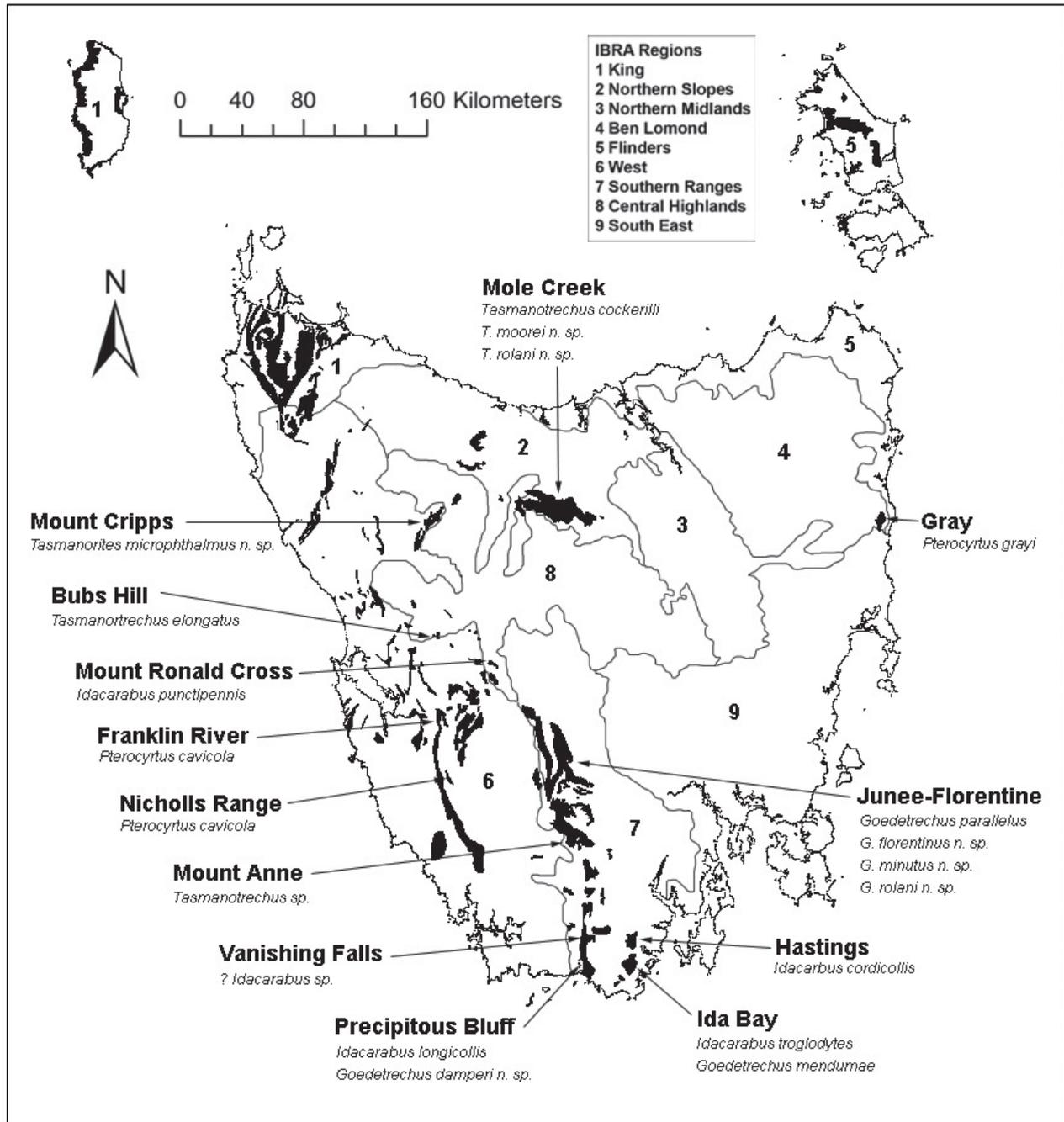
The taxonomic body of this paper details 109 collection sites for 59 species in 17 genera. Eighty-eight (88) of these collection records, mostly made by the authors, are published here for the first time, and as such represent the most comprehensive contribution since Moore's (1972) major treatise. Of our records detailed herein, 63 pertain to previously described species, for which new localities and some significant extensions of distribution range, altitude, and habitat are documented. Eighteen new species are described, comprising eleven epigeal species collected in forest, montane and alpine habitats across southern, western and northern Tasmania, in addition to seven obligate hypogean species (troglobites) collected from caves in five discrete karst areas. Eight previously described species belonging to four trechine genera were not detected or reexamined during our surveys: *Mimaniulus gracilis* (Moore 1972), *Mimotrechus carteri* (Sloane), *Paratrechodes macleayi* (Sloane), and *Pogonoschema* spp. (Table 2).

To evaluate local (versus regional) diversity and identify potential 'hotspots' we examined the collec-

tion records at several localities which have been popular with collectors over many years (Table 3). The most well-sampled, and diverse, localities are Cradle Mountain (18 species), Lake St Clair (11) and Waratah (11) in the Central Highlands region, and Junee-Florentine (11), Mount Field (8), and Hartz Mountains (11) in the Southern Ranges region. The mountains in NE Tasmania have also received repeated attention, namely Blue Tier (6 species), Ben Lomond (4) and Mount Barrow (4). Cradle Mountain stands out as a hotspot for carabid beetles; however it has probably received the most intensive survey efforts, which also span a range of altitudinal and vegetation environments extending from montane forest to alpine herbfields. At Cradle Mountain, and other localities, one sieve sample of leaf litter may contain up to five species of Trechini, including multiple congeneric species. In karst areas, the Junee-Florentine has the highest diversity of troglobitic carabids with four species of *Goedetrechus* currently described, although three species of *Tasmanotrechus* have been described from the Mole Creek karst in the Northern Slopes region. Further collections of beetles from these relatively large and hydrogeologically complex karst areas is considered likely to reveal additional species in these genera.

Seventeen (17) described species of Zolini and Trechini are obligate hypogean forms (troglobites) displaying progressive troglomorphic characters and apparently restricted to caves in karst (Map 19). The genera involved are: Zolini: *Idacarabus* (4 spp.) and *Pterocyrtus* (2); Trechini: *Tasmanotrechus* (4) *Tasmanorites* (1) and *Goedetrechus* (6). Three as yet undescribed troglobitic species are also known from the Vanishing Falls karst (? *Idacarabus* sp.; Eberhard et al 1991; 1992) and the Mount Anne karst (*Tasmanotrechus* sp. and *Idacarabus* sp.) (B.P. Moore pers. comm. to S.E. 28th October 1987), with additional specimens required to enable description.

This study has confirmed the typical pattern, also noted by Moore (1972), that each troglobitic species ap-



Map 19 - Tasmanian karst areas (black) and IBRA regions indicating karst areas with troglobitic carabid species. Karst data provided courtesy of Department of Industry & Water, Tasmania.

pears to be confined to a single karst area, however an important new finding is that individual karst areas may support more than a single troglobitic species, for example: Junee-Florentine karst (four species of *Goedetrechus*) and Mole Creek (three species of *Tasmanotrechus*). Moreover, individual caves may harbour two congeneric species which differ in their degree of troglomorphic specialization, suggesting heterochronic colonisation, such as *Tasmanotrechus moorei* sp. nov. and *T. rolani* sp. nov. which occur sympatrically in Kubla Khan Cave at Mole Creek. The radiations of *Goedetrechus* and *Tas-*

manotrechus may be partly related to the relatively large, and hydrogeologically complex karst areas in which they occur; both the Junee-Florentine and Mole Creek karsts contain hundreds of caves which are geographically scattered and characterised by complex hydrogeologic relationships. In contrast, the Ida Bay karst is geographically compact and hydrogeologically well-integrated, and supports only a single described species of *Goedetrechus*. Another factor influencing diversity within karsts may be their proximity to Quaternary glaciations, discussed in more detail later below.

Subfamily: Tribe: Subtribe: Genus	Gen. et sp.	Authority	Gen. et sp. endemic	Localities/ Records	K	NS	NM	BL	F	W	SR	CH	SE
	<i>T. intermedius</i>	Moore, 1972	Y	2							1		
	<i>T. laticollis</i>	Moore, 1983	Y	1									
	<i>T. longinotatus</i>	(Sloane, 1920)	Y	3				1		1			
	<i>T. lynceorum</i> <i>n. sp.</i>	Eberhard & Giachino	Y	1									1
	<i>T. madidus</i>	Moore, 1972	Y	5							1	1	
	<i>T. magnus</i>	Moore, 1972	Y	3				1					
	<i>T. microphthalmus</i> <i>n. sp.</i>	Eberhard & Giachino	Y	1								1	
	<i>T. nitens</i>	(Putzeys, 1874)	Y	1									1
	<i>T. perkini</i>	Donabauer, 2001	Y	1							1		
	<i>T. pullus minor</i>	Moore, 1972	Y	2								1	
	<i>T. pullus pullus</i>	Moore, 1972	Y	1							1		
	<i>T. riparius</i>	Moore, 1972	Y	5						1		1	
	<i>T. tasmaniae</i>	(Blackburn, 1901)	Y	2								1	
<i>Tasmanotrechus</i>	<i>T. cockerilli</i>	Moore, 1972	Y	5		1							
	<i>T. rolani n. sp.</i>	Eberhard & Giachino	Y	3		1							
	<i>T. moorei n. sp.</i>	Eberhard & Giachino	Y	1		1							
	<i>T. elongatus</i>	Moore, 1994	Y	1						1			
	<i>T. leai</i>	(Sloane, 1920)	Y	5						1		1	
	<i>T. concolor</i>	Moore, 1972	Y	1							1		
	<i>T. alticola n. sp.</i>	Eberhard & Giachino	Y	1								1	
	<i>T. gordonii n. sp.</i>	Eberhard & Giachino	Y	1						1			
	<i>T. montisfieldi</i> <i>n. sp.</i>	Eberhard & Giachino	Y	1							1		
	<i>T. compactus</i>	Moore, 1983	Y	1						1			
	<i>T. osbornianus</i> <i>n. sp.</i>	Eberhard & Giachino	Y	1							1		
<i>Trechimorphus</i>	<i>T. diemenensis</i>	(Bates, 1878)	N	6		1					1	1	1
<i>Trechistus</i>	<i>T. gordonii n. sp.</i>	Eberhard & Giachino	Y	2							1		
	<i>T. humicola</i>	Moore, 1972	Y	2							1		1
	<i>T. inconspicuus</i>	Moore, 1972	Y	1				1					
	<i>T. stenoderus</i>	Moore, 1972	Y	1				1					
	<i>T. sylvaticus</i>	Moore, 1972	Y	2								1	
	<i>T. terricola</i>	Moore, 1972	Y	1							1		
Trechodini:													
<i>Cyphotrechodes</i>	<i>C. gibbipennis</i>	(Blackburn, 1901)	N	5						1	1	1	
<i>Paratrechodes</i>	<i>P. macleayi</i>	(Sloane, 1920)	N	1			1						
<i>Trechobembix</i>	<i>T. baldiensis</i> <i>baldiensis</i>	(Blackburn, 1894)	N	3	1							1	
Zolini:													
<i>Idacarus</i>	<i>I. cordicollis</i>	Moore, 1967	Y	2							1		
	<i>I. longicollis</i>	Moore, 1978	Y	2							1		
	<i>I. punctipennis</i>	Moore, 1994	Y	1								1	
	<i>I. troglodytes</i>	Lea, 1910	Y	2							1		
<i>Percodermus</i>	<i>P. niger</i>	Sloane 1920	Y	2								1	
<i>Pterocyrtus</i>	<i>P. cavicola</i>	Moore, 1994	Y	3						1	1		

Subfamily: Tribe: Subtribe: Genus	Gen. et sp.	Authority	Gen. et sp. endemic	Localities/ Records	K	NS	NM	BL	F	W	SR	CH	SE
	<i>P. grayi n. sp.</i>	Eberhard & Giachino	Y	1				1					
	<i>P. globosus</i>	Sloane, 1920	Y	3							1	1	
	<i>P. meridionalis n. sp.</i>	Eberhard & Giachino	Y	1							1		
	<i>P. rubescens</i>	Sloane, 1920	Y	1								1	
	<i>P. striatulus</i>	Sloane, 1920	Y	4				1		1	1	1	1
	<i>P. tasmanicus</i>	(Castelnau, 1867)	Y	2			1	1					
<i>Sloaneana</i>	<i>S. tasmaniae</i>	(Sloane, 1915)	N	10	1	1				1	1	1	
	Totals			196	3	6	2	14	0	18	32	31	7

The complexities in diversity and distribution have important implications for conservation management, especially in areas such as the Mole Creek karst where multiple congeneric species exhibiting heterochronic and complex phylogeographic relationships occur within a complex hydrogeologic setting that is further impacted / fragmented by anthropogenic disturbances associated with rural land-use activities.

Eight species have been recorded from both cave and surface habitats, namely: *Tasmanotrechus leai*, *Tasmanorites flavipes* and *T. grossus*, *Trechistus sylvaticus* and *T. gordonii* sp. nov., *Pterocyrtus globosus* and *P. striatulus*, *Theprisa convexa*. While not overtly troglomorphic, these species appear able to opportunistically exploit subterranean habitats as troglaphiles or troglloxenes. Other species of *Tasmanotrechus*, *Tasmanorites* and *Pterocyrtus* are fully troglobitic, indicating a predisposition for exploitation of subterranean habitats by these genera. Several of the species found in ground litter habitats exhibit mild degrees of regressive troglomorphy such as ocular reduction and reduced pigmentation indicative of endogean adaptation, for example *Goedetrechus talpinus* recorded from ground litter / soil on the Blue Tier in NE-Tasmania. The six other described species in the genus *Goedetrechus* are all troglobites restricted to karst areas in the Southern Ranges.

ECOLOGY

In Tasmania, Carabidae are found in moist terrestrial habitats ranging from sea level to the highest mountain peaks (ca. 1400 metres). They are common in ground litter, underneath stones and logs, in rainforest, wet sclerophyll, dry sclerophyll, and mixed-forest types, as well as shrubland and grassland vegetation communities, and caves.

While some species have apparent narrowly delimited distribution and altitude ranges, and ecological tolerances, others have wide distribution ranges and ecological tolerances. An example of the latter is *Dystrichothorax tasmaniensis*, which ranges from sea level to montane-alpine habitats, dry and wet forest types, southwest to northeast Tasmania. Examples of the former include

species in the genus *Goedetrechus*, such as *G. talpinus* known only from montane habitats on the Blue Tier, and *G. mendumae* restricted to caves in the Ida Bay karst.

ZOOGEOGRAPHY

We identify three broad zoogeographic groups of Trechinae genera in Tasmania, distinguished by their distribution ranges (endemism), degrees of radiation and / or specialization to subterranean life, and presumed age of origin:

Tasmanian endemic genera of presumed ancient origin (pre-Quaternary or pre-Pliocene?) that include distributional relicts, and morphologically highly-modified subterranean species. Genera: *Tasmanotrechus*, *Goedetrechus*, *Idacarabus*. All known species in the genus *Idacarabus* are distributional relict forms confined to hypogean habitats, as are all species in the genus *Goedetrechus*, with the exception of *G. talpinus* which is endogean but restricted to the Blue Tier in NE Tasmania. The genus *Tasmanotrechus* has undergone extensive radiation in Tasmania (11 described species) and includes both epigeal (7) and hypogean (4) forms.

Tasmanian endemic genera of presumed less-ancient origin (pre-Quaternary?) that includes, normally, forest-dwelling species which have radiated here including *Tasmanorites* (24 described species), *Pterocyrtus* (7), *Sloanelia* (5), *Trechistus* (6). This group is characterised by morphologically less-modified subterranean forms in the genera *Tasmanorites* and *Pterocyrtus*. The genus *Tasmanorites* has undergone extraordinary radiation in epigeal habitats (23 described species) but with only one hypogean form known. This genus provides a contrast to Group 1 genera where extant radiation diversity is predominantly confined to hypogean forms.

Non-endemic genera also distributed on the Australian mainland, and presumed to be recent immigrants to Tasmania (during Last Glacial?). Genera: *Trechobembix*, *Cyphotrechodes*, *Trechimorphus*.

IMPACT OF QUATERNARY CLIMATE CHANGE

Historically, in most temperate climate regions of Australia the cave dwelling beetle fauna was thought to

Table 3 - Recorded diversity at selected localities subjected to repeated survey effort. Karst localities and cave records / troglobitic taxa shown in brackets “()”.

IBRA Region	Well-Sampled Localities	No. Records (cave)	No. Genera (troglobites)	No. Species (troglobites)
Ben Lomond	Ben Lomond Mountain	6	3	4
	Mount Barrow	4	3	4
	Blue Tier	7	5	6
Central Highlands	Cradle Mountain	22	8	18
	Lake St Clair	14	8	11
	Waratah	11	8	11
Southern Ranges	Mount Field	13	4	8
	(Junee-Florentine)	20 (15)	8 (1)	11 (4)
	Hartz Mountains	14	7	11

be dominated by troglaphiles that were not highly specialized for subterranean existence (Moore 1965), although subsequently Moore (1995) described an exception to this pattern with two highly modified carabids (*Zuphiini*) from the the Nullarbor Plain. In Australia's tropical climate regions, extremely diverse and specialized subterranean faunas have been discovered in lava tube caves in North Queensland (Howarth and Stone 1990), and more recently in meso-cavernous habitats developed within weathered iron-ore bearing rocks in the Pilbara region of Western Australia (Eberhard et al 2008). The Pilbara subterranean fauna includes *Zuphini* and *Anilini* carabids. In the Pilbara (including Cape Range and Barrow Island) the terrestrial troglobitic fauna predominantly comprises distributional relict forms presumed to be derived from epigeal lineages which inhabited wet forest environments present across the region during the Tertiary (Humphreys 2000). As inferred for the rich aquatic subterranean fauna of Western Australia, increasing aridity during the Quaternary is considered the principal environmental factor driving colonization and isolation in subterranean environments here.

In the northern hemisphere, troglobite distribution patterns concordant with ice limits were explained by the 'Pleistocene Effect Model' or 'Climatic Relict Hypothesis' (CRH) (eg. Holsinger 2000). This model assumes that climatic and associated environmental changes (eg. altitudinal or latitudinal retreat or expansion of forest versus alpine vegetation) causes local extirpation of surface populations and the genetic isolation of troglophile populations in subterranean habitats thus facilitating troglogenesis. Underground isolation of trogliphilic species normally associated with alpine environments could occur during altitudinal retreat of the alpine zone (with concomitant expansion of the forest zone) during interglacial periods. Conversely, isolation of trogliphilic species normally associated with moist forest habitats would be more likely during glacial periods when the tree-line retreats and the alpine zone expands. Subterranean Coleoptera have been repeatedly cited as classic examples supporting the CRH, based on numerous studies undertaken in Europe (see for examples Juberthie and Decu

1994 – 2001; Gibert and Deharveng 2002) and North America (Barr 1960; Peck 1984).

In remarking on Tasmania's diverse assemblage of specialized subterranean carabids, Moore (1965) postulated a linkage with Quaternary climate changes and glaciations, which he presumed was analogous to the situation in the northern hemisphere where the distribution limits of troglobitic beetle (and other invertebrate troglobite groups) dovetailed with limits of maximal Pleistocene glaciations. In North Temperate regions glaciated areas have a depauperate terrestrial cave fauna, and cave areas near glacial boundaries have an exceptionally diverse fauna (Culver and Pipan 2009). This mid-latitude biodiversity ridge (Culver et al 2006) is evident across continental Europe, Asia and North America, however it remains to be seen if this pattern is repeated in the southern hemisphere. Southern hemisphere mid-latitude land masses encompass South Africa, Australia (Tasmania), New Zealand and South America. While climate change mechanisms and processes may be essentially the same, and globally broadly synchronised, South Temperate regions are dominated by oceanic versus continental climatic influences. The main difference expressed during Quaternary glaciations was that the large northern hemisphere continental land masses experienced massive southward progressing ice sheets with well-demarcated ice-limit boundaries. While ice sheets developed in the comparatively smaller southern hemisphere land-masses of South America, New Zealand and Tasmania, oceanic proximity moderated temperatures and ice sheet development, while topographic heterogeneity promoted cirque and valley-style glaciation. In Tasmania this resulted in a complex mosaic of glacial ice limits, still incompletely mapped, thus complicating interpretation of present-day biodiversity distribution patterns. Terrestrial troglobitic faunas are known from each of the South Temperate land masses, albeit poorly described and mapped in comparison with Europe and North America. With addition of the new species described herein, we take this opportunity for a reappraisal of the 'Pleistocene effect' (CRH) in attempting to understand the present day distribution of Tasmanian cave beetles.

While Tasmania was known to be extensively glaciated in the Pleistocene, the rugged mountainous topography with strong altitudinal and longitudinal gradients in climate and vegetation have resulted in a complex glacial history with at least four pre-last Interglacial glaciations (Augustinus & Macphail 1997). The Last Glaciation was smaller than middle and early Pleistocene glaciations (=Pre-Last Glaciations), and during lowered sea levels of glacial periods Tasmania was a peninsula connected to the Australian mainland (Map 20).

The chronologies and finer scale complexities of ice extent and associated vegetation changes, and the geomorphic impacts of glaciation on karst, have been better elucidated in the last few years (eg. Augustinus and Macphail 1997; Colhoun, et al 1996, Eberhard, R. 1997; Kiernan et al 2001; Kirkpatrick & Fowler 1998). The Last Glaciation commenced after 26-25 ka BP, peaked at 19 ka BP and all known ice had decayed by 10 ka BP (Colhoun et al 1996). The snowline was lowered by about 1000 m, and mean temperature was depressed by about 6-6.5°C from present. Icecaps and associated outlet valley glaciers developed on the Central Plateau and West Coast Range, and isolated cirque glaciers formed leeward of mountain ranges in the east (Colhoun et al 1996) (Map 20).

Pre-Last glaciations were more extensive than the Last Glaciation, and involved a much more extensive icecap covering the Central Plateau and major valley outflow glaciers that extended nearly to the present northern coastline (Map 20). Mountain ranges in the south were also extensively ice covered, as well as Ben Lomond Plateau in the northeast. Differentiating the ice limits and chronologies of Pre-Last glaciations remains less well resolved than for the Last Glaciation, however the most extensive glacial event, the Bulgobac Glaciation, is early Pleistocene to latest Pliocene in age (Augustinus and Macphail 1997). Other glacial event(s) occurred in the middle Pleistocene.

Glacial/interglacial cycles involved profound changes in climate and vegetation. Interglacial climates were warmer with more effective precipitation and forest cover increased as the treeline advanced upslope. Glacial climates were colder and drier, and forest cover decreased as the treeline retreated and alpine vegetation expanded. Kirkpatrick & Fowler (1998) modelled vegetation changes at the height of the Last Glacial, which indicated that rainforest/wet eucalypt forest covered 7.2% compared with 71.3% at present. Conversely, alpine and grassland/grassy woodland covered 45.5 % and 32.5 % compared with 0.1 and 8.7% at present. Kirkpatrick & Fowler's (1998) model of the vegetation changes suggested that at the height of the Last Glacial, Tasmania was largely covered by alpine vegetation, grassland and grassy woodland, while rainforest was restricted to valleys near the present coast, some deep continental inland western valleys, and to tiny refugia in the east (Map 21). During earlier more extreme glaciations, the extent of al-

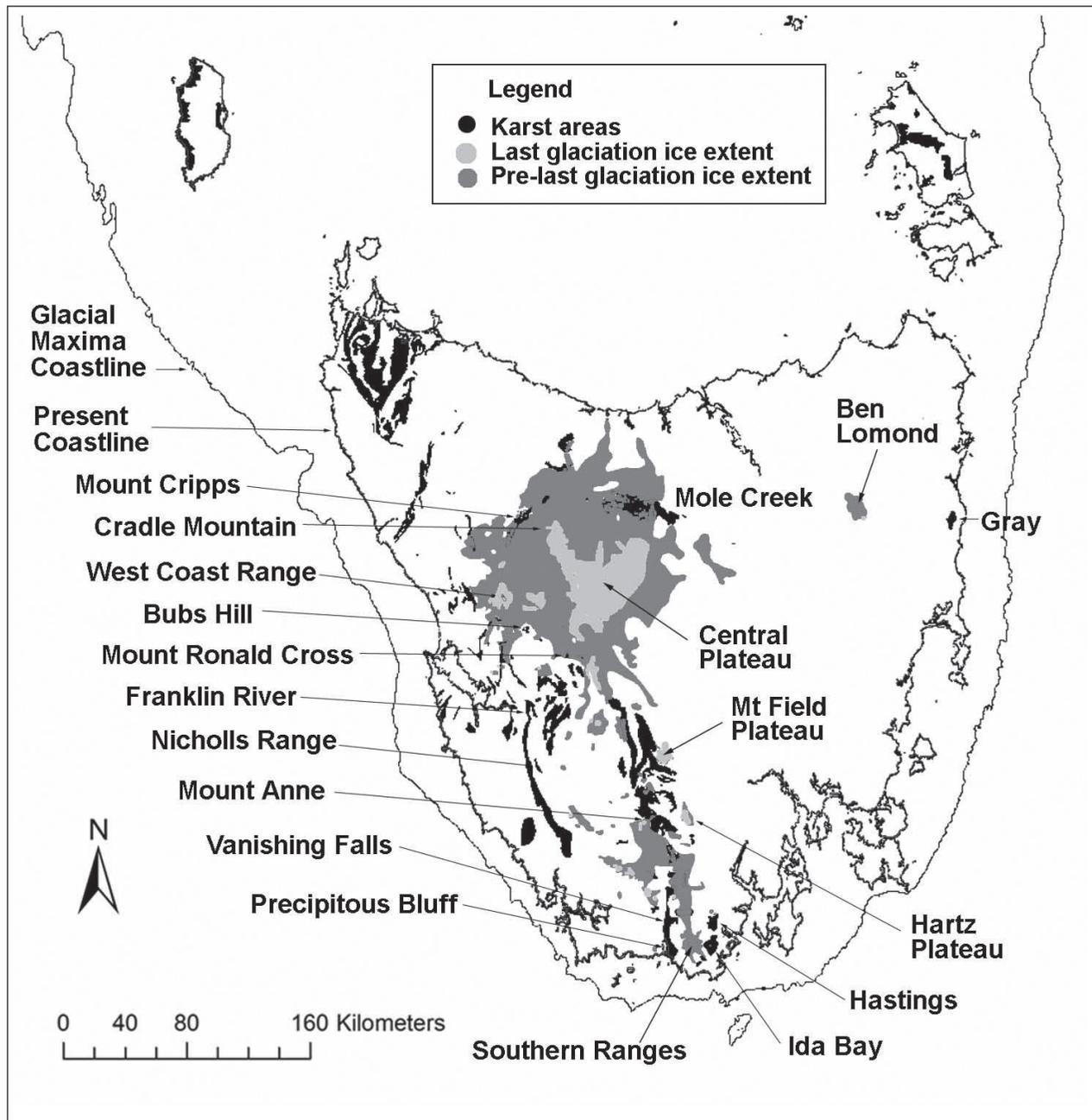
pine vegetation would have been greater, and the areas of rainforest refugia presumably even more contracted.

Probably upwards of one dozen Tasmanian karsts were overridden by glaciers during the Pleistocene, while others lay marginal to ice (Kiernan 1982). Some karsts, including Mole Creek, Mount Cripps and Mount Ronald Cross, were over-ridden by ice during the Pre-Last Glaciations but assumed marginal peri-glacial positions during the Last Glaciation (Map 20). It is therefore predicted that the present-day cave beetle fauna colonised these karsts after the Pre-Last Glaciation, possibly during the Last Glaciation when forest cover retreated from the karst and isolated the putative troglomorphic progenitors in caves. The troglobitic trechines in each of these three karst areas belong to moderately troglomorphic forms (*Tasmanotrechus*, *Tasmanorites*, *Idacarabus punctipennis*) consistent with a more recent derivation.

The centrally located karsts (Junee-Florentine and Bubs Hill) may not have been completely overridden by ice during any of the Pleistocene glaciations, however they were certainly profoundly affected by peri-glacial conditions and processes as they lay immediately marginal to glaciated massifs and would have been subjected to major changes in thermal, hydrological, sediment and vegetation regimes during cold climate episodes (Map 20). In the Junee-Florentine (and other glaci-proximal karsts) for example, the caves received inflows of proglacial meltwater laden with sediment which in-filled the caves, which were then partially re-excavated after return to milder conditions with lower clastic load (Goede 1973; Kiernan 1982). Speleothem dates indicate multiple episodes of sediment aggradation correlating with Last Glaciation and Pre-Last Glaciation, including > 350 ka (Eberhard 1997; Kiernan et al 2001).

How peri-glacial conditions and processes in the glaci-proximal karsts affected the subterranean habitat for beetles remains speculative, however it may help in explaining the absence of more highly troglomorphic, presumably older, cave colonists in the glaci-proximal karsts such as Mole Creek, Mount Cripps, Bubs Hill, Junee-Florentine, and Mount Anne (Maps 19 & 20). If older troglobites had existed in these karsts, it seems more probable they were extinguished during the more extreme Pre-Last Glaciations. Extinction of pre-existing forest and cave faunas during glacial periods would have provided unoccupied niches for new colonists during subsequent interglacials when the forests and forest fauna, including taxa with troglomorphic tendencies, recolonised deglaciated terrains including karsts.

Rainforest and wet eucalypt forest persisted in far-southern near-coastal areas during the height of the Last Glacial (Map 21), including in the vicinity of Ida Bay and Precipitous Bluff karsts where the highly troglomorphic *Goedetrechus mendumae* group is found. These karsts lie adjacent to the Southern Ranges which remained ice-free during the Last Glaciation (Map 20). The Southern Ranges were glaciated during Pre-Last Glaciations when

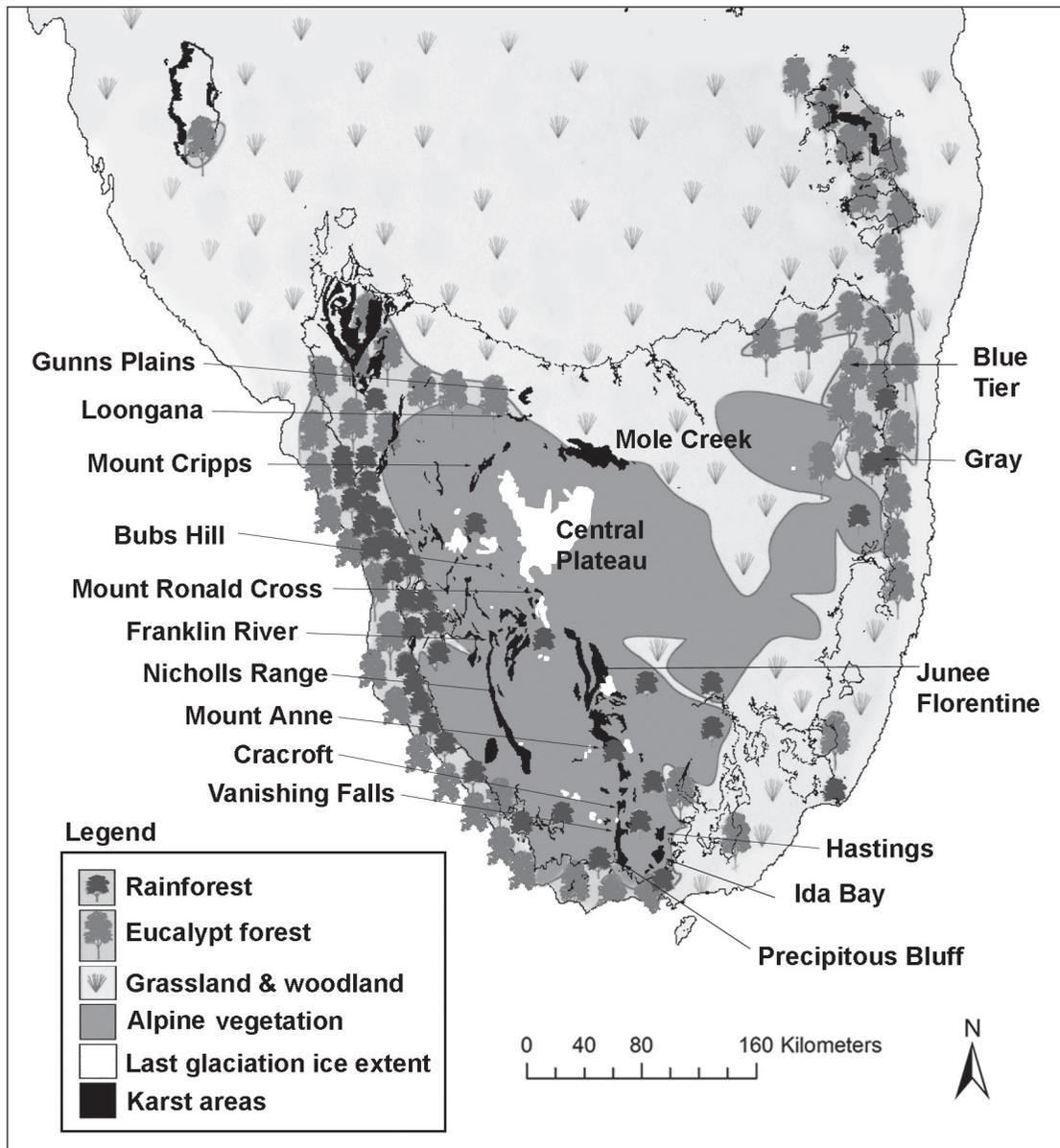


Map 20 - Tasmania showing present coastline and glacial maxima coastline, karst areas and ice extent in Last glaciatiion and Pre-Last glaciatiions. Karst and glacial data provided courtesy of Department of Industry & Water, Tasmania.

proglacial streams deposited extensive gravels in base level stream passages at Ida Bay, although higher level sections of this karst remained unaffected by sedimentation. Glacial and periglacial effects on Precipitous Bluff were comparatively mild compared to all other Tasmanian karsts, as evidenced by the paucity of sediment infilling in the caves there, and comparatively little evidence of cold climate freeze-thaw weathering processes such as dolerite talus slopes which characterise other dolerite-capped mountains in Tasmania.

For epigeal species whose present-day distribution range encompasses localities situated within the ice lim-

its of the Last Glaciatiion, then these populations must have colonised these localities post- Last Glaciatiion. Perhaps coincidentally there is a notable paucity of published collection records from within the Last Glaciatiion ice extent, although this may well be an artefact of limited sampling, especially inside the area of the Central Plateau ice-cap (Maps 19, 20). During glacial periods the ice-covered and peri-glacial Central Highlands and Southern Ranges would have formed an extensive barrier separating forested lowland habitats on the west and east sides of the island, as well as accentuating the disconnection between northern and southern lowland habitats



Map 21 - Tasmania showing modelled distribution of vegetation types at the height of Last Glacial (based on Kirkpatrick & Fowler 1998) and karst areas. Modified from map prepared by Dr Greg Jordan (University of Tasmania). Karst and ice data provided courtesy of the Department of Industry and Water, Tasmania.

(Maps 20, 21). This 'Pleistocene Effect' has been invoked to explain the east-west parapatric distribution patterns observed in epigeal genera of grasshoppers, frogs, freshwater decapods, and terrestrial amphipods, although some other faunal boundaries in Tasmania are less obviously congruent with (paleo-) climatic, topographic, geologic, or vegetation gradients (Mesibov 1994).

For populations whose present-day distribution lies outside the Last Glaciation ice limits, but within Pre-Last Glaciation limits, establishment of these populations must post-date the Pre-Last Glaciation(s). An apparent pattern of biodiversity hotspots, in both epigeal and hypogean carabid diversity, is suggested for mountainous localities situated just outside the Last Glaciation ice

limits but where peri-glacial conditions still occurred. Examples of peri-glacial localities with high epigeal species richness recorded are Cradle Mountain, Lake St Clair, Mount Field and Hartz Plateaux, and Ben Lomond (Table 1, Map 20). Similarly, high diversity in hypogean species is suggested for karsts located marginal to glaciated massifs, as demonstrated for Mole Creek and Mount Field (Junee-Florentine). Other glaci-proximal karsts known to contain troglobitic trechines include Mount Cripps, Bubs Hill, Mount Ronald Cross, Mount Anne, Vanishing Falls, Hastings and Ida Bay (Map 19). Exceptions to this pattern are evident, with troglobitic beetles apparently absent in other Tasmanian karsts with well-developed cave systems (eg. Loongana, Gunns Plains,

Cracroft) (Map 21), although it is noted that troglobitic trechines (cf. zolines) are rarely encountered during biological surveys, with most described species known from a single, or just a few, specimens. Because of their inherent rarity, additional survey effort in these and other glaci-proximal karsts is warranted.

When local hotspots are interpolated based on broad altitudinal topography, a gross contour of biodiversity richness may be inferred which roughly encircles the Central Plateau, and similarly, other glaciated massifs in the Southern Ranges IBRA including the Mt Field Plateau and the Hartz Plateau (Maps 19, 20, 21). Replicated sampling in strategically selected, geographically intermediate localities (including glaci-proximal and glaci-distal karsts) is required to test if the inferred patterns are real, or an artefact of patchy survey effort and historical sampling biases. In the meantime, the observed patterns are broadly consistent with North Temperate regions in respect of enhanced diversity near glacial boundaries (Culver and Papan 2009). Accordingly, we propose that present-day troglobitic Trechinae in Tasmania are derived from troglomorphic progenitors that colonised subterranean habitats from adjacent forest ground litter habitats during Pleistocene interglacial periods, while retreat of forests during glacial periods isolated subterranean populations from surface populations facilitating troglogenesis.

Subterranean colonisation by forest-dwelling (sylvicolous) versus alpine-dwelling (alticolous) progenitors is suggested by the present-day ecology of epigeal congeners of subterranean forms, which are predominantly sylvicoles (*Tasmanotrechus*, *Tasmanorites*, *Pterocyrtus*, *Goedetrechus*). While no epigeal forms of *Idacarus* are known, the present-day patterns in *Goedetrechus* spp. support the case for forest-dwelling progenitors in this lineage. All known species in this genus are hypogean, except for *G. talpinus*, which is described by Moore (1972) as endogean. This species has very reduced eyes and was collected from soil and humus at 600 m altitude on Blue Tier in northeast Tasmania, where the present-day vegetation is rainforest. Parts of northeast Tasmania seem to have maintained climates suitable for rainforest and wet eucalypt forest from the height of the Last Glacial to the present, and the Blue Tier refugium is almost certainly the source for re-colonization of the north-eastern highlands that now support large tracts of rainforest (Kirkpatrick and Fowler 1998). It seems probable therefore, that the now extinct surface ancestors of troglobitic *Goedetrechus* spp. in the southern karsts colonised caves from adjacent rainforest habitats during interglacial periods, with isolation of cave populations occurring when forests retreated during glacial periods.

In both *Tasmanotrechus* and *Goedetrechus*, typical troglomorphisms include progressive elongation of legs and antennae, and progressive reduction in body pigmentation and eye size. Other modifications are contrastingly different between genera, and are related to the shape of the pronotum, changes in body size, and degree of eye regres-

sion. Cave-dwelling *Tasmanotrechus* and *Goedetrechus* exhibit differing degrees of troglomorphic specialization, with cave-dwelling *Tasmanotrechus* spp. overall less-troglomorphic than cave dwelling *Goedetrechus* spp. The only other trechine genus exhibiting troglobitic tendencies is the speciose genus *Tasmanorites*, with a single known subterranean species, *T. microphthalmus* from the Mount Cripps karst. This species has well-developed troglomorphy albeit less specialized than *Goedetrechus* spp.

Excepting the singleton species *T. microphthalmus* the most highly troglomorphic Trechinae (*Goedetrechus* and *Idacarus*) are found in southern karsts, while central and northern karsts appear to be characterised by less troglomorphic genera and species (*Tasmanotrechus* and *Pterocyrtus*). Assuming that the degree of troglomorphy equates to time of isolation underground, it is hypothesised that the highly troglomorphic species group (*Goedetrechus mendu-mae* group) found in southern karsts (Ida Bay, Precipitous Bluff) represent an earlier phase of cave colonisation, while the less troglomorphic species groups (*Goedetrechus parallelus* and *Tasmanotrechus cockerilli* groups) found in the central (Junee-Florentine, Bubs Hill) and northern karsts (Mole Creek) represent more recent colonisation(s).

Idacarus spp. are distributional relicts represented entirely by subterranean forms, all from Southern Ranges karsts, with a single species in the centrally located Mount Ronald Cross karst. No representatives of this genus have been recorded from northern karst areas. In the southern karsts, Moore (1978) noted that the three species of *Idacarus* formed a graded series in terms of decreasing cave adaptation from northeast to southwest, and he suggested that this reflected time of isolation underground, and therefore also, timing of the onset of Pleistocene glaciation. Considering the relatively small geographic distance separating these three karsts (< 50 km) the timing of glacial onset is unlikely to have differed significantly, although time of isolation underground may have varied depending on which, of multiple Pleistocene glaciation(s), were the vicariant events. This question could be investigated using DNA 'molecular clock' methods.

The broad North-South differences in taxonomic representation, and degree of troglomorphy, do not obviously conform to the glacial history and/or palaeo-vegetation maps, hence we do not discount additional or alternative mechanisms to explain the observed patterns in cave dwelling beetles. We note that troglobitic trechines are not restricted to mid and high-altitude karsts which were more strongly influenced by glacial and peri-glacial conditions in the past. Troglobites are also present in low-altitude karsts geographically distant from glaciated mountains, notably the Gray karst in northeast Tasmania, and the Franklin River and Nicholls Range karsts in the West (Maps 19 & 20). In these karsts troglobitic trechines are represented by zoline species of *Pterocyrtus*, a genus which also holds several extant epigeal species which are a typical element of forest litter. The subterranean forms of *Pterocyrtus* are only weakly troglomorphic sug-

gesting they are more recent colonisers of subterranean habitats. Kirkpatrick and Fowler's (1998) model suggests that during the Last Glaciation the Franklin River and Nicholls Range karsts were covered by alpine vegetation, whereas the Gray karst maintained climates suitable for rainforest and wet eucalypt forest (Map 21).

Overall, a broad-scale phylogeographic pattern in Tasmanian cave beetles is suggested which involves more highly troglomorphic forms in southern karsts, and less-troglomorphic forms in western, central and northern karsts. Interestingly, this pattern of troglomorphic adaptation is also suggested in several other invertebrate groups with cave dwelling representatives, including: dalodesmid millipedes (Mesibov 2005); hydrobiid molluscs (Ponder 1992; Ponder et al 2005); triaenonychid harvestmen (Hunt 1990; Hunt & Hickman 1993); synotaxid (Forster et al 1990), amphinectid (Davies 2003) and micropholcommatid (Rix & Harvey 2010) spiders.

This study has rekindled our interest in four fundamental questions: (1) Is the degree of troglomorphy and apparent heterochronous colonisation exhibited by sympatric subterranean congeners concordant with the palaeoclimatic history?; (2) What is the evidence of Pleistocene glacial / inter-glacial influences on distribution patterns of other Tasmanian invertebrate groups, including epigeal and hypogean species?; (3) To what extent do the observed patterns support or reject the "Climatic Relict Hypothesis" (see Holsinger 2000) or the "Adaptive Shift Hypothesis" (see Howarth 1987) in driving the evolution of hypogean and epigeal species?; (4) To what extent does the cave fauna described to date represent the tip of the iceberg in relation to non-karstic MSS / SSH subterranean biodiversity?

Future research should focus on systematic field surveys of both karst and MSS/SSH habitats to elucidate the phylogeographic patterns in selected taxa and test how the observed distributions fit with the processes and chronology of Pleistocene glacial / inter-glacial cycles. Alternative, or additional, environmental mechanisms driving troglomorphogenesis need to be considered. Investigations should not be limited to subterranean taxa and their related epigeal relatives, they should also embrace taxa without subterranean connections. Undoubtedly future serious collecting efforts will reveal many additional new subterranean species, including from previously well-collected caves and karst areas, not to mention the many caves, karsts and non-karstic MSS habitats that remain to be surveyed. We conclude that a crucial element, biogeographically and palaeoclimatically, of Australia's rich hypogean and endogean biodiversity, hitherto only recently recognised as globally significant (Humphreys 2008; Guzik et al 2010), lies undiscovered beneath Tasmania's dark forests.

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New species of scuttle flies (Diptera: Phoridae) recorded from caves in Nevada, USA

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ABSTRACT

Five new species of scuttle fly are reported from caves in Nevada, USA, namely *Aenigmatias bakerae* Disney, *Megaselia excuniculus* Disney, *M. krejcae* Disney, *M. folliculorum* Disney, *M. neupleuralis* Disney and a female *Megaselia* that can not be named until linked to its male.

Key words: Diptera, Phoridae, new species, caves, USA

INTRODUCTION

Our knowledge of the scuttle flies (Diptera: Phoridae) reported from subterranean habitats in the USA has been recently expanded along with a revision of some of the identities and nomenclature for the records from the 19th and 20th centuries (Disney et al 2010). Subsequent records (Disney & Campbell 2011) extended our knowledge of the most common of these species. It was therefore surprising when a biological survey of caves and a mine in White Pine County, Nevada produced an entirely new list of species, all but one of which proved to be undescribed. The new species are described below.

METHODS

The specimens were collected by hand and were preserved in alcohol (70-80% ethanol) and were mounted on slides in Berlese Fluid (Disney 2001) and described by RHL. The morphological terms employed in the descriptions are based on those covered by Disney (1994), with some amendments (Disney et al 2010).

RESULTS

The depository for the specimens is the University of Cambridge Museum of Zoology (UCMZ).

Aenigmatias Meinert, 1890

A dozen species are known from the Nearctic and Palearctic Regions. The males are keyed by Disney (2002) and some females are covered by Borgmeier (1963), Schmitz (1955) and Disney (1993).

Aenigmatias bakerae Disney, sp. nov.

Description

Male. A generally brown species. Frons with a pair of pre-ocellar bristles level with the anterior ocellus and in front of the posterior ocelli. Postpedicels brown and arista very short haired (appearing bare at low magnifications). Palps brown and each with 7 bristles at its tip. Thoracic scutellum with 7 bristles each side. Abdominal tergites with short hairs dorsally but longer ones at sides, the longest being on T6. Hypopygium as Fig. 1a. Venter grey. All legs brown. Front tibia and tarsus as Fig. 1b. Mid tibia with an anterior hair palisade in addition to the dorsal one; and likewise the hind tibia, but it has 2-3 gaps. Wings 1.9-2.0 mm long. Costal index 0.49. Costal ratios 6.5 : 1.5 : 1. Costal cilia 0.03-0.04 mm long. 11 hairs on Rs, Vein Sc vestigial. 6 bristles on axillary ridge. All veins brown but 7 pale. Veins 4-7 do not reach wing margin, and in the case of 7 the outer third is missing. Membrane lightly tinged grey. Haltere brown.

Material

Holotype male, NEVADA: White Pine Co., Pine Cone Cave, 17 July 2007, J. K. Krejca, M. Horner, M. E. Slay, C. M. Slay and B. Roberts (470 NPS-GRBA, Project 411, Catalog 7157) (UCMZ, 31-131).

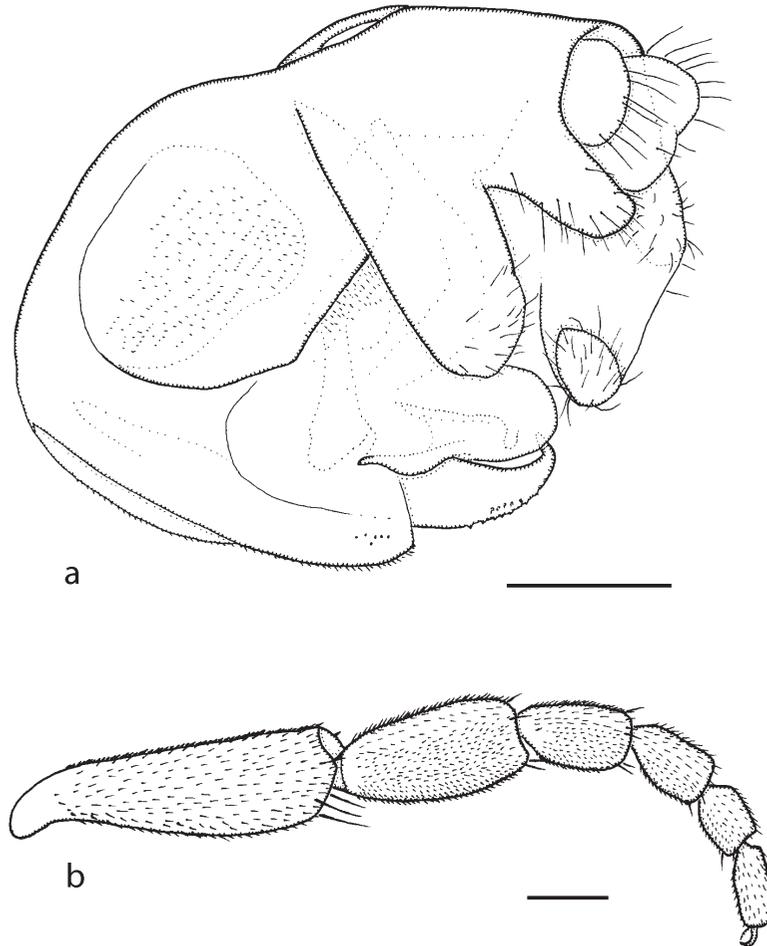


Fig. 1. *Aenigmatias bakerae* sp. nov. male. a, left face of hypopygium; b, front tarsus. Scale bars = 0.1 mm.

Habitat

Pine Cone Cave is at an elevation of 3020 m, and the specimen was collected in the cave on a dry bedrock wall.

Etymology

Named after Gretchen Baker (ecologist at the Great Basin National Park) who played a major role in seeing this project through to the end, as well as taking

Lead role in field visits and collections.

Recognition

In the key to males (Disney, 2002c) it runs to couplet 6 but is distinguished from the two species of this couplet by its thicker front basitarsi and by the details of the hypopygium.

Megaselia Rondani. 1856

The Nearctic species of this giant genus are still poorly known. Borgmeier (1964, 1966) provides baseline keys. Subsequent revisions and additions are summarized by Disney (1994). Further additions are covered by Disney (2004, 2008), Disney et al (2009) and Disney et al (2010).

Megaselia excuniculus Disney, sp. nov.

Description

Male. Frons brown, clearly broader than long, with 60-64 hairs and fairly dense but very fine microtrichia. Supra-antennal bristles (SAs) with the lower pair a little shorter and less robust than upper pair. The antials a little lower on frons than anterolaterals (ALs), and about twice as far from upper SAs as either is from an AL bristle. Pre-ocellars a little closer together than either is from a mediolateral bristle, which is slightly higher on frons. Cheek with 4 bristles and jowl with two that are longer. The subglobose postpedicels brown, without subcutaneous pit sensilla (SPS) vesicles. Palps pale yellow, at most 0.4 times as broad as postpedicel, with 3 long, 1 medium and 3 short bristles and 8 hairs. Labrum dusky straw yellow and about 0.8 times as wide as a postpedicel. Labella pale apart from pale brown bands dorsally towards sides, with only a few short spinules below and their combined widths about 1.2 times as wide as a postpedicel. Thorax brown. Three notopleural bristles and no cleft in front of these. Mesopleuron with 11-12 hairs. Scutellum with an anterior pair of hairs (about as long as those in middle of scutum) and a pos-

terior pair of bristles. Abdominal tergites brown with small hairs except for longer one at rear of T6 (Fig. 2b). Venter grayish brown, and with hairs on segments 5 and 6 (Fig. 2b). Hypopygium brown, with a yellow brown anal tube, and as Fig. 2. Legs mid and hind femora brown, front femora pale brown and front tibiae and all tarsi straw yellow. Fore tarsus with posterodorsal hair palisade on segments 1-5 and 5 longer than 4. Dorsal hair palisade of mid tibia extends about 0.6 times its length. Hairs below basal half of hind femur a little longer than those of anteroventral row of outer half. Hind tibia with 15-17 only weakly differentiated posterodorsal hairs and spinules of apical combs simple. Wings 1.9 mm long. Costal index 0.40. Costal ratios 4.4 : 1.1-1.2 : 1. Costal cilia (of section 3) 0.12-0.13 mm long. No hair at base of vein 3. With 3 axillary bristles, the outer being slightly shorter than costal cilia. Sc not reaching R1. Thick veins and thin veins 4-6 yellowish brown and 7 paler. Membrane very lightly tinged grey (not evident to naked eye when viewed against a white background). Haltere brown.

Material

Holotype male, NEVADA: White Pine Co., Lincoln Mine, 15 July 2007, S. J. Taylor, J. K. Krejca, M. E. Slay, C. M. Slay (421 NPS-GRBA, Project 411, Catalog 6873) (UCMZ, 31-132)

Habitat

Lincoln Mine is located at an elevation of 2621 m. The species was collected on a dry bedrock wall in the entrance zone, where the air temperature was 9.7 °C, soil temperature was 10.8 °C, relative humidity was 52.5%, and ambient light was 1755 lux.

Etymology

The name means from a mine.

Recognition

In the keys of Borgmeier (1964) this species will run to couplet 4 or couplet 7 on page 268, where none of the options apply. It also fails to run down in the keys for other regions.



Fig. 2. *Megaselia excuniculus* sp. nov. male hypopygium. a, right face; b, left face. Scale bar = 0.1 mm.

Megaselia krejcae Disney, sp. nov.*Description*

Male. Frons brown, clearly broader than long, with 24-30 hairs and numerous but very fine microtrichia. Supra-antennal bristles (SAs) with the lower pair clearly shorter and less robust than upper pair. The antials a little lower on frons than anterolaterals, which are very slightly lower than the upper SAs, and at least 3 times as far from upper SAs as either is from an AL bristle. Pre-ocellars slightly closer together than either is from a mediolateral bristle, which is at about the same level on frons. Cheek with 5 bristles and jowl with 2 that are longer. The subglobose postpedicels brown, with about 3 dozen SPS vesicles, the larger being about the same size as the sockets of the lower SAs, and each embraces several small vesicles. Palps with a short brown basal segment and the second segment mainly brown but mostly yellow in the basal third. They are at most two fifths as broad as postpedicel, with 5 long bristles, 2 short bristles and 7-10 hairs. Labrum brown and about 0.6 times as wide as a postpedicel. Labella largely pale apart from brown bands dorsolaterally, together about 0.8 times as broad as a postpedicel, and with very few short spinules below. Thorax brown. Three notopleural bristles and no cleft in front of these. Mesopleuron bare. Scutellum with an anterior pair of hairs (about as long as those in middle of scutum) and a posterior pair of bristles. Abdominal tergites brown with fine hairs that are a little longer at the rear of T6. Venter brownish grey, and with fine hairs on segments 5 and 6 only. Hypopygium mainly brown, with a paler brown anal tube, and as Fig. 3. Legs brown. Fore tarsus with weak posterodorsal hair palisades on segments 1 and 2, but these are vestigial on segments 3-5, and 5 slightly longer than 4. Dorsal hair palisade of mid tibia extends about 0.7 times its length. Hairs below basal half of hind femur longer than those of anteroventral

row of outer half. Hind tibia with about 20 only moderately differentiated posterodorsal hairs and spinules of apical combs simple.

Wings 1.7 mm long. Costal index 0.40. Costal ratios 3.8-3.9 : 1.3-1.4 : 1. Costal cilia (of section 3) 0.14-0.15 mm long. A very small hair at base of vein 3. With 4 axillary bristles, the outer being shorter than costal cilia. Sc reaching R1. All veins light brown but costa more yellowish. Membrane only slightly tinged grey (not evident to naked eye when viewed against a white background). Haltere knob yellow.

Material

Holotype male, NEVADA: White Pine Co., Cave 24, 17 July 2007, G. M. Baker, S. J. Taylor (459 NPS-GR-BA, Project 411, Catalog 7074) (UCMZ, 31-132).

Habitat

Cave 24 is located at an elevation of 3013 m. The species was collected on the cave floor in a mixture of soil, pine needles, and rocks, in the twilight zone, where the air temperature was 6.6 °C, soil temperature was 5.5°C, relative humidity was 82.6%, and ambient light was 120 lux.

Etymology

Named after Jean Krejca.

Recognition

In the key of Borgmeier (1966) it runs to couplets 7 lead 2 or couplet 10 lead 1, as at couplet 5 the separation is between species with bristles on the epandrium and those with hairs only. With *M. krejcae* there are hairs and two very short bristles on the left side but hairs only on the right side. At both couplets the hypopygium is obviously different, the very short anal tube being especially noteworthy.

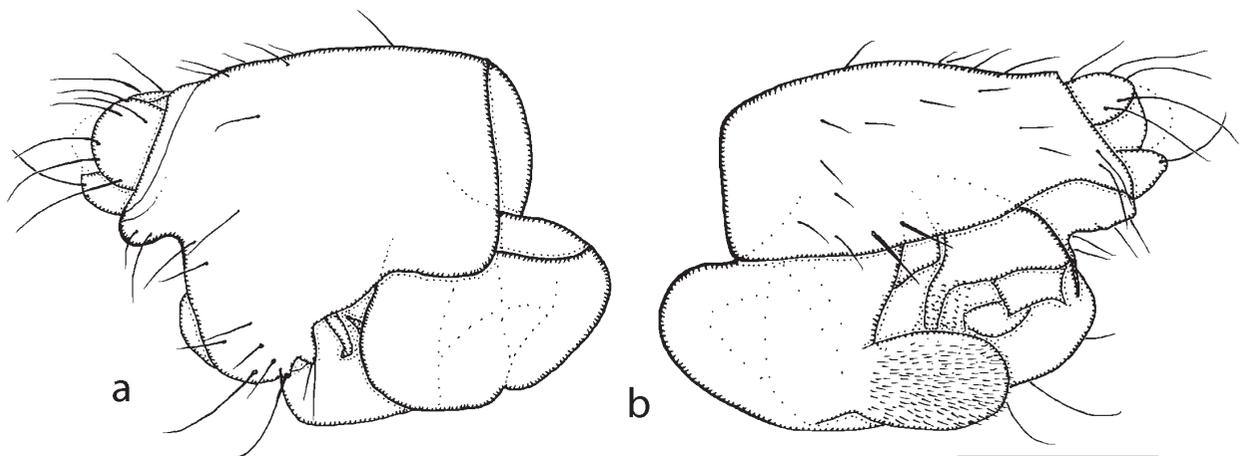


Fig. 3. *Megaselia krejcae* sp. nov. hypopygium. a, right face; b, left face. Scale bar = 0.1 mm.

Megaselia folliculorum Disney, sp. nov.*Description*

Male. Frons brown, clearly broader than long, with 80-88 hairs and not very dense but very fine microtrichia. Supra-antennal bristles (SAs) with the lower pair not quite as robust and long as upper pair. The antials lower on frons than anterolaterals, and about as far from upper SAs as either is from an AL bristle. Pre-ocellars about as far apart as either is from a mediolateral bristle, which is at about the same level on frons. Cheek with 5 bristles and jowl with two that are longer. The subglobose postpedicels brown, with 1-2 small SPS vesicles. Palps with a short brown basal segment and pale dusky yellow segment 2, which has 3 long bristles at tip (longer than upper SAs), 5-6 short bristles and up to 10 hairs. Labrum dusky straw yellow and about 0.8 times as wide as a postpedicel. Labella coloured as labrum, about 1.2 times as wide as a postpedicel and with only a few short spinules below. Thorax brown. Three notopleural bristles and no cleft in front of these. Mesopleuron bare. Scutellum with an anterior pair of hairs (about as long as hairs in front of prescutellar dorsocentral bristles) and a posterior pair of bristles. Abdominal tergites brown with numerous fine hairs and longer ones at rear of T6. Venter brownish grey, and with fine hairs on segments 3-6. Hypopygium mainly brown, including the paler brown anal tube, and as Fig. 4. Legs brown to yellowish brown with the front legs being paler than the rest. Fore tarsus with posterodorsal hair palisade on segments 1-4 and basitarsus with 1 to 1.5 rows of hairs below reduced to small spinules. Dorsal hair palisade of mid tibia extends at most two thirds of its length. Hairs below basal half of hind femur about as long as those of anteroventral row of outer half. Hind tibia with at least 16 differentiated posterodorsal hairs and spinules of apical combs simple. Wings 1.6-1.7 mm long. Costal index 0.37. Costal ratios 6.0 : 1.5-1.6 : 1. Costal cilia (of section 3) 0.11-0.12 mm long. Two very small hairs at base of vein 3. With 3 axillary bristles, the outer being about as long as costal cilia. Sc not reaching R1. Thick veins yellowish brown thin veins 4-6 light brown and 7 paler. Membrane lightly tinged grey (just evident to naked eye when viewed against a white background). Haltere knob light brown.

Female. Head similar to male but labrum brown and about as wide as diameter of postpedicel. Otherwise head similar to male. Thorax as male. Abdominal tergites brown and T5-T7 as Fig. 5b. Venter brown, with hairs below segments 3-6, and below the spiracles on segment 4 there is an eversible balloon shaped structure. Sternite 7 very narrow, with 6 small hairs and 3 longer ones at its slightly wider rear end. Posterolateral lobes at rear of sternum 8 pale brown and as Fig. 5a. Cerci pale brown and about 2.8 times as long as broad. Furca not evident. Dufour's crop mechanism pale, narrow in posterior half, and more than 4 times as long as its greatest breadth. Legs similar to male. Wing as male except 1.9-2.0 mm long. Costal index 0.39. Costal ratios 3.4-5.3 : 1.0-1.8 : 1. Costal cilia 0.12 mm long. A single hair or none at base of vein 3. With 4-5 axillary bristles, the outermost being longer than costal cilia. Otherwise it and haltere as male.

Material

Holotype male, NEVADA: White Pine Co., Cave 24, 17 July 2007, G. M. Baker, S. J. Taylor (459 NPS-GRBA, Project 411, Catalog 7073) (UCMZ, 31-132). Paratypes: 1 female as holotype except (457, Catalog 7141) (UCMZ, 31-131); 1 female, Lincoln Mine, 15 July 2007, S. J. Taylor, J. K. Krejca, M. E. Slay, C. M. Slay (423 NPS-GRBA, Project 411, Catalog 6886) (UCMZ, 31-132).

Habitat

This species was collected at two sites, ranging from 2621 m (Lincoln Mine) to 3013 m (Cave 24) elevation. The species was collected on cave floors in the entrance and twilight zones, where the air temperature ranged from 6.6-9.7°C, soil temperature ranged from 5.5-10.8°C, relative humidity ranged from 52.5-82.6%, and ambient light ranged from 120-1755 lux.

Etymology

The name refers to the balloon like structures on the sides of the female's abdominal segment 4.

Recognition

In the key of Borgmeier (1966) as the haltere knob is dusky yellow to yellowish brown, the male runs to cou-

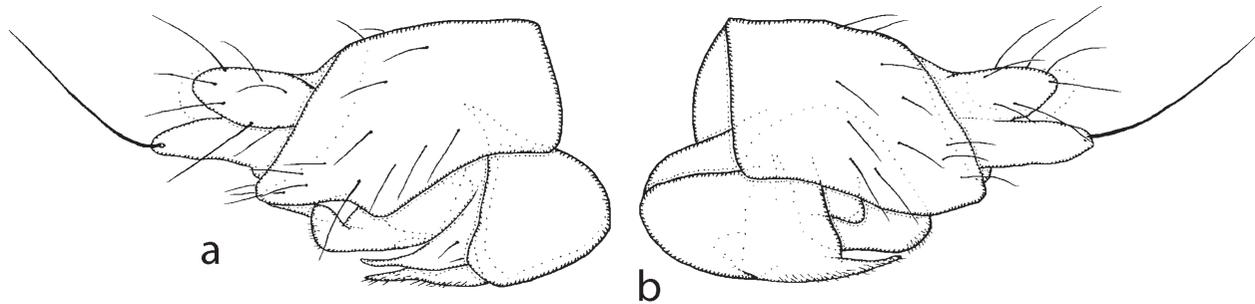


Fig. 4. *Megaselia folliculorum* male hypopygium. a, right face; b, left face. Scale bar = 0.1 mm.

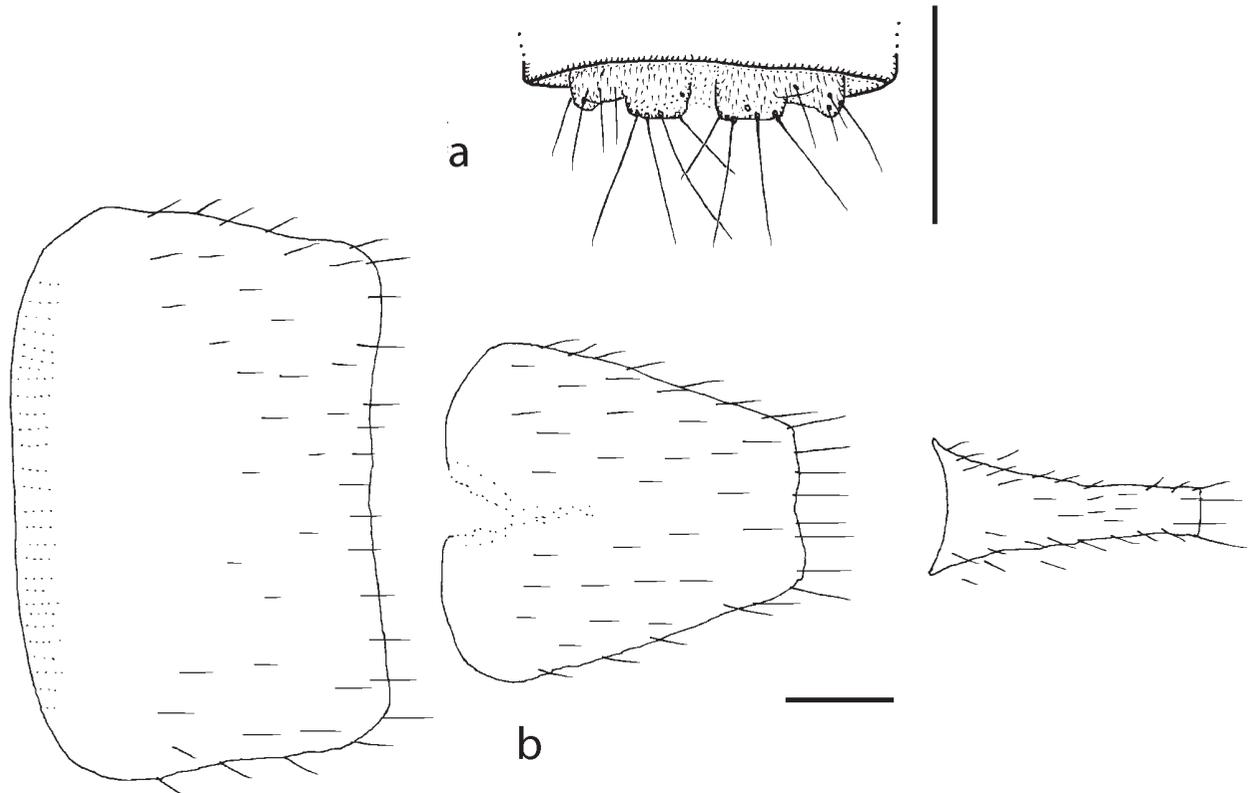


Fig. 5. *Megaselia folliculorum* sp. nov. female, details of abdomen. a, lobes at rear of ventral face of segment 8; b, tergites 5-7. Scale bars = 0.1 mm.

plet 11 lead 2 on page 6 or to couplet 18 lead 2 on page 7. It is immediately distinguished from *M. brevicostalis* (Wood) by the presence of 3 bristles on the notopleuron, as opposed to 2 preceded by a notopleural cleft. Furthermore Wood's species is generally much darker. At couplet 18 *M. folliculorum* closely resembles *M. huachuca* Borgmeier, but the latter has a dark brown haltere knob and only 2 axillary bristles, as opposed to 3 in the male and 4 in the females of *M. folliculorum*. Females cannot be run through Borgmeier's key unless one refers to the males because several couplets are based exclusively on male features.

Megaselia necpleuralis Disney, sp. nov.

Description

Male. Frons brown, clearly broader than long, with 40-44 hairs and dense but fine microtrichia. The lower supra-antennal bristles (SAs) almost as long as upper pair and about as far apart as either is from an antial bristle situated at about the same level. The antials about the same level, and 2-3 times as far from upper SAs as either is from an AL bristle. Pre-ocellars slightly closer together than either is from a mediolateral bristle, which is at about the same level on frons. Cheek with 5 bristles and jowl with 2 that are longer and more robust. The subglobose postpedicels brown and without SPS vesicles. Palps

pale dusky yellow, at most two thirds as broad as postpedicel, with 5 moderately long bristles, 1-2 very short bristles and up to 10 hairs. Labrum coloured and about as wide as a palp. The two labella combined about 1.7 times as wide as a postpedicel, each with a brown band dorsally and with numerous short spinules below. Thorax brown. Three notopleural bristles and no cleft in front of these. Mesopleuron with 3-8 hairs and a clearly differentiated bristle near hind margin. Scutellum with an anterior pair of hairs (shorter than those at rear of scutum) and a posterior pair of bristles. Abdominal tergites brown with hairs, which are longer at rear of T6. Venter grayish brown, and with hairs on segments 3-6. Hypopygium with brown epandrium and hypandrium, apart from latter's posterior lobes which are straw yellow, with a pale brown anal tube, and as Fig. 6. The right paraphysis of the penis complex as Fig. 7. Legs brown to yellowish brown, the front legs being palest but with the fifth tarsal segment brown. Fore tarsus with posterodorsal hair palisade on segments 1-4 and 5 a little longer than 4. Dorsal hair palisade of mid tibia extends about 0.7 times its length. Hairs below basal half of hind femur shorter than longest hairs of anteroventral row of outer half. Hind tibia with about a dozen differentiated posterodorsal hairs, which are weakly differentiated in the basal third, and spinules of apical combs simple. Wings 2.3-2.6 mm long. Costal index 0.47-0.48. Costal ratios 3.5-4.4 : 2.7-3.7 : 1.

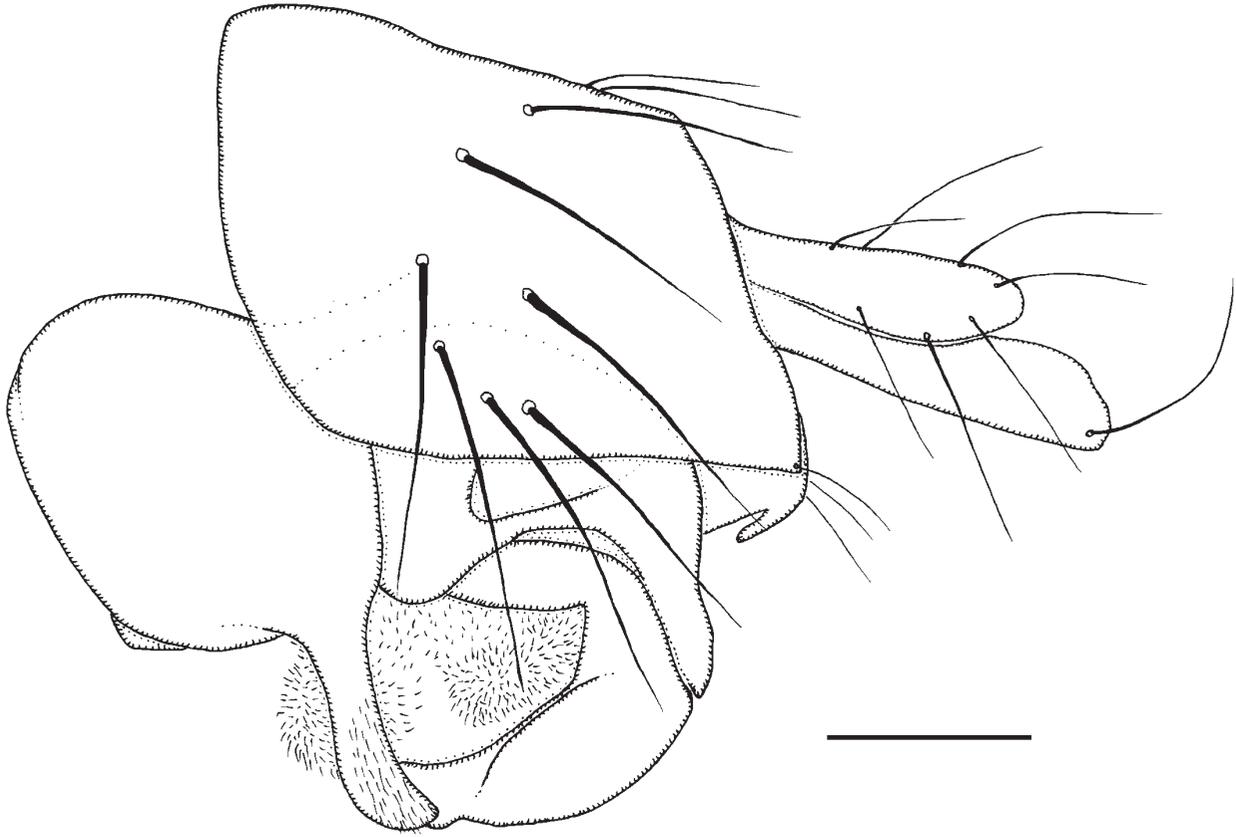


Fig. 6 *Megaselia necpleuralis* sp. nov. male, left face of hypopygium. Scale bar = 0.1 mm.

Costal cilia (of section 3) 0.19 mm long. Hair at base of vein 3. With 6-7 axillary bristles, the outer being a little shorter than costal cilia. Sc not reaching R1. Thick veins brown but costa more yellowish brown, thin veins brown but 7 paler and more grey. Membrane lightly tinged grey, being darkest towards leading edge beyond costa (just evident to naked eye when viewed against a white background). Haltere with brown stem and yellow knob.

Material

Holotype male, NEVADA: White Pine Co., Great Basin National Park, Lehman Cave, under natural entrance, 3 May 2010, G. M. Baker (UCMZ, 31-133). Paratype male as holotype.

Habitat

Lehman Cave is located at an elevation of 2096 m. The species was collected in the twilight zone, where the air temperature was 9.6 °C, soil temperature was 10.0°C, and relative humidity was 78.5%.

Etymology

Named after its close resemblance to *M. pleuralis* (see below).

Recognition

In the key of Borgmeier (1964) this species runs to couplet 11 on page 264, where it is excluded by the much

shorter hairs below the basal half of the hind femur. At couplet 8 on page 263 it is seemingly excluded from being *M. pleuralis* (Wood) because its costal index is less than 0.5. However, this distinction is not valid as the costal index of Palaearctic specimens of *M. pleuralis* ranges from 0.47 to a little over 0.52 or more. The new species is indeed very similar to the Holarctic *M. pleuralis*, whose type series was from England. In view of this 4 males of Nearctic voucher specimens of this species listed by Borgmeier were borrowed by RHL, through the co-operation of Dr Brian Brown (Natural History Museum, Los Angeles), and were remounted on slides. These specimens were from Glen Echo, Mt Rainer, Priest Lake (Lookout Mountain) and Rock Creek. Their costal indexes range from 0.48 to almost 0.52 (mean 0.49), thus confirming the observed variation in Palaearctic specimens of this species.

The hypopygia of the new species closely resembles that of *M. pleuralis* (cf Figs 6 and 8). The two species are best distinguished by the details of the penis complex. However, these structures vary in appearance when viewed from different angles, as evidenced by their rotation when withdrawn or extruded (cf Fig. 8 and 9). Nevertheless the larger of the two heavily sclerotised paraphyses (P2 in Fig. 9) is clearly different in the two species (cf. Figs 7 and 10). Furthermore, this paraphysis allows confirmation that Borgmeier's voucher specimens belong *M. pleuralis* and that the Nevada specimens are a new, sibling species.

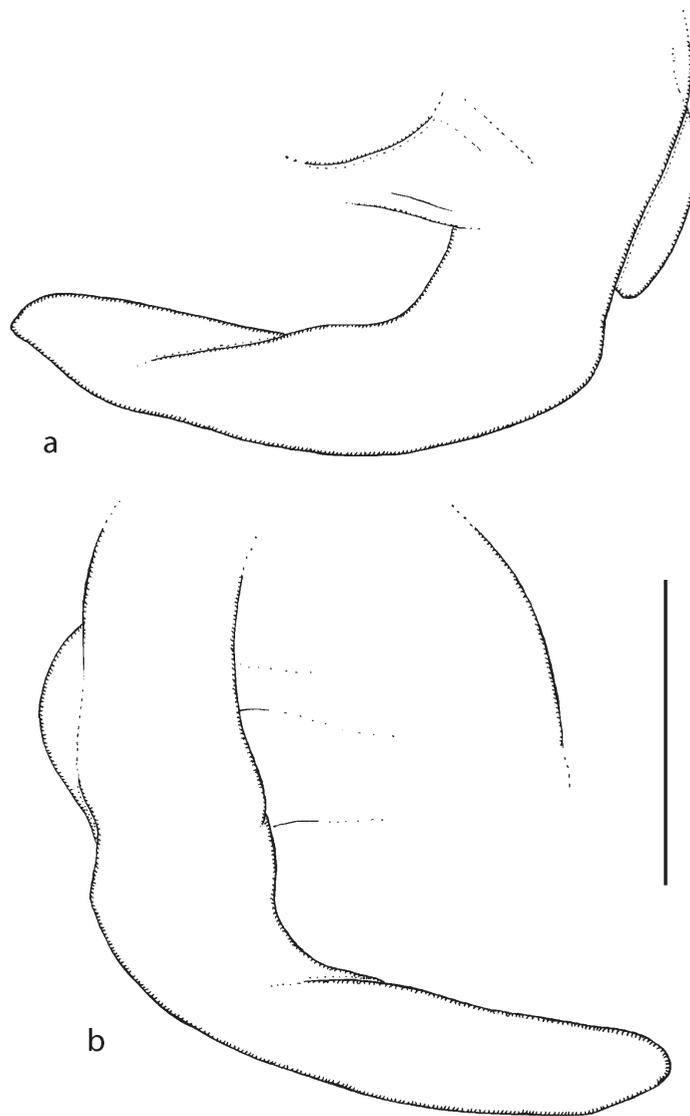


Fig. 7. *Megaselia necpleuralis* sp. nov. male, right paraphysis of penis complex when withdrawn. a, left face; b, right face. Scale bar = 0.1 mm.

Megaselia sordida (Zettersted)

Trineura sordida Zetterstedt, 1838: 796.

Trineura carbonaria Zetterstedt, 1848: 1848.

Aphiochaeta alaskensis Malloch, 1919: 52.

Aphiochaeta scaura Schmitz, 1921: 322.

Megaselia semiscaura Schmitz, 1927: 130.

Megaselia eminens Schmitz, 1953: 219. Disney,
1985: 246.

Remarks

In the keys of Borgmeier (1964) the males readily run to couplet 15, on page 266, to *M. alaskensis* (Malloch), a synonym of *M. sordida* (Zetterstedt), apart from its palps being yellow to dusky yellow. However, the palps of *M. sordida* range from being yellowish brown to grayish brown. Furthermore the legs, wings and colouring

in general are paler than typical *M. sordida*. However, smaller specimens from Europe tend to have paler wings. The specimens from Nevada are at the lower end of the range of variation in size for this species. Although the legs are unusually pale for this species the male hypopygium is indistinguishable from typical *M. sordida*.

Material

1 male, NEVADA: White Pine Co., Fissure Cave, 16 July 2007, B. Roberts, M. E. Slay, C. M. Slay (447 NPS-GRBA, Project 411, Catalog 7039) (UCMZ, 31-131); 1 male, Lincoln Mine, 15 July 2007, S. J. Taylor, J. K. Krejca, M. E. Slay, C. M. Slay (421 NPS-GRBA, Project 411, Catalog 6872) (UCMZ, 31-132); 1 female, Broken Cave, 16 July 2007, M. Baker, G. M. Baker, B. Roberts, M. Horner (442 NPS-GRBA, Project 411, Catalog 6993) (UCMZ, 31-128).

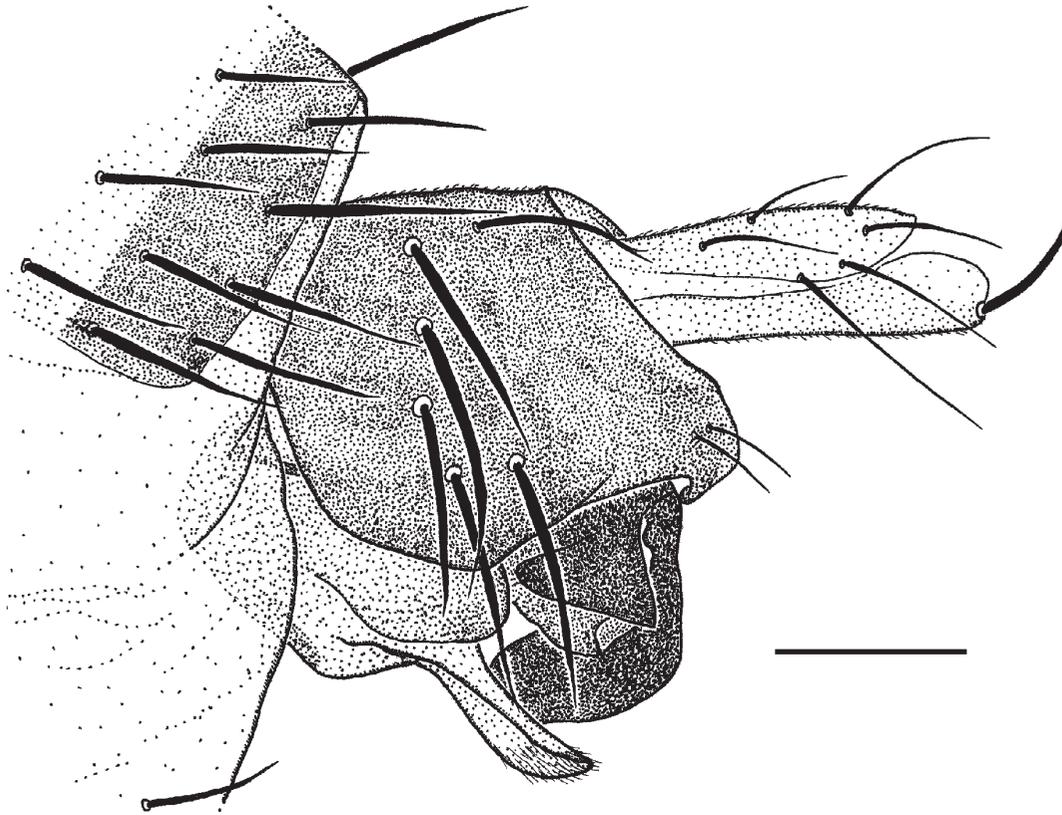


Fig. 8. *Megaselia pleuralis* male, left face of hypopygium. Scale bar = 0.1 mm.

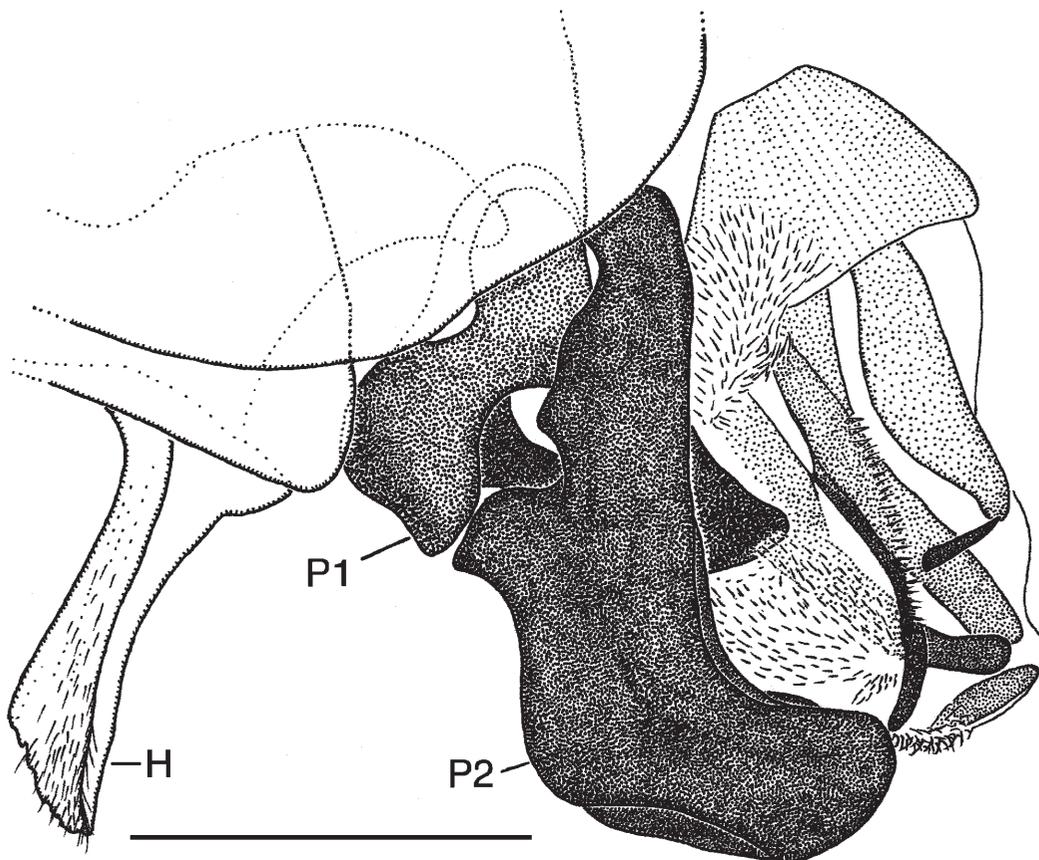


Fig. 9. *Megaselia pleuralis* male, left face of penis complex when extruded (H = left lobe of hypandrium, P1 and P2 = left and right paraphyses). Scale bar = 0.1 mm.

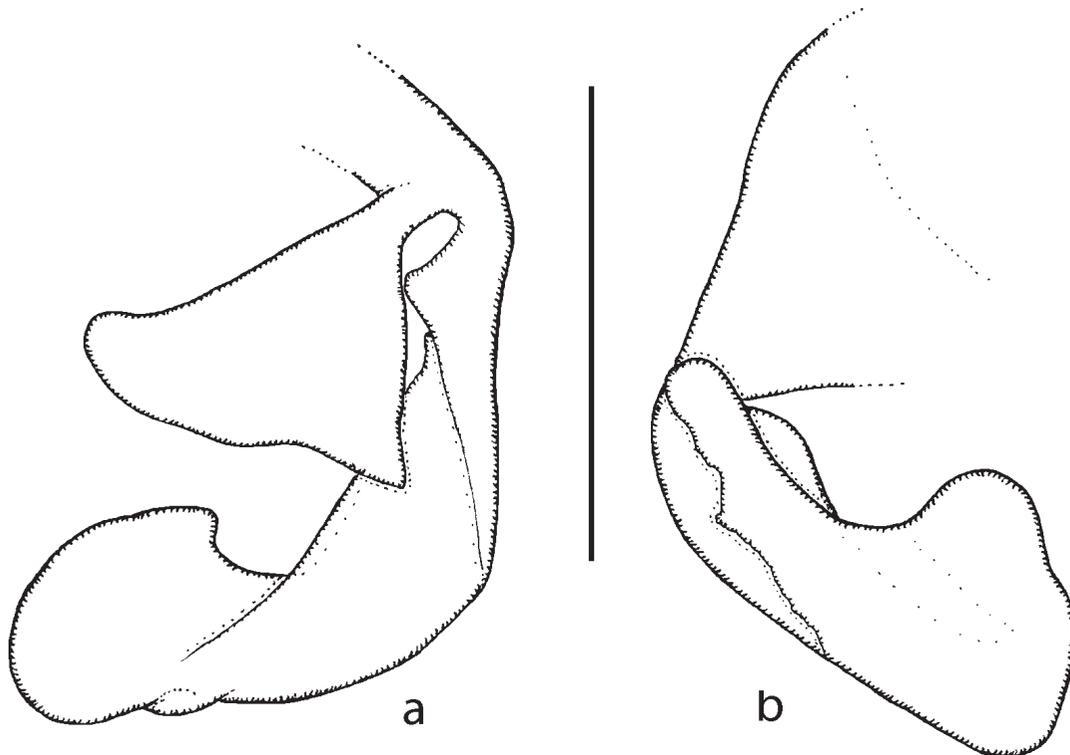


Fig. 10. *Megaselia pleuralis* male, paraphyses of penis complex when withdrawn. a, left face; b, right face of right (larger) paraphysis. Scale bar = 0.1 mm.

Habitat

This species was collected from three sites, ranging from 2621 m (Lincoln Mine) to 3407 m (Broken Cave) elevation. The species was collected on bedrock walls in the entrance and twilight zones, where the air temperature ranged from 9.7-13.9 °C, soil temperature ranged from 10.8-12.1 °C, relative humidity ranged from 52.5 to 52.5-59.2%, and ambient light ranged from 198-1755 lux.

Megaselia species A

Remarks

This cannot be named until linked to its male.

Female. Frons brown and clearly wider than long. The antials closer to anterolaterals than to upper SAs and the lower pair of latter about as strong. Postpedicels subglobose and with at least a dozen SPS vesicles. Palps are mainly brown but with a contrasting yellow patch in their basal halves, and with 5 strong bristles at tip, 1-3 shorter ones behind and about a dozen small hairs. The brown labrum about 1.3 times as broad as a postpedicel. The pale labella combined only about 0.8 times as wide as a postpedicel. Mesopleuron bare. With 2 notopleural bristles and no cleft in front of these. Scutellum with an anterior pair of hairs (about as long as those in middle of scutum) and a posterior pair of bristles. Abdominal tergites brown and with numerous small hairs. Venter

brown and with hairs below segments 3-6. Cerci pale brown. Dufour's crop mechanism narrowing in front and to a rounded tip behind. Legs brown but not dark. Front tarsi with long, slender segments. Dorsal hair palisade of mid tibia extends about two thirds of length. Hind femur with hairs below basal half a little shorter than those of the anteroventral row. Hind tibia with about two dozen moderately differentiated posterodorsal hairs and spinules of apical comb simple. Wings 3.3 mm long. Costal index 0.47. Costal ratios 4.1 : 1.8 : 1. Costal cilia 0.22 mm long. Sc reaches R1. A small hair at base of vein 3. With 8 axillary bristles which are shorter than costal cilia. All veins brown but costa more yellowish. Membrane only slightly tinged grey (not evident to the naked eye when viewed against a white background). Haltere knob yellow.

Material

Female, NEVADA: White Pine Co., Indian Burial Cave, 3 March 2007, S. J. Taylor, J. K. Krejca (308 NPS-GRBA, Project 411, Catalog 6736) (UCMZ, 31-128).

Habitat

Indian Burial Cave is located at an elevation of 1724 m. The species was collected on the cave floor on breakdown in the twilight zone, where the air temperature was 9.4 °C, soil temperature was 9.2 °C, relative humidity was 70.6%, and ambient light was less than 1 lux.

Recognition

In Borgmeier's (1966) keys it runs to couplet 24 lead 1 on page 4, to *M. rufipes* (Meigen), whose male is highly distinctive but whose female falls within the notoriously difficult *M. pulicaria* complex. However, Dufour's Crop Mechanism narrows towards its rounded rear margin in species A, which immediately distinguishes it from that of *M. rufipes*, which has a pair of pale lobes behind. In species A the palps are mainly brown but with a contrasting yellow patch in their basal halves. In *M. rufipes* they are entirely yellow.

DISCUSSION

None of the species collected were taken from the dark zone of caves, but all were taken in areas with reduced light. A nearby weather station (MMTHN2, Baker, Nevada) at an elevation of 2823 m recorded an average annual relative humidity of 43.8%, with the July average being 32.6%. Our collections were made in cave areas with relative humidity ranging from 52.5% to 82.6%. These data, then, are consistent with the idea that while these flies may not be troglotic, but they may be using the cave entrance and twilight zones as a refuge from temperature extremes and the harsh, drying conditions on the surface. Deep cave temperatures fluctuate little, approximate the average annual temperature of the region on the surface, and typically have elevated humidity levels. Studying fauna in caves is an opportunity to learn about organisms that may typically live in inaccessible places in the subsurface such as talus piles, mesocaverns, and soils.

The description of five new species based on sampling only of caves in the southern Snake Range of White Pine County, Nevada, underscores how little we know about the phorid fauna of western North America. It also highlights the degree to which western cave faunas are poorly known. With these five species included, a total of nine new species of invertebrates have been described from caves in Great Basin National Park in less than ten years, including springtails, millipedes and amphipods (see Shear 2007, Shear et al 2009, Zeppelini et al 2009, and Taylor & Holsinger 2011). Many of these cave sites were never sampled prior to this inventory effort, and during this survey collectors visited some sites only once. Thus, it is likely that more species remain to be discovered with a greater sampling effort.

Effective management of western North American natural resources, especially cave resources, then, may suffer from a lack of knowledge about the true levels of diversity, and, potentially, endemism, of invertebrate natural communities, at least in cave habitats. Understanding the distribution of species is a key component of successful management strategies. Caves are particularly sensitive to management decisions made in National Parks because they are small features that, in some cases,

attract atypically high levels of human visitation. Visitation can compact substrates where invertebrates shelter or forage, alter nutrients via introduction or removal of food substrates, and bring in exotic species. Caves also can collect and store contaminants washed in from entire watersheds. The discovery of so many new species in sensitive cave environments points toward need for continued inventory and taxonomy study

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The groundwater oligochaetes (Annelida, Clitellata) of Slovenia

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ABSTRACT

Historical data on the biodiversity of oligochaetes inhabiting ground waters of Slovenia depicted a fauna of 25 species, 19 of which are stygobiotic. Over about the last 35 years, faunistic surveys carried out in Slovenian ground waters has enabled us to conduct extensive studies on the oligochaete fauna of this environment. Three primary sources of information have been integrated to summarize in this paper: a campaign in Slovenian caves conducted by Fabio Stoch, a large collection of groundwater fauna made available to us by Boris Sket, and samples collected during the European project PASCALIS. The data derived from the examination of this large amount of material has enabled us to broaden our knowledge of the oligochaete diversity of Slovenia, increasing the number of species to one hundred, and has allowed us to summarize the biological diversity in Slovenian waters to be a substantial percentage of the known diversity present elsewhere in Europe. Endemic, rare and new species constitute a remarkable proportion of the stygobiotic oligochaete fauna. Among these, species of the genera *Trichodrilus*, *Rhyacodrilus*, *Rhyacodriloides*, *Parvidrilus*, *Epirodriulus* and *Abyssidrilus* are some of the most noteworthy taxa because of their endemism, range-size, rarity, habitat selection, and/or taxonomic isolation (including phylogenetic relictuality).

Key words: biodiversity, stygobiont, endemic, groundwater oligochaetes, Slovenia

INTRODUCTION

This study summarizes the results of an extensive survey of the groundwater oligochaete fauna of Slovenia, integrating all literature data available for the area. The classification adopted here follows the definition of the large taxon Naididae (see Erséus et al. 2008, 2010) – including the taxa in the former family Tubificidae and the recently erected subfamily Rhyacodriloidinae (Martin et al. 2010). The study of oligochaetes in Slovenia began in 1880 with the description of an enchytraeid from a cave (*Enchytraeus cavicola* Joseph, 1880), but the species was not considered valid thereafter (Michaelsen 1900). In 1941, Černosvitov reported *Haplotaxis gordioides* (Hartmann). Our knowledge increased with the contributions of Hrabě (1942, 1963, 1966, 1973) who described 10 new species, and those of Karaman (1974, 1976, 1983, 1987), who studied the Dinaric fauna and described six new Slovenian species. The first general synthesis on the fauna of Slovenia was in the “Catalogus Faunae Jugoslaviae”, where Kerovec and Mršić (1981) listed all the oligochaete species known at that time; it was soon followed by the data compiled in “Stygofauna

mundi” (Juget and Dumnicka 1986) and “Encyclopedia Biospeologica” (Dumnicka and Juberthie 1994) – each of which focused only on groundwater species. In their publications on the Slovenian fauna, Sket (1995, 1997, 1999) and Bole et al. (1993) presented data on oligochaete diversity. Recent publications, including those in which six species new to science were described, have further increased our knowledge of groundwater fauna (Martínez-Ansemil et al. 1997; Sambugar et al. 1999; Giani et al. 2001; Martin et al. 2010).

Data that has been examined and summarized in this paper was obtained from three geographical regions in Slovenia: the Centre, the South, and certain areas in the North-eastern part of the country. About 40% of the territory of Slovenia is a karst area. The karst is divided in three units: 1) the Alpine karst, situated in the North-western part of the country; 2) the Dinaric karst in Western and Southern Slovenia, consisting of three elongated parallel belts; and 3) the isolated patches of karst of the sub-Alpine and sub-Dinaric Slovenia (Sket et al. 1994). The Slovenian karst is a natural reservoir of underground waters inhabited by one of the richest and most endemic troglotic and stygobiotic fauna of the world (Sket

2010). Examples of the rich surface and underground Slovenian landscapes include: great cave systems with streams, lakes and percolating waters from rock crevices; subterranean rivers; sinking rivers born on the surface, flowing kilometers through the caves and giving birth to wide resurgences (like the Postojna-Planina Cave System, Sket and Velkovrh 1981a; Sket 2004); surface rivers (i.e.: Sava, Drava, Mura) with broad exposed gravelly river beds highly suitable for interstitial fauna (e.g. Sket and Velkovrh 1981c); and slightly thermal springs (Sket and Velkovrh 1981b). We had the opportunity to study the oligochaete fauna linked to many of these habitats. This contribution will summarize our knowledge, to date, of oligochaete communities inhabiting the freshwaters of Slovenia, and establish a basis for future research focusing on subterranean oligochaete fauna.

MATERIALS AND METHODS

Samples of oligochaetes from 261 localities were studied. Some of these samples were kindly provided by colleagues Boris Sket and Fabio Stoch. The studied material of the collection from the biology department of the Biotechnical faculty, University of Ljubljana (mainly collected by B. Sket and F. Velkovrh) is only a part of a large collection of approximately 400 samples from the Dinaric region, collected from caves, wells, springs, and interstitial areas over many years (1960s through 1990s). The study of this material is still in progress. The Fabio Stoch collection consists of 46 samples from Slovenian caves, all taken in the 1990s; our review of the specimens in these samples has been completed. In 2001, the European project PASCALIS (Protocols for the Assessment and Conservation of Aquatic Life in the Subsurface) was initiated to compliment our knowledge of groundwater biodiversity in Europe (Gibert 2001; Gibert and Culver 2009). Six European regions were studied, including the Slovenian 'Krim Massif' area by A. Brancelj and B. Sket. The Annelida were an integral part of that project, and results associated with the oligochaetes are presented here.

Samples were collected from different underground habitats such as pools, lakes and rivulets of caves, interstitial of rivers, springs, phreatic layer of wells. All sampled sites, with related localities, are listed in Appendix 1. In caves and springs, the fauna was sampled by sieving sediments through a hand net (100 µm mesh); in hyporheic areas, the Bou-Rouch pump or the Karaman-Chappuis method were used; wells were sampled by using a Cvetkov closing vertical net. Sampling strategy and used methods are explained in Malard et al., 2002. Samples were fixed in the field with 4% formaldehyde solution and sorted in the laboratory under a stereomicroscope; the collected specimens were stored in vials and preserved in 70% ethanol. Oligochaetes were mounted as whole specimens in glycerin on slides; mature specimens were stained with Mayer's Paracarmin, destained

in 70% acid alcohol, at times dissected, dehydrated in ethanol, cleared in xylene and mounted in Canada Balsam on slides. Immature specimens were stored in 70% ethanol. The specimens were observed with a compound light microscope equipped with differential interference contrast optics. Oligochaetes were identified to the species level except for poorly preserved specimens or very scarce material (in these cases we often used 'cf' when referencing this material in the inventory). For practical purposes, throughout the text, we will refer to all of these as species taxa. All studied material discussed below has been deposited in the collections of the authors.

RESULTS

An updated checklist

Table 1 presents a list of aquatic oligochaete taxa presently known to occur in subterranean waters of Slovenia: 25 taxa are known to occur in this country based upon historical records published in the literature, and 78 are added as new records for the country based upon the results of this study. One hundred and three species taxa, thirty-nine genera and six families (Enchytraeidae, Haplotaxidae, Lumbricidae, Lumbriculidae, Naididae, Parvidrilidae) constitute the total number of oligochaetes currently known from Slovenian ground waters. This list represents in fact the majority of the oligochaete fauna known, collectively, from all freshwater habitats in this country; only 10 additional species could be added (Kerovec and Mršič 1981) if we were to also consider those occurring in epigeal freshwaters: *Lumbriculus variegatus* Müller, 1774), *Limnodrilus udekemianus* Claparède, 1862, *Psammoryctides albicola* (Michaelsen, 1901), *Psammoryctides moravicus* (Hrabě, 1934), *Potamothenix heuscheri* (Bretschler, 1900), *Chaetogaster diaphanus* (Gruithuisen, 1828), *Uncinaxis uncinata* (Ørsted, 1842), *Nais simplex* Piguët, 1906, *Stylaria lacustris* (Linnaeus, 1767), and *Aulophorus furcatus* (Oken, 1815). The results of this present study increases the total number of stygobiotic species from 19 to 29. In addition, 15 other species could be considered as stygophiles (*Cernosvitoviella atrata*, *Haplotaxis gordioides*, *Marionina argentea*, *Pristina aequisetata*, *P. jenkinsae*, *P. osborni*, *P. rosea*, *Rhyacodrilus coccineus*, *R. falciformis*, *Spirosperma velutinus*, *Stylodrilus brachystylus*, *S. heringianus*, *S. lemani*, *S. parvus*, *Trichodrilus strandi*) and one as crenophile (*Rhynchelmis tetraheca*). During this study, several species identified as new to science are aligned with the following genera: *Fridericia*, *Abyssidrilus*, *Epirodilus* and *Parvidrilus*.

Habitat and distributional information for stygobiotic species is presented below; taxonomical remarks have also been included for the most relevant species. Brief information for all species considered new to science

is also presented, but limited to some anatomical and diagnostic features; complete descriptions for these new taxa will be completed and properly described in upcoming publications. The specific status of some specimens thought likely to represent undescribed taxa is uncertain

due to the scarcity or the poor quality of the material; however, we will soon examine additional material in the collection provided by Boris Sket, perhaps allowing us to resolve some of the taxonomic and morphological issues with the material already examined.

Table 1 - List of oligochaetes (Annelida, Clitellata) reported from ground waters in Slovenia. Original data are integrated with literature in an updated checklist of Slovenian groundwater oligochaetes. The new findings reported here are referred by the number of the locality adopted in Appendix 1. Species we consider to be stygobiotic are marked with an asterisk; the symbol ° indicates that the species is new to Science.

	Family	Subfamily	Species	Reference	Present study
1	Enchytraeidae		<i>Achaeta</i> sp.		6, 66, 101, 107, 180, 189, 192, 254
2			<i>Buchholzia</i> cf. <i>appendiculata</i> (Buchholz, 1862)		13, 18, 30, 31
3			<i>Buchholzia simplex</i> Nielsen & Christensen, 1963		25, 29, 36, 53, 82, 233
4			<i>Cernosvitoviella atrata</i> (Bretscher, 1903)		201
5			<i>Cernosvitoviella</i> cf. <i>palustris</i> Healy, 1979		77
6			<i>Cernosvitoviella</i> cf. <i>aggtelekiensis</i> Dozsa-Farkas, 1970		23
7			<i>Cognettia cognettii</i> (Issel, 1905)		14, 102
8			<i>Cognettia glandulosa</i> (Michaelsen, 1888)		27
9			<i>Cognettia sphagnetorum</i> (Vejdovský, 1878)		7, 12, 14, 19, 55, 60
10			<i>Enchytraeus buchholzi sensu lato</i>		7, 10, 16, 19, 31, 32, 35, 51, 59, 128, 129, 143, 144
11			<i>Enchytraeus cavicola</i> Joseph, 1880 species inquirenda	Joseph, 1880	
12			<i>Enchytraeus</i> cf. <i>bulbosus</i> Nielsen & Christensen, 1963		103
13			<i>Fridericia benti</i> Schmelz, 2002		55
14			<i>Fridericia discifera</i> Healy, 1975		37
15			<i>Fridericia galba</i> (Hoffmeister, 1843)		89
16			<i>Fridericia maculata</i> Issel, 1905		36
17			<i>Fridericia semisetosa</i> Dózsa-Farkas, 1970		25
18			<i>Fridericia striata</i> (Levinsen, 1884)		11
19			° <i>Fridericia</i> sp. 1		31
20			° <i>Fridericia</i> sp. 2		6
21			° <i>Fridericia</i> sp. 3		6
22			° <i>Fridericia</i> sp. 4		55
23			° <i>Fridericia</i> sp. 5		107
24			<i>Henlea perpusilla</i> Friend, 1911		6, 7, 21, 30, 31, 32, 36, 37, 60, 203
25			<i>Henlea ventriculosa</i> (d'Udekem, 1854)		7, 31, 32

	Family	Subfamily	Species	Reference	Present study
26			<i>Marionina argentea</i> (Michaelsen, 1889)		12, 34, 196
27			<i>Marionina cf. argentea</i> (Michaelsen, 1889)		57, 82
28			<i>Marionina cf. southerni</i> Černosvitov, 1937		58, 63, 77
29			<i>Marionina riparia</i> Bretscher, 1899		1, 3, 6, 7, 13, 19, 27, 28, 29, 30, 31, 32, 35, 37, 165, 187, 207, 249
30			<i>Marionina</i> sp. 1		31, 34
31			<i>Mesenchytraeus armatus</i> (Levinsen, 1884)		198
32	Haplotaxidae		* <i>Delaya bureschi</i> (Michaelsen, 1925)	Hrabě, 1963	
33			<i>Haplotaxis gordioides</i> (Hartman, 1821)	Černosvitov, 1941	7, 4, 107, 156, 213, 250, 260
34	Lumbricidae		<i>Eiseniella tetraedra</i> (Savigny, 1826)		3, 5, 13, 33, 192, 200, 205, 234, 237
35	Lumbriculidae		* <i>Guestphalinus wiardii</i> (Michaelsen, 1933)	Hrabě, 1973	
36			<i>Lumbriculus variegatus</i> (Mueller, 1774)		189
37			<i>Rhynchelmis limosella</i> Hoffmeister, 1843		45, 121, 184, 190, 191, 192, 207
38			<i>Rhynchelmis tetratheca</i> Michaelsen, 1920		39, 136, 137, 140, 142
39			<i>Stylodrilus cf. asiaticus</i> (Michaelsen, 1905)		119, 120
40			<i>Stylodrilus brachystylus</i> Hrabě, 1928		23, 206
41			<i>Stylodrilus heringianus</i> Claparède, 1862	Hrabě, 1973	3, 4, 6, 21, 114, 143, 147, 153, 184, 192, 195, 196, 197, 198, 202, 204, 206, 245, 249, 250
42			<i>Stylodrilus lemani</i> Grube, 1879	Hrabě, 1973	19
43			<i>Stylodrilus parvus</i> (Hrabě & Černosvitov, 1927)		118, 136, 137, 146
44			* <i>Trichodrilus cernosvitovi</i> (Hrabě, 1937)		29, 90
45			* <i>Trichodrilus leruthi</i> Hrabě, 1937		103
46			* <i>Trichodrilus pragensis</i> Vejdovsky, 1875		3, 10, 12, 15, 23, 29, 121, 143, 148, 154
47			* <i>Trichodrilus ptujensis</i> Hrabě, 1963	Hrabě, 1963	
48			* <i>Trichodrilus sketi</i> Hrabě, 1963	Hrabě, 1963	
49			* <i>Trichodrilus stammeri</i> Hrabě, 1937	Hrabě, 1937	
50			<i>Trichodrilus strandi</i> Hrabě, 1936	Karaman, 1987	1, 3, 4, 36, 115, 116, 117, 192, 193, 194, 191, 192
51			* <i>Trichodrilus tacensis</i> Hrabě, 1963	Hrabě, 1963	

	Family	Subfamily	Species	Reference	Present study
52			* <i>Trichodrilus tenuis</i> Hrabě, 1960		14, 99
53	Naididae	Naidinae	<i>Chaetogaster diastrophus</i> (Gruithuisen, 1828)		23, 75, 95, 113, 114, 119, 176, 197, 201, 241
54			<i>Chaetogaster langi</i> Bretscher, 1896		77, 239
55			<i>Nais alpina</i> Sperber, 1948		58, 74, 116, 151, 153, 154, 156, 166, 167, 196, 197, 199, 205
56			<i>Nais barbata</i> Mueller, 1774		34, 87
57			<i>Nais bretscheri</i> Michaelsen, 1899		14, 114, 119, 195, 197, 199, 200, 202, 203, 204, 224, 235, 240
58			<i>Nais communis</i> Piguët, 1906		27, 28, 29, 35, 77, 94, 95, 107, 135, 163, 186, 190, 191, 192, 198, 201, 202, 205, 231, 239, 241, 246
59			<i>Nais elinguis</i> Mueller, 1774		28, 29, 30, 32, 33, 116, 119, 133, 183, 231, 233
60			<i>Nais pardalis</i> Piguët, 1906		142, 146, 149, 152, 154, 197, 200, 241, 259
61			<i>Nais pseudobtusa</i> Piguët, 1906		35
62			<i>Nais stolci</i> Hrabě, 1981		155
63			<i>Nais variabilis</i> Piguët, 1906		29, 30, 32, 107, 116, 186, 205, 230, 232
64			<i>Opidonais serpentina</i> (Mueller, 1774)		35
65			<i>Vejdovskyella intermedia</i> (Bretscher, 1896)		55
66		Pristininae	<i>Pristina aequisetata</i> Bourne, 1891		29, 32, 34, 54, 189, 198, 200, 205, 206, 231, 241, 242, 247, 250, 253, 256, 257, 258, 259
67			<i>Pristina bilobata</i> (Bretscher, 1903)		163
68			<i>Pristina jenkinae</i> (Stephenson, 1932)		18, 24, 29, 30, 54, 57, 70, 76, 77, 105, 143, 196, 197, 198, 199, 200, 204, 221, 224, 225, 231, 232, 233, 234, 240, 243, 249, 253, 257, 259
69			<i>Pristina menoni</i> (Aiyer, 1929)		119
70			<i>Pristina osborni</i> (Walton, 1906)		195, 197
71			<i>Pristina rosea</i> (Piguët, 1906)		32, 151
72		Phallodrilinae	* <i>Abyssidrilus</i> cf. <i>cuspis</i> (Erséus & Dumnicka, 1988)	Sambugar et al., 1999	
73			°* <i>Abyssidrilus</i> sp.1		9
74			* <i>Spiridion phreaticola</i> (Juget, 1987)		107, 147, 182, 205

	Family	Subfamily	Species	Reference	Present study
75		Rhyacodrilinae	<i>Bothrioneurum vej dovskyanum</i>		35, 191
76			* <i>Epirodri lus slovenicus</i> Karaman, 1976	Karaman, 1976	
77			° <i>Epirodri lus</i> sp.1		12
78			* <i>Rhyacodri lus caudosetosus</i> Karaman, 1983	Karaman, 1983	
79			<i>Rhyacodri lus coccineus</i> (Vejdovsky, 1876)		41, 43
80			<i>Rhyacodri lus falciformis</i> Bretscher, 1901		8, 106, 187, 239
81			* <i>Rhyacodri lus gasparoi</i> Martínez-Ansemil, Sambugar, Giani, 1997		3, 4, 91, 93, 105, 212
82			* <i>Rhyacodri lus maculatus</i> Karaman, 1983	Karaman, 1983	
83			<i>Rhyacodri lus</i> cf. <i>maculatus</i>		177
84			* <i>Rhyacodri lus omodeoi</i> Martínez-Ansemil, Sambugar, Giani, 1997	Martínez-Ansemil et al., 1997	36
85			* <i>Rhyacodri lus sketi</i> Karaman, 1974	Karaman, 1974	
86			* <i>Rhyacodri lus</i> cf. <i>sketi</i>		18
87			* <i>Stochidri lus glandulosus</i> Martínez-Ansemil, Sambugar, Giani, 1997	Martínez-Ansemil, et al., 1997	
88		Rhyacodriloidinae	* <i>Rhyacodri loides latinus</i> Martin, Martínez-Ansemil, Sambugar, 2010	Martin et al., 2010	29, 96, 107, 110, 120, 123, 168, 169
89		Tubificinae	<i>Aulodri lus pluriseta</i> (Piguet, 1906)		39, 100
90			* <i>Haber zavreli</i> (Hrabě, 1942)		58, 63, 99, 100, 160, 208, 210
91			<i>Limnodri lus hoffmeisteri</i> Claparède, 1862		33, 35, 36, 39, 186
92			<i>Lophochaeta ignota</i> (Stolc, 1886)		206, 248, 250, 252, 254, 255, 259, 260
93			<i>Potamo thr ix hammoni ensis</i> (Michaelsen, 1901)		3, 70, 87, 100, 101, 102, 137, 182, 186, 193, 199
94			* <i>Potamo thr ix postojnae</i> Karaman, 1974	Karaman, 1974	
95			<i>Psam moryctides barbatus</i> (Grube, 1861)		3, 28, 41, 85, 186, 193, 198, 199, 206
96			* <i>Psam moryctides hadzii</i> Karaman, 1974	Karaman, 1974	
97			* <i>Sketodri lus flabellisetosus</i> (Hrabě, 1966) aumg. Karaman, 1976	Karaman, 1976	
98			<i>Spirosperma ferox</i> Eisen, 1879		142
99			<i>Spirosperma velutinus</i> (Grube, 1879)	Hrabě 1973	1, 4, 27, 39, 54, 55, 85, 193, 232, 236, 238
100			* <i>Tubifex pescei</i> (Dumnicka, 1980)	Martínez-Ansemil et al., 1997	
101			<i>Tubifex tubifex</i> (Mueller, 1774)		1, 19, 22, 24, 32, 35, 36

	Family	Subfamily	Species	Reference	Present study
102	Parvidrilidae		* <i>Parvidrilus spelaeus</i> Martínez-Ansemil, Sambugar, Giani, 2002	Martínez-Ansemil, et al., 2002	92, 178, 182
103			°* <i>Parvidrilus</i> spp.		23, 256
					: presence : absence

* stygobiont species

° new species

Comments on stygobiotic species

1 - Haplotaxidae

Delaya bureschi. Known from the Slovenian caves Križna (Lož) and Mrzla (Planina) (Hrabě 1963). Trans-dinaric distribution from Slovenia to Bulgaria.

2 - Lumbriculidae

Guestphalinus wiardii. This species is known from the interstitial area of Vipava river, Dornberk (Nova Gorica) (Hrabě 1973). Very rare species; sporadic citations for localities in Europe (Slovenia, Germany).

Trichodrilus cernosvitovi. New to Slovenia, found in a spring and in hyporheic habitat. Rare species; sporadic citations for localities in Europe (Belgium, France, Romania, Italy).

Trichodrilus leruthi. New to Slovenia, found in a spring. Rare species; sporadic citations for localities in Europe (Belgium, France, Italy).

Trichodrilus pragensis. New to Slovenia, widespread, found in caves, springs, hyporheic habitats, and phreatic habitats. Rather common in Europe.

Trichodrilus ptujensis. Species described from wells in Ptuj (Maribor) and in Tacen (Ljubljana) (Hrabě 1963). Known only from the original localities (the type locality, however, was not stated in Hrabě's paper).

Trichodrilus sketi. Known only from the type locality: interstitial habitat of Sava river, near Ljubljana (Hrabě, 1963).

Trichodrilus stammeri. Species described from ground waters of Carso/Kras (Timavo river) (Hrabě 1937). Known only from the type locality.

Trichodrilus tacensis. This species was described from a well in Tacen (Ljubljana) (Hrabě 1936). Known only from the type locality.

Trichodrilus tenuis. New to Slovenia, found in two caves. Sporadic citations for localities in Europe (France, Germany, Spain).

3 - Naididae

3.1 Phallodrilinae

Spiridion phreaticola. New to Slovenia, found in springs and hyporheic habitats. Prior to this current study, *S. phreaticola* was only known from subterranean habitats in France (Juget 1984, 1987; Erséus et al. 1992; Sambugar et al. 1999; Giani et al. 2001; Route et al. 2004).

Abyssidrilus* cf. *cuspis. Some specimens, which differ from the typical diagnose of *A. cuspis*, were found in the cave Škocjanske (Sambugar et al. 1999).

3.2 Rhyacodrilinae

Epirodrius slovenicus. Known from the type locality: cave Planinska (Karaman, 1976), and from a spring in Creta (Martin and Giani 1995).

Rhyacodrilus caudosetosus. Known only from the type locality: cave Planinska (Karaman, 1983).

Rhyacodrilus gasparoi. New to Slovenia, found in springs, phreatic habitats, and a cave. Previously known only from an Italian cave (Martínez-Ansemil et al. 1997), this species now appears to be more widespread in the Alpine Arc (unpublished data).

Rhyacodrilus maculatus. Known only from the type locality: cave Planinska (Karaman 1983). ***Rhyacodrilus omodeoi***. Described for the cave Križna (Martínez-Ansemil et al. 1997), it is first reported here from a spring. Endemic in Slovenia.

Rhyacodrilus sketi. Known only from the type locality: cave Planinska (Karaman 1974).

Stochidrilus glandulosus. Known only from the type locality: cave Viršnica (Martínez-Ansemil et al. 1997).

3.3 Rhyacodriloidinae

Rhyacodriloides latinus. Described from a cave in Italy, hyporheic habitats and a spring in Slovenia (Martin et al. 2010), we include here the additional records for springs, hyporheic habitats and phreatic habitats based upon specimens we have collected from Krim Massif and from the hyporheic areas of the Sava river.

3.4 Tubificinae

Haber zavreli. New to Slovenia, found in caves, a spring, and phreatic habitats. Rare species; sporadic citations for localities in Europe (Italy, Poland, Slovakia).

Potamoithrix postojnae. Known only from the type locality: cave Planinska (Karaman 1974).

Psammoretydes hadzii. Known only from the type locality: cave Planinska (Karaman 1974).

Skotodrilus flabellisetosus. Originally described from specimens from a cave near the sources of the Timavo river (Monfalcone) in Italy (Hrabě 1966), this species was redescribed in 1976 by Karaman from specimens collected from the cave Planinska.

Tubifex pescei. Found in the cave Križna (Martínez-Ansemil et al. 1997), this species was previously known only from Italian wells (Dumnicka 1981; Dumnicka 1990).

4 - Parvidrilidae

Parvidrilus spelaeus. Described from caves of Italy and Slovenia (Martínez-Ansemil et al. 2002), it is now mentioned for springs in the Krim Massif.

TAXONOMICAL REMARKS

1 - Enchytraeidae

Cernosvitoviella cf. *palustris*

Two specimens, site 77

Chaetae, size of male glands and shape and size of spermathecae are very similar to those observed in known specimens of *C. palustris*, although we have observed a conspicuous seminal vesicle in XI of these two specimens, which are absent or small in *C. palustris*. The spermathecal ectal pore has the form of a transverse slit, and the clitellum is girdle-shaped. Both traits are unknown in *C. palustris*.

Cernosvitoviella cf. *aggtelekiensis*

Two specimens, site 23

Chaetae in our specimens are smaller (20-30 µm) than originally described (35 µm). Very similar is *C. parviseta*, distinguishable from *C. aggtelekiensis* only by smaller chaetae (15 µm). *C. aggtelekiensis* was originally described from caves; it has subsequently been recorded from epigeic habitats (e.g., Erséus et al., 2005).

Cognettia sphagnetorum

Twenty-two specimens, sites 7, 12, 14, 19, 55, 60

Specimens belong to two of the three forms distinguished in Schmelz and Collado (2010): one form has

2 chaetae in anterior lateral bundles and a regular set of pharyngeal glands, the other has 2 and 3 chaetae in anterior lateral bundles and irregular pharyngeal glands in VII and VIII, enlarged and with ventral lobes.

Fridericia sp. 1

One mature specimen, site 31

Body length ca. 18 mm, 57 segments, up to 6 chaetae per bundle. Clitellum girdle-shaped, dense rows. Seminal vesicle large, extending to septum 9/10. Sperm funnel pear-shaped, about as long as body diameter. Male glands large, oval, compact, 240 µm long, twice as long as wide or high, bursal slit longitudinal. Subneural glands in XIII – XV. Spermathecae with two irregularly shaped diverticula bent ectad, without subchamber; ectal gland small, if present at all (trait not fully confirmed due to poor preservation of specimen). The combination of traits in this single specimen is unique in the genus *Fridericia*; a more complete description of this taxon will be possible if additional specimens can be collected.

Fridericia sp. 2

One mature specimen, site 6

Body length ca. 7.5 mm, 41 segments, up to 4 chaetae per bundle. Clitellum absent dorsally, present ventrally. Seminal vesicle large, 2 segments. Male glandular bulb small, length 45-50 µm, with a median incision. Subneural gland in XIII and perhaps also in XIV. Ectal duct of spermatheca short, ampulla with two sessile, thin-walled diverticula of ca. 35 µm diameter; ectal gland not ascertained. Only one Chinese species of *Fridericia* (*F. unisetosa* Xie et al. 2000) has a clitellum that appears similar to the clitellum observed in this *Fridericia* sp. 2 specimen: absent dorsally, but present ventrally. However, *F. unisetosa* lacks lateral chaetae and has ventrally only 1 chaeta per bundle. Although several morphological characteristics were not clearly observable in our specimen, the peculiar chaetal pattern will certainly allow re-identification and formal description should additional specimens be collected.

Fridericia sp. 3

One mature specimen, site 6

49 segments, up to 4 chaetae per bundle. Body wall thin (10-15 µm), septa 5/6 – 9/10 thickened. Clitellum girdle, flat, cells absent anteriorly of bursal slits, cell pattern reticulate. Seminal vesicle one complete segment, sperm heads at least 70 µm long. Sperm funnel c. 2x as long as wide, barrel-shaped, collar slightly wider than funnel body, separated by a constriction. Spermatheca with small ectal gland, 2 small diverticula with subchamber oriented towards the ampulla, and separate attachments to oesophagus.

In consideration of the spermatheca (2 diverticula with subchamber), the species belongs to the *F. perrieri*-group as established in Schmelz (2003: 185, 265f., 296, 312, 341f.), but differs from it in the presence of spermathecal ectal glands.

***Fridericia* sp. 4**

One submature specimen, site 55

Body length c. 12 mm, 53 segments, up to 5 chaetae per bundle. Body wall thick (20-30 μm), cuticle c. 2 μm thick; septa 7/8 to 9/10 thickened. Clitellum girdle-shaped, cells in indefinite rows. Seminal vesicle large, 2 segments. Sperm heads ca. 45 μm long. Sperm funnel tapering distad, collar as wide as funnel body. Male gland small, bursal slits T-shaped. Spermathecae with ectal glands, 2 diverticula each and separate attachments to oesophagus. Ectal duct widening proximad, ampulla much widened distally, almost as long as ectal duct. Diverticula oriented towards ampulla or ear-shaped, outline irregular, lumen smaller than ampullar lumen.

This species is a part of the *F. aurita*-species complex as established in Schmelz (2003, p. 112f.). It is also similar to *F. humicola* Bretscher 1900, especially regarding the overall shape of the spermatheca, but in our specimen the spermathecae are smaller, the proximal widening of the ectal duct is much less pronounced (comp. Schmelz 2003, Fig. 39A), and sperm heads are shorter (80 μm in *F. humicola*).

***Fridericia* sp. 5**

One specimen, site 107

Chaetae absent laterally, ventrally 2 chaetae per bundle. Cuticle thick. Spermatheca without diverticula. Ampulla large, globular. The combination of traits is unique in *Fridericia*; a more complete description of this taxon will be possible if additional specimens can be collected.

Marionina* cf. *argentea

Six specimens, sites 57, 82

Specimens identifiable as *M. argentea* on behalf of body size, chaetal pattern, coelomocyte texture and size of the male reproductive apparatus, have a clitellum that is only laterally developed, i.e. absent ventrally and dorsally. Since in *M. argentea* the clitellum is dorsally present (Schmelz and Collado 2010), this is perhaps a new species.

Marionina* cf. *southerni

Four specimens, all submature, sites 58, 63, 77

Most traits agree with the diagnosis of *M. southerni*. Noteworthy are chaetal pattern, size of seminal vesicle and male gland, coelomocyte texture. The latter is surprisingly conserved, probably as a result of the use of creosote as dehydrating medium. The spermathecal ampulla lacks the typical ring of sessile diverticula, but these may develop only in fully mature specimens (Schmelz, unpublished observations). Inner traits were not seen in all specimens. With 5 mm body length and 25 segments, specimens are in the lower size and segment range of the species. *M. southerni* is the only *Marionina* species with *argentea*-like chaetal pattern (i.e. bisetose, chaetae lacking only in II laterally) and large seminal vesicles and male glands. Our records suggest that viable populations of this brackish water species live independently of marine coastal pools.

***Marionina* sp. 1**

Four immature specimens, sites 31, 34

Body length 1 mm, segment number 11-22. Shorter specimens with elongate pygidium. Chaetae 2 in all bundles, sharply pointed, with minute distal bend, anteriorly ca. 30 μm long and < 2 μm thick, posteriorly up to 38 μm long and > 2 μm thick. Body wall c. 5 μm thick, cuticle almost 1 μm thick. Preclitellar nephridia at 6/7 and 7/8. Coelomocytes small, diameter c. 6-10 μm . This species is unidentifiable but cannot be assigned to any of the species listed here.

Enchytraeus cavicola Joseph, 1880 - species inquirenda

The first subterranean record of an enchytraeid in Slovenia was by Joseph (1880), who erected the new species *Enchytraeus cavicola*. The species was never recorded again and type material has not been found. Michaelsen (1900) and Nielsen and Christensen (1959) considered *E. cavicola* as "species dubia". The original description of this taxon is insufficient to recognize genus or species. The combination of traits described is not found in any of the known enchytraeid species, but we suggest that traits may have been erroneously observed by Joseph. For example, he describes the female pores as large lateral clefts, which seems more inspired by an erroneous figure in Vejdovsky (1879, Pl. 5 Fig. 9) than by actual observation. Resampling of the type locality (cave Potiskavec in Dolenjsko) may lead to revalidation of the species. It should be noted that Joseph was the author of a number of fictitious cave species (Brancelj and Sket 1990).

2 - Lumbriculidae

Stylogrilus* cf. *asiaticus

Two mature and four immature specimens, sites 119, 120

In the hyporheic areas of Želimejščica river very few specimens belonging to *Stylogrilus* genus were found. They share characters with *Stylogrilus asiaticus*: simple chaetae in the anterior segments, replaced by bifid chetae with reduced distal tooth in the following segments, atria pear-shaped, penes undistinguishable, spermathecae with short ducts and large ampullae. They appear to be morphologically close to *Stylogrilus asiaticus*, but the scarcity of mature specimens does not allow a more precise characterization of this material.

3 - Naididae

***Abyssidrilus* sp. 1**

Five mature specimens, site 9

This taxon is a new species of *Abyssidrilus*, with spermathecae in the segment XII. It is similar to *A. cuspis*, from which it differs by the preclitellar chaetae, the position of the spermathecal pores, the shape of the spermathecal ampullae, the absence or very short penial

chaetae, and the absence of posterior prostate glands. The specimens from Italy (cave Romana, Trieste) and Slovenia (cave Škocjanske), previously named by Sambugar et al. (1999) as *Abyssidrilus* cf. *cuspis*, seem to belong to this species.

***Epirodrius* sp. 1**

Two mature and fourteen immature specimens, site 12.

These specimens of *Epirodrius* sp. 1 likely represent a new species, close to *Epirodrius slovenicus*. In comparison with the latter, this taxon mainly differs by shorter atria, the anterior position of spermathecal pores, and the shape of chaetae in preclitellar dorsal bundles.

Haber zavreli

Many mature specimens, sites 58, 63, 99, 100, 160, 208, 210

A re-evaluation of the specimens in our collection (sites 58, 63), previously assigned to *H. monfalconensis* (Sambugar et al. 1999), and subsequent comparison of those specimens with new material collected during the PASCALIS project in Krim Massif, has led us to assign all of these specimens found in Slovenia to *H. zavreli*. The spermathecal pores are lateral rather than in line with the ventral chaetae, as defined by Hrabě (1965) for *H. monfalconensis* when described it as a subspecies of *Tubifex speciosus* Hrabě, 1931.

Rhyacodrilus* cf. *maculatus

One mature and one immature specimens, site 177

Specimens determined as *Rhyacodrilus* cf. *maculatus* were found in a spring; the scarcity of material does not allow a more precise determination of this material.

Rhyacodrilus* cf. *sketi

Two mature and three immature specimens, site 18

To date, *Rhyacodrilus sketi* has only been reported from the type locality: cave Planinska (Karaman 1974). In 1983, Karaman examined new material of the same cave, concluding from his observations that vasa deferentia enter atria subapically. The presence of a single penial chaeta per bundle – and especially the presence of a single and compact prostate gland attached to each atrium – are two characters that clearly differentiate *R. sketi* from all other known rhyacodrilines. Specimens examined by us also have just a single penial chaeta per bundle and a single compact prostate gland per atrium, yet the prostate gland is attached to the anterior side of the atrium (apical in *R. sketi*), together with the vas deferens entrance. All other anatomical characters of our specimens – including the shape and number of the somatic chaetae – strongly suggest an affinity with the taxon described in the original diagnosis of *R. sketi*. The atrial wall of our specimens is composed of a thick granular ectal part and a thin, not granular ental part. Unfortunately, Karaman (1974), in his original description of *R. sketi*, did not describe the structure of its atrial wall. Unfortunately, the type mate-

rial of *R. sketi* is unavailable; thus, new material from the type locality is needed to resolve the taxonomical status of our material. Noting the presence of compact prostates and single penial chaetae in *R. sketi*, Brinkhurst and Wetzel, 1984 queried the inclusion of *R. sketi* in the Rhyacodrilinae; however, the presence of coelomocytes of rhyacodriline type, and the broad attachment of prostates to atria – in all of our specimens – supports the inclusion of this species in this naidid subfamily.

4 - Parvidrilidae

***Parvidrilus* spp.**

A single specimen clearly belonging to *Parvidrilus* genus was found in the phreatic of the Podlipščica valley (site 256). The atria and spermatheca of this single undescribed specimen are in XII (different from that observed in *P. spelaeus*, in which the atria are in XII and spermathecae are in XIII). The atria in this undescribed specimen are very large and globular, occupying the whole segment. In the cave Pajsarjeva jama (site 23), a unique specimen that was found is characterized by very long atria reaching 13/14, with a thin wall and full of spermatozooids. Spermatheca is not seen due to the poor preservation of the specimen. Unfortunately, the scarcity of material thus far collected has prevented us from fully describing these two taxa that we consider new to Science.

DISCUSSION

At present, 103 species of oligochaetes have been identified from subterranean waters in Slovenia. The oligochaete assemblage can be organized around two components. The first component includes ubiquitous species – predominantly present in surface habitats – with wide geographical distribution and ecological tolerance (great dispersal power), and without habitat partition, e.g., *Nais communis*, *Potamothrix hammoniensis*, *Psammoryctides barbatus*. The second component includes 44 species (29 stygobionts and 15 stygophiles), some of them are new to science or for the first time registered for Slovenia (e.g. *Spiridion phreaticola*, *Trichodrilus leruthi*, *Trichodrilus cernovitovi*). Many of these are strictly endemic, while others are linked to a peculiar habitat (e.g. *Trichodrilus ptujensis* to phreatic waters).

Naididae, Enchytraeidae and Lumbriculidae are the richest and most diverse families in Slovenian groundwaters, similar to the fauna present in other subterranean areas of Southern Europe (Giani et al. 2001, Sambugar et al. 2008, Achurra and Rodríguez 2010).

The family Naididae comprises 49 species here: *Nais* Müller (9), *Rhyacodrilus* Bretscher (9) and *Pristina* Ehrenberg (6) are the most diverse genera. *Nais* is a generalist and cosmopolitan genus, living in all epigeal waterbodies and frequently in subterranean habi-

tats of Italy (PASCALIS project: Lessinian mountains) and Spain (PASCALIS project: Cordillera Cantábrica) (Sambugar et al. 2009; Stoch et al. 2009; Martin et al. 2009; Achurra and Rodríguez 2010). *Rhyacodrilus* is a large genus consisting of 44 species, of which 17 are subterranean (4 stygophilic and 13 stygobiotic) (Creuzé des Châtelliers et al. 2009). Of the 9 species belonging to *Rhyacodrilus* found in Slovenia, 5 are stygobiotic (4 of them strictly endemic) and 2 stygophilic. The genus *Pristina*, with many stygophilic species, is also well represented, and, to some extent, illustrates the connections between subterranean and surface environments (Lafont and Vivier 2006). *Tubifex pescei* is the only stygobiotic species of the cosmopolitan genus *Tubifex*; the expansion of its biogeographic range to Slovenia suggests a wide distribution of this species in South European ground waters. *Epirodrius slovenicus*, *Potamothrinx postojnae*, and *Psammoryctes hadzii* are the only stygobiotic species in their respective genera. *Haber* Holmquist, *Sketodrilus* Karaman, and *Stochidrilus* Martínez-Ansemil, Sambugar and Giani are genera inhabiting exclusively subterranean habitats. *Sketodrilus* and *Stochidrilus* are monospecific, and *Stochidrilus* is endemic in Slovenia.

Enchytraeidae is the second most diverse family, with 31 species identified. The most diverse genera include *Fridericia* Michaelsen (11 species) and *Marionina* Michaelsen (5 species). There may be stygobiotic species among the unidentified *Cernosvitoviella* and *Marionina* specimens discussed herein, but the new species of *Fridericia*, each represented by one specimen only, likely are surface taxa that are incidentals in the hyporheic community. The enchytraeid fauna of Slovenia is practically unknown; many as-yet undescribed species are likely to be discovered, especially of *Fridericia*, a genus dominant in both species and specimen numbers in calcareous (i.e., pH-neutral) soils, but thus far poorly represented in our collections (25 specimens altogether). It seems that up to now there is no confirmed case of a truly stygobiotic enchytraeid species. Creuzé des Châtelliers et al. (2009) list 12 stygobiotic enchytraeid species (i.e., those originally described from subterranean habitats). However, these species either (1) have records from surface soils, or (2) they have been synonymized with a known epigeic species, or (3) they have been considered doubtful because of insufficient original description, or (4) they were recorded from sites where information on the surrounding epigeic enchytraeid fauna is limited or absent. Hypogean and epigeic enchytraeid fauna were studied in parallel in Austria (Bauer 1996) and Hungary (Dózsa-Farkas 1990, Zicsi 1999); in each of these studies, species identified from subterranean habitats also were noted as occurring in surrounding surface soils, representing mostly very common and not rare species. Many enchytraeids live either in soils or at the soil/freshwater interface proper, known as a “critical transition zone” (Bardgett et al. 2001). This explains their repeated and species-rich occurrence in subterranean habitats, whereas the restriction

of enchytraeid species to these habitats still awaits demonstration.

Concerning the Lumbriculidae, the third family in diversity (17 species), *Trichodrilus* Claparède and *Stylodrilus* Claparède are the richest genera with 9 and 5 species, respectively. *Trichodrilus* reaches a high rate of endemism. The diversification and radiative evolution in Slovenian ground waters by some large genera like *Trichodrilus* and *Rhyacodrilus* – with many stygobiotic species with narrow distribution pattern – could be in relation with the condition of subterranean environment characterized by stable temperatures, as judging by the overall distribution of these genera in freshwaters.

The 29 stygobiotic species now known to occur in Slovenia represent nearly 1/3 of all stygobiotic freshwater oligochaete species known in the world (104: Creuzé des Châtelliers et al. 2009) –strongly suggesting that Slovenia is a hotspot of biodiversity for freshwaters, and particularly for subterranean taxa (Culver and Sket 2000). If we compare the oligochaete microdrile biodiversity of Slovenia with that present in bordering Italy (the larger Venetian region, Eastern Alps), it appears that its richness is quite similar (103 species in Slovenia, 108 in Italy); however, the number of stygobiont oligochaetes in Slovenia (29) is twice that present in Italy (14). Even if the stygobiotic biodiversity of Italy has been underestimated (our unpublished data show that about eight other undescribed species live in this country), Slovenian data remain quite remarkable. Note that the surface of Slovenia is only 20, 273 km². In his opening lecture of the 20th International Conference on Subterranean Biology [ICSB] (Postojna, 2010), Boris Sket highlighted Slovenia as a biodiversity hotspot, reporting 240 stygobiotic species among all aquatic fauna present in the county. He also focused specifically on the Postojna-Planina Cave System – emphasizing the importance of research in this unique system and the number of faunal discoveries (Sket 2010).

The diversity of oligochaetes now known to be present in this geographic unit strengthens its importance, especially since several species seem to be strictly endemic to this area, e.g., *Psammoryctes hadzii*, *Potamothrinx postojnae*, *Rhyacodrilus caudasetosus*, *Rhyacodrilus maculatus*, and *Rhyacodrilus sketi*. Several other species are highly localized in distribution, known to be present in a single cave, e.g., the dubious *Enchytraeus cavicola* (Potiskavec), *Stochidrilus glandulosus* (Viršnica), *Abysidrilus* sp.1 (Jama 4101), and *Epirodrius* sp.1 (Kevderc). Moreover *Trichodrilus sketi* was collected only in the interstitial of Sava river, *Trichodrilus tacensis* in a well in Tacen (at the same river), *Trichodrilus stammeri* in Timavo river: all these species are probably linked to isolated patches of karst. Of the total fauna known to occur in the Krim Massif, 55 species (more than half of the whole subterranean oligochaete diversity) were found in a relatively small karst area. Taking into account the high rate of endemism of Slovenian stygofauna, an intensive-

ly sampled unit can depict a representative survey of a large region. In fact, the Krim Massif is a marginal karst area ca 10 km south of Ljubljana; samples were taken in numerous sites along three small streams traversing an approximately 35 x 10 km (i.e. 350 km²) area.

Many species recorded here are new to Slovenia, which expands their geographical range known so far: *Tubifex pescei*, *Trichodrilus cernosvitovi*, *Trichodrilus leruthi*, *Trichodrilus pragensis*, *Stylodrilus brachystylus*, *Stylodrilus parvus*, *Rhynchelmis tetratheca* and *Spiridion phreaticola*. *Rhyacodrilus omodeoi*, endemic to Slovenia, enlarges its range inside the country; *Rhyacodrilus gasparoi* displays a wide occurrence in many habitats of Slovenia, and also in the Italian Alpine arc (unpublished data). However the disjunct distribution of many of these species, and of others (i.e., *Epirodilus slovenicus* – known only from Slovenia and Greece), emphasizes our limited knowledge of subterranean fauna present in many countries, and of cryptic species.

For some taxa, as in the case of genus *Rhyacodriloides* Chekanovskaya, a disjunct distribution allows us to assume that some species are relicts – descendants of an old fauna that long ago became extinct in the surrounding areas, yet persist in environments that can be considered refugia (Martin et al. 2010).

Historical factors explain the biodiversity patterns of Phallo-drilinae, pointing to the marine origin of part of the subterranean fauna: seven genera of Phallo-drilinae are presently known in continental subterranean waters in the world (Sambugar et al. 1999, Pinder et al. 2006, Stoch et al. 2009, Rodríguez and Achurra 2010); among the 32 genera in this subfamily, two are present in Slovenia: *Abyssidrilus* Erséus (with one probably new species), and *Spiridion* Knöllner.

The stygobiotic family Parvidrilidae, Holarctic in distribution, presently includes two species, *P. strayeri* (North America – one location: Hendrick Mill Branch, Blount County, Alabama, USA [Erséus, 1999]) and *P. spelaus* (Europe – 12 locations in Italy and Slovenia [see also Martínez-Ansemil et al. 2002]); however, six new species are currently in the process of being described (Martínez-Ansemil et al. in prep.). This family is represented in Slovenia by *P. spelaus* and likely two additional (as-yet undescribed) species, thus increasing the diversity of the genus and suggesting a wider biogeographic range of the family in European groundwaters.

The patchwork of endemism, the species regional differences and the biodiversity patterns displayed by the Slovenian fauna reflect the long and complex history of the Slovenian Karst, and suggest that the relative distribution of species may be the consequence of different histories, life conditions and patch partitioning, only partially explicable as our knowledge of groundwater biodiversity is still far from being complete.

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APPENDIX 1

List of the sites of studied samples.

Data reported for each site are as follows: site number in the catalogue, name of the site; municipality (larger town); WGS84 decimal degrees coordinates; year of collection; sampling habitat.

The sampling habitats are abbreviated as follows: C= Cave; S= Spring; W= Well; H= Hyporheic, Bou-Rouch method; H, K.C.= Hyporheic, Karaman-Chappuis method; P= Phreatic.

From 1 to 41 samples are of the Ljubljana University collection (by B. Sket and F. Velkovrh); from 42 to 87 of Fabio Stoch collection; from 88 to 261 of PASCALIS project (in Biology department, University of Ljubljana, and National Institute of Biology, Ljubljana; all collected in 2002).

- Anže 9; Brestanica (Krško); 15.51962222; 45.99015556; 1976; S.
- Belinca; Sežana; 13.91351713; 45.72346414; 1978; C.
- Bistra; Bistra (Vrhnika); 14.33310623; 45.94603575; 1977-1980-1989; S.
- Bizjakova jama; Studena (Kostanjevica); 15.43382204; 45.83901632; 1998; C.
- Bučerca 18; Kremen (Krško); 15.51390278; 45.98025556; 1976; S.
- Hrastje; E Ljubljana; 14.63712446; 45.97160774; 1975; W.
- S W of Bogatinsko sedlo (ca 1700 m a.s.l.); Komna; 13.73229722; 46.28157778; 1985; S.
- Jama v Kamnolomu; Suha pri Šentjurju; 15.39389413; 46.14407739; 1979; C.
- Jama 4101; Brje (Sežana); 13.8622; 45.77765556; 1979; C.
- Jama II v Repoluskovih pečinah; Šentilj (Maribor); 15.61543042; 46.67950307 . 1978; C.
- Jelendol ; Kočevje; 76239444; 45.67097778; 1974; S.
- Kevderc; Todraž (Gorenja vas); 14.16141389; 46.08620278; 1975-1977; C.
- Kovaceva 1; Šmartno (Ljubljana); 14.55538333; 46.07772778; 1998; W.
- Krapljetova jama; KŠ 484 (Štajerska); 14.95860241; 46.28511499; 1977; C.
- Krapljetova; Radizelj (Maribor); 14.95860241; 46.28511499; 1977; C.
- Vrtojba. Krožna 18; Vrtojba (Nova Gorica); 13.63122778; 45.91126667; 1977; W.
- Kuperče; Maribor; 15.68054444; 46.54677222; 1977; S.
- Loke 7; Nova Gorica; 13.71086667; 45.95856667; 1977; S.
- Mejame; Kačiče (Divača); 13.98765624; 45.65148211; 1992; C.
- Novokrajjska jama; Novokračine (Jelšane); 14.30155106; 45.49109181; 1978; C.
- Vrtojba. Operkarniška 43; Vrtojba (N. Gorica); 13.64497778; 45.91625278; 1977; S.
- Osp 6; Osp (Koper); 13.85860; 45.5705; 1977; W.
- Pajsarjeva jama; Podlipa (Vrhnika); 14.26574747; 45.99765285; 1998; C.
- Potočnik; Polzela; 15.0708; 46.2814; 1977; C.
- Potok; Mirtoviči (Brod na Kolpi); 14.76945; 45.51073056; 1979; S.
- confluence of Želimeljščica; Zelimlje (Ljubljana); 14.57211944; 45.91711944; 1976; S.
- Rov; Grič Grad (Podčetrtek); 14.55535804; 46.0483949; 1978-1979; C.
- Sava river; Litija; 14.83184722; 46.05880556; 1965; H K.C.
- Sava river; Tomačevo (Ljubljana); 14.54057499; 46.08280703; 1978-1987-1998; H.
- Sava river; Tomačevo (Ljubljana); 14.54057499; 46.08280703; 1978; H K.C.
- Sava river; Tomačevo (Ljubljana); 14.54057499; 46.08280703; 1978; H K.C.; C levi breg.
- Sava river; Tomačevo (Ljubljana); 14.54057499; 46.08280703; 1978; H K.C.; C otok.
- Sava river; Jarški prod; 14.55059444; 46.081525; 1987; H.
- Sava river; upstream Ježica (Ljubljana); 14.52072222; 45.09406389; 1987; H.
- Sotla; Vonarje (Rogaška Slatina); 15.62689167; 46.17444444; 1979; H.
- Spring near Želimeljščica; Želimlje (Ljubljana); 14.57211944; 45.91711944; 1976; S.
- Studenc; Fužine (Ljubljana); 14.55535804; 46.0483949; 1998; S.
- Sveto; Banjska planota; 13.68993889; 46.03633056; 1976-1977; W.
- Verd 121; Vrhnika (Ljubljana); 14.30084444; 45.95181389; 1977; S.
- Želimeljščica; Želimlje - Turjak; 14.59013611; 45.89666944; 1976; H.
- Zaloka S; Male Lipljene (Grosuplje); 14.95860241; 46.28511499; 1982; S.
- Boltaceva jama; Trojica; Domžale; 14.68622; 46.12461; 1992; C.
- Ciganska jama pri Predgrizah; Crni Vrh; Idrija; 14.07017; 45.93738; 1993; C.
- Hudournik; Turjak; Ljubljana; 14.59512; 45.89158; 1993; C.
- Planinska jama; Kacja vas; Postojna; 14.24566; 45.8199; 1993; C.
- Zelške jame; Rakov Škocjan; Cerknica; 14.30349; 45.79066; 1993; C.
- Lipiška jama; Gropada; Sežana; 13.88277; 45.68371; 1993; C.
- Lukova jama pri Zdihovem; Škrilj; Kocevje; 14.89423; 45.52556; 1993; C.
- Štefakova pecina; Materija; Sežana; 14.00743; 45.57937; 1993; C.
- Raciška pecina; Racice; Ilirska Bistrica; 14.15023; 45.50336; 1993; C.
- Mackovica; Laze; Logatec; 14.27066; 45.85893; 1993; C.
- Krempļjak; Materija; Sežana; 13.99529; 45.57259; 1993; C.
- Križna jama; Blocice; Cerknica; 14.46727; 45.7452; 1993; C.
- Stobe; Petrova vas; Crnomelj; 15.17065; 45.60421; 1993; C.

- Viršnica; Racna; Grosuplje; 14.70549; 45.90392; 1995; C.
 Dolenjska jama; Dolenje; Ilirska Bistrica; 14.26103; 45.50267; 1995; C.
 Ponikevska Draga; Avber; Sežana; 13.86258; 45.78983; 1994; C.
 Kompoljska jama; Kompolje; Grosuplje; 14.73094; 45.7995; 1993; C.
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Assessing copepod (Crustacea: Copepoda) species richness at different spatial scales in northwestern Romanian caves

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ABSTRACT

The aim of the present study was to assess copepod species richness in groundwater habitats from the Pădurea Craiului Mountains, Transylvania (northwestern Romania). Five species richness estimators (one asymptotic, based on species accumulation curves, and four non-parametric) were compared by testing their performances in estimating copepod species richness at three hierarchical spatial scales: cave, hydrographic basin, and karstic massif. Both epigeal and hypogean species were taken in account. Two data sets were used in computing copepod species richness: 1. samples collected continuously during one year (dripping water) and seven months (pools) from five caves, and 2. samples collected from pools in twelve additional caves (data gathered from literature). Differences in copepod species richness among caves and hydrographic basins suggest that local environmental features are important in determining local species richness trends.

Key words: copepods, species richness, groundwater habitats, Romania

INTRODUCTION

The vadose zone, i.e. the unsaturated karstic layer between surface and groundwater table, consists of the epikarst (the uppermost unsaturated zone of the carbonate bedrock) and the void network through which water percolates towards the phreatic zone (Mangin 1994; Ford and Williams 2007). Communities inhabiting the vadose zone are diverse, consisting of surface dwellers and specialized subterranean species (Rouch 1968; Lescher-Moutoué 1973; Gibert 2001; Pipan 2005; Pipan and Culver 2007). The faunal assemblages of the vadose zone can be studied by sampling drip water systems and pools (Pipan 2005).

Assessing species diversity is a challenge for ecologists, due to difficulties in collecting and identifying all species and estimating their relative abundance with a limited sampling effort (Chao et al 2005). This challenge becomes even more difficult for diversified communities with many rare representatives (Colwell and Coddington 1994; Chazdon et al 1998; Colwell et al 2004; Magurran 2004), such as the case of the vadose zone with diverse and confined aquatic assemblages.

In the vadose zone of the caves from the Pădurea Craiului Mountains (western Romanian Carpathians) the most often encountered taxa in decreasing number are: harpacticoid and cyclopoid copepods, insect larvae (mainly Diptera Chironomidae), Collembola, Ostracoda, Oligochaeta, Nematoda, Amphipoda, Acari, Gastropoda

and Isopoda (Moldovan et al 2007; Meleg et al 2011). Among these taxa, copepods are the most diversified and abundant, probably the most characteristic taxon dwelling the voids of the vadose zone, as was also mentioned in other karst systems of Southern Europe (Stoch 1997, 2000; Brancelj 2002; Pipan and Brancelj 2001, 2004a, b; Pipan 2005; Sket et al 2004; Camacho et al 2006).

Species richness is the simplest parameter used in assessing community diversity (Chao 2005), being the most frequently used indicator (Gaston 1996) in biodiversity conservation and ecological research (Brown et al 2001). Therefore, species richness as the core component of biodiversity (Gaston 1996) may be used in assessing the groundwater diversity of the Pădurea Craiului Mountains, partly still unknown. Among the methods developed for estimating species richness, species accumulation curves and non-parametric estimators are widely used (Bunge and Fitzpatrick 1993; Colwell and Coddington 1994; Chao 2005).

In the present study we assessed copepod species richness by using different species richness estimators for copepod communities in the vadose zone of the Pădurea Craiului Mountains at different spatial hierarchical scales (cave, hydrographic basin, and massif), and along a vertical gradient in two different habitats (void networks and pools). The obtained results are used to define the best species richness estimator for each spatial scale mentioned above.

MATERIALS AND METHODS

Study area

The Pădurea Craiului Mountains are a karstic “island” that lies in North-Western Romania. As part of the Apuseni Mountains (the western part of the Romanian Carpathians), they cover about 1150 km², with an altitude range between 300 and 1000 m a.s.l (Rusu 1988). In Pădurea Craiului Mountains a Natura 2000 Site of Community Interest (SCI) has been designated: Defileul Crișului Repede-Pădurea Craiului, code ROSCI0062. The Natura 2000 habitat type “caves not open to the public” represents the second habitat as surface in the SCI mentioned above (18.9%). All caves reported in the present study are located in this site.

Data analysis

Two data sets were included in the study. The first data set is represented by five caves from two hydrographic

basins: the Crișul Repede basin (CR) with Ungurului Cave (UC), Vadu Crișului Cave (VC) and Peștera cu Apă din Valea Leșului Cave (LC), and the Crișul Negru basin (CN) with Ciur Izbuc Cave (CC) and Doboș Cave (DC) (Fig. 1). In these caves, the dripping water was sampled monthly over one year and the associated pools were sampled monthly over seven months. This set was used in computing species richness at cave and hydrographic basin scale and in different habitats (voids and pools). The second data set is represented by fauna from pools from 12 additional caves existing in the data base of the “Emil Racoviță” Institute of Speleology (in Cluj). This set was used in computing species richness at the massif level.

The dripping water fauna was sampled according to the funnel method described by Brancelj (2004). Animals from the dripping water system and also those sampled directly from the associated pools were retrieved from the sampling device and pools respectively by a 100 μm mesh-sized hand net and fixed in 96% ethanol.

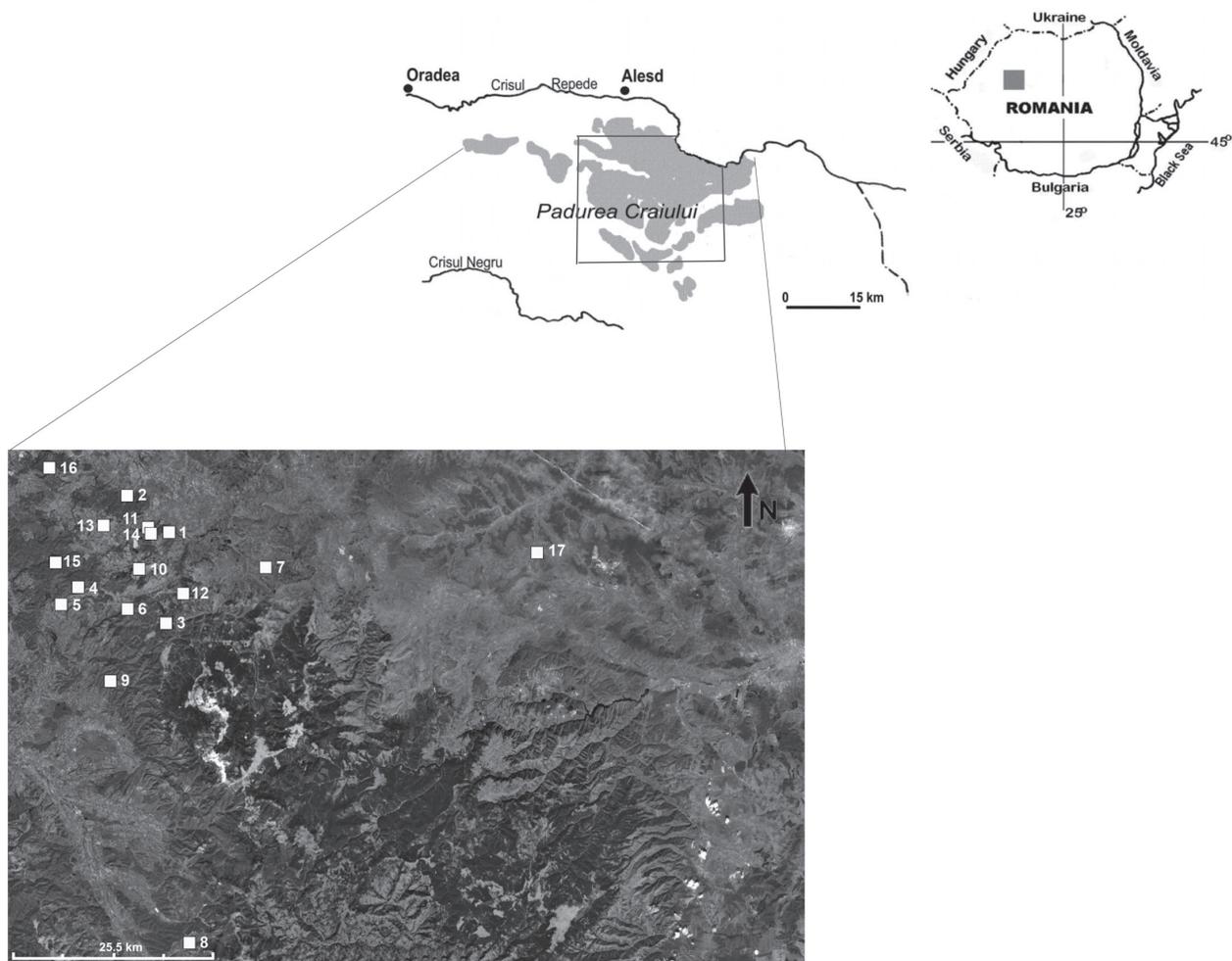


Figure 1 - Location of investigated caves in the Pădurea Craiului Mountains (north-western Romania): 1. UC; 2. VC; 3. LC; 4. CC; 5. DC; 6. Întorsuri Cave; 7. Săncuța Cave; 8. Cubleş Cave; 9. Meziad Cave; 10. Moanei Cave; 11. Vântului Cave; 13. Fanului Cave; Bătrânului Cave; 14. Napiștileu Cave; 15. Vizu Cave; 16. Igrîța cave; Gălășeni Cave.

We considered two ecological categories, epigeal vs. hypogean species (Rouch 1968; Rouch 1982; Rouch and Carlier 1985), based on their occurrence in the subterranean environment and in the surface habitats respectively.

Four non-parametric species richness estimators were selected. For the first data set, Chao 1 and Abundance-based Coverage Estimator (ACE) as abundance-based estimators were used, while incidence-based estimators (Chao 2 and Incidence-based Coverage Estimator (ICE) were used for the second data set, due to the lack of abundance data (Chao et al 1993; Lee and Chao 1994; Chazdon et al 1998). Chao estimators were used for the vadose community due to the presence of many endemic species encountered and rare species which carried most of the information about the number of missing species, i.e. singletons (species known from a single individual) and doubletons (species known from two individuals) for Chao 1, uniques (species that occur in only one sample) and duplicates (species that occur in only two samples) for Chao 2. ACE and ICE were selected to overcome the species richness overestimation, in caves where the number of samples was low, and where very abundant species were found together with very rare species. Mao Tau procedure (expected species accumulation curves-SACs) was used to represent inventory exhaustivity. Comparisons of species richness estimators' performance on sample-based data were represented graphically, by plotting the estimated and observed species richness against the number of sampled sites (Chazdon et al 1998).

At the cave scale and at the basin scale, the monthly copepod abundance in each sample was included. Copepod incidence per cave was used in computing and plotting species richness at massif scale. The effect of non-random spatial distribution on the estimator performance was tested by modifying the degree of patchiness on samples at basin scale. The same pattern was examined also for hypogean/epigeal species. This was performed in EstimateS software by defining a patchiness parameter ranging from 0 (random distribution) to 0.5 (moderate patchiness) and 0.9 (high degree of patchiness).

All computations were based on 50 randomized runs and were performed using EstimateS version 8.2. (Colwell 2009).

RESULTS

Thirteen copepod species were sampled from dripping water and pools in the five caves studied over one year (UC, VC, LC, CC and DC). Twenty-two copepod species collected from pools of 12 caves were added to the analysed data set (Table 1). The number of observed species and samples collected differed at all scales taken into account (cave, hydrographic basin, massif, drips and pools) (Table 2).

The SACs for the three caves from CR basin (UC, VC and LC) showed that sampling completeness was not achieved. When sampling is close to be exhaustive, the number of singletons should be close to zero which is not the case here, reinforcing the results obtained from SACs (Fig. 2 UC, VC and LC; Table 2). For UC and VC the number of species approached an asymptote, but still increased slowly. For UC and VC, Chao1 provided the least biased estimate of species richness, reaching a stable estimate of eight species in UC after 12 samples out of 13, and seven species in VC after 32 samples out of 33. For LC, both estimators failed to reach a stable value. The SACs for caves of the CN basin were asymptotic. The SAC obtained for CC, rapidly followed an asymptote, reaching 75 % of the maximum after eight samples and about 95 % after 18 samples out of 47. In DC the SAC asymptote was reached after eight samples out of nine (Fig. 2 CC, DC; Table 2). In CC, both Chao1 and ACE satisfied the criteria of ideal species richness estimators by performing well at low sample number: a stable estimate of five species was reached after only 29 samples out of 47. In DC, Chao1 was the best estimator with a stable value of three species, after seven samples out of nine. Both caves from CN basin had zero singletons and zero doubletons.

The data computed for CR and CN based on the samples collected in three and two caves respectively are plotted in Fig. 3 and summarized in Table 2. The species richness estimation at the CR and CN basin scale followed the species richness pattern estimated for caves belonging to the CR basin (UC, VC and LC) and to the CN basin (CC and DC) respectively. In CR, sampling completeness was not achieved, and the two non-parametric estimators failed to reach a stable value. In CN, the situation was different; the SAC did reach an asymptote, zero singletons were encountered and both Chao1 and ACE encountered the stable value of five species after 34 samples out of 52.

The effect of patchiness on estimated species richness was tested at basin level. The simulations showed that for CR the rate of species accumulation with sampled area was higher when species were distributed randomly among samples. Moreover, more the degree of patchiness increased (from 0.5 to 0.9), more the initial rate of species richness decreased (Fig. 3). In CN, the species richness estimators were not sensitive to patchiness. Furthermore, the Chao1 and ACE performed well at 0.9 and 0.5 degree of patchiness respectively, being less sensitive to sample size (Fig. 3).

At massif level, 20 species were found in six caves and 75% of the maximum number of observed species was reached after collecting in 12 caves. Chao2 and ICE did not reach a steady value, though it appeared they were approaching a stable estimate: around 60 species after 16 sampled caves; the number of uniques was very high: 19 (Fig. 4; Table 2). These two estimators performed well at a moderate (0.5) and high (0.9) degree of patchiness.

Table 1 - List of copepod species found in caves from Pădurea Craiului Mountains. Hydrographic basins are indicated between brackets (CR-Crișul Repede basin; CN-Crișul Negru basin). Data gathered from literature is indicated in bold; *-hypogean species; underlined-endemic species; 0-absence; +-presence.

Copepod species/cave	Ungurului (CR)	Vadu Crișului (CR)	Peștera cu apă din Valea Leșului (CR)	Ciur Izbuic (CN)	Doboș (CN)	Întorsuri (CN)	Săncuța (CR)	Cubleș (Cugliș) (CN)	Meziad (CN)	Moanei (CR)	Vântului (CR)	Fanului (CR)	Bătrânului (between basins)	Napiștileu (CR)	Vizu (CN)	Igrita (CR)	Gălășeni (CR)
<i>Attheyella (Attheyella) crassa</i> Sars, 1862	0	+	0	0	0	0	0	0	+	0	0	0	0	0	0	+	0
<i>Attheyella (Attheyella) wierzejskii</i> wierzejskii Mrazek, 1893	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0
<i>Bryocamptus (Bryocamptus) cfr. baikalensis</i> Borutzky, 1931	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0
<i>Bryocamptus (Bryocamptus) minutus</i> Claus, 1863	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0
<i>Bryocamptus (Bryocamptus) vej dovskiyi</i> Mrazek, 1893	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bryocamptus (Echinocamptus) dacicus</i> (Chappuis 1923) *	0	+	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0
<i>Bryocamptus (Echinocamptus) echinatus</i> Mrazek, 1893	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0
<i>Bryocamptus (Rheocamptus) caucasicus</i> Borutzky, 1930	+	+	+	+	+	0	0	0	+	0	0	0	0	0	0	0	0
<i>Bryocamptus (Rheocamptus) spinulosus</i> Borutzky, 1931	0	+	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0
<i>Bryocamptus (Rheocamptus) tatrensis</i> Minkiewicz, 1916	+	+	0	0	0	0	0	0	+	+	0	0	0	0	+	0	0
<i>Bryocamptus (Rheocamptus) typhlops</i> Mrazek, 1893	+	+	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0
<i>Bryocamptus (Rheocamptus) unisaetosus</i> Kiefer 1930 *	+	0	0	0	0	0	0	0	0	+	0	0	0	0	+	0	0
<i>Bryocamptus (Rheocamptus) zschokkei</i> zschokkei Schmeil, 1893	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bryocamptus</i> sp. 1	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bryocamptus</i> sp. 2	+	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bryocamptus</i> sp. 3	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ceuthonectes serbicus</i> Chappuis 1924 *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0
<i>Elaphoidella putealis</i> (Chappuis 1925) *	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Maraenobiotus brucei carpathicus</i> Chappuis, 1928	+	+	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Maraenobiotus vej dovskiyi vej dovskiyi</i> Mrazek, 1893	0	+	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0
<i>Moraria (Moraria) brevipes</i> Sars, 1863	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Moraria (Moraria) poppei</i> Mrazek, 1893	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Parastenocaris</i> sp. 1*	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Parastenocaris</i> sp. 2*	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Parastenocaris</i> sp. 3*	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0
<i>Pesceus schmeili</i> Mrazek, 1893	+	+	0	0	0	0	0	0	0	+	0	0	0	0	+	0	0

Copepod species/cave	Ungurului (CR)	Vadu Crişului (CR)	Peştera cu apă din Valea Leşului (CR)	Ciur Izbuca (CN)	Doboş (CN)	Întorsuri (CN)	Săncuţa (CR)	Cubleş (Cugliş) (CN)	Meziad (CN)	Moanei (CR)	Vântului (CR)	Fanului (CR)	Bătrânului (between basins)	Napiştileu (CR)	Vizu (CN)	Igrita (CR)	Gălăşeni (CR)
<i>Spelaecamptus spelaeus</i> (Chappuis, 1925) *	+	0	+	+	+	+	0	+	+	0	0	0	+	+	0	+	+
<i>Acanthocyclops deminutus</i> (Chappuis 1925) *	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0
<i>Acanthocyclops kieferi</i> (Chappuis 1925) *	0	+	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0
<i>Acanthocyclops transylvanicus</i> *	+	0	+	+	+	0	0	0	0	0	0	0	0	0	0	0	0
<i>Diacyclops bisetosus</i> Rehberg, 1880	0	+	0	0	+	0	0	0	0	0	+	0	0	0	0	0	0
<i>Diacyclops stygius</i> (Chappuis 1924) *	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0
<i>Eucyclops serrulatus</i> Lilljeborg, 1901	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Graeteriella unisetigera</i> Graeter, 1908	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Megacyclops viridis</i> Jurine, 1820	0	+	0	0	0	0	0	0	+	+	0	0	0	0	0	0	0
<i>Paracyclops fimbriatus</i> Fischer, 1853	+	+	0	0	0	0	+	0	0	+	0	0	0	0	0	0	0
<i>Speocyclops troglodytes</i> (Chappuis, 1923) *	0	+	0	0	0	+	0	+	0	0	+	0	0	0	0	0	0

Tabel 2 - Species richness estimators computed at different spatial scales

	Ungurului Cave	Vadu Crişului Cave	Peştera cu apă din Valea Leşului Cave	Ciur Izbuca Cave	Doboş Cave	Dripping water	Pools	Crişul Repede basin	Crişul Negru basin	Pădurea Craiului Mountains
No. of samples	6	33	39	47	9	67	22	78	52	17
Observed species	6	5	5	5	3	9	9	10	5	17
Chao 1 (no. of singletons/doubletons)	8 (2/1)	7 (2/2)	8 (3/0)	5 (0/0)	3 (0/0)	12 (3/0)	9 (1/0)	12 (3/2)	5 (0/0)	
ACE	8	9	8	5	3	12	9	13	5	
Chao 2 (no. of uniques/duplicates)										64 (19/5)
ICE										59

The effect of collecting from different habitats of the vadose zone on sampling completeness and species richness was tested in the five caves (UC, VC, LC, CC and DC) over seven months sampling period. The asymptote was not reached, in none of the two habitats. Nevertheless, the SAC based on drip water samples approached an asymptote, reaching 70% of the maximum number of species after 46 samples out of 67. In each of the two habitats (void network and pools), the species richness estimators failed to reach a stable value. When cumulating samples from both habitats, no differences were observed: the SACs did not reach an asymptote and the

estimators failed to reach stable values (Fig. 5 a, b, c; Table 2).

Even if the sampling completeness was not achieved, the SAC based on epigeal (Fig. 6 a) and on hypogean species (Fig. 6 b) approached an asymptote, reaching about 90% of the maximum observed species after 10 caves out of 11 for epigeal species and after 15 caves out of 16 for hypogean species. Both species richness estimators failed to reach a stable value for hypogean species, while ICE reached the stable value of 35 epigeal species after seven out of nine caves. Both estimators recorded higher estimates for patchy distribution and exhibited

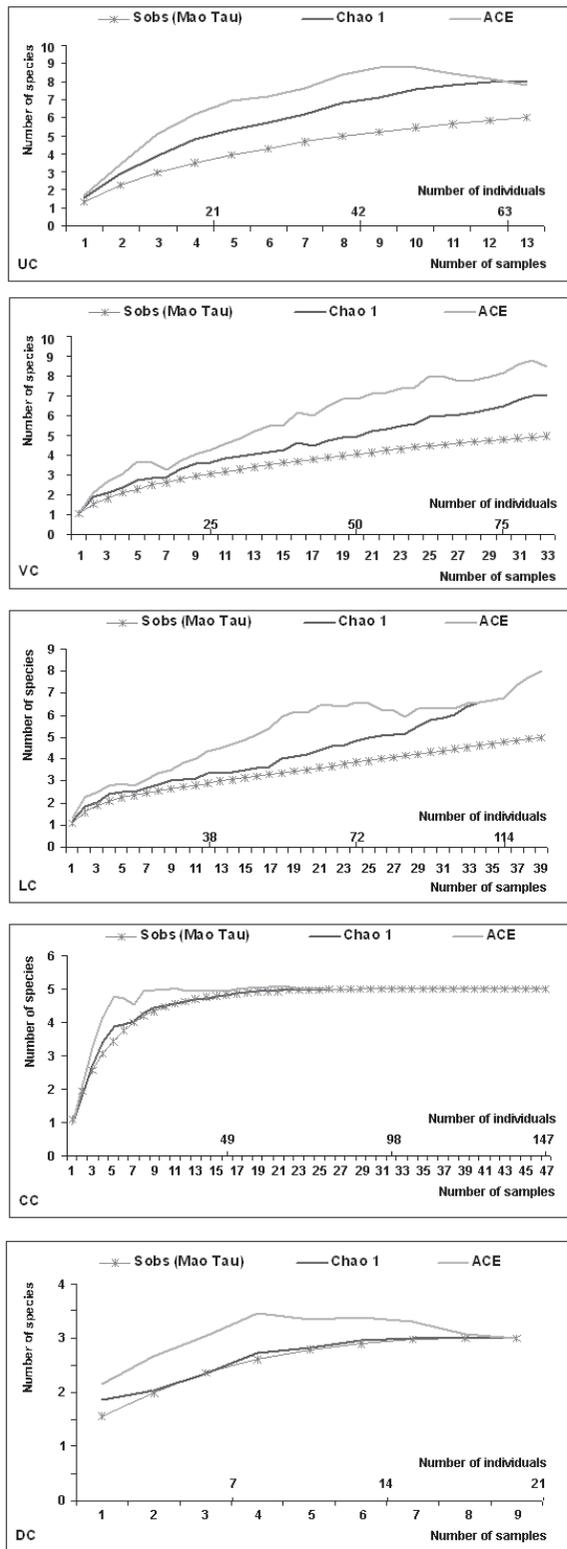


Figure 2 - Rarefaction curves of observed copepod species richness and estimates for the five studied caves: UC (6 species, 13 samples); VC (5 species, 33 samples); LC (5 species, 39 samples); CC (5 species, 47 samples); DC (3 species, 9 samples).

stronger dependence on sample size with increasing degree of patchiness, but were more stable when the analysis was computed for hypogeal species.

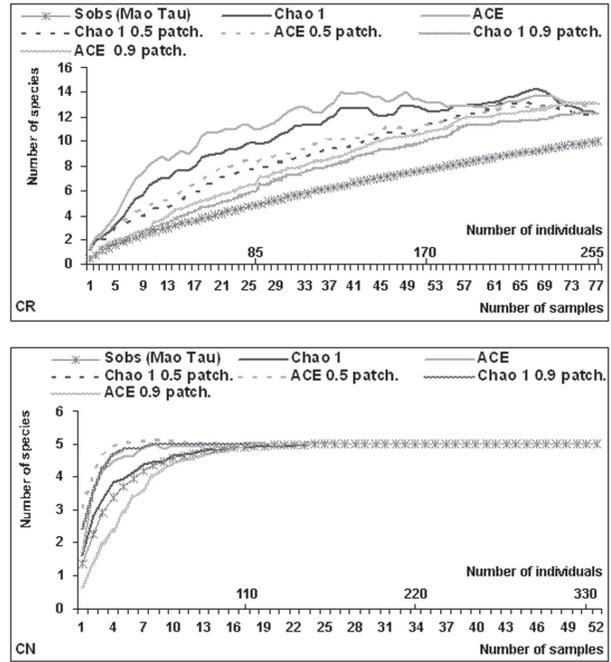


Figure 3 - Rarefaction curves of observed copepod species richness and estimates for: CR basin (10 species, 78 samples); CN basin (5 species, 52 samples) based on the cumulated data from all five caves.

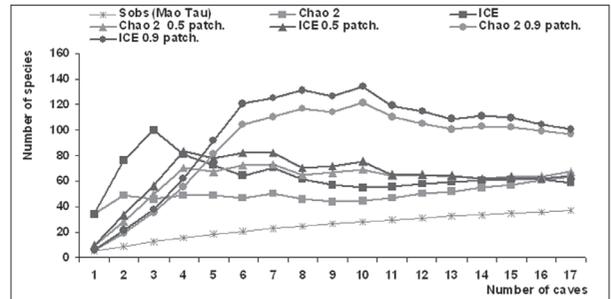


Figure 4 - Rarefaction curves of observed copepod species richness and estimates for Pădurea Craiului Mountains based on the cumulated data from all five caves (UC, VC, LC, CC, DC) and from the database (37 species, 17 caves).

DISCUSSION

From the available estimators (Chazdon et al 1998; Walther and Morand 1998; Chiarucci et al 2001; Brose 2002; Brose and Martinez 2004; Martínez-Sanz et al 2010) some were tested for a more accurate picture of species richness patterns. To date, for vadose assemblages, only rarefaction curves and Chao estimator were used to assess copepod species richness at local and regional scale in the Dinaric Mountains of Slovenia (Pipan and Culver 2007).

In our study, the selected non-parametric estimators (Chao 1, Chao 2, ACE and ICE) performed better than the accumulation curves, because usually they are less biased and more accurate than these latter ones, as al-

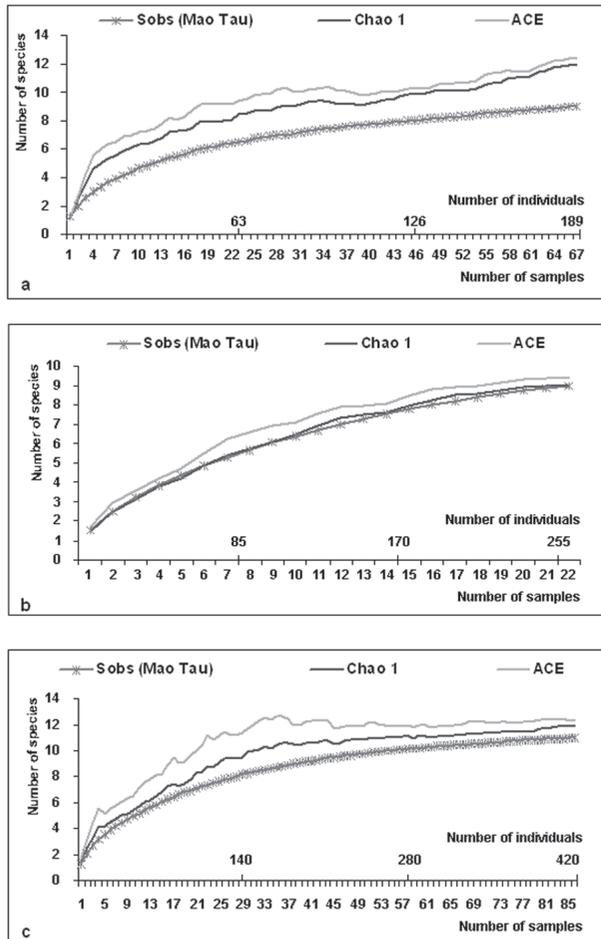


Figure 5 - Comparison of observed and estimated copepod species richness in different habitats for five caves (UC, VC, LC, CC, DC): a. dripping water (9 species, 67 samples); b. associated pools (9 species, 22 samples); c. dripping water and associated pools (11 species, 87 samples).

ready stated by Brose et al (2003) on a landscape model. The same observation was done by Martínez-Sanz et al (2010) on macroinvertebrate communities of mountain ponds in Spain. All four non-parametric estimators could be considered good estimators, because they do not underestimate the richness measured by sampling (observed species) (Martínez-Sanz et al 2010).

The species richness estimates and the SACs obtained at cave scale were more or less similar. Abundance-based Chao 1 and ACE non-parametric estimators performed well for CC, probably because of more varied habitats observed in this cave (wide and narrow void network based on the dripping rate, pools with bottoms on clay and on calcite), which allow the presence of more species. According to Pipan and Culver (2007), for individual caves, five drips sampled for one year appeared to be sufficient to capture most of the species. In our study, in the caves where sampling completeness was achieved, nine drips (CC) and four drips (DC) sampled over one year, were sufficient to sample most of

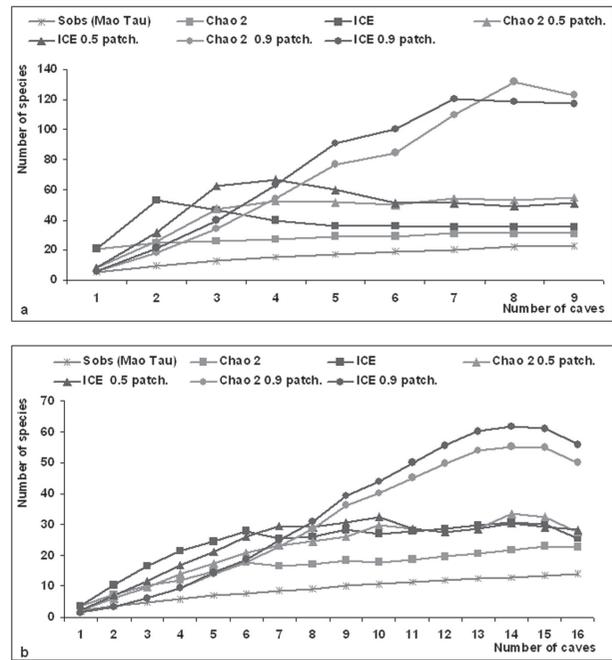


Figure 6 - Comparison of estimates of copepod species richness based on the cumulated data from five caves (UC, VC, LC, CC, DC) and from the database: a. epigeal species (23 species, 9 caves); b. hypogean species (14 species, 16 caves).

the species, reinforcing the important role played by the local context in copepod species richness.

For other caves (UC, VC and LC), where the number of singletons was high, Chao 1 was the least biased estimator, because it takes into account rare species as bearers of data about the number of possible missing species. The higher number of singletons and doubletons suggests a higher level of copepod endemism within caves, as was already stated by Pipan and Culver (2007). The ACE performance for vadose communities is in agreement with the results emphasized in other studies: ACE performed well for species-rich assemblages as Chazdon et al (1998) observed in rain forests, and are unsuitable for communities characterized by low diversity, as Walther and Morand (1998) studied on parasite communities.

Cave-specific trends of species richness could be extrapolated at basin level. Based on SAC, CN basin seems to offer more suitable spots for collecting the fauna of the vadose zone, compared to caves from the CR basin. Evidence is also the low number of hypogean species and the high number of epigeal species sampled in caves from the CR basin. For the CN caves, there is a limited exchange with the surface, proved by few epigeal widespread species. This leads to the conclusion that local-scale patterns in diversity tend to be more evident in stenotopic species, as was already mentioned by Adams (2009) for land plants and aquatic animals. It is the case of some hypogean species confined to different sites in caves from the CN basin (i.e. *Acanthocyclops transylvanicus*, *Bryocamptus* sp. 3, *Parastenocaris* sp. 2).

Chazdon et al (1998) defined three features for an ideal species richness estimator: 1. independence of sample size (sampling effort); 2. lack of sensitiveness to patchiness of species distribution across the samples; 3. lack of sensitiveness to sample order. In CN, the efficiency of both species richness estimators (Chao 1 and ACE) was not influenced by patchiness or by sample size, being ideal estimators at basin scale in contrast with the results obtained for CR. A possible explanation could be the already mentioned heterogeneity of habitats in CC, located in the CN basin, supporting a diverse and more specialized fauna, with heterogeneous and patchy distribution within cave. This was stated by Colwell et al (2004) hypothesizing that space and time “patchiness” among samples is influenced by the heterogeneous character of natural assemblages. This is translated in variation of the total number of species occurrences and non-random patterns of species co-occurrence among samples.

At massif level, sampling from 17 caves was not enough for assessing species richness. In the study conducted by Pipan and Culver (2007) at regional scale, drips from six caves sampled for one year seemed to offer an almost complete picture. In the present study, the species richness estimates at massif scale were higher than those obtained at both cave and basin levels, probably because the number of endemics increased with the studied hierarchical levels (cave, hydrographic basin and massif). The findings of Malard et al (2009) stated that endemic species contribution to regional richness increased with the number of sampled karst aquifers. The narrowly distributed species are the driving factor influencing the regional species richness (Stoch and Galassi 2010). The incidence-based estimators (Chao 2 and ICE) were also insensitive to the patchy species distribution, but unlike the abundance-based estimators, they were dependent on sampling size, suggesting that species richness may be properly calculated after a longer sampling effort in more caves.

Taking into account all five caves from the two basins, sampling completeness was not achieved by sampling only dripping water or by sampling only pools, even when we analyzed the cumulated results from the two habitats. Though, because the SACs based on drips approached an asymptote and copepod diversity was higher in drips than in pools, drips appear to provide a more complete picture of species richness in the vadose zone, as already observed by Pipan and Culver (2005, 2007). The higher species richness in drips could be a consequence of a more lasting habitat in the void network compared to pools, which can be dry during summer periods.

Regarding the two ecological categories, epigean vs. hypogean species, the importance of the degree of patchiness was observed in assessing copepod species richness. Even if ICE was the best estimator, it performed differently on the two ecological categories. The stable performance at higher degree of patchiness of hypogean co-

pepods supports the hypothesis that subterranean species have patchy distribution in groundwater habitats (Galassi et al 2009). Moreover, the vadose zone characterized by habitat patchiness (Musgrove and Banner 2004) harbors species confined to peculiar microhabitats. On the contrary, the estimators of epigean copepod species reached less stable values at high degree of patchiness, probably due to the widespread distribution and eurytopic requirements of surface species.

Even if many estimators are available and some of them were tested here, the estimation of species richness seems to be a difficult task. Estimators may be functional if they can give us a fair insight into the species richness trends (Hortal et al 2006). The sampling limitations and the high proportion of rare species made species richness estimation more challenging in the vadose zone. Our results highlighted how the sampling size, the degree of patchiness and the selected spatial scale influence the performance of species richness estimators, and should be taken into account when choosing the best estimator for species richness assessment. However, for abundance-based data Chao 1 is a good option being robust to sample size. For incidence-based data Chao 2 seemed to be efficient, even if it is more sensitive to the number of samples.

Finally, assessing species richness is important for conservation purposes. Different trends in copepod species richness observed at different spatial scales emphasize the importance of scale in developing and improving the strategies for monitoring protected sites.

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Diversity and dynamics of microarthropods from different biotopes of Las Sardinias cave (Mexico)

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ABSTRACT

An ecological study of the microarthropod communities from Las Sardinias cave was undertaken. Four different biotopes were studied over the course of a year: bat guano, litter, soil under the chemoautotrophic bacteria colonies and as a control, plain soil without litter or guano. A total of 27,913 specimens of a total of 169 species were collected. Analysis of Variance (ANOVA) showed that there is a significant effect of biotope on the recorded density, and the post hoc Tukey's test showed that guano is the most different biotope with the highest value of density recorded. The interaction between season and biotope variables was not significant. In the most extreme case, 99 percent of the microarthropods in soil under chemoautotrophic bacteria were mites, mainly in the family Histiotomidae.

Key words: Cave communities, distribution, energy fluxes, food resources, microarthropods

INTRODUCTION

Caves are environments with relatively stable climatic conditions, compared to those outside. This environment is characterized by the lack of light and very often limited food resources, usually coming from the outside, via streams, gravity, feces of animals or their own remains. But those with big populations of bats can produce large amounts of guano that in many cases are used as fertilizer.

Most animals living inside caves, were considered as "cavernicolous" (Barr 1963), and others as accidental. Among cavernicoles there are troglonexes, troglóphiles or troglóbites according to their life cycle, in agreement to Schinner-Racovitza classification (Racovitza 1907). The number of species living exclusively in the subterranean environments has been estimated between 50,000 and 100,000 (Culver and Holsinger 1992), and the invertebrates, mainly arthropods, constitute the majority of cave animals (Gibert and Deharveng 2002).

Springtails (Collembola) and mites (Acari) are the most diverse and abundant microarthropods in soils and other subterranean environments. They play such an important role in the trophic webs that some authors consider them as the "subterranean plankton" (Ginet and Decou 1977). The movements and dispersion routes of this fauna have been better understood after the discovery of the "milieu souterrain superficiel" (Juberthie et al. 1981). The vertical migration of the animals from surface to caves has been also explained thanks to their transpor-

tion through the microcaves of the superficial environment, and the movement of carbon from the soil to the superficial subterranean environment (Gers 1998). The most important energy flow in caves is input of particulate organic carbon or dissolved organic carbon in water (Simon and Benfield 2001; Simon et al. 2007).

The vast geologic diversity of Mexico makes it very interesting for speleological studies. About 20% of the Mexican territory is karst and more than 1,200 caves have been recorded, and some are among the deepest caves of the World (Lazcano 1983, Espinasa 1990, Arias 2001).

Therefore, Mexico is very attractive for biospeleological research. There is a rich cave fauna and their representatives present interesting adaptations for this peculiar environment. Compilation of all the information about the Mexican fauna has been done by Reddell (1981) and Hoffmann et al. (2004). The most interesting species for their adaptation to cave life were listed by Palacios-Vargas (1994).

The State of Tabasco, which is located in the South of Mexico, is a region with well developed karst (Espinasa 1990), and the fauna of 14 Tabascan caves have been recorded (Reddell 1981). Cueva de Las Sardinias is located on "Villaluz" Ranch, in a small relict of what was once a rich tropical rain forest. Villaluz Ranch is located about two kilometers from Tapijulapa town, in Southeastern Mexico.

The first scientific record about this cave dates back to 1944, when Stirling collected flatworms of the genus *Dugesia*, fish of genus *Poecilia*, trichodactylid crabs of

the species *Trichodactylus bidens*, one amblypidid of the genus *Phrynus*, several genera of spiders such as *Tetragnatha*, *Maymena* and *Eidmanella*, and one hemipteran of the genus *Belostoma*.

Gordon and Rosen (1962) made a systematic study about the fishes from Las Sardinias and their adaptations to cave life. They also cited three species of bats: *Mormoops megalophylla* Peters, *Pteronotus davyi* Gray and *Pteronotus parnellii* Gray. In 1998, Gamboa and Kú made the first topographical description of the cave and gave a list of the surroundings vegetation. Mejía and Palacios-Vargas (2001) collected 31 specimens of *Poecilia sphenops*, among which there was a pregnant female with 15 embryos. Stomach contents of those specimens were analyzed and some arthropods and plant remains were observed. They also recorded ostracods (possible *Cyclocypris*) and one crab (*Avotrichodactylus bidens* Bott).

Hose and Pizarowicz (1999) made a complete and detailed description of this cave which included a map. The importance of Las Sardinias, as a special environment was pointed out by Hose (1999) who described several of the bacteria living there. The bacteria described by Hose and Pizarowicz (1999) are chemoautotrophic, and the secretions of their colonies were called “snottites” because of their appearance. Chemoautotrophic bacteria survive without sunlight, and take energy from an exothermic reaction, in which sulfidric acid is broken down into sulfuric acid. The products of this natural reaction increase the erosion of cave walls. This process was named “replacement solution” by Egeimer (1981). This process produces deposition of the sulfur and gypsum on the walls and ceiling of the cave which are very heavy and weak, and easily crumbles and is dissolved by water very quickly.

The sulfur-eating bacteria constitute the base of the food webs. This was discovered for the first time in the

Movile cave in Romania, where the ecosystem is chemoautotrophically based (Sarbu and Popa 1992, Sarbu et al. 1996). The difference of Movile cave and Cueva de Las Sardinias is that the Mexican cave has three different supplies of energy: guano from the bat colonies, litter and other detritus which fall through the different skylight holes (originated by the action of acids) and the “snottites”, the bacteria colonies. Movile was a closed old system and Las Sardinias is a relatively new and open system.

Several studies of arthropods in Las Sardinias cave have been done, but they are mainly taxonomic (Estrada and Iglesias 2003; Estrada and Mejía-Recamer 2005; Palacios-Vargas and Estrada 2003; Palacios-Vargas et al. 2009) or morphological (Fuentes et al. 2007), but very few of them are related to communities and dynamics. This study mainly focuses on communities and the position of different groups in the complex food chains or trophic web existing in the cave. The study was done during one year and allowed us to make an inventory of the fauna living in this cave.

MATERIALS AND METHODS

Four different biotopes, including the control biotope were studied in the cave for terrestrial communities, which were chosen in twelve different chambers along the cave. They were: a) bat guano; b) litter, debris with soil associate to skylights; c) soil under bacteria colonies; d) soil as control, principally limestone (Fig. 1).

The sampling was done every three months, from March 2001 to March 2002. Twelve samples were taken each time (one from each chamber), every sample was about 600 cm³ and all of them were put in plastic boxes and taken to the laboratory. In the laboratory the samples were processed by Berlese-Tullgren funnels to extract the microarthropod specimens. Specimens were stored in

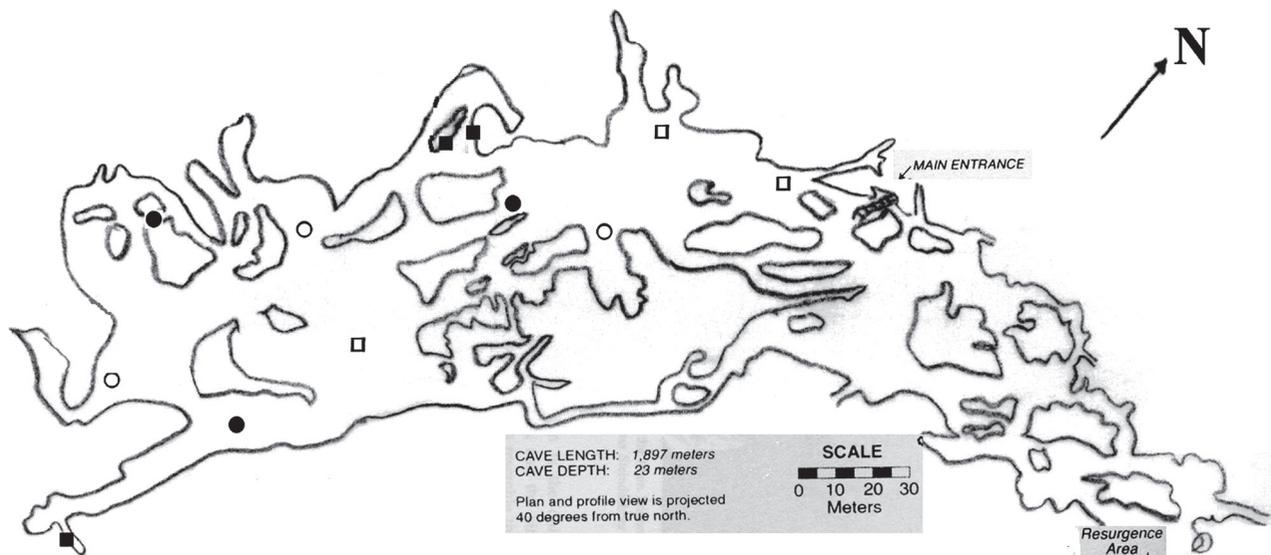


Fig. 1 - Map of the Las Sardinias cave with the location of the samples stations. ■ Bat guano, □ Litter, ● Soil under bacteria colonies and ○ Soil control (Map modified from Hose et al. 2000)

75% alcohol. After that, they were isolated by morphospecies and counted in order to obtain the abundance and the diversity index for each season of the year. For the identification, many specimens of each morphotype were cleared and mounted in Hoyer's solution.

Species richness (S), Shannon diversity ($H' = \sum p_i \ln p_i$) and Pielou's evenness ($J' = H'/\ln S$) indices were calculated. Diversity index were compared between pairs with a t test modified (Magurran 1988; Zar 1984), using PAST software (Hammer et al. 2001). An analysis of variance (ANOVA) was used to evaluate the effect of biotope and that of the season on the density of microarthropods. The affinity of the species to the biotopes was studied with cluster analysis, using the dissimilarity rate (difference between two percentage distributions) as a distance and graphically represented using UPGMA as the aggregation method. All analyses were performed using STATISTICA 5.0 software (Statsoft 1996).

According to the available bibliographic information about the biology of the spotted species, the feeding relationships were inferred in order to show the potential trophic relationships in the cave. In some cases information observed in field on feeding behavior was recorded, as well the gut content observed in slides preparations of microarthropods.

RESULTS AND DISCUSSION

A total of 27,913 specimens were collected (Table 1). The largest number was taken from guano (21,422; 7 individuals m^{-3}), followed by litter (4,455; 1.5 individuals m^{-3}), the soils with the bacteria colonies (1,614; 0.5 individuals m^{-3}) and control soil (422; 0.1 individuals

m^{-3}). ANOVA (Table 2) showed a significant effect of the biotope upon the microarthropod density ($F_{3,40} = 25.67$, $p < 0.0001$), the *post hoc* Tukey test ($p < 0.001$) showed that guano differs from the others biotopes in the density of organisms (Table 3). The interaction between season and biotope variables was not significant, that means that the arthropod density does not change depending on the biotope according to the date (Date: $F_{4,40} = 0.60$, $p > 0.05$; interaction: $F_{12,40} = 1.25$, $p > 0.05$).

Twenty-four microarthropod species were found in soil under the bacteria colonies, forty-four in the control soil, fifty-seven in the guano and one hundred and thirty-six in the litter. The total number of species of this cave was 169. The variation in the number of species in each biotope through the year is shown in Fig. 2.

The most important results of our studies are: 99% of the microarthropods in soil under the chemoautotrophic bacteria colonies were mites, 80% belongs to the cohort Astigmatina (mainly family Histiostomidae), 15% to the Oribatei (mainly family Oppiidae) and only 4% of order Mesostigmata. The remaining arthropods were mainly pseudoscorpions and spiders.

In the control soil, the mites represent 81% microarthropods; among them 38% are Astigmatina (also mainly of the family Histiostomidae). Then, the order Trombidiformes is represented by 22% (mainly the predatory family Cunaxidae) and the other groups are similar to those in the soil under the chemoautotrophic bacteria.

The litter has the highest diversity of microarthropods, but mites are again the dominant group (79%). Among mites, Astigmatina represent 43%, but one important difference is that there were at least 15 morphospecies of Oribatei and 12 of Mesostigmata, almost twice the number found in the other biotopes. Collembola oc-

Table 1 - Abundance of microarthropods, by biotope, found on "Las Sardinas" cave. Trophic groups: B = Bacteriophagous; D = Depredator; F = Phytophagous; L = Litter feeder (Panphytophagous); M = Mycophagous; N = Nematophagous; O = Omnivorous; P = Parasite; S = Scavenging; ND = No Determinate.

Phylum Arthropoda	Litter	Bat Guano	Soil under bacteria colonies	Soil control	Trophic Group	Feeding habit reference
Class Arachnida						
Order Pseudoscorpiones	2	7	11	17	D	De Andrade and Gnaspini 2002
Family Chernetidae	6				D	Johnson and Wellington 1980
<i>Cordylochernes</i> sp.		247			D	Taxa generalized
<i>Lustrochernes</i> sp.		19			D	Taxa generalized
Family Lechytiidae						
<i>Lechytia</i> sp.		2			D	Taxa generalized
Family Olpiidae			1		D	Taxa generalized
Family Syarinidae						
<i>Ideoblothrus</i> sp.	10		1	4	D	Taxa generalized
Order Schizomida	2				D	Taxa generalized

Phylum Arthropoda	Litter	Bat Guano	Soil under bacteria colonies	Soil control	Trophic Group	Feeding habit reference
Order Araneae						
Family Dipluridae	2	2			D	Jiménez 1998
Family Linyphiidae	19				D	Harwood et al. 2001
Family Mimetidae	6				D	Kloock, 2001
Family Pholcidae	3	1				Jiménez 1998
Family Salticidae	27		3	19	D	Jiménez 1998
Order Opiliona	1				D	Santos and Gnaspini 2002
Subclass Acari						
Order Ixodida						
Superfamily Ixodoidea						
Family Ixodidae	1				P	Taxa generalized
Family Argasidae						
<i>Antricola</i> sp.	7	43			C, P	De la Cruz and de Armas 1990
Order Mesostigmata						
Morphospecies 1	9				ND	
Morphospecies 2	1				ND	
Morphospecies 3	6			2	ND	
Suborder Sejida						
Superfamily Sejoidea						
Family Sejidae						
<i>Sejus</i> sp.		11	67	19	D	Walter and Proctor 1998
Suborder Trigynaspida						
Cohort Antennophorina						
Superfamily Celanopsoidea						
Family Diplogyniidae		6			F	Hunter 1993
Superfamily Megisthanoidea						
Family Megisthanidae	3				F, N	Hunter 1993
Suborder Monogynaspida						
Cohort Uropodina						
Subcohort Uropodiae						
Superfamily Uropodoidea	1				L, H	Nawar et al. 1993
Family Metagynuridae						
<i>Metagnella</i> sp.		13		5	L	Taxa generalized
Family Uropodidae						
<i>Uropoda (Phaulodinychus)</i> sp.	11	12931			L	Vazquez and Klompen 2007
Family Trematuridae						
<i>Trichouropoda</i> sp.		21			L, M	Lindquist et al. 2009
Cohort Gamasina						
Subcohort Dermanyssiae						
Superfamily Rhodacaroidea						
Family Ologamasidae						
<i>Gamasellus</i> sp.	1	1		1	D	Lister et al. 1998
Family Rhodacaridae						
<i>Rhodacarus minimus</i>	81				D, N	Sardar and Murphy 1987
Superfamily Eviphidoidea						
Family Macrochelidae						
<i>Glyptholaspis</i> sp.		392		7	D	Lindquist et al. 2009
Superfamily Ascoidea						
Family Ascidae						
<i>Gamasellodes</i> sp.	1	1424	2		D, N	Walter 1987 ^a

Phylum Arthropoda	Litter	Bat Guano	Soil under bacteria colonies	Soil control	Trophic Group	Feeding habit reference
Family Melicharidae						
<i>Proctolaelaps</i> sp.			1		D	Lindquist et al. 2009
Superfamily Phytoseioidea						
Family Blattisociidae						
<i>Lasioseius</i> sp.	199			6	D, M, N	Walter and Lindquist, 1989
Family Phytoseiidae		140			D	McMurtry and Croft 1997
Superfamily Dermanyssoidea						
Family Laelapidae						
<i>Gaeolaelaps</i> sp.	47	5			D, N	Walter and Oliver 1989
<i>Hypoaspis</i> sp.	4				D	Taxa generalized
Family Macronyssidae				1	P	O'Connor 1998
Order Trombidiformes						
Morphospecies 1	3	1		4	ND	
Morphospecies 2	2	1			ND	
Morphospecies 3	20				ND	
Morphospecies 4	1				ND	
Morphospecies 5	1				ND	
Morphospecies 6				1	ND	
Suborder Prostigmata						
Supercohort Eupodides						
Superfamily Bdelloidea						
Family Cunaxidae						
<i>Coleoscurus</i> ca. <i>breslauensis</i>	22	10	2	3	D, N	Walter and Kaplan 1991
<i>Coleoscurus</i> ca. <i>simplex</i>	9			1	D, N	Walter and Kaplan 1991
<i>Cunaxoides</i> ca. <i>nicobarensis</i>	3				D	Fain et al. 1993
<i>Cunaxoides</i> sp.	16	654			D	Fain et al. 1993
<i>Dactyloscirus</i> sp. 1	4		15	25	D	Taxa generalized
<i>Dactyloscirus</i> sp. 2	6		1		D	Taxa generalized
<i>Neoscirula</i> ca. <i>luxtoni</i>	4				D	Taxa generalized
<i>Neoscirula</i> ca. <i>delareyi</i>	1				D	Taxa generalized
<i>Neoscirula</i> sp.	6		1	18	D	Taxa generalized
<i>Pseudobonzia</i> sp.	39		1	4	D	Taxa generalized
<i>Pulaeus</i> ca. <i>pectinatus</i>	1				D	Taxa generalized
<i>Pulaeus</i> sp. 1	10	616		3	D	Taxa generalized
<i>Pulaeus</i> sp. 2	29	7			D	Taxa generalized
Superfamily Eupodoidea						
Family Rhagidiidae						
<i>Robustocheles</i> sp.	1				D	Taxa generalized
Supercohort Trombidiae						
Superfamily Trombidoidea		13		1		Azevedo et al. 2002
Superfamily Trombiculoidea						
Family Neotrombidiidae		2			P	Taxa generalized
Supercohort Eleutherengonides						
Cohort Heterostigmatina						
Superfamily Tarsonemoidea						
Family Tarsonemidae	2	2			L, F	Estebanes-Gonzalez 1997
Order Sarcoptiformes						
Suborder Endeostigmata						
Cohort Alycina						
Superfamily Alycoidea						
Family Nanorchestidae	31			11	L, M	Walter 1987b
Suborder Oribatida						

Phylum Arthropoda	Litter	Bat Guano	Soil under bacteria colonies	Soil control	Trophic Group	Feeding habit reference
Supercohort Palaesomatides						
Superfamily Palaeacaroidae	2				L	Taxa generalized
Supercohort Enarthronotides						
Superfamily Hypochthonioidea						
Family Lohmanniidae						
<i>Javacarus (Euryacarus) pilosus</i>	6				L	Taxa generalized
Supercohort Mixonomatides						
Superfamily Euphthiracaroidae						
Family Euphthiracaridae	1				L	Taxa generalized
Superfamily Phthiracaroidae						
Family Phthiracaridae	13				L	Taxa generalized
Supercohort Desmonomatides						
Cohort Nothrina						
Superfamily Crotonioidea						
Family Malaconothridae						
<i>Malaconothrus ca. angulatus</i>	1				L	Palacios-Vargas and Iglesias 1997
<i>Malaconothrus ca. pervensis</i>	5				L	Palacios-Vargas and Iglesias 1997
<i>Malaconothrus ca. granulatus</i>	27				L	Palacios-Vargas and Iglesias 1997
<i>Malaconothrus (Cristonothrus) peruanensis</i>	29				L	Palacios-Vargas and Iglesias 1997
<i>Malaconothrus</i> sp.		3			L	Palacios-Vargas and Iglesias 1997
Cohort Brachypylina						
Superfamily Microzetoidea						
Family Microzetidae						
<i>Berlesezetes brazilozetoides</i>	1				L	Taxa generalized
Superfamily Gustaviodea						
Family Liacaridae						
<i>Cultroribula</i> sp.	1				L	Taxa generalized
Superfamily Carabodoidea						
Family Carabodidae						
<i>Cubabodes ca. radiatus</i>	39				L	Taxa generalized
Family Dampfiellidae						
<i>Beckiella</i> sp.	1				L	Taxa generalized
Superfamily Oppioidea						
Family Oppiidae						
Subfamily Oppiinae						
<i>Aeroppia ca. nasalis</i>	3				L	Taxa generalized
<i>Aeroppia nasalis</i>	11				L	Taxa generalized
<i>Aeroppia</i> sp.				1	L	Taxa generalized
<i>Amerioppia similis</i>	37			2	L	Taxa generalized
<i>Taiwanoppia (Vietoppia) sp.</i>	1				L	Taxa generalized
Subfamily Multioppiinae						
<i>Intermedioppia ca. alvarezi</i>	136		250	111	L	Guevara et al. 2002
Subfamily Mystroppinae	6			2	L	Taxa generalized
Subfamily Arcoppiinae						
<i>Similoppia (Reductoppia) sp.</i>		2			L	Subias and Rodriguez 1987

Phylum Arthropoda	Litter	Bat Guano	Soil under bacteria colonies	Soil control	Trophic Group	Feeding habit reference
Family Suctobelbidae						
<i>Suctobelbella (Flagrosuctobella) multiplumosa</i>	1				L	Taxa generalized
Superfamily Oriopodoidea						
Family Haplozetidae						
<i>Trachyoribates (Rostrozetes) foveolatus</i>	420	453			L	Taxa generalized
Family Scheloribatidae				1	L, M	Hubert et al. 2000
<i>Scheloribates elegans</i>	22				L, M	Hubert et al. 2000
<i>Scheloribates</i> sp.	95	1			L, M	Hubert et al. 2000
Superfamily Ceratozetoidea						
Family Ceratozetidae						
<i>Ceratozetes</i> sp.	2				L, M	Walter 1987b
Superfamily Galumnoidea						
Family Galumnidae						
<i>Galumna</i> ca. <i>hamifer</i>	66				L	Schatz 1998
<i>Galumna hamifer</i>	23				L	Schatz 1998
Cohort Astigmatina (Astigmata)						
Superfamily Histiostomatoidea						
Family Guanolichidae						
<i>Neoguanolichus</i> sp.	7	802	866	3	C	Fain 1979
Family Histiostomatidae						
<i>Histiostoma</i> ca. <i>himalayae</i>				5	B	Vreeken-Bujin et al. 1997
<i>Histiostoma</i> ca. <i>bakeri</i>	25				B	Vreeken-Bujin et al. 1997
<i>Histiostoma</i> ca. <i>piloseta</i>		1209			B	Vreeken-Bujin et al. 1997
<i>Histiostoma</i> ca. <i>sextoni</i>	293				B	Vreeken-Bujin et al. 1997
<i>Histiostoma</i> sp. 1	699	367	114	57	B	Vreeken-Bujin et al. 1997
<i>Histiostoma</i> sp. 2	5				B	Vreeken-Bujin et al. 1997
<i>Histiostoma</i> sp. 3	1				B	Vreeken-Bujin et al. 1997
<i>Histiostoma</i> sp. 4	109			5	B	Vreeken-Bujin et al. 1997
Superfamily Hemisarcoptoidea						
Family Winterschmidtidae						
<i>Winterschmidtia</i> sp.		2			F	Rodriguez-Navarro et al. 2003
Superfamily Glycyphagoidea						
Family Rosensteiniidae						
<i>Nycteriglyphagus</i> sp.	4	8			L	OConnor 1998
Superfamily Acaroidea						
Family Acaridae						
<i>Rhizoglyphus</i> ca. <i>callae</i>	130	2		1	F	Díaz et al. 2000
<i>Rhizoglyphus</i> ca. <i>robini</i>	59	1			F, N	Estebanes-Gonzalez & Rodriguez-Navarro 1991
<i>Sancassania</i> ca. <i>mycophagus</i>	7	126	262	24	F	Estebanes-Gonzalez & Rodriguez-Navarro 1991
<i>Schwiebea</i> sp.	737	1	22	6	M	Okabe 1999
<i>Tyrophagus</i> ca. <i>neiswanderi</i>	10	1		1	M	Okabe 1999
<i>Tyrophagus</i> ca. <i>similis</i>		1			F, M	Okabe 1999
Class Crustacea						
Subclass Copepoda						
Order Harpacticoida	34				B	Rieper 1978
Order Isopoda	10				L	Reeves and McCreadie 2001

Phylum Arthropoda	Litter	Bat Guano	Soil under bacteria colonies	Soil control	Trophic Group	Feeding habit reference
Class Collembola						
Order Poduromorpha						
Superfamily Neanuroidea						
Family Neanuridae						
Subfamily Neanurinae						
<i>Americanura sardinensis</i>	28				L, M	Taxa generalized
Subfamily Pseudachorutinae						
<i>Pseudachorutes</i> sp.	7				L	Taxa generalized
<i>Neotropiella quinqueoculata</i>	6				L, M	Taxa generalized
Family Odontellidae						
<i>Xenyllodes</i> sp.	1				L, M	Taxa generalized
Superfamily Hypogastruroidea						
Family Hypogastruridae						
<i>Ceratophysella</i> ca. <i>succinea</i>	1			1	L, M	Zettel et al. 2002
<i>Xenylla</i> ca. <i>humicola</i>		17		2	L, M	Castaña-Meneses et al. 2004
Superfamily Onychiroidea						
Family Tullbergiidae						
<i>Mesaphorura yosii</i>	36			1	L, M	Sabatini and Innocenti 2000
Order Entomobryomorpha						
Superfamily Isotomoidea						
Family Isotomidae						
Subfamily Anurophorinae						
<i>Cryptopygus</i> ca. <i>thermophilus</i>	15				L, M	Castaña-Meneses et al. 2004
<i>Cryptopygus thermophilus</i>	20				L, M	Castaña-Meneses et al. 2004
Subfamily Proisotominae						
<i>Folsomina onychiurina</i>	5				L, M	Taxa generalized
Subfamily Isotominae						
<i>Isotoma</i> sp.	18				L, M	Walter 1987b
<i>Isotomiella minor</i>	9				L, M	Taxa generalized
<i>Isotomurus retardatus</i>	15				L, M	Castaña-Meneses et al. 2004
Superfamily Entomobryoidea						
Family Entomobryidae				1	L, M	Castaña-Meneses et al. 2004
Subfamily Orchesellinae						
<i>Heteromurus major</i>	3				L, M	Scheu et al. 1999
Subfamily Entomobryinae						
<i>Entomobrya</i> sp.	9				L, M	Chen et al. 1996
Subfamily Lepidocyrtinae						
<i>Lepidocyrtus</i> sp.	1				L	Taxa generalized
<i>Pseudosinella</i> ca. <i>colina</i>	2			1	L, M	Walter 1987b
<i>Pseudosinella orba</i>	7			7	L, M	Walter 1987b
Family Paronellidae				2	L	Taxa generalized
Order Neelipleona						
Family Neelidae						
<i>Megalothorax minimus</i>	1				L	Taxa generalized
Order Symphypleona						
Superfamily Katiannoidea						
Family Katiannidae						
<i>Sminthurinus quadrimaculatus</i>		2			L	Taxa generalized
Family Arrhopalitidae						
<i>Arrhopalites</i> sp.	2				L	Taxa generalized
Superfamily Dicyrtomoidea						

Phylum Arthropoda	Litter	Bat Guano	Soil under bacteria colonies	Soil control	Trophic Group	Feeding habit reference
Family Dicyrtomidae						
Subfamily Ptenothricinae						
<i>Ptenothrix marmorata</i>	7				L	Taxa generalized
Class Symphyla	1				L	Umble and Fisher 2003
Class Insecta						
Order Microcoryphia		1	1		L	Taxa generalized
Order Zygentoma	1				L	Taxa generalized
Order Thysanoptera						
<i>Adraneothrips</i> sp.	6	1			M	Childers et al. 1998
<i>Zeugmatothrips priesneri</i>	20				F, M	Taxa generalized
Order Psocoptera	2				L, M	Taxa generalized
Order Hemiptera-Heteroptera	1				F	Taxa generalized
Order Homoptera-Homoptera	3	1	1	3	L, F	Taxa generalized
Order Coleoptera						
Larvae 1	19	416	2	8	ND	
Larvae 2	337				ND	
Larvae 3		6			ND	
Family Curculionidae	2				F	Navarrete-Heredia 2001
Family Histeridae						
<i>Hister</i> sp.		14			N, D	Moreno et al. 1998
Family Platypodidae		1			F	Equihua-Martínez et al. 1984
Family Ptiilidae	1				L, M	Navarrete-Heredia 2001
Family Scydmaenidae	1	2	1	4	D	O'Keefe 2000
Family Staphylinidae	2				D	Leschen and Newton 2003
<i>Anotylus</i> sp.	6				L, N, M, S	Jimenez-Sanchez et al. 1990
Order Lepidoptera		5			F	Taxa generalized
Order Diptera	9	22	2	3	L	Taxa generalized
Larvae 1	9	227			ND	
Larvae 2	19				ND	
Larvae 3	8	172			ND	
Larvae 4	22	4			ND	
Larvae 5	3				ND	
Family Chironomidae						
Larvae 1	11	767			L	Delettre 2000
Order Hymenoptera	1				F	Taxa generalized
Family Formicidae						
Subfamily Amblyoponinae						
<i>Prionopelta modesta</i>	24				D	Taxa generalized
Subfamily Myrmicinae						
<i>Leptothorax</i> sp. 1	18				O	Fernández 2001
<i>Leptothorax</i> sp. 2	10				O	Fernández 2001
<i>Solenopsis</i> sp. 1	29		1		D, O	Fernández 2001
<i>Solenopsis</i> sp. 2	3				D, O	Fernández 2001
<i>Strumigenys</i> sp.	2				D	Fernández 2001
<i>Tetramorium</i> sp.	2				D	Bendicho and Gonzalez 1986
<i>Wasmannia auropunctata</i>	2				D	Taxa generalized
Subfamily Ponerinae						
<i>Hypoconera</i> sp.	12					Taxa generalized
<i>Pachycondyla</i> sp.	1				D	Dejean 1990

Table 2 - Results of ANOVA test to evaluate the effect of biotope and collecting date on the microarthropods density from Las Sardinias Cave, Tabasco Mexico. * $p < 0.05$. $N=40$

Source	F	Df	p
Biotope	25.67	3	0.0001*
Date	0.60	4	0.10
Interaction	1.25	12	0.20

Table 3 - Average density of microarthropods (ind/cm³) from Las Sardinias Cave, Tabasco Mexico. Different letters denote differences according with *post hoc* Tukey's test.

Biotope/Date	Average \pm sd
Soil under bacteria colonies	0.53 \pm 0.77a
Soil control	0.14 \pm 0.08a
Litter	1.48 \pm 0.99a
Bat Guano	7.09 \pm 3.99b

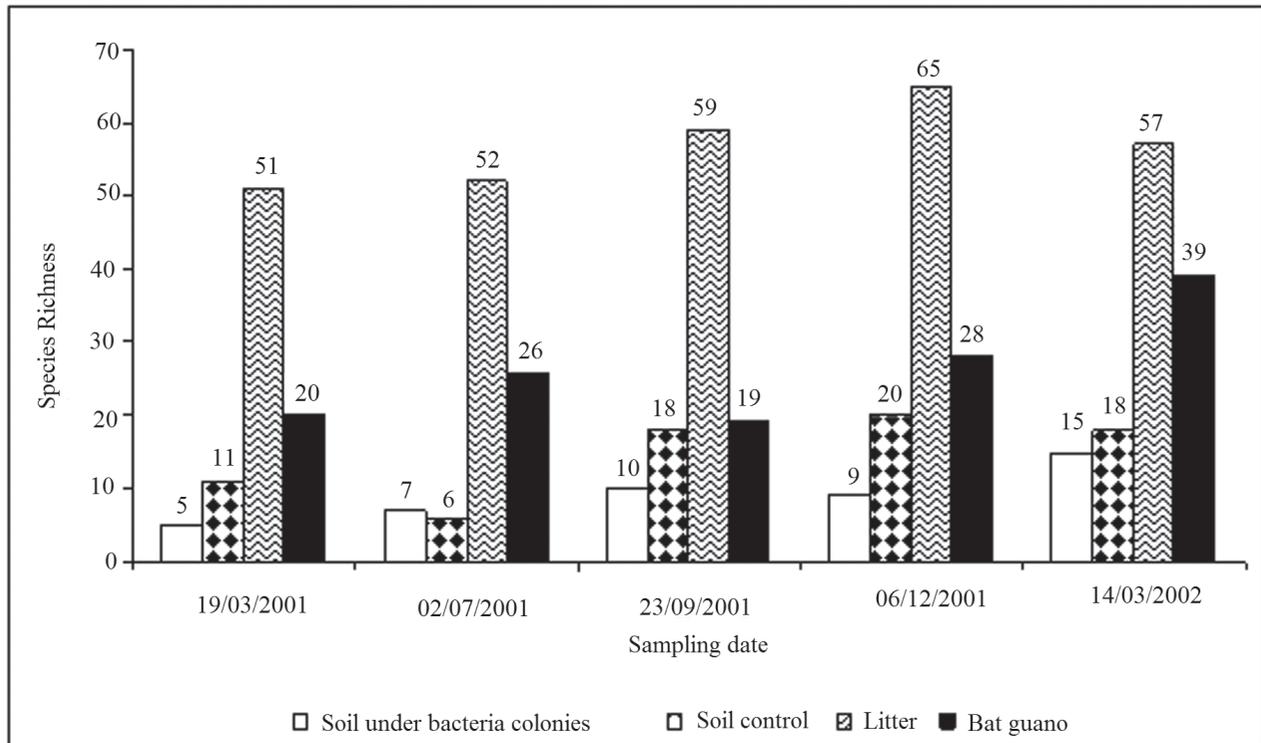


Fig. 2 - Number of species for each biotope at different dates in Las Sardinias cave, Tabasco, Mexico.

copy the sixth place after three different species of mites and one of Coleopteran larvae.

Guano has high abundance of Mesostigmata mites (79% of total microarthropods), followed by Dipteran larvae and Astigmatid mites (6% each taxon), and the Trombidiformes (mainly Cunaxidae 3%). Figs 3 and 4 show the most abundant microarthropods from different biotopes in the cave.

There were important and statistical significant differences among the biotopes except between diversity of the litter and control soils. This suggests that the biotopes of this cave have four independent communities,

in which the vegetal debris had the highest diversity according to the Shannon index ($H' = 3.34$), followed by the control soil ($H' = 2.85$), bat guano ($H' = 1.72$), and the soil under the bacteria ($H' = 1.43$). The evenness follows more or less the same pattern, but the guano communities present the lowest value in evenness ($J' = 0.75$ plant debris > 0.68 control soil > 0.45 bacteria > 0.43 guano). The guano probably has the lowest diversity because it has different fauna depending on maturation and the high abundance of few species. The t test results have shown significant differences between all the diversity indexes recorded in the study (Table 4).

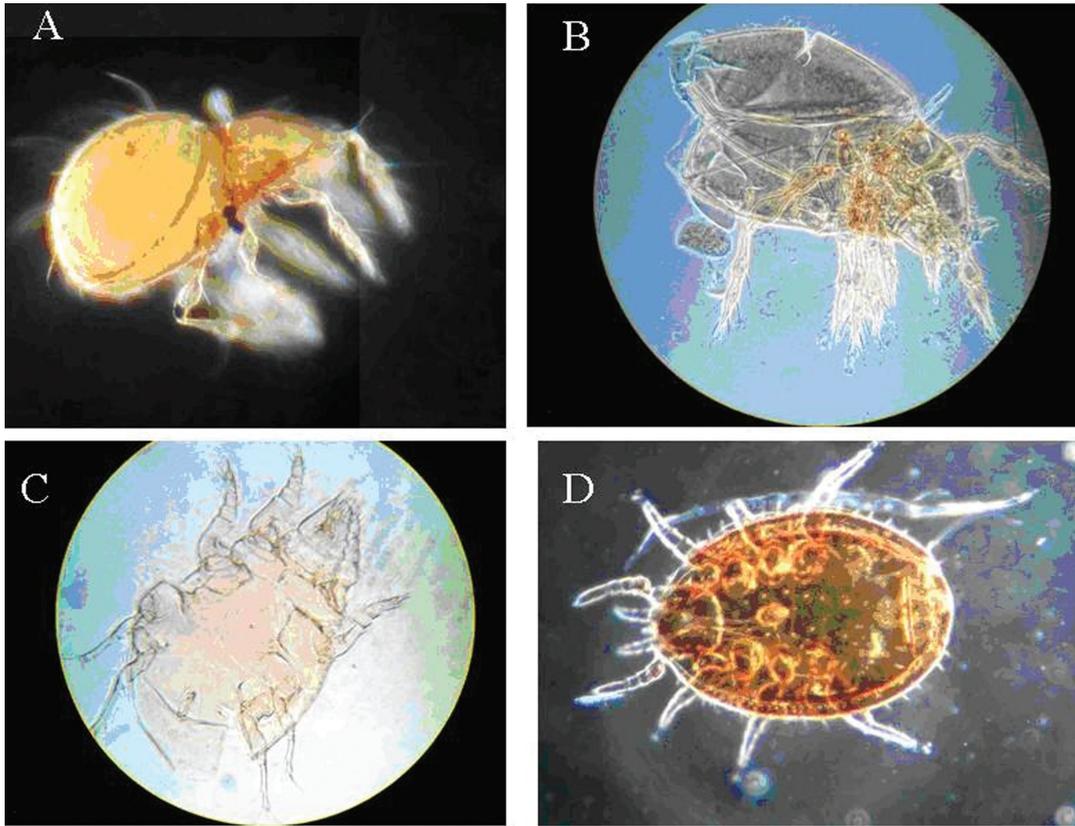


Fig. 3 - Mites found at Las Sardinas cave. A. Cryptostigmata: Oppidae; B. Cryptostigmata: Scheloribatidae; C. Astigmata: Histios-tomidae; D. Mesostigmata: Uropodidae.

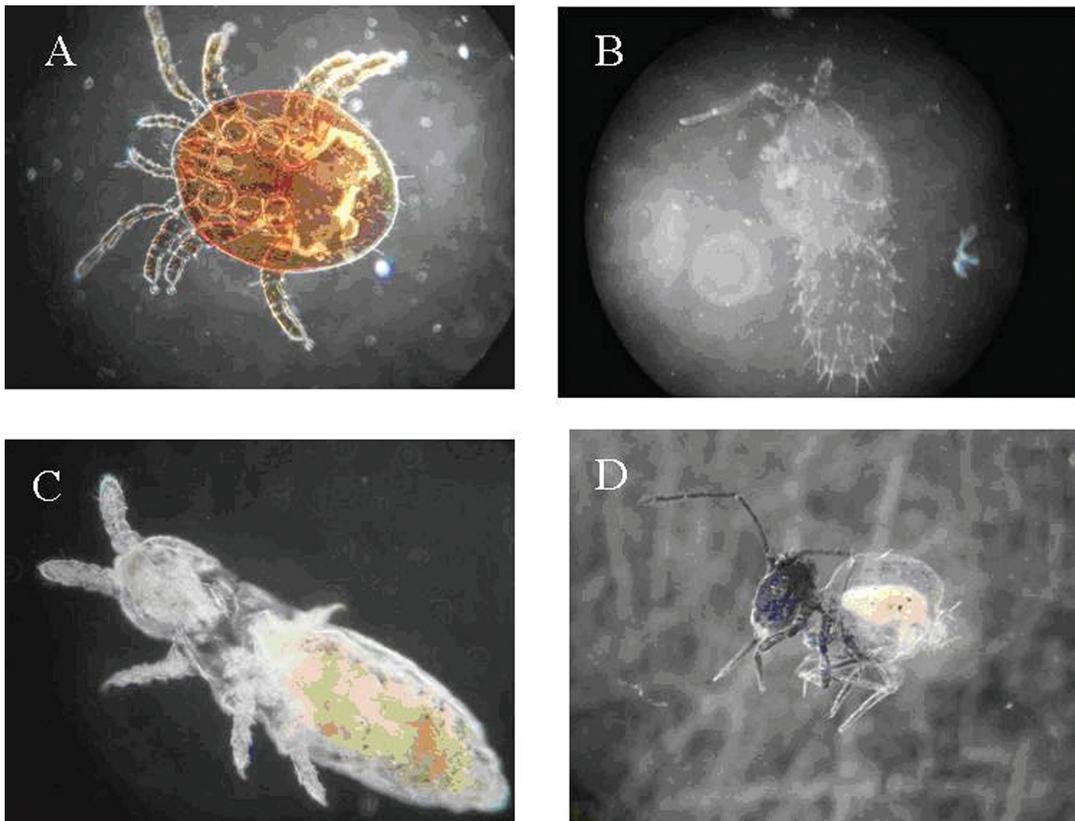


Fig. 4 - Mites and springtails from Las Sardinas cave. A. Mesostigmata: Uropodidae; B. Collembola: Neanuridae; C. Collembola: Hypogastruridae; D. Collembola: Dicyrtomidae.

Table 4 - Results of paired t test between diversity indices. Degree freedom in parenthesis *p<0.05

Biotope	Soil under Bacteria	Soil control	Litter	Bat guano
Soil under Bacteria	-	19.54 (597)*	50.64 (4000)*	9.65 (2134)*
Soil control	19.54 (597)*	-	7.63 (547)*	16.55 (445)*
Litter	50.64 (4000)*	7.63 (547)*	-	60.08 (6322)*
Bat guano	9.65 (2134)*	16.55 (445)*	60.08 (6322)*	-

Cluster analysis used to compare the four biotopes in relation to the shared species shows isolation of the litter from the others biotopes. This is the biotope more different in species composition than the others. The other group is grouping the more similar biotopes in the cave and among these the soil under bacteria colonies, and control soil are more similar to each other than the guano (Fig. 5).

The species richness can be explained because of the great diversity of habitats within of Las Sardinias cave. Those habitats together along with other factors such as the vegetation around the cave (Gamboa and Ku 1998), and the connection with the environmental conditions of the area where the cave is located, play an important role in explaining diversity too. The presence of diverse

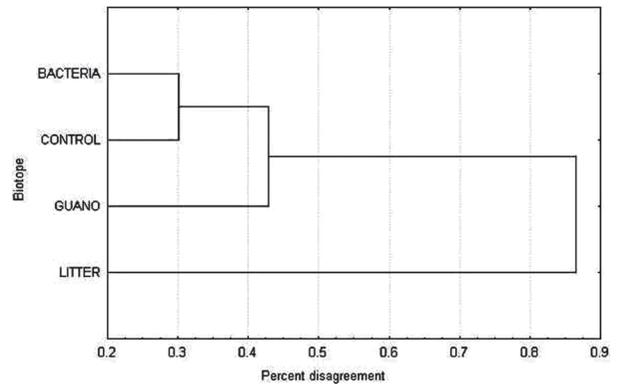


Fig. 5 - Cluster diagram showing the percent of disagreement of the biotopes according with its species composition.

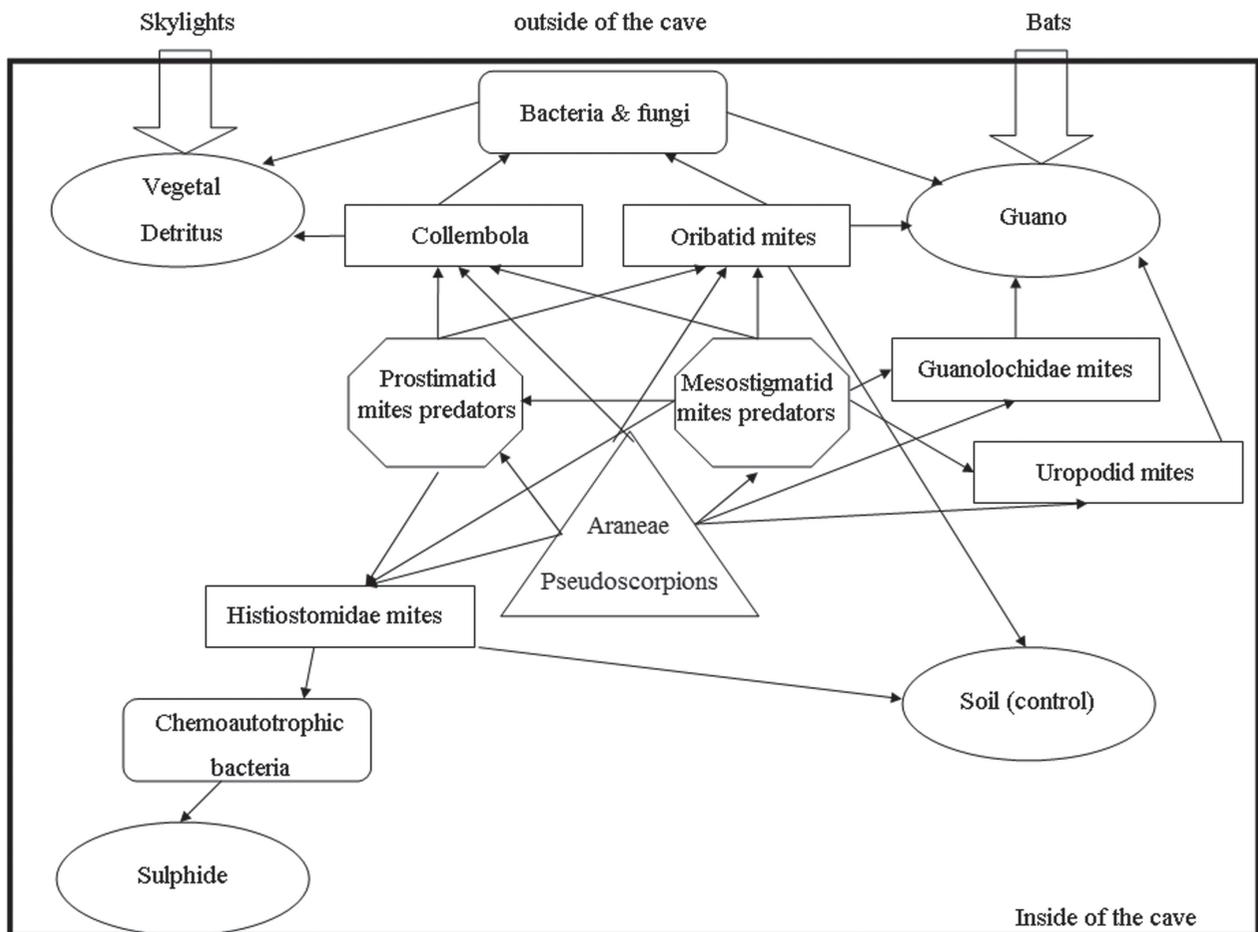


Fig. 6 - Proposed trophic web at Las Sardinias cave, Tabasco, Mexico. ○ = Energy source; □ = Microorganisms; □ = Arthropods first consumers; □ = Arthropods first predators; △ = Arthropods second predators.

sources of nutrients increases the resources availability that can be exploited by different microarthropods, increasing the possibility to support a diversity of communities. Studies about the diversity of habitats and species richness in caves suggest that, for the terrestrial animals, the local patterns of diversity are very important (Christman and Culver 2001).

Due to the different food resources in Las Sardinias cave, the food webs are very complex. There are four trophic levels which interact, and result in an increase of the energetic fluxes in the system. The main food resources are: plant detritus which come from the surrounding vegetation (Fig. 6). The other important food source is bat guano, and the bacteria colonies are less important. The plant detritus feeds many fungi and some bacteria which are consumed by many Collembola, Oribatid and Uropodid mites, most of them are preys of Prostigmata and Mesostigmata mites, ants, and different arachnids as spiders, pseudoscorpions, amblypygids, and the Scutigera centipides. The bat guano contains mites and Collembola very similar to those found at the vegetal detritus, but with some species very specialized as guanophiles.

One important remark is the fact that we found two other species of mormoopid bats (*Pteronotus personatus* and *Pteronotus gymnotus*) which always form huge colonies. There are also other less abundant species in families Emballonuridae (possible *Baliantopteryx*), Phyllostomidae (*Carollia*) and the vampire bat (*Desmodus rotundus* Thomas) in subfamily Desmodontinae, additional to the previous recorded species (Gordon and Rosen 1962).

CONCLUSIONS

This cave is by far the most diverse we have studied, with a least 169 terrestrial microarthropod species. The soil under the chemoautotrophic bacteria and the litter have the lowest value of the diversity index, while the guano has the largest microarthropod abundance. The species found belonging to the families Histiostomidae (Astigmata) and Oppiidae (Cryptostigmata) indicate they have the highest resistance to acid conditions of the environment.

Among microarthropods, the mites are the most abundant group, and Mesostigmata are the dominant group in presence. This result is very different of what is commonly found in the caves, where the springtails are usually the dominant group (Gers 1998). In our results, springtails occupy the sixth place in abundance, after Mesostigmata, Astigmata, Cryptostigmata, Prostigmata and Coleoptera larvae. The presence of many predatory mites suggests that the available resources in the cave can support higher trophic levels.

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Trophic Dynamics in a Neotropical Limestone Cave

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ABSTRACT

The temporal budgets of the input, retainment and use by invertebrates of detritus and root tufts were evaluated in a short tropical limestone cave (337 m long). Detritus penetrate only through the stream in lower quantities in the dry season, contrary to what happens in the rainy season. However, water transport energies in the rainy season prevent detritus retainment. Roots tufts that emerge from the bottom of the stream provide shelter and food for several species. The abundance (\log_{10}) ($R^2 = 0.63$; $P < 0.02$) and richness (\log_{10}) ($R^2 = 0.63$; $P < 0.01$) related positively with the root tuft biomass (\log_{10}). In the terrestrial environment (ground), guano is the main secondary resource available for the invertebrates; the constant production of this resource has shown to influence the structure and distribution of invertebrates. Unfavorable temperature conditions and, especially low soil moisture, promote low plant detritus consumption rates. Historically, different authors assumed that organic resources imported by water are more available in caves in rainy seasons. It is clear that the importation of organic detritus in the rainy season is higher than in the dry season, but as shown in this work, the stochastic pulse flows continually disturb and remove the previously accumulated resource. So, the food that is truly used by the cave communities is that transported at the end of the rainy season (and during all the dry season) that becomes available for the cave fauna. The cave functionality depends, so, directly of the epigeal food resources.

Key words: cave, invertebrates, organic matter, resource availability, trophic budgets

INTRODUCTION

Caves are underground environments in which the absence of light impedes the presence of photoautotrophic organisms and determines a dependence on different allochthonous organic matter transfer processes for the biota maintenance (Simon et al. 2007). The primary autochthonous production rarely occurs, mainly through chemoautotrophic bacteria (Sarbu et al. 1996, Chivian et al. 2008).

The allochthonous organic matter penetrates in the caves carried by rivers, runoffs and water that percolates from the roof or wall, through openings or fractures (Simon et al. 2003). The biological transport is made mainly through root growth, animals that transit at the caves or even by the animals that randomly enter there (Howarth 1983, Jasinska et al. 1996, Ferreira and Martins 1998).

Underground ecosystems with streams connected to the surface, receive organic matter from upstream, which is transformed, retained and exported downstream. The water that serves as means of transportation, acts on the movement of large amounts of organic matter (Gibert et al. 1994, Webster et al. 1999, Simon and Bienfield 2001).

The most appropriate method for the study of the flow of organic matter in the underground environments

is that which includes food resources relevant to the biota maintenance and in which the balance between the input and output of energy can be quantified (Simon et al. 2007). However, studies that relate the balance between the availability and processing of food resources in caves are still scarce (Gibert 1986, Jasinska et al. 1996, Graening and Brown 2003, Simon and Benfield 2002 and 2003, Simon et al. 2007, Souza-Silva et al. 2007). Such studies, however, are crucial for the understanding of the trophic dynamics and their influence on the maintenance of the underground diversity. The movement of resources among habitats can increase the productivity in locals poor in resources and influence the structure and stability of food networks (Huxel and McCann 1998).

Most works concerning the trophic dynamics in caves have focused on Chemoautotrophically based cave ecosystems (Sarbu et al. 1996, Chivian et al. 2008). Furthermore, recent studies are using stable isotopes to determine different energy fluxes in cave environments (Simon et al. 2003). However, it is important to understand the coarse particulate organic matter dynamics in a cave, since these dynamics determine all its systemic functionality.

With the intention of contributing to a better understanding of the trophic dynamics in underground envi-

ronments, the present study had as a general objective, to understand the balance among the import, consumption and retainment rates of food resources in a limestone cave, based on the following questions: (1) what are the coarse particulate organic matter importation, retainment and consumption and root primary production rates in a short subterranean stream, (2) what are the secondary production rates in a short cave system, (3) What are the ecological relationships of the root biomass and the structure of the associated aquatic macrofauna (4) What are the associated mesofauna in terrestrial and aquatic detritus in a short cave system?

METHODS

STUDY AREA

This study was carried out in a limestone cave, “Lapa do Córrego dos Porcos” (LCP) located in Damianópolis, Goiás, Brazil (14°33’S 46°10’W) from August, 2001 to July, 2002. The vegetation surrounding the cave is “*cerrado*” a tropical savannah (Rizzini 1996). The dry season occurs from April to September (up to 50 mm) and the rainy season, from October to March, with up to 100 mm of rain (INMET 2003, Fig. 5).

The cave possesses 337m of horizontal projection and the main conduit has a small stream. There are six openings to the epigeal environment: entrances 1 and 2, accessed through the perennial stream; entrances 3 and 4 only receive pluvial water contribution and entrances 5 and 6, situated on the higher slope of the emerging limestone ridge, do not receive any pluvial water contribution (Fig. 1).

The stream water originates from an epigeal swamp and continues 100m in a small depression surrounded

by riparian vegetation up to the entrance of the cave. At the end of the depression, water flows through limestone blocks and reaches the main cave conduit.

PROCEDURES

The environmental variables in the terrestrial environment (temperature and air humidity) and in the stream (pH, current speed and flow) were measured bimonthly in different parts of the cave.

The primary production in the cave was estimated through the quantification of the of the root growth of the external vegetation in the hypogean stream. The roots were completely sectioned, conditioned in plastic bags, dried (100°C/48 h) and weighed. Bimonthly, the roots that had grown at each point were collected again, dried and weighed. Such procedure supplied temporal variations in the primary production measure through the root growth. Once the natural growth of the roots is strongly altered by the cutting, which is a totally non-natural process, our data represents an estimate of the root growth capacity (Kuroha and Satoh 2007).

The secondary production was evaluated bimonthly through the collection, drying and weighting of all the bat guano present in the terrestrial environment of the cave (100°C/48 h). The material was collected in the deposits (in the case of the aggregated bat colonies) or was obtained through sweeping of the cave floor.

To quantify the detritus transported to the cave, three contention nets were installed (PVC, 0.65 cm² mesh) covering the whole transverse extension of three stations in the hypogean stream (Fig.1). Net 1 (75cm x 176cm), located 30 meters downstream from the sinkhole, withheld the detritus coming from the entrances 1 and 2 of the cave. Net 2 (79cm x 140cm) was installed 20 me-

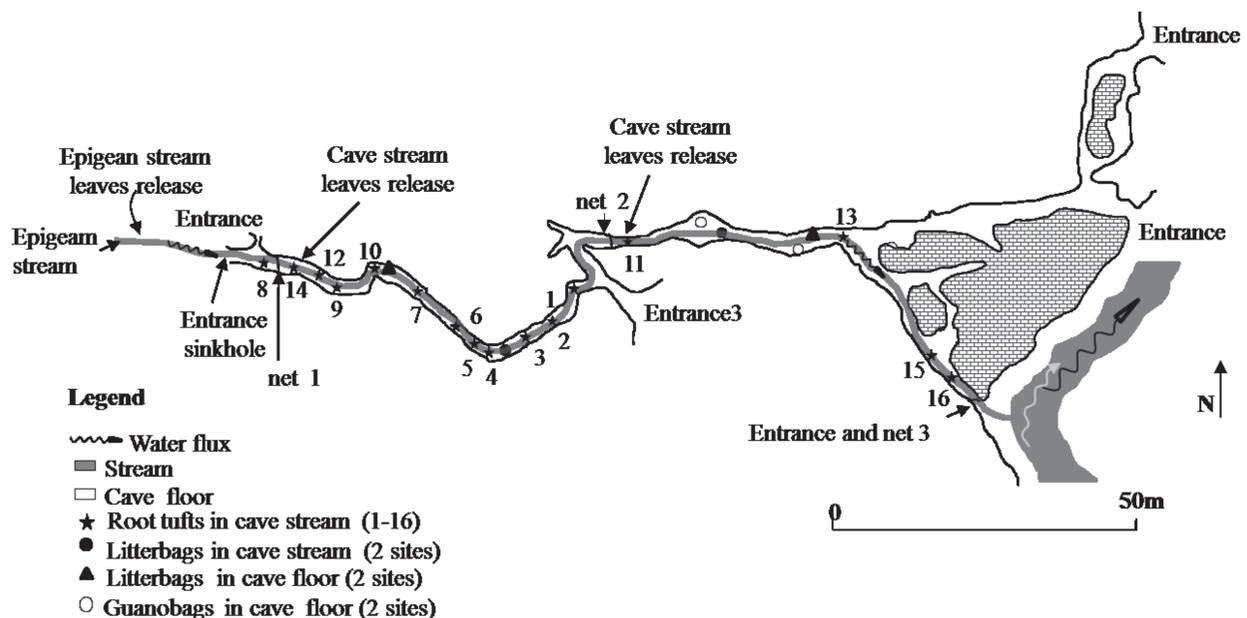


Fig 1 - Schematic map of “Lapa do Córrego dos Porcos” cave (LCP). Topography by Emilio Manoel Calvo, José Augusto O. Motta and Gerson B. Soares from IBAMA-CECAV.

ters downstream from entrance 3. Net 3 (82cm x 180cm) was installed 30 meters upstream from entrance 4 (resurgence), with the purpose of capturing detritus exported from the cavity. All retained detritus was removed bi-monthly, dried and weighed (100°C/48 h). Furthermore, the separation of the material into leaves, seeds, fruits, roots, trunks and animal carcass fragment categories was conducted. Since the detritus retained in the nets was exposed to the leaching action and processed by the fauna, the correction factor was carried out for the value of the retained matter using the daily rate of resource processing in the hypogean stream (litter bag method).

The detritus retainment capacity by the sediment of the stream bottom, in the dry and rainy seasons, was estimated from the liberation, in the water, of plant leaves marked with spray paint (Simon and Benfield 2001). The leaves retained in the bottom sediment were collected along the stream 24 hours after their release at each point. Fifty leaves were released in the epigeal stream (in the vicinity of the sinkhole), fifty leaves after net 1 and fifty leaves after net 3 (Fig. 1).

The analysis of the detritus processing was performed by conditioning plant detritus in 216 nylon bags (10x10 cm) and placed in the cave at the same time and divided into four distinct stations. Three types of bag mesh (with 5x7 mm; 1x1 mm and 0.1x 0.1 mm of mesh size) were used to exclude different invertebrate sizes (Gallas et al. 1996). Fifty dry disks (10 from each species) were previously weighed and packed into the litter bags (corresponding to an area of 63.6 mm² of plant material in each bag). The plant disks were taken from leaves from five tree species present in the adjacent epigeal environment: *Ficus calyptroceras* (Moraceae), *Piper* sp. (Piperaceae), *Ilex* sp. (Aquifoliaceae), *Eschweilera* sp. (Lecythidaceae) and *Acalypha* sp. (Euphorbiaceae). The litter bags were placed at two equally distant stations at the stream and in the terrestrial environment (Fig. 1). Triplicates of bags were bi-monthly sampled at each mesh size and distinct stations. Only the first sampling was taken after one month.

In order to analyze the processing of animal detritus, feces from the carnivore bat *Chrotopterus auritus* were used. Twenty four bags of bat feces with 1x1 mm mesh size were distributed in two terrestrial stations on the floor of the cave at the same time. Triplicates of bags were bi-monthly sampled at distinct stations.

The amount of organic matter remaining after the period of exposure for processing was expressed in percentage of dry weight. Processing of food resources (k-day) at LCP was described by the model $M_t = M_0 e^{-Kt}$. The values for k.day⁻¹ may be slow (0.005 k.day⁻¹) and fast (0.1 k.day⁻¹) in stream and slow (0.009 k.day⁻¹) and fast (0.2 k.day⁻¹) in terrestrial habitats (Osion 1963, Allan and Castillo 2007, Simon and Benfield 2001).

The invertebrates were extracted bi-monthly, from all the organic resources sampled in the cave (root tufts, plant detritus, guano, carcass, etc). The bi-monthly extraction of invertebrates, before drying, was made with man-

ual collections of the animals, still alive, using white-bottomed trays and under fluorescent light, with the aid of tweezers, brushes and manual magnifying glasses.

Invertebrates not directly associated to organic resources (especially terrestrial arthropods and zooplankton) as well as vertebrates (bats and fishes) were analyzed in a single quantitative sampling, conducted at the end of the experiment.

Terrestrial invertebrates species found in the cave had some of their specimens collected using manual collections with the aid of tweezers, brushes and entomological nets. The other invertebrates observed during the collections were counted (Hunter and Millar 2001). In the stream the zooplankton were collected with a 160 µm mesh net (Merle and Schneider 2000, Hunter and Millar 2001). Fish were collected with hand nets (Reis et al. 2006). Chiroptera fauna were collected during the summer with mist nets suspended near bat colonies (Weller and Lee 2007).

All organisms were identified to the highest accessible taxonomic level and grouped into morpho-species or species (Oliver and Beattie 1996). Species composition allowed categorization of fauna into functional groups (Triplehorn and Johnson 2005, Allan and Castillo 2007).

DATA ANALYSIS

The term *trophic dynamic*, used here, refers to the relationships among the import, retainment, production and processing processes of the coarse particulate organic matter. In the aquatic environment larger detritus than 0.6 cm were analyzed and in the terrestrial environment those larger than 0.1cm. For such, the following measures were used: (1) importation (daily percentage of coarse particulate organic matter imported to the cavity via stream and terrestrial means), (2) retainment or accumulation (daily percentage of coarse particulate organic matter retained in the cave), (3) exportation (daily percentage of coarse particulate organic matter retained in the retainment net located near the resurgence of the stream), (4) processing (daily percentage of the plant material and bat feces breakdown), (5) primary productivity (daily percentage of organic matter produced through the growth of roots in the cave), (6) secondary productivity (daily percentage of bat feces deposited in the cave).

The qualitative similarity of the fauna for only eight root tufts was obtained using the Bray-Curtis; the dominance through the Berger-Parker index and the diversity and evenness were estimated through the Shannon-Wiener index (Magurran 2004). The program used for the analyses was PAST (Hammer et al. 2001). In order to verify relationships between the richness, abundance, diversity and dominance of the macro invertebrates with the biomass and the distance of the roots in relation to upstream entrance, linear regressions were used (Zar 1984). The linear regression analyses were also used in the evaluation of the eventual relationships between the root biomass and the distance from the upstream entrance.

RESULTS

In the terrestrial environment, air humidity did not change substantially (70-77 %), and the temperature was constant (24-25°C). Water pH was alkaline (8-9) and water temperature (24-25°C), current speed (4-5 m.s⁻¹) and discharge (0.003 – 0.1 m³.s⁻¹) varied during the year. The most intense discharge occurred in February. However, other rainy periods caused intense punctual flood flows that were discovered especially because of the marks left on the lateral walls of the cave and the damage caused to the collecting nets.

Initially eight root tufts that reached the hypogean stream sediment were found. During the study, eight new root tufts appeared, due to the erosion of the sediment or root tuft growth, totaling 16 points (Table 1). A total of 16 root growth points were observed in the hypogean stream. The biomass initially collected of the 8 root tufts corresponded to 1.138 kg and the average primary productivity along the sample period corresponded to 1.470 g/day (Table 1).

The incorporation in the biomass measured through the dry weight was of 1.482 g/day in October, 1.937 g/day in December, 0.502 g/day in February, 1.470 g/day in April and 0.591 g/day in June (Table 1).

The carnivorous and insectivorous bats were the main agents of the secondary production in the cave. These were responsible for depositing of 97 percent of the detritus present in the terrestrial environment of the cave (guano and prey carcasses). Owl regurgitation (rodent bones and skin) contributed to 3 percent of the detritus

produced. The guano of carnivorous bats was deposited in a larger amount than the produced by insectivorous bats (Fig. 2). The highest guano deposition in the cave occurred in February, coinciding with the rainy period (Fig. 3).

Leaves were the most intensely imported resources (70.5%), followed by trunks (27.4%), dry fruits (1.5%), seeds (0.5%) and died roots (0.5%). The capture of detritus was 53.4 percent in net 1 and 46.6 percent in net 2. Comparatively, the capture of detritus in net 3 (export) corresponded to 89 percent of the material retained in nets 1 and 2 (Fig. 4).

The highest import of detritus (nets 1 and 2) happened at the end of October (45.4%), coinciding with the beginning of the rainy season. In February the highest detritus export rate (57.3%) occurred, coinciding with the highest rainfall index (Fig. 5).

In the dry season, there was retainment of 96 percent of the leaves released in the epigean stream close to the sinkhole. Inside the cave, 66 percent of the leaves liberated after net 1 were retained and 79 percent of the leaves liberated after the net 2 were retained. In the rainy season, there was retainment of 94 percent of the leaves liberated in the epigean stream close to the sinkhole. Inside the cave, 22 percent of the leaves liberated after net 1 were retained and 10 percent after net 2 were retained. Flood events were observed in the hypogean stream during the rainy season.

The plant detritus processing rate in the hypogean stream was fast (Table 2). During the first 31 days a rapid weight loss occurred, represented by the loss

Table 1 – Productivity (dry weight in grams/day) of submerged root tufts in a short subterranean stream.

Root tufts	July-01	October-01	December-01	February-02	April-02	June-02
1	41.624	0.159	0.540	0.070	0.036	0.177
2	426.571	0.235	0.115	0.013	0.035	0.066
3	448.294	0.102	0.095	0.013	0.200	0.037
4	139.490	0.251	0.039	0.031	0.061	0.009
5	14.910	0.112	0.338	0.029	0.090	0.020
6	35.798	0.062	0.002	0.042	0.002	0.012
7	24.767	0.067	0.017	0.012	0.062	0.001
8	7.521	0.050	0.004	0.034	0.001	0.037
9	-	0.128	0.008	0.009	0.018	0.005
10	-	0.316	0.053	0.008	0.294	0.013
11	-	-	0.725	0.045	0.013	0.005
12	-	-	-	0.195	0.133	0.068
13	-	-	-	-	0.004	0.004
14	-	-	-	-	0.267	0.057
15	-	-	-	-	0.132	0.000
16	-	-	-	-	0.124	0.080
Total	1138.975	1.482	1.937	0.502	1.470	0.591
Mean	142.372	0.148	0.176	0.042	0.092	0.037
SD	186.753	0.091	0.249	0.051	0.094	0.046

Numbers in bold represent the initial weight of each root in the first collection.

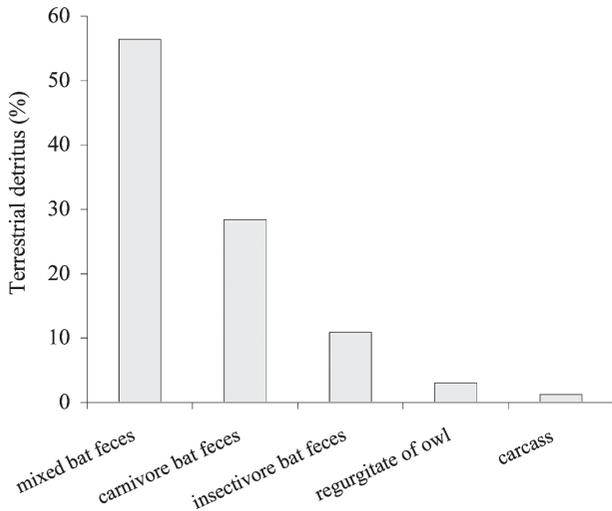


Fig 2 - Type of detritus transported to terrestrial environment in a tropical limestone cave.

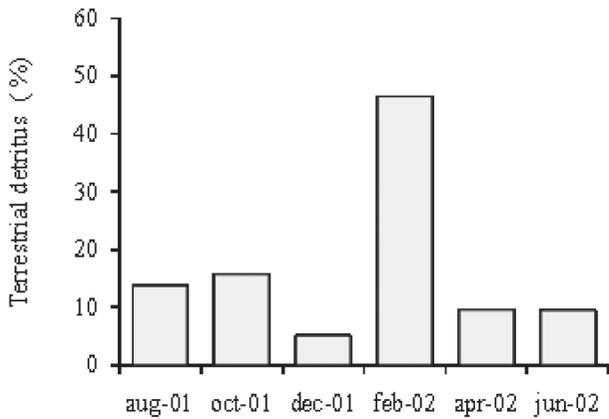


Fig 3 - Variation in detritus input to terrestrial environment in a tropical limestone cave.

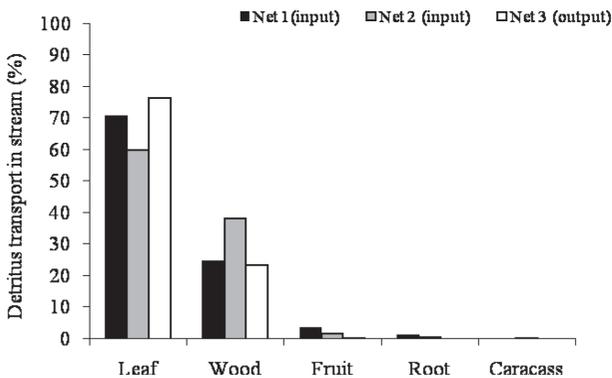


Fig 4 - Types of detritus input (nets 1 and 2) and output in a short cave stream.

about 80 percent of the plant mass (Figs 6A and 6B). In the terrestrial environment, the plant detritus processing rate was slow (Table 2). At 31 days of exposure, the plant detritus mass loss was approximately 50 percent

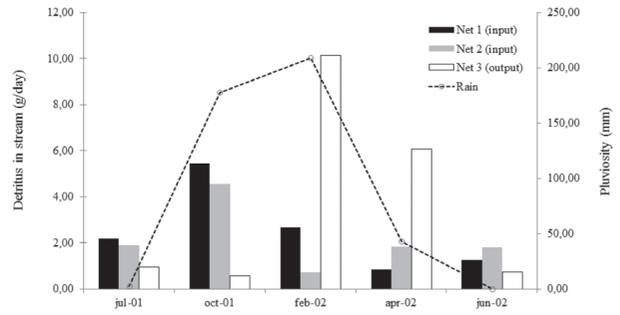


Fig 5 - Variation in the rain, amount of input (nets 1 and 2) and output (net 3) of detritus transported in a short cave stream.

in relation to the initial mass. After 31 days, there was only an additional 15 percent loss of the initial mass (Figs. 6C and 6D). The processing rate of the guano of carnivorous bats can be considered fast in the cave (Table 2). At the 44 days of exposure there was a fast guano weight loss (72 % loss). After this period, the weight loss was slow (Fig. 7).

Considering all the organic matter (100 %) that enters daily in the cave, 61.7 percent is carried by the stream water. The roots that grow in the sediment represent 23.8 percent of this matter and the remaining 76.2 percent include detritus. In spite of this larger contribution of detritus, only 10.7 percent is retained by the sediment of the stream. The experiment of the leaf liberation-recapture reveal that retention of detritus by the sediment is higher in the dry season of the year (79%). However, larger volumes of water and flood pulses in the rainy season impose lower retainment rates for the sediments (42%). In this period, the detritus banks are frequently washed and tend to be less available for the invertebrate fauna in function of this water flow instability (Fig. 8).

On the other hand, of all the organic matter (100%) that enters the cave daily, 38.3 percent is carried through the terrestrial environment, by the bats that deposit feces and carcasses (Fig. 8). The organic resource carrier species were the bats *Chrotopterus auritus*, *Natalus stramineurus*, *Furipterus horrens* and *Loncophylla* sp. (Fig. 8). This carrying process represents secondary production, since the carried detritus (guano) is of animal origin (carnivorous habits).

Those food resources are not carried to the exterior of the cave, remaining available for a long time for invertebrate use. However, the guano deposited in the cave is an ephemeral resource demonstrating a fast weight loss rate (Fig. 8). In spite of plant detritus (litterbag method) having registered slow processing rates, it was not found in sediment banks in the terrestrial environment of the cave (Fig. 7).

The number of species present in the several “habitat compartments” of the aquatic system was variable, although, in all of them, the orders Coleoptera and Diptera showed to be the richest (Table 3 and 4). The highest richness was sampled in eight root tufts (111 spp).

Table 2 - Breakdown rates (k) from time and mass for leaves and guano in cave.

Site	Resource	Mesh (mm)	K	Use	Cases	Starting weight	Final weight
Ground	Leaf	0.1 x 0.1	0.007	Slow	34	0.673	0.262
Ground	Leaf	1 x 1	0.006	Slow	34	0.655	0.272
Ground	Leaf	5 x 7	0.007	Slow	35	0.615	0.245
Ground	Guano	1 x 1	0.017	Fast	24	2.031	0.490
Stream	Leaf	0.1 x 0.1	0.043	Fast	33	0.645	0.035
Stream	Leaf	1 x 1	0.0521	Fast	33	0.623	0.020
Stream	Leaf	5 x 7	0.598	Fast	33	0.591	0.017

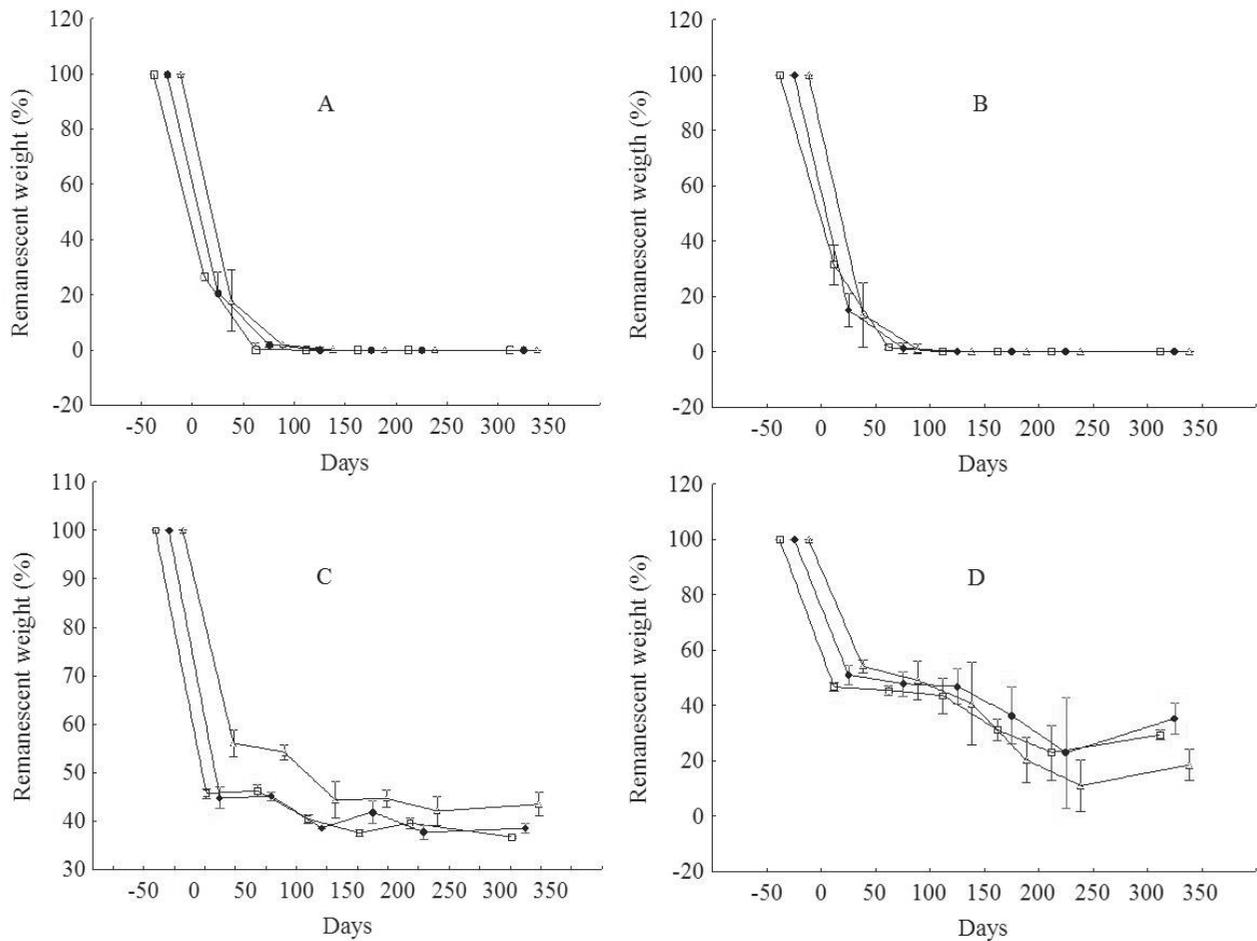


Fig 6 - Plant detritus processing in a cave stream (A and B) and terrestrial cave habitat (C and D). A, B, C, D refer to different sites in the cave.

The group of the shredders stood out in the plant detritus collected in the contention nets and litter bags. In the root tufts, the grazer organisms showed more representatives (Table 5).

The diversity was higher in root tufts 2 ($H' = 2.78$) and the highest dominance in root tufts 5 ($d = 0.35$) (Ta-

ble 6). Roots tufts closer to each other and also those closer to the upstream entrance were the more similar in fauna composition than those located in the inner portions of the cave (Table 7).

The abundance (\log_{10}) ($R^2 = 0.63$; $P < 0.02$) and richness (\log_{10}) ($R^2 = 0.63$; $P < 0.01$) related positively with

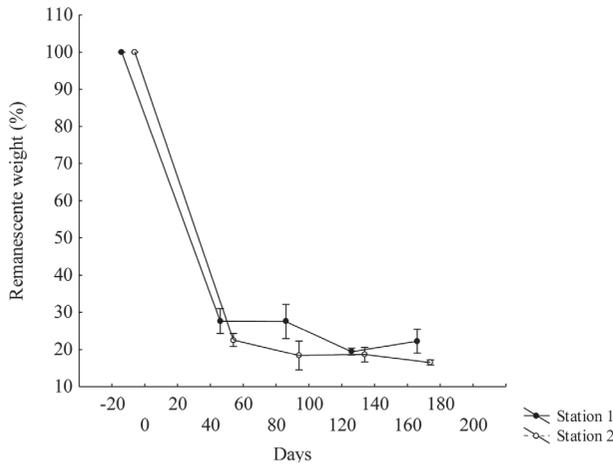


Fig 7 - Bat feces processing in terrestrial environment in a tropical limestone cave.

the root tuft biomass (\log_{10}). The dominance related negatively with distance from the upstream entrance (\log_{10}) ($R^2 = 0.76$ $p < 0.004$). The diversity ($R^2 = 0.87$, $p < 0.0005$) and the richness (\log_{10}) ($R^2 = 0.75$, $p < 0.004$) were positively related with the distance from the up-

stream entrance. The root tuft biomass (\log_{10}) related positively with the distance from the upstream entrance (\log_{10}) ($R^2 = 0.52$, $p < 0.04$).

In the submerged roots tufts, Lepidoptera larvae (Pyralidae), Coleoptera larvae (Elmididae and Ptylodactylidae), Mollusca (Gastropoda) and as phytophagous Acari (Hydrachnidae, Smarididae and Rhynchohydracaridae) and Homoptera (Ortheziidae) were found as primary consumers (grazers and scrapers). These, in turn, can serve as food for Trichoptera (Leptoceridae, Hydroptilidae and Hydropsychidae), Megaloptera (Corydalidae), Odonata (Calopterygidae and Gomphidae), Heteroptera (Naucoridae, Hebridae and Belostomatidae) and fishes (*Ancystrus* sp and *Astyanax scabripinnis*). Other taxa can use the roots or detritus only as stable substrate (Ephemeroptera (Baetidae), Diptera (Ceratopogonidae, Chironomidae, Simuliidae, Stratiomyiidae and Tipulidae) Heteroptera (Veliidae), Coleoptera (Carabidae, Coccinellidae, Dytiscidae, Elmididae, Ptilodactylidae and Staphylinidae), Plecoptera (Perlidae), Rotifera (*Lecane* sp., *Bdelloidela* sp., *Cephalodella* sp., *Collotheca* sp., *Filinia* sp., *Keratella* sp., *K. Americana*, *Lepadella* sp., *Lepadella Patella*, and *Ptygura* sp) e.g. Annelida, Amphipoda, etc), Platyhelminthes (Planariidae) and Nematomorfa (Gordioidea).

Table 3 - Invertebrate species composition, distribution and richness (i.e. number) associated in distinct cave “habitat compartments”. in stream and ground.

	Stream			Ground				
	Roots	Detritus	Litterbags	Guano	Owl pellets	litterbags	Guanobags	Carcass
Acari	8	1	3	9				
Annelida	5	2		1				
Amphipoda	1							
Araneae				5		2		
Coleoptera	28	21	17	8				
Diplopoda				1		2	1	
Diptera	26	18	7	3				
Blattodea						1	1	
Ephemeroptera	6	4	5					
Heteroptera	4	5		1		1		
Homoptera							1	
Hymenoptera				4	1	1		
Isopoda				1				
Isoptera				1		1	1	
Lepidoptera	3	2		2	1	4	2	1
Megaloptera	1	1	2					
Mollusca	5	2	3					
Odonata	7	3	2					
Ostracoda	3	1	2					
Plecoptera	3	2						
Pseudoscorpiones				1				
Psocoptera				4			1	
Trichoptera	10	5	3					
Turbellaria	1	1		1				
Total	111	68	44	42	2	12	7	1

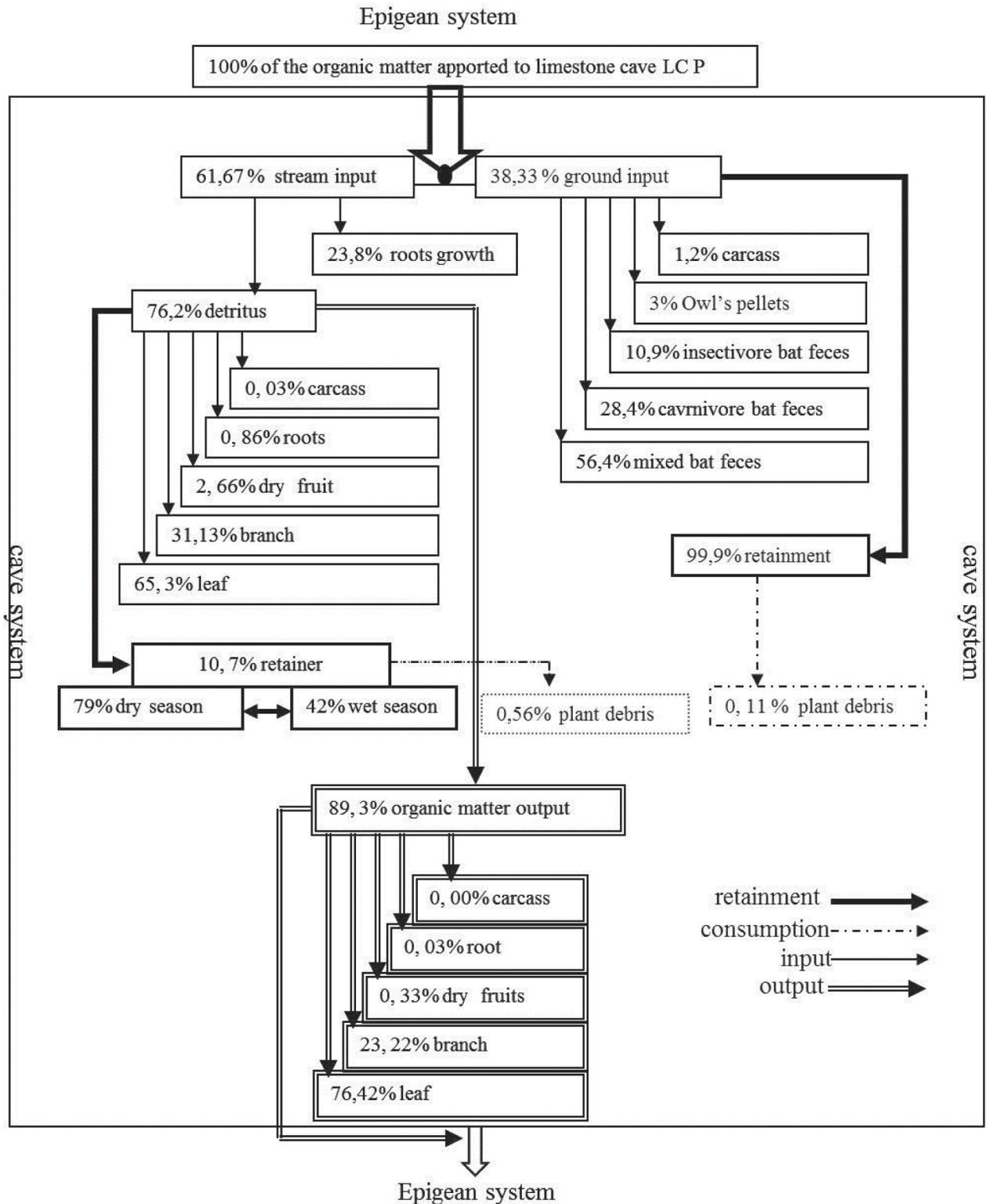


Fig 8 - Terrestrial and aquatic detritus budgets through a short tropical limestone cave.

For the terrestrial system, the richness of species was also variable, although always inferior to the values observed in the aquatic system (Table 3 and 4). However, there was no preponderance of a same taxon in the diverse compartments, as observed for the aquatic system.

The shredder groups dominated all of the organic substrate observed in the terrestrial system (Table 5).

Therefore, in the terrestrial environment, the invertebrates have only associated to the bat guano, the carcasses of birds and owl regurgitate. Such invertebrates,

Table 4 - Cave fauna richness and abundance in different cave “habitat compartments”.

Site	“habitat compartments”	Richness	Abundance
Stream	Root	111	1163
	Detritus	68	880
	Litterbags	44	785
	Watercourse	24	160
Ground	Wall and floor	62	136
	Guano	42	763
	Litterbags	12	26
	Guanobags	7	126
	Owl pellets	2	13
	Carcass	1	39
Total		270	4091

in turn, are prey of a large number of predator species. In the guano, the main scavengers are composed of species from the Armadillidiidae, Tineidae, Psyllipsocidae Pseudocaecillidae, and Dermestidae families, besides mites, composing the base of the trophic web. In the terrestrial environment there are organisms that do not associate directly to the guano patches, but they occur dispersed throughout the cavity. These were located on the floor or walls of the cave (Heteroptera (Ploiariidae and Reduviidae), Collembola (Entomobryidae), Ensi- fera (Phalangopsidae), Opiliones (Cosmetidae), Polydes- mida (Cryptodesmidae), Homoptera (Cixiidae), Hyme- noptera (Apidae, Evaniidae, Formicidae and Sphecidae), Coleoptera (Carabidae, Curculionidae, Scarabeidae and Sthaphylinidae), Blattodea, Diptera, Diplura (Campodeidae), Neuroptera (Chrysopidae), Isoptera (Termiti-

Table 5 - Functional groups (% abundance) associated in distinct cave “habitat compartments” in stream and ground.

	Stream			Ground				
	Litterbags	Roots	Detritus	Carcass	Guano	Guanobags	Litterbags	Owl pellets
Collector	8	7.8	6,7	0	0	0	0	0
Filter feeding	0	2.4	0.1	0	0	0	0	0
Grazers	0	47.9	0					
Parasites	0	0	0	0	2.4	0	0	15
Predator	19,2	18.8	33.9	0	24.5	0,8	11.5	0
Scrapers	0,4	0.9	1.4					
Shredder	71,5	15.4	56.7	100	73.1	99.2	88.15	84
Sucker	0	2.4	0					

Table 6 - Macroinvertebrate community structure in root tufts submerged in a short subterranean stream.

	Root 1	Root 2	Root 3	Root 4	Root 5	Root 6	Root 7	Root 8
Richness (s)	27	19	38	34	10	8	5	4
Abundance	100	51	410	260	34	30	24	9
Dominance	0.11	0.08	0.17	0.17	0.38	0.32	0.37	0.26
Diversity (H)	2.73	2.75	2.58	2.31	1.49	1.48	1.19	1.37
Evenness(J)	0.83	0.93	0.71	0.65	0.65	0.71	0.74	0.99

Table 7 - Qualitative similarity of macroinvertebrates in discrete roots submerged in subterranean stream.

Root tufts	1 ⁺	2	3	4	5	6	7	8*
1 ⁺	-	0.304	0.123	0.164	0.216	0.171	0.125	0.194
2		-	0.281	0.264	0.207	0.074	0.083	0.087
3			-	0.444	0.042	0.087	0.093	0.048
4				-	0.136	0.146	0.103	0.105
5					-	0.222	0.267	0.429
6						-	0.154	0.167
7							-	0.444
8*								-

The sequence of numbers indicates the neighbors
 * indicates root closest to the upstream entrance
 + indicates root farthest from the upstream entrance

dae), Psocoptera (Psyllipsocidae and Pseudocaecilli- dae), Acari (*Ornithodoros* sp).

Species of the orders Pseudoscorpiones (Cherneti- dae) Scutigermorpha, Scorpiones (Buthidae) and Ara- neae (Pholcidae, Theraphosidae, Salticidae, Scicariidae, Theridiidae, Mysmetidae and Oonopidae) were the top predators in the terrestrial environment.

DISCUSSION

The vegetation of tropical limestone outcrops fre- quently has a high proportion of deciduous species, which provide a higher accumulation of leaves in the lit- ter during the dry season (Crowther 1987, Brina 1998).

This accumulated plant detritus in the soil during the dry season is carried in great amounts to the cave in the rainy season.

High detritus retainment rates in the sediment occur especially during the dry season. However, these retainment rates are higher than the processing speed of the detritus in the stream. In case the detritus was not removed by the current, certainly it would accumulate in large sediment banks on the underground stream bed. In relation to the LCP cave, what actually removes detritus from the stream bed is not the constancy of the outflow, but the flood pulses that are frequent in the rainy periods. Such a fact can be evidenced through the high output values and the detritus retainment rate falls during the rainy season.

Flood pulses make up one of the few environmental characteristics common to natural lotic ecosystems (Lake 2000, Robinson et al. 2002, Olsen and Townsend 2005). These floods frequently result from great storms, causing large volumes of water to move quickly down stream (Minshall et al. 1983). The volume and the speed of the water create high shearing tension in the channel and banks of a stream, moving substrata and sediment (Carling 1987, Matthaei and Townsend 2000). Those changes in the habitat structure have corresponding effects on the biotic environment (Fisher et al. 1982, Bunn and Arthington 2002, Downes and Street 2005).

For the LPC hypogean stream, the primary productivity (via submerged plant roots tufts) is what sustains the highest number of species in the invertebrate communities. Such a fact differs from the epigeal aquatic ecosystems, where the trophic webs are based mainly on allochthonous detritus (Allan and Castillo 2007, Webster et al. 1999) and hypogean aquatic ecosystems, where the trophic webs are based on dissolved organic matter (Simon et al. 2007).

Roots are important resources for invertebrate animals in the terrestrial and aquatic environments of many caves (Jasinska et al. 1996, Howarth 1983, Ferreira 2005). Besides offering food resources, the submerged roots are also microhabitats with structures different from those that the sediment offers (Jasinska et al. 1996).

The richness and diversity increase pattern and reduction of dominance with the increase of the distance from the cave entrance can be due to the influence of the root tuft biomass or the effect of the drift on the fauna transport. The benthic invertebrate species penetrate in the cave through the upstream entrance and apparently use the water currents to reach the roots farthest away from that entrance. Thus, it may not be the distance from the cave entrance that directly influences the structuring of the invertebrate communities in roots of this stream, but the available biomass of each root (that was shown casually related to the distance from the entrance) that can maintain abundant, richer and uniform populations.

The dispersion by drift is a frequent condition in benthic macroinvertebrate communities in streams, and the increase of the water flow works as one of the main de-

terminants in the increase of the taxa richness under drift (Waters 1981, Callisto and Goulart 2005). According to Waters (1981), the number of individuals under drift can be reduced or stabilize with the increase of the distance traveled from the entrance. Such a fact can explain an increase of the diversity and reduction of the dominance in roots farther away from the entrance.

The guano makes up one of the main organic resources for the terrestrial invertebrate fauna in caves, mainly those permanently dry (Ferreira and Martins 1999). Such a fact was corroborated by the present study, keeping in mind the enormous contribution of the guano as a main food resource for terrestrial communities in the terrestrial LCP system.

Since seasonal variations in the external vegetation can influence the bat food resource use patterns, the highest guano deposition inside the cave in the rainy season could be associated to an increase in the food availability for these animals (Faria 1996). The forests on limestone outcroppings in tropical karst terrain present well defined seasonal phenophases, with an increase of flowering and fructification in the beginning of the rainy season (Crowther 1987, Brina 1998). In the tropics, the insect species are more active in humid periods, seemingly in function of the higher availability of food, flowers and fruits (Wolda 1988).

In LCP, the bats are fundamental for the structuring of the terrestrial invertebrate communities, because they contribute to the maintenance of a considerable number of invertebrate scavenger and predator species. The guano, deposited in places not accessible by water, seems not to have a means of transport to the exterior of the cave, which can make it available for a long period of time. However, as it is an ephemeral resource, the guano can become dehydrated or to have its nutritional value quickly reduced for the invertebrate fauna (Ferreira et al. 2000). Therefore, a continuous deposition, to allow the maintenance of its humidity and nutrient quality, which is essential for maintenance of the scavenger fauna and their predators, is necessary.

The plant detritus processing rates in the hypogean stream of the cave were similar to those observed in other epigeal streams (Allan and Castillo 2007). Initially, fast nutrient loss rates occur, as observed in this study, due to the lixiviation by the abrasive force of the water associated to the action of shredder invertebrates (Simon and Bienfield 2001).

The low consumption rates of the plant detritus in the terrestrial environment of the cave can be related to the unfavorable temperature and mainly humidity conditions of the substrata in the soil. Those variables are essential to regulate the metabolism of decomposer organisms, besides being able to act differentially in the liberation of phenolic compounds and lixiviation elements during decomposition (Goley 1978, Wieder and Lang 1982, Nicolai 1988, Humphreys 1991).

The plant organic matter degradation process in the terrestrial environment of LCP can be compared to that observed in epigeal environments with low water availability (e.g. deserts).

Thus, the higher carnivorous bat guano consumption speed, compared to plant detritus consumption speed, is probably due to the higher attractiveness and nutrient quality of the guano, usually richer in organic compounds (Ferreira et al. 2000). Another factor to be considered is the ephemeral characteristic of the guano that deteriorates due to the volatilization of ammonia compounds (McFarlane et al. 1995).

There is an historical assumption that organic resources imported by water are more available in caves in rainy seasons but, as shown in this work, the stochastic pulse flows continually disturb and remove the previously accumulated resource.

It is clear that the trophic dynamics in LCP cave have been influenced by external seasonal events. The strong dependence of the cave ecosystem on the epigeal environment that surrounds it is also clear. Thus, the necessity of preservation of the entire external surroundings, when we intend to preserve some caves or cave species, is obvious.

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New taxa described in this volume

INSECTA

Coleoptera, Carabidae, Trechinae

- Pterocyrtus grayi*, sp. nov. Eberhard and Giachino: Tasmania, Gray, Elephant Farm Cave.
Pterocyrtus meridionalis, sp. nov. Eberhard and Giachino: Tasmania, Hartz Mts. National Park, Lake Osborne.
Tasmanorites beatricis, sp. nov. Eberhard and Giachino: Tasmania, Cradle Mts National Park, Cradle Mts Lodge m 800.
Tasmanorites lynceorum, sp. nov. Eberhard and Giachino: Tasmania, Hobart, Mt. Wellington, m 1200.
Tasmanorites daccordii, sp. nov. Eberhard and Giachino: Tasmania, Cradle Mts National Park, Cradle Plateau m 1250.
Tasmanorites microphthalmus, sp. nov. Eberhard and Giachino: Tasmania, Mount Cripps, Philrod Cave.
Sloanella gordonii, sp. nov. Eberhard and Giachino: Tasmania, Strahan, Franklin-Gordon Wild River National Park, Gordon River, Heritage Landing Walk.
Tasmanotrechus gordonii, sp. nov. Eberhard and Giachino: Tasmania, Strahan, Gordon River, Heritage Landing Walk.
Tasmanotrechus alticola, sp. nov. Eberhard and Giachino: Tasmania, Cradle Mts. National Park, Cradle Plateau m 1250.
Tasmanotrechus montisfieldi, sp. nov. Eberhard and Giachino: Tasmania, Mt. Field National Park, road for Lake Dobson, m 700.
Tasmanotrechus osbornianus, sp. nov. Eberhard and Giachino: Tasmania, Hartz Mts., Lake Osborne.
Tasmanotrechus moorei, sp. nov. Eberhard and Giachino: Tasmania, Mole Creek, Kubla Khan Cave.
Tasmanotrechus rolani, sp. nov. Eberhard and Giachino: Tasmania, Mole Creek, Little Trimmer Cave.
Goedetrechus minutus, sp. nov. Eberhard and Giachino: Tasmania, Junee-Florentine, Niggly Cave
Goedetrechus rolani, sp. nov. Eberhard and Giachino: Tasmania, Junee-Florentine, Pendant Pot
Goedetrechus florentinus, sp. nov. Eberhard and Giachino: Tasmania, Junee-Florentine, Cauldron Pot,
Goedetrechus damperi, sp. nov. Eberhard and Giachino: Tasmania, Precipitous Bluff, Damper Cave
Trechistus gordonii, sp. nov. Eberhard and Giachino: Tasmania, Gordon River Rd., Creepy Crawly Walk, m 565

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Diptera, Phoridae

- Aenigmatias bakerae*, sp. nov. Disney: USA, Nevada, White Pine Co., Pine Cone Cave.
Megaselia excuniculus, sp. nov. Disney: USA, Nevada, White Pine Co., Lincoln Mine.
Megaselia krejcae, sp. nov. Disney: USA, Nevada, White Pine Co., Cave 24.
Megaselia folliculorum, sp. nov. Disney: USA, Nevada, White Pine Co., Cave 24.
Megaselia necpleuralis, sp. nov. Disney: USA, Nevada, White Pine Co., Great Basin National Park, Lehman Cave, under natural entrance.

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